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Microbial light-driven ion pumps and channels

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Motivation and Aim: Rhodopsins are probably the most universal biological light energy transducers and abundant phototrophic mechanisms evolved on Earth [1]. They are found in all the domains of life and in viruses and have a remarkable diversity and potential for biotechnological applications. Channel rhodopsins, H^+ and Cl^- pumps have become indispensable means of optogenetics and revolutionized neuroscience promising new approaches to the treatment of severe diseases. However, among thousands of identified rhodopsin genes only a few are characterized. This dramatically limits our knowledge of their functions, mechanisms and biotechnological applications. Moreover, high-resolution structures and molecular mechanisms of recently studied new rhodopsins are either not known or limited to non-active states. The amazing scientific and technological potential of rhodopsins is still to be explored.
Results: Since the discovery of the first microbial rhodopsin – a light-driven proton pump bacteriorhodopsin (BR), a seven alpha helical membrane protein comprising the retinal, in 1971 [2], BR was one of the major drivers of ground breaking developments in membrane protein research. However, before 2000 there were only several and only archaeal known rhodopsins, functioning as proton, chloride pumps and also sensory rhodopsins. At the end of the XX^{th} century not many of us, if any at all, would imagine a new era of the rhodopsin world and their breaking contributions to the optogenetics applications in neuroscience.
Conclusion: In 2000 the first bacterial rhodopsin – a proton pump proteorhodopsin was discovered [3]. Then it appeared that there are unexpectedly many rhodopsins and they are present in all the domains of life [4] and even in viruses [5]. It was also unexpected that these 'seemingly the same' proteins can execute diverse functions. Ground breaking discoveries and characterization of channel rhodopsins in 2002/2017 [6, 7], sodium pump KR2 in 2013/2015/2019 [8, 9, 10] rhodopsin-guanylyl cyclase in 2014 [11], outward proton pumps xenorhodopsins in 2016/2017 [12, 13], pH [14] and divalent ion dependent rhodopsins support this conclusion.
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