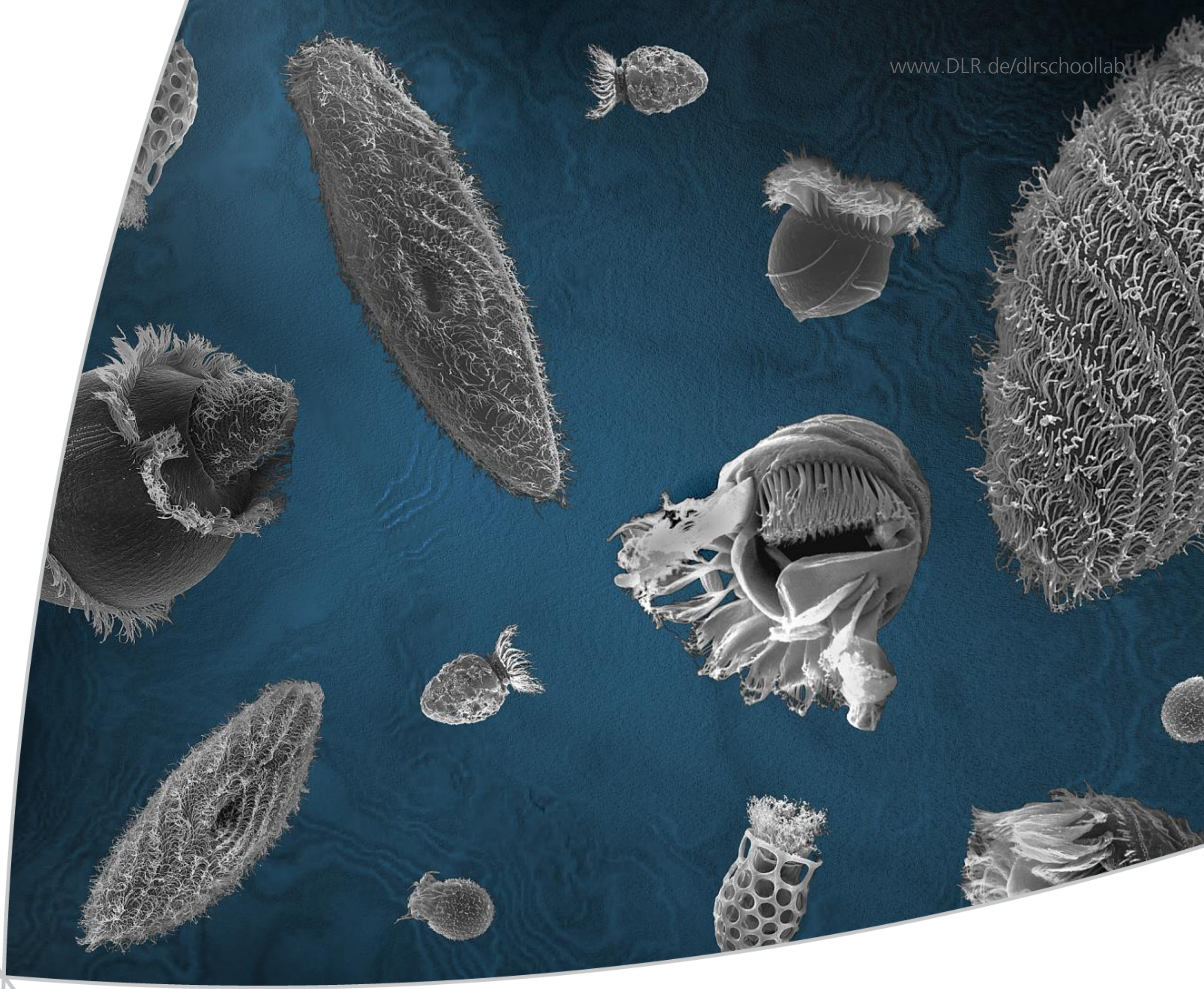


DLR_School_Lab Köln

Gravitational Biology

How single-cell organisms perceive directions

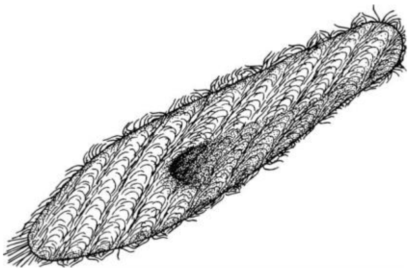
Life first evolved on our planet over four billion years ago. In order to survive and advance, organisms need to be able to avoid inhospitable environments and find food. For this, they have to be able to orient themselves within their habitats.

There are many possible stimuli that primitive organisms might use as a means of orientation: perhaps they use light or temperature, various types of radiation or even the existence of certain chemical compounds. However, nearly all imaginable environmental stimuli have one big disadvantage: They are changeable, that is their quality can fluctuate greatly (difference in light intensity during the day and at night; distribution of temperature in summer and winter).

The only reliable environmental stimulus is gravity. Gravity is always present and almost equally strong all over the world. Its direction is always the same. It is for these reasons that scientists in the 19th century asked themselves:

Can a single cell perceive and respond to gravity?

This is the question you will seek to answer in today's experiment. You will be able to observe primordial organisms: slipper animals (paramecia). They are ciliates and are single-cells organisms. Ciliates evolved around 1.3 to 1.5 billion years ago. They live in large puddles and ponds.



Paramecium caudatum (slipper animal)

Verworn makes an observation

The German physiologist Max Verworn studied paramecia 115 years ago. He observed that these single-cell organisms gather at the top of a volumetric flask within a short space of time. You will be able to try this out yourself.

Hypotheses – scientists' ideas

But how do we know that the paramecia used gravity as a means of orientation and not light, temperature or the concentration of oxygen in the water? (Think about that.) If it is true that these cells "feel" which direction is "up" and which is "down", how does this work?

Some scientists thought that the cells' posterior end might be heavier. Consequently, a cell would act like a buoy and its anterior end would point upwards, therefore ensuring that the cells swim to the surface.

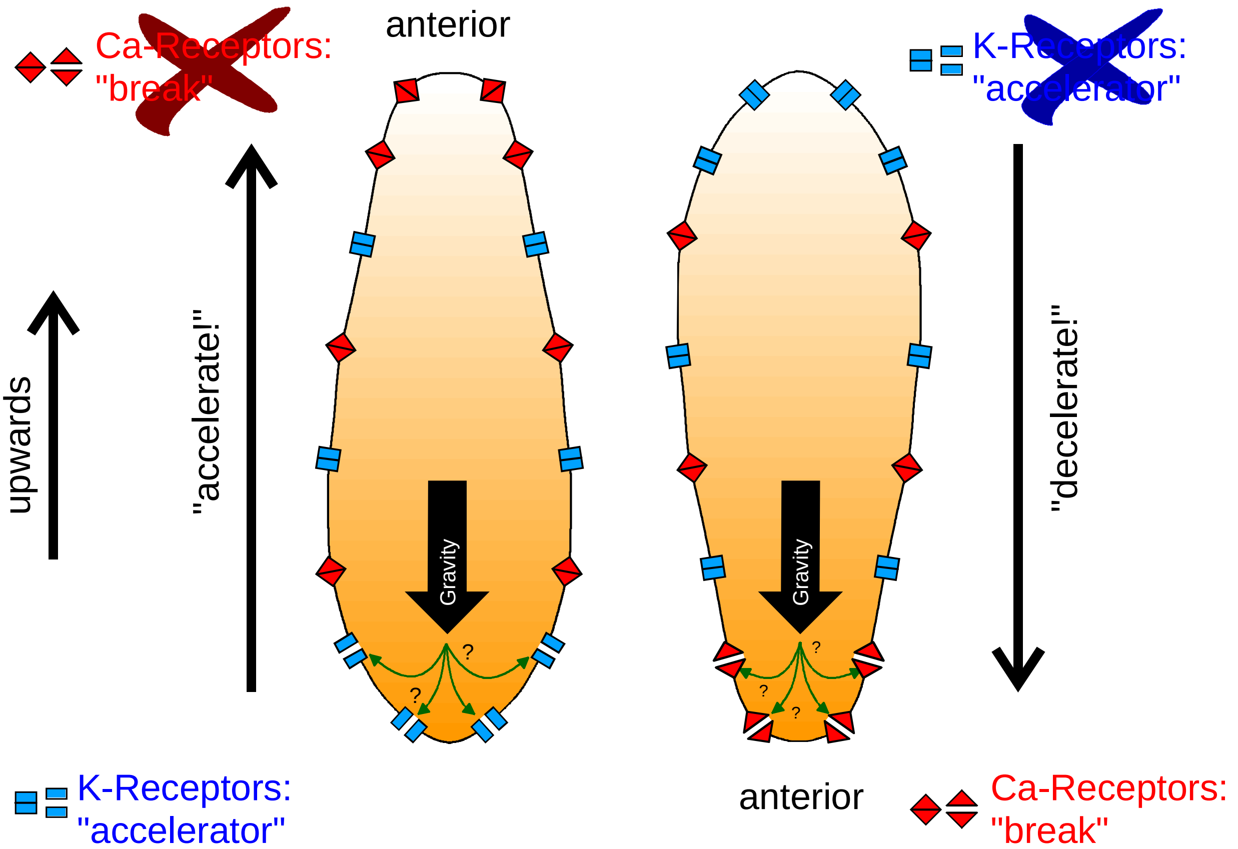
Fehler! Es ist nicht möglich, durch die Bearbeitung von Feldfunktionen Objekte zu erstellen.

Max Verworn's experiment: paramecia swim to the surface of a volumetric flask

But it is also possible that paramecia perceive the directionality of gravity, a phenomenon that is known in almost every "higher" animal or plant.

We will discuss different organs needed for graviperception ("statocysts"). But wait! A paramecium cannot have such an organ as it is only a single-cell organism! It also does not have a nervous system or a brain.

In 1905, the British scientist Lyon considered whether the whole single-cell organism could act as a proprioceptor –



The extended statocyst hypothesis on graviperception in paramecia (according to Machemer, Bräucker and colleagues) that is, as a sensory receptor that is sensitive to weight. The inside of the cell is heavier than the surrounding water; therefore it should exert pressure onto the cell membrane below it (similar to a balloon filled with water, where the plastic membrane is stretched).

Lyon was not able to verify his idea. It was not until 1989, with the discovery of the relationship between the paramecia's behaviour and the perception of stimuli via ion channels, that Machemer and his colleagues were able to continue the research.

Is paramecium a "statocyst"?

The cell membrane of ciliates contains channels - proteins that we can think of as tiny gates. Charged atoms (ions) can pass through these channels when they are open. The illustration shows channels that only react to mechanical stimuli. They transport either K^+ or Ca^{++} ions. If the K^+ channels at the posterior end are opened, the cell accelerates. If the Ca^{++} channels (at the anterior end) are opened, the cell slows down. If we assume that the mass of the inside of the cell stimulates the respective membrane below it, then a cell swimming upwards should accelerate, while a cell swimming downwards should slow down. It is therefore more probable that the cell will get to the surface.

The hypothesis is tested

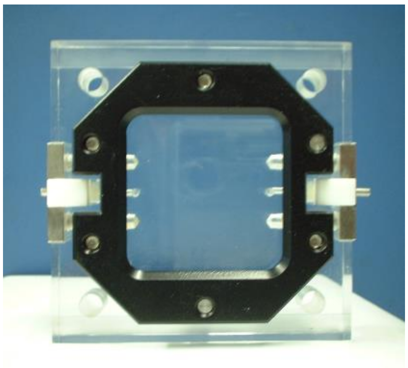
Scientific hypotheses are only useful if they are testable. You will be able to verify Machemer's assumption yourself. With the help of observation equipment and computer aided image processing, we will measure the direction in which the many paramecia will be swimming and their respective velocities. If the cells do not slow down while swimming downwards or do not accelerate while swimming upwards, then our hypothesis is wrong.

Why do we want to know all this?

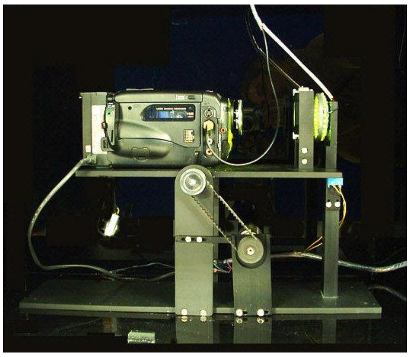
Evolutionary history shows us that structures or functions that proved useful

Equipment for the experiment: At the front the container with the paramecium culture and the required solutions, in the background the observation equipment

early on in the development of life survive in later stages as well. Therefore it is possible that human cells too "feel" gravity. This could have consequences when these cells are put in an exceptional state that never occurred throughout the whole evolutionary process: the state of weightlessness. To be able to understand problems that may occur within these cells – and perhaps to be able to prevent them – we have to know more about the processing of gravitational stimuli in specialised cells. And our 1.6 billion year old ancestors can help us in this undertaking by being a model organism.



Observation chamber for paramecia



Camera system for the filming of the video data

Literature

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