How things work: Algae quantum mechanics

For nearly 150 years, physicists around the world have been trying to work out the intricate details of various quantum mechanical phenomena. More recently, much thought has gone into making quantum computing possible — a move seen by many as essential for the world of computing to truly progress. In the race to come up with quantum mechanics-based devices, physicists lost to algae. According to Greg Scholes, lead author of a study published in *Nature*, algae have been using quantum mechanical processes to perform photosynthesis for over 2 billion years.

As is well known, plants convert light energy into the plant equivalent of food, adenosine triphosphate (ATP), in a process called photosynthesis. Plants perform photosynthesis by harnessing light energy to react carbon dioxide with other simple compounds to make more complicated sugars for later use. During photosynthesis, light is absorbed by organelles inside of the plant cells called chloroplasts. Chloroplasts contain a number of photosynthetic reaction centers where the complex sugars are generated with the help of light-capturing pigment called chlorophyll. This pigment gives plants their green color.

This model adequately explained photosynthesis for decades. However, scientists have suspected the use of quantum mechanics at some point during this process, as the process seems uncannily efficient with the harnessing and usage of light. Until early this year, this idea was widely publicized, but with little proof or understanding of the role of quantum mechanics in the process. To provide some hard scientific proof, scientists at the University of Toronto conducted a battery of tests on a common algae called cryptophytes, and they have shown that the algae do indeed utilize quantum mechanical phenomena to help improve the efficiency of photosynthesis.

The study highlighted the role of certain proteins referred to as antennae. Antennae intercept incoming photons and redirect them to the photosynthetic reaction centers, performing a function that puzzled scientists for years, as it seemed redundant. The reaction centers are fully capable of receiving light themselves without any assistance. It is this apparent redundancy that aroused such interest in the antenna proteins. The team led by Scholes fired low-power laser light in very short bursts at the algal cells and studied the electron transmission patterns using a second laser.

Under normal circumstances, energetic photons transfer their energy to electrons in atoms. These electrons then vibrate at a frequency related to the amount of energy imparted to them.
With time, however, these vibrations attenuate, or lose intensity, and the electrons return to their initial states of lower energy. Scholes’ team noticed that, in the algal cells, the excited electrons remained in a state of higher energy for a period 20 times longer than normally possible. This is due to a quantum mechanical phenomenon known as quantum coherence.

Quantum coherence was discovered while conducting an experiment called Young’s double-slit experiment, using electrons instead of light. The experiment involves passing a stream of electrons through a screen with two parallel slits in it. When the electrons hit a target on the other side of the screen, the result is an interference pattern similar to that obtained by passing light waves through the slits.

This means that, unlike previously believed, once within the cell, light is transmitted not as photons but as waves. This also means that photons (or any particle small enough) are capable of doing things that might seem unreal. One example of this is a possible reason Scholes has proposed this mechanism. He believes it may be possible for every photon to decide which path to the reaction center is the most energy efficient and travel to the target via that particular best path. “That vibrating electron could put some feelers out and see which path to take,” Scholes said. This ensures light travels from the antenna to the reaction center without any loss of energy, improving the efficiency of photosynthesis.

This study shows the possibility of quantum phenomena occurring at room temperature in biological systems. Graham Fleming, a chemist at the University of California at Berkeley, who performed some earlier experiments on the same topic, predicted this possibility. He feels this is a general feature of all photosynthetic light-harvesting complexes.

Scholes’ study could dramatically improve our present light-capturing and light-sensitive devices. Considering the present efficiency of solar cells, with a record efficiency of around 40 percent for a particular prototype under test conditions, this could come as a pleasant find for the renewable energy industry.