In times of great famine, microalgae digest themselves

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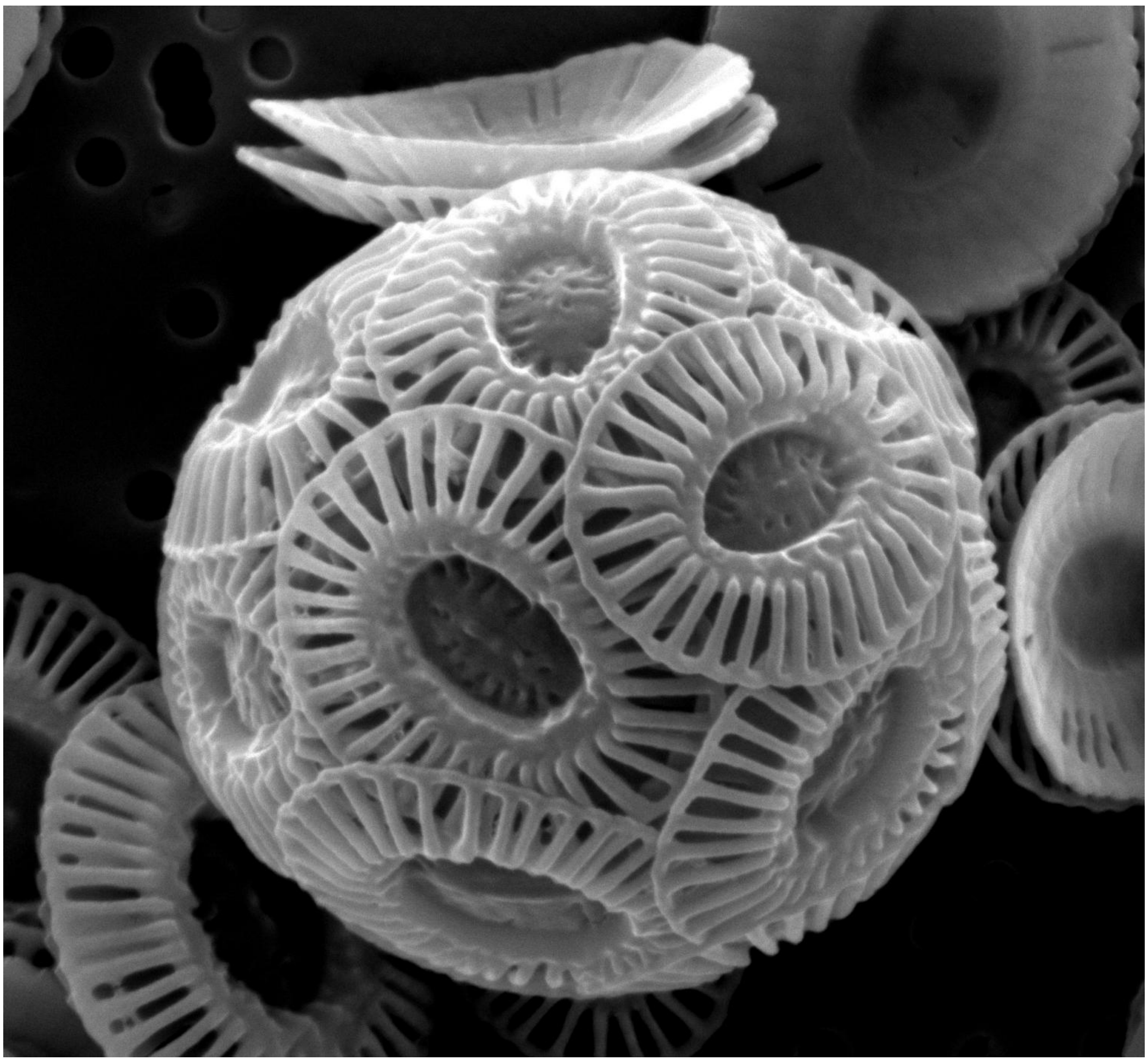

The coccolithophore Emiliania huxleyi. Credit: Clara Hoppe

In a recent study, scientists of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) have determined the molecular mechanisms which microalgae apply in order to switch from rapid cell division to growth-arrest during times of acute nutrient deficiency. In laboratory experiments, the scientists have been able to observe that calcifying microalgae in a state of nutrient deficiency initially tweak their metabolism to be more economic and efficient before, out of necessity, they even partially digest themselves. The molecular switches for these basic functions of cells are strikingly similar in all living things. Apparently, it is these switches, which, when malfunctioning in humans, cause cells to lose control of their division activity and potentially become cancer cells. The new findings are being published online this week in the journal *Frontiers of Marine Science*.

"Like all living things, algae depend on the nutrients phosphorus and nitrogen, which are introduced into coastal areas by rivers, or -in the open ocean- are carried up from depth by eddies. If the surface water is fertilized by such nutrients, a race for the precious elements begins in which the various algae compete for the nutrients. This race only ends when the nutrients which are necessary for cell division are exhausted and the algae are suddenly facing a famine situation," explains Dr Sebastian Rokitta, AWI biologist and lead author of the current study.

Because the algae apparently react differently to the lack of various nutrients, scientists have long assumed that the single-celled organisms take several different countermeasures to efficiently accommodate for each missing nutrients. However, past studies on this subject have often neglected one important aspect: the molecular machinery of the cells.

Usually, the uptake mechanisms for the lacking nutrients, as well as the biomass and lime production of algae have been studied under starvation conditions. A holistic 'screening' of many cellular functions at the same time was previously only possible to a very limited extent. "Only recently, genomic sequence data became available for the most common microalgae in the world, *Emiliania huxleyi*, so we can finally make effective use of our molecular toolbox," explains AWI microbiologist and co-author Dr Uwe John.

By using so-called microarrays, the scientists have been able to simultaneously observe the activity of more than 10,000 genes under different hunger scenarios. The new results show that the genetic programs which run in different hunger situations are largely the same in terms of arresting the cell division and are only slightly modified, depending on the particularly lacking nutrient, e.g., to switch on specific transporters and storage mechanisms. This strategy is very useful for the algae, since it greatly simplifies the management of the complex cellular apparatus.

What is striking, is the close integration of nutrient availability and cellular energy supply in the algal metabolism. "Apparently, the triggered genetic programs also include molecular sensors that stop the cell division, so to speak, in case of low nutrient levels", says the AWI biologist Dr Björn Rost, who was also involved in the study. This mechanism is known to be disturbed, for example, in human cancer cells, accordingly signalling them to continue cellular division and proliferation. Thus, the study also underlines that the molecular mechanisms that control cell division, and which evolved in the early phase of life about 2 billion years ago are still operative.

The research results also demonstrate that, in the case of ongoing life-threatening nutrient starvation, the microalgae begin to 'digest' their own cellular components, to ensure their survival as long as possible. They cannot maintain this process for very long, though. All those cells that destroy themselves through this emergency measure then unintentionally make their nutrient-containing components available to other algae as well as to their conspecifics. This previously underestimated process seems to favour the long-term evolution of particularly frugal and self-sustaining individuals and is certainly partly responsible for the robustness and resilience of microalgae in the face of nutritional deficiencies.

In the coming years, Sebastian Rokitta and his colleagues will continue to investigate how different species of algae react when their habitat is changed; which types benefit and which suffer. However, the focus of the AWI scientists will then be on the phytoplankton of the North Atlantic and the Arctic Ocean.

More information: Sebastian D. Rokitta et al, P- and N-Depletion Trigger Similar Cellular Responses to Promote Senescence in Eukaryotic Phytoplankton, *Frontiers in Marine Science* (2016). DOI: 10.3389/fmars.2016.00109

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