



## Photoreceptors and Calcium (Advances in Experimental Medicine and Biology)

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The role of Ca<sup>2+</sup> as an internal messenger in visual transduction of vertebrate and invertebrate organisms has been explored intensely in the recent past. Since the early 1970s, calcium ions and cyclic GMP (whose levels are controlled by Ca<sup>2+</sup> in vertebrates) have been recognized as important second messengers.

Particularly in the last decade, however, the role of Ca<sup>2+</sup> in visual transduction has been re-evaluated and a proliferation of research has documented a multiplicity of roles. It is now evident that Ca<sup>2+</sup> modulates phototransduction by acting at several sites through a host of small Ca<sup>2+</sup>-binding proteins. For example, in phototransduction of vertebrates, Ca<sup>2+</sup>-free forms of guanylate cyclase activating proteins (GCAPs) activate guanylate cyclase, modulating levels of cGMP, a key event in the return of photoreceptors to pre-bleach conditions. Defects in genes encoding guanylate cyclase or guanylate cyclase activating proteins lead to severe diseases of the retina (e.g., Leber congenital amaurosis, rod/cone dystrophy, or cone dystrophy), thus emphasizing the important role of these proteins in phototransduction. Similarly, mutant genes encoding cation or Ca<sup>2+</sup> channels (cyclic nucleotide-gated cation channels located in the cell membrane and L-type voltage-gated Ca<sup>2+</sup> channels located at the synapse of photoreceptors) lead to retinitis pigmentosa or congenital stationary night blindness. In phototransduction of invertebrate organisms (e.g., *Drosophila* and *Limulus*), the role of Ca<sup>2+</sup> is similarly central, but distinct, from that of vertebrates.



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