Photosynthesis more ancient than thought, and most living things could do it

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Inspired by water transport in natural leaves (shown), researchers have created a synthetic, microfabricated "leaf" that can generate power from evaporative flow. Image credit: pdphoto.org

Most modern bacteria descended from ancestors who could convert the Sun's energy to fuel more than 3.5 billion years ago.

Photosynthesis is the process by which plants, algae and cyanobacteria use the energy from the Sun to make sugar from water and carbon dioxide, releasing oxygen as a waste product. But a few groups of bacteria carry out a simpler form of photosynthesis that does not produce oxygen, which evolved first.

A new study by an Imperial researcher suggests that this more primitive

form of photosynthesis evolved in much more ancient bacteria than scientists had imagined, more than 3.5 billion years ago.

Photosynthesis sustains life on Earth today by releasing oxygen into the atmosphere and providing energy for food chains. The rise of oxygen-producing photosynthesis allowed the evolution of complex life forms like animals and land plants around 2.4 billion years ago.

However, the first type of photosynthesis that evolved did not produce oxygen. It was known to have first evolved around 3.5-3.8 billion years ago, but until now, scientists thought that one of the groups of bacteria alive today that still uses this more primate photosynthesis was the first to evolve the ability.

But the new research reveals that a more ancient bacteria, that probably no longer exists today, was actually the first to evolve the simpler form of photosynthesis, and that this bacteria was an ancestor to most bacteria alive today.

"The picture that is starting to emerge is that during the first half of Earth's history the majority of life forms were probably capable of photosynthesis," said study author Dr Tanai Cardona, from the Department of Life Sciences at Imperial College London.

The more primitive form of photosynthesis is known as anoxygenic photosynthesis, which uses molecules such as hydrogen, hydrogen sulfide, or iron as fuel - instead of water.

Traditionally, scientists had assumed that one of the groups of bacteria that still use anoxygenic photosynthesis today evolved the ability and then passed it on to other bacteria using horizontal gene transfer – the process of donating an entire set of genes, in this case those required for photosynthesis, to unrelated organisms.

However, Dr Cardona created an evolutionary tree for the bacteria by analyzing the history of a protein essential for anoxygenic photosynthesis. Through this, he was able to uncover a much more ancient origin for photosynthesis.

Instead of one group of bacteria evolving the ability and transferring it to others, Dr Cardona's analysis reveals that anoxygenic photosynthesis evolved before most of the groups of bacteria alive today branched off and diversified. The results are published in the journal PLOS ONE.

"Pretty much every group of photosynthetic bacteria we know of has been suggested, at some point or another, to be the first innovators of photosynthesis," said Dr Cardona. "But this means that all these groups of bacteria would have to have branched off from each other before anoxygenic photosynthesis evolved, around 3.5 billion years ago.

"My analysis has instead shown that anoxygenic photosynthesis predates the diversification of bacteria into modern groups, so that they all should have been able to do it. In fact, the evolution of oxygneic photosynthesis probably led to the extinction of many groups of bacteria capable of anoxygenic photosynthesis, triggering the diversification of modern groups."

To find the origin of anoxygenic photosynthesis, Dr Cardona traced the evolution of BchF, a protein that is key in the biosynthesis of bacteriochlorophyll a, the main pigment employed in anoxygenic photosynthesis. The special characteristic of this protein is that it is exclusively found in anoxygenic photosynthetic bacteria and without it bacteriochlorophyll a cannot be made.

By comparing sequences of proteins and reconstructing an evolutionary tree for BchF, he discovered that it originated before most described groups of bacteria alive today.

More information: Tanai Cardona et al. Origin of Bacteriochlorophyll a and the Early Diversification of Photosynthesis, *PLOS ONE* (2016). DOI: 10.1371/journal.pone.0151250

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