Scientists report the first family of extracellular Rickettsia-like bacteria

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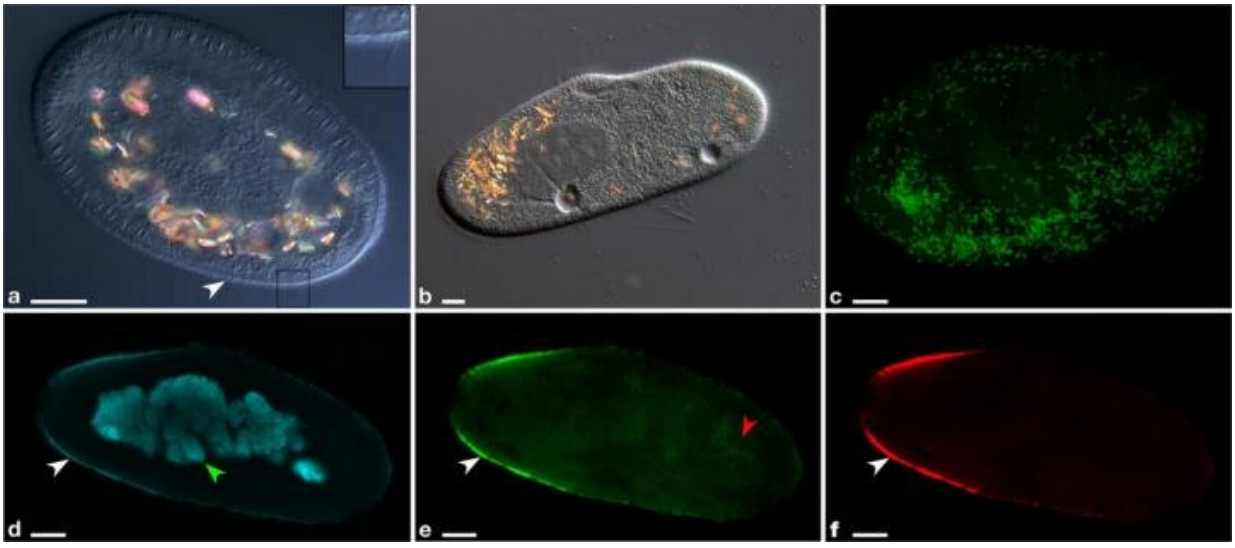


Invasion of a Paramecium cell by Deaniraea bacteria. Credit: *ISME Journal*

Microbiologists of St Petersburg University, together with researchers from the University of Milan, the University of Pisa, and the University of Pavia, have discovered a new family of bacteria of the order Rickettsiales—Deianiraeaceae. This is the first report of the Rickettsia-like bacteria that display a unique extracellular lifestyle and are in fact predators.

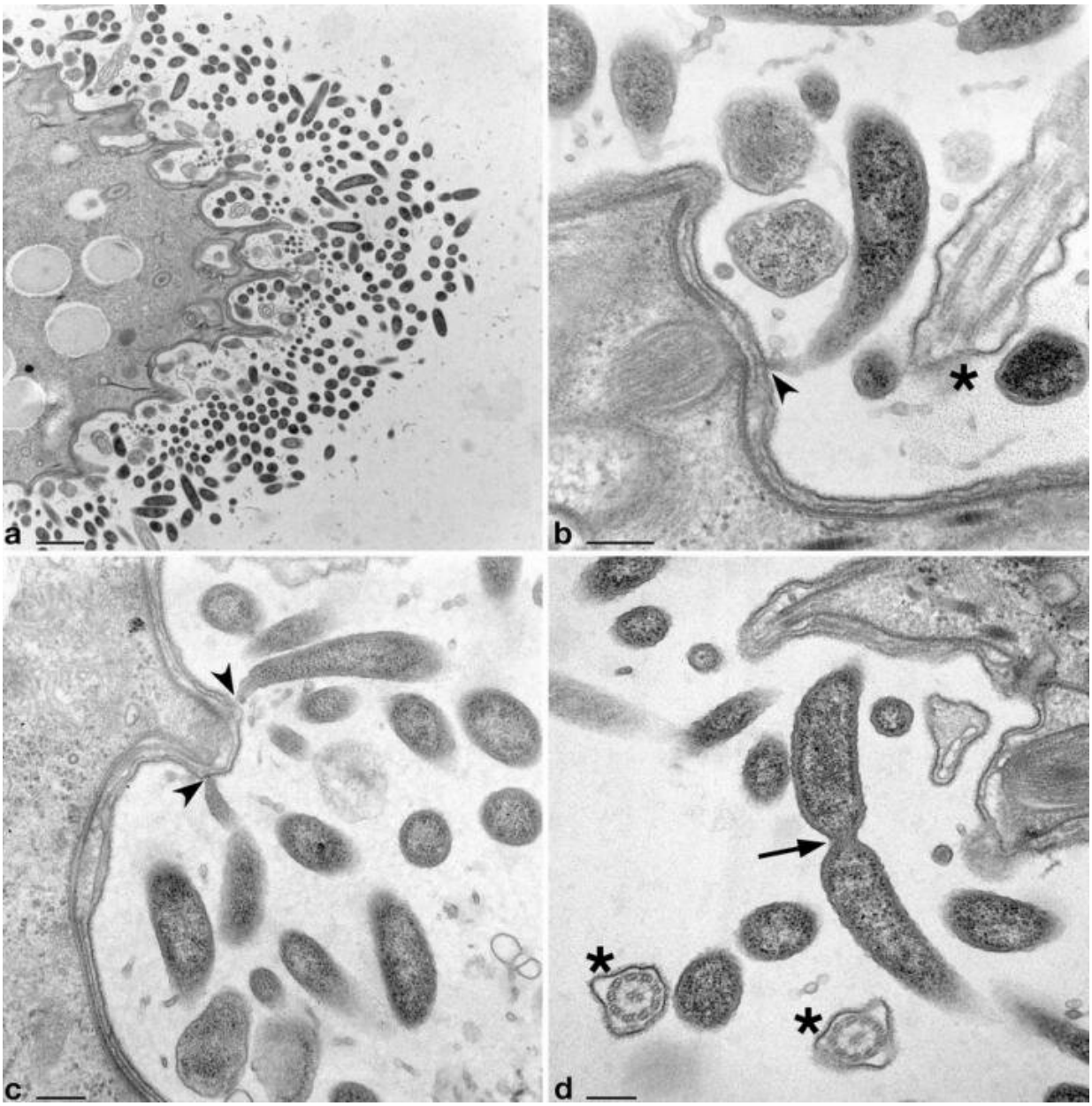
The Deianiraeaceae, which has become the fourth family in the order Rickettsiales, currently contains one genus, Deianiraea. All previously

investigated Rickettsiales are obligate intracellular specialised parasites. By contrast, Deianiraea not only attacks the victim from the outside, but also it never enters the host cell throughout its entire life cycle. Deianiraea colonises the extracellular surface of the ciliate Paramecium: the predatory bacterium attacks the ciliate and replicates on its surface, taking the victim's resources, and eventually its life.

The name for the newly discovered bacterium, Deianiraea, refers to the myth of Deianira, the wife of Heracles, who unwittingly killed her husband with a tunic poisoned with the Hydra's venom. "Similarly, the Deianiraea bacterium kills the ciliates, covering the host cell like a poisoned tunic," notes Alexey Potekhin, Professor at the Department of Microbiology of St Petersburg University and a member of the international research team.

Predator of the microworld

The novel bacterium was discovered by chance. Natalia Lebedeva is one of the co-authors of the study and a leading expert of the Centre for Culture Collection of Microorganisms at the St Petersburg University Research Park. She took a sample of water from a waste water stream in Larnaca, Cyprus. Microbiological analysis of the water sample revealed that it contained a large number of ciliates. Laboratory observation showed massive loss of cilia, which are employed for locomotion and feeding. This resulted in the death of the affected ciliate. Other paramecia, which were added into the same culture, also soon died. Upon closer inspection of the affected ciliates it became evident that the deciliated areas of the cell surface were covered by tightly packed bacteria—unknown to science at that moment.



Electron microscopy images of Deianiraea bacteria on the surface of Paramecia cells. Credit: *ISME Journal*

"New bacterial families are rarely discovered these days. It is always an important finding, no matter what order this family may belong to. In our case, a new family has been found in a very well-studied order—the

Rickettsiales. Previously, only DNA of related bacteria were detected in the samples. Therefore, the bacteria were classified as Rickettsia-like, as the scientists were not able to place them into the existing system of families of the order. It was the first time that we had found these bacteria alive. The molecular phylogenetic analysis enabled us to reassemble all the data fragments and, consequently, to establish a new bacterial family—Deianiraeaceae. One may say we were lucky," says Alexey Potekhin.

Strong and almost independent

Unlike other Rickettsia-like bacteria, Deianiraea is not only able to replicate—to reproduce outside the cell—but also to sustain itself with less dependence on the host. "Deianiraea possesses a higher capability to synthesise amino acids, compared to all other Rickettsiales. It can synthesise 16 amino acids, including the eight that other representatives of the order cannot produce. 16 out of the 20 main amino acids is almost a full set. The rest it is most likely to acquire from its victims, but we do not know that for certain. Moreover, Deianiraea can synthesise nucleotides: other Rickettsiales do not do this because they receive them from the host," Alexey Potekhin explains.

Another feature of Deianiraea is that it has several secretion systems. In bacteria, this enables protein secretion that can be employed for interaction with other cells as well. Deianiraea does have a specialised secretion system for interacting with other bacteria. It also has a specialised type IV secretion system which putatively enables it to establish contact with the ciliate. At present, the researchers have not yet established the exact mechanism of the parasite-host cell interaction, and what the bacterium may acquire from the ciliate or other host organisms.

Related to mitochondria

The order Rickettsiales encompasses three previously known families of highly diverse representatives of intracellular symbionts and parasites associated with eukaryotes, including animal and human pathogens (e.g., typhus). It has been suggested that all Rickettsia-like may have shared a common ancestor with mitochondria. Mitochondria in are responsible for ATP synthesis in all eukaryotic cells, i.e. for energy metabolism. The discovery of a novel—extracellular—Rickettsiales bacterium suggests that the evolutionary path of mitochondria may have been different, contrary to what has been previously assumed.

"Evolution, whenever possible, tends to choose the path of least effort, reducing the number of redundant functions: all that is unnecessary is eliminated. It has been assumed that the common ancestor of all Rickettsia-like bacteria was a specialised intracellular parasite with a low biosynthetic potential. In other words, it was unable to synthesise many of the essential substances, acquiring them from the host. It could sustain itself and reproduce only inside host cells. The results of our research allow us to assert with confidence that the last common ancestor of all Rickettsia-like bacteria led an extracellular lifestyle, lived in water, had a flagellum and was metabolically independent. It also must have had cellular systems that enabled parasite-host interactions. Adaptation to the lifestyle of intracellular parasites of the modern families of the Rickettsiales order would have evolved later in parallel and independently in different sub-lineages. The discovery of Deianiraea impels us to reopen the debate about the time when the ancestor of mitochondria would have established itself inside a proto-eukaryote, and the particular traits this mitochondrial ancestor would have possessed," the scientist concludes.

More information: Michele Castelli et al, Deianiraea, an extracellular bacterium associated with the ciliate Paramecium, suggests an alternative scenario for the evolution of Rickettsiales, *The ISME Journal* (2019). DOI: 10.1038/s41396-019-0433-9

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