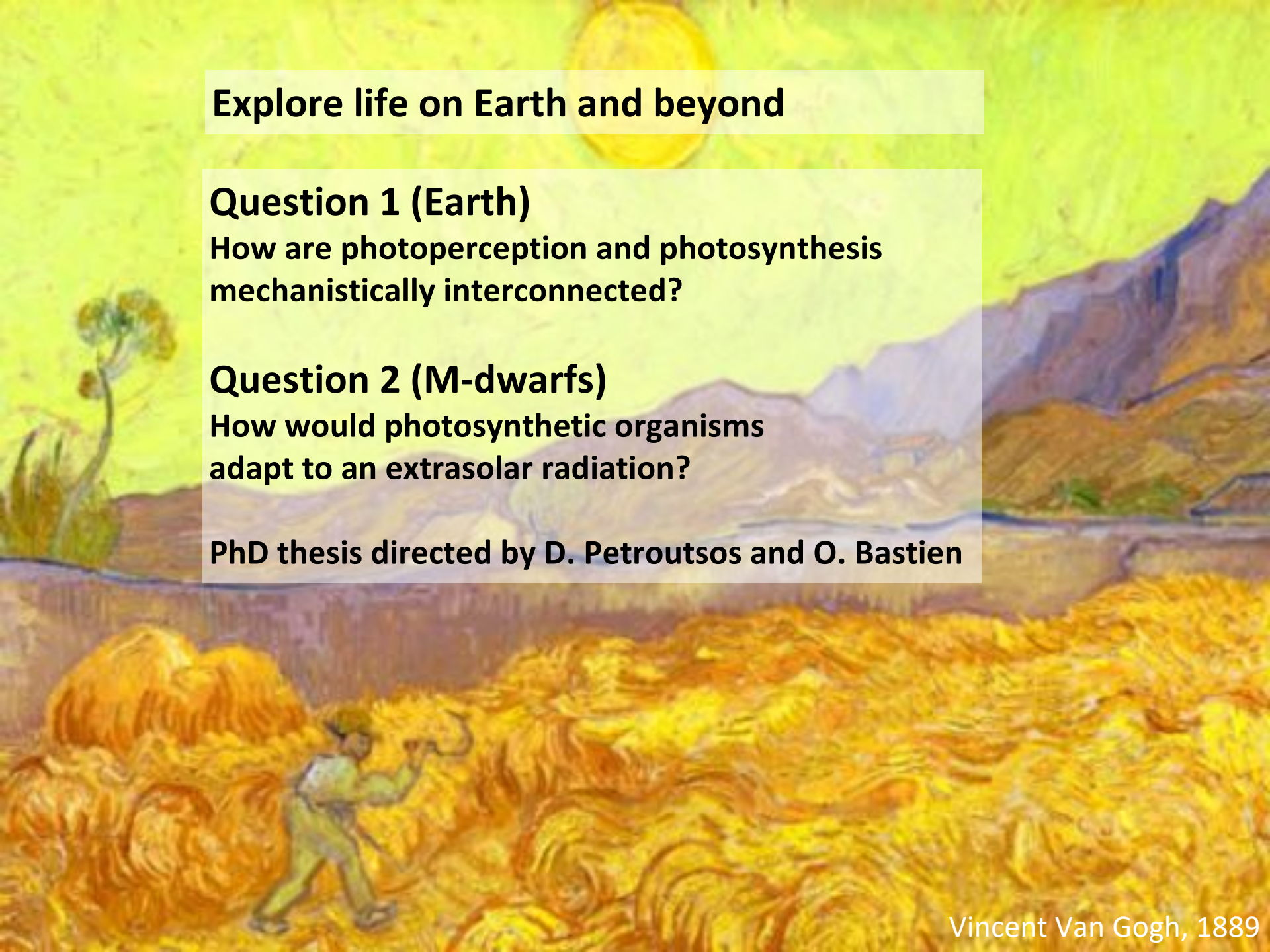
Acclimation of photosynthetic organisms to solar and extrasolar radiation

Origin of Life: kick off meeting
15 April 2018, Grenoble

Dimitris Petroutsos
Light, Photosynthesis and Metabolism Research Team
Cell & Plant Physiology Lab
CNRS, CEA Grenoble, France



Explore life on Earth and beyond

Question 1 (Earth)

How are photoperception and photosynthesis mechanistically interconnected?

Question 2 (M-dwarfs)

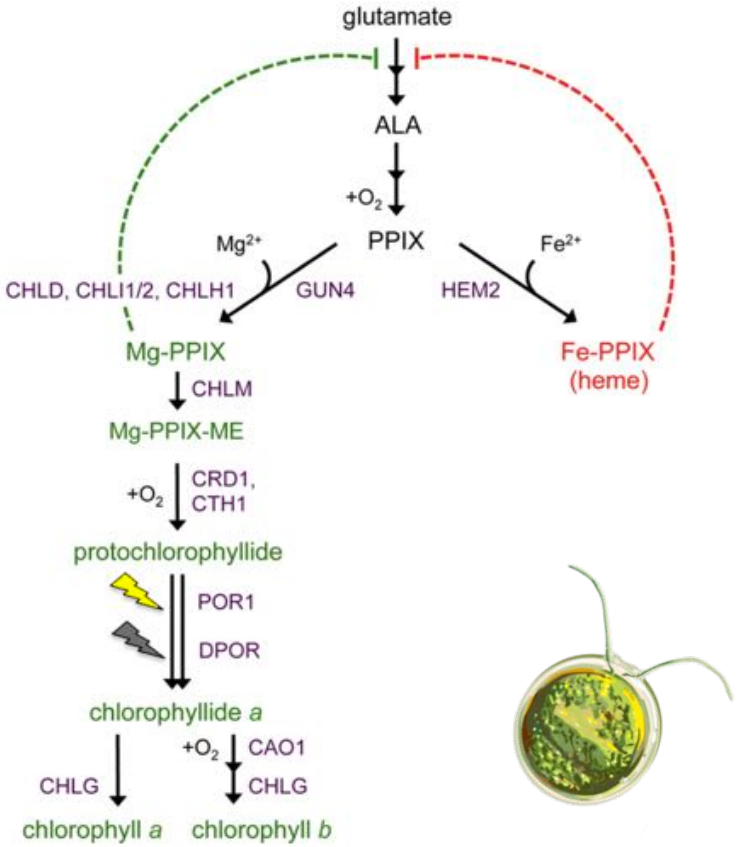
How would photosynthetic organisms adapt to an extrasolar radiation?

PhD thesis directed by D. Petroutsos and O. Bastien

Vincent Van Gogh, 1889

The green microalga *Chlamydomonas reinhardtii*: an excellent model organism to study photosynthesis

Chlorophyll biosynthesis pathway in Cr



Model Photosynthetic organism

Model organism for studies of human ciliopathy

Can grow in the dark in the presence of acetate

Full genome is sequenced (ca. 15000 genes)

Genetic tools are available

DNA-free two-gene knockout in *Chlamydomonas reinhardtii* via CRISPR-Cas9 ribonucleoproteins

Kwangryul Baek[1,*], Duk Hyoung Kim[2,*], Jooyeon Jeong[1], Sang Jun Sim[3], Anastasios Melis[4], Jin-Soo Kim[5,6], EonSeon Jin[1] & Sangsu Bae[2]

LARGE-SCALE BIOLOGY ARTICLE

An Indexed, Mapped Mutant Library Enables Reverse Genetics Studies of Biological Processes in *Chlamydomonas reinhardtii* OPEN

Xiaobo Li,[a,1] Ru Zhang,[a,1] Weronika Patena,[a,1] Spencer S. Gang,[a] Sean R. Blum,[a] Nina Ivanova,[a] Rebecca Yue,[a] Jacob M. Robertson,[a] Paul A. Lefebvre,[b] Sorel T. Fitz-Gibbon,[c] Arthur R. Grossman,[a] and Martin C. Jonikas[a,2]

The Plant Cell, Vol. 29: 2498–2518, October 2017, www.plantcell.org © 2017 ASPB.

Targeting of Photoreceptor Genes in *Chlamydomonas reinhardtii* via Zinc-Finger Nucleases and CRISPR/Cas9

Andre Greiner,[a,1,2] Simon Kelterborn,[a,1] Heide Evers,[a] Georg Kreimer,[b] Irina Sizova,[a,2,3] and Peter Hegemann[a]
[a] Institute of Biology, Experimental Biophysics, Humboldt University of Berlin, 10099 Berlin, Germany
[b] Department of Biology, Friedrich-Alexander University, 91058 Erlangen, Germany

Light fuels photosynthesis to generate chemical energy for CO_2 fixation

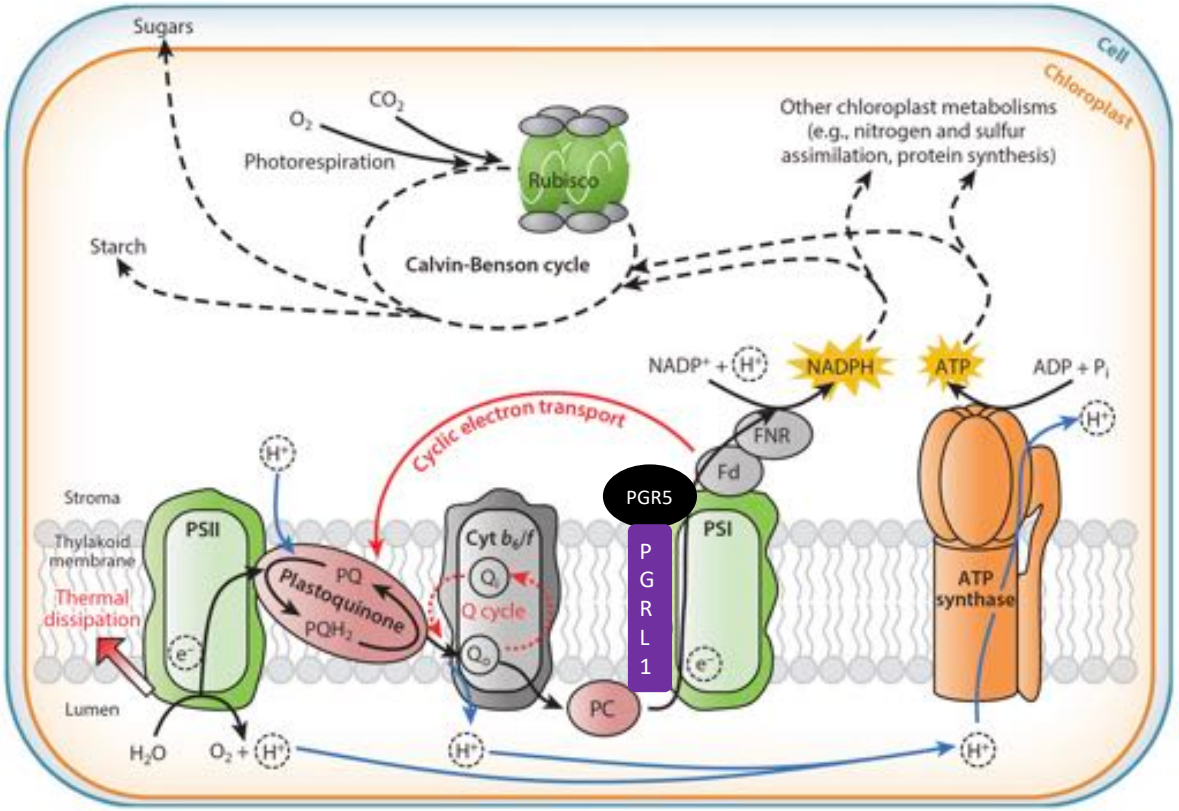
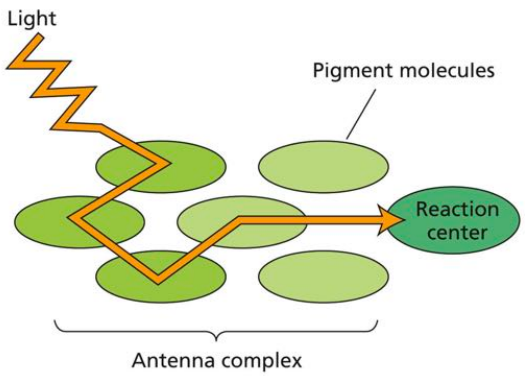
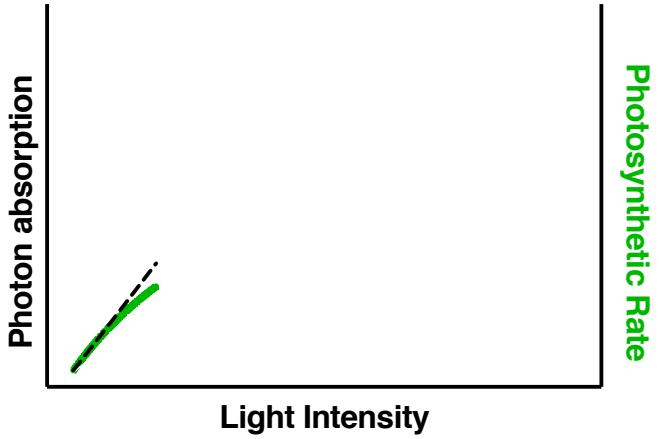
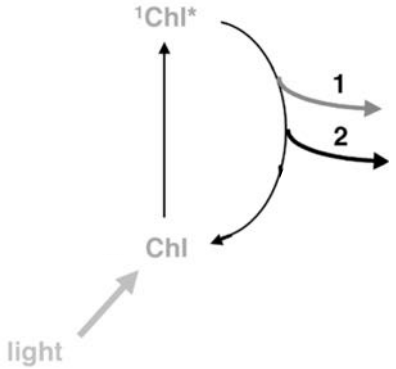


Illustration modified from: Yamori and Shikanai (2016) *Annual Rev Plant Biol*

At low light intensities absorption of light is mainly used for photosynthesis





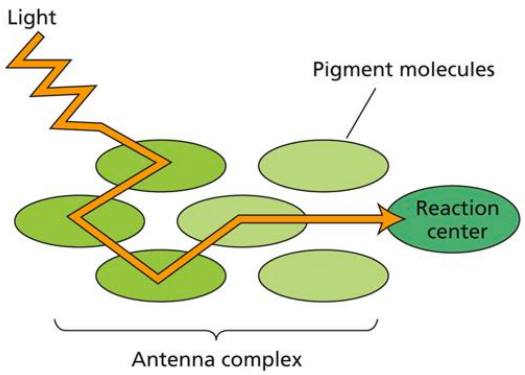


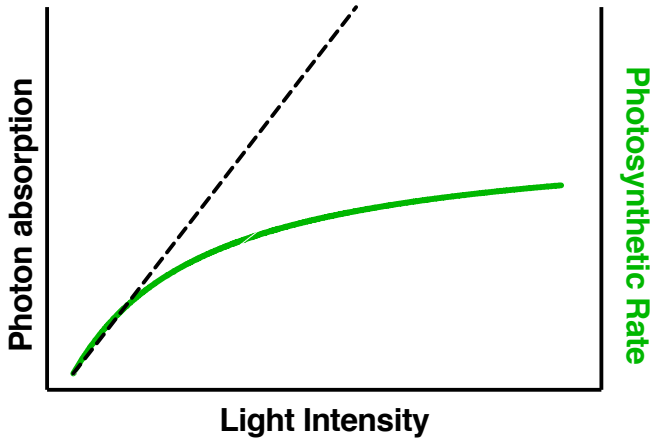
fluorescence

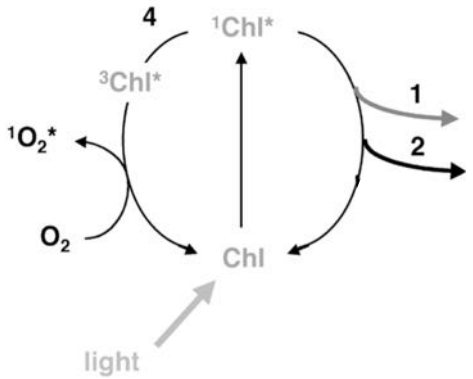
photosynthesis → biomass

Mueller et al (2001) *Plant Physiol*

At high light intensities photosynthesis is saturated but light continues being absorbed





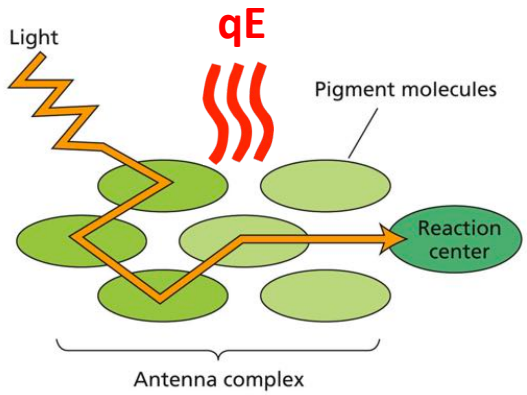


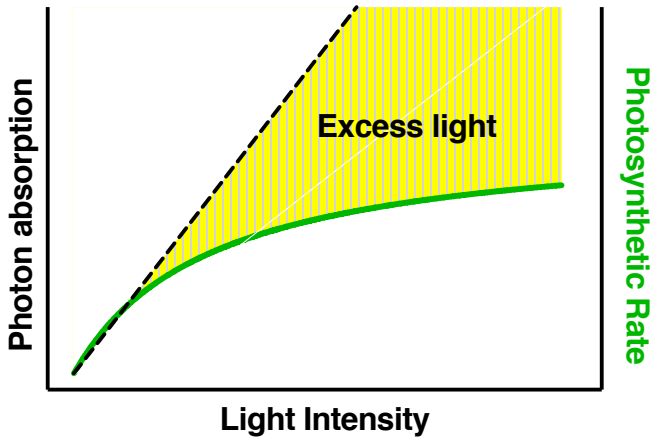
fluorescence

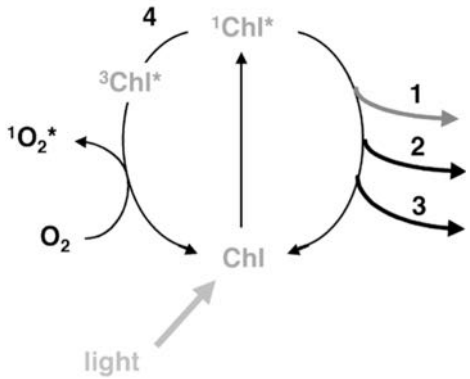
photosynthesis → biomass

Mueller et al (2001) *Plant Physiol*

Excess-light toxicity is prevented by the photoprotective mechanism qE (quenching of energy)







fluorescence

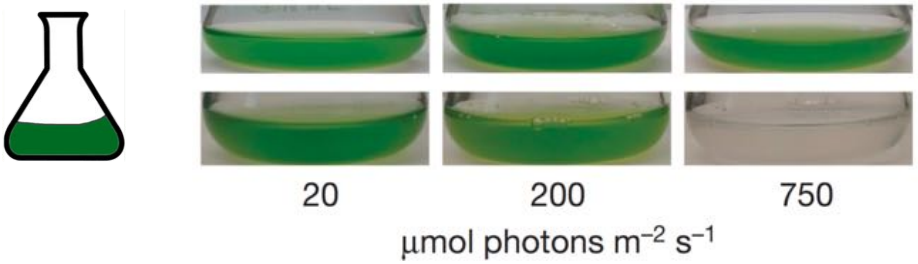
photosynthesis → biomass

heat (qE; quenching of energy)

Mueller et al (2001) *Plant Physiol*

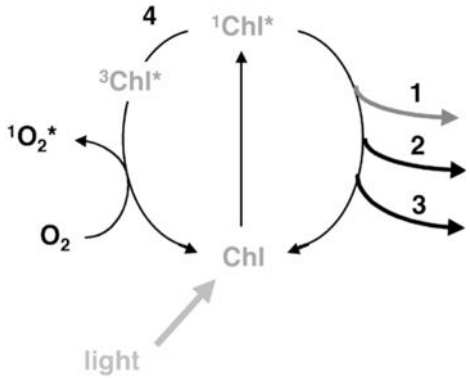
qE (quenching of energy) is a process of major biological importance

From a <u>biological</u> point of view: qE ensures survival under excess light conditions



Wild Type

Mutant defective in qE



fluorescence

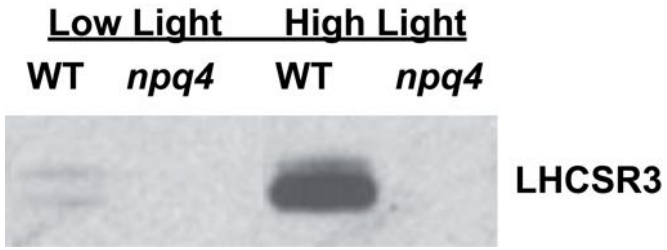
photosynthesis → biomass

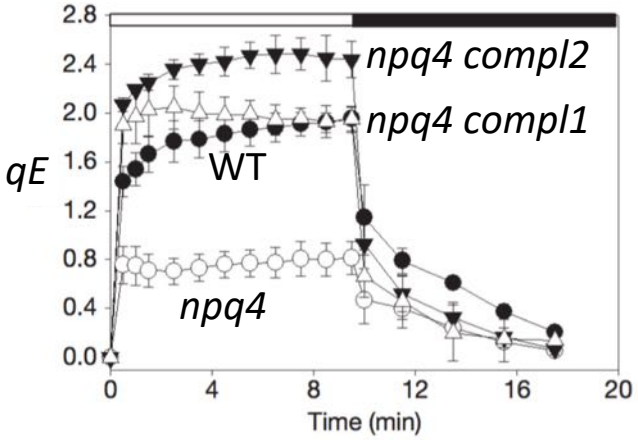
heat (qE; quenching of energy)

Mueller et al (2001) *Plant Physiol*

In Chlamydomonas LHCSR3 is the protein effector of qE

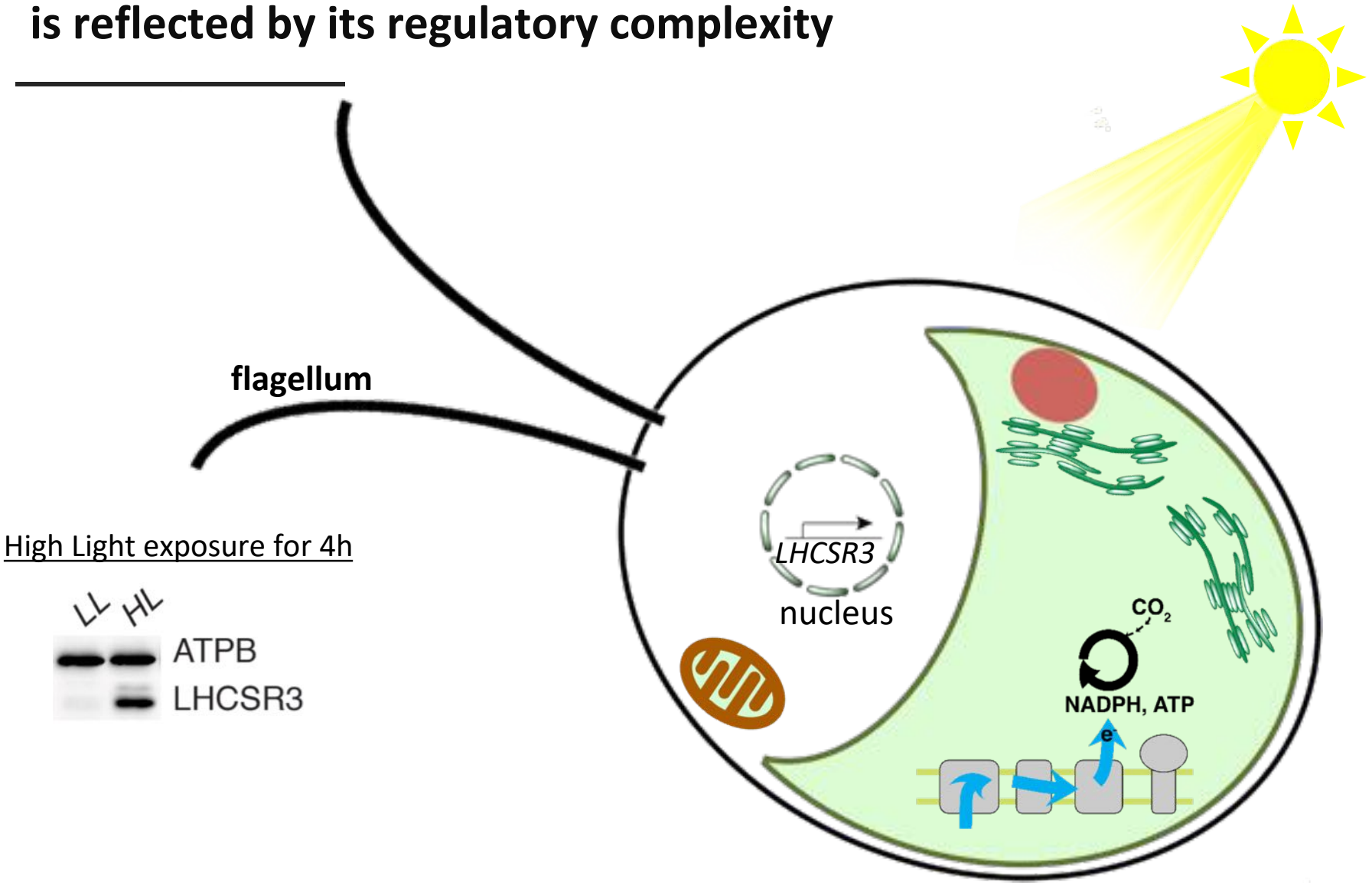
LHCSR3: Light Harvesting Complex Stress Related protein





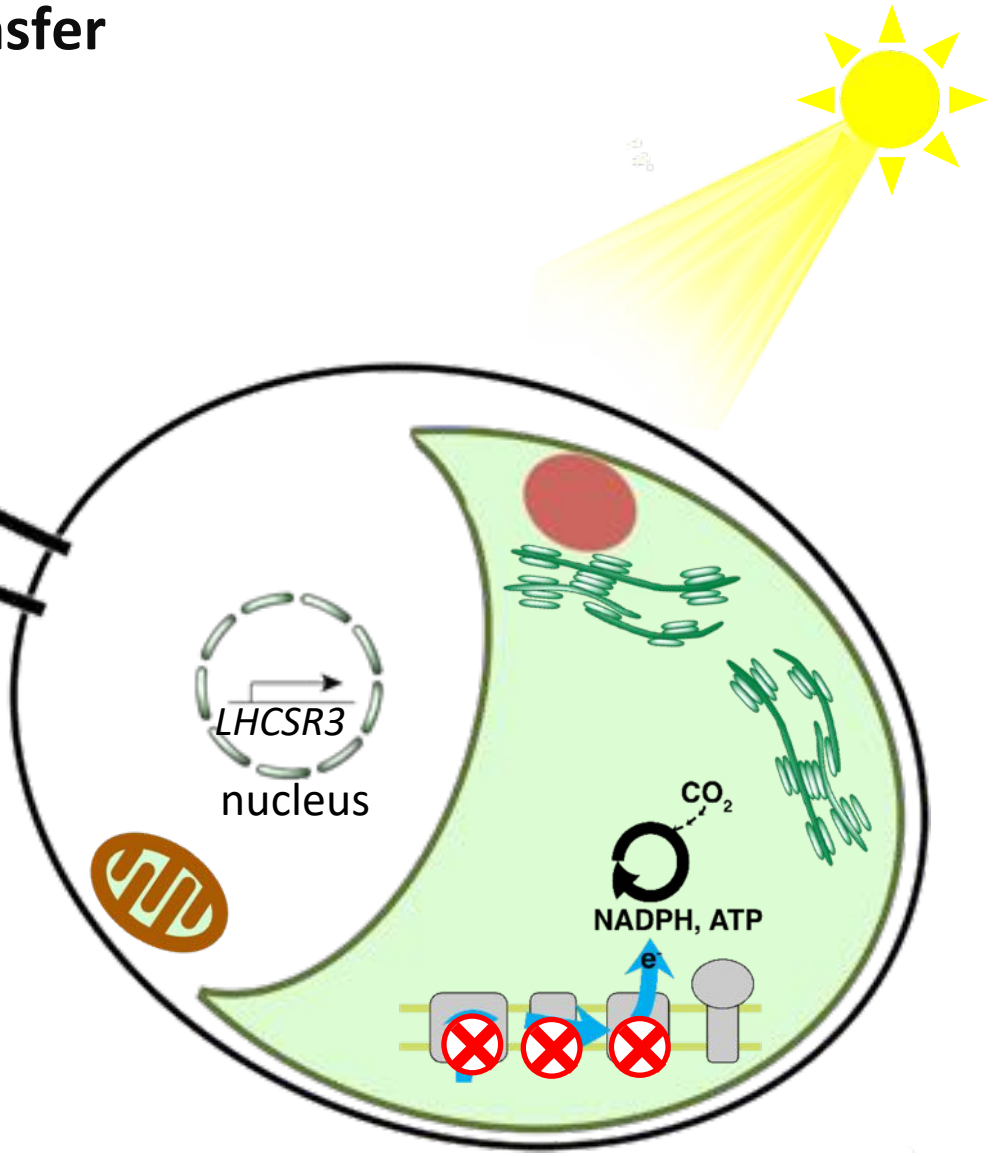
Peers et al (2009) *Nature*

The biological importance of LHCSR3 is reflected by its regulatory complexity

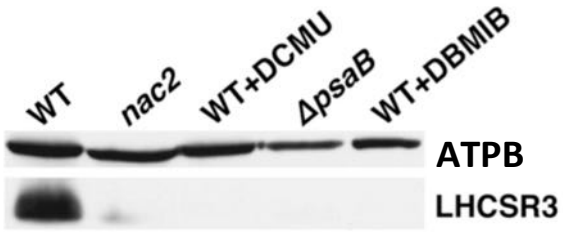


Expression of LHCSR3 requires photosynthetic electron transfer

flagellum

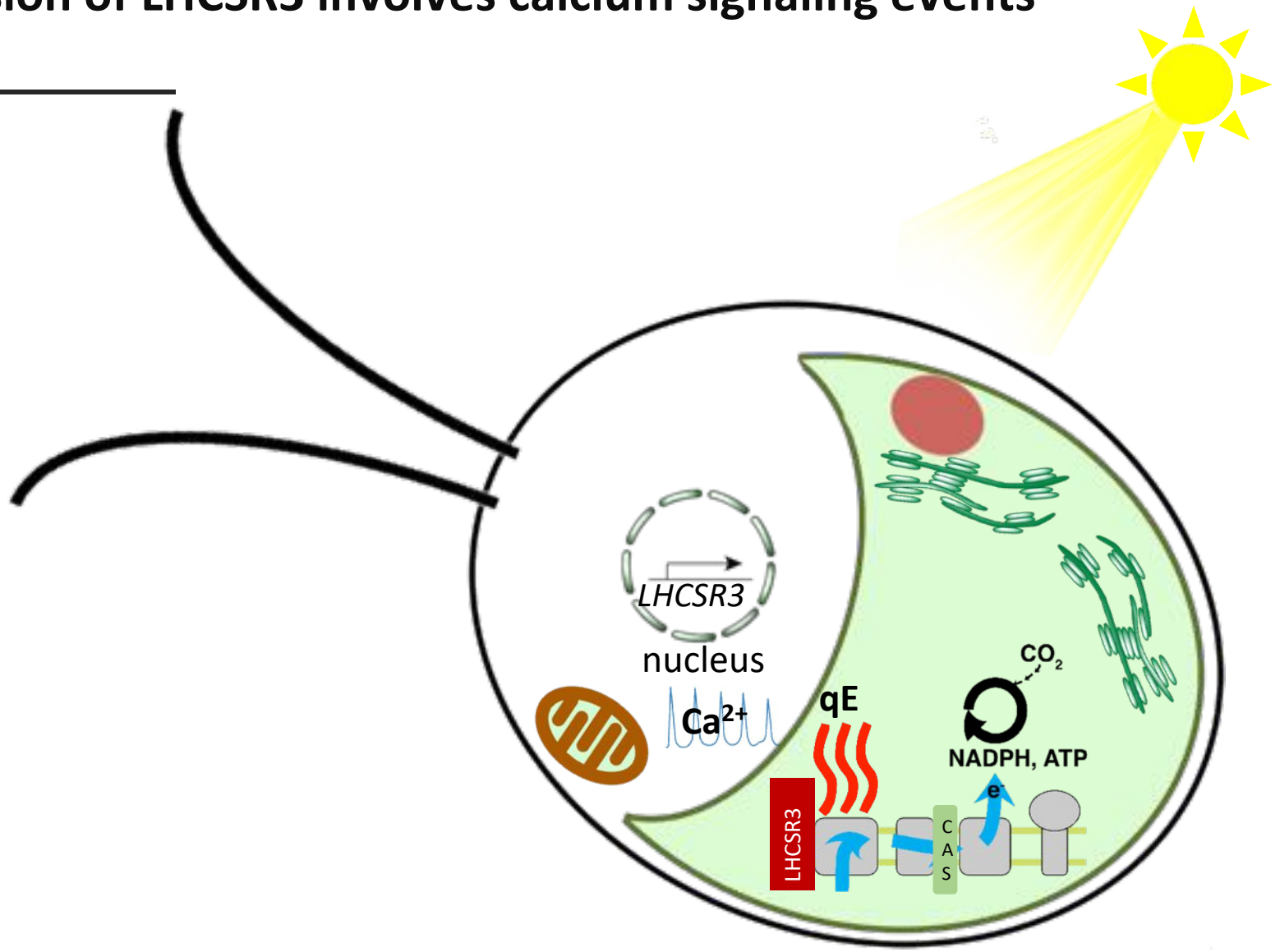


High Light exposure for 4h



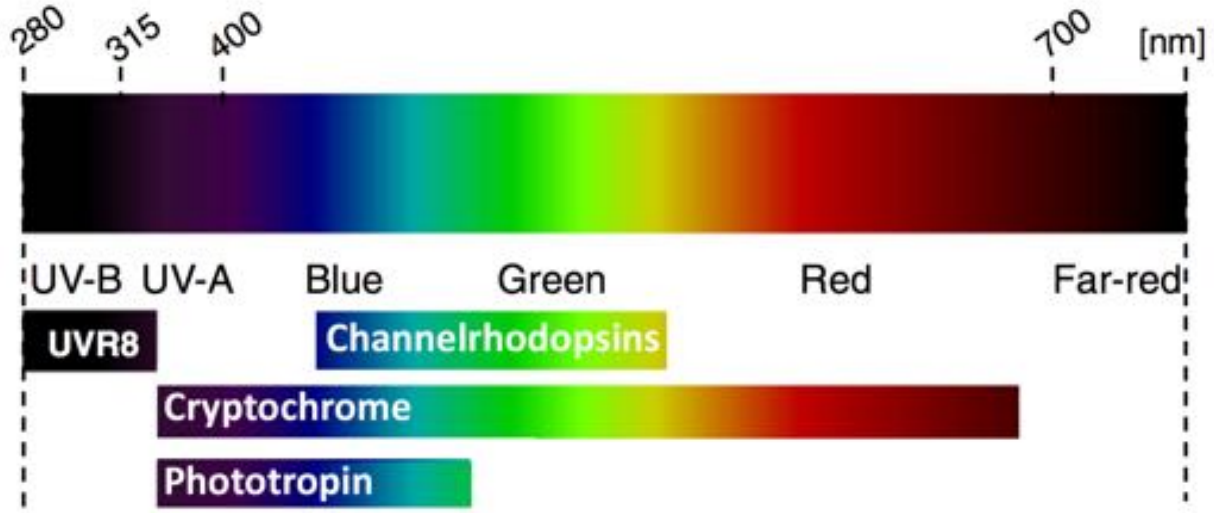
Petroutsos et al (2011) *Plant Cell*

Expression of LHCSR3 involves calcium signaling events



Petroutsos et al (2011) *Plant Cell*

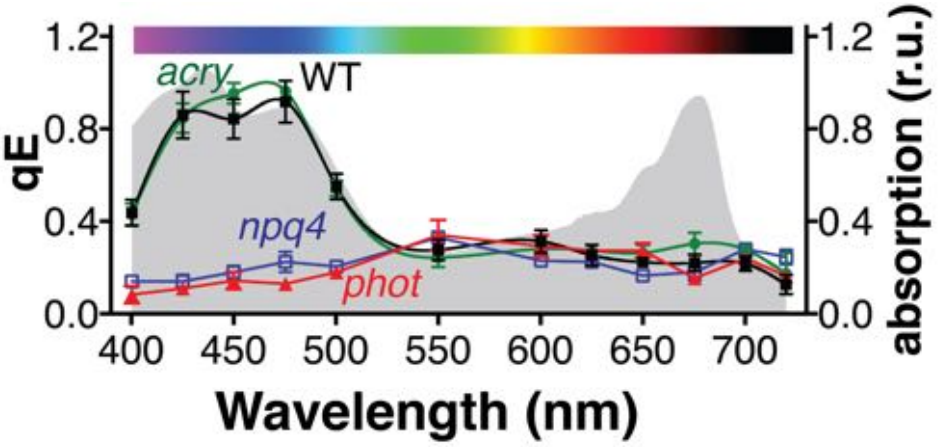
Light is an informational signal perceived by photoreceptor proteins

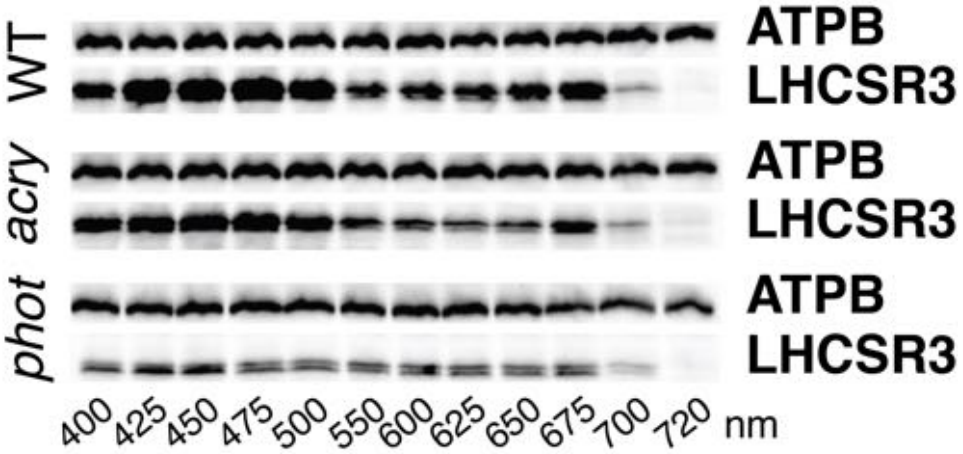


Control of: chlorophyll and carotenoid biosynthesis genes, cell cycle control, circadian clock, phototaxis, eyespot size

Petroutsos (2017) *In "Chlamydomonas: Biotechnology and Biomedicine";*

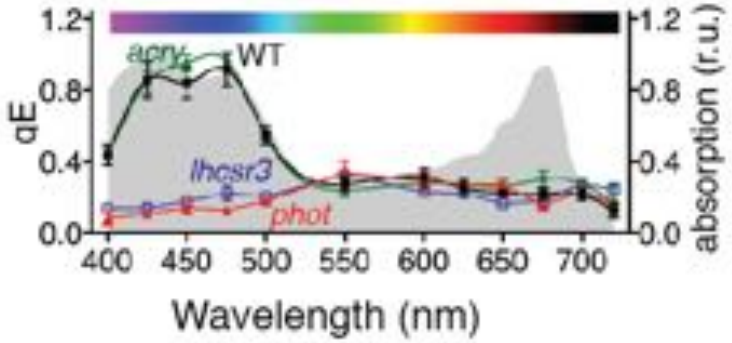
Phototropin (PHOT) controls LHCSR3 and qE in Chlamydomonas

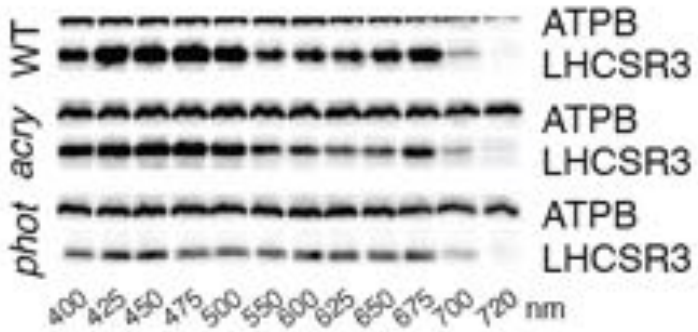


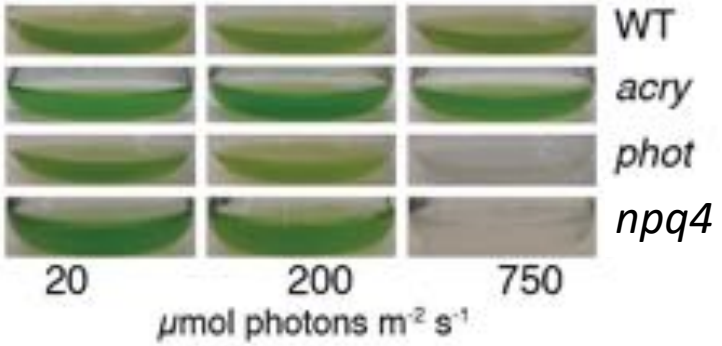


Petroutsos et al. 2016, Nature

PHOT controls photoprotection and is crucial for survival in high light

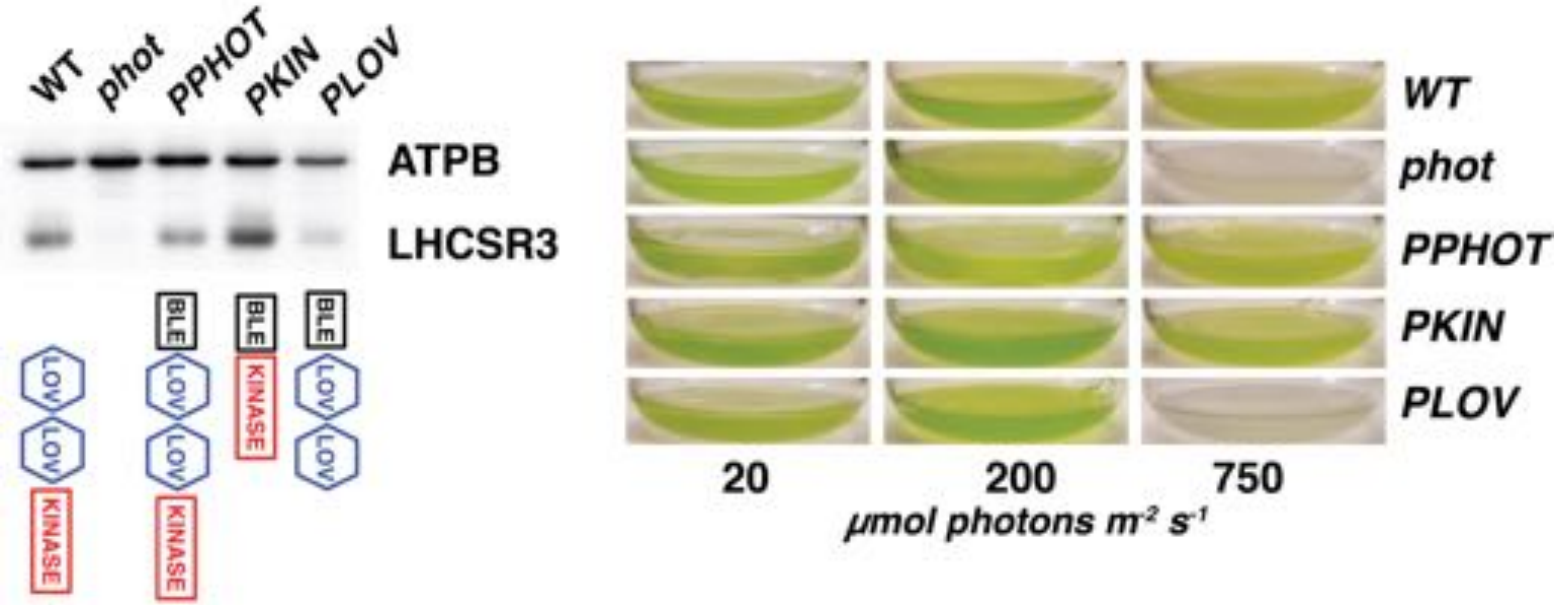






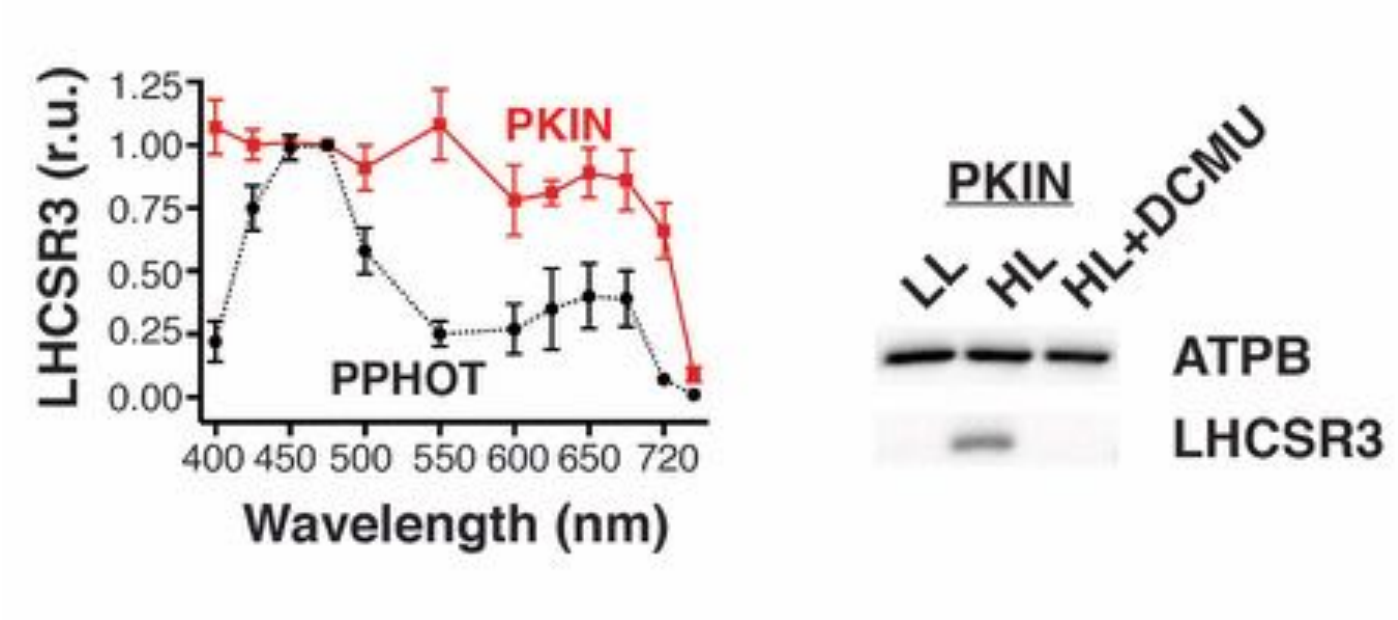
Petroutsos et al. 2016, Nature

Contribution of the different domains of PHOT to the control of LHCSR3 expression



Petroutsos et al. 2016, Nature

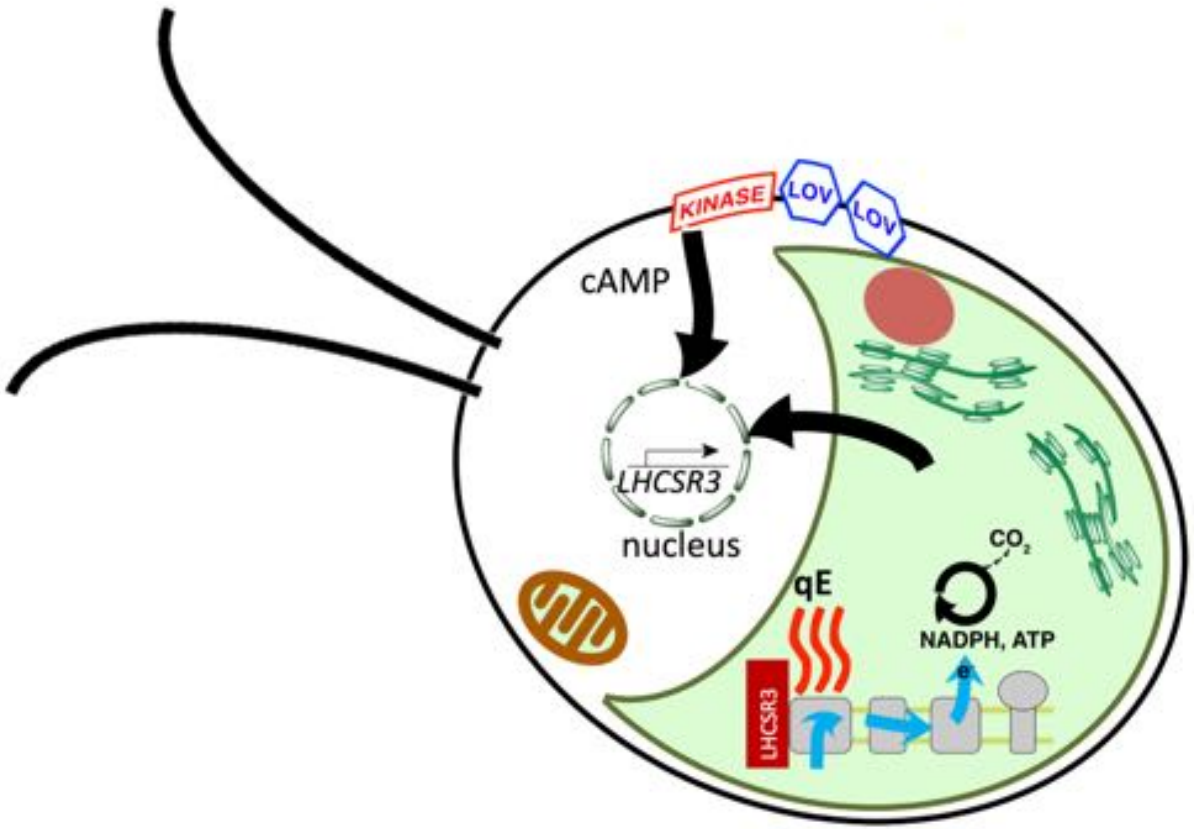
Constitutive activation of PHOT kinase renders LHCSR3 wavelength-insensitive



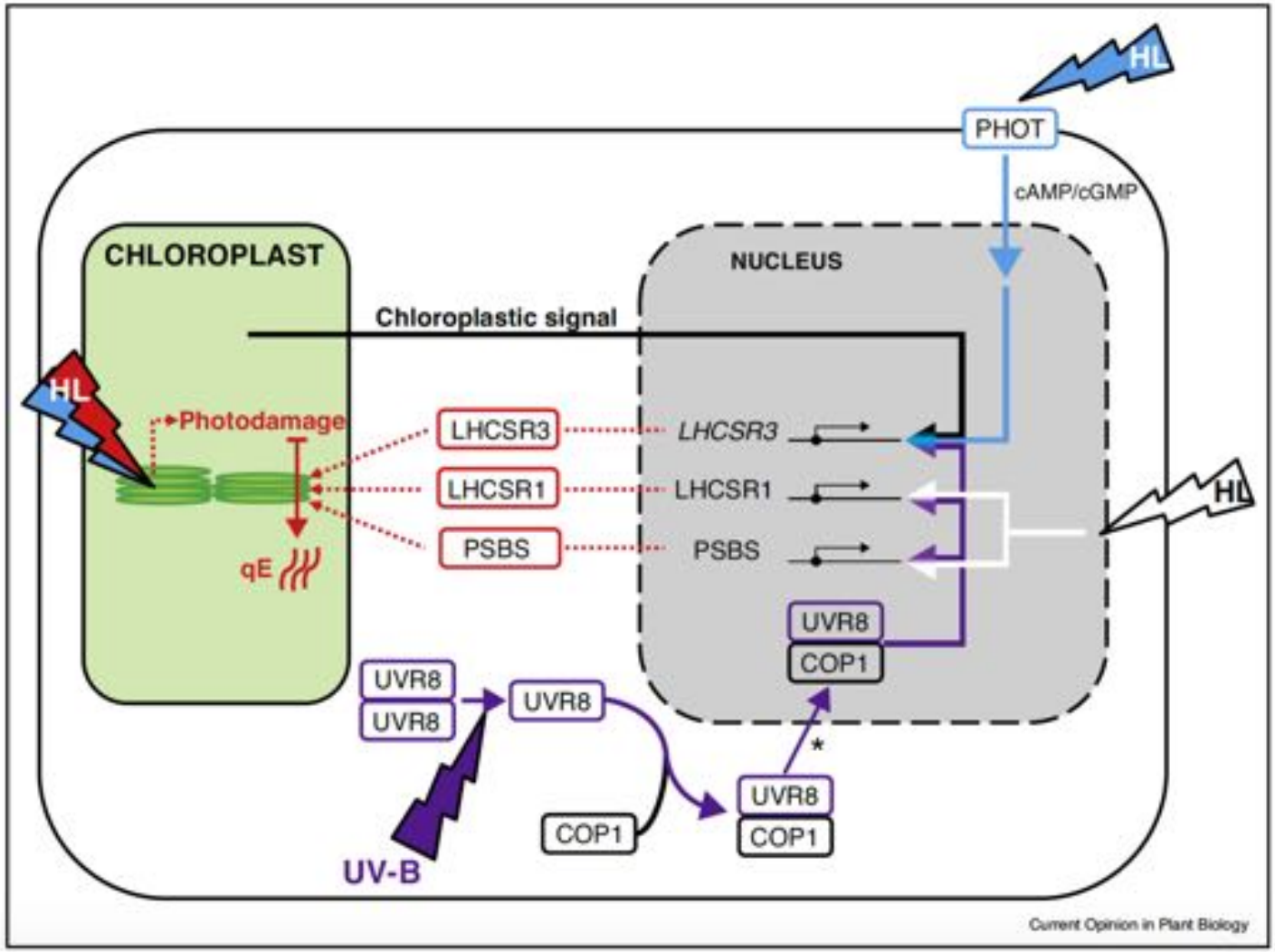
LHCSR3 remains PET-dependent

Petroutsos et al. 2016, Nature

Chlamydomonas PHOTOTROPIN provides a novel link between photoperception, photosynthesis and photoprotection.

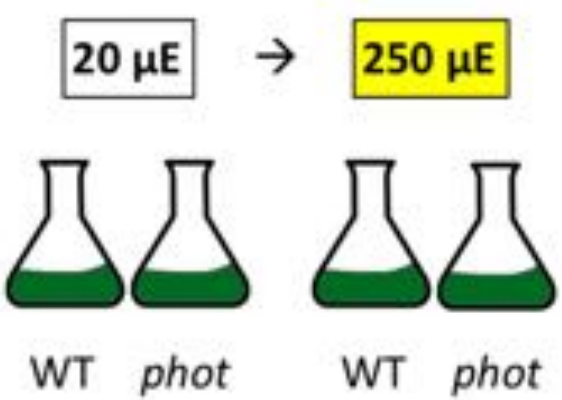


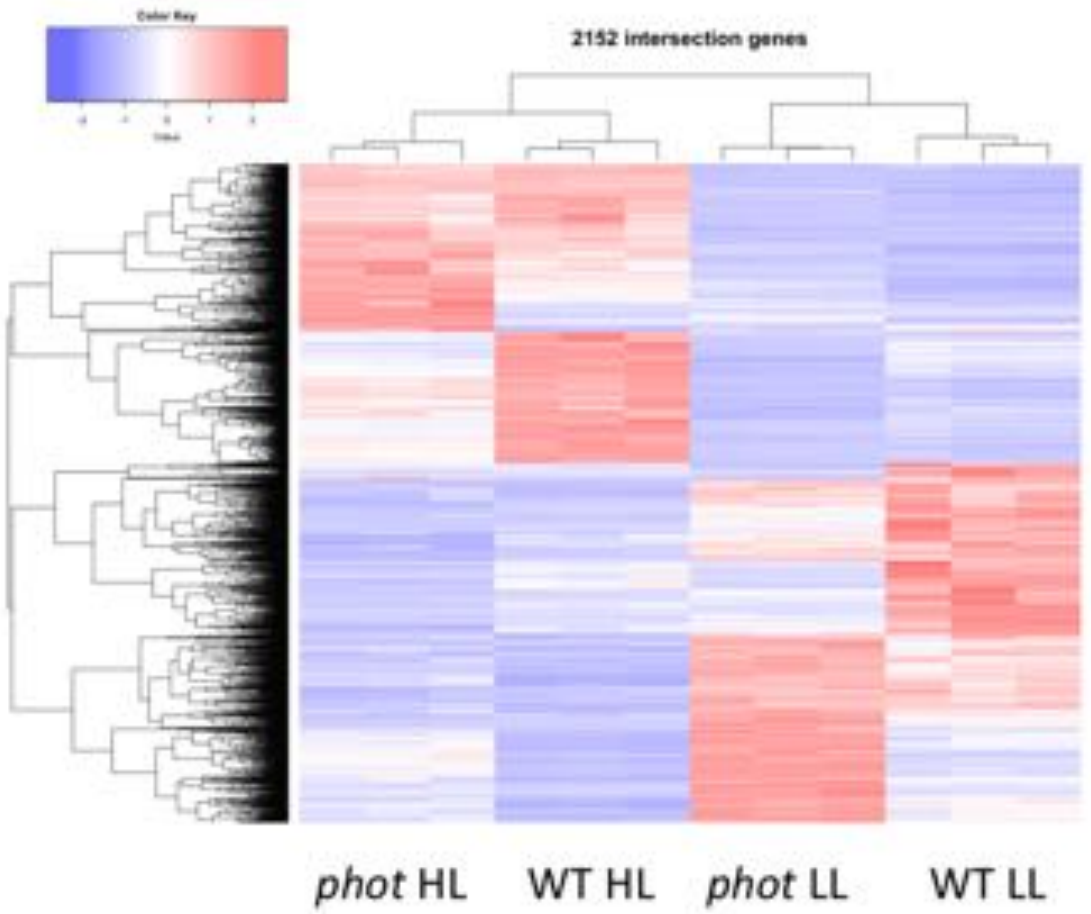
Regulation of photoprotection in Chlamydomonas: a case study of cell signaling biology



Allorent and Petroutsos (2017) *Curr Opin Plant Biol*

Genome wide comparative transcriptomics





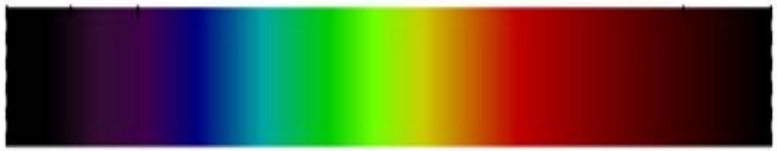
Experimental Plan of the PhD thesis

Explore life on Earth

… and beyond

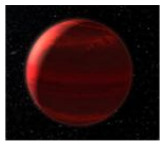
Question 1 (Earth)
How are photoperception and photosynthesis mechanistically interconnected?

Question 2 (M-dwarfs)
How would photosynthetic organisms adapt to an extrasolar radiation?



Low
High
Light Intensity

Low
High
Light Intensity



Low
High
Light Intensity

- Genome wide transcriptomics
- Phylogenetics
- *In vivo* photosynthesis
- Cells ultrastructure