Magnetised algae as microrobots for medical and environmental purposes

Algae, for most of us, is something that lives in water courses that we occasionally find unpleasant. However, that is to do them a wrong. These extremely versatile and frugal organisms might in future prove to be extremely important. Scientists at the University of Stuttgart are investigating how algae can be used as microrobots in biomedicine and environmental remediation.

The idea of using algal microrobots for delivering drugs where they are needed has been around for a few years. The idea is to specifically control these cell-sized algal robots to deliver drugs to tissues and body cavities that are hard to reach or to use them for imaging procedures. They are biodegradable and can be used as often as required without harming patients. Treatment using algae could therefore be considered a minimally invasive intervention.

What sounds more like science fiction to non-experts, is already at the early stages of development; researchers have carried out experiments that show that various microorganisms can serve as wireless transporters and drug delivery systems. Swimming microorganisms such as bacteria have been shown to be particularly suited for this purpose due to their self-powered movements. Magnetotactic bacteria, whose path through the human body can be controlled with a magnetic field, are particularly suitable for transporting drugs. However, using bacteria has its limitations. Depending on species and dose, they can be harmful for animals and humans or trigger unwanted immune system reactions. In addition, magnetotactic species are difficult to grow in the laboratory and the cultivation process is relatively expensive. Moreover, they are not the most efficient cargo carriers; their swimming speed decreases significantly with the weight of the cargo.

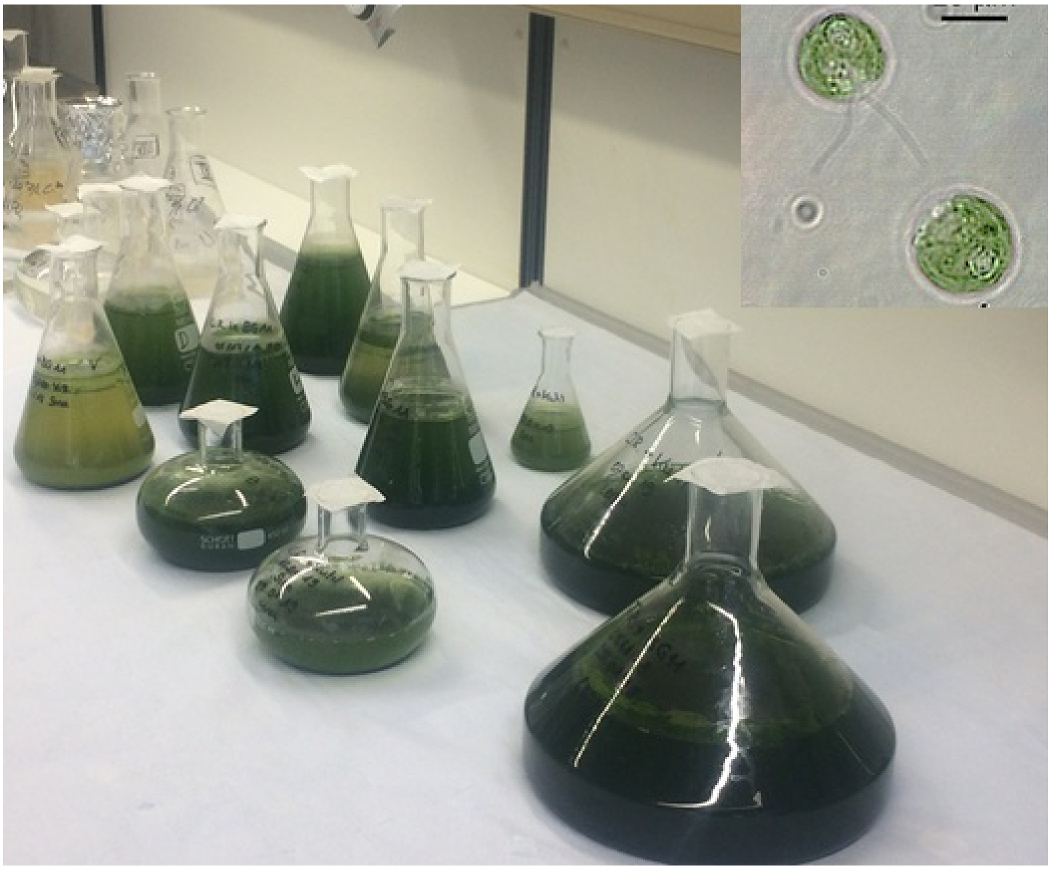
Algae as fast microtransporters for medical purposes

Microalgae could be an excellent alternative to bacterial swimmers. Dr. Giulia Santomauro from the Institute of Materials Science at the University of Stuttgart has been researching the green eukaryotes for years. Chlamydomonas reinhardtii are spherical microalgae about ten micrometers in size and very easy to grow in culture. The scientist and her team have shown that these microalgae can incorporate foreign matter. “I keep the algae in medium with chemical elements such as zinc," she says. "They incorporate and metabolise these elements. I then study the effects these substances have on the algae.” The scientist also feeds the green experimental organisms with elements such as terbium, a rare earth metal that is used for fuel cells, lasers and cell phones. "The algae are very fast swimmers, and become magnetic once they have incorporated terbium ions. This is very special,”

Dr. Giulia Santomauro from the University of Stuttgart investigates how algae can be used for a broad range of different applications.

says Santomauro about the idea of using algae for transporting a wide variety of substances.

Microalgae - luminous, superparamagnetic and biocompatible



Chlamydomonas reinhardtii microswimmers become magnetotactic when they have taken up terbium, and can thus be guided to their final destination in a targeted way.

Santomauro's experiments have been successful. Together with colleagues from the Max Planck Institute for Intelligent Systems in Stuttgart, she investigated the magnetic properties of terbium-ion (Tb3 +) treated algae. Not only were the living algae easily attracted by magnets, they also aligned themselves along an applied magnetic field, which guides them to swim in a directional motion towards the magnets. Since this is a superparamagnetic phenomenon, i.e. the cells only display magnetism when magnets are present, the algae do not agglomerate, but revert to their natural behaviour when no longer exposed to terbium.

Furthermore, the microorganisms and the human cells were incubated in medium at human body temperature. "The temperature of 37 degrees is very hot for these algae, but both algal and human cells nevertheless survived without any problems," says Santomauro. "That means that human and algae cells are biocompatible, something that is of crucial importance when algae are used as microrobots in the human body. After delivering the drug, the algae are eliminated by the body's detoxification organs in the same way as any other foreign substance. The terbium that is incorporated is luminescent, so the microalgae are easy to track in the human body, in either urine or stool." The next step for the researchers is to attach suitable particles as drug placeholders on the algae cells to study particle transport and discharge.

Magnetic particles are easy to collect and the accumulated metal can be recycled

The marine algal species Emiliania huxleyi produces finely structured lime platelets that could be used for technical applications.

The microalgae are not only useful for medical applications, but could also be used for environmental remediation and recycling rare earths or other metals. "As the algae incorporate foreign matter, I could envisage using them for accumulating and recovering valuable materials," she says. "It would be perfect if we could use them for recovering and recycling terbium and other metals. We currently need large quantities of rare earths, for cell phones for example. However, they are difficult to mine and recovery with existing methods is complicated."

Over the next few months, Santomauro therefore wants to systematically investigate how much terbium the algae can incorporate. In addition, she will test whether the algae also take up other rare earths such as europium and neodymium, which are also used in many high-tech devices.

In general, the idea is to add microalgae to sewage systems or sewage treatment plants for the purpose of environmental remediation. Here the algae would incorporate metals for subsequent recovery. The microalgae could be attracted by magnets to a place in the sewage system where they could easily be removed and the metals used for recycling purposes. "This process would be much, much more environmentally friendly than current recycling methods - especially in the case of rare earths," says the scientist. "In addition, the algae have the great advantage that they can be kept in an environmentally friendly way in bioreactors – as if they were on a green field. They only need light and some nutrient medium, they are uncomplicated and willingly incorporate all sorts of elements." The researchers are still looking for ways to finance this recycling project.

Looking to a future when algae materials might be even more valuable

In addition, the biologist is also very interested in how the biomineralisation processes works in algae, and what actually happens in the cells when they have taken up metal elements. "On the one hand, this is still basic research," she says. "On the other hand, I'm also investigating technical applications for coccoliths, which are microscopic lime platelets produced by marine algae. There are definitely a lot more valuable algal materials that we could exploit and that are produced from materials which the algae incorporate and detoxify readily." Many questions still have to be answered, which is exactly what the researcher plans to do in ongoing and future projects.

Article

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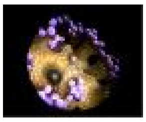

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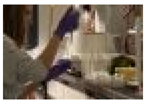

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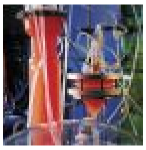

Biotechnology – driver of innovation in the pharmaceutical industry

algae

imaging methods

materials research

recycling

basic research

active pharmaceutical ingredient