Characterization of a Rapid, Blue-Light-Mediated Change in Detectable Phosphorylation—Commentary

Short TW, Briggs WR (1990) Characterization of a rapid, blue light-mediated change in detectable phosphorylation of a plasma membrane protein from etiolated pea (*Pisum sativum* L.) seedlings. Plant Physiol **92:** 179–185

The above article presented the first evidence in vitro that blue-light irradiation could activate the phosphorylation of a plasma membrane protein isolated from etiolated pea stem tissue as well as the recovery of the protein to its dark state over a matter of minutes. Fluence-response data indicated that the light reaction was extremely sensitive (with a threshold of 10^{-1} μmol m^{-2}) and showed that the reciprocity law was valid, suggesting that the reaction was limited by first-order photochemistry. Citations thereafter were few as, with the exception of a couple of papers from Hager's lab in Germany, no other lab was working on the system. In 1997, we cloned the gene and showed that the protein itself was a Ser/Thr kinase, and in 1998, we demonstrated that it was also the photoreceptor: indeed, the photoreceptor for phototropism (Christie et al., 1998). This protein served all three roles: kinase, substrate, and photoreceptor. The chromophore associated with the protein turned out to be FMN. We had demonstrated in the 1997 study that there were two similar domains upstream from the kinase domain and that their amino acid sequences were quite similar to sequences of PAS domains in proteins detecting light (*NifL* in *Azotobacter*), oxygen (e.g. *FixL* in *Bradyrhizobium*), or voltage (the *eag* subunit of a *Drosophila* voltage-sensing potassium channel) and therefore designated them as LOV domains.

In 2000, we showed that isolated LOV domains alone bound FMN and underwent a unique photochemistry: blue-light-activated formation of a covalent bond between the C(4a) carbon of the flavin and the sulfur of a nearby Cys. Suddenly, the field was no longer lonely. In 1998, there had been only two labs in the world involved with LOV domain proteins. In 2004, we identified 42 labs that were. People soon discovered LOV domain-containing proteins in nonvascular plants, in several groups of algae, in all of the major groups of fungi, and in many eubacteria, cyanobacteria, and archaea. The proteins were all very different: LOV-His kinases, LOV-zinc finger, Leu zipper, and other transcription factors, LOV phosphatases, LOV cyclases, and a host of other LOV proteins, many with unknown function. Biophysicists in Germany, Japan, and elsewhere grabbed the opportunity to do sophisticated spectral and photochemical investigations on this new system; structural biologists obtained LOV domain crystal structures; others used mutational analysis to probe photochemical mechanisms and light-induced protein structural changes. The incredibly diverse roles of LOV domains in different organisms were elucidated: blue-light induction of reversible responses such as stomatal opening and solar tracking; blue-light induction of transcriptional changes (*Chlamydomonas*, *Neurospora*); induction of biofilm formation (*Caulobacter*); induction of virulence (*Brucella*); and induction of other responses. Indeed, an entirely new field, the photophysiology of nonphotosynthetic bacteria, has been opened up.

LITERATURE CITED

Christie JM, Reymond P, Powell GK, Bernasconi P, Raibekas AA, Liscum E, Briggs WR (1998) Arabidopsis NPH1: a flavoprotein with the properties of a photoreceptor for phototropism. Science **282:** 1698–1701

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