PBIO-141
Sensory and Physiological Ecology of Plants

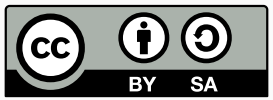
7: Light sensing

Pedro J. Aphalo

January–February 2022

M.Sc. in Plant Biology, University of Helsinki

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



Outline

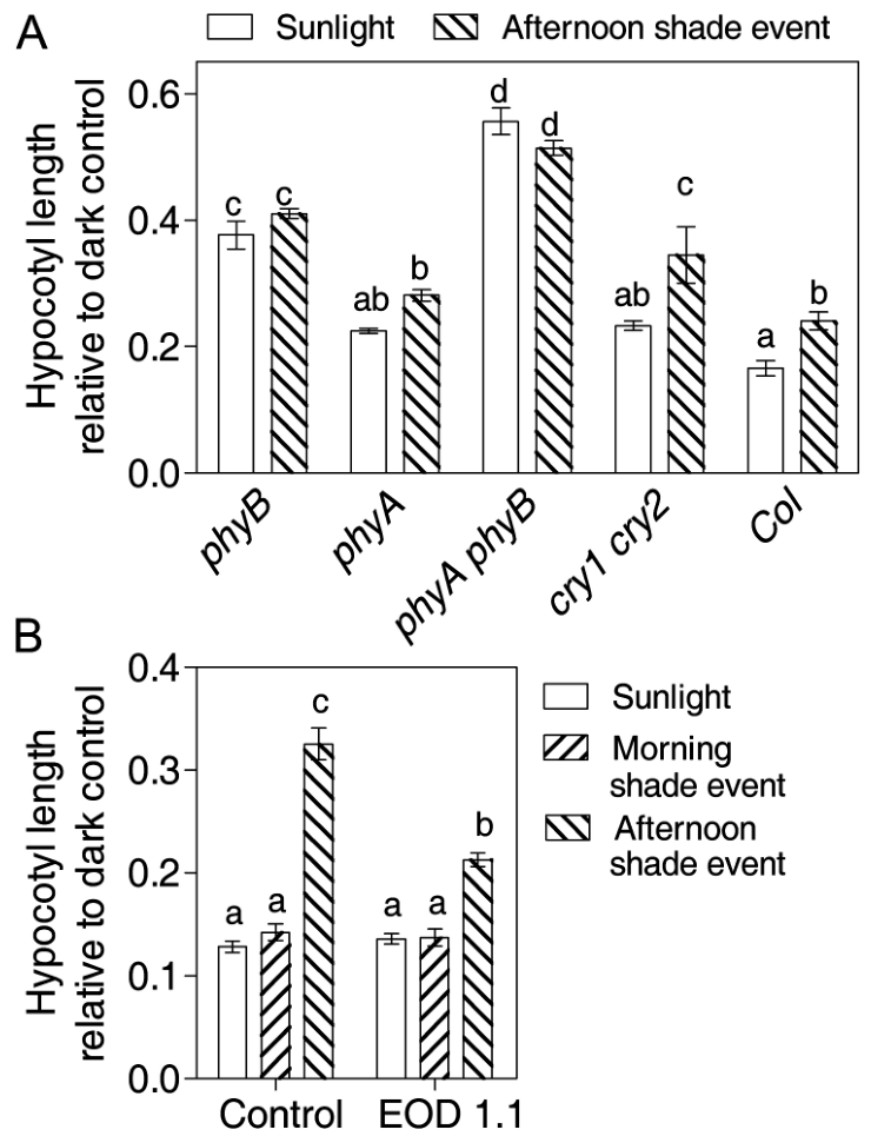
Responses to shade (cont.)

The photoreceptors

Responses to shade (cont.)

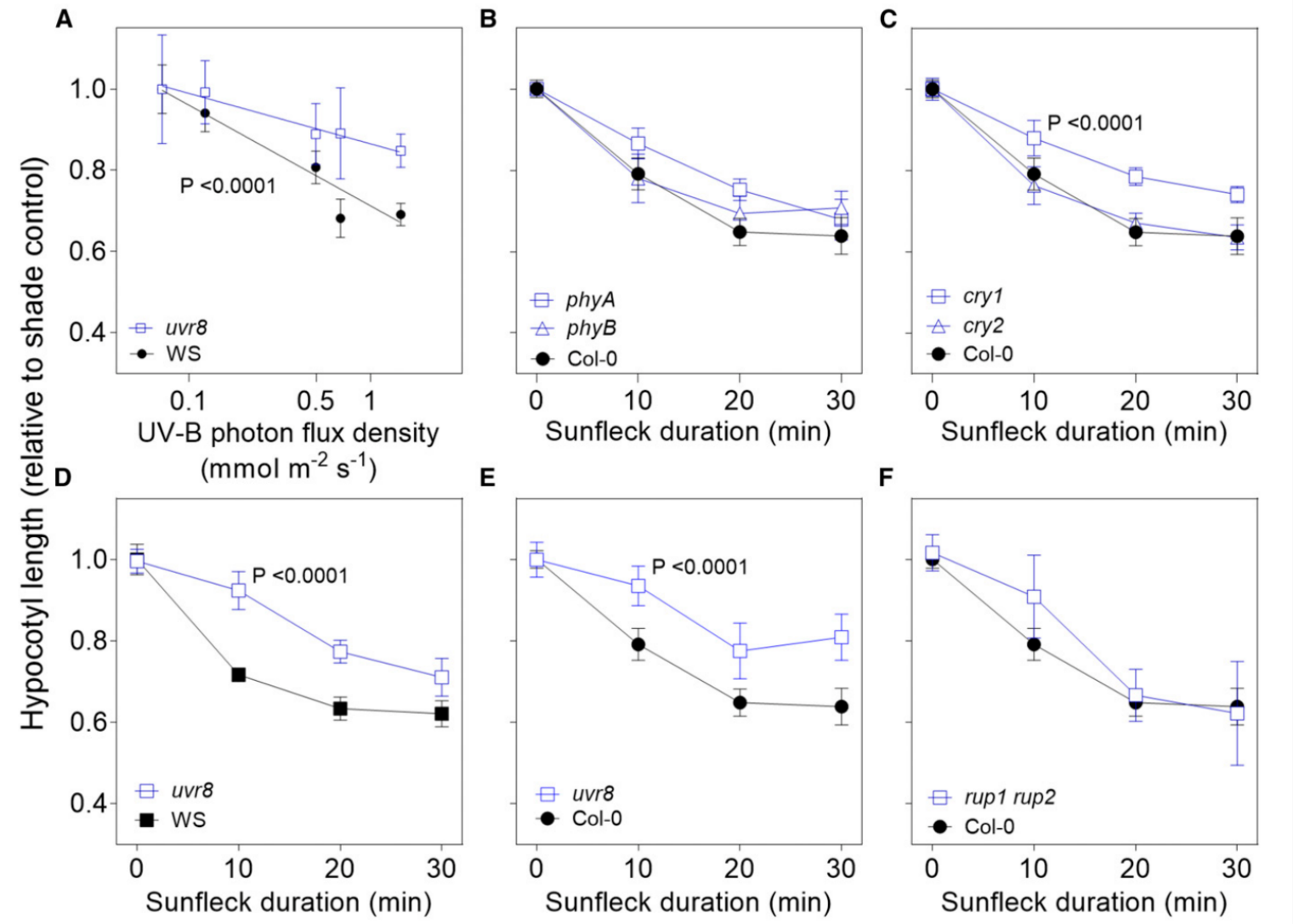
Timing of shade

Arabidopsis seedlings (from Sellaro et al. 2012).

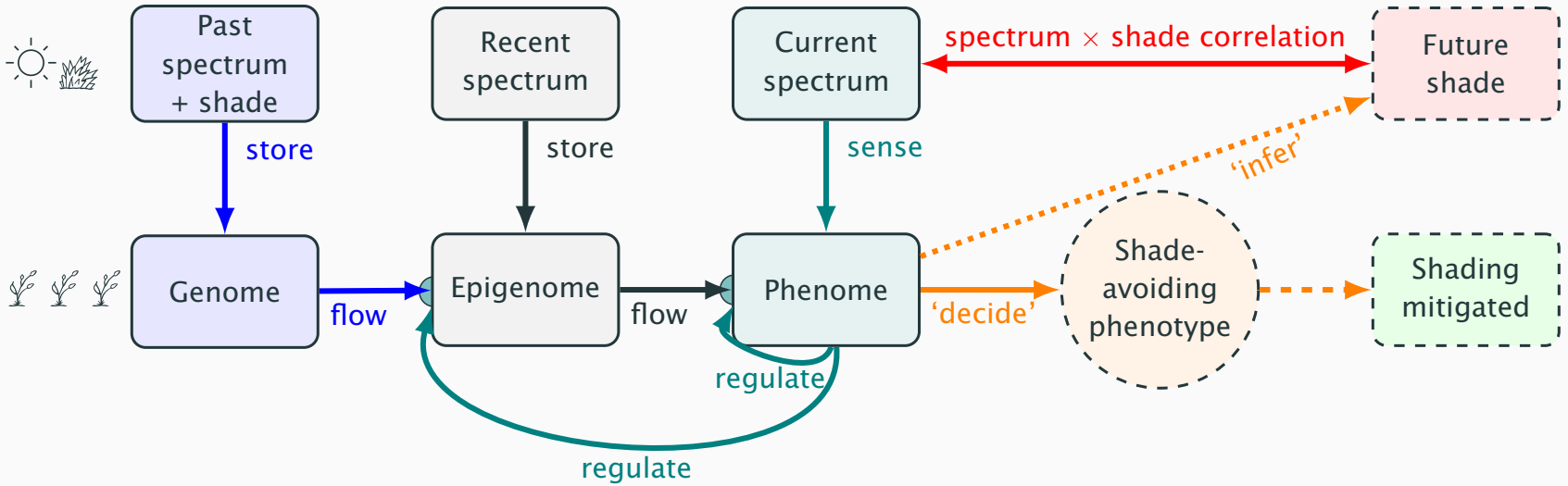


Sunflecks, UVR8, CRY1

Arabidopsis seedlings (from Moriconi et al. 2018). In A $\mathrm{mmol\,m^{-2}\,s^{-1}}$ should read $\mu\mathrm{mol\,m^{-2}\,s^{-1}}$.



Preemptive acclimation: shade



Flow of information in preemptive acclimation to shade by perception of radiation changes. Arrows represent flows of information: **blue** = retrieved from genome (stored during earlier generations), **black** = acquired and/or 'memorized' during an individual's or its progenitor's lifetime, **teal** = regulation of gene expression by phenome or downward causation, **red** = lagged correlation between early changes in spectral irradiance and future low PAR irradiance, **orange** = outcome of information processing: a 'decision', based on an 'implicit forecast of impending shade', leading to developmental adjustments that would increase the probability of higher fitness in the presence of neighbours in comparison with phenotypes lacking preemptive acclimation. **green** = 'Shading mitigated' compared, in probabilistic terms, to no acclimation. Dashed boxes and arrows represent the likely or forecasted future.

Preemptive acclimation: What is the evidence?

- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.
- Preemptive shade avoidance as a response to reflected far-red light from neighbouring plants.
- Winter hardening and dehardening, timing of bud burst, timing of flowering, etc.
- *Anticipatory responses* and *future perception* are terms also used in this context.

Acclimation vs. rapid/reversible responses 5 min

(from Casal 2013). What about the balance between light reactions and carbon reactions of photosynthesis?

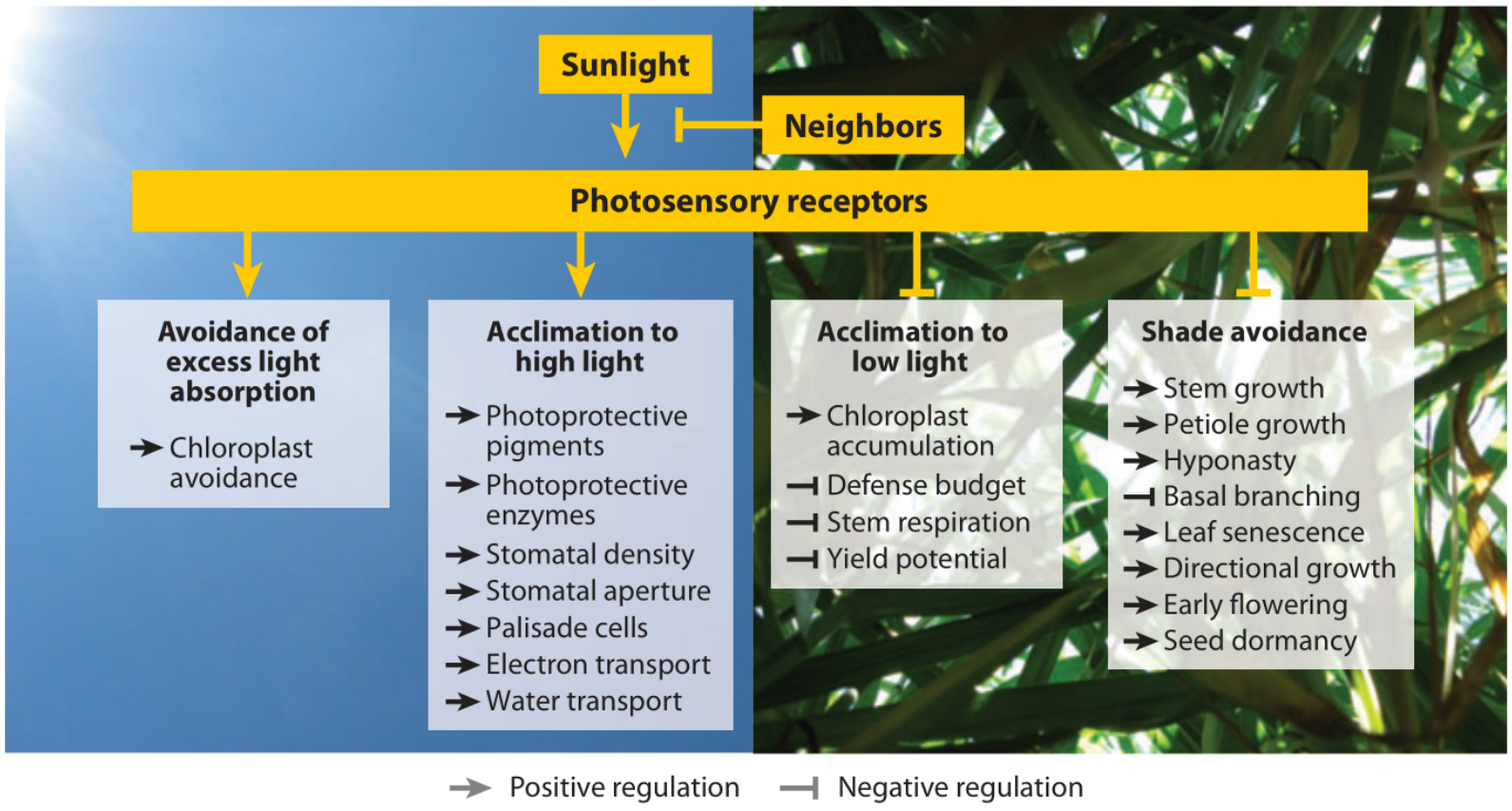


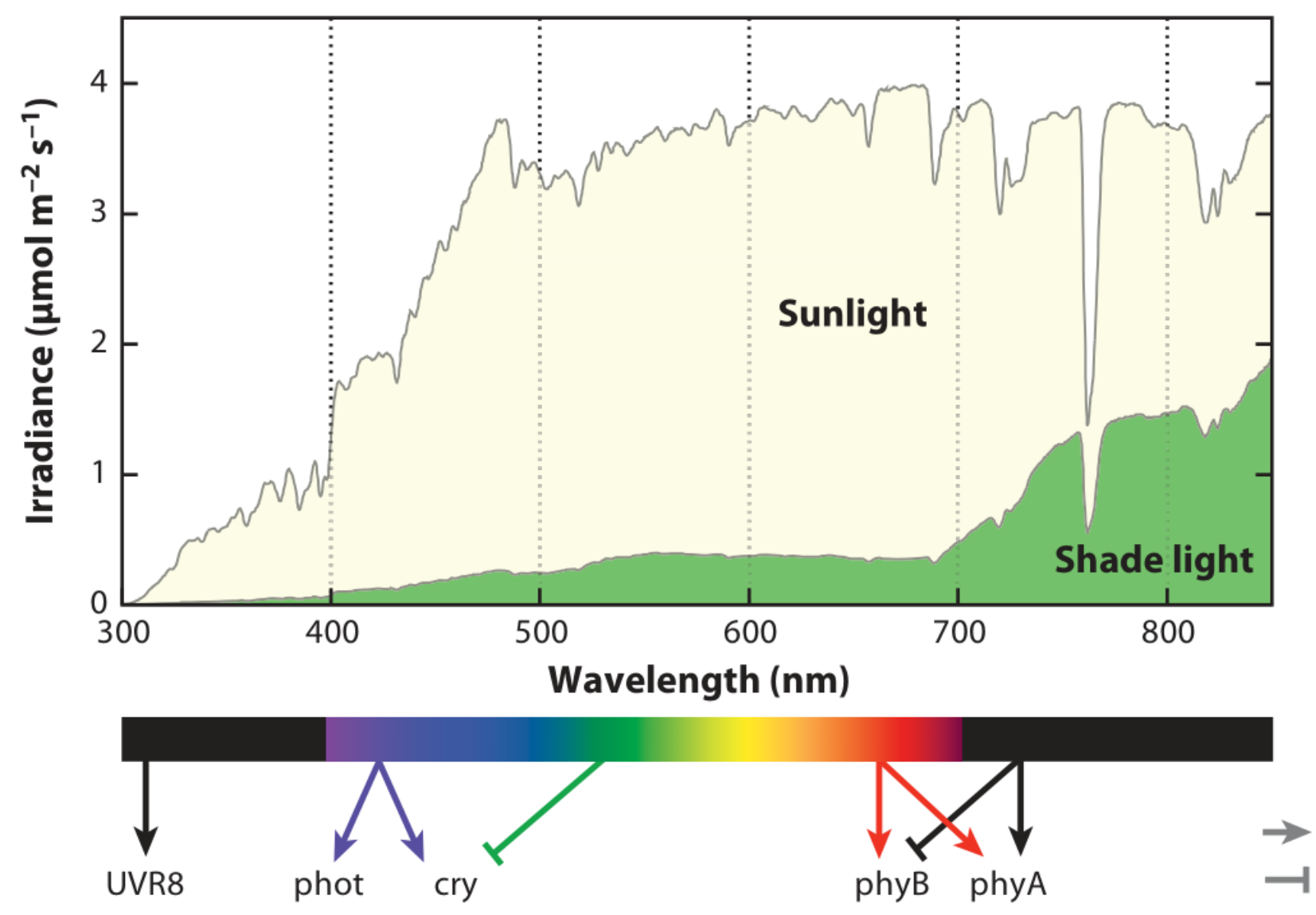
Figure 3

Plant responses to either sunlight (*left*) or shade light (*right*) perceived by photosensory receptors.

The photoreceptors

Role of photoreceptors in responses to shade

(from Casal 2013).

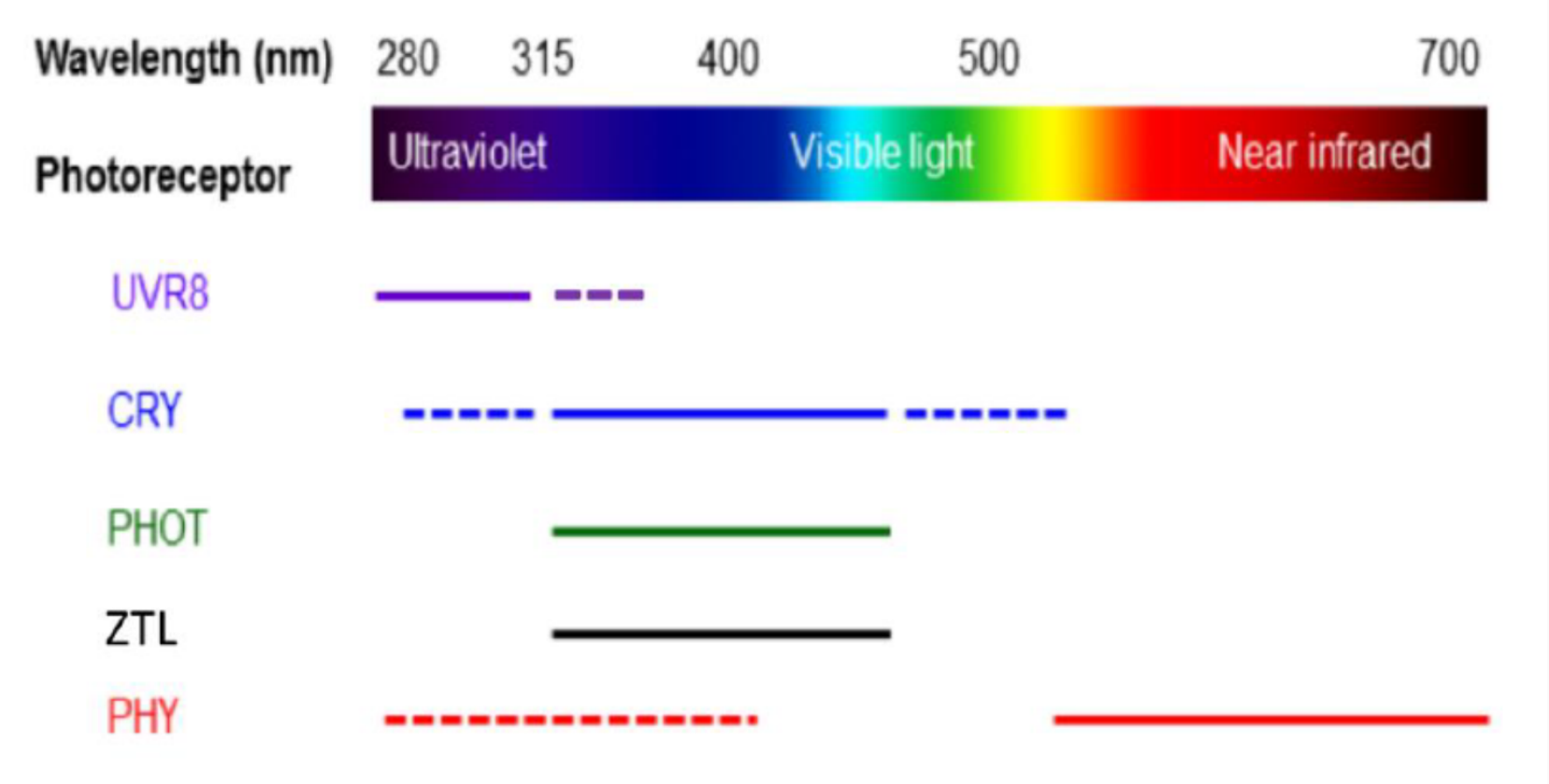


Photoreceptors: Chromophores

- Photoreceptors are proteins, like enzymes
- Except for UVR8 (UVB photoreceptor) the light is not absorbed by the protein
- A different type of molecule coupled to the protein absorbs the photons
- The type of chromophore is the main determinant of what wavelengths are absorbed
- The protein transfers the energy through different mechanisms to a signalling pathway
- In most cases changes in gene expression are triggered

Photoreceptors vs. wavelength

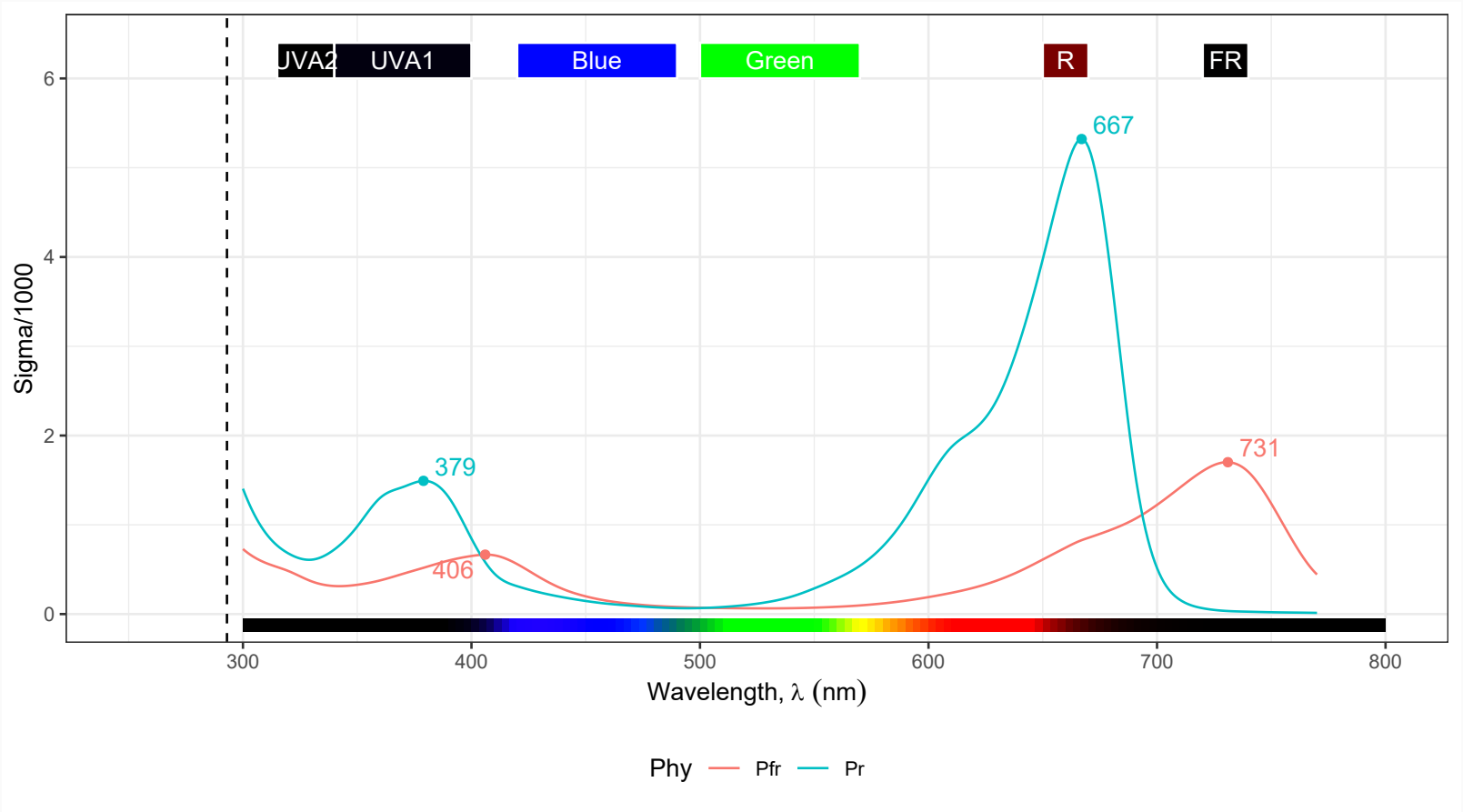
Several variations on this figure exist (from Rai 2020).



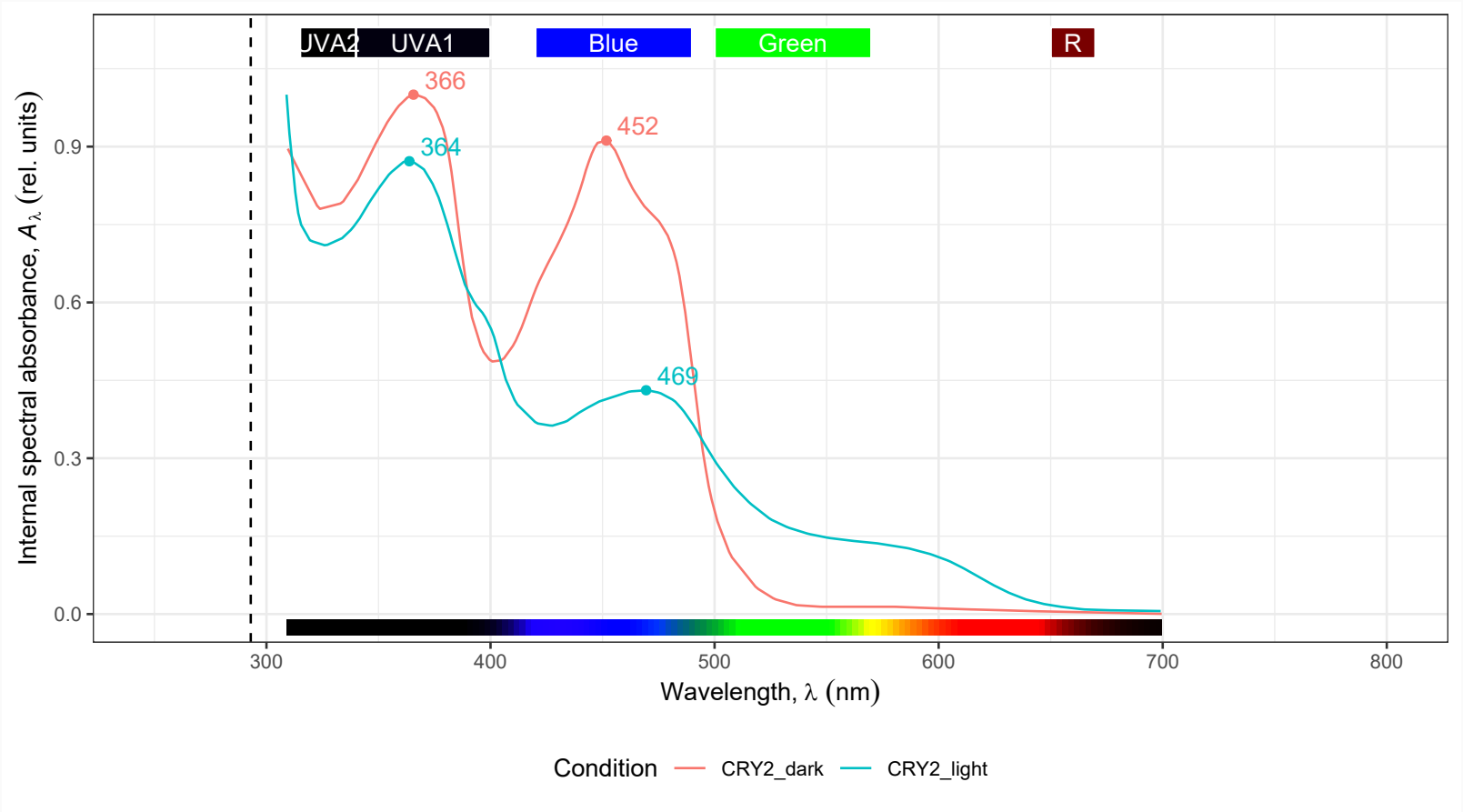
Photoreceptors

- Phytochromes: PhyA, PhyB, PhyC, PhyD, PhyE
- Cryptochromes: Cry1, Cry2, (Cry3)
- Phototropins: Phot1, Phot2
- UV-receptor: UVR8
- Blue-green receptor: (Zeaxanthin)
- other LOV-containing proteins
- ?

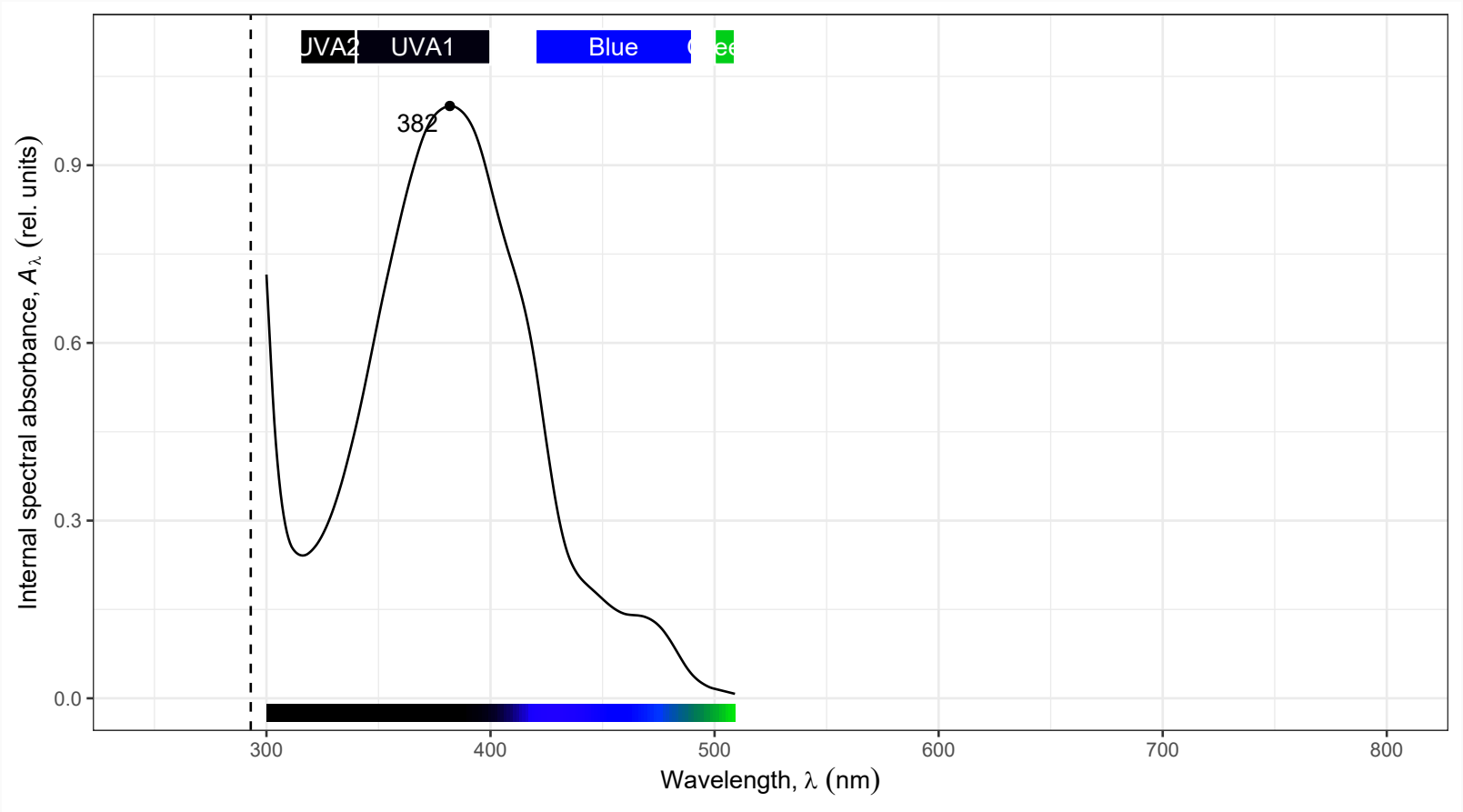
Photoreceptors: Phy (in vitro)



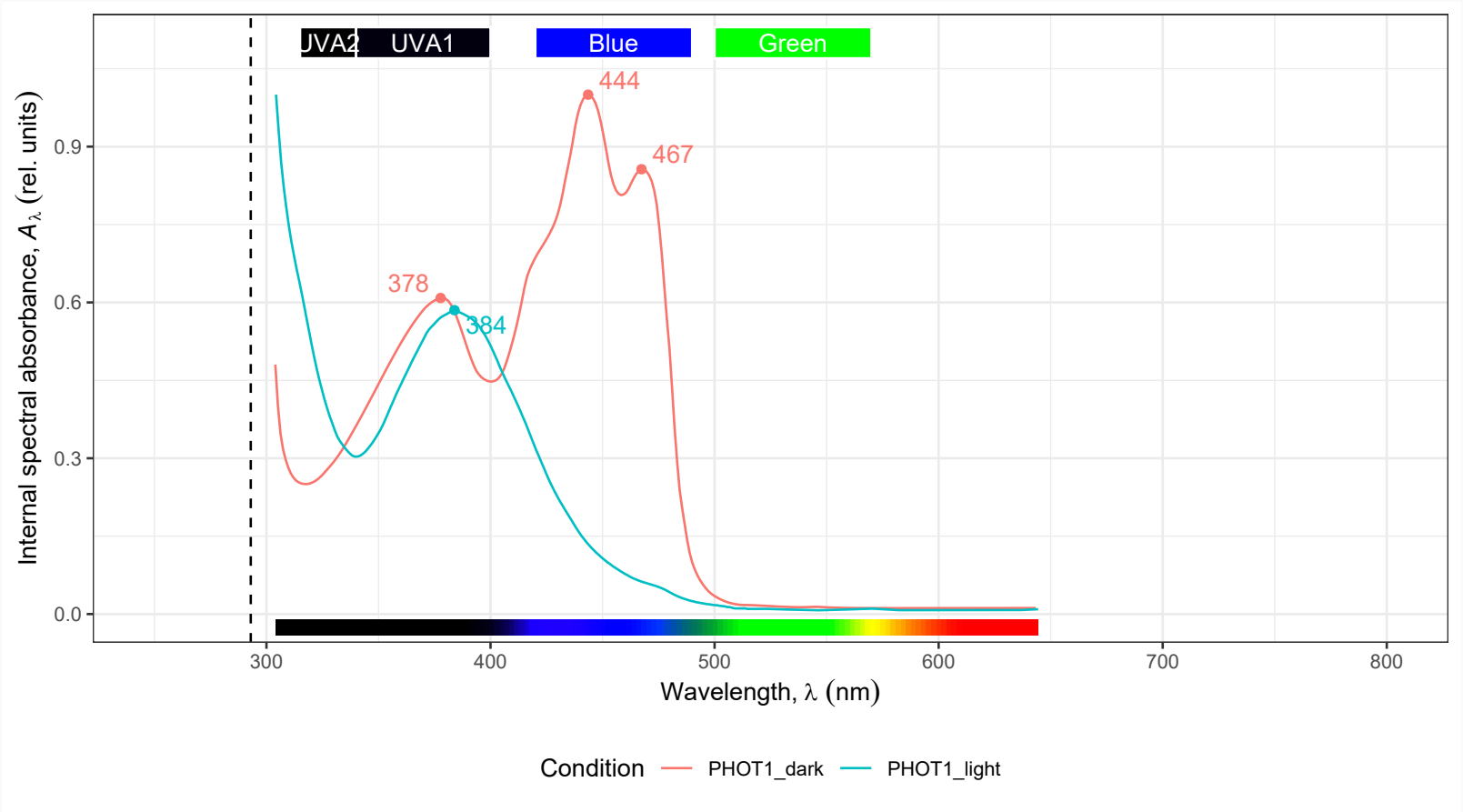
Photoreceptors: Cry2 (in vitro)



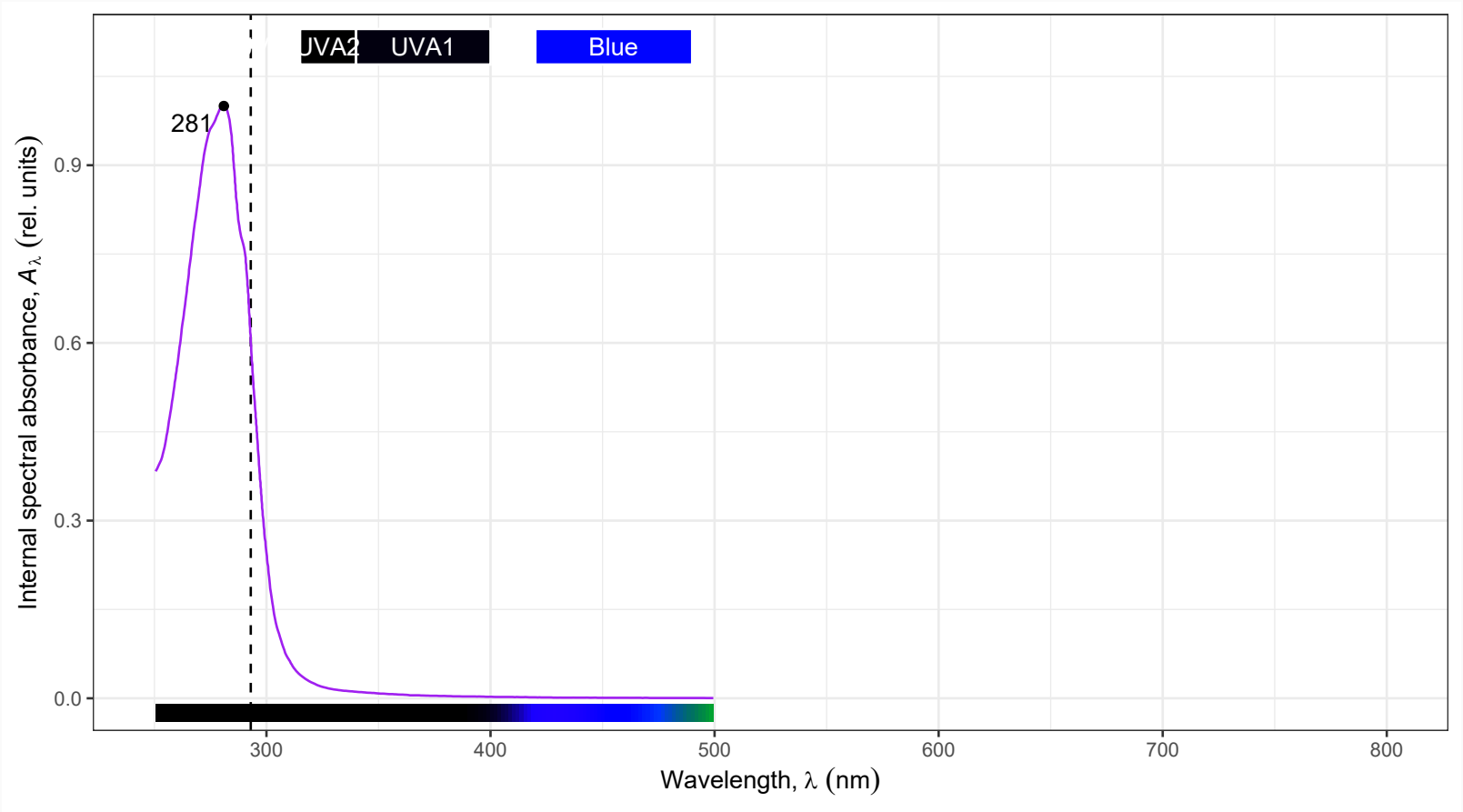
Photoreceptor (?): Cry3 (in vitro)



Photoreceptors: Phot1 (in vitro)



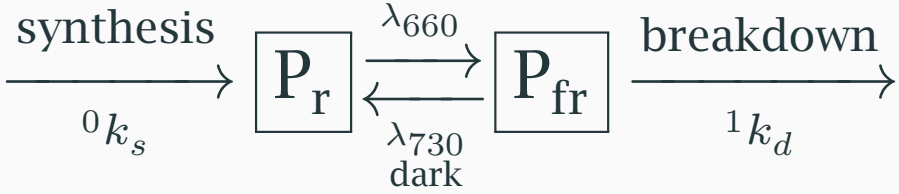
Photoreceptors: UVR8 (in vitro)



Photoreceptors: Phytochromes

- Phytochromes are *photochromes*: change colour when they absorb light
- Tetrapyrrole chromophore
- $\mathrm{P_r} \rightleftarrows \mathrm{P_{fr}}$
- Photoequilibrium
- Photo-steady state
- Modes of action
- Family of apoproteins PHYA–PHYE (in *Arabidopsis*)

Phytochromes: Photo-conversion



- Short irradiation time: *photoequilibrium*
- Long irradiation time: *photo-steady state*

References

References


Aphalo, P. J. and V. O. Sadras (Dec. 2021). “Explaining preemptive acclimation by linking information to plant phenotype”. In: *Journal of Experimental Botany*. DOI: 10.1093/jxb/erab537.


Casal, J. J. (2013). “Photoreceptor Signaling Networks in Plant Responses to Shade”. In: *Annual Review of Plant Biology* 64.1, pp. 403–427. DOI: 10.1146/annurev-arplant-050312-120221.


Christie, J. M., L. Blackwood, J. Petersen and S. Sullivan (Dec. 2015). “Plant Flavoprotein Photoreceptors”. In: *Plant and Cell Physiology* 56, pp. 401–413. DOI: 10.1093/pcp/pcu196.

References ii


Christie, J. M., T. E. Swartz, R. A. Bogomolni and W. R. Briggs (2002). “Phototropin LOV domains exhibit distinct roles in regulating photoreceptor function”. In: *The Plant Journal* 32. DOI: 10.1046/j.1365-313X.2002.01415.x.


Mancinelli, A. L. (1994). “The physiology of phytochrome action”. In: *Photomorphogenesis in Plants*. Springer, pp. 211–269. DOI: 10.1007/978-94-011-1884-2_10.


Moriconi, V., M. Binkert, M. C. C. Rojas, R. Sellaro, R. Ulm and J. J. Casal (2018). “Perception of sunflecks by the UV-B photoreceptor UV RESISTANCE LOCUS 8”. In: *Plant physiology* 177, pp. 75–81. DOI: 10.1104/pp.18.00048.

References iii


Rai, N. (2020). “Perception of solar UV radiation and blue light by plants: phptpreceptors, transcriptome and environmental acclimation”. PhD thesis. Helsinki: University of Helsinki. 56 pp. ISBN: 978-951-51-6736-1. URL: http://urn.fi/URN:ISBN:978-951-51-6737-8 (visited on 07/02/2022).


Sellaro, R., M. Pacín and J. J. Casal (2012). “Diurnal dependence of growth responses to shade in Arabidopsis: role of hormone, clock, and light signaling.”. In: *Molecular plant* 3, pp. 619–628. DOI: 10.1093/mp/ssr122.


Song, S.-H., B. Dick, A. Penzkofer, R. Pokorny, A. Batschauer and L.-O. Essen (2006). “Absorption and fluorescence spectroscopic characterization of cryptochrome 3 from Arabidopsis thaliana”. In: *Journal of Photochemistry and Photobiology B: Biology* 85, pp. 1–16. DOI: 10.1016/j.jphotobiol.2006.03.007.

References iv

Zeugner, A., M. Byrdin, J. Bouly, N. Bakrim, B. Giovani, K. Brettel and M. Ahmad (2005). “Light-induced Electron Transfer in Arabidopsis Cryptochrome-1 Correlates with in Vivo Function”. In: *Journal of Biological Chemistry* 280, pp. 19437–19440. DOI: 10.1074/jbc.C500077200.