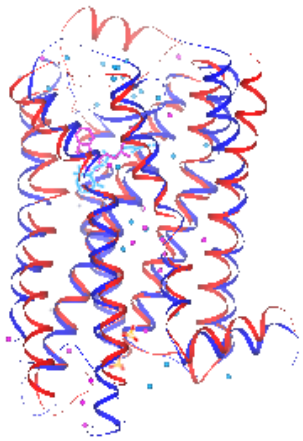
Structure and function of bovine rhodopsin

Tetsuji Okada

Biological Information Research Center, National Institute of Advanced Industrial Science and Technology, Tokyo 135-0064, Japan.



Photoreceptor proteins of rods and cones in the retina, rhodopsin and color pigments, are the members of heptahelical G protein-coupled receptors (GPCRs). They have a covalently bound inverse agonist, 11-*cis* form of retinal (Vitamin A aldehyde), as the chromophore for capturing photons. The initial process of vision is triggered by *cis-trans* photoisomerization of the retinal protonated Schiff base attached to a lysine side chain in transmembrane helix VII. This reaction can be considered as an instantaneous conversion from an inverse-agonist to an agonist, which subsequently evokes the activation of the protein.

The first crystal structure of rhodopsin was determined at 2.8 Å resolutions in 2000.[1] Since then, several new coordinates have been obtained, including the ground state at higher resolution (blue ribbon in the figure),[2,3] two photoreaction intermediates [4,5] and a 9-*cis*-analogue pigment.[6] In addition, some other crystal structures have been reported in different space groups.[7-9] These recent advances are summarized in the context of visual function, and the discussion will also include some comparison with the new structure of the human β_2-adrenergic receptor (red ribbon).[10]

X-ray crystallographic and quantum chemical studies of bovine rhodopsin in $P4_1$ space group have been contributed by the following researchers: (alphabetical order) CA Behnke, AN Bondar, V Buss, M Elstner, P Entel, BA Fox, Y Fujiyoshi, T Hori, T Kumasaka, EM Landau, I Le Trong, M Miyano, H Motoshima, H Nakamichi, J Navarro, K Palczewski, M Schreiber, S Sekharan, Y Shichida, M Silow, RE Stenkamp, M Sugihara, DC Teller, M Yamamoto, O Weingart. Support at the beamlines of SPring-8 is gratefully acknowledged.

[1] Palczewski, K., Kumasaka, T., Hori, T., Behnke, C.A., Motoshima, H., Fox, B.A., Le Trong, I., Teller, D.C., Okada, T., Stenkamp, R.E., Yamamoto, M., and Miyano, M. (2000) *Science* **289**, 739-745..

[2] Okada, T., Fujiyoshi, Y., Silow, M., Navarro, J., Landau, E. M. & Shichida, Y. (2002) *Proc. Natl. Acad. Sci. USA.* **99**, 5982-5987.

[3] Okada, T., Sugihara, M., Bondar, A. N., Elstner,, M., Entel, P., and Buss, V., (2004) *J. Mol. Biol.*, **342**, 571-581.

[4] Nakamichi, H., and Okada, T., (2006) *Angew Chem Int Ed* **45**, 4270-4273

[5] Nakamichi, H., and Okada, T., (2006) *Proc Natl Acad Sci USA* **103**, 12729-12734

[6] Sekharan, S., Sugihara, M., Weingart, O., Okada, T., and Buss, V., (2007) *J Am Chem Soc* **129**, 1052-1054

[7] Li, J., Edwards, P. C., Burghammer, M., Villa, C., and Schertler, G. F., (2004) *J. Mol. Biol.* **343**, 1409-1438.

[8] Standfuss, J., Xie, G., Edwards, P. C., Burghammer, M., Oprian, D. D., Schertler, G. F., (2007) *J. Mol. Biol.*, **372**, 1179-1188.

[9] Salom, D., Lodowski, D.T., Stenkamp, R.E., Le Trong, I., Golczak, M., Jastrzebska, B., Harris,T., Ballesteros, J.A., and Palczewski , K. (2006) *Proc. Natl. Acad. Sci. USA* **103**, 16123-16128.

[10] Cherezov, V., Rosenbaum, D. M., Hanson, M. A., Rasmussen, S. G., Thian, F. S., Kobilka, T. S., Choi, H. J., Kuhn, P., Weis, W. I., Kobilka, B. K., snd Stevens, R..C., (2007) *Science* **318**, 1258-1265.