

Diversity and evolution of LOV-dependent blue-light signaling proteins

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Plants and Fungi respond to environmental light stimuli by employing different photoreceptor proteins. One class, the photoreceptors containing so-called Light, Oxygen, Voltage (LOV) domains as light sensor-modules, respond to the blue-region of the spectrum by utilizing the spectral-properties of a protein bound flavin-chromophore to capture photons of the incident radiation. In Eukaryotes three major families of LOV domain-containing photoreceptor proteins have currently been identified: i) the plant PHOTOTROPINS, ii) the plant circadian photoreceptors of the ZEITLUPE(ZTL)/ADAGIO(ADO)/Flavin-binding-Kelch-Repeat F-Box protein (FKF1) family and iii) the fungal circadian photoreceptor WHITE-COLLAR-1 (WC-1). In recent years it became apparent, that blue-light sensitive LOV signaling modules are equally widespread throughout the prokaryotic world. This prompted us to conduct a phylogenetic analysis based on LOV domain sequences all three kingdoms of life. Our results suggest a prokaryotic origin of the three major eukaryotic LOV-photoreceptor families. We suggest that eukaryotic LOV families have originated by endosymbiosis from certain cyanobacterial or α -proteobacterial lineages. Consequently, the respective endosymbiotic uptake event should mark the time of the appearance of LOV among the eukaryotes. Moreover, our analysis implies that the plant circadian photoreceptors of the ZTL/ADO/FKF1-LOV family and the plant phototropin-LOVs/fungal WC-1-LOVs have originated from two distinct endosymbiotic events separated by a few hundred million years in time.

Furthermore, we propose prokaryotic LOV histidine-kinases, found today in marine phototrophic α -proteobacteria (*Erythrobacter litoralis*, *Rhodobacter sphaeroides*), plant pathogen γ -proteobacteria (e.g. *Pseudomonas syringae*, *Xanthomonas campestris*), in certain animal/human pathogens (e.g. *Brucella abortus*, *B. melitensis*) and in a few halophilic Archaea, as among the evolutionary oldest and thus primordial LOV photoreceptor systems. In conclusion it appears that phototrophy may have played a primary role in the evolutionary processes occurring in ancient marine habitats, which has resulted in the "invention" of the blue-light LOV photoreceptor systems which we find today dispersed in the three kingdoms of life.