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Photochemistry Governing Bacteriorhodopsin and Bacterial Reaction Center

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Abstract

Bacteriorhodopsin (bR) is a light driven proton pump that converts sunlight to chemical energy. BR is an integral membrane structured protein found in the purple membrane of Halobacterium halobium. It is composed of 248 amino acids and a chromophore in the middle which captures light. Electricity can be generated through the process of light-chemical conversion, when photons are absorbed by thechromophore, the photo cycle begins. Bacterial Reaction Center (bRC) is a light driven electron transfer reaction that converts solar energy to chemical energy. bRC are integral membrane structured proteins found in the purple membrane of Rhodobacter sphaeroides. It is composed of 3 major co-factors such as bacteriochlorophylls, bacteriopheophytin and quinone. Its primary mechanism is to execute photo synthesis. In this interaction, electron transfer occurs through light ejection of electron that passes through the membrane. Conversion of sunlight to chemical energy simultaneously precipitates. This review aims to compare the function and structure of Bacteriorhodopsin and bacterial reaction centers, underscoring the energy generated in both membranes. Through calculating the ATP, protons and photons that cross the membrane, exact value of energy emission in the order of electron volts present the energy generated. Advantages and mechanisms of photoreactions including bioelectronic, bio energy production in bacteriorhodopsin and bacterial reaction centers will be exemplified. Ultimately, energy efficiency of bacteriorhodopsin and bacterial reaction center will be determined.

Keywords: Bacteriorhodopsin; Bacterial reaction center; Photochemistry; Electrochemical efficiency

Introduction

Bacteriorhodopsin (bR) is an integral membrane protein found in the purple membrane of the *Halobacterium halobium*. As a light driven proton pump, bRs capture photons in the order of 500nm-650nm. Existing research found that 300mv of electricity generated per purple membrane [1]. Conversely, bacterial reaction center (bRC) is found in *Rhodobacter sphaeroides*. It generates 800mv of electricity in total, considering the transfer of 4 protons in the membrane. Multiple interventions to denature and modulate the structure of bR should be considered, including pH, temperature, detergent and wavelength of laser light. Bacteriorhodopsin has been known to function between0C to 45C at a pH of 1-11. It tolerates temperature over 80C in water and up to 140C in dry [2]. Conventionally, laser is utilized to precipitate the photoisomerization of bR, consequently shifting all trans-13 to structure. The chromophore which is covalently attached to Lys216 through a Schiff base is modulated through this method. Bacterial Reaction Center (bRC) is a light driven electron transfer reaction that converts solar energy to chemical energy. bRC are integral membrane structured proteins found in the purple membrane of *Rhodobacter sphaeroides*. It is composed of 3 protein subunits--L, M and H. It has 3 major co-factors composed of 4bacterio-chlorophylls, 2 bacteriopheophytins and 2 quinones [3]. In this interaction, electron transfer occurs through light ejection of electron that passes through them embrane. Conversion of sunlight to chemical energy simultaneously precipitates. Both bR and bRC from *Halobacterium halobium* and *Rhodobacter sphaeroides* respectively generate a considerable worth of electricity that can be used in the industry today. Although bRC emits power in a rather limited merit, future research would determine its potential for catalyzing electrically reliant applications such as optics, instrumentation and therapeutic values. bRC can be utilized for solar energy and drive photovoltaic cells. Its usage is ubiquitous at this point and has generated multitude of photovoltaic and solar energy driven applications. Further research will enhance the efficacy of bRC generated solar cells and related interventions.

Computation and Methods for Calculating ATP in Bacteriorhodopsin and Bacterial Reaction Center

Bioenergetic quantification through converting and comparing the proton, photon, and voltage in bR and bRC. Chromophore absorption of photon varies between bR and bRC. Permeability of membrane may affect absorption and transport of protons. Hence, data for photo cycle bR efficiency is 60% reliable, while bRC efficiency is 100%.

Efficiency for Converting Light Energy into Electrochemical Energy

Electrochemical energy produce electric energy from chemical energy.bR emits 1 proton/photon, cross-membrane voltage 300mV: 300meV/photon [4] while bRC generates 4 protons/photon equal to 200mV multiplied by 4 resulting to 800meV/photon [5].

Efficiency for Converting Light Energy into ATP

BR generates 22 photons per ATP while bRC generates 1 photon per ATP. Therefore, bR constitutes 22 photons multiplied by 300meV equals to 6600meV which is equivalent to 6.6V [6]. BRC generates 1 photon multiplied by 800meV is equal to 800meV equivalent to .8V [5].

Comparing Power and Efficiency of Bacteriorhodopsin and Bacterial Reaction Center

bR and bRC are both directly correlated with power and efficiency. The higher the unit of power (i.e. milli volts), the more efficient it is in driving industrial applications. Typical instrumentations driven by bR and bRC include bioreactors for hydrogen production, molecular detection and biosensing to name a few [2]. Calculating the power and efficiency of bR and bRC involve the formulas below Figure 1.

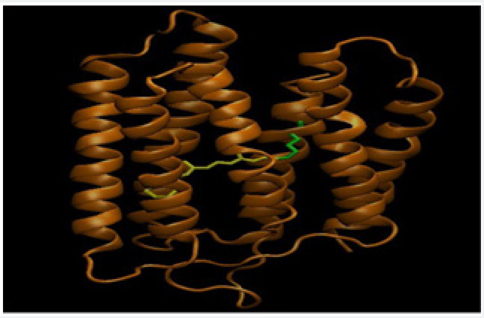

Figure 1: 3D molecular structure of bR. Yellow chromophore, green- Lysine-216 covalently attached to chromophore.

P=iV

i= current, V= voltage

Efficiency= Work Output/Work Input * 100%

Efficiency= Energy Output/ Energy Input *100 %(Thermodynamic Efficiency) [7].

W=Fd

To get electrochemical efficiency, photo cycle efficiency multiplied by cross membrane voltage gradient times number of protons per photo cycle divided by photon energy. For chemical efficiency, photo cycle efficiency is multiplied by energy per ATP which is always 300meV, divided by number of photons per ATP multiplied by number of protons per photon divided by photon energy. Hence, bR electrochemical efficiency is 7 % (.6*300meV* 1 proton/2.5eV) while bRC electrochemical efficiency is 1 6% (.200meV*1*1*1proton/2.5eV). Chemical efficiency of bR is .54% (.300meV/ 22 * 2.5eV) while bRC chemical efficiency is 3% (.300meV/ (2.5 eV* 4 protons) [5]. Photon energy (2.5eV) was obtained by using the formula E= hc/ λ, where h is the Planck's constant (6.63x10-34), c is the speed of light (3.0x108m/s) and wavelength in the order of 500nm, when green light is emitted, blue and red light are absorbed Figure 2.

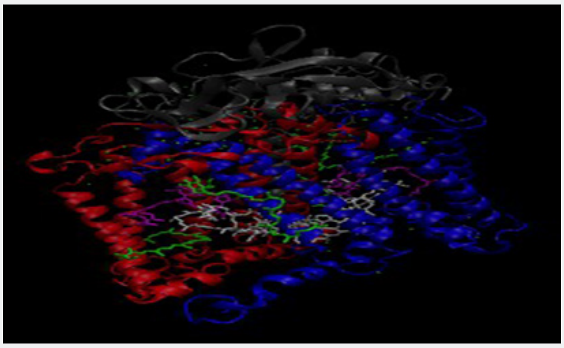

Figure 2: 3Dmolecular structure of bRC. Red, blue and grey-proteins. Pink Bacteriopheophty in. White-Bacteriochlorophyll. Green- Ubiquinone. Ribbon surrounding are helices.

Efficiency of Converting Chemical to Electrical Energy

Kim YC et al. [8] this equation derived from Hummer et al. entails the mechanism of converting chemical to electrical energy: γ= (1+η)Vm/ΔGp Chemical Energy symbolizes Δ Gp, which is equal to (.5eV) (mimic Cco) ((1 + 1).150mv/.5)-100%= 40% while electrical energy symbolizes (1+η)Vm. Vm is them embrane potential, η is pumping efficiency; equivalent to the equation J pump/Jel. And bR constant value is 300meV while bRC constant value is 80meV. BR efficiency of converting chemical to electrical energy is ((1+1).300meV/6.6V)=9% while bRC efficiency of converting chemical to electrical energy is (1+1).200meV/.8V)= 50%. (bR: 100%) (bRC:) [9,10].

Functional and Structural Differences of Bacteriorhodopsin and Bacterial Reaction Center

BR and bRC are both proton pumps that utilize solar energy and convert it to chemical energy Table 1. Although the function of both proteins are the same, they have distinct structural features and consequently have differing energy emissions.BR has a simpler structure than bRC. It is composed of 1740 atoms, while bRC contains 7155 atoms. BR has a chromophore in the middle while bRC contains Bph, Bchl and Q chromophores. BR is composed of seven transmembrane helices; while bRC compose

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five helices in the L and M subunits and one in the H subunit [3] (Solution structure of the loops of bacteriorhodopsin closely resembles the crystal structure). Both proteins, bR and bRC, come from purple membranes of *Halobacterium halobium* and *Rhodobacter sphaeroides*, respectively [11-20].

Table 1: Properties of Bacteriorhodopss in (bR) and Bacterial Reaction Center (bRC).

	Absorption	Bacterium	Energy
bR	500-650nm	Halobacterium Halobium	300meV
bRC	870nm	Rhodobacter sphaeroides	800meV

Conclusion

bRC is more efficient in converting solar energy to chemical energy and solar energy to ATP than bR, while bR generates more electricity, considering the photons emitted by each. BR generates 22 photons, multiplied by 300meV equaling to 6600meV equivalent to 6.6V, while bRC generates 1 photon, multiplied by 800meV equaling to 800meV equivalents to .8V. With 6.6 voltages, lanterns, flashlights and automobiles can be powered.

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