Photosynthetic Membranes in Far-Red Light

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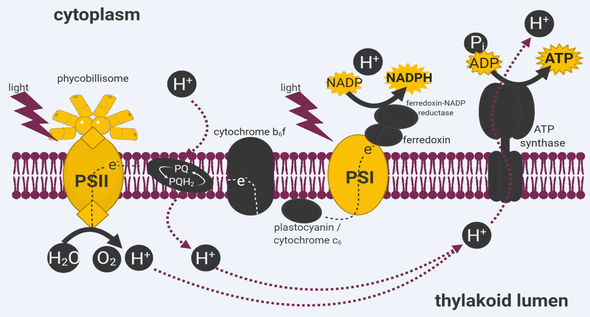
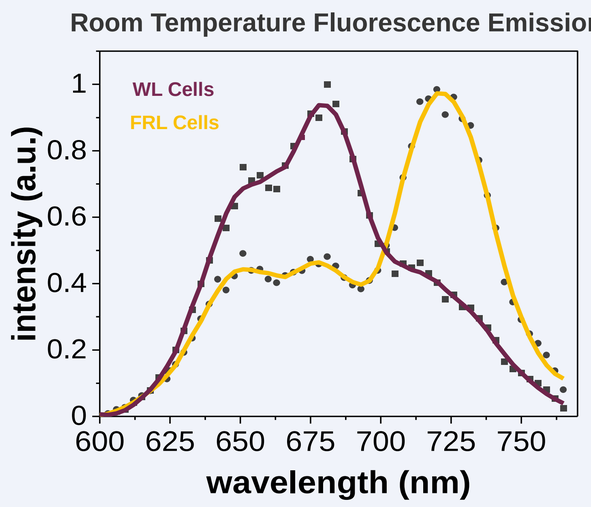
Background

Most photosynthetic organisms only use visible light between 400 nm and 700 nm for oxygenix photosynthesis, but some specialized cyanobacteria are able to use light up to 750 nm (far-red light)[1]. To efficiently harvest far-red light (FRL) cyanobacteria undergo a photoacclimation process[2].





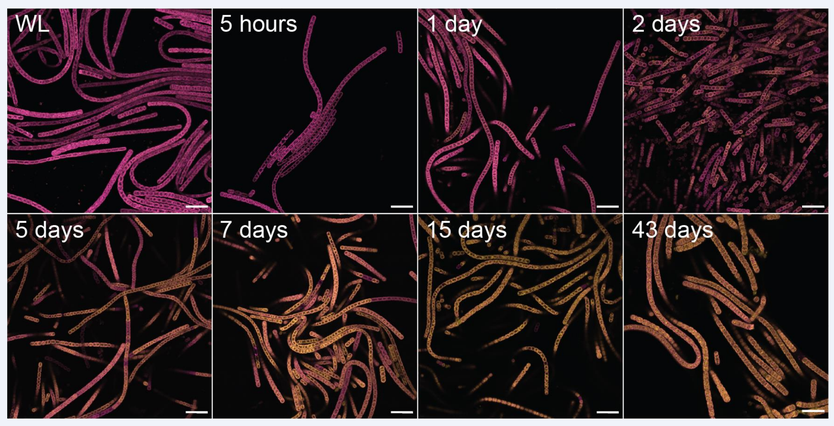
During far-red light photoaclimation (FaRLiP) expression levels of ~3000 genes change, importants subunits of phycobilisomes, photosystem I and II are replaced and new long-wavelength chlorophylls (chl d & chl f) are integrated. As a result, far-red light acclimated cells shift their fluorescence emission to longer wavelengths[2].

FaRLiP is still not fully understood, but knowledge about the process could be applied in biotechnical or bioengineering approaches to extend the usable light spectrum for photosynthesis. It also helps to broaden our understanding of the possibilities and limits of oxygenic photosynthesis and allows for new experimental approaches to answear open questions about photosynthesis and thylakoid membrane organisation.

Far-red Light Acclimation

Far-red light photoacclimation in the filamentous cyanobacterium *Calothrix*

- Photoacclimation (shift in main fluorescence emission) takes 15 days
- First changes in fluorescence after 2 days
- Emission shifts due to new protein environment and chl d and chl f
- No consistent starting point for acclimation in the filament
- No synchronisation of the acclimation process
- Intra filamentous cell to cell communication over aclimation status is likely

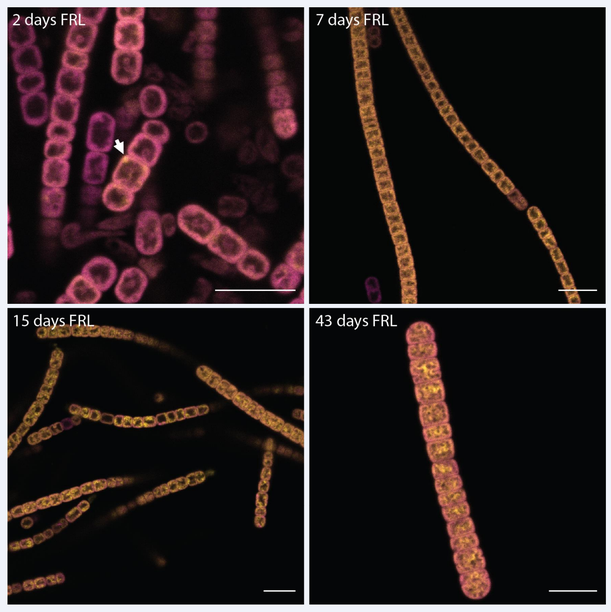


FRL acclimation process: Confocal fluorescence images of *Calothrix* cells after different incubation periods in FRL. Dominant chl a fluorescence in magenta and chl f fluorescence in yellow. Scale bars, 20 µm.

Potential Biogenesis Centers

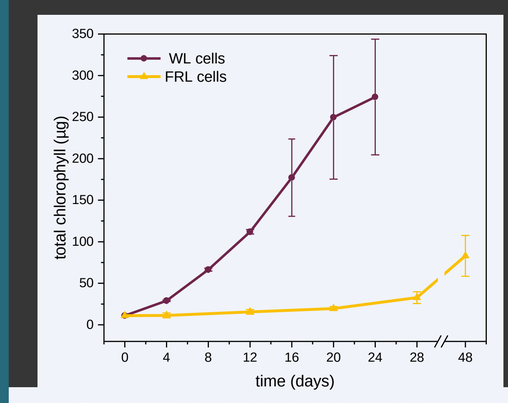
Biogenesis of thylakoid membranes has been studied by cryo electron tomography[3] and mRNA fluorescence in situ hybridization (FISH)[4]. Here, the shift in fluorescence emission during FaRLiP is used to track newly formed thylakoid membrane parts.

- Yellow spots after 2 days indicate biogenic active regions
- Patchy fluorescence emission during the acclimation process
- Heterogenous fluorescence emission even after 43 days
  ↳ Acclimation process not complete or final form?



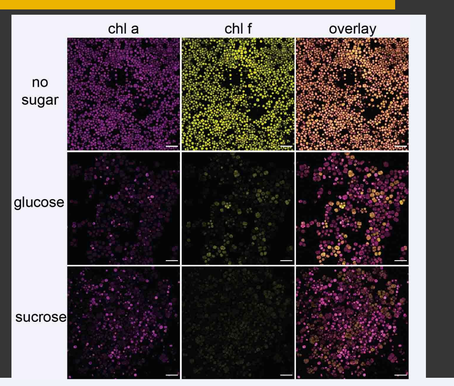
"Yellow" fluorescence emission indicates biogenic active regions: Confocal fluorescence images of *Calothrix* cells after different incubation periods in FRL. Dominant chl a fluorescence in magenta and chl f fluorescence in yellow. Scale bars, 10 µm.

Growth



Growth curve in WL and FRL: Total chlorophyll amount of *Calothrix* cultures plotted over time. Doubling time in WL ~5 days. Growth much slower in FRL.

Sugars Inhibit FaRLiP



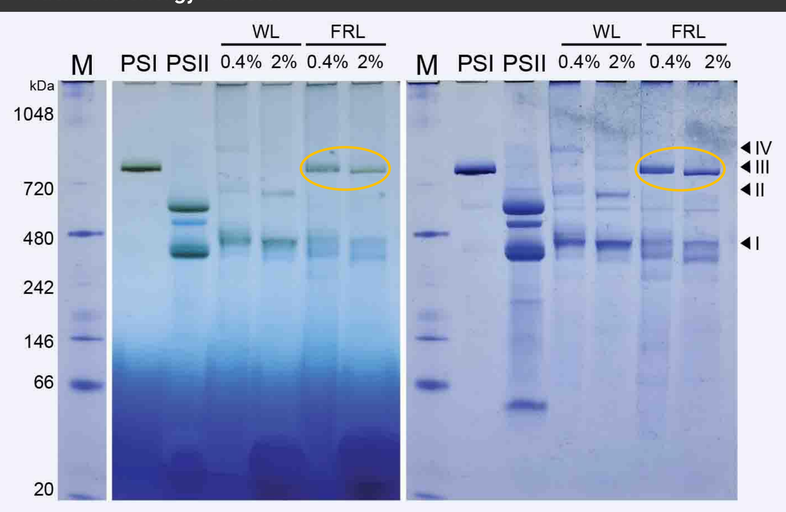
FaRLiP with sugars: Confocal fluorescence images of *C. thermalis* cells in FRL. Less cells are shifted when incubated with glucose or fructose. Scale bars, 20 µm.

PSI Oligomerisation

Photosystem I (PSI) is only monomeric in plants[5]. In cyanobacteria it assumes different oligomeric states depending on environmental conditions[6], but how is it in FRL? Here, oligomeric states of PSI in WL and in FRL are shown on native protein gels.

- In WL: Tetramers, Dimers, Monomers
- In FRL: Trimers, Monomers

Trimers are exclusively found in FRL. Theire bigger cross section could help catch more photons and be a more stable docking site for phycobilisomes. Increased antenna system by the interfaces could also facilitate energy transfer.



Oligomeric forms of PSI: Native protein gels with thylakoid membrane protein complexes of *Calothrix*. Bands are stained by native chromophores (e.g. chl) on the left and by Coomassi blue on the right. FRL and WL samples were solubilized with 0.4% and 2% DDM. Oligomeric states are indicated by I, II, III and IV. PSI and PSII from *T. elongatus* BP-1 were used as size markers.

Outlook

Further experiments and collaborations that are planned:

- Cryo electron tomography of cells in the FaRLiP process – Observe thylakoid membrane structures in high detail
- FISH – See if mRNA translation is co-localised with biogenic active thylakoid membranes
- *ΔpsaL* Mutants – PsaL is involved in PSI trimerisation and FaRLiP cyanobacteria have two gene variants. One of them is expressed under FRL. Mutants will reveal more insight about the importance of Trimers in FRL.
- Atomic force microscopy (AFM) – Observe PSI oligomeric forms in their native state, still embedded in the membrane

References

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