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THE IMPORTANCE OF DWARFS IN AN OCEAN OF GIANTS

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The sea-ice and the oceans of Antarctica are full of life. The smallest organisms are tiny plants that consist of only one cell. These small cells come in large numbers: a single droplet of seawater may contain thousands of tiny plant cells called microalgae. Like all plants, they use carbon dioxide and produce oxygen when they grow. Together, the microalgae in the oceans produce 50% of the oxygen in the atmosphere. They also influence the global climate by producing a gas that causes clouds to form. In the oceans, especially along the underside of sea ice, microalgae make a colorful meal for plant-eating ocean animals. In this article, we will show you not only how beautiful microalgae can be in color and shape, but also how important these tiny organisms are for all life on Earth—from the small shrimps and large whales that feed on them to the humans that need oxygen to breathe.

ANTARCTIC ICE AND OCEANS ARE FULL OF LIFE

Antarctica is the southern-most continent of our planet, and it is about twice the size of Australia. The landmass is permanently covered with snow and ice that can reach 3 km in thickness. In winter the Southern Ocean, which surrounds the Antarctic continent, is almost completely covered with **sea ice** that averages about 2 m thick. The Southern Ocean is more than 20,000,000 km^2 in size—approximately the size of the entire continent of South America.

SEA ICE

The ice that is floating on top of the ocean. Some ice is only there in winter, but in many places the ice never thaws away.

This cold and pristine place hosts a wealth of wildlife. Whales and penguins are the most famous inhabitants, while the smallest organisms of Antarctica are less well-known. The ice and ocean around Antarctica are occupied by very small plants that consist of only one cell. These tiny plants are known as **microalgae**.

MICROALGAE

They are small plants that exist of one single cell. There also exist macroalgae that are greater plants, consisting of many different cells that form a stem and roots.

Individual microalgae cannot be seen with the naked eye—only through a microscope. They come in large numbers: a single droplet of seawater may contain thousands of cells. When conditions are perfect, microalgae can grow and multiply so much that they can turn the water green. Along the underside of the sea ice, they can form thick layers, with millions of cells per cm^2, that create colors of green, brown, or red.

MICROALGAE AND THE AIR WE BREATHE

It may seem strange, but the microalgae that populate the oceans are of great importance for the atmosphere (for more information about climate gases, see this Frontiers for Young Minds article). Like all plants, microalgae use the sun's energy to take up carbon dioxide (CO_2) and turn it into materials to build their cells and to grow. At the same time, they produce oxygen (O_2). This process is called **photosynthesis**. Together, the large numbers of microalgae in the oceans produce 50% of all the oxygen in the atmosphere (Figure 1). This is the same oxygen that we breathe, which shows how essential these algae are for all life on Earth.

PHOTOSYNTHESIS

The process by which plants can create small molecules from the energy of the sun and the uptake of carbon dioxide. During photosynthesis, oxygen is produced.

The CO_2 that microalgae take from the ocean is replenished with CO_2 from the atmosphere. This means that, when a lot of microalgae are growing, large amounts of CO_2 are transferred from the air into the oceans. In this way, microalgae remove part of the CO_2 that humans put into the atmosphere when we burn fossil fuels like oil and gas. Since CO_2 in the atmosphere results in global warming, the tiny algae in the ocean help us to reduce that.

Besides taking up CO_2, microalgae also produce a gas that is important for Earth's climate. This gas is called **dimethyl sulfide** (DMS in short). When DMS gets into the atmosphere, it can be converted into tiny particles that form clouds when water vapor condenses on them.

DIMETHYL SULFIDE

DMS is a gas with a sulfur compound. It is the typical smell of the sea. DMS is important for the climate, as it affects cloud formation.

Figure 1

Microalgae live in the ocean and attached to and in sea ice. They produce gases that go into the atmosphere. When microalgae grow, they consume CO_2 and produce O_2. Many species also produce dimethyl sulfide (DMS) a gas that is important for cloud formation and can also attract animals that eat the microalgae (or animals that eat the animals that eat microalgae), like krill, birds, fish, seals, and whales.

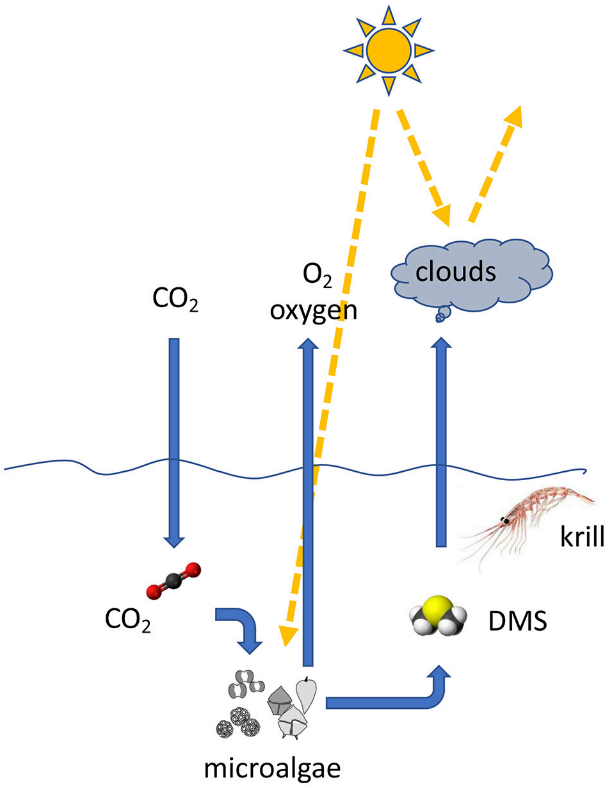

Figure 1

Clouds shield the Earth from the sun, which prevents the Earth from heating up too much.

So, microalgae are important for Earth's climate in two ways: by taking up CO_2 from the atmosphere and by emitting DMS into the atmosphere. Both processes result in a cooler climate, which is very helpful now that humans are heating up the Earth. Many of the microalgae that produce DMS are found associated with the sea ice in Antarctica. So, who are they?

THE HIDDEN WORLD OF MICROALGAE

Microalgae exist everywhere in the oceans. They can be free living and drift with the currents (called phytoplankton), or they can live attached to surfaces like rocks or other ocean plants called macro algae, or they can live in the **brine pockets** and channels of sea ice, which contain very salty water. Brine pockets are created when sea ice forms. When the water freezes, the salt stays in tiny pockets that become more and more salty as the ice gets colder. These brine pockets provide an important habitat for some types of microalgae. The microalgae that live inside brine pockets are called sympagic algae [1, 2].

BRINE POCKETS

They are small channels in the sea ice that are formed when ice freezes. Many small organisms find food and good shelter in these pockets.

So far, ~50,000 species of sympagic microalgae have been described and it is estimated that there are probably more than 200,000 species of these microalgae on our planet. The shapes and sizes of these microalgae vary a lot (Figure 2). One of the most well-known groups of microalgae is the **diatoms**, which can live alone or in colonies. Diatoms have a thick cell wall, which is made out of silica (the same material as glass). This cell wall has unique structures, forms, and shapes for each species. Some species also have spines that can grow to be very large.

DIATOMS

They are microalgae with a thick shell, which is made of silica. They have many different forms, from centric to elongated.

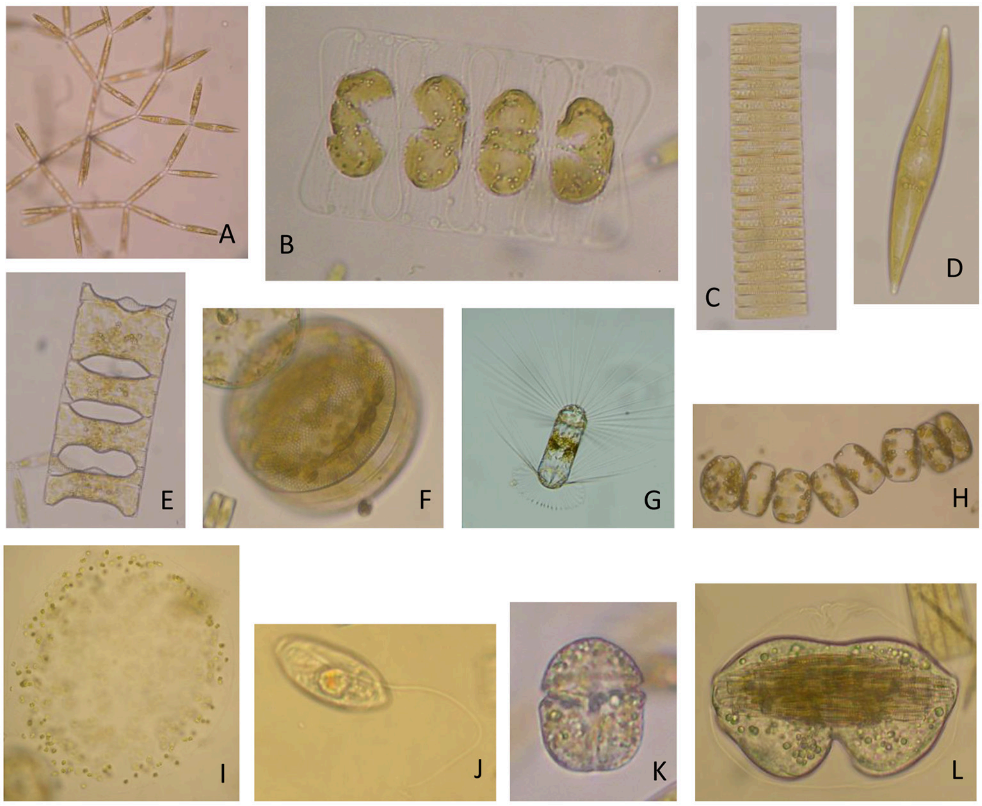

Figure 2

Figure 2

(A–D) Pennate diatoms are long and thin. They can move in the ice by producing a slimy substance. **(E–H)** Centric diatoms look like little boxes with lids. From above, they have a round shape. They often have spines that sometimes link them together (pictures copyright Stefels). **(I–L)** Flagellate algae have one or more flagella, like a sweeping tail. Whereas most diatoms look brownish, flagellates can also be green and red. Microalgae often stick together, making large chains **(A, B, C, E, H)**, or thick blobs **(I)** of cells. This helps protect them against grazing animals.

Another group of algae frequently found in sea-ice communities is called **flagellates**. This group has flagella, long, tail-like structures that can be used for swimming and feeding. Observations of live samples have revealed several types of "swimming" behavior. One species, called *Pavlova*, was named for its distinctive swimming motion, which resembles a famous ballet dancer, Anna Pavlova. They use their flagella to spin around at great speed, like the pirouettes of a ballerina.

FLAGELLATES

They are microalgae without a silicate wall. They exist in many different colors, and have flagella that they can use to swim or to feed.

Flagella can also be used for feeding. In addition to using the energy of the sun, many microalgae also feed on small molecules floating in the ocean water, including other microalgae and bacteria. These kinds of algae are called **mixotrophs** because they use a mixture of food sources. Dinoflagellates are an example of mixotroph microalgae. Some dinoflagellates can eat other microalgae and even use the organelles of their prey to perform photosynthesis. In the ocean, it is not always easy to tell plants apart from animals!

MIXOTROPHS

They are microalgae that use a mixture of food. They may use photosynthesis, but can also feed on small organic molecules, or even other microalgae.

MICROALGAE PROVIDE FOOD FOR BIG ANIMALS

Because microalgae are so diverse, they can grow under many conditions (from −2 to +20°C, from almost complete darkness to full sunlight), and they can grow to very high densities. The underside of sea ice is like a rich grassland in spring, but upside down (Figure 3). These dense communities of microalgae provide a colorful meal for tiny animals that graze upon them, such as copepods (a kind of shrimp) and Antarctic krill. Here is another important role for DMS: not only is it important for the climate, but it is also smelly. You can smell it yourself when walking along the beach, especially in springtime. If you think "Now I smell the sea," you are actually smelling DMS.

Figure 3

Figure 3

Scientists that study sea ice use a big drill, a bit like an apple corer, to collect a column of ice. The brown color at the underside of the ice indicates high numbers of microalgal cells.

When krill eat algae, a lot of DMS is released. When that happens, larger animals like birds and maybe also seals and whales can smell it. This is called a chemical cue, and it helps ocean organisms to find their food, since they eat the krill and the fish that are eating the krill [3].

Antarctic krill is one of the most abundant species on Earth. Together with similar animals like copepods, krill form the basis of the whole food web in Antarctica, sustaining all the seals, birds, penguins, fish, and whales. Krill and copepods all eat microalgae, so this shows you just how important microalgae are. These microscopic algae are the dwarfs that are the food source for all the ocean's giant animals. In addition to supporting the ocean food web, microalgae are important for their role in the global climate, since they can slow down global warming by moving carbon out of the atmosphere into the ocean. The Southern Ocean, specifically the sea ice around Antarctica, is an important habitat for these algae. They may be tiny, but they are vital for all life on Earth!

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LAURUS INTERNATIONAL SCHOOL OF SCIENCE, AGES: 10–11

Hello! We are the Y6 class with 20 students from Laurus. Our everyday is chaos, but we have a lot of fun here! We all love to challenge new things. Our class has good friendship and we are very glad to review science articles.

LICEO MACHIAVELLI—CLASS 2C HUMAN SCIENCES, AGE: 15

Hi, we are a very funny and bizarre class. We are all different, but we have one thing in common: we like to contradict the teachers and to express our opinions. By the way we have a good friendship and we like studying a lot. No kidding with us!

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Maria van Leeuwe is a marine biologist working at the University of Groningen, the Netherlands. She is strongly interested in the growth of microalgae, and especially wants to know how algae survive in the cold and sometimes dark regions of Antarctica. Since her first expedition in 1990, she is addicted to Antarctica. She combines field work in polar waters with experiments in the laboratory. *m.a.van.leeuwe@rug.nl

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Jacqueline Stefels studied biology in Amsterdam. She is now a marine biologist and lecturer at the university of Groningen in the Netherlands. During her Ph.D. on "The Smell of the Sea," she became expert on the role of microalgae in the production of DMS. Later, she got the chance to do research on the production of DMS in Antarctic sea ice. To investigate this, she combines field work with laboratory experiments. She is passionate about the polar regions, especially Antarctica.