AquaFEED

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Partners

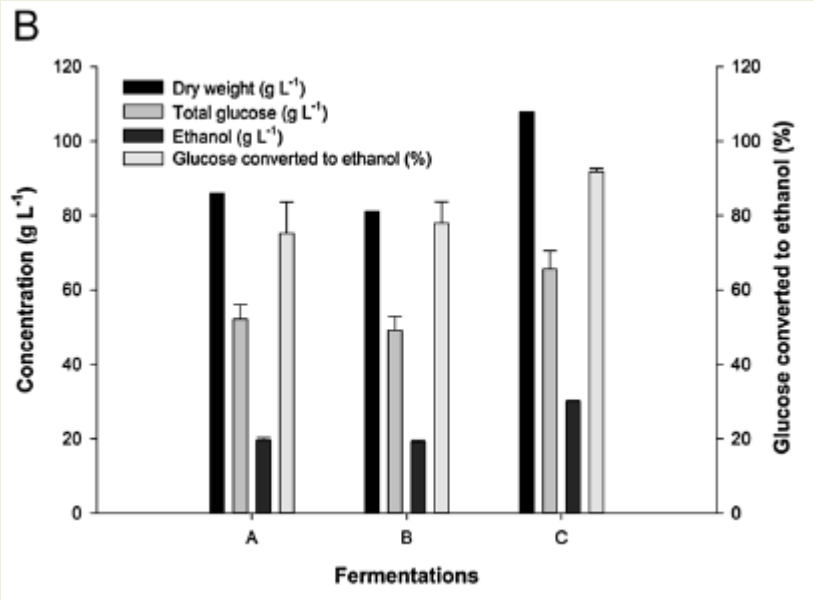
- University of Turku, Biochemistry
- University of Turku, Chemistry
- University of Copenhagen, Biology and Biotechnology, two research groups
- Uppsala University, Photochemistry and Molecular Science, two research groups
- NIBIO (formerly Bioforsk)

Why microalgae and cyanobacteria?

- Nearly all renewable energy is based on sunlight
  - direct solar energy, hydro and wind power, biomass
- Photosynthesis consumes carbon dioxide and thereby mitigates climate change
- Aquatic photosynthetic microorganisms do not consume energy for building root, stem, flower, seed
  - High productivity expected

1. Production of aquatic biomass for fermentation to ethanol

- The cyanobacterium *Synechococcus* sp. PCC 7002
  - Growth in nitrogen limitation => 60 % sugar content
  - Broth obtained by enzymatic lysis is immediately fermentable by yeast
  - Cyanobacteria as nutrient source for fermentation
  - *Möllers et al., Biotechnol Biofuels 7: 64 (2014)*
- A continuous process for growing the green alga *Chlorella sorokiana* with 60 % starch



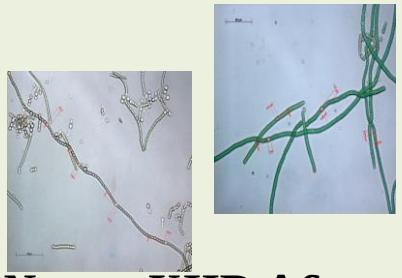
2. Biohydrogen production

- Screening of nitrogen-fixing cyanobacteria from Finnish lakes and the Baltic Sea
  - 10 strains produce H_2 faster than Δ*HupL* strain that lacks a H_2-consuming enzyme
  - Best producer *Calothrix* 336/3 has been sequenced
  - *Leino et al. Int I Hydrogen Energy 39: 8983-8991 (2014)*
  - *Isojärvi et al. Genome Announc 3: 40174-14 (2015)*
- Hydrogen production by Δ*HupW* strain of *Nostoc* sp. PCC 7120 was characterized in a photobioreactor
  - Custom designed photobioreactors
  - Photon to energy conversion at max 4 %; 6.89 % H_2
  - *Nyberg et al. J Biotechnol, in press (2015)*

Calothrix **Becid 33**

Nodularia **AV33**

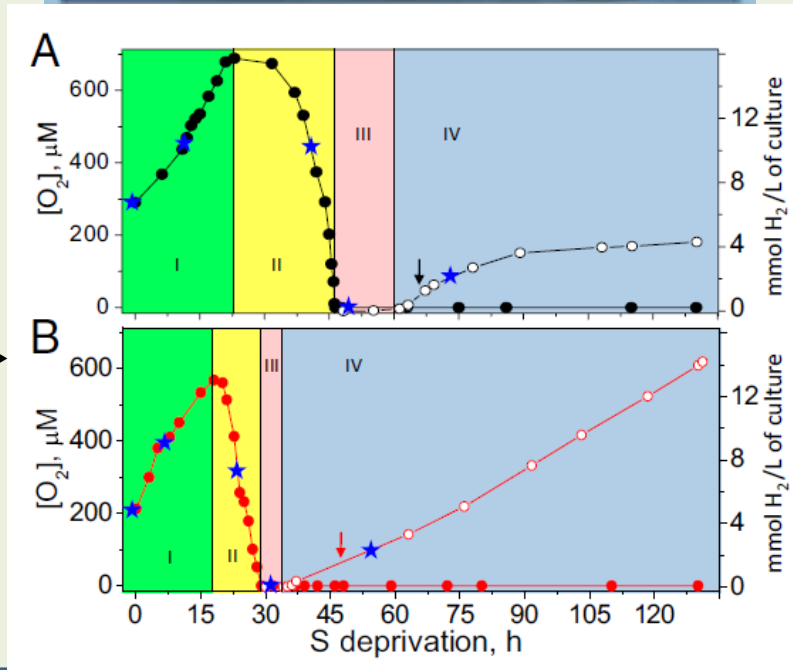
Nostoc **Becid 19A**



Nostoc **XIID A6**

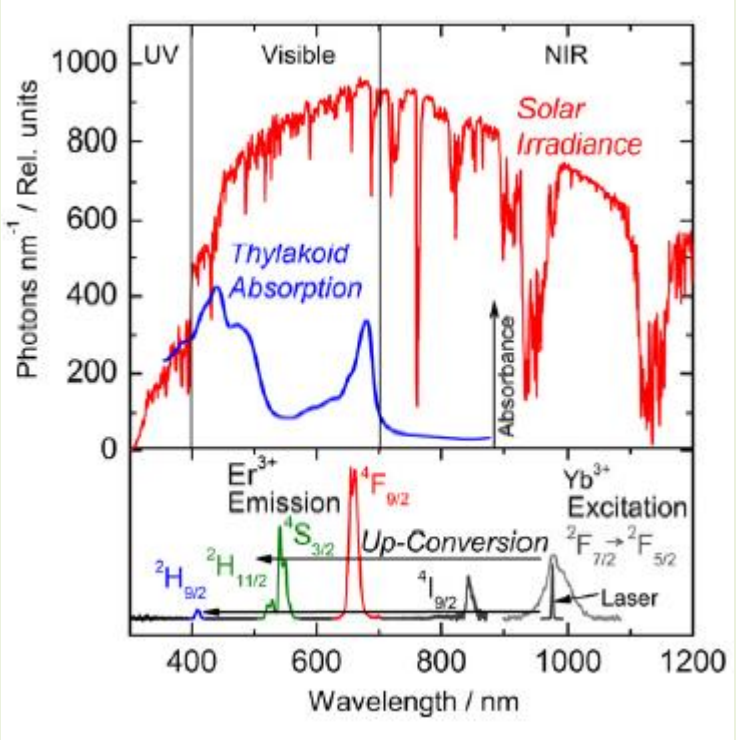
2. Biohydrogen production (continued)

- H_2 yield of nitrogen-fixing cyanobacteria can be improved by immobilizing the cyanobacteria with alginate
  - *Kosourov et al. Appl Environ Microbiol 80: 5807-5817 (2014)*
- Flavodiiron protein accelerates the establishment of anaerobiosis and ensures induction of hydrogenase.
  - *Jokel et al. Plant Cell Physiol 58: 1598-1607 (2015)*
- Magnesium deficiency induces H_2 production by the green alga *Chlamydomonas*
  - *Volgusheva et al. RSC Adv 5: 5633-5637 (2015)*
- Increased stability of Photosystem II improves H_2 yield in *Chlamydomonas*
  - *Volgusheva et al. Proc Nat Acad Sci USA 110: 7223-7228 (2013)*



3. Combination of material chemistry, biology and wastewater technology

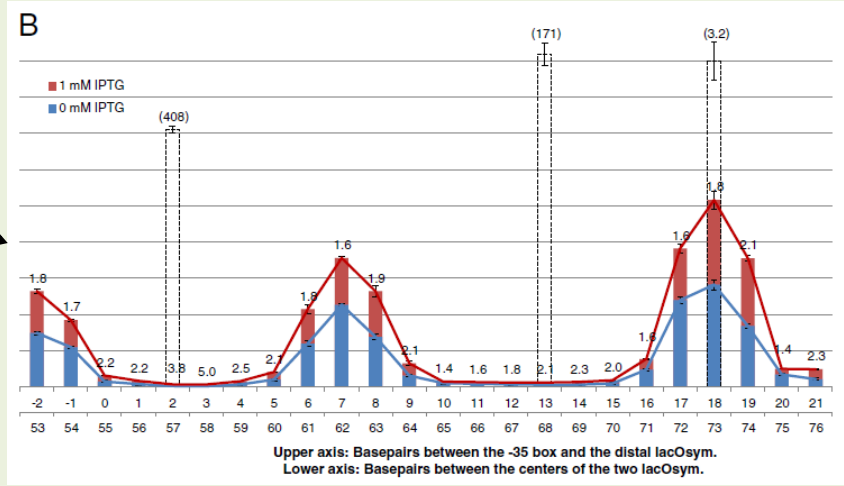
- Photon up-conversion can be used to drive photosynthetic reactions
  - *Antal et al., Int J Hydrogen Energy 37: 8859-8863 (2012)*
- Finnish cyanobacteria and green algae were screened for their potential to purify waste waters and to produce biodiesel oil
  - *Lynch et al. Algal Res, in press (2015)*

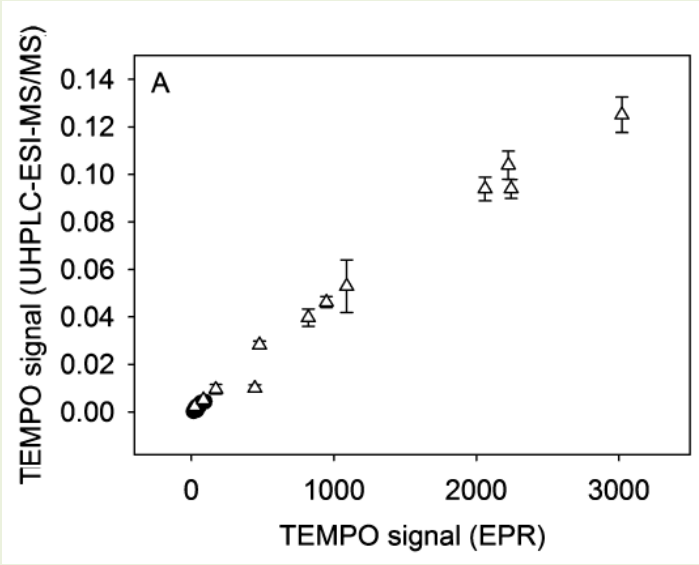


Up-conversion luminescence of $NaYF_4$ doped with Yb^{3+},Er^{3+} under 976 nm NIR excitation

4. Design of biotechnological and analysis tools

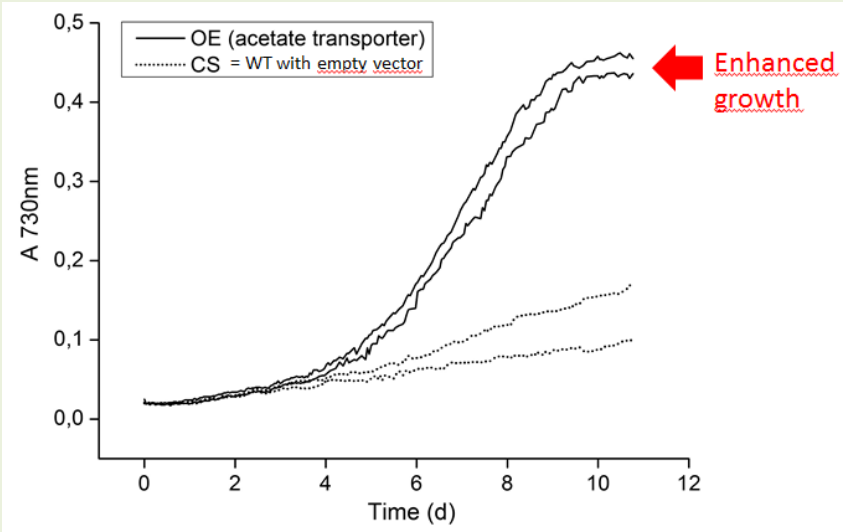
- Artificial constitutive promoters for cyanobacteria
  - *Camsund et al. J Biol Eng 8:4 (2014)*
- Measurement of singlet oxygen with mass spectrometry
  - *Karonen et al. Photochem Photobiol 90: 965-971 (2013)*





5. Utilization of acetate by mixotrophic hosts

- Waste waters contain organic substances like acetate
- The cyanobacterium *Synechocystis* sp. PCC 6803 can use acetate for mixotrophic growth
- Acetate transporter overexpression strain mobilizes glycogen storage efficiently
  - Manuscript under preparation



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Hydrogen production by
PCC 7120 Δ*hupW* exam

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REVIEW ARTICLE

Potential for green
pharmaceuticals an
combined process

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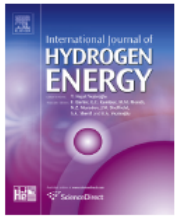

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