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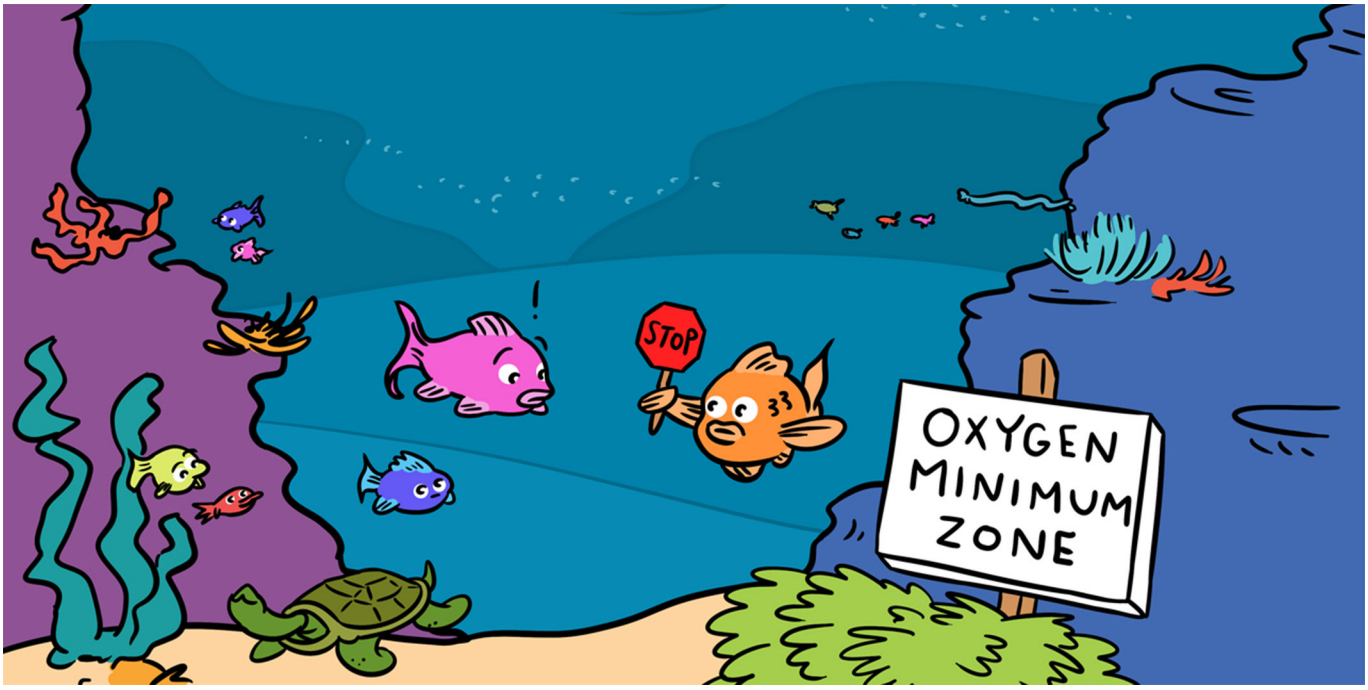
EARTH AND ITS RESOURCES
Published: 07 January 2019
doi: 10.3389/frym.2018.00075



DOES THE OCEAN LOSE ITS BREATH?

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YOUNG REVIEWERS:

STRETTON STATE COLLEGE
AGES: 12-13

GREG
AGE: 15

We usually do not think about how we breathe unless our breath becomes labored, like when we have a cold or have been exercising. Of course, we all know that breathing is essential for human life and many life forms on Earth, because it brings oxygen (O_2) into our bodies. Why do we need oxygen? Our food can only be converted to energy when oxygen is available. When the food we eat is processed in our bodies, it gets converted to carbon dioxide (CO_2), amongst other things, and the CO_2 is exhaled. The Ocean also breathes: it inhales oxygen at certain places, but it also loses it in others. This happens naturally, through a combination of physical and biological processes. Nowadays, we humans produce increasing amounts of CO_2; because we burn a lot of fuels in our industries, we drive cars, and we do many other things that increase the amount of CO_2 in our atmosphere. This disturbs the natural functioning of the Earth, because CO_2 contributes to global warming. Droughts, floods, and the melting of the polar ice caps are some of the consequences of global warming, but global warming may also disturb the way the Ocean breathes.

HOW DOES THE OCEAN BREATHE IN?

In this article, we are going to talk about the different ways that the Ocean can breathe. First there are tiny organisms; including **cyanobacteria** and **phytoplankton**, which take up CO_2 from the atmosphere and produce oxygen in a process called **photosynthesis** (see Figure 1). Since photosynthesis needs light, this process can only occur in the water layers closest to the surface, about the top 10–100 meters of the Ocean. Even though this area seems very thin, photosynthesis in the Ocean is very important for the Earth, as it is estimated to produce up to 70% of the oxygen on our planet [1] and to remove 30% of human-made CO_2 from the atmosphere [2]. It is important that the Ocean keeps doing this, to keep our planet in a stable condition where the life we know today can continue to exist.

Another way that oxygen gets into the Ocean is when the waves break, and small air bubbles are pushed down into the water. This mechanism mostly takes place in surface waters and at the coasts, and the air bubbles in the water are the main reason waves look white when they break on the beach.

However, there is a place in the Ocean where oxygen is inhaled so deeply that it is taken down into the deep waters where it can stay for thousands of years. This happens in the very north of the Atlantic Ocean, in the Greenland Sea and the Labrador Sea [3], but also in the Southern Ocean in the Weddell and Ross Seas off the Antarctic coast (see Figure 2). Here, oxygen dissolves in the cold water, and the colder the water is,

CYANOBACTERIA

Bacteria that can perform photosynthesis and produce oxygen. They have different shapes; some are small round cells, others are chain-like colonies (one of those chain-like colonies is shown in Figure 1A).

PHYTOPLANKTON

Free-floating tiny organisms, living in the Ocean and other waters, which can perform photosynthesis. Phytoplankton contains a pigment called chlorophyll, which gives them their green color. They have many different shapes and can consist of one or many cells. They are different from cyanobacteria because phytoplankton cells have a nucleus and a cell wall, and their cells also contain other special structures.

Figure 1

(A) Microscopic picture of a drop of seawater, which contains cyanobacteria and phytoplankton. These organisms produce oxygen in the ocean surface waters, where enough sunlight is available to provide energy for this process. **(B)** This is a model of a cell, for example a cyanobacterium, which takes up CO_2 during photosynthesis. By doing so, it removes some human-made CO_2 from our planet and helps to reduce global warming. The cell needs water and sunlight for photosynthesis, and it produces oxygen, which is released into the environment. The bar at the bottom of each figure indicates the size. A µM is 1/1,000 of a millimeter.

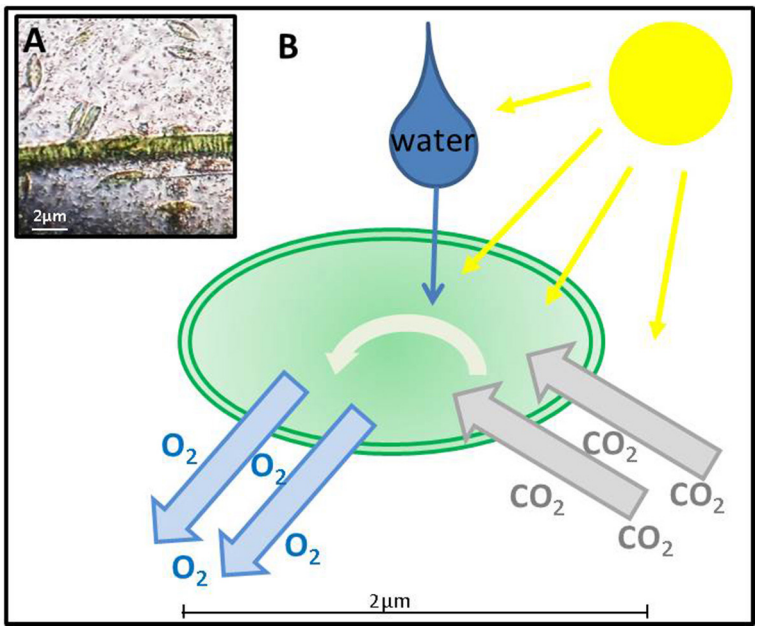

Figure 1

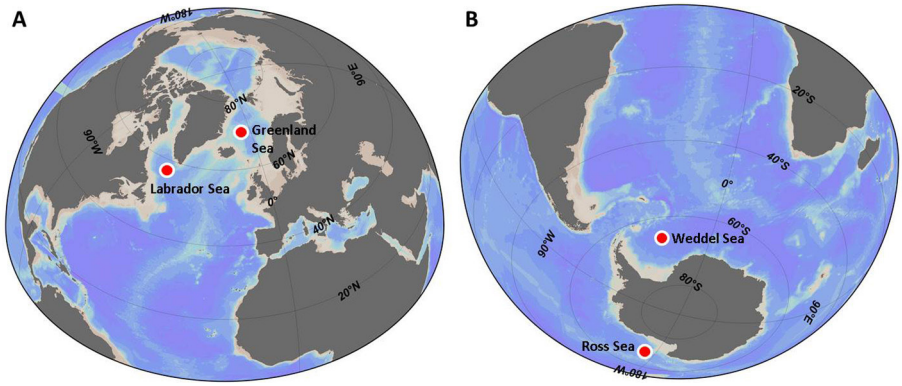

Figure 2

(A) In the Northern hemisphere, surface water is drawn into the deep ocean in the Greenland and Labrador Seas. **(B)** In the Southern hemisphere, the same happens around the Antarctic coast, in the Ross Sea, and the Weddell Sea. The areas where the water is taken down into the deep Ocean by the process of deep convection are marked with red dots.

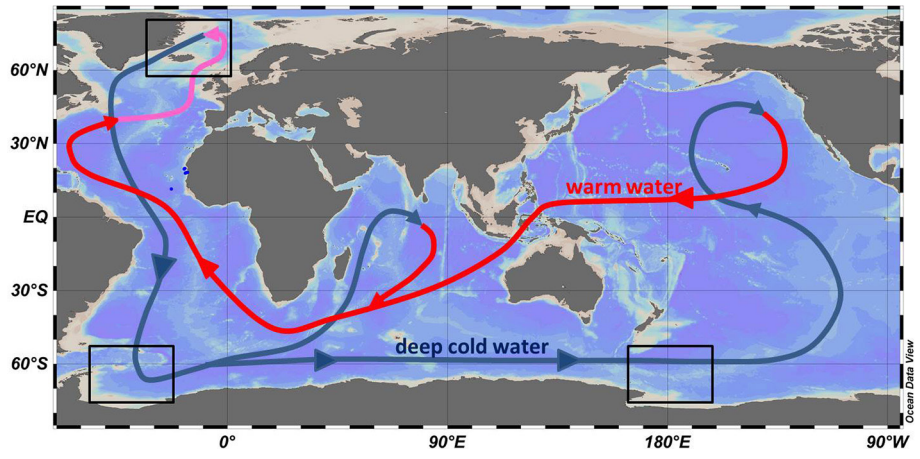

Figure 3

After the water takes up oxygen from the air in the Polar regions, it starts its journey through the deep Ocean (blue lines), where it passes through the Atlantic, Indian, and Pacific Oceans. When the water comes to the surface again, it warms up and travels back through the Oceans at the surface (red lines). In the Atlantic, the Gulf Stream transports the water back to the Labrador and Greenland Seas (pink line), and the travel can start again. This big circulation system, called the global conveyor belt, is the most important circulation system in the Ocean. By transporting oxygen down into the deep waters, it allows animals to live there. The regions where deep convection occurs are indicated with black boxes.

the more oxygen can dissolve (The opposite happens when you boil water, for example when making pasta. There you can see that gases, including oxygen, start to bubble out of the water, and the warmer the water is, the more bubbles come out). Most of the oxygen is therefore taken up in the winter, and because cold water is also denser than warm water, the cold water with oxygen in it sinks down into the deep Ocean, where oxygen would otherwise be rather scarce. This process is called **deep convection**.

The way the water circulates through the Oceans is called "the **global conveyor belt**" and is shown in Figure 3. This movement of water through the ocean starts in the areas of deep water (Figure 2), such as the Labrador Sea, where warm water from the Gulf Stream (see Figure 3) heats the atmosphere in those cold regions. When the water cools down, it becomes denser. This cold, dense water then sinks down to ocean floor. More and more warm surface water is transported to the Labrador Sea by wind currents, where the cold water is continuously sinking down to the deep sea, thus making room for the incoming warm water. When

PHOTOSYNTHESIS

The process by which organisms, such as plants and algae, and microorganisms like cyanobacteria and phytoplankton, take CO_2 from the atmosphere and turn it into oxygen and sugar. Photosynthesizing organisms are usually found only in the top 10–100 meters of the ocean, because these organisms need sunlight as an energy source for photosynthesis.

the deep water reaches the bottom of the ocean, it flows south and passes through the Atlantic Ocean, then through the Indian Ocean, and then through the Pacific Ocean. In the end, the cold water returns to the surface mostly through mixing and a process called upwelling. When the cold water reaches the surface, the water warms up and is transported back to the Labrador Sea by the winds. Thus, the global conveyor belt is a big circulation system connecting all the Oceans.

HOW DOES THE OCEAN LOSE ITS BREATH?

Deep convection in the Ocean depends on the water temperature, but also on the salinity (the "saltiness") of the water. The colder and the saltier the water is, the more oxygen it can take up. Now that the Earth is warming up, snow, glaciers, and the polar ice caps may melt. This is particularly bad in the Polar regions, because the fresh water from this melting ice flows into the sea and forms a layer of water that is far less salty than the seawater. This may lead to less oxygen being taken up by the ocean, which means there will be less oxygen for life in the oceans.

Another reason that the Ocean is losing its breath is that, if the surface layer of water becomes warmer, it does not mix that well with deeper water layers. When the layers stop mixing, the oxygen that is produced by photosynthesis and by exchange with the air cannot get into deeper waters anymore. A lot of life forms in the deeper Ocean breathe oxygen, including fish, starfish, shrimps, jellyfish, and microbes. Particularly in areas where there is a lot of life around, this leads to the formation of **oxygen minimum zones**, which are areas where the water has little or no oxygen left (Figure 4). Those oxygen minimum zones are mostly found in the tropical Oceans, where most of the fish are living. If those

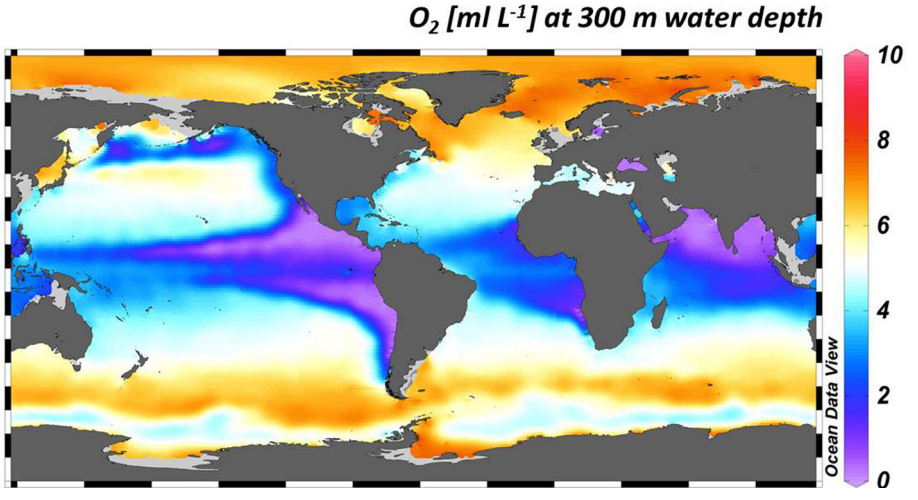

Figure 4

This is the distribution of oxygen in the Ocean at a water depth of about 300 m (data from data from the World Ocean Atlas, WOA09). The scale on the right shows the oxygen concentration in the water, measured in milliliters of oxygen per liter of water. There are regions in the Ocean where there is a lot of oxygen in the water, mostly in the Polar regions, and this is shown in the orange/red. Blue colors mark the regions where oxygen is low. These regions are called oxygen minimum zones. In large parts of the Pacific and the Indian Oceans, there is no oxygen left (shown in purple). Those are the strongest oxygen minimum zones in the Ocean. The oxygen minimum zone in the Pacific Ocean is also one of the most important fishing areas in the world.

waters lose more and more oxygen, and if less oxygen reaches deeper waters, there is not much space left for fish and other animals to live. This also means that there will be fewer and fewer fish left that humans can eat. The decrease in fish is a big problem, since fish make up 16% of the animal protein consumed by humans around the world [4]. Fish also provide healthy fatty acids that are not found in any other foods. When the oxygen supply of the world's fish is threatened, so is one of our primary food sources [5].

WHAT WILL HAPPEN IF THE OCEAN LOSES ITS BREATH?

We do not know what will happen. Scientists have confirmed that the Ocean is indeed losing its breath, which is to say that oxygen concentrations are going down, at least in certain areas of the Ocean. This means that the oxygen minimum zones are expanding [6]. It is hard to predict what else will happen, mainly because we only have data from the last 50–60 years. This is not a whole lot of time, if you compare it with how long it takes for water to move all the way through the global conveyor belt (thousands of years) or if you compare it with the age of our planet, which is around 4.6 billion years.

One way that scientists try to understand the situation is to compare Earth's present to its past: the Earth and the Oceans have been through similar or worse times, in terms of **global warming** and CO_2 levels. For example, massive changes occurred in the **Cretaceous**, a time in Earth's history that started 145 million years ago and ended 65 million years ago. In this period, there was more than three times as much CO_2 in the Earth's atmosphere than there is now. This CO_2 came from volcanic eruptions [7]. The ocean surface waters had temperatures of up to 40°C, which is more than twice as high as today's ocean temperatures. In the Cretaceous, large amounts of oxygen were lost from the Ocean, until it had no oxygen left for two long episodes called ocean anoxic events. During these events, many life forms became extinct. However, afterwards, new life evolved and the Earth and the Oceans recovered again.

Considering all of this, most people understand why scientists want to find ways around the problem of global warming and stop the Ocean from losing its breath. We want to do something about climate change because we do not want to become extinct. So, we as humans need to become active and stop global warming. This is not so easy to do, because we must drastically reduce the amount of CO_2 we produce; each one of us currently produces tons of CO_2 per year. Everything in our life that needs electricity, like our fridges and computers, as well as wearing clothes that are industrially produced, using cars, eating meat, and many more things in our daily life all produce CO_2.

DEEP CONVECTION

When surface waters in the polar seas cool down, they absorb oxygen and sink to the bottom of the ocean. This process provides oxygen rich water for the global conveyor belt to transport around.

GLOBAL CONVEYOR BELT

When waters circle through first the Atlantic Ocean, then through the Indian Ocean, and then through the Pacific Ocean, we think of the water as traveling along the global conveyor belt. This conveyor belt provides oxygen for a variety of life forms in the ocean.

OXYGEN MINIMUM ZONE

A zone of the ocean that is very low in oxygen.

GLOBAL WARMING

When gases, such as CO_2 increase in quantity in the Earth's atmosphere, the Earth heats up. This effect is known as global warming. CO_2 can come from volcanos, but these days it often comes from burning fossil fuels, which include the oil that was buried deep under the ocean. Fossil fuels are used to generate electricity, fuel our cars, and produce/run a lot of things in our daily lives, such as clothing, fridges, computers, etc.

CRETACEOUS

A time in earth's history that started 145 million years ago and ended 65 million years ago. During this period the Earth was very warm, CO_2 levels are high, and the Ocean turned anoxic several times.

WHAT CAN WE DO TO HELP THE OCEAN CONTINUE TO BREATHE?

The most important way to help keep oxygen in the oceans is to slow down global warming. Around the world, there are several groups working on this. One initiative to track climate change and to study the impact of global warming on the Earth and its oceans is called the Intergovernmental Panel on Climate Change (IPCC). This group collects data, predicts what exactly could happen if the climate keeps getting warmer, and gives recommendations to politicians [8]. By doing these things, the IPCC hopes to directly reduce the CO_2 output on our planet. Many countries also signed an agreement called the Kyoto protocol [9]. This protocol contains guidelines on how much every country has to reduce its CO_2 emissions in order to reduce global warming. By doing these things, scientists and politicians hope to reduce global warming, so that, among other things, the polar ice will stop melting and the Ocean can continue to breathe so that oxygen minimum zones will stop expanding and ocean life will continue to exist.

If you would like to check how much CO_2 you are producing in your daily life, to see if you can do your own part to reduce global warming and help the oceans continue to breathe, you can use these links: https://www.earthday.org/take-action/footprint-calculator, https://www.carbonfootprint.com/calculator.aspx.

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SUBMITTED: 24 August 2018; **ACCEPTED:** 06 December 2018;
PUBLISHED ONLINE: 07 January 2019.

EDITED BY: Mark A. Brandon, The Open University, United Kingdom

CITATION: Löscher CR and Canfield A (2019) Does the Ocean Lose its Breath? Front. Young Minds 6:75. doi: 10.3389/frym.2018.00075

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YOUNG REVIEWERS

STRETTON STATE COLLEGE, AGES: 12–13
Stretton State College is a school outside Brisbane, Australia with a strong values base which strives to ensure a culture of high expectations for students and staff. Our school is one where students look forward to the challenges and opportunities each day, with an increasing focus on eLearning and the advancements of digital learning. The students who performed this review were enthusiastic 12–13 year olds.

GREG, AGE: 15
Hi, I am 15 years old and having a Transition Year (year out from school between exam courses) from home. My main interest is in physics but I am happy to read most science information that comes my way.

AUTHORS

CAROLIN R. LÖSCHER

I am an Assistant Professor of Marine Biogeochemistry at the University of Southern Denmark, and I am most interested in how climate change influences life in the Ocean and how it will change in the future. I am particularly fascinated by investigating the effects of warming, Ocean acidification, and the loss of oxygen on microbes in the Ocean, because those microbes are very important for all life in the Ocean. *cloescher@biology.sdu.dk

ANDREAS CANFIELD

I am a student at the University of Southern Denmark, currently studying Psychology. I do not have a lot of finished thoughts about my field of study (Psychology) but I am curious to learn and to explore more. I am 23 years old, and still feel as if I have barely scratched the surface of what there is to discover. I am the son of Donald Canfield, an important Earth Scientist, and Marianne Olsen, who has a Degree in Biology. As such, I find myself at an intersection between the "hard" sciences and the "softer" sciences.