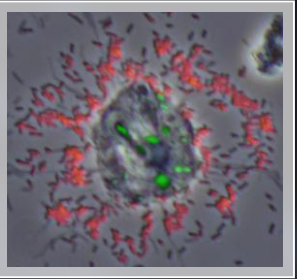
Symbiosis

All animals and plants show intimate associations with bacteria, whereby the character of this 'living-together' (symbiosis) may reach from parasitism to mutualism. However, even protists may harbour symbiotic bacteria. *Nuclearia* is a host for several bacterial symbionts. Notably, these amoeboid protists are phylogenetically 'closely' related to animals. Thus, species of *Nuclearia* are **ideal model organisms to study basic principles of symbiotic interactions**.

Symbiotic bacteria are identified by using fixatives and specific staining techniques:
A *Nuclearia* cell with ectosymbionts (red) and endosymbionts (green).

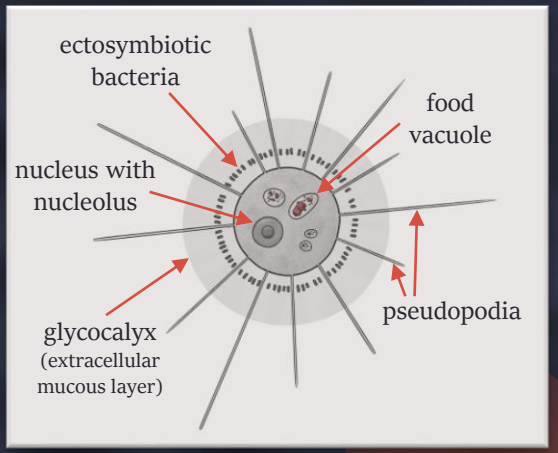


Nuclearia cells are covered by an extracellular mucous layer (glycocalyx), which can be colonized by **ectosymbiotc bacteria**. In addition, this protist often harbours bacteria living in its cytoplasm (**endosymbionts**). Some associations with bacteria have positive effects on the growth of *Nuclearia*. However, distinct bacteria may also reduce the fitness of their host. The diversity and different natures of these relationships are currently investigated.

In addition to cell associated symbionts, environmental bacteria living together with the protist play a pivotal role. They help ***Nuclearia* to feed on toxic cyanobacteria**. Toxins of the digested prey are released by *Nuclearia* and get degraded by accompanying bacteria.

Characteristics

- Protist (unicellular eukaryote) with **spherical** or **amoeboid** appearance
- Size: 10 µm – 30 µm (1 µm = 0.001 mm)
- **Nucleus** with its **nucleolus** (site of ribosome biogenesis) clearly visible – hence the **genus name *Nuclearia***
- Often **symbiotic bacteria** inside the cell and in the **extracellular mucous layer**
- Ubiquitous in **freshwater ecosystems**
- Are able to feed on **toxic cyanobacteria** without being harmed
- The genus *Nuclearia* is assigned to the taxonomic group Opisthokonta, together with animals and fungi



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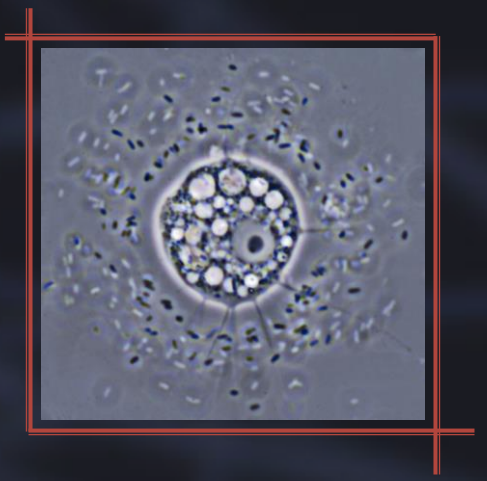
Protist of the Year 2019



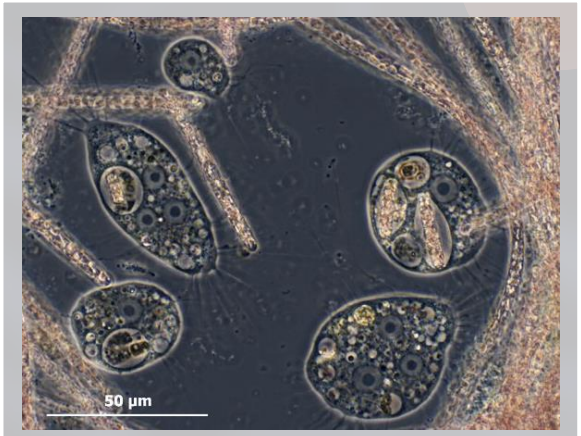
Nuclearia

It is not a
'Dinner for One'

German Society for Protozoology (DGP)
www.protozoologie.de

Biology & Ecology

Global warming strikingly affects physicochemical and biological parameters in freshwater ecosystems. Blue-green algae (cyanobacteria) are among the winners of this climate induced changes. These organisms tend to form mass developments ('algal blooms') in lakes and ponds, and many species are harmful (also for humans). Their toxicity seems to be an effective grazing protection against most predators.



Amoeboid *Nuclearia* cells feeding on filamentous harmful cyanobacteria.

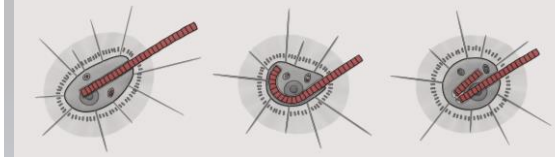
However, a few 'protistan specialists' as, e.g. species of the genus *Nuclearia*, are able to feed and live on harmful cyanobacteria. It is remarkable, that these protists are not harmed by toxins of their digested prey organisms.

Likely, with the help of bacteria, *Nuclearia* evolved distinct strategies, to make use of this toxic but highly nutritive food source (please see chapter on Symbiosis).

Feeding behaviour

The cells of *Nuclearia* are either spherical or amoeboid. They are covered by an extracellular mucous layer. *Nuclearia* cells have fine hyaline cell projections (pseudopodia) for locomotion and feeding processes. Depending on the species, cells have one or more clearly visible nucleus (nuclei).

Nuclearia shows a peculiar feeding behaviour by ingesting filamentous cyanobacteria. Short fragments are engulfed by the protist and directly digested. Long filaments are partially transported into the cell and then mechanically broken into smaller units.



Nuclearia can break filamentous cyanobacteria

As a third strategy, *Nuclearia* holds the end of a long filamentous cyanobacterium with a large pseudopodium and digests one cell after another. This behaviour enables the amoeboid protists to feed on filaments which are far larger than themselves.

Left: A spherical *Nuclearia* cell sequentially digests cyanobacterial filaments.
Right: *Nuclearia* can directly ingest short filaments.

Science & History

Nuclearia (Artari, 1889)

In 1865 Leon Cienkowski described protists with fine hyaline pseudopodia and established the genus *Nuclearia*. Three decades later (1889), Alexander Artari reported on the striking feeding behaviour. The author also described the extracellular mucous layer, which was densely packed with 'granules' of unknown origin. It lasted until the 1980's that microscopic studies showed that these 'granules' were gram-negative bacteria.

Twenty years later there was another scientific surprise when the first genetic analyses elucidated the phylogeny of *Nuclearia*. This genus is a sister group of fungi.

Current research is focused on the isolation and identification of symbiotic bacteria. In laboratory experiments, the ecological reasons for the symbioses are examined. Analyses of the genomes of this 'protist-bacteria consortium' (meta-genome) will provide further insights into the molecular interaction between symbionts and their host.

Literature to read

Artari (1889) Morphologische and biologische Studien über *Nuclearia delicatula* Cienk. Zoologischer Anzeiger 12:408-416.

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