Photosythesis in sugarcane: is it possible to improve it artificially?

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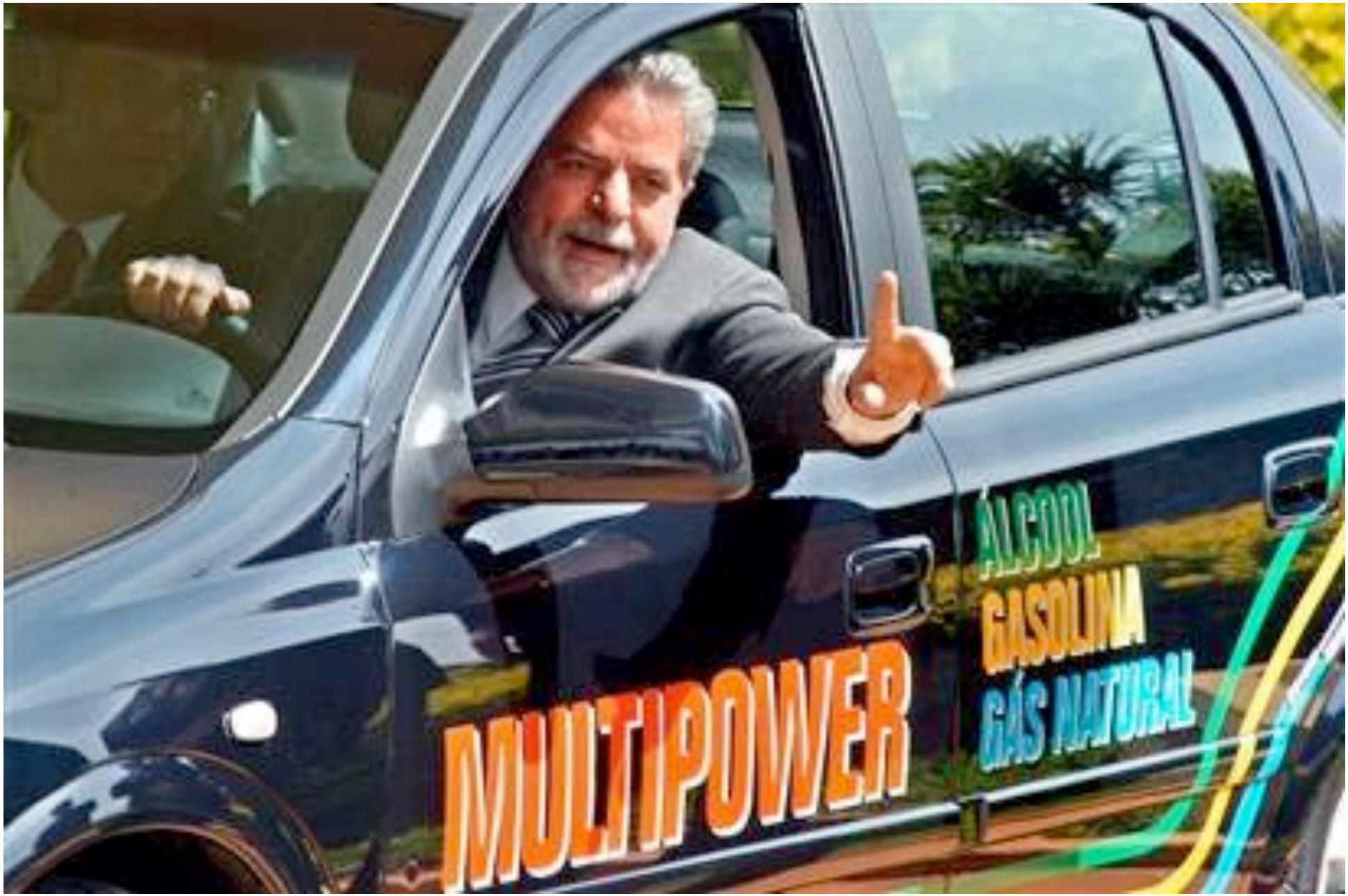
INCT BIOETANOL

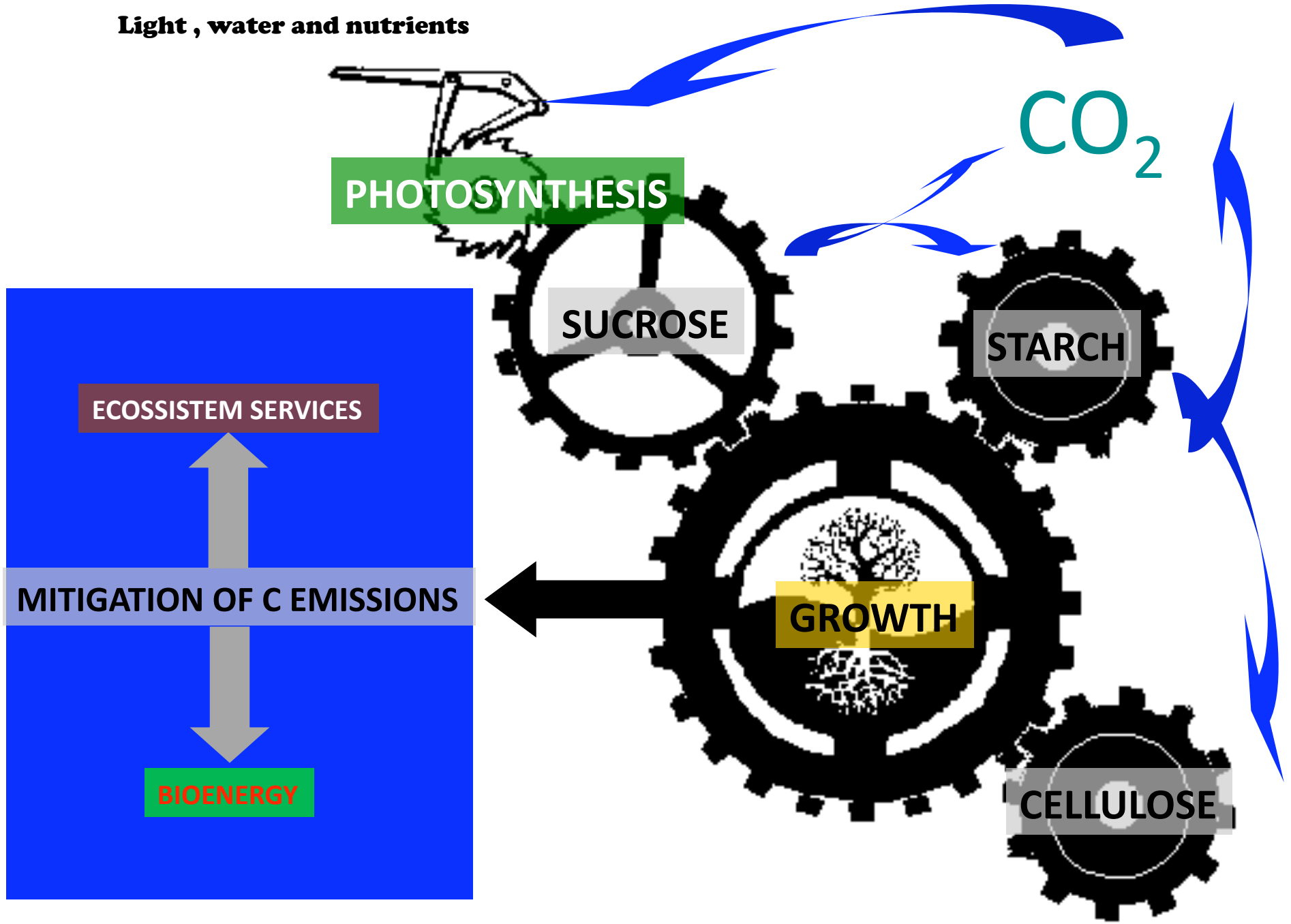
FAPESP, Photosynthesis workshop, Feb. 2009

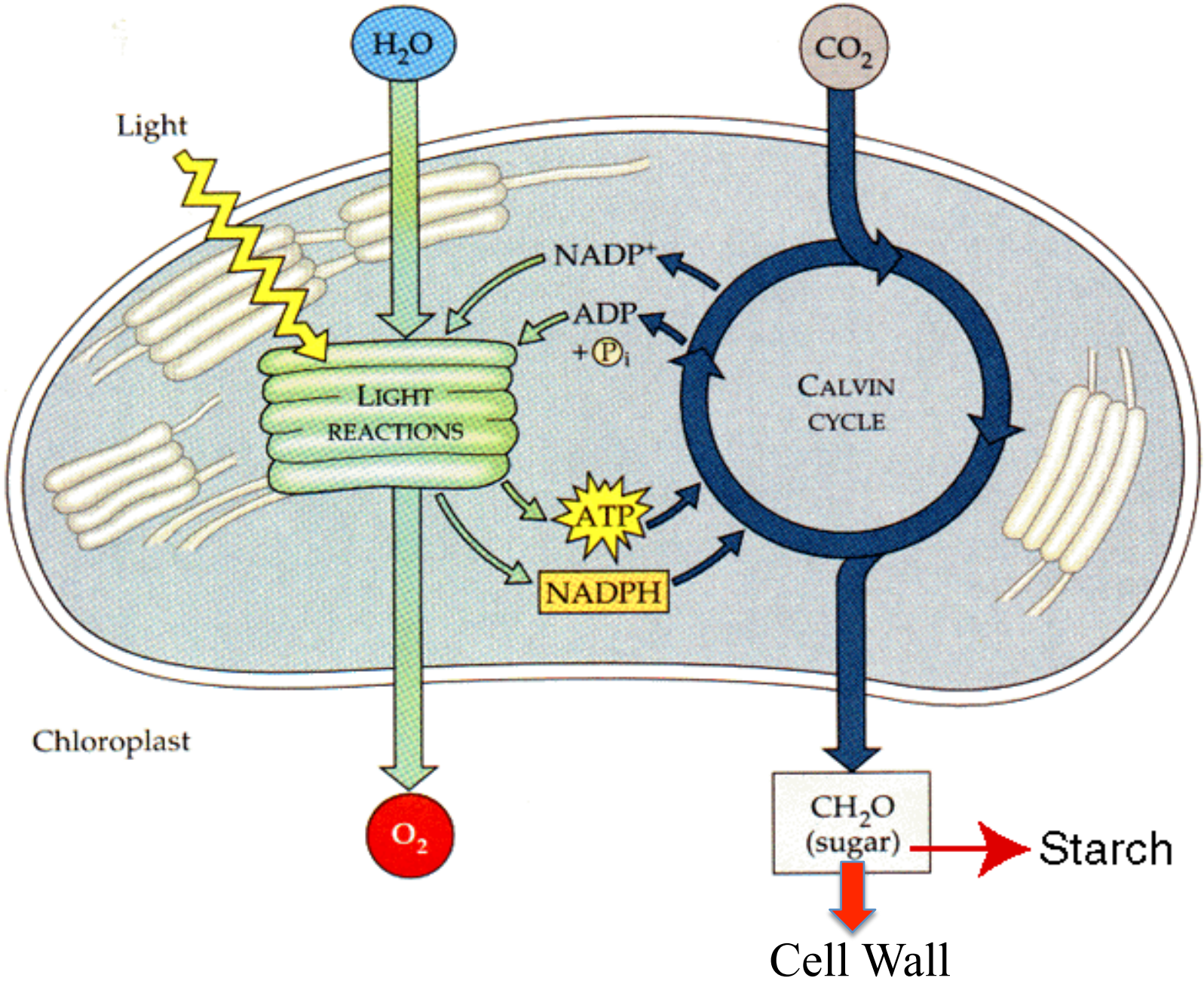
MOTIVATION FOR USE OF BIOENERGY

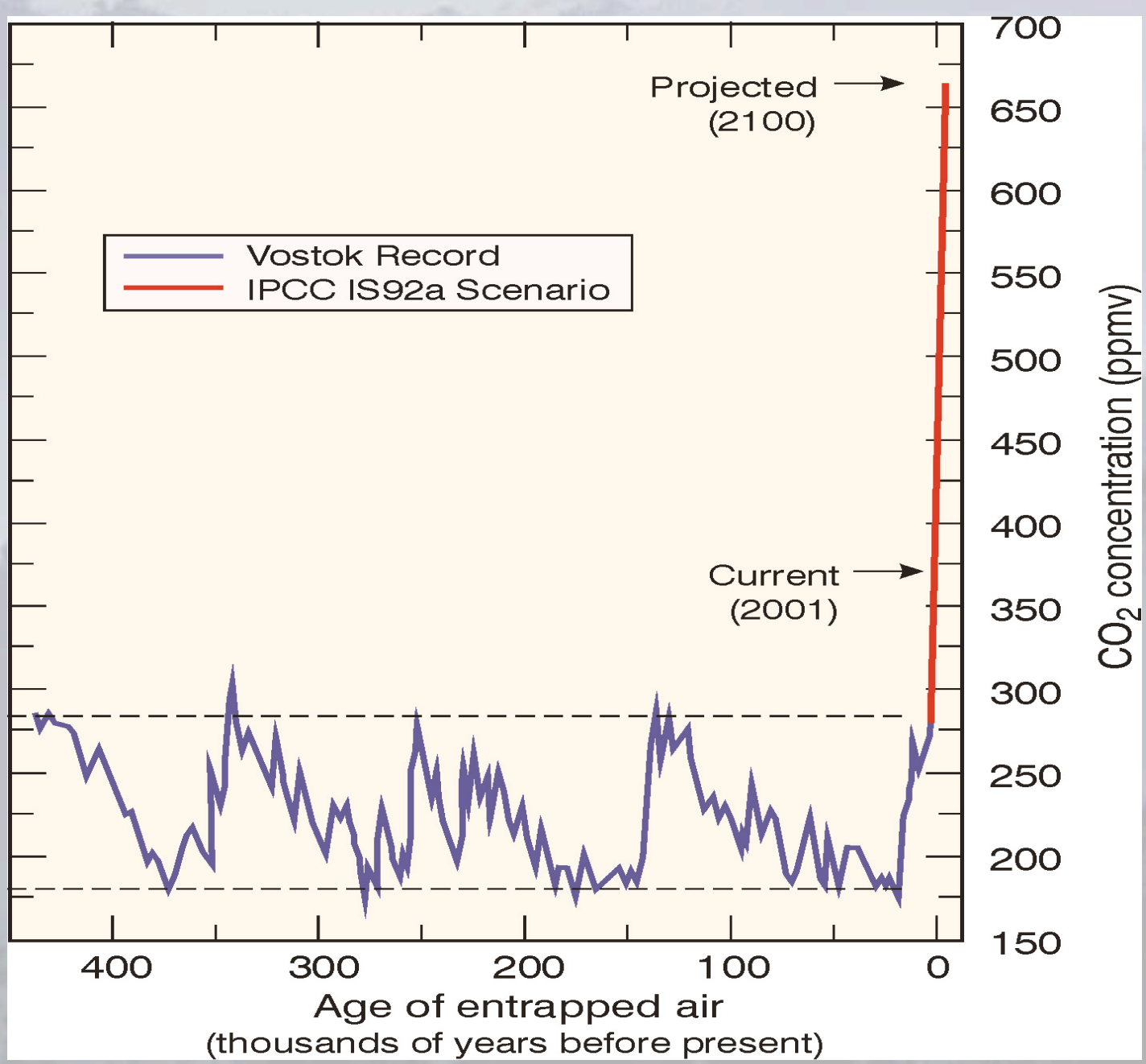
Energy Security

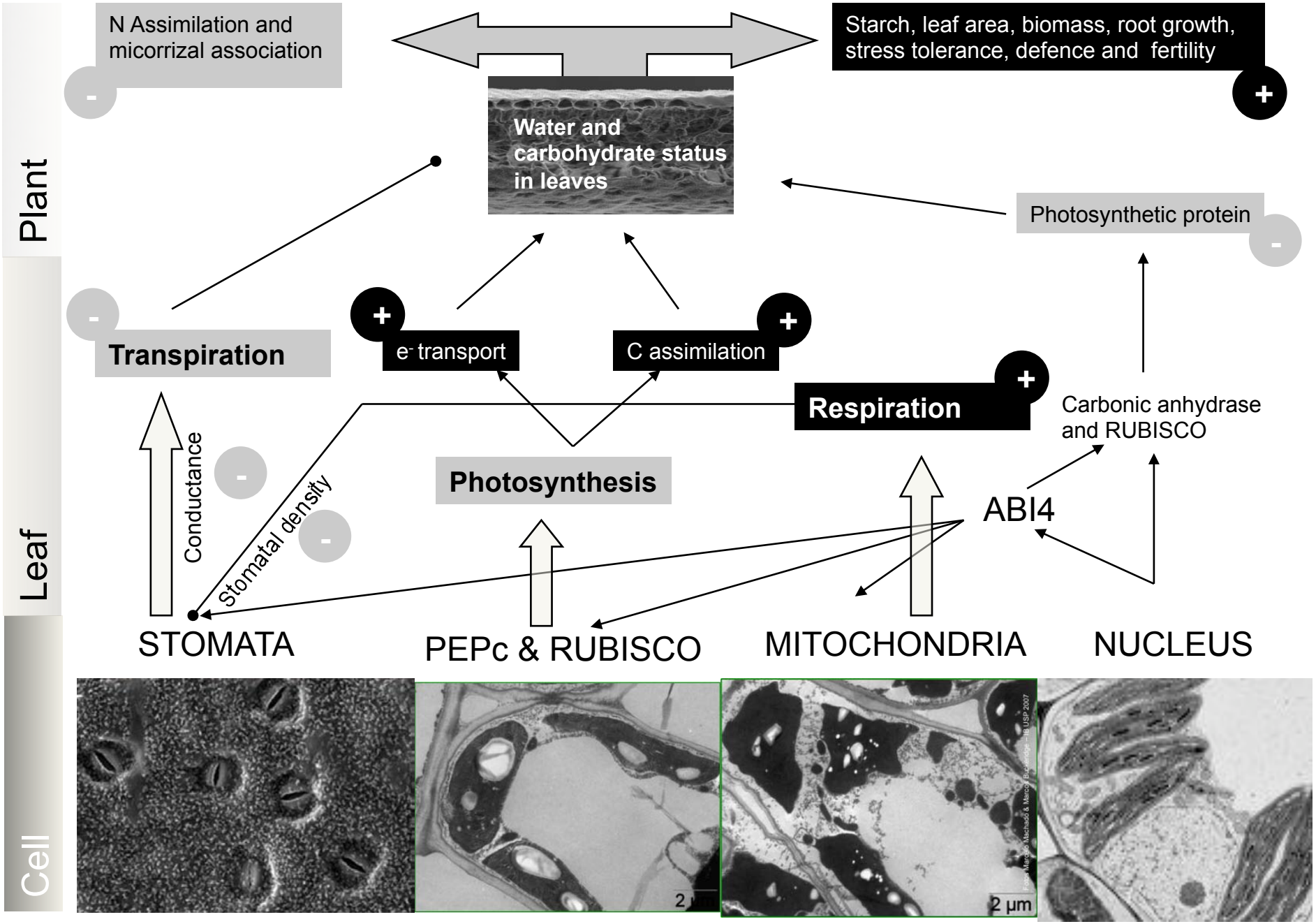
Global Climate Change


MULTIPOWER
ÁLCOOL
GASOLINA
GÁS NATURAL


Light , water and nutrients
PHOTOSYNTHESIS
CO_2
SUCROSE
STARCH
ECOSSISTEM SERVICES
MITIGATION OF C EMISSIONS
GROWTH
BIOENERGY
CELLULOSE


H_2O
CO_2
Light
$NADP^+$
ADP
$+ P_i$
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
Chloroplast
O_2
CH_2O (sugar)
Starch
Cell Wall


Projected
(2100)
Current
(2001)
Vostok Record
IPCC IS92a Scenario
700
650
600
550
500
450
400
350
300
250
200
150
CO_2 concentration (ppmv)
400
300
200
100
0
Age of entrapped air
(thousands of years before present)


Plant
Leaf
Cell
N Assimilation and micorrizal association
Starch, leaf area, biomass, root growth, stress tolerance, defence and fertility
Water and carbohydrate status in leaves
Photosynthetic protein
Transpiration
e- transport
C assimilation
Respiration
Carbonic anhydrase and RUBISCO
Conductance
Stomatal density
Photosynthesis
ABI4
STOMATA
PEPc & RUBISCO
MITOCHONDRIA
NUCLEUS
2 µm

Plant, Cell and Environment (2008) **31**, 1116–1127 doi: 10.1111/j.1365-3040.2008.01822.x

Elevated CO_2 increases photosynthesis, biomass and productivity, and modifies gene expression in sugarcane

AMANDA PEREIRA DE SOUZA[1], MARILIA GASPAR[3], EMERSON ALVES DA SILVA[3], EUGÊNIO CÉSAR ULIAN[4], ALESSANDRO JAQUIEL WACLAWOVSKY[2], MILTON YUTAKA NISHIYAMA JR.[2], RENATO VICENTINI DOS SANTOS[5], MARCELO MENOSSI TEIXEIRA[5], GLAUCIA MENDES SOUZA[2] & MARCOS SILVEIRA BUCKERIDGE[1]

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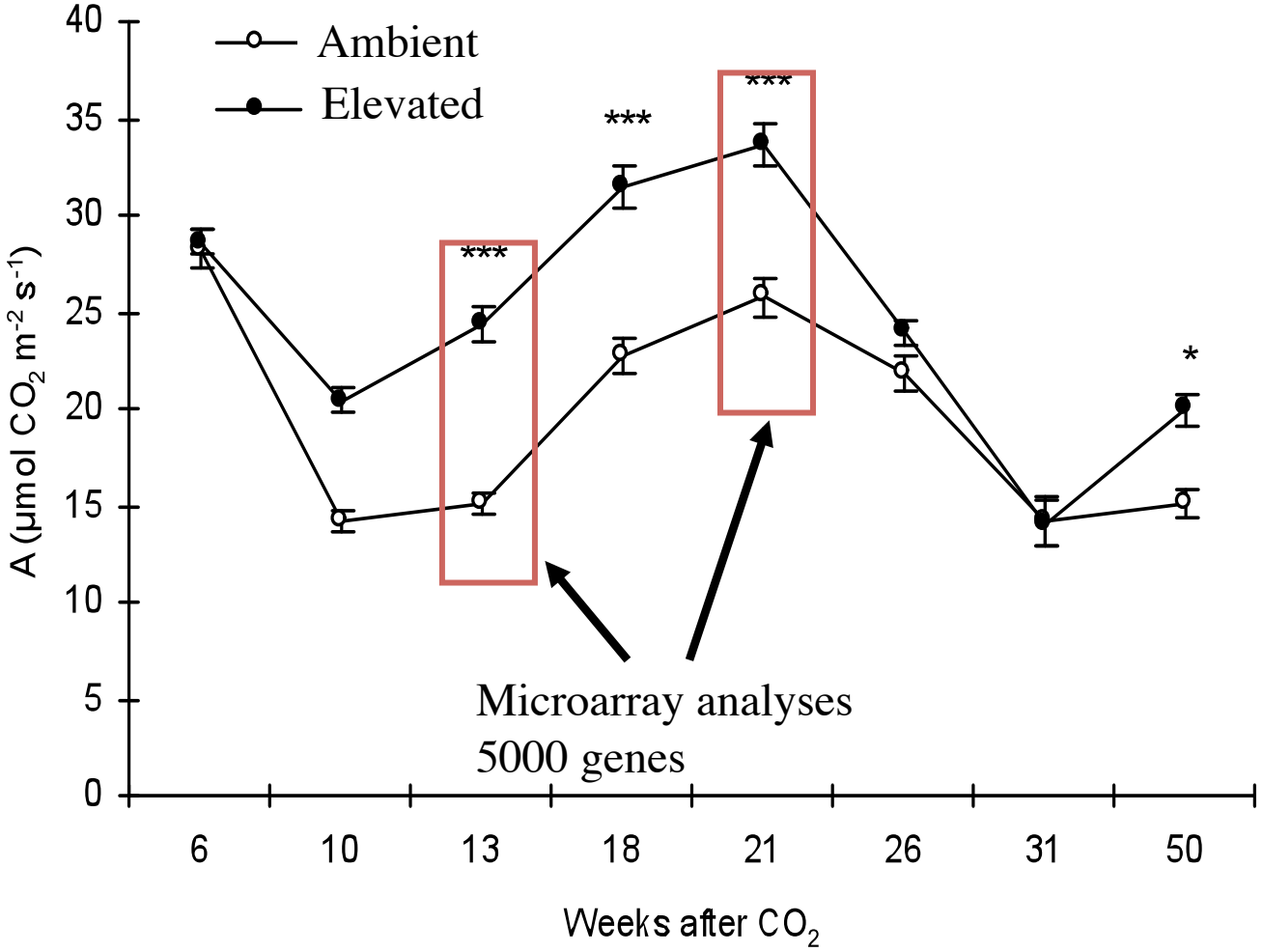
Sugar cane in the open top chambers 2005

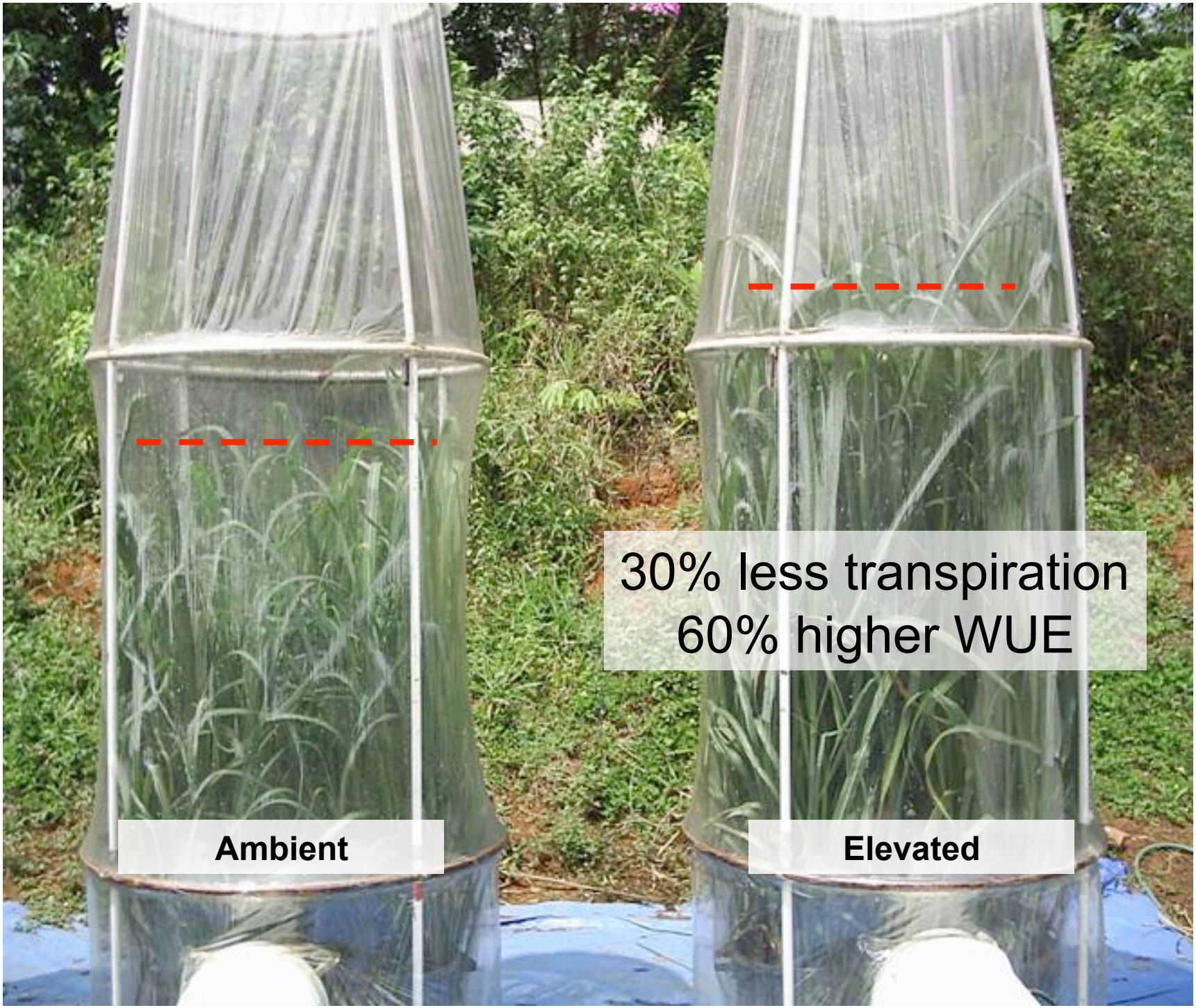
Funded by Centro de Tecnologia Canavieira - Piracicaba

Photosynthesis



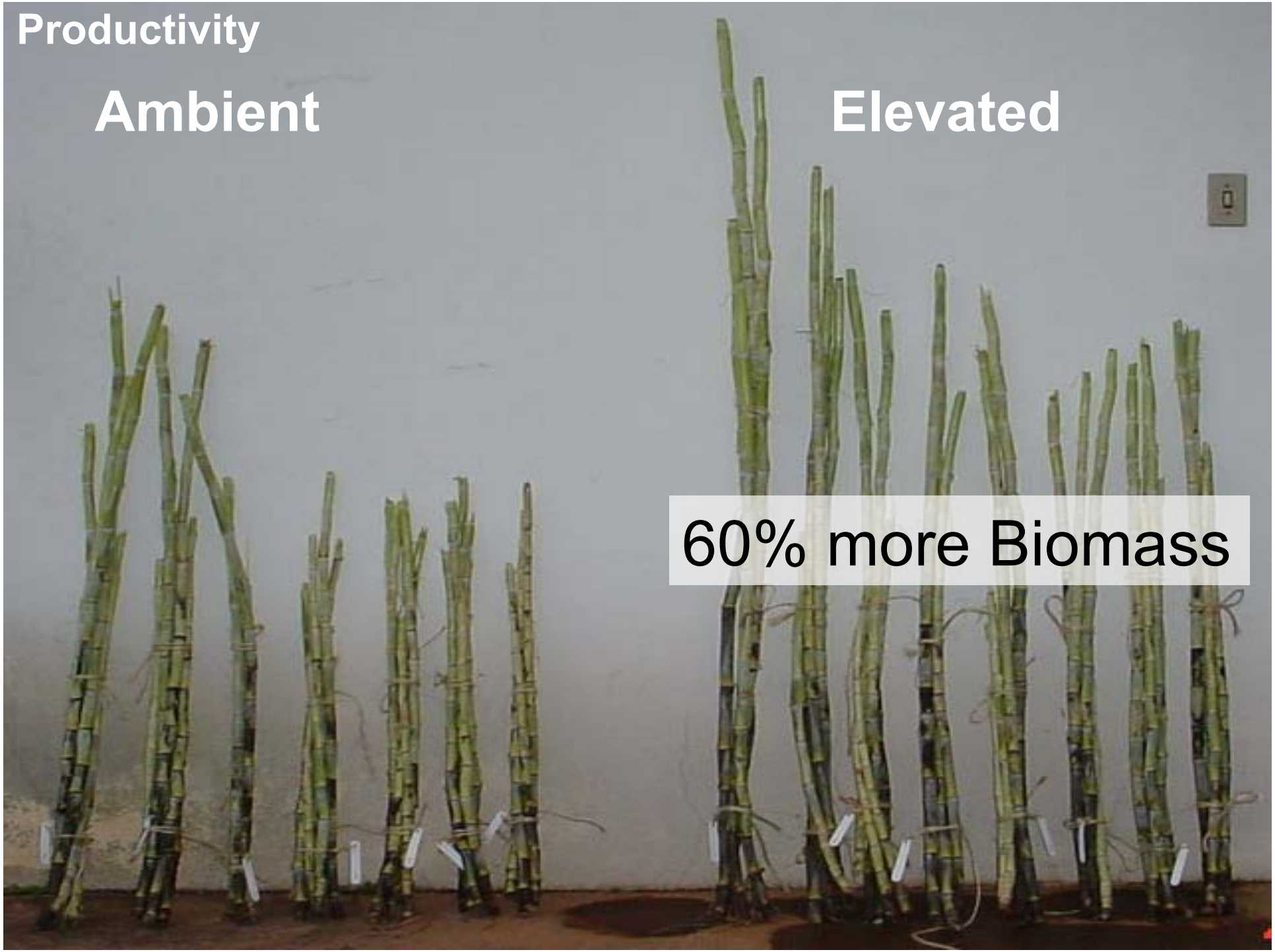
Microarray analysis of the CO_2 experiments

3 months		
Categories	**Gene description**	**Ratio (elevated/ ambient)**
Development	light-induced protein	1,194
Photosynthesis	photosystem II protein K; psbK	1,315
Photosynthesis	Ferredoxin I; chloroplast precursor	1,26
Photosynthesis	photosystem I reaction centre subunit n, chloroplast precursor	1,583
Cell wall metabolism	xyloglucan endo-transglycosylase/ hydrolase	2,582
Photosynthesis	Chlorophyll A-B binding protein	1,508
Stress response	ASR-like	1,735
Lipid, fatty-acid and isoprenoid metabolism	AE9 stearoyl-ACP desaturase	3,59
Carbohydrate metabolism	beta-glucosidase isozyme 2 precursor	-2,189
Carbohydrate metabolism	putative glucose-6-phosphate dehydrogenase	-1,232
Protein metabolism	translational initiation factor eIF-4A	-1,606


30% less transpiration
60% higher WUE
Ambient
Elevated

Roots of sugar cane

ASPECT AFTER 3 MONTHS - Note that the comparison is between 3 plants from 360ppm agains two plants from 720ppm of CO_2


Productivity
Ambient
Elevated
60% more Biomass

SUGAR & FIBER

	BRIX	Fiber(% FW)	Sucrose (% FW)
Ambient	7.17 ± 0.21	6.62 ± 0.13	2.18 ± 0.20
Elevated	7.75 ± 0.17	7.13 ± 0.21	2.82 ± 0.14*

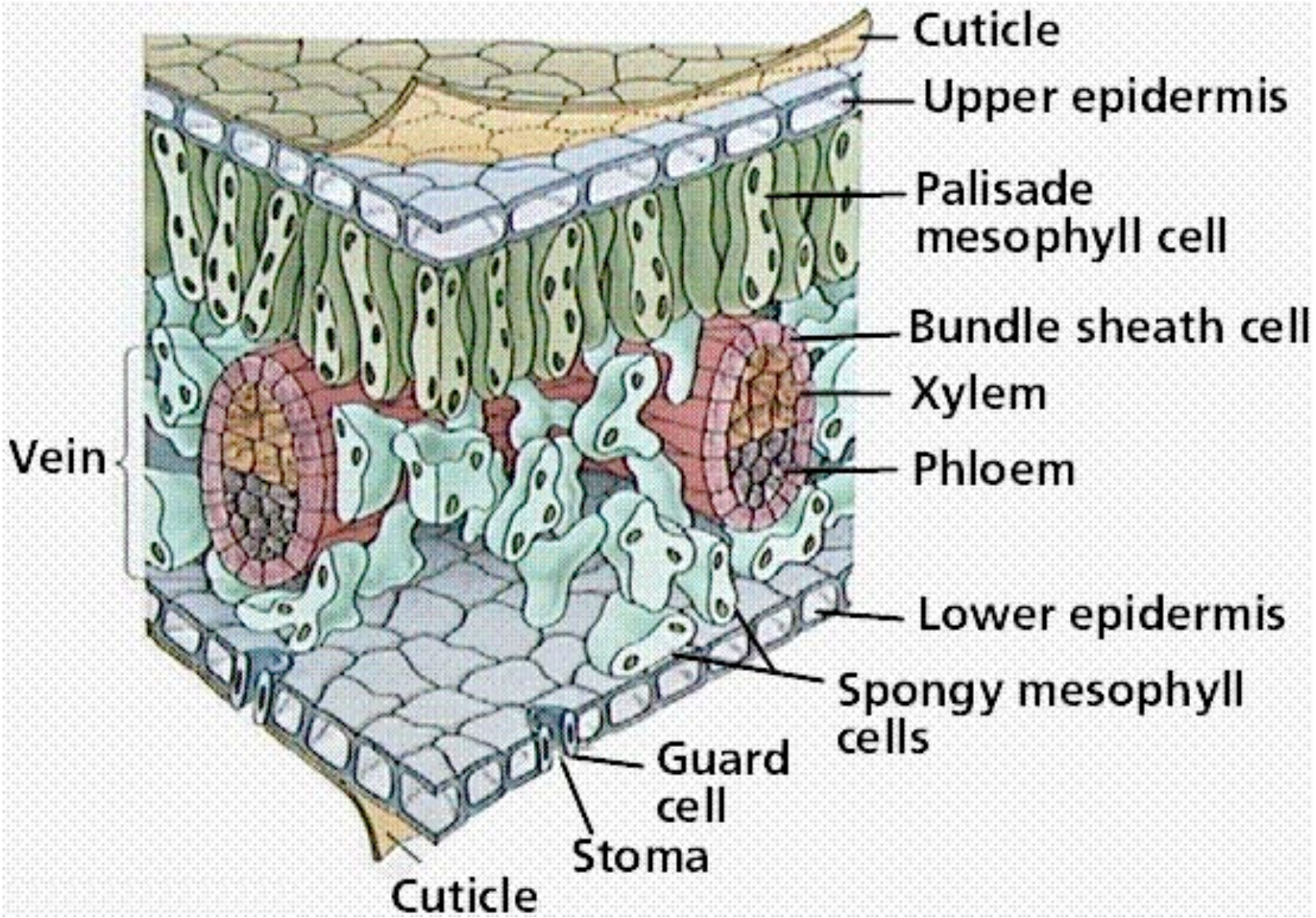
Speculative calculations

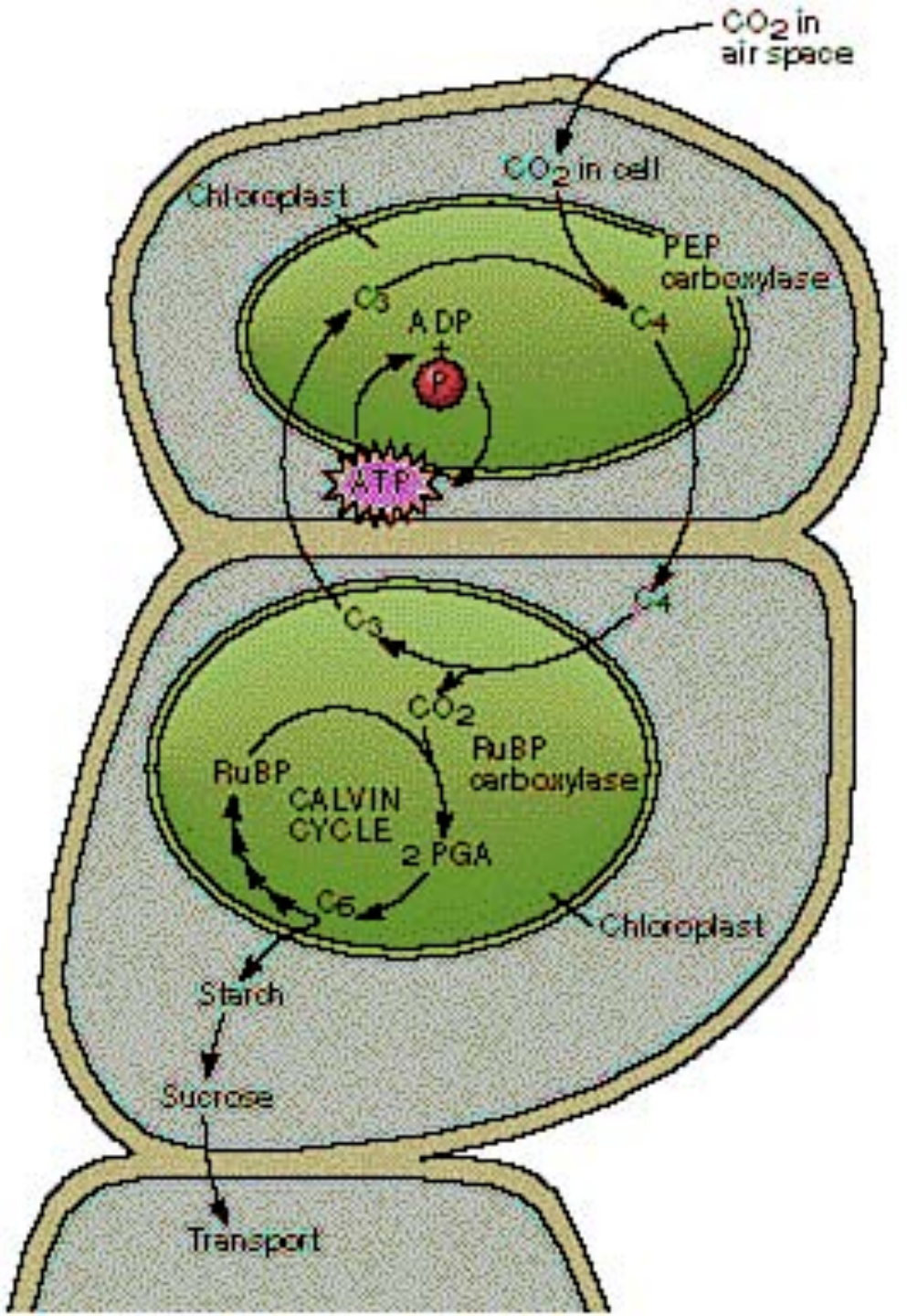
2006 – 386.6 millions of tons
Alcohol – 15.93 millions of m^3
Fiber – 25,69 millions of tons

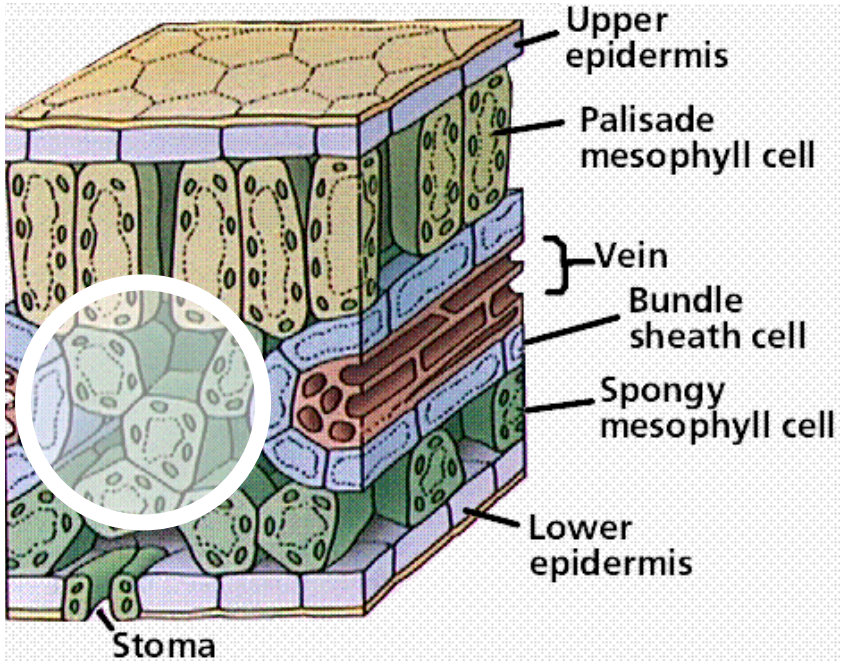
2050 – 649.5 millions of tons
Alcohol 26.76 millions of m^3
Fiber - 46.31 millions of tons

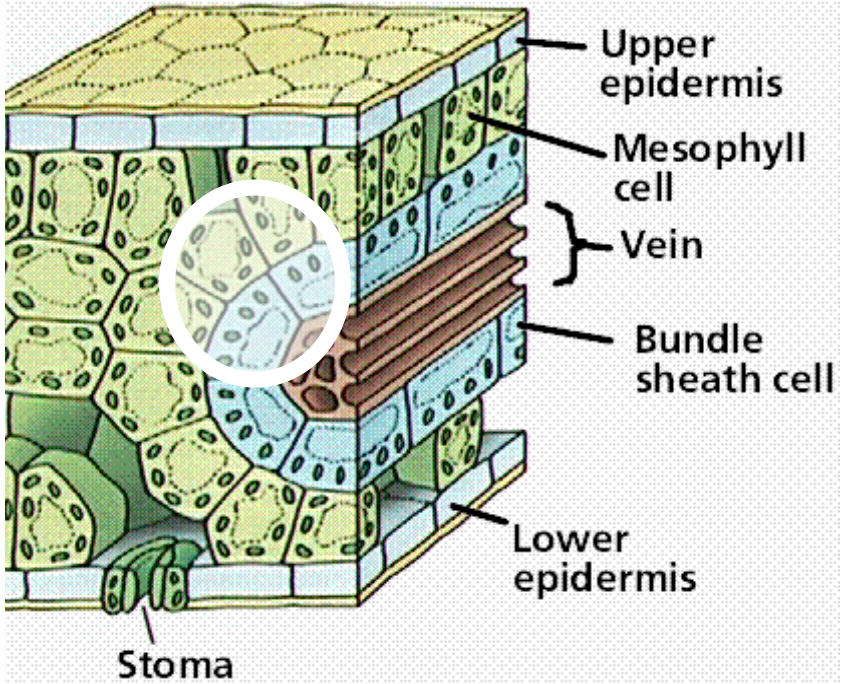
Can we use what we have lernt to obtain higher productivity before 2050

2008
75 days under elevated CO_2

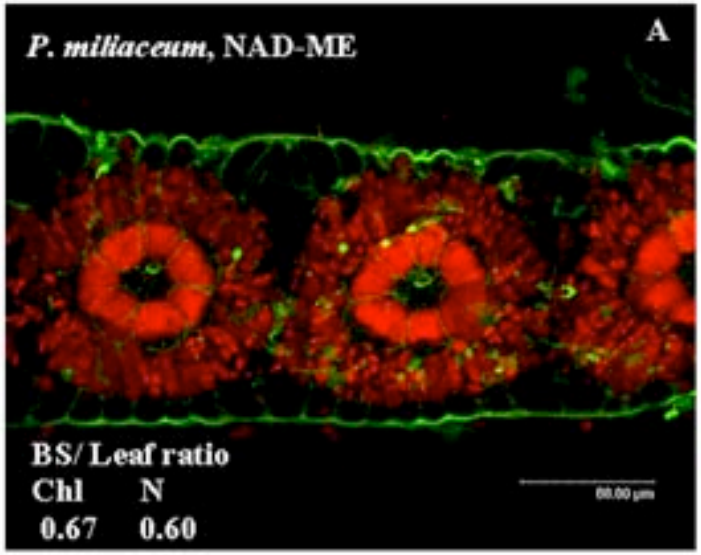

Cuticle
Upper epidermis
Palisade mesophyll cell
Bundle sheath cell
Xylem
Phloem
Vein
Lower epidermis
Spongy mesophyll cells
Guard cell
Stoma
Cuticle

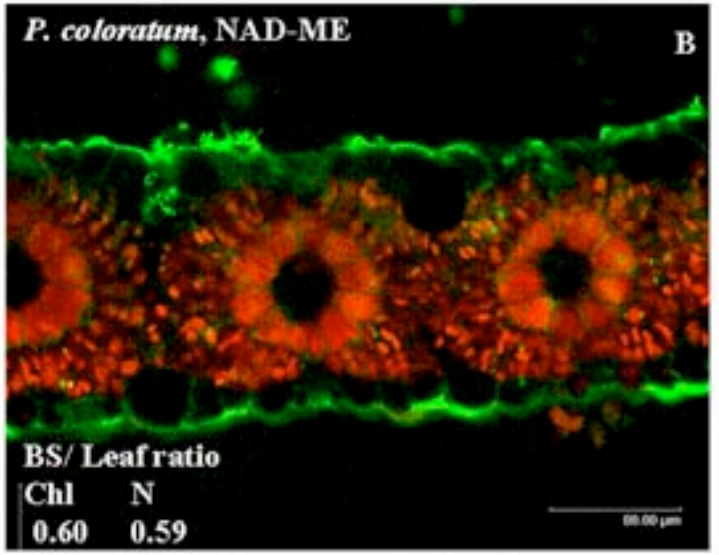

CO_2 in air space
CO_2 in cell
Chloroplast
PEP carboxylase
C3
ADP
+
P
C4
ATP
C3
C4
CO_2
RuBP carboxylase
RuBP
CALVIN CYCLE
2 PGA
C6
Chloroplast
Starch
Sucrose
Transport

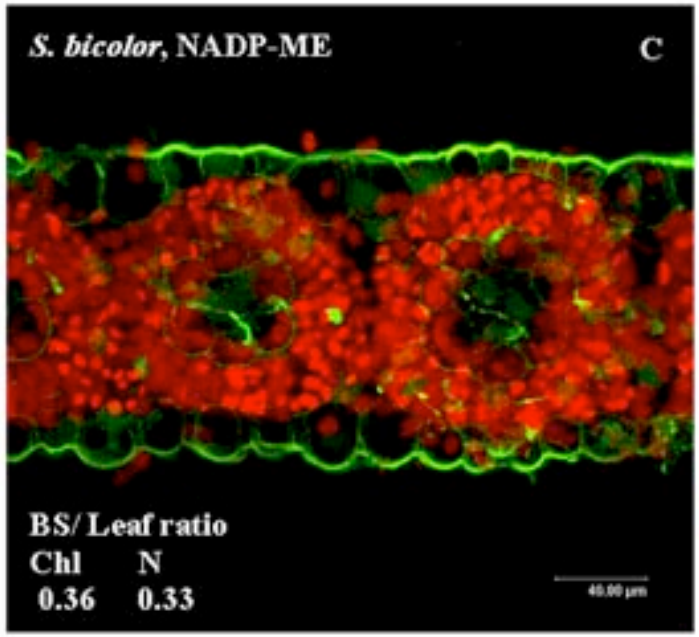

Upper epidermis
Palisade mesophyll cell
Vein
Bundle sheath cell
Spongy mesophyll cell
Lower epidermis
Stoma

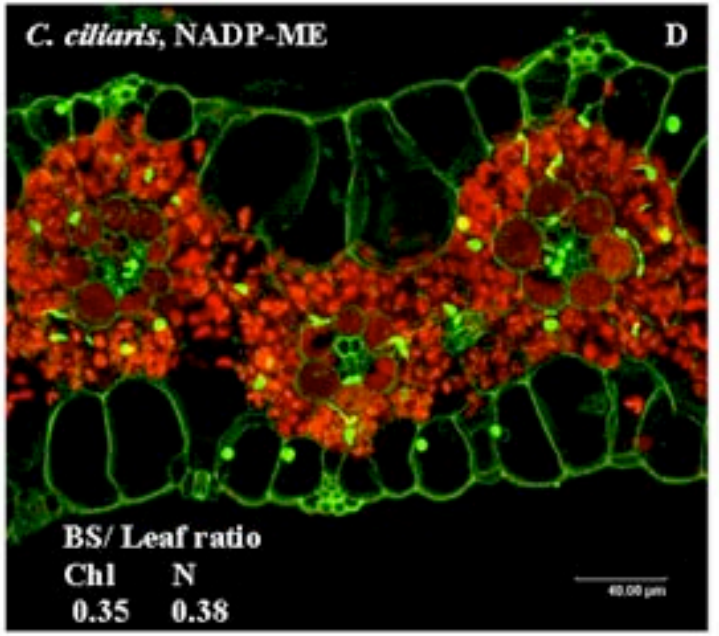

Upper epidermis
Mesophyll cell
Vein
Bundle sheath cell
Lower epidermis
Stoma

Chlorophyll auto-fluorescence using confocal microscopy

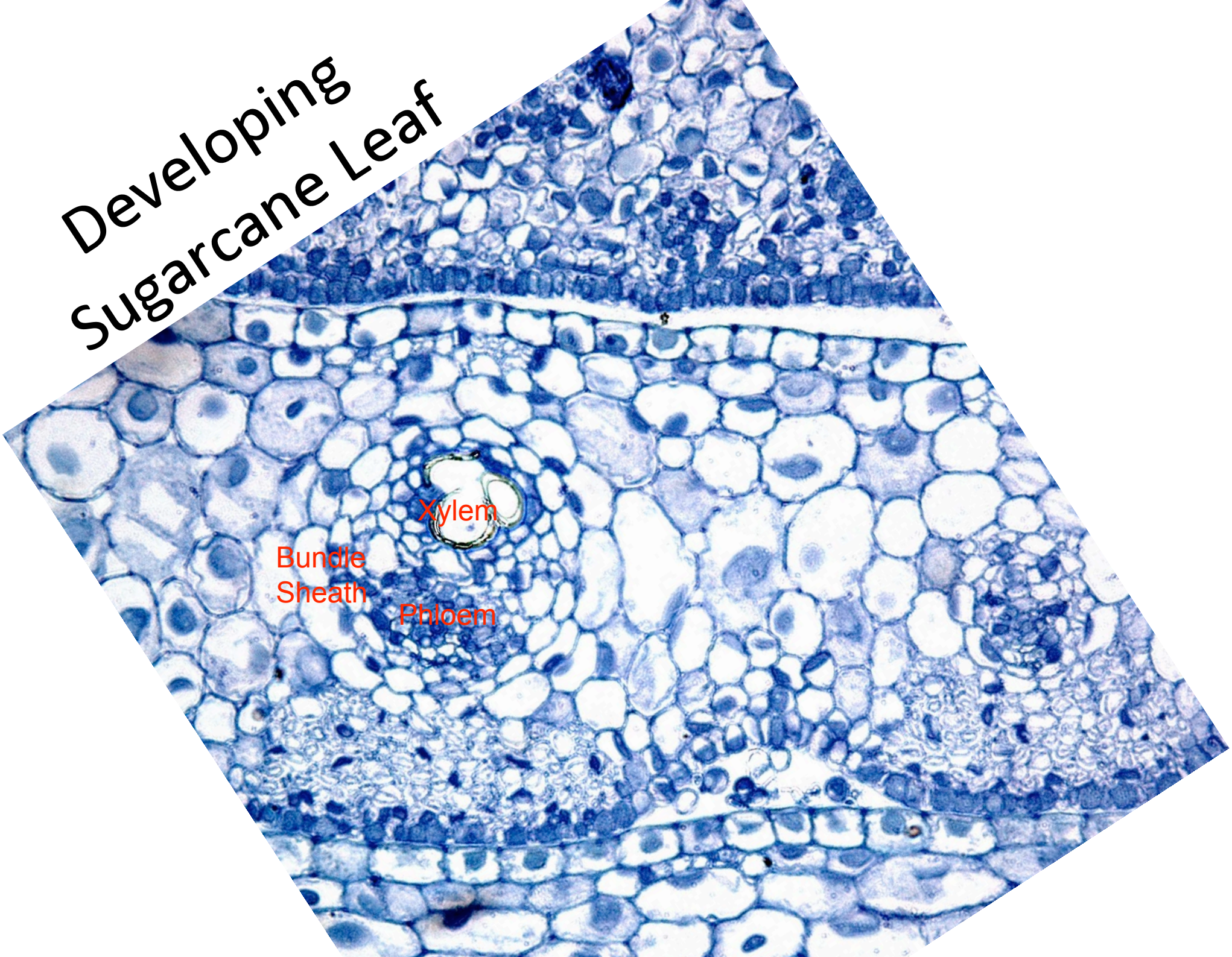


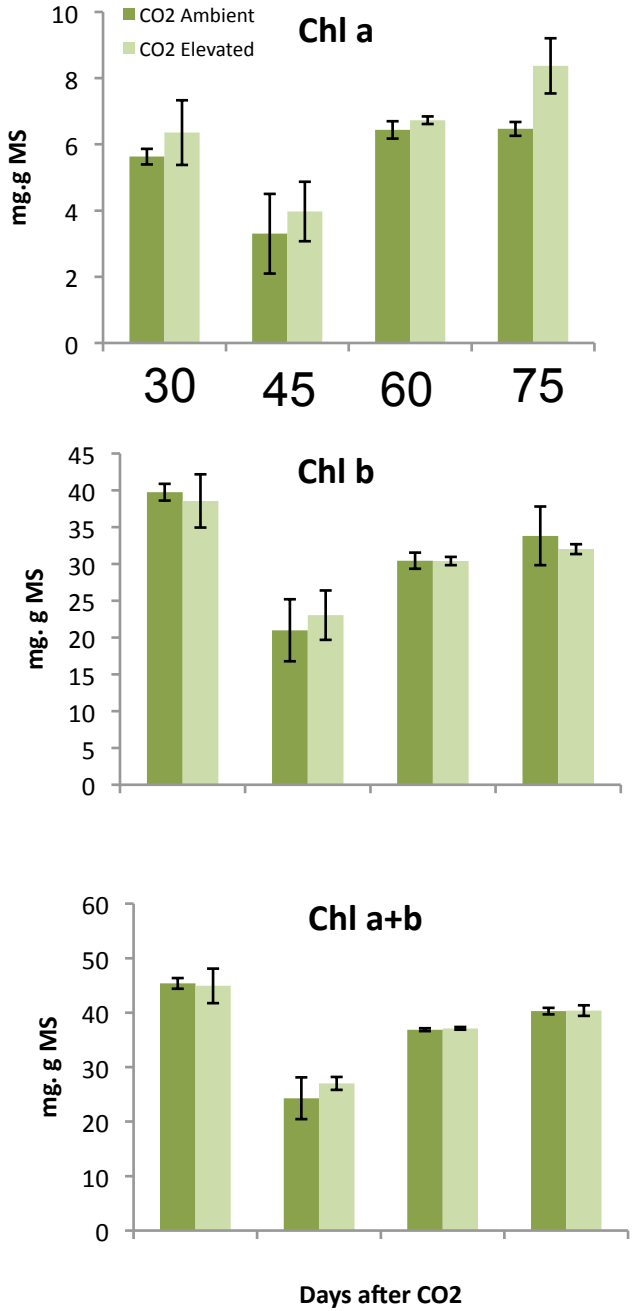






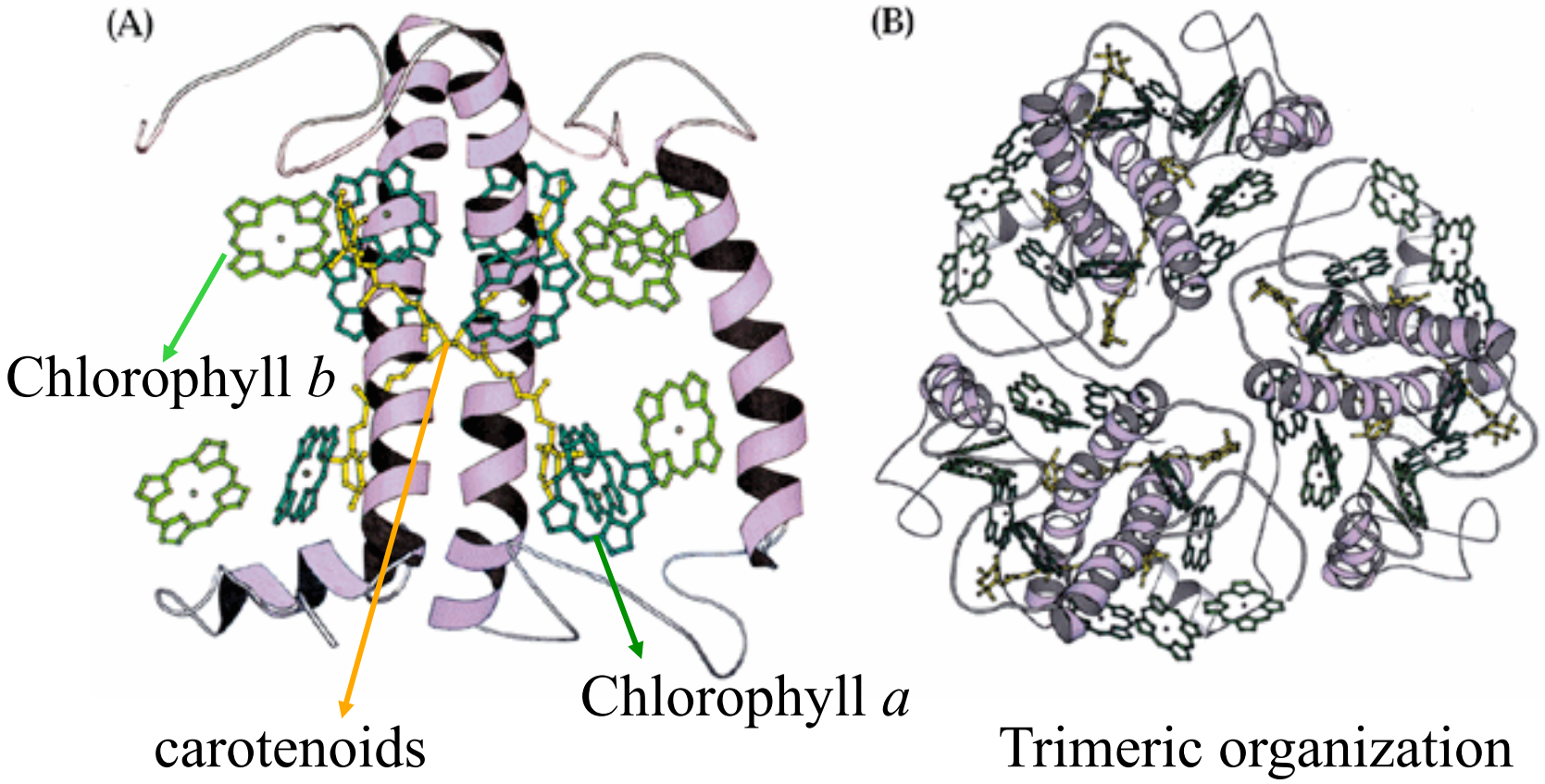
Developing Sugarcane Leaf





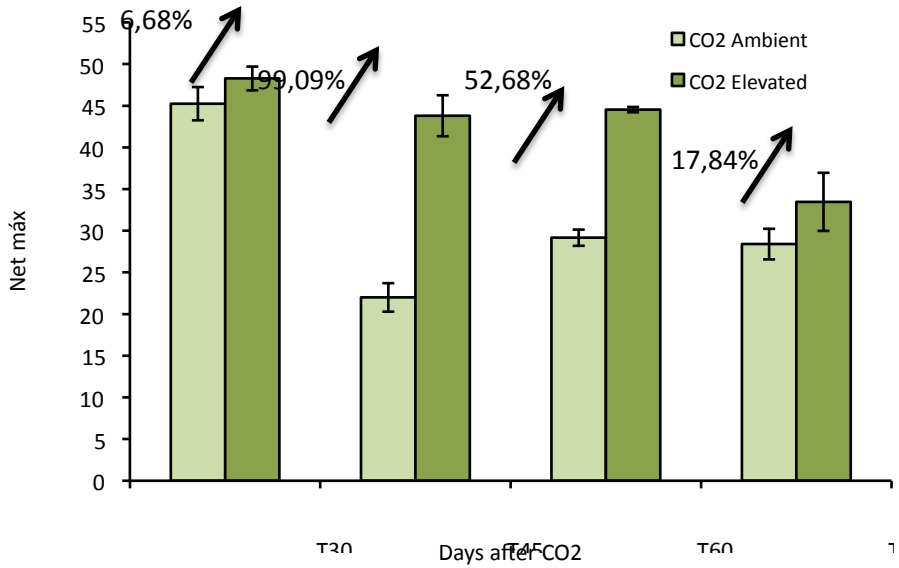
CHLOROPHYLL CONTENT IN SUGARCANE LEAVES UNDER ELEVATED CO_2

Structure of the light harvesting proteins

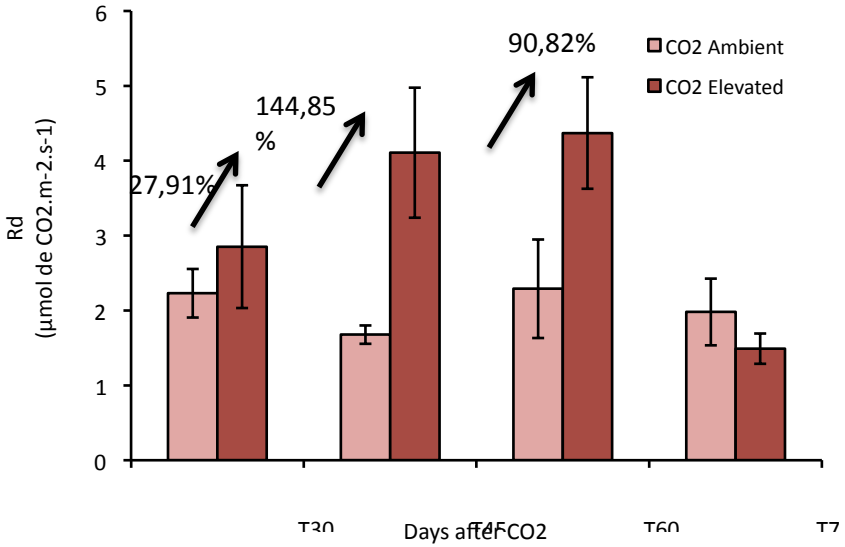


Photosynthesis in sugarcane under elevated CO2

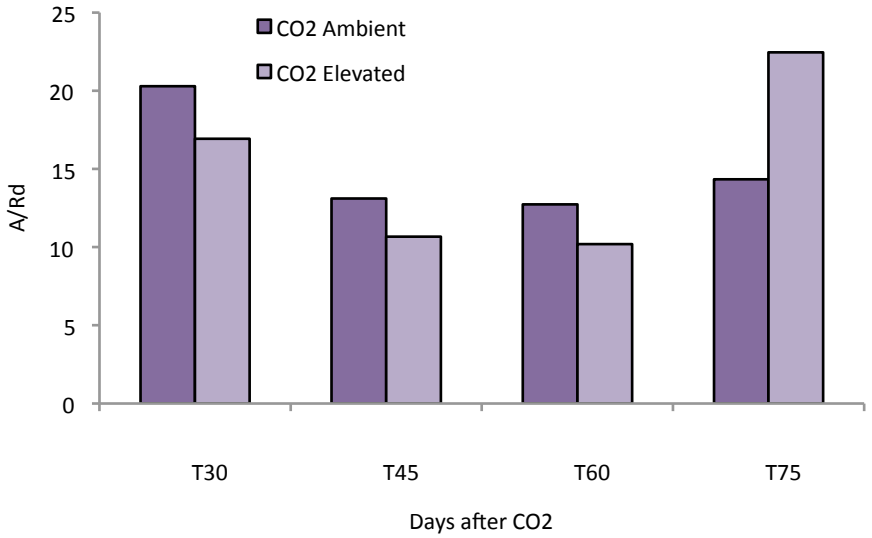
NET PHOTOSYNTHESIS



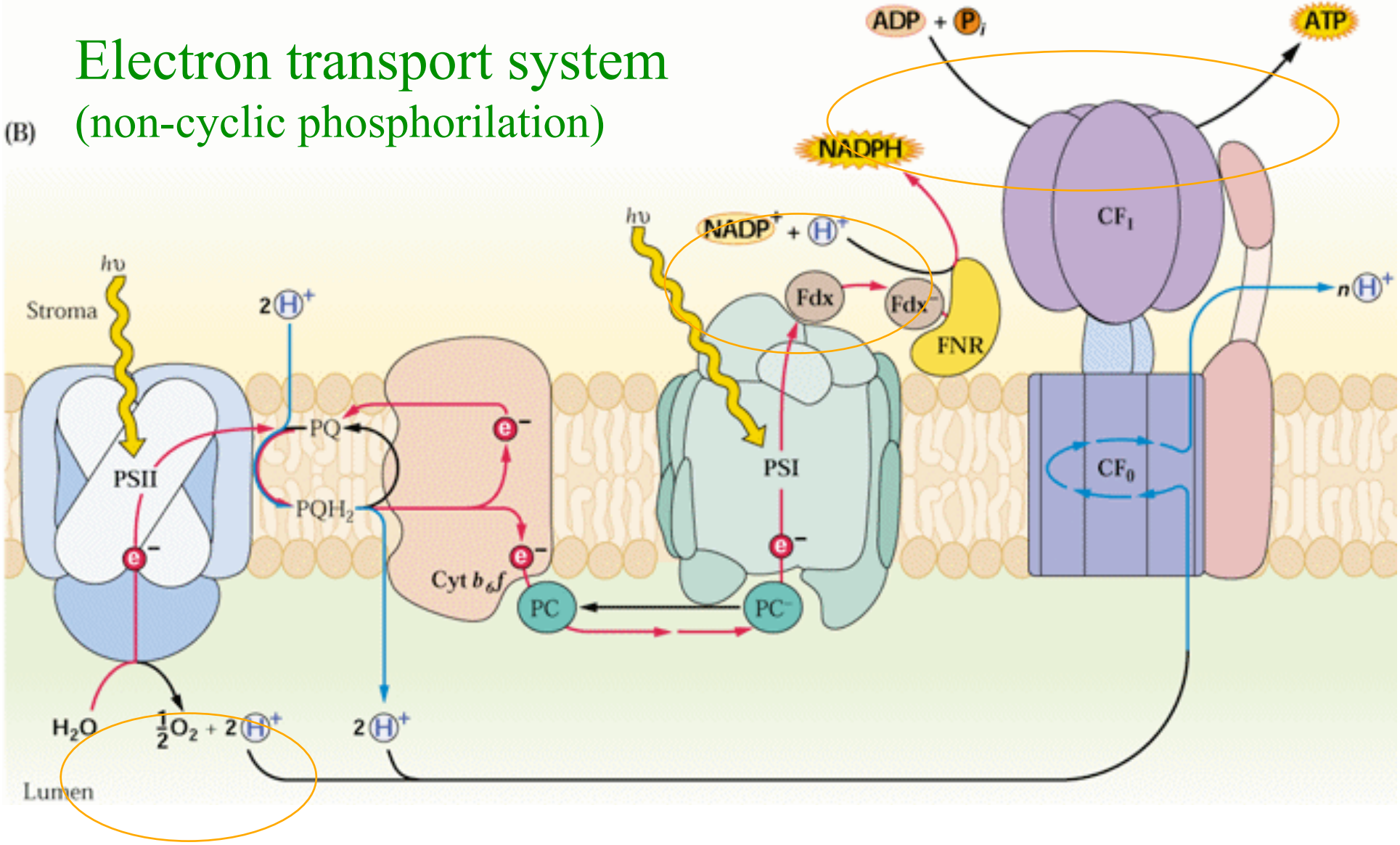
DARK RESPIRATION

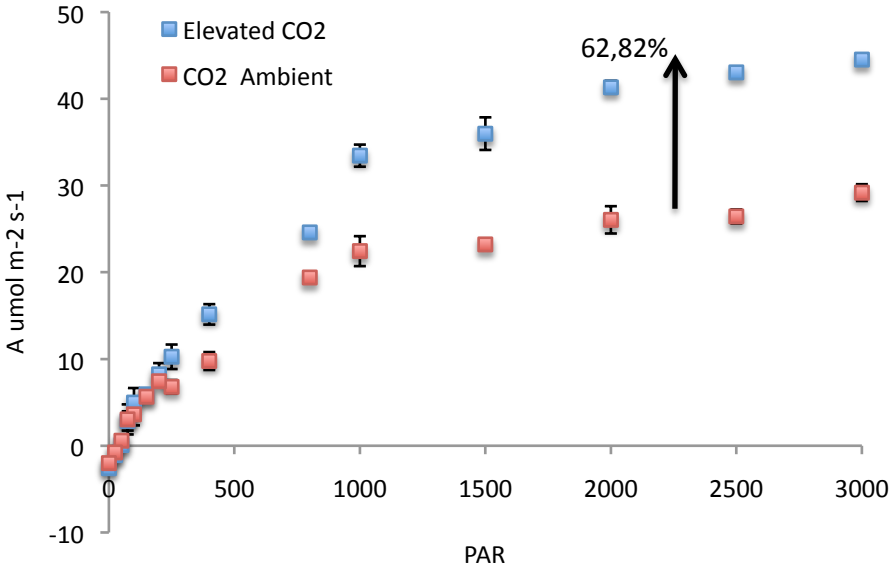


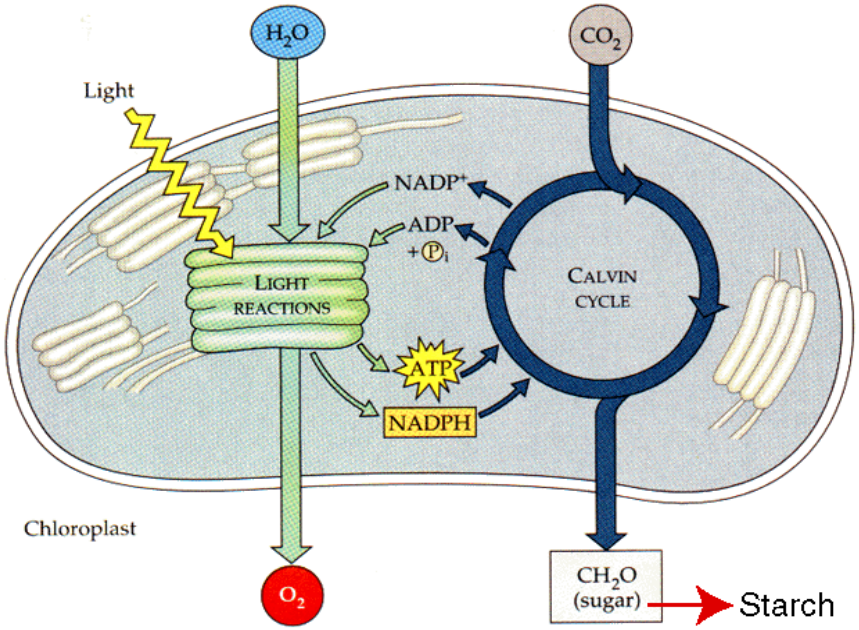
ASSIMILATION/RESPIRATION

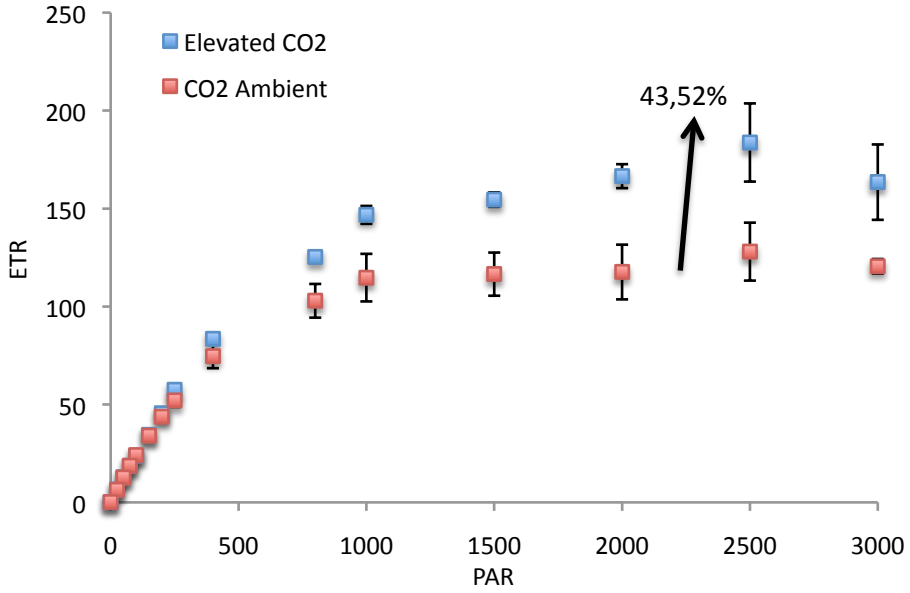


Electron transport system
(non-cyclic phosphorilation)

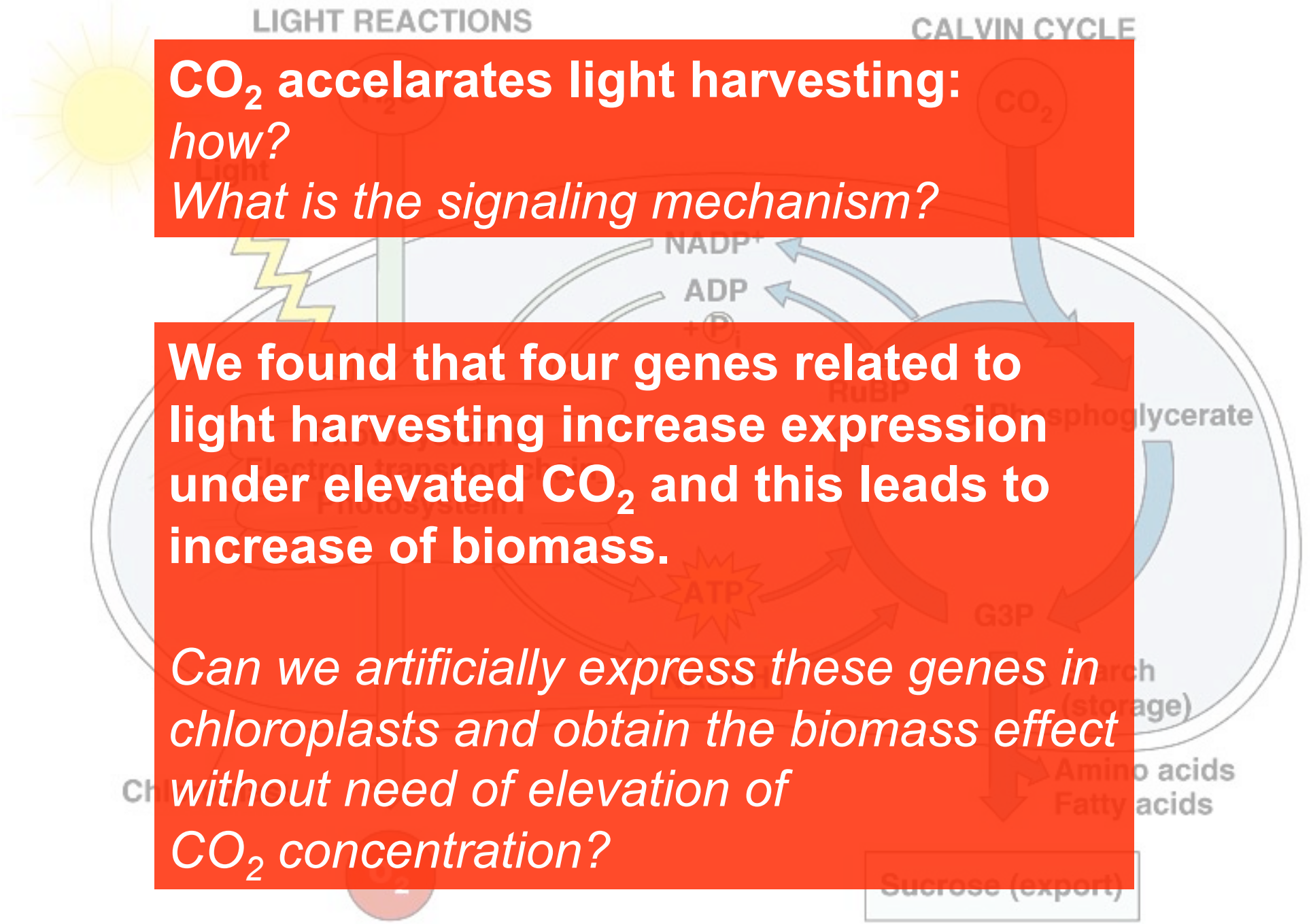








CO_2 assimilation and electron transport rate of sugarcane under elevated CO_2



CO_2 accelarates light harvesting:
how?
What is the signaling mechanism?

We found that four genes related to light harvesting increase expression under elevated CO_2 and this leads to increase of biomass.

Can we artificially express these genes in chloroplasts and obtain the biomass effect without need of elevation of CO_2 concentration?

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THANK YOU

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