Symbiotic ciliates and bacteria have a common ancestor

July 14 2017

Several Kentrophoros ciliates from the Mediterranean Sea under the microscope. The sulfur in the bacteria reflects the light and makes them appear white. One of the objects is not a ciliate, but an intruder, a multicellular flatworm. Each ciliate is up to three Millimeter in length. Credit: MPI f. for Marine Microbiology/ O. Jäckle

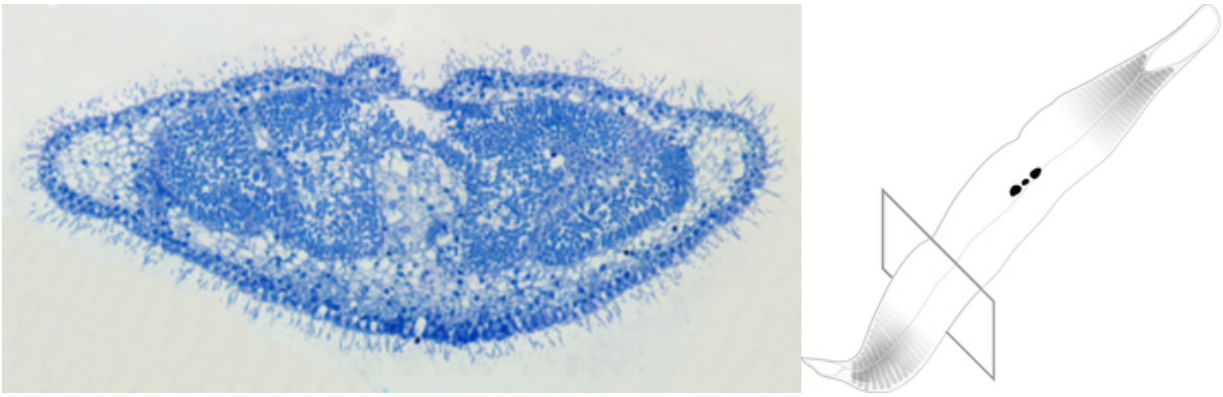
Ciliates, just like humans, are colonized by a vast diversity of bacteria. Some ciliates and their bacterial symbionts have become friends for life, as researchers from the Max Planck Institute for Marine Microbiology in Bremen demonstrated by comparing a group of these single-celled ciliates and their bacterial partners from the Caribbean and the Mediterranean Seas. The bacteria provide their ciliate hosts with nutrition by oxidizing sulfur. Surprisingly, they found that this partnership originated once, from a single ciliate ancestor and a single bacterial ancestor, although a whole ocean separates the sampling sites.

Ciliates are minute, single-celled organisms with several nuclei, and are abundant in freshwater, the oceans and soil. The name "ciliate" comes from 'cilia', tiny hair-like structures, which cover these organisms and are used for movement and to transport food to the mouth-shaped opening. A well-known ciliate is the slipper animalcule Paramecium. Under the microscope, the elegance and beauty of ciliates becomes obvious. Some species grow to be quite large and are even visible to the naked eye as small dots in a drop of water.

In their study, Brandon Seah from the Max Planck Institute for Marine Microbiology and colleagues describe the partnership between ciliates of the genus Kentrophoros, which have lost their mouth opening and the symbiotic sulfur oxidizing bacteria that they depend on. This type of symbiosis is termed mutualism, i.e. both partners depend on each other.

Chemosynthesis and symbiosis as a strategy

Many organisms are known which use sulfur-oxidizing bacteria as a source of energy. The first were found by pure chance near the hydrothermal vents in the deep sea in the 1970s. The deep-sea mussel Bathymodiolus and the tubeworm Riftia are two examples. Until now it was not known who the symbionts of Kentrophoros are: are they related to other symbionts, or are they entirely new species of bacteria?



A transverse cut through a Kentrophoros ciliate stained with a coloured dye, showing how the ciliate's cell body folds around the thousands of rod-shaped bacteria to increase surface area. Credit: MPI for Marine Microbiology

In their study, the researchers compared Kentrophoros species from the Caribbean and the Mediterranean Seas. The researchers found 17 species of Kentrophoros that are all related to each other, that share the same basic body plan even though each has their own unique features. Although the overall appearance varied, DNA sequence analysis showed that the ciliates all originated from a single common ancestor. This was also the case for the bacteria, which all belonged to one group of close relatives from a lineage that is new to science.

This means that at some point millions of years ago, the first Kentrophoros and the ancestor of these bacteria formed a partnership that has endured through the years, and their descendants are now found around the world. "The bacterial symbionts grow only on one side of the ciliate's body. Some ciliates have special folds in order to increase the area for optimal growth. These ciliates carry their personal vegetable patch that they harvest by phagocytosis," explains Brandon Seah, PhD student at the Max Planck Institute for Marine Microbiology.

Nicole Dubilier, Director at the Max Planck Institute in Bremen, adds:" One of the surprising results of our study was that the partnership between the ciliates and their symbionts has been highly stable and specific over a very long evolutionary time period, perhaps tens to hundreds of millions of years. We assumed that because the symbionts sit on the outside of their hosts and could be easily lost when the ciliates move through water or sand, that these symbioses might not be as specific as ones in which the symbionts live inside their hosts. But it turns out that the physical location of partners is not necessarily related to their intimacy."

The next step on the agenda is genome sequencing of the bacterial symbionts and their hosts. Also, cultivation of the ciliates and their symbionts would open the door for future studies on what contributions each partner in this symbiotic team brings to their relationship.

More information: Brandon K. B. Seah et al. Specificity in diversity: single origin of a widespread ciliate-bacteria symbiosis, *Proceedings of the Royal Society B: Biological Sciences* (2017). DOI: 10.1098/rspb.2017.0764

Provided by Max Planck Society