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Light-capturing protein found in oceanic bacteria

As sunlight penetrates the surface of the ocean, underwater plants and other single-celled organisms like algae acquire energy and create their own food through a process known as photosynthesis. These organisms contain unique organelles called chloroplasts which allow them to generate usable energy in the form of sugar, and thus are considered significant contributors to the solar energy captured in the marine environment. But do all light-absorbing organisms found in the ocean need chloroplasts? Surprisingly, they don't. Other collectors of solar energy in the ocean possess proteins called proteorhodopsins. These proteins, like chloroplasts, store sunlight to carry out metabolic activities and other processes.

The marine environment is home to a wide range of organisms. Some of them are fairly common and others have impressive characteristics. For example, the blue whale is the largest animal on the planet and weighs up to 380,000 pounds. The anglerfish, a deep-sea organism that produces light, carries around a tiny light bulb to attract prey. Furthermore, the most abundant organism in the ocean is a type of marine bacteria known as Pelagibacterales (SAR11) and it has a population size of approximately 10^{28} cells. To put this number into perspective, "If you go to the ocean, and you go for a swim, and you accidentally swallow a mouthful of seawater, you've probably swallowed a million SAR11 cells," according to Steve Giovanni, a microbiology professor at Oregon State University.

But what makes the SAR11 organisms more interesting is that most of them carry the light-absorbing protein proteorhodopsin. Acting as natural rivals to the chloroplasts found in many plant cells, these proteins are light-activated and use retinal chromophores – tiny parts inside of the molecules responsible for their color – to convert the light into usable energy. In fact, these retinal-based proteins collect as much solar energy as some chlorophyl-based organisms in the marine environment, according to Gomez-Consarnau et al., in “Microbial rhodopsins are major contributors to the solar energy captured in the sea” published in Science Advances on August 09, 2019.

Proteorhodopsins in marine bacteria were first discovered in the year 2000. No long after, scientists confirmed that they can convert the light from the sun into energy by regulating the number of protons that flow in and out of the organism. And although previous studies have shown that this energy plays a major role in the bacteria’s growth, as well as their ability to survive in low-nutrient parts of the ocean, there has been limited research estimating their overall contribution to the energy produced in the marine environment.

In their research study, Gomez-Consarnau et al. determined the circulation of retinal-based organisms and their contribution to the solar radiation captured in the marine environment. To accomplish this objective, they came up with a strategy to locate the chromophore retinal. Since every proteorhodopsin shares a similar structure, and one is only capable of carrying a molecule of retinal, they quantified the retinal chromophores by measuring the total number of proteorhodopsins. They calculated the proteorhodopsin concentrations in various water samples from the Eastern Atlantic Ocean and the Mediterranean Sea and then compared them with the number of chlorophyl-based organisms found at similar depths. Consequently, they found that proteorhodopsins were more abundant in low-nutrient areas of the Mediterranean Sea, where chlorophyl-based organisms were less frequent.

Depending on the water samples and the station they came from, Gomez-Consarnau et al. compared the light intensity to the concentration levels of proteorhodopsins and estimated the solar radiation absorbed. Similarly, they emulated these calculations based on concentration levels of chlorophyl-a molecules, which are mostly found in microorganisms that perform photosynthetic activity.

In the Eastern Mediterranean, for instance, the solar radiation captured by organisms with proteorhodopsins exceeded 100 kilojoules per meter squared per day. On the other hand, the highest amount of solar radiation collected by chlorophyll-a based organisms in the same station was approximately 9 kilojoules per meter squared per day. At depths in which photosynthetic activity was unusual, proteorhodopsins were more efficient and replenished the zone with a vast amount of energy.

Overall, Gomez-Consarnau et al. show that proteorhodopsins retain as much sunlight as chlorophyll-a, and consequently produce equal amounts of usable energy. Additionally, Gomez-Consarnau et al. reveal, "… the most extremely oligotrophic marine environments (e.g., Eastern Mediterranean) have such low primary production from photosynthesis that complementary light-dependent metabolisms can supply as much or possibly more energy to heterotrophic prokaryotes than they can obtain from organic matter through classic food web–based energy transfers." In other words, the abundance of proteorhodopsins in different parts of the sea, especially where plants and algae cannot thrive, help the biodiversity flourish. Furthermore, they give other organisms living in low-nutrient areas access to an energy-rich environment.

Asides from bringing to light the startling process through which proteorhodopsins store sunlight and produce energy, this research study paves the way for future investigations on the topic. For example, investigations exploring the factors that increase or decrease light retention, and how this mechanism plays a major role in the marine carbon cycle. Adding on, it raises curiosity on the complex functions that many deep-sea organisms possess.

All in all, it is extremely important for us to become familiar with retinal-based light absorption as it will become more frequent in the future. As human activities and climate change disrupt our oceans, low-nutrient areas expand and become ideal places for proteorhodopsins to thrive. Also, less plants and algae survive, which indicates that photosynthetic processes equally decrease. In other words, proteorhodopsins will play a bigger role in harvesting sunlight and generating energy in the marine environment.

Works cited

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