

# PBIO-141

## Sensory and Physiological Ecology of Plants

### 8: Photoreceptors and signalling

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Pedro J. Aphalo

January–February 2022

M.Sc. in Plant Biology, University of Helsinki

<http://blogs.helsinki.fi/aphalo/>

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University of Helsinki, Finland.

<http://blogs.helsinki.fi/senpep-blog/>

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# Outline

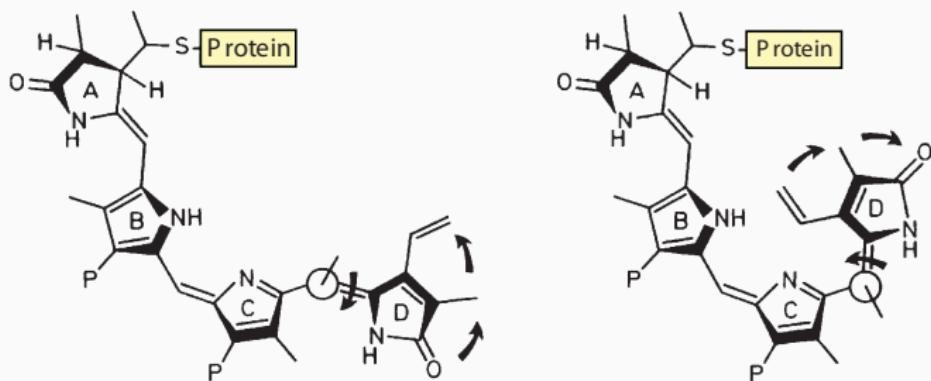
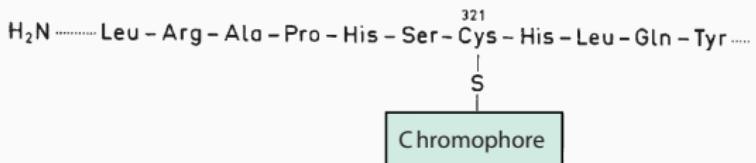
The photoreceptors

Transduction

# The photoreceptors

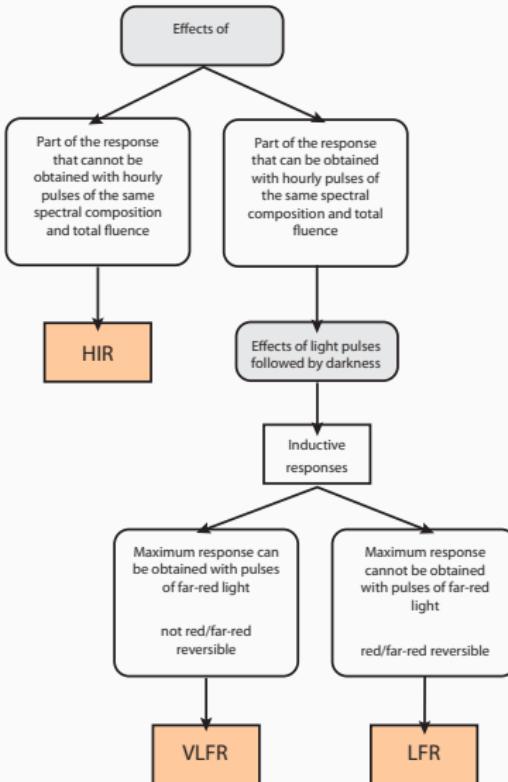
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# Phytochromes: Molecular configuration



Left: P<sub>r</sub>, right: P<sub>f</sub>r (from Mohr and Schopfer 1995).

# Phytochromes: Modes of action



# Photoreceptors: Typographical convention

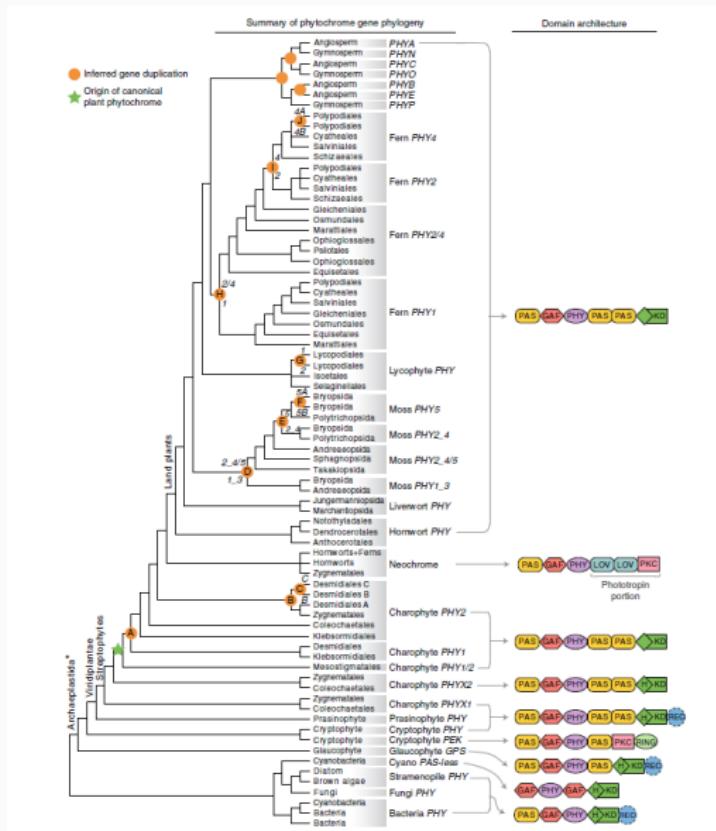
Holoprotein (apoprotein + chromophore) → phyA

Apoprotein → PHYA

Gene → *PHYA*

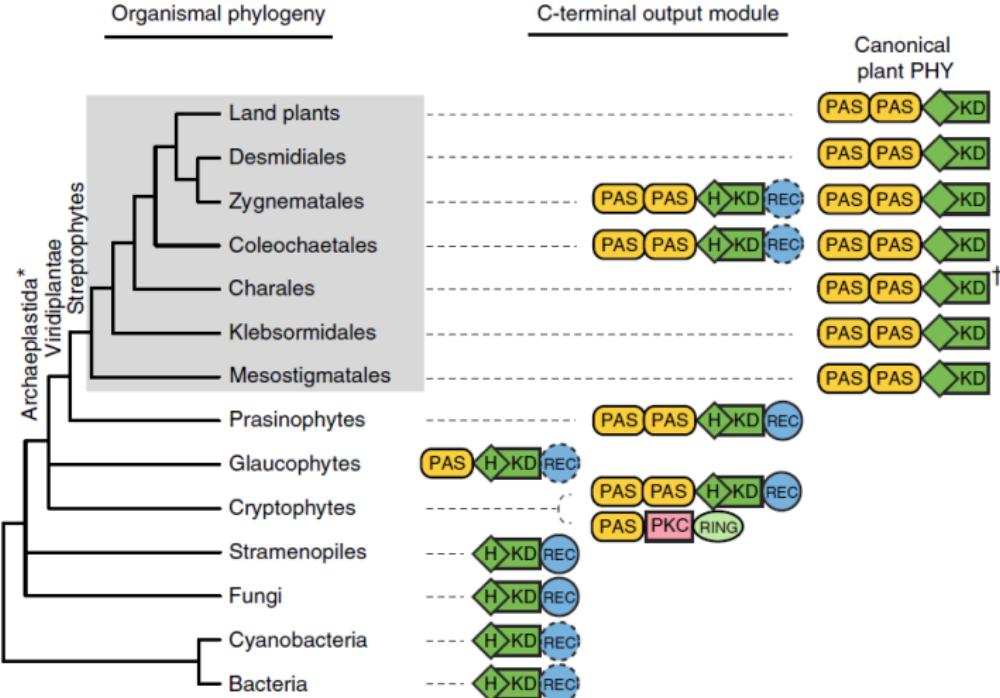
Mutant → *phyA*

# Phytochromes: Phylogeny of apoprotein



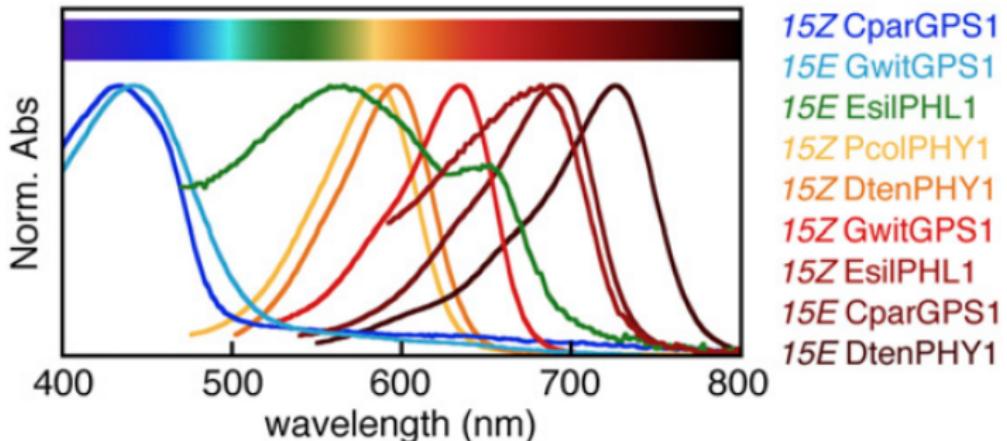
(Fig. 1 in Li et al. 2015).

## Phytochromes: Diversity and evolution of phytochrome



(Fig. 2 in Li et al. 2015).

# Phytochromes



**Fig. 6.** Full coverage of the visible spectrum by algal phytochromes. Normalized absorption peaks are shown for the indicated algal phytochromes. Approximate color ranges within the visible region for humans are indicated on the color bar.

(Fig. 6 in Rockwell et al. 2014).

# The photoreceptors: Blue/UV-A

- Flavoproteins
  - CRY1, CRY2 (FAD, flavin adenine dinucleotide + MTHF, methenyltetrahydrofolate)
  - PHOT1, PHOT2, ZTL (FMN, flavin mononucleotide)
- Carotenoid chromophore
  - ? (zeaxanthin)

# Cryptochromes: structure

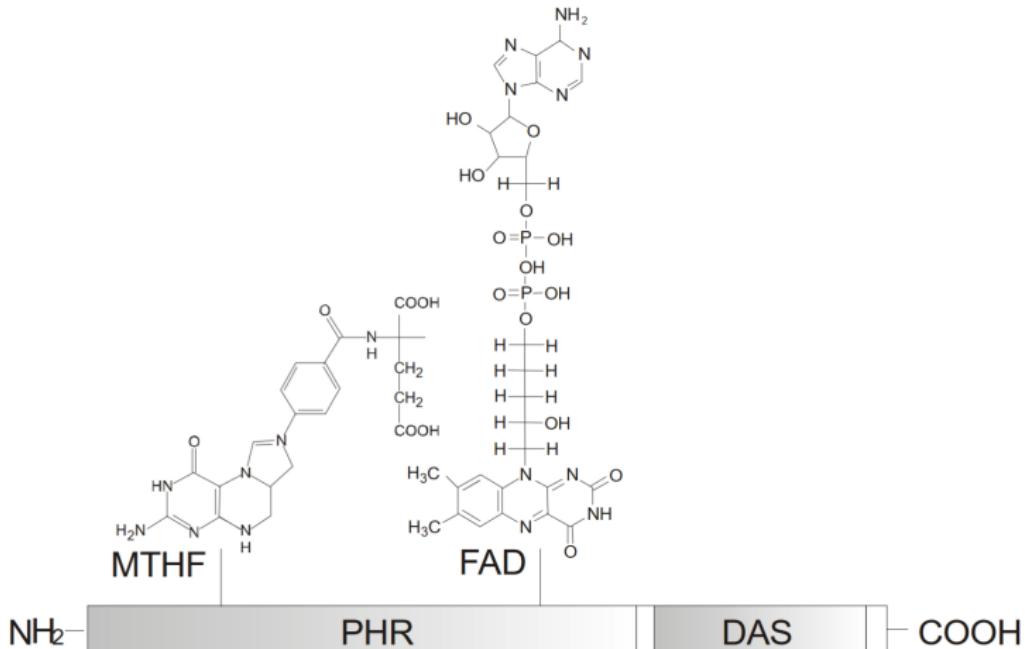


Fig. 2.14 Cryptochrome contains two non-covalently bound chromophores. One chromophore is flavin-adenine dinucleotide (FAD) and the other is methenyltetrahydrofolate (MTHF) [76].

# Cryptochromes (*Arabidopsis thaliana*)

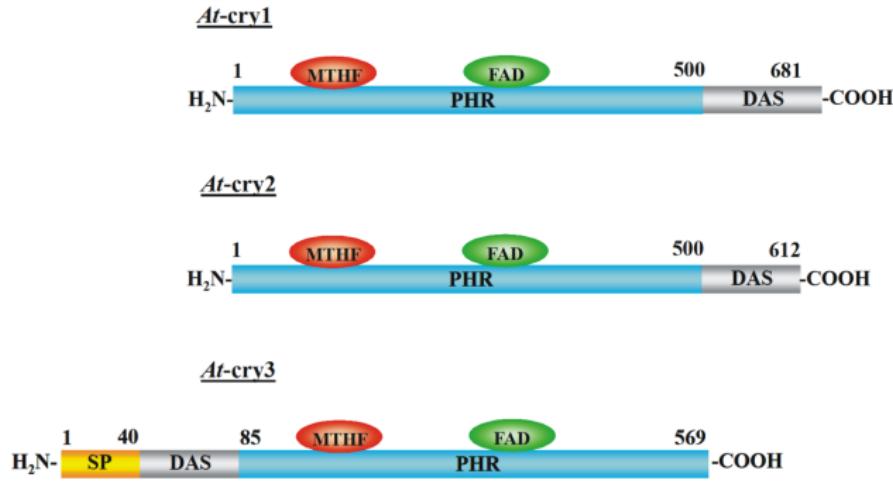


Fig. 2.15 Schematic primary structures of full-length *At-cry1*, *At-cry2* and *At-cry3* [77].  
PHR : photolyase homology region (contains binding sites for MTHF and FAD cofactors).  
SP : signal peptide (contains signal sequences for import into chloroplasts and mitochondria; this signal peptide is cleaved off after import).  
DAS : N-terminal extension unique for *At-cry3* containing DAS-like motif.

(from Song 2006).

# Phototropins: structure

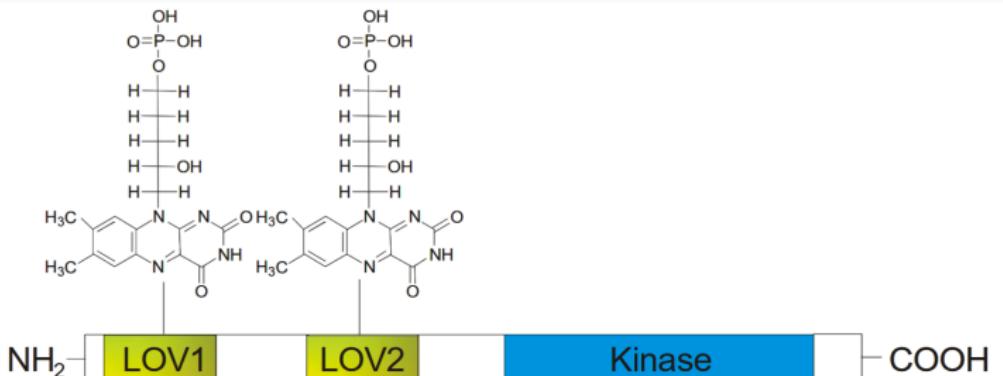


Fig.2.1 Primary structure of the amino acid sequence in phototropin of *Chlamydomonas reinhardtii*. Each LOV domain contains one FMN.

(from Song 2006).

# Cryptochromes vs. phototropins

**Cryptochromes** ‘Slow responses to blue light’: many responses.

**Phototropins** ‘Movements’: phototropism, stomatal opening, chloroplast movements.

**Cryptochromes** plants, bacteria, fungi, animals, humans.

**Phototropins** plants (also ferns, mosses, green algae)

**Neochrome** Adiantum (fern). Phototropin fused to phy photosensory domain.

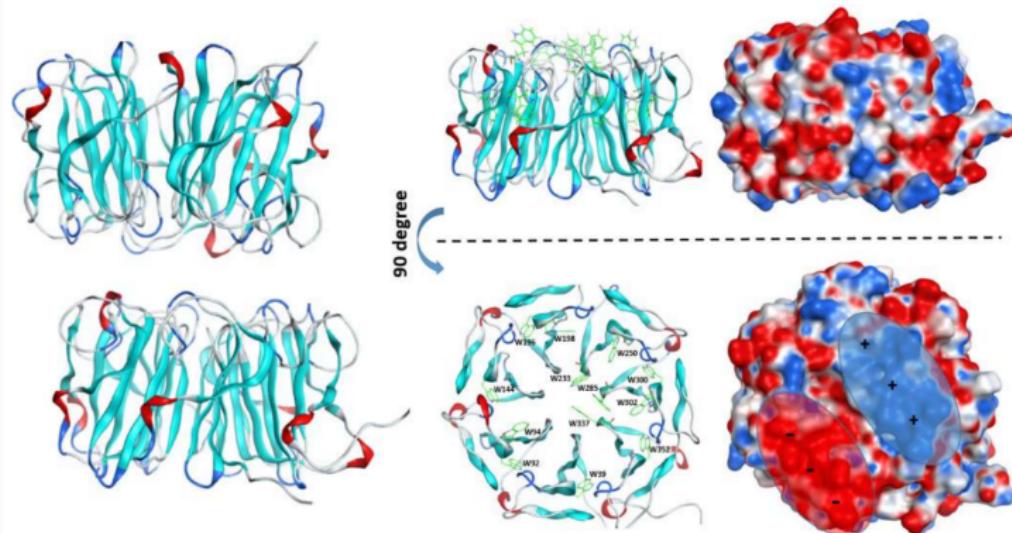
**LOV proteins** plants, fungi, bacteria. Arabidopsis: ZTL/ADO family of blue photoreceptors.

# The photoreceptors: UV-B

- Photoreceptor: UVR8
- Responses:
  - *CHS*: induction
  - *Rbc S* (Rubisco small subunit): repression
  - anthocyanin synthesis: +
  - some flavonoids: +
  - other flavonoids: - | 0
  - stem elongation and other morphological effects

Also damage is caused by UV-B, because it is absorbed by DNA and proteins.

# UVR8: structure



**Figure 5.** The 3D crystal structure of UVR8 dimer, UVR8 monomer with all tryptophan residues presented in crystal structure highlighted and the electrostatic surfaces of UVR8 monomer with the positively charged surfaces are presented in blue and negatively charged surfaces are presented in red.

(from Wu 2017).

# Transduction

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# Transduction: signalling networks

## Cellular responses

- Gene transcription (up- or down regulation)
- Post-transcriptional regulation (e.g. enzyme activity)
- Post-transcriptional modification
- Membrane permeability (e.g. opening/closing of ion channels)

# Cellular transduction chains

## Transduction chains

- Complex interactions
- More like *webs* than *chains*
- Different for:
  - different photoreceptors (even within families)
  - different modes of action
  - different end responses
  - different tissues and developmental stages

This complexity implies many possibilities for evolution and natural selection.

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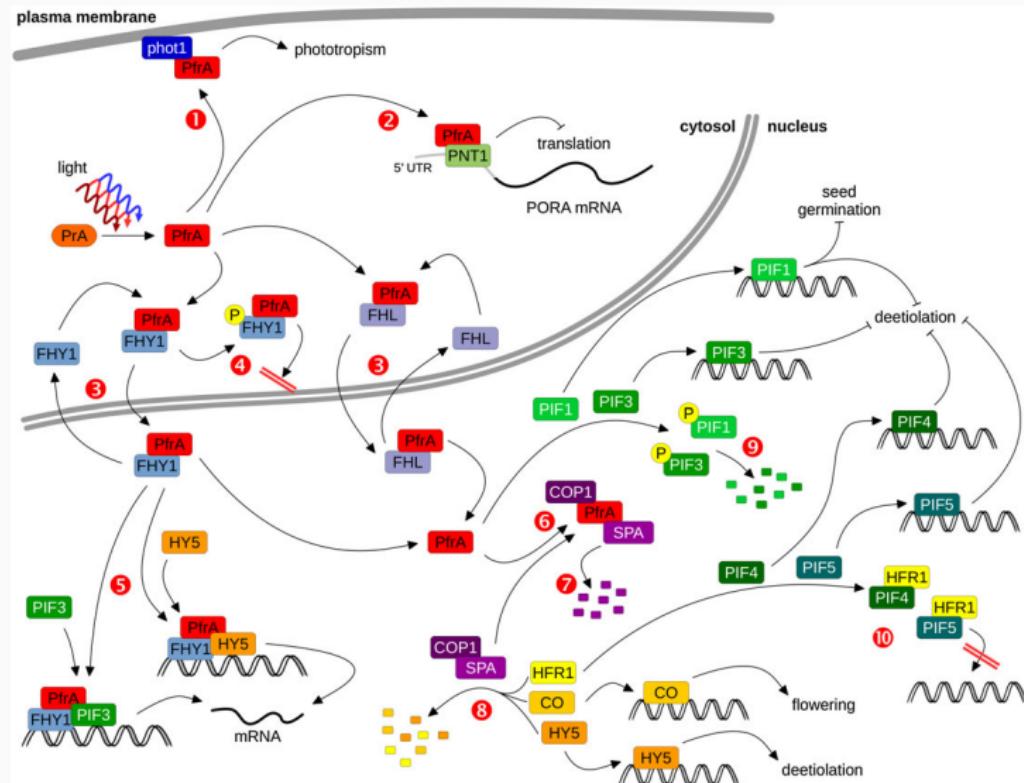
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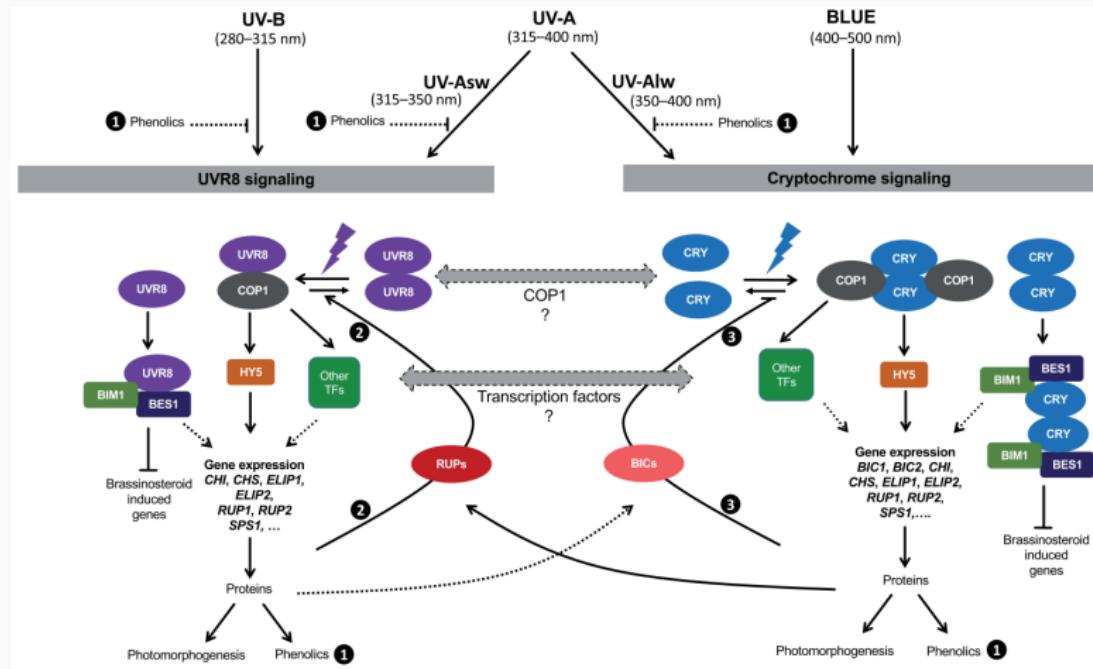
This complexity implies many possibilities for evolution and natural selection.

# Schematic model for phyA signalling



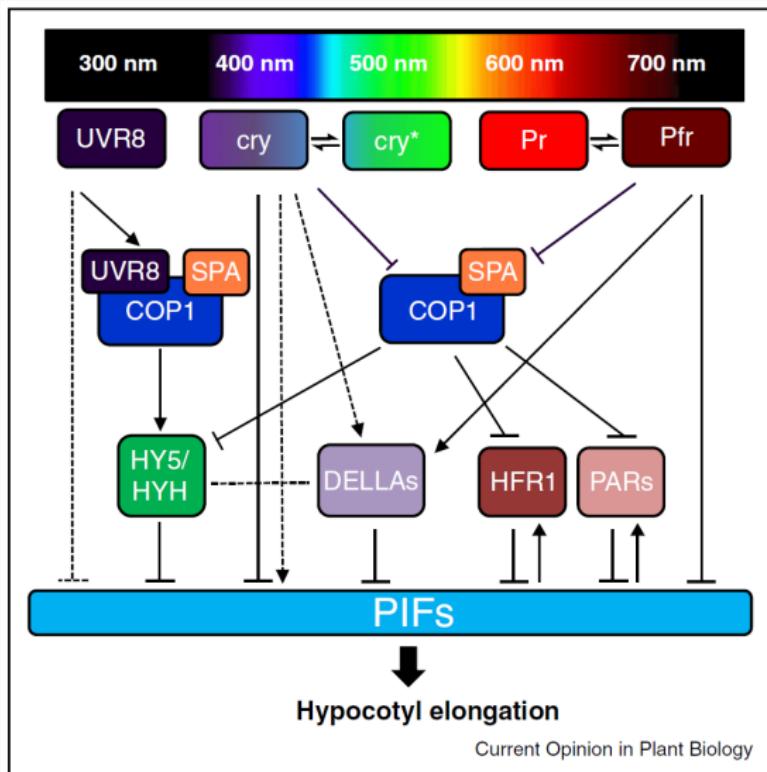
(Fig. 2 in Sheerin and Hiltbrunner 2017).

# Schematic model for UVR8 and CRY signalling



(Fig. 5 in Rai et al. 2021).

# PIF signalling



(Fig. 6 in Fraser et al. 2016).

# HY5 signalling

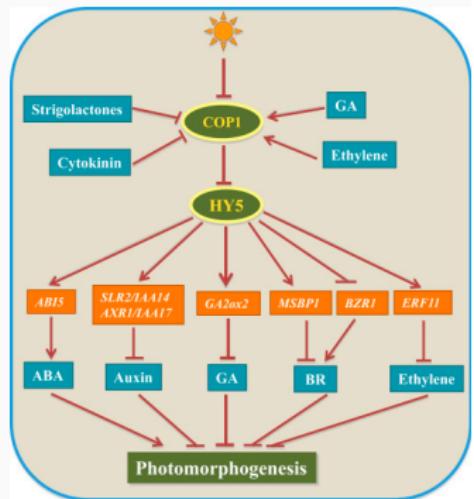
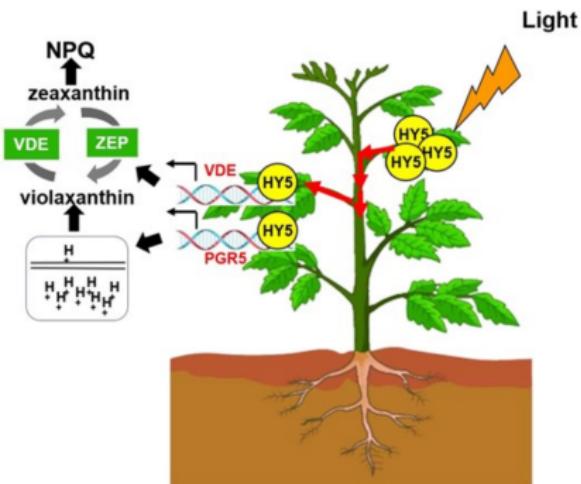
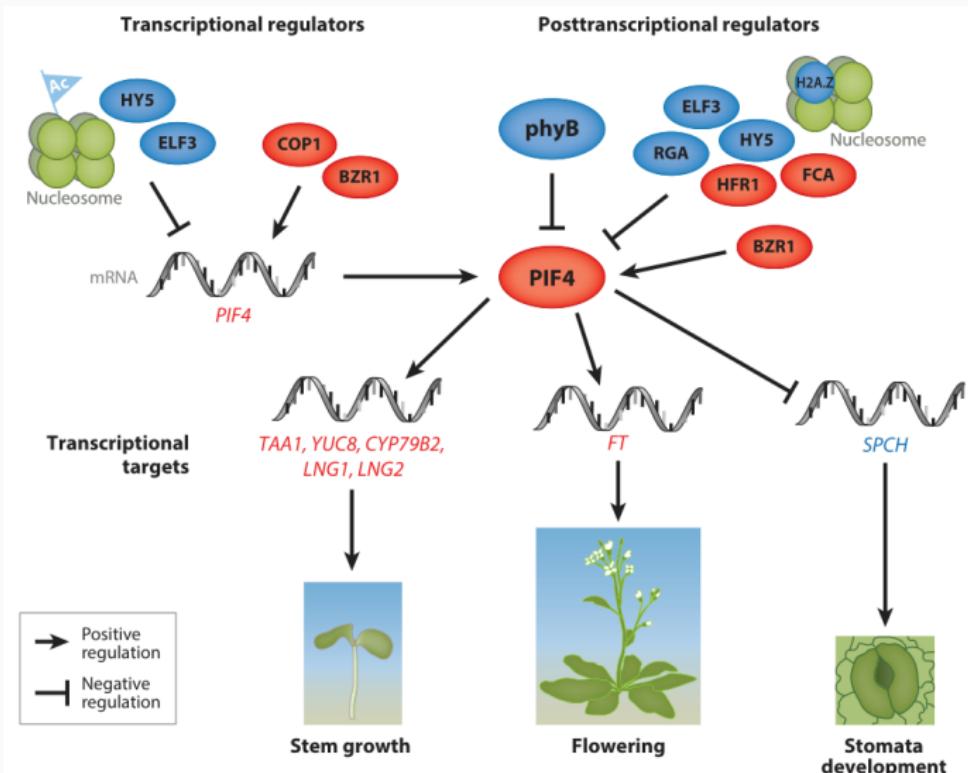


Figure 9.



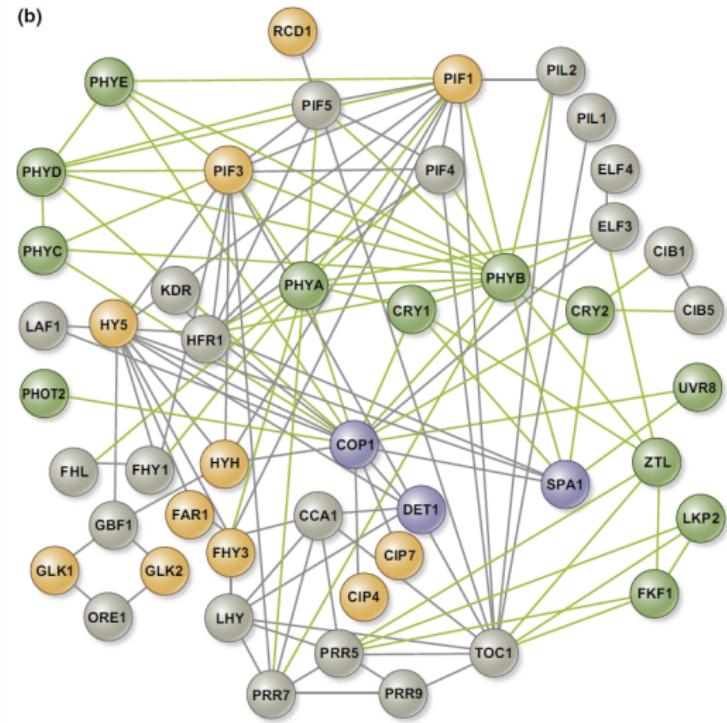
(Fig. 6 in Gangappa and Botto 2016; Jiang et al. 2020).

# Thermomorphogenesis



(Fig. 6 in Casal and Balasubramanian 2019).

# Photosynthetic capacity: Transcription factor interaction network



(Fig. 2 in Wang et al. 2017).

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