5.11D: Bacteriorhodopsin

Bacteriorhodopsin acts a proton pump, generating cellular energy in a manner independent of chlorophyll.

Learning Objectives

- Discuss the function of bacteriorhodopsin

Key Points

- Bacteriorhodopsin is a proton pump found in Archaea, it takes light energy and converts it into chemical energy, ATP, that can be used by the cell for cellular functions.
- Bacteriorhodopsin forms chains, which contain retinal molecule within, it is the retinal molecule that absorbs a photon from light, it then changes the confirmation of the nearby Bacteriorhodopsin protein, allowing it to act as a proton pump.
- While chlorophyll based ATP generation depends on a protein gradient, like bacteriorhodopsin, but with striking differences, suggesting that phototrophy evolved in bacteria and archaea independently of each other.

Key Terms

- isomerized: converted from one isomer to another
- retinal: One of several yellow or red carotenoid pigments formed from rhodopsin by the action of light; retinene
- phototrophy: The synthesis of an organism’s food from inorganic material using light as a source of energy

Bacteriorhodopsin is a protein used by Archaea, the most notable one being Halobacteria. It acts as a proton pump; that
is, it captures light energy and uses it to move protons across the membrane out of the cell. The resulting proton gradient is subsequently converted into chemical energy. The resulting proton gradient is subsequently converted into chemical energy.

Figure: **ATP generation via bacteriorhodopsin**: Chemiosmotic coupling between sun energy, bacteriorhodopsin and phosphorylation by ATP synthase (chemical energy) during photosynthesis in Halobacterium salinarum (syn. H. halobium).

Bacteriorhodopsin is an integral membrane protein usually found in two-dimensional crystalline patches known as “purple membrane”, which can occupy up to nearly 50% of the surface area of the archaeal cell. The bacteriorhodopsin forms repeating elements that are arranged in chains. Each chain has seven transmembrane alpha helices and contains one molecule of retinal buried deep within, the typical structure for retinylidene proteins. It is the retinal molecule that changes its conformation when absorbing a photon, resulting in a conformational change of the surrounding protein and the proton pumping action. This releases a proton from a “holding site” into the extracellular side (EC) of the membrane. Reprotonation of the retinal molecule by restores its original isomerized form. This results in a second proton being released to the EC side. The releases the proton from its “holding site,” where a new cycle may begin.

The bacteriorhodopsin molecule is purple and is most efficient at absorbing green light (wavelength 500-650 nm, with the absorption maximum at 568 nm). Bacteriorhodopsin belongs to a family of bacterial proteins related to vertebrate rhodopsins, the pigments that sense light in the retina. Many molecules have homology to bacteriorhodopsin, including the light-driven chloride pump halorhodopsin, and some directly light-activated channels like channelrhodopsin. All other phototrophic systems in bacteria, algae, and plants use chlorophylls or bacteriochlorophylls rather than
bacteriorhodopsin. These also produce a proton gradient, but in a quite different and more indirect way involving an
electron transfer chain consisting of several other proteins. Furthermore, chlorophylls are aided in capturing light energy
by other pigments known as “antennas”; these are not present in bacteriorhodopsin-based systems. Last, chlorophyll-
based phototrophy is coupled to carbon fixation (the incorporation of carbon dioxide into larger organic molecules) and
for that reason is photosynthesis, which is not true for bacteriorhodopsin-based system. Thus, it is likely that phototrophy
independently evolved at least twice, once in bacteria and once in archaea.