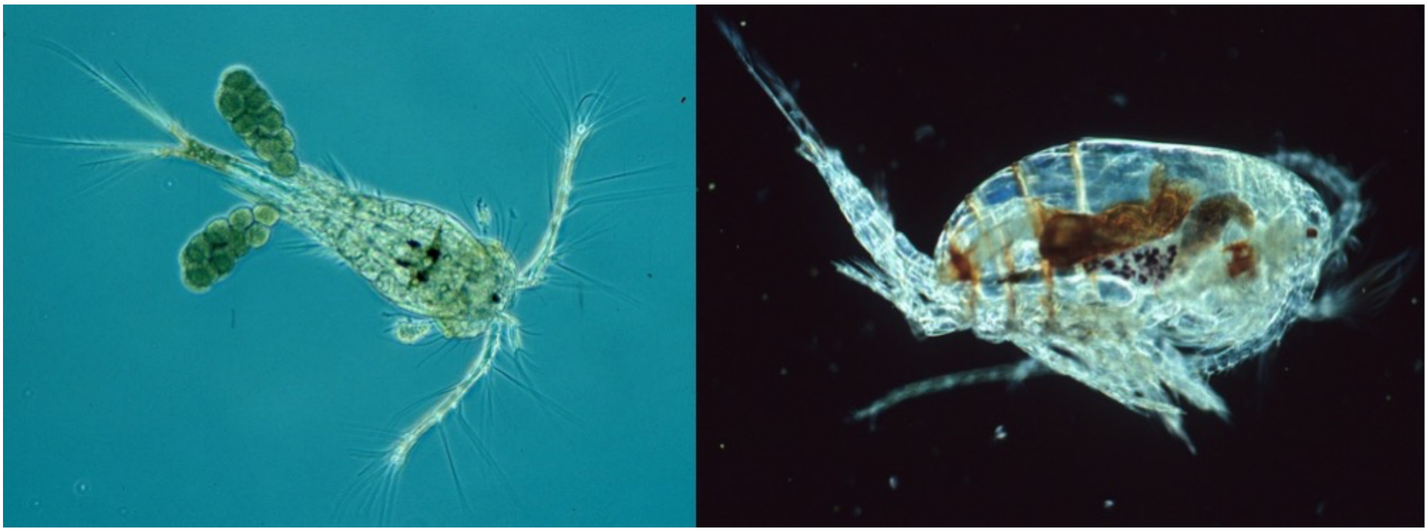
Feeding mechanisms in zooplankton

Strange numbers and viscous media

Who doesn't remember the famous movie "Fantastic voyage" 1966, starring the iconics Raquel Welch and Stephen Boyd? The plot is about a scientist from the East who falls into a coma due to an attack. The only way to save this character, who keeps tremendously important secrets in his mind, is to miniaturize a submarine to the size of a little more than a blood cell and get inside his body to get to the brain and remove a life-threatening clot. You may also remember that the submarine used a propeller to move, as with most water vehicles. However, a submarine of this size would not advance even a couple of millimeters using a propeller. Why? Because of a magic number called a Reynolds number.

No, I didn't go bananas. Reynolds number is a mathematical concept separating fluids with laminar regimes from turbulent ones. In other words, it describes the relationship between viscous and inertial forces. Tiny particles have low Reynolds numbers and are moving in the viscous world, where the water acquires a density similar to honey or syrup. Large particles have high numbers, which correspond to the inertial world, which we all know, and where water is fluid and slips between our fingers. What are the implications of this? The "Fantastic voyage's" submarine (with low Reynolds) would make little use of a propeller to move forward because it would turn and turn without going anywhere. To move, it would benefit from other methods, such as a long flagellum or, why not, thousands of cilia. Within zooplankton, we find organisms that live in the viscous world (e.g., protozoa) and others in the inertial one (salps, jellyfish, etc.), or even some that straddle the two worlds, such as the copepods. Being in one or the other of the two worlds will mark the different feedingstrategies.



Oithona and *Clausocalanus* are two genera of copepods with different feeding mechanisms. Images Albert Calbet

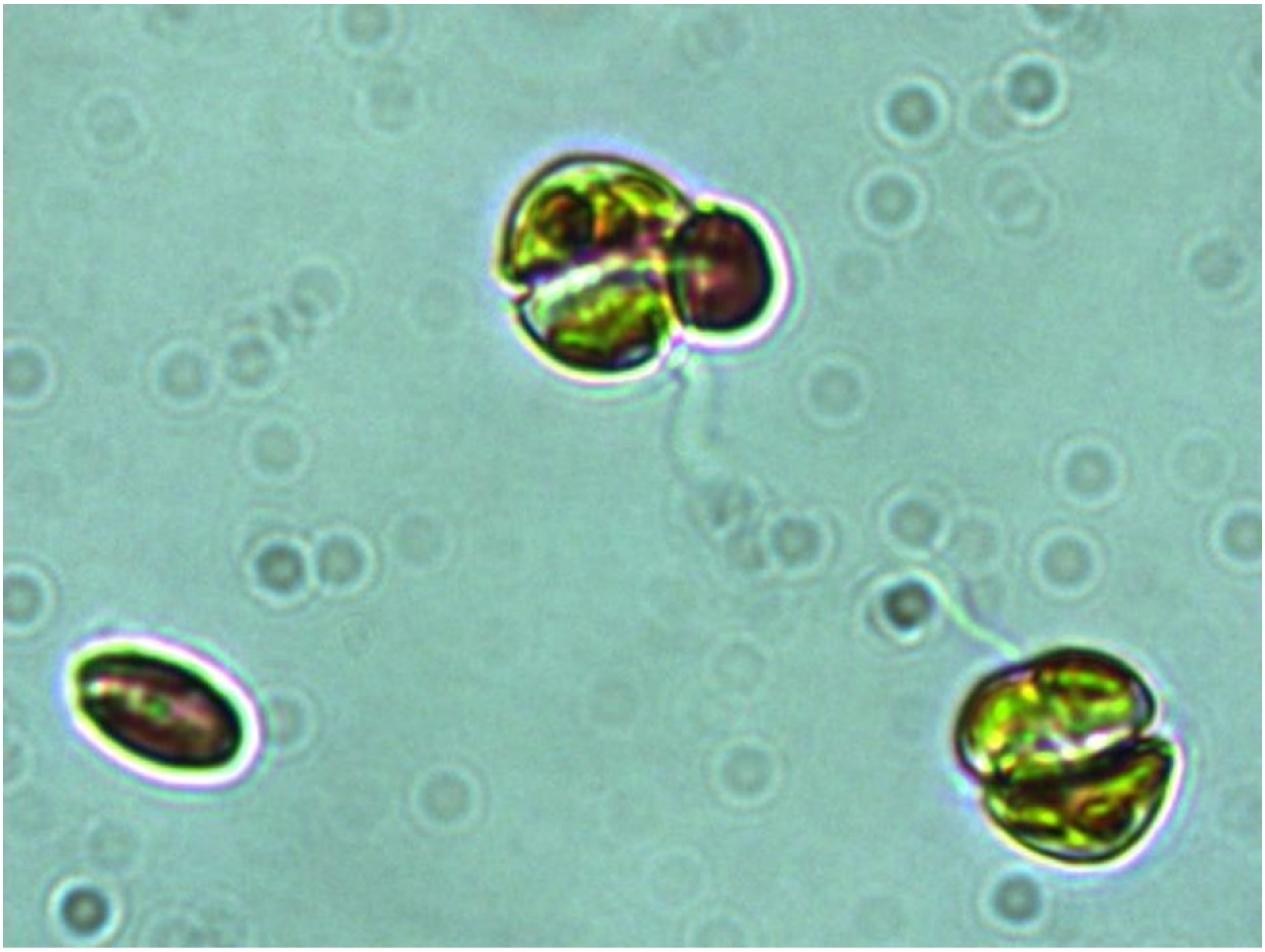
Prey, where are you?

But before I go into detail to explain how zooplankton feeds, I would like to mention a small fact that all members of zooplankton share; all of them have to get their food in a highly dilute environment. For example, to eat a ciliate (the equivalent in size to an apple for us, and found at an abundance of less than one individual per milliliter in our waters), a copepod would have to scan at least 1000 mm^3. It doesn't seem like much, but if we think that a copepod is only a millimeter long, it means that it has to scan and travel at about ten times its length in any direction. Imagine that to eat an apple you had to seek into a sphere of 10-20 meters diameter. If you had to do it with closed eyes (copepods don't use sight to locate prey), you'd probably be starving. Fortunately, copepods, and other members of zooplankton, have different mechanisms for detecting and attracting prey.

Zooplankton feeding mechanisms

Feeding by diffusion of inorganic or organic solutes

Many members of the unicellular zooplankton, especially mixotrophs, can feed like algae, absorbing dissolved nutrients into the cell. Diffusion feeding is usually linked, though it is not a necessary condition, to motility to break gradients and prevent solutes from depleting around the cell. There are organisms such as *Karlodinium veneficum* that can incorporate solutes through their membrane and eat prey simultaneously.

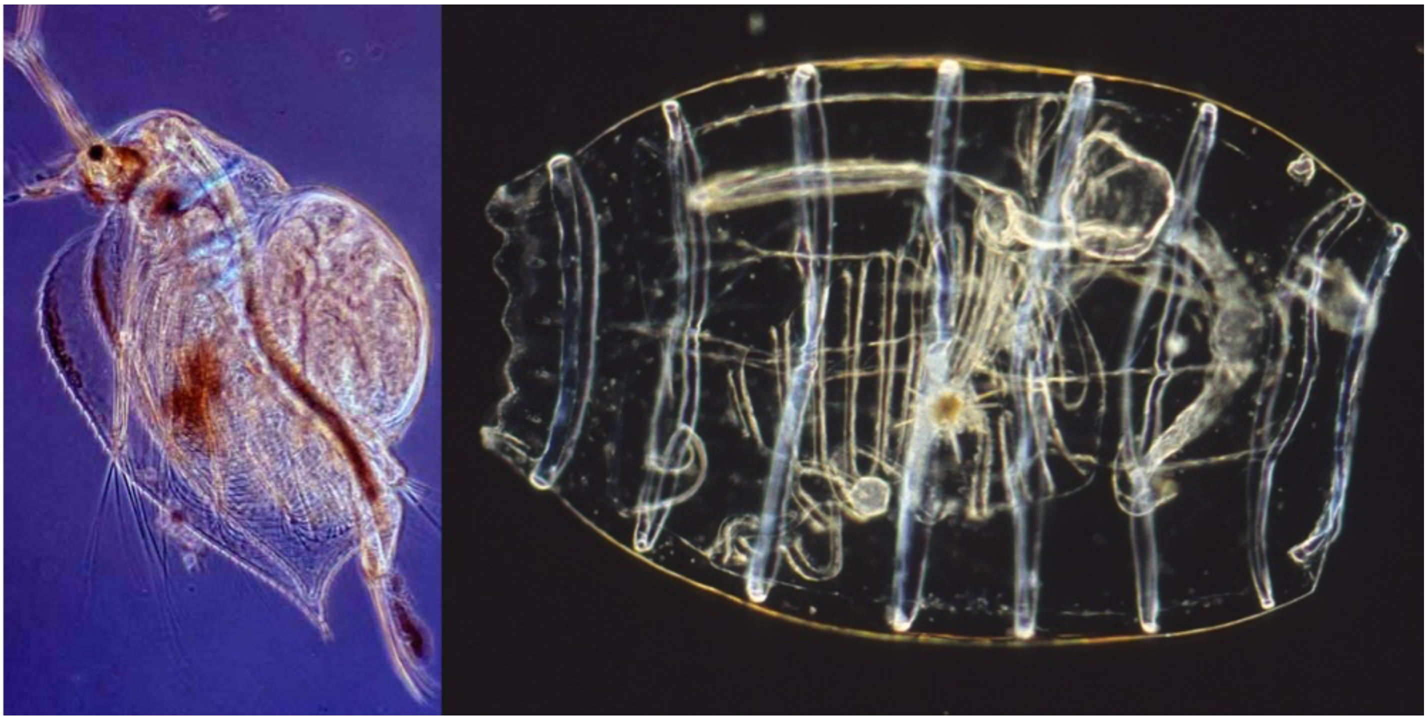


The dinoflagellate *Karlodinium veneficum* can feed by spreading dissolved substances and capturing live prey.Image Albert Calbet

Passive ambush feeding

Jellyfish, ctenophores, and some protozoa, such as radiolarians and foraminifera, keep adrift on the lookout for prey. If you want to see a video of a foraminifera eating a copepod and other videos of protozoa's prey capture, here is the link of a previous post: **https://planktonocean.com/2020/10/05/microzooplankton-** terrible-predators-of-the-oceans-the-movies.

These types of feeding are usually accompanied by toxic structures responsible for immobilizing the prey and by other capture mechanisms, such as sticky pseudopods, facilitating the attraction of the prey to the mouth/vacuole. A particular case is that of some pteropods (tiny planktonic snails) that, like spiders, secrete nets of adhesive mucus to collect prey.



Cladocerans and doliolids are filter-feeders. Images Albert Calbet

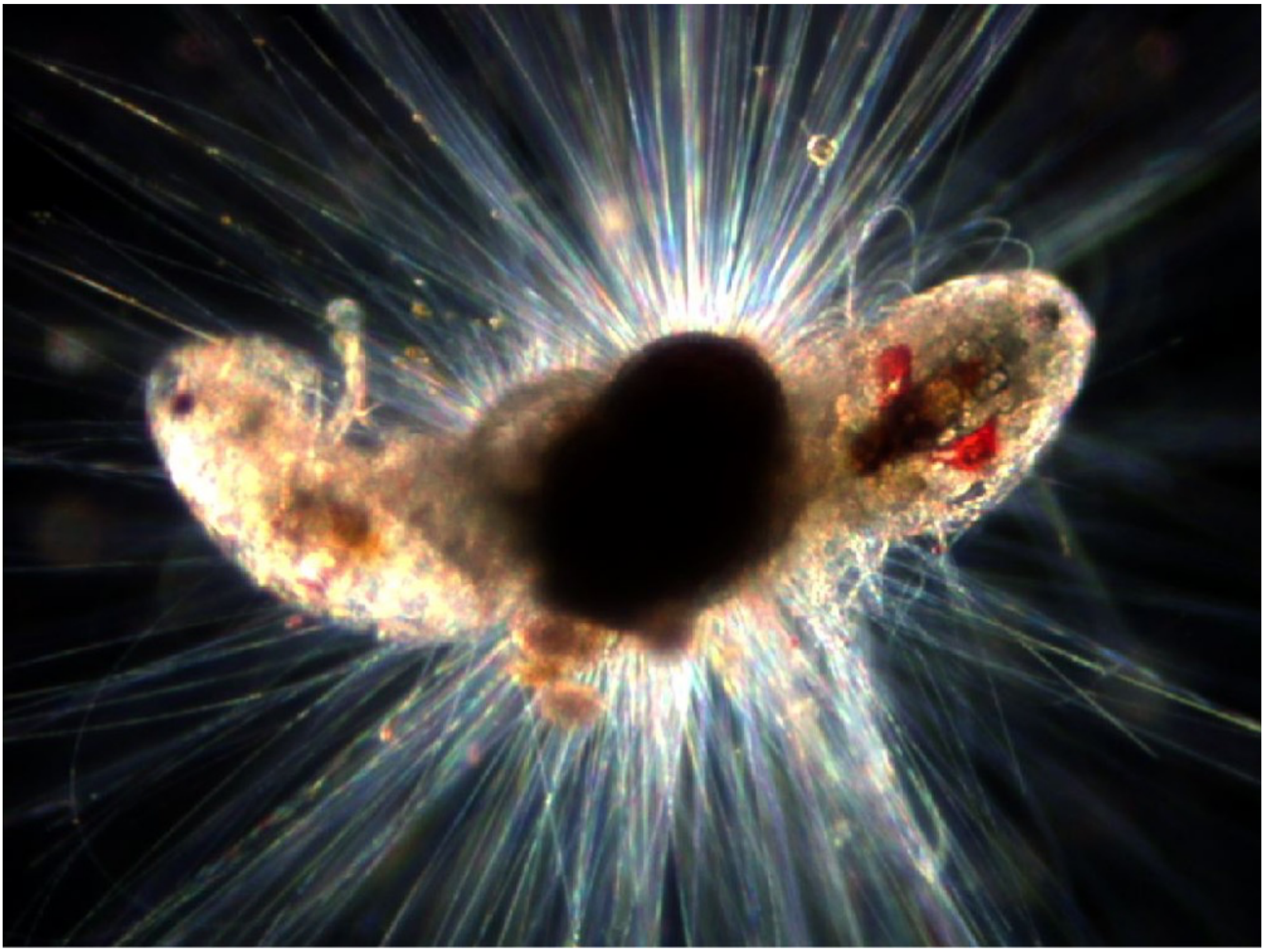
Active ambush feeding

Some ciliated species, such as *Didinium nasutum* or *Mesodinium rubrum*, many copepods, such as the ubiquitous *Oithona* spp., and also chaetognaths, among others, are some of the members of this group of organisms. They all share a capture mechanism similar to that of large felines in the savannah or the jungle: they await on the lookout for prey, and when they locate one, they jump over it. However, the difference between lions and zooplankton (apart from size and fur) is that the former are based on sight to detect prey and the latter have mechanosensitive structures that guide them towards them. At long distances, also specific chemical receptors (similar to the olfactory ones of large terrestrial predators) can guide zooplankton to the most favorable direction to find prey.

Filter-feeders and cruisers

Appendicularians, salps, doliolids, cladocerans, and some choanoflagellates use water currents to attract small prey, such as bacteria and tiny phytoplankton, to highly efficient filter structures. Many crustaceans, such as barnacles, some calanoid copepods, and Krill, also create feeding currents to attract prey. They do so without these currents involving a displacement of the organism. In contrast, other species of copepods and protozoa also create feeding currents but at the same time use them to move (cruising feeding).

The particular case of copepods is quite curious because it was believed they were filter-filters until early eighties. We now know that they are suspensivorous and manipulate prey one by one or in small groups in an active way. Dr. Alcaraz and collaborators, in 1980, were the first to describe the mechanism by which copepods attract, manipulate, capture, and sometimes even try and reject prey. They do all this with the help of mouth appendages called maxillipeds. The first movies of the mechanism were made with a *Eucalanus crassus* attached by the thorax to a dog's hair (the pet of a member of the group) with Crazy glue. These movies are on the website of one of the article's co-authors: (**http://www.planktonsafari.net/video-archive**).



Foraminifera feeding on two copepods it has captured. Image Albert Calbet

As you can see, the ways by which zooplankton detect and capture prey can be very diverse and are not exclusive of any group. Evolutionary convergences to one mechanism or another are common. If you want a more scientific view on the subject, I recommend an article by Professor Thomas Kiørboe in 2011, which I quote below.

Literature

Alcaraz, M., Paffenhöfer, G.-A., and Strickler, R. (1980). Catching the algae: a first account of visual observations on filter-feeding calanoids. Evolution and ecology of zooplankton communities, ed. W.C. Kerfoot. (New England: University Press), 241-248.

Kiørboe, T. (2011). How zooplankton feed: mechanisms, traits and trade-offs. Biol. Rev. Camb. Philos. I am. 86, 311-339.

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