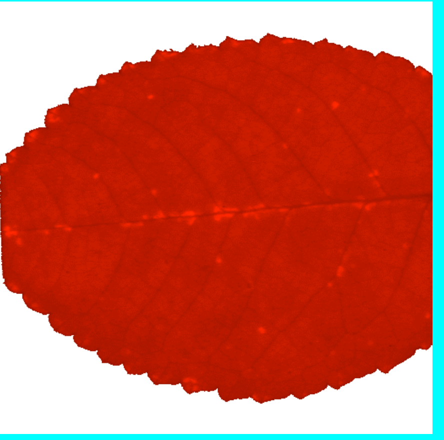
The basic relationships between chlorophyll fluorescence and photosynthesis in plants :

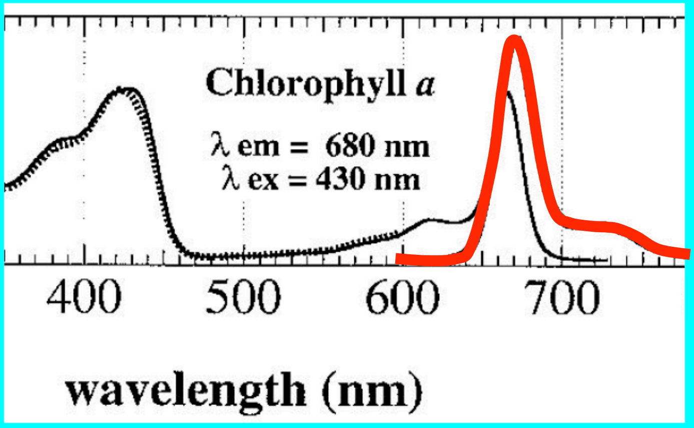
some theory and experimental evidence

- background
- examples

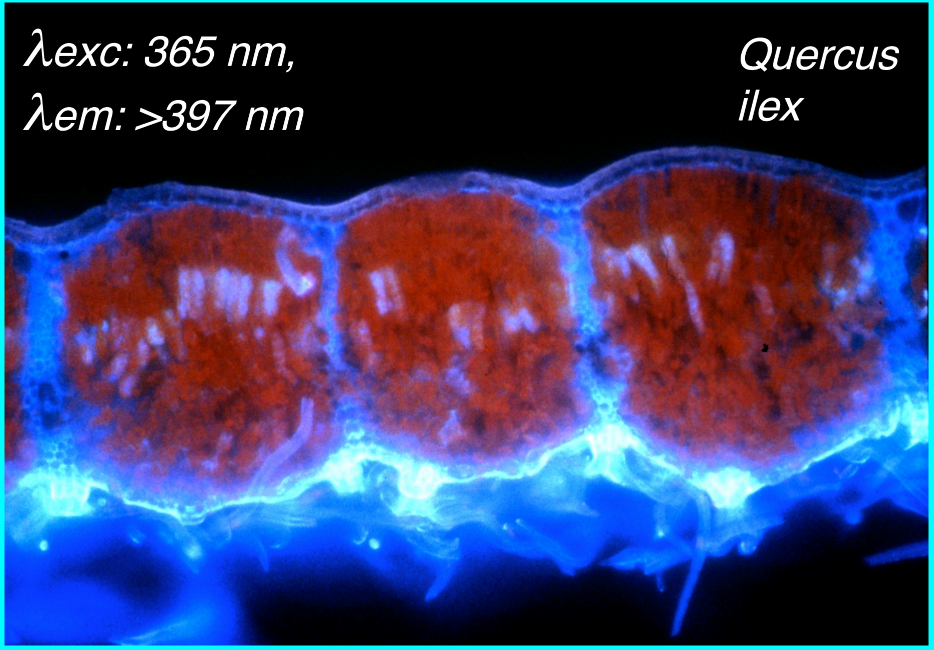


Bernard Genty, Cadarache

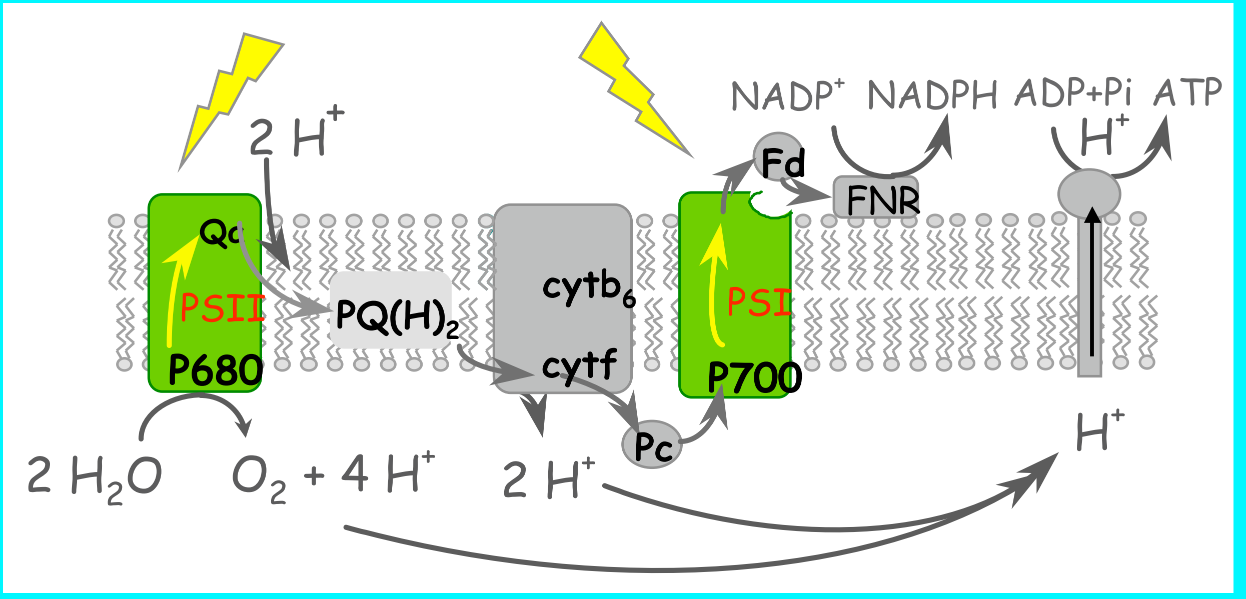
chlorophyll fluorescence in higher plants :



- red, far-red emission by Chl a

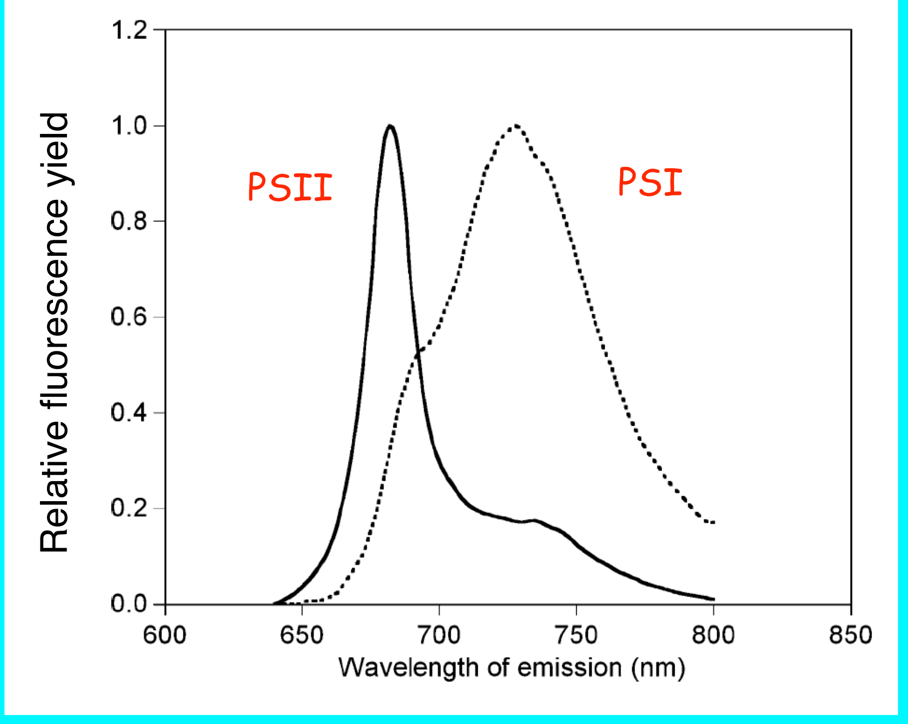


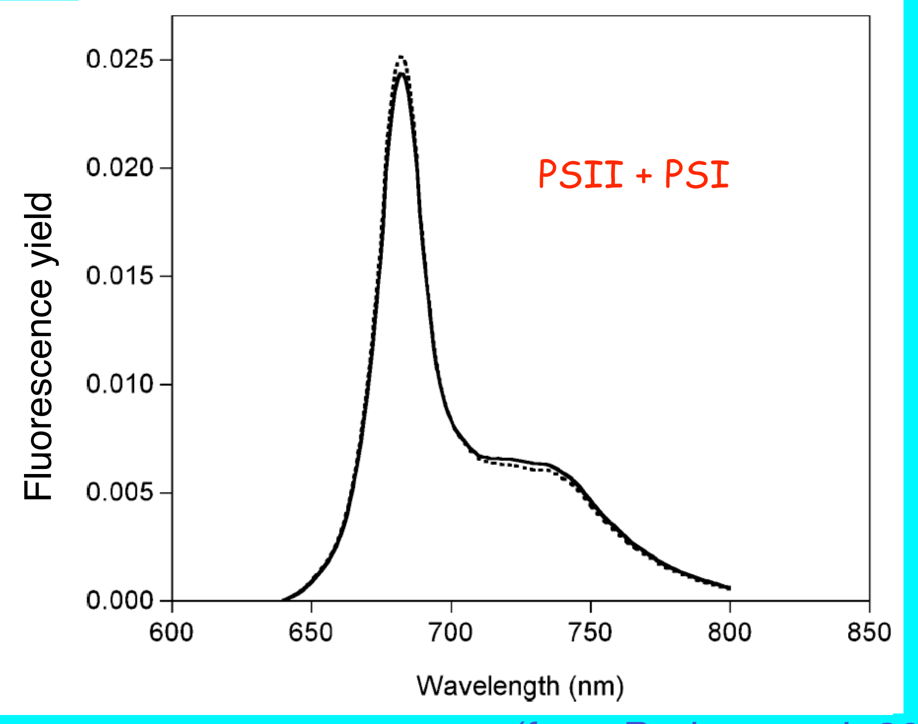
- radiative de-excitation of absorbed light in antenna of photosystems



[PSII] / [PSI] ≈ 1.5

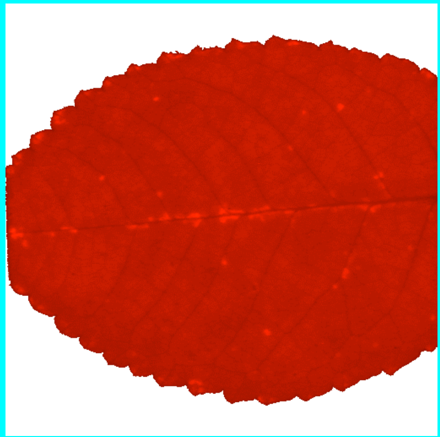
$\Phi_{PSII} \approx 5\ \Phi_{PSI}$

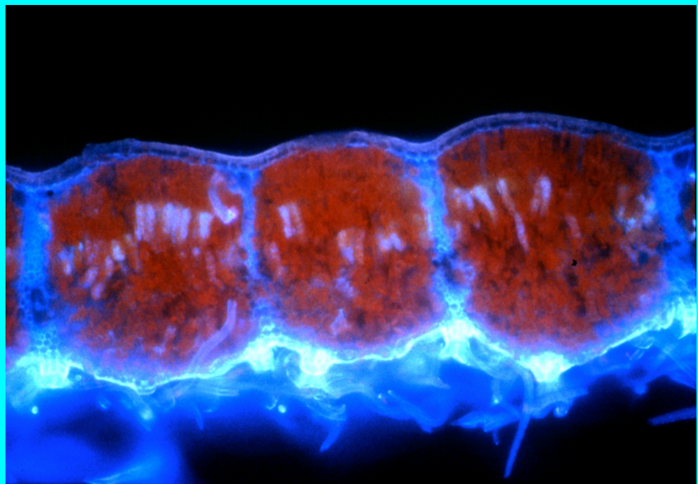


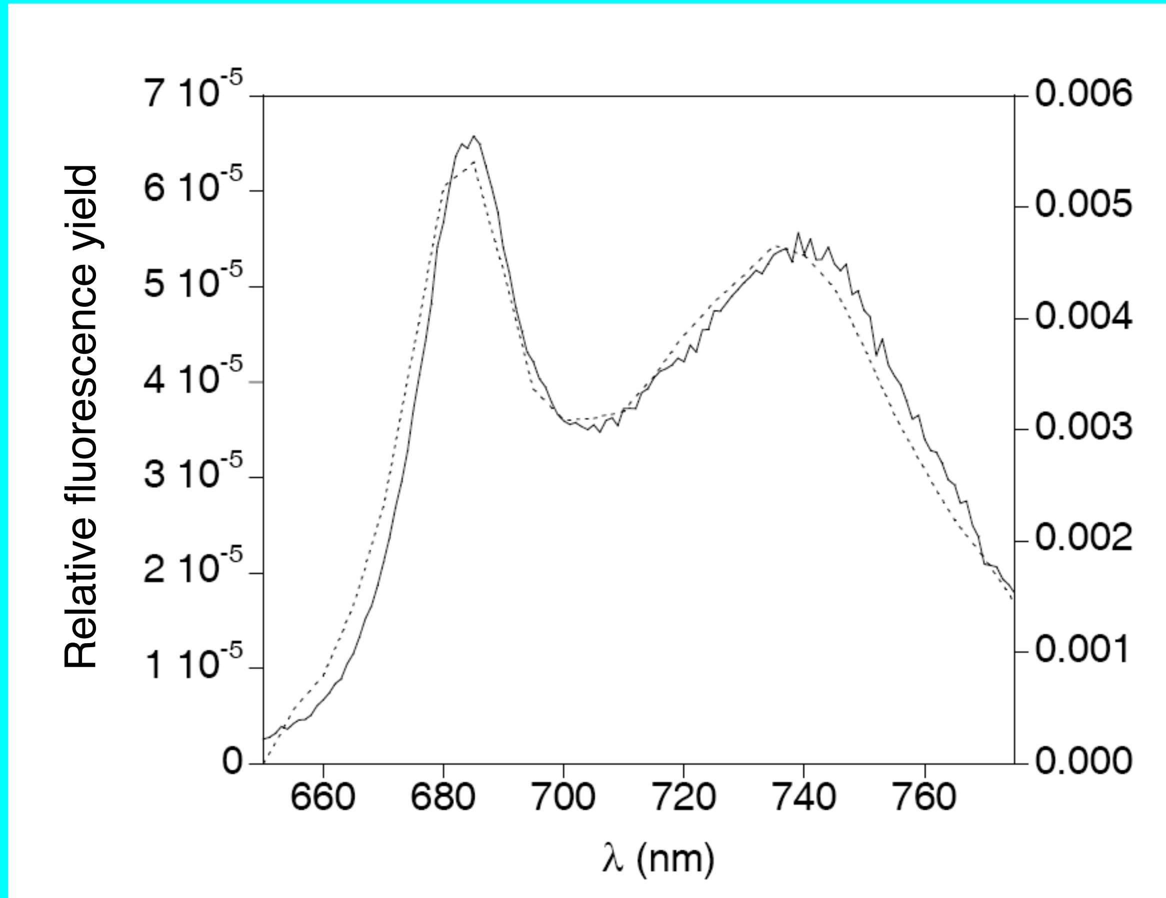


(from Pedros et al. 2008)

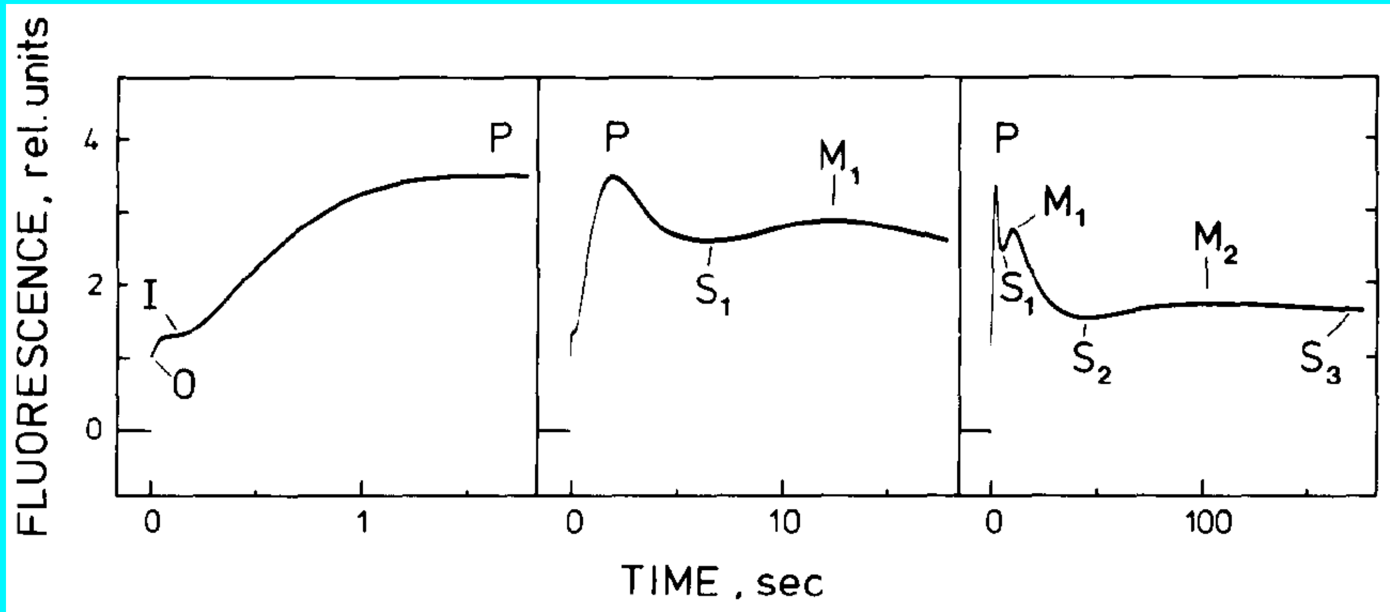
but in leaf, strong re-absorption !

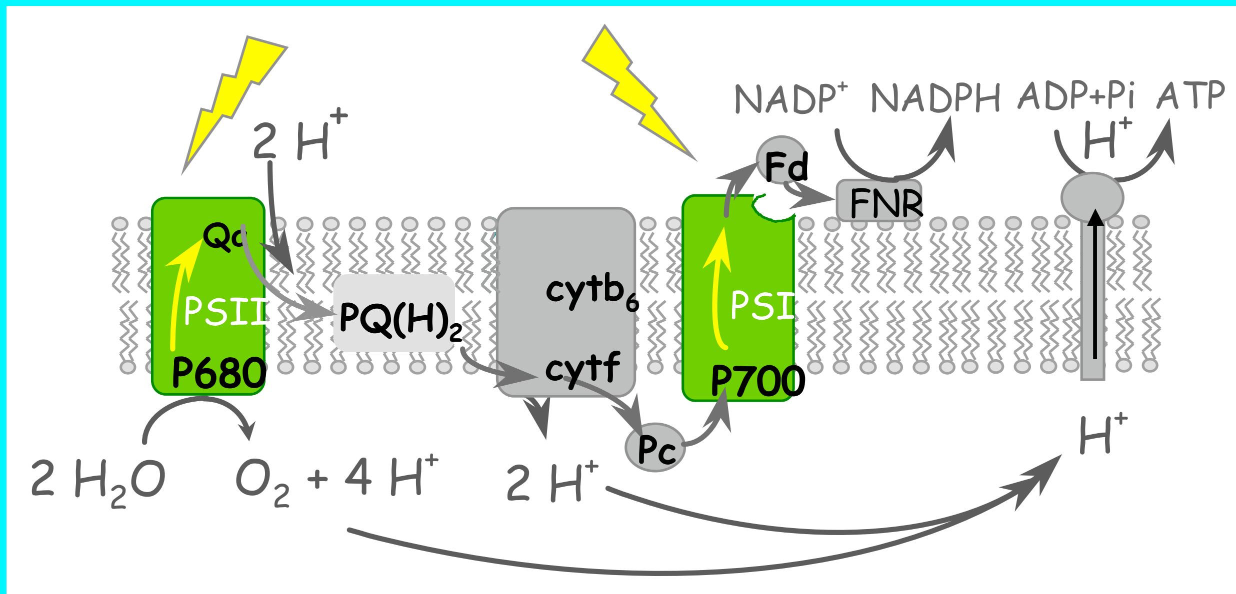


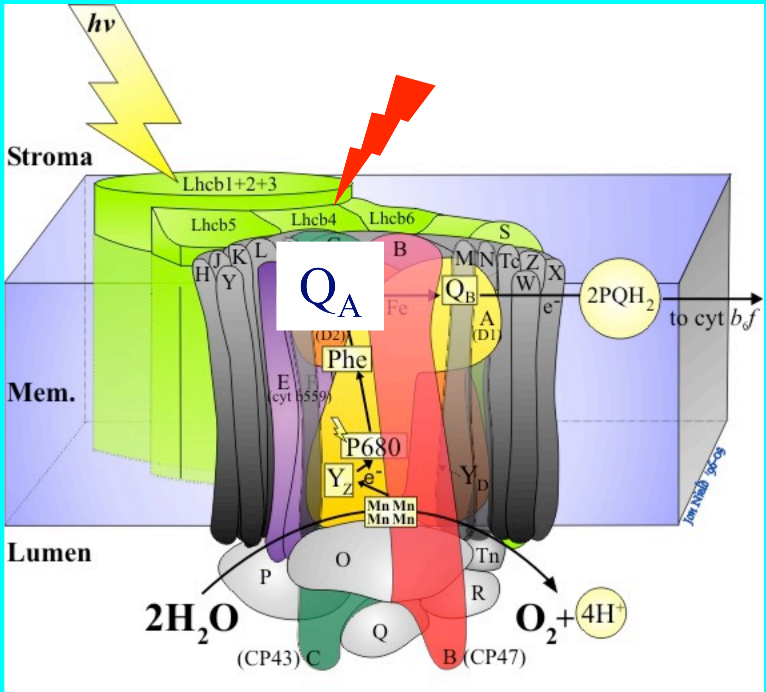


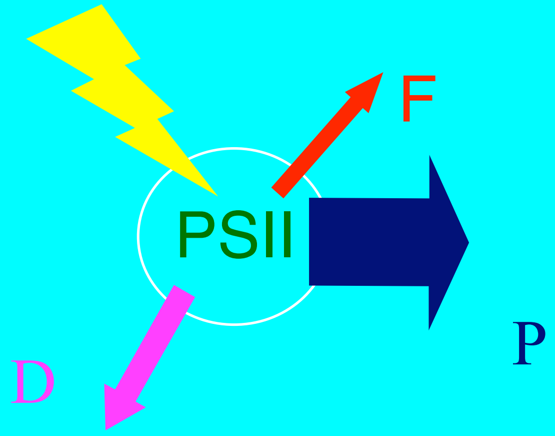


(from Pedros et al. 2004)


FLUORESCENCE, rel. units
0
2
4
I
O
P
M1
S1
M2
S2
S3
0
1
0
10
0
100
TIME , sec


2 H+
NADP+
NADPH
ADP+Pi
ATP
H+
Fd
FNR
Qa
PSII
PQ(H)2
cytb6
cytf
PSI
P680
P700
Pc
2 H2O
O2 + 4 H+
2 H+
H+





- *in vivo*, at PSII, fluorescence yield is variable and is modulated by competitive pathways for de-excitation at PSII : photochemistry and thermal dissipation the fluorescence yield at PSII can be described as :

$$\Phi_F = \frac{F}{I_a} = \frac{k_F}{k_F + k_D + k_P}$$

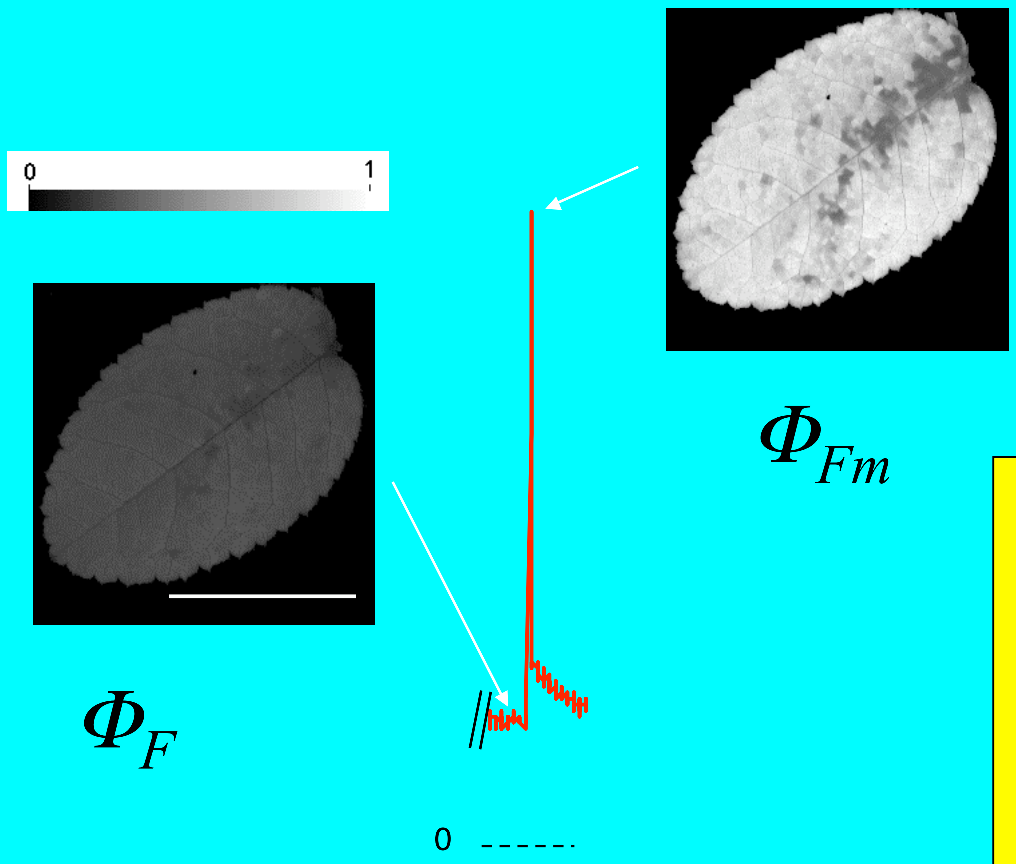
with

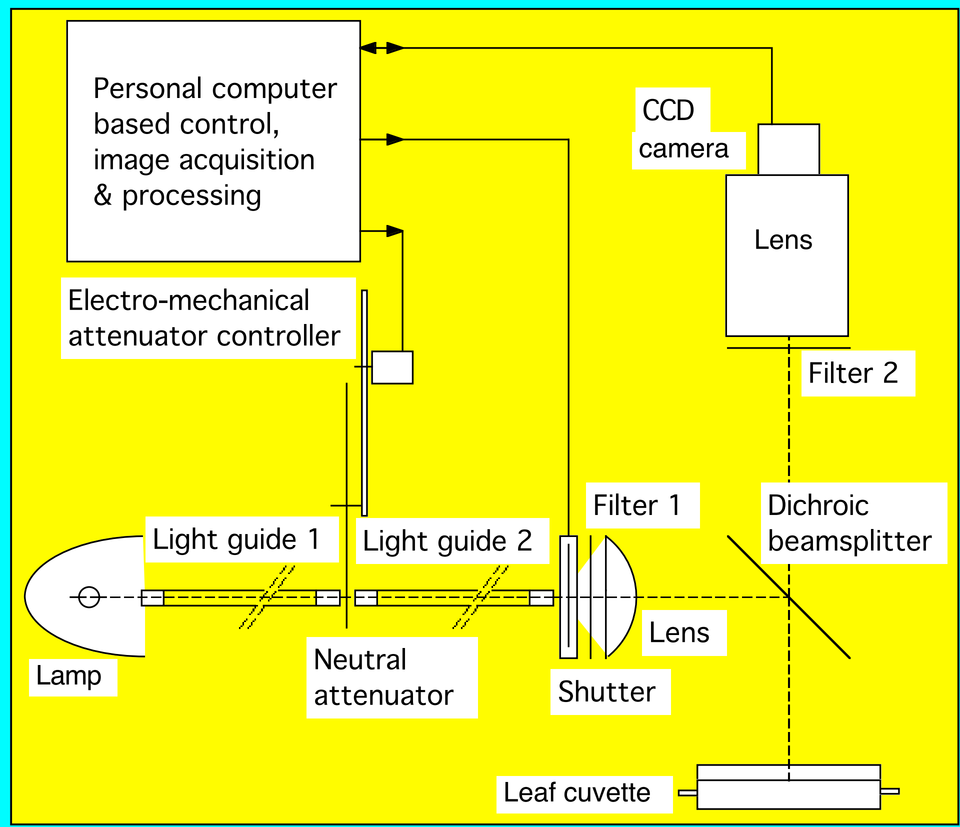
F *and* I_a : *intensity of fluorescence and absorbed light respectively*

k_F, k_D *and* k_P :
rate constants for de-excitation through fluorescence, thermal dissipation and photochemistry respectively

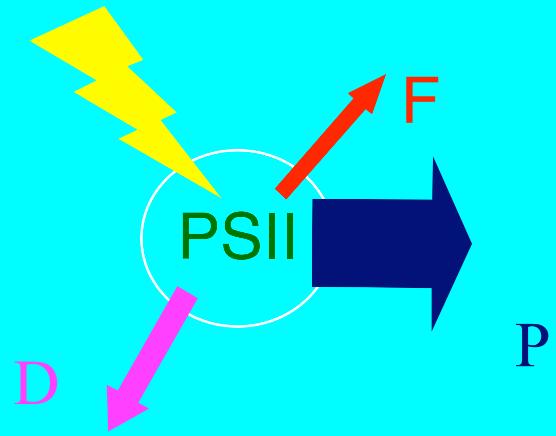
qP : *photochemical quenching*

qN : *non-photochemical quenching (NPQ)*





(Genty et al.1994)



at PSII :

Φ_P *probability of de-excitation through photochemistry (non radiative dissipation)*

Φ_D *probability of de-excitation through thermal dissipation (non radiative dissipation)*

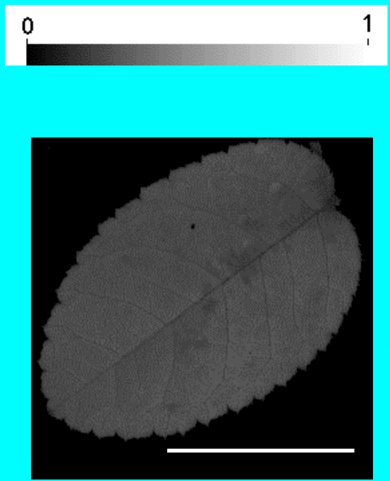
Φ_F *probability of de-excitation through fluorescence (radiative dissipation)* at steady-state: $$\Phi_P + \Phi_D + \Phi_F = 1$$

at saturation of photochemistry: $$\Phi_P \rightarrow 0 \qquad \Phi_{D_M} + \Phi_{F_M} = 1$$

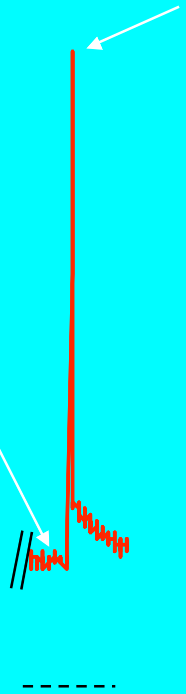
assumption: $$\frac{\Phi_D}{\Phi_F} = \frac{\Phi_{D_M}}{\Phi_{F_M}}$$

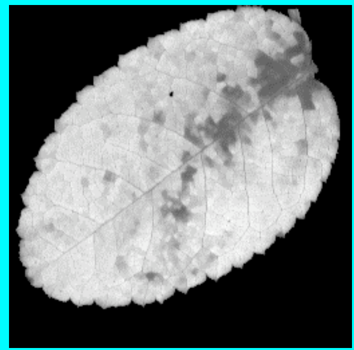
then: $$\Phi_P = 1 - \frac{\Phi_F}{\Phi_{F_M}} = \frac{\Phi_{F_M} - \Phi_F}{\Phi_{F_M}} = \frac{\Delta\Phi_F}{\Phi_{F_M}}$$

(Genty et al. 1989)



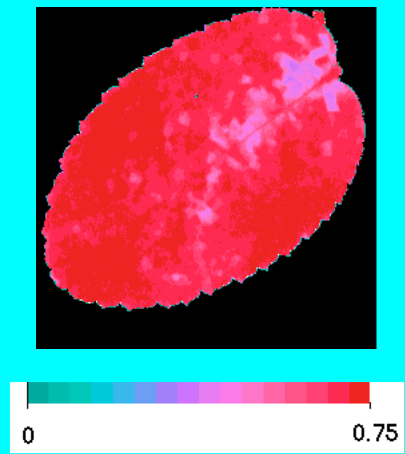
Φ_F



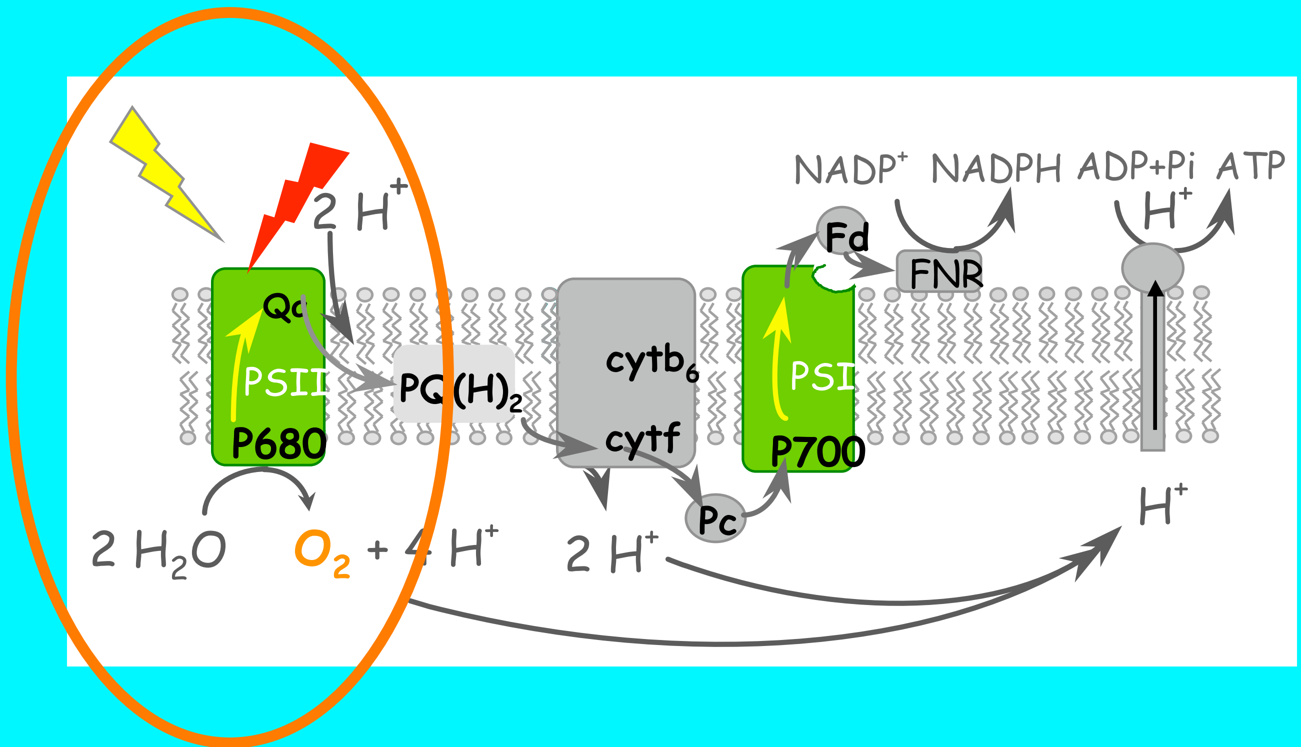


Φ_{Fm}

$$(\Phi_P)_i = 1 - (\Phi_F)_i / (\Phi_{Fm})_i$$

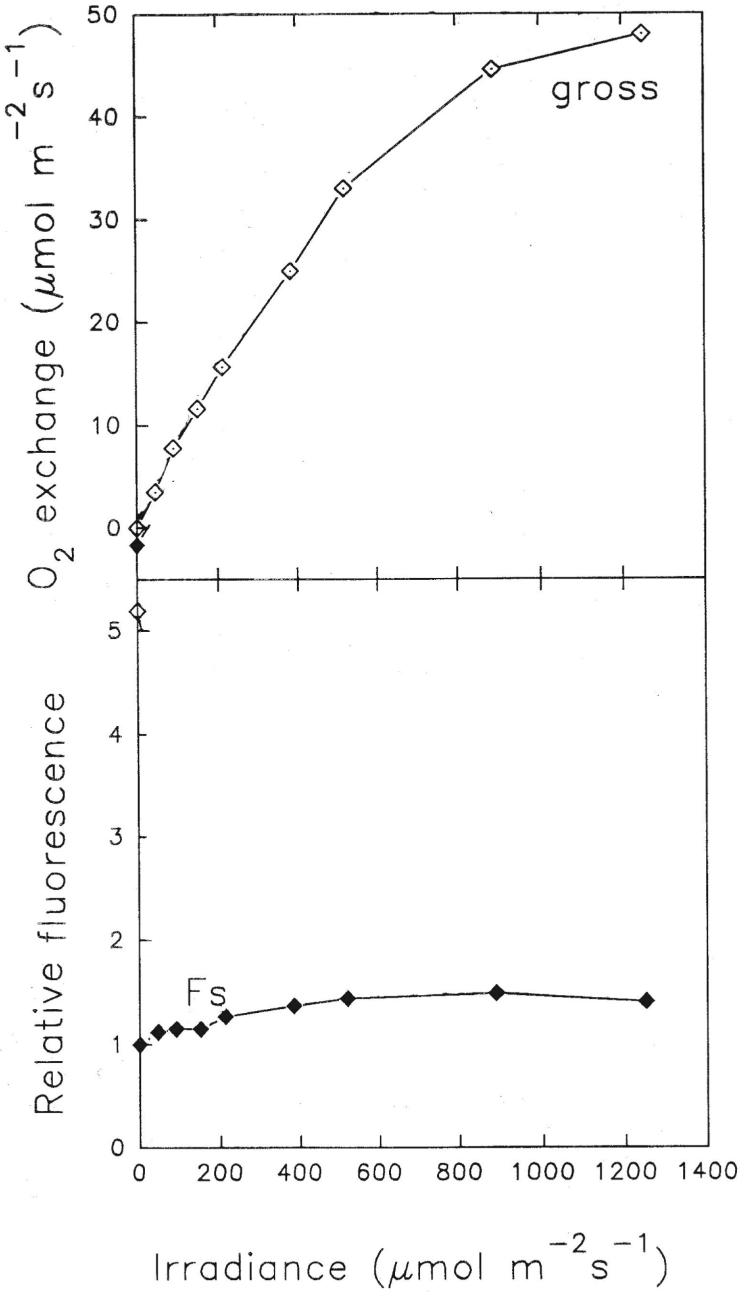


(Genty et al.1994)



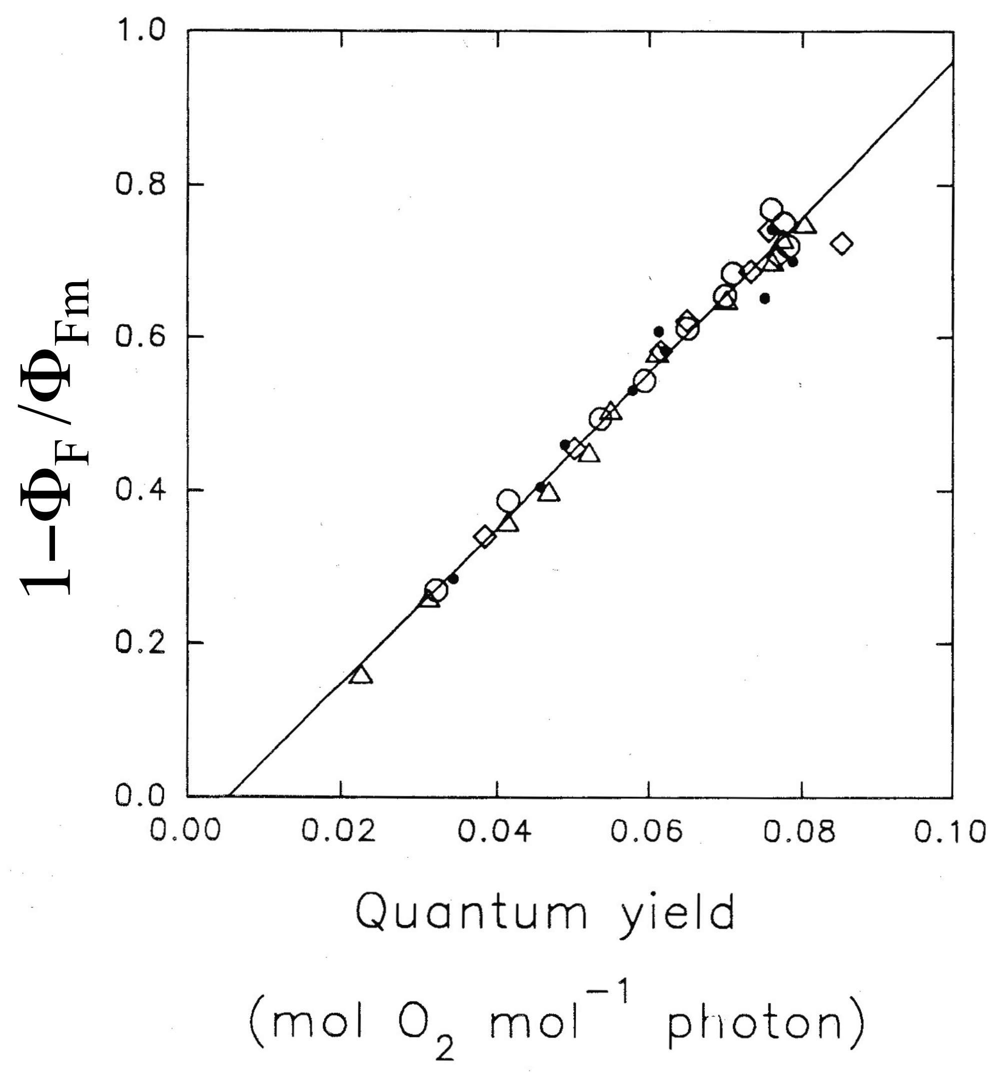
2 H+
Qa
PSII
P680
PQ(H)2
cytb6
cytf
PSI
P700
Fd
FNR
Pc
NADP+
NADPH
ADP+Pi
ATP
H+
H+
2 H2O
O2 + 4 H+
2 H+

French bean in air



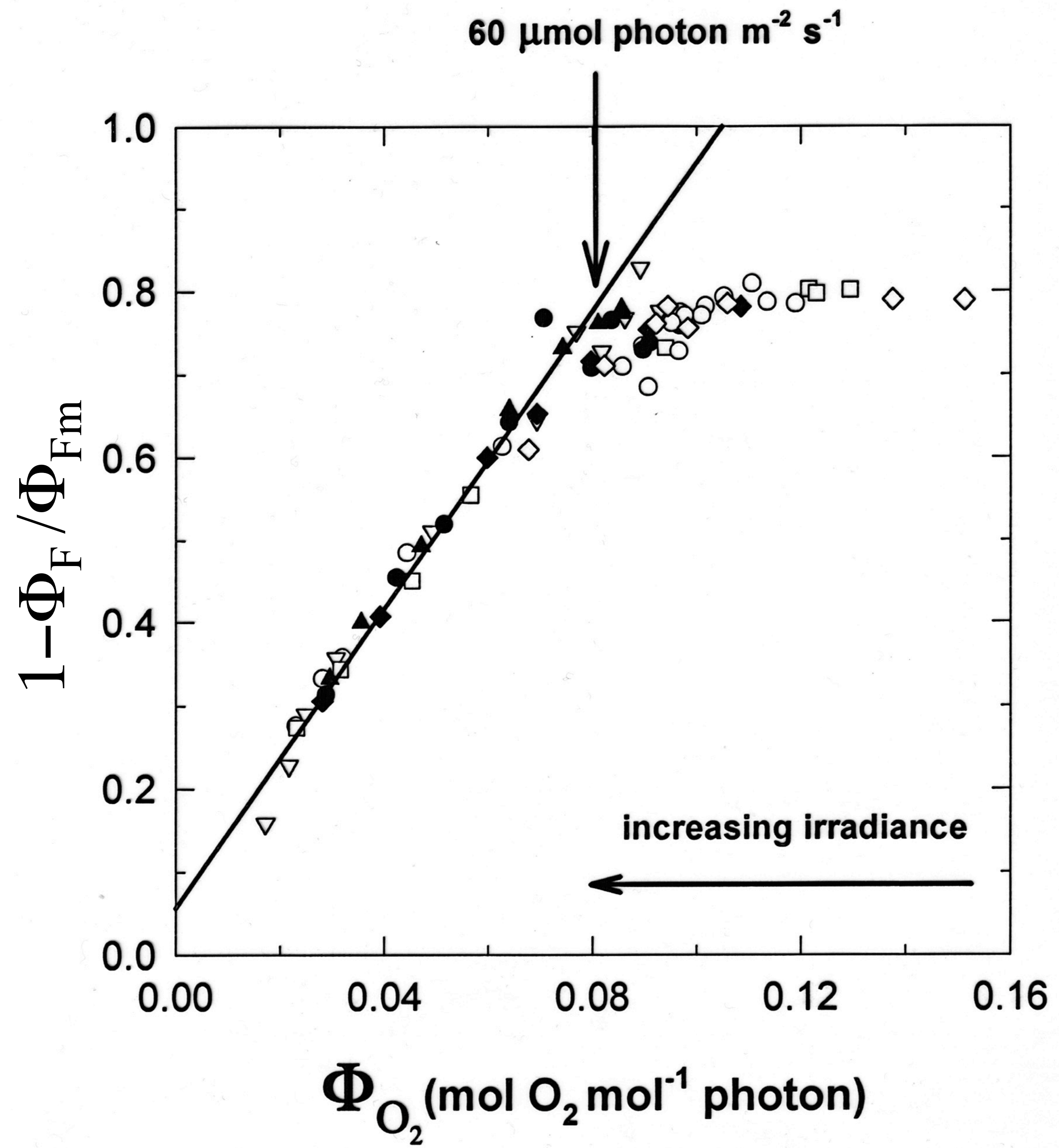
(Genty et al. 1992)

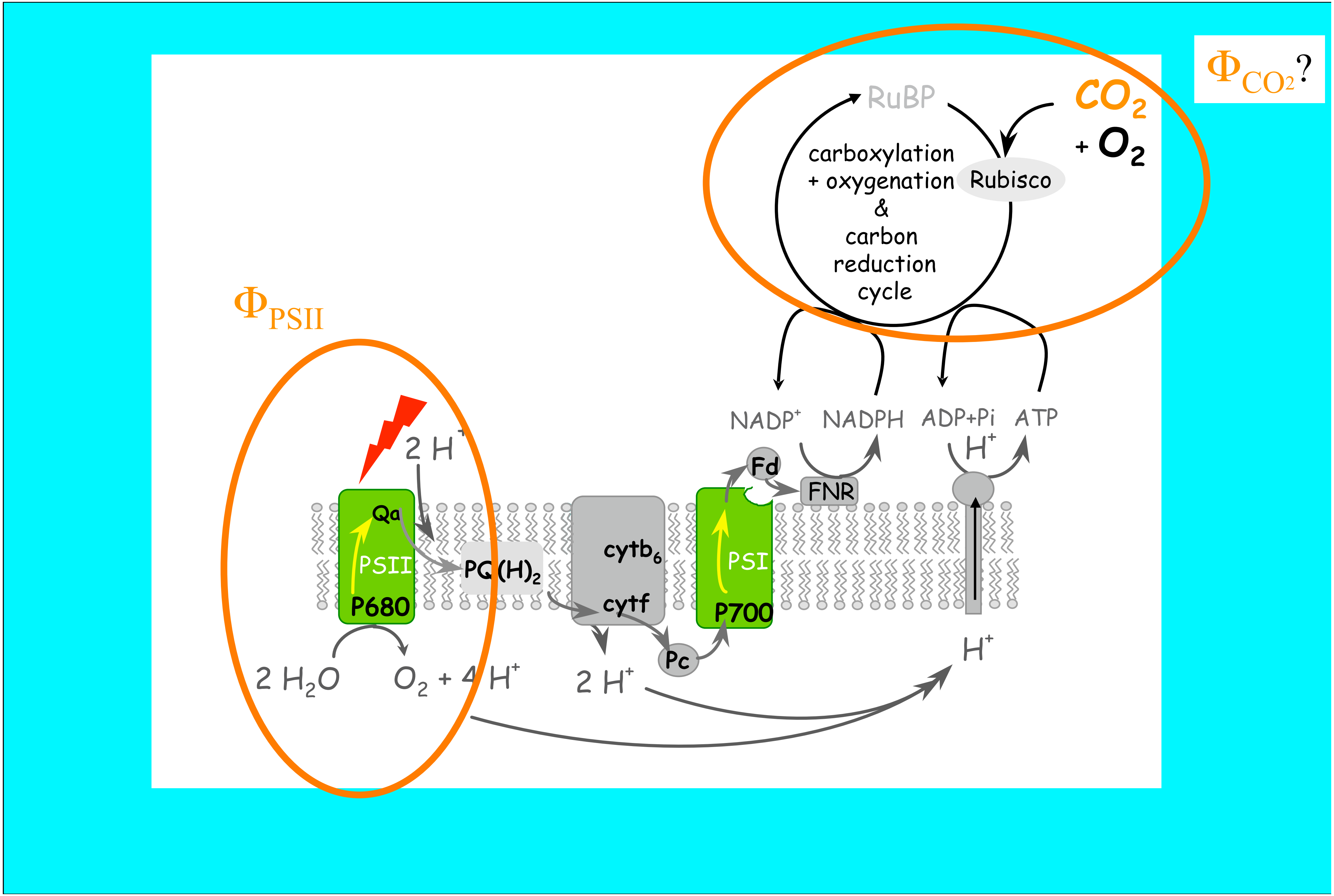
French bean in air



(Genty et al. 1992)

French bean in air

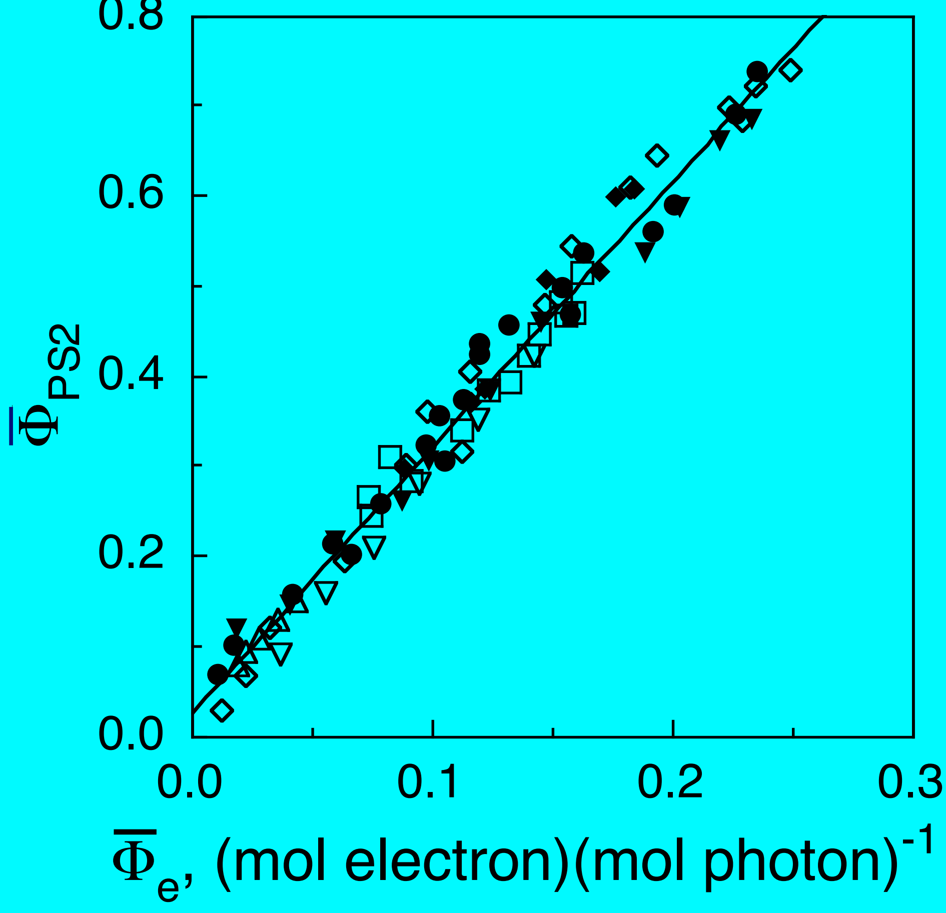




Φ_{CO_2}?
RuBP
CO_2
+ O_2
carboxylation
+ oxygenation
&
carbon
reduction
cycle
Rubisco
Φ_{PSII}
NADP+
NADPH
ADP+Pi
ATP
2 H+
H+
Fd
FNR
Qa
PSII
P680
PQ(H)2
cytb6
cytf
PSI
P700
Pc
2 H_2O
O_2 + 4 H+
2 H+
H+

Variations induced by irradiance, atmospheric CO_2 concentration, variable photosynthetic induction, DCMU feeding

Phaseolus vulgaris L.
Xanthium strumarium L.
Rosa canina L.

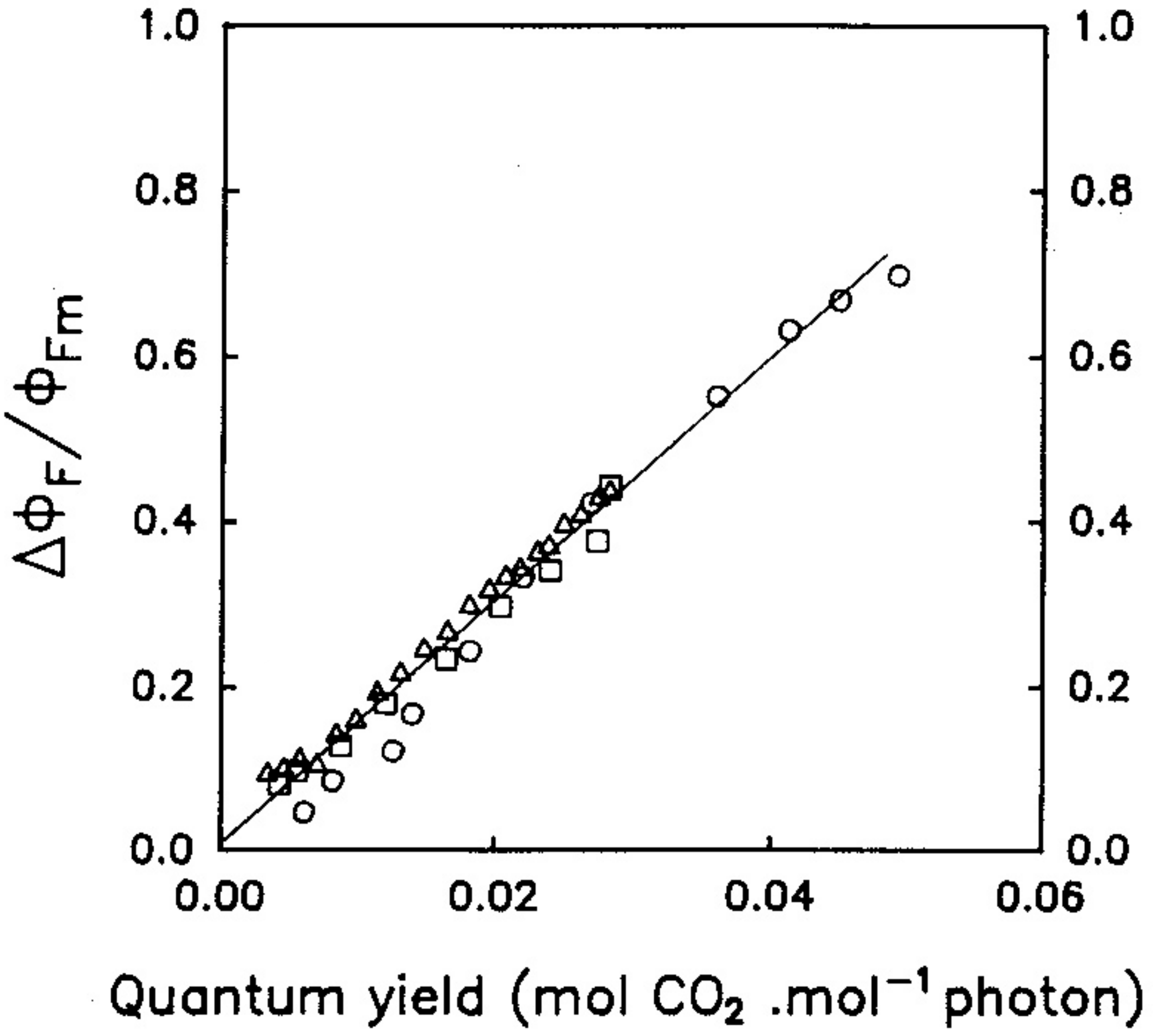


in low O_2

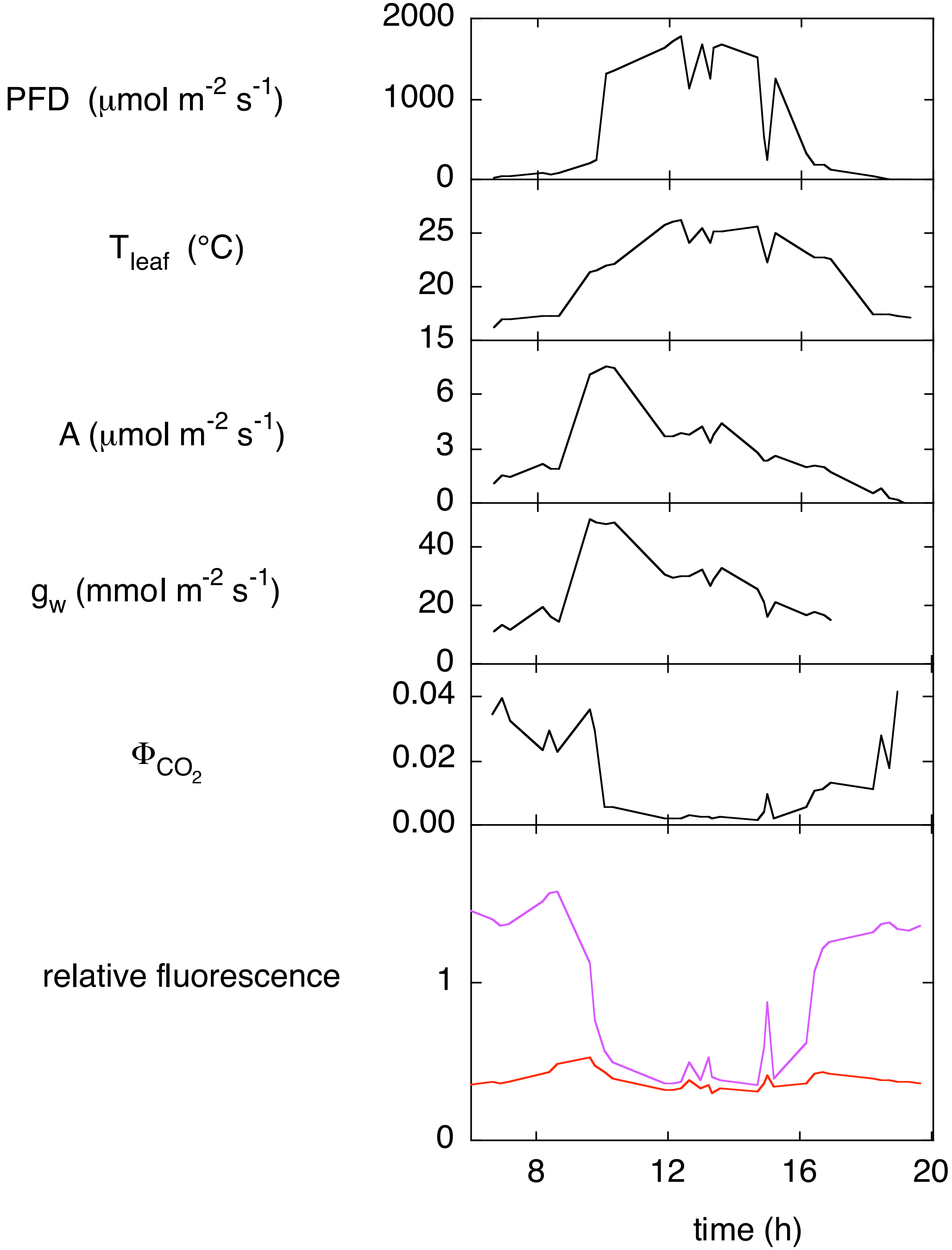
with $\Phi_e = 4\ \Phi_{CO2}$

(Genty et al. 1989, 1994)

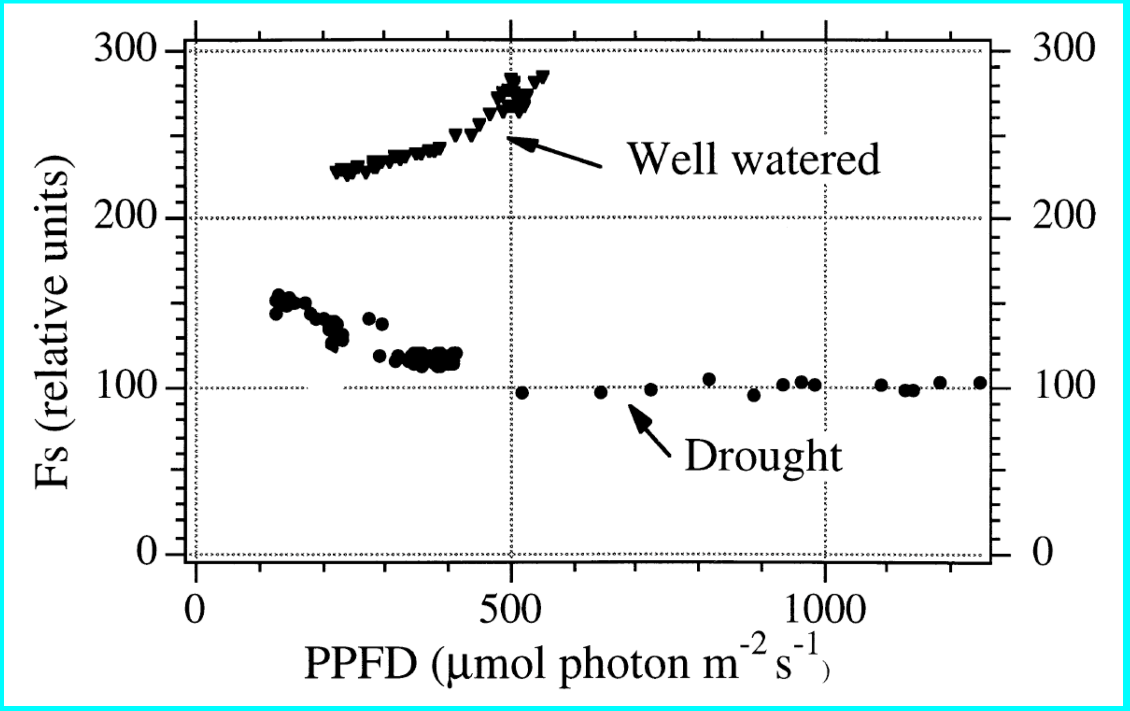
maize in 21% O_2



(from Genty & al. 1989)

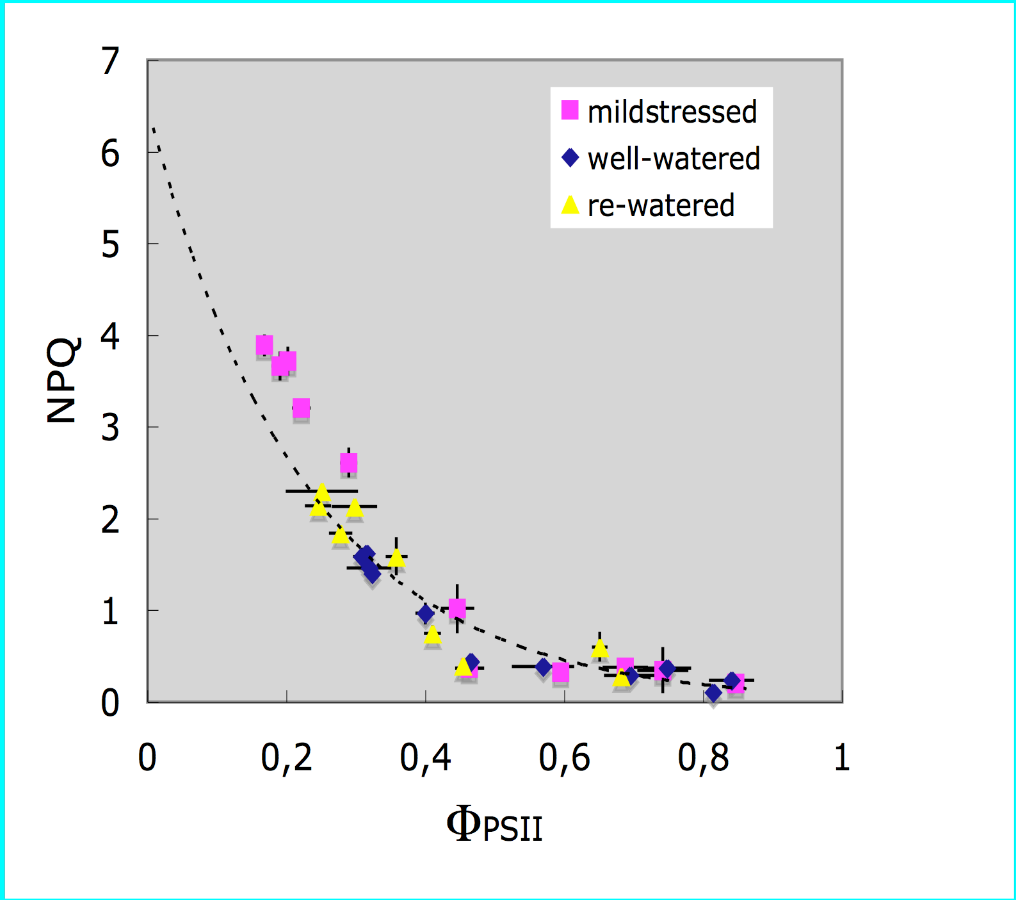


(calculated from Valentini et al. 1995)



Vitis vinifera L.

(from Flexas & al. 2000)



Vitis vinifera L.

(recalculated from Flexas & al. 1999)

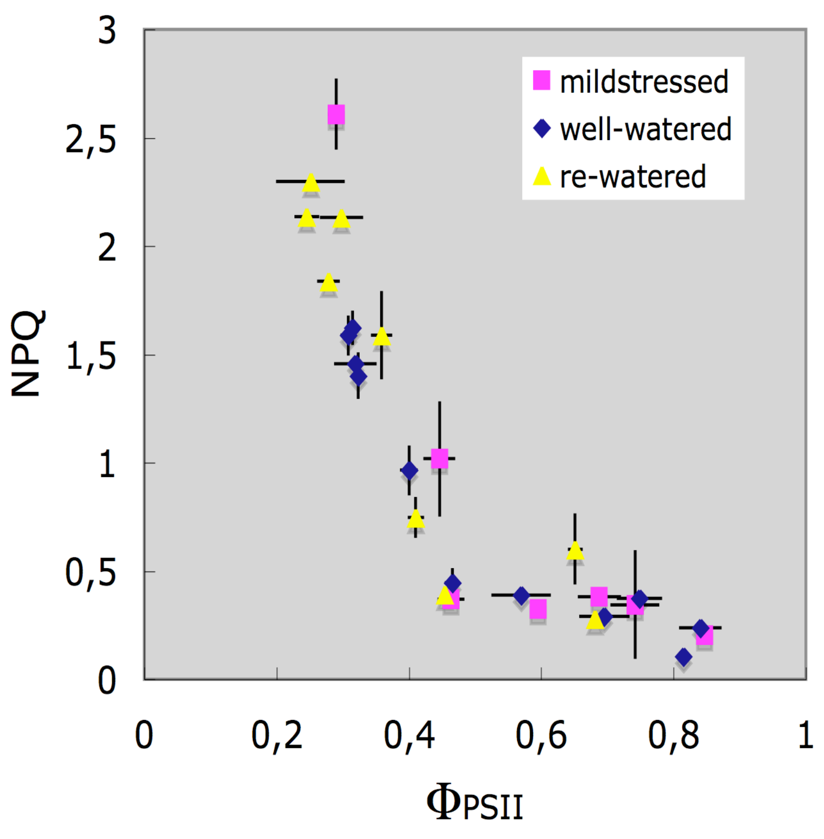
$$\Phi_P = 1 - \frac{\Phi_{Fs}}{\Phi_{F_M}}$$

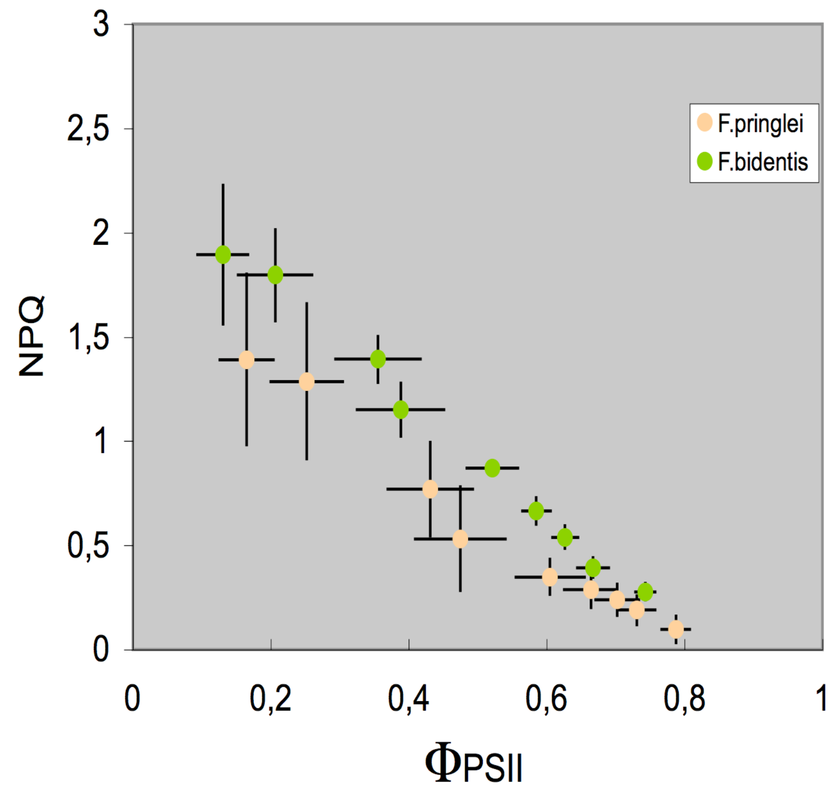
$$\Phi_{Fs} = (1 - \Phi_P)\,\Phi_{F_M}$$

$$NPQ = \frac{\Phi_{F_M{}^{dark}}}{\Phi_{F_M}} - 1$$

$$\Phi_{Fs}{}^{rel} = \frac{\Phi_{Fs}}{\Phi_{F_M{}^{dark}}} = (1 - \Phi_P)\,(NPQ + 1)^{-1}$$

with $NPQ = f(\Phi_P)$





Vitis vinifera L.

C3: *Flaveria pringlei*
C4: *Flaveria bidentis*

(Aresheva & al. 2012)

take home

Chl fluorescence:

. probe for non-invasive quantification of plant photochemical efficiency including temporal and spatial variations from molecular to global scales.

. Using active probing, potential for estimation of photosynthetic electron transport rate and CO_2 assimilation rate.

. Using passive probing, the variation of fluorescence yield is small as a result of 2 convoluted factors, photochemical quenching & non-photochemical quenching. Solving requires to describe NPQ.

more work!!!