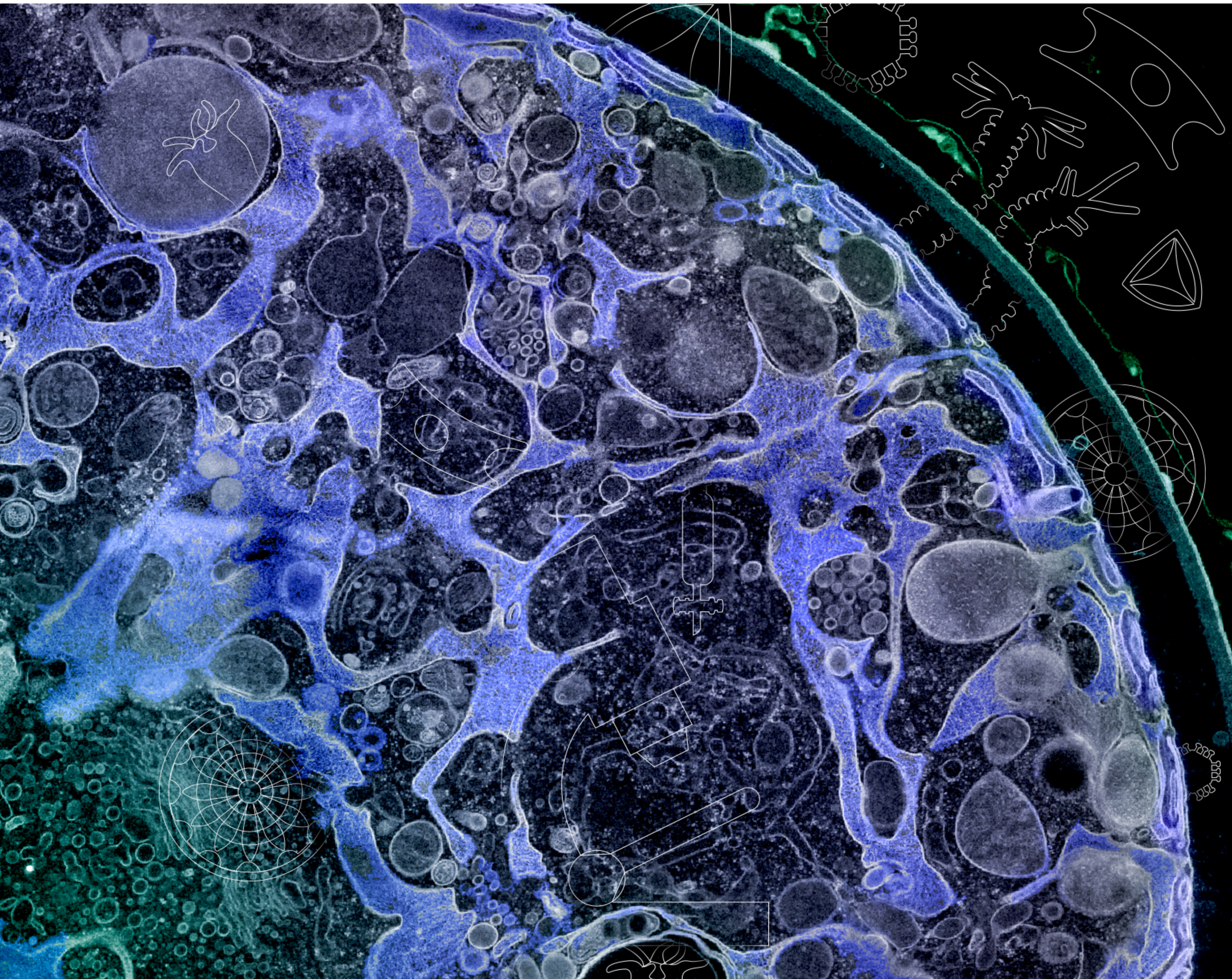
EMBL

BIOcean5D

Diving into the world of plankton using the Curiosity Microscope

Learning materials



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Formerly known as European Learning Laboratory for the Life Sciences, ELLS, we are building on EMBL's long history of science education and public engagement, and support EMBL's commitment of sharing and discussing our research with young learners, teachers and diverse publics.

Our science education activities share the scientific discoveries of EMBL through inspiring teaching and learning experiences with school science teachers and young people of all backgrounds aged between 10 and 19 years.

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Table of Contents

Information for teachers

Introduction

The focus of this learning material is on plankton as a diverse group of free-living organisms in the world's oceans. Plankton generally refers to microscopic organisms that occur in both fresh and saltwater. They play a crucial role in marine ecosystems by linking different trophic levels of food and also contribute to the cycling of elements such as carbon and nitrogen. Although plankton and marine ecosystems occupy a large part of the Earth and are essential for a healthy planet, curricula often emphasize topics related to land mass and neglect marine biodiversity and similar topics. The main purpose of this material is to contribute to knowledge about our oceans and to stimulate conversation and discussion in the classroom.

Overview

The material is aimed at pupils aged 15-19. It consists of a worksheet for the pupils, an answer table and information sheets with information on plankton, the Curiosity microscope and ocean currents. In the first section of the worksheet, students use the Curiosity microscope and worksheet to investigate planktonic life in the water. In the second section of the worksheet, which does not require the use of microscopes, students focus on the role of plankton in marine ecosystems. All tasks take approximately two lessons to complete. Please note that the suggested duration of the tasks is only a rough estimate and strongly depends on factors such as the students' prior knowledge and the way teachers implement the respective activities in their classes.

To help students familiarise themselves with the biology of plankton and its role in the marine ecosystem, information sheets on plankton, ocean currents and the Curiosity microscope are provided.

Learning objectives

The pupils should:

- Identify different types of plankton.
- Operate a light microscope.
- Describe visible details of plankton.
- Explore the importance of plankton to marine ecosystems and humans.
- Interpret visual information.

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Curriculum links

International Baccalaureate	A2.2.3, A2.2.10, C4.2.2, C4.2.3, C4.2.6, C4.2.8, C4.2.10
GCSE	4.1.1.1, 4.1.1.5, 4.4.1.1, 4.7.1.3, 4.7.4.1, 4.7.5.3
AP - Fall 2020	2.1, 3.5, 8.2
Baden Württemberg	3.2.3, 3.3.4, 3.4.4 oder 3.5.4

Prerequisites

It is recommended that students are familiar with the following concepts before working with the material: Cells, producer, consumer, food chain and photosynthesis.

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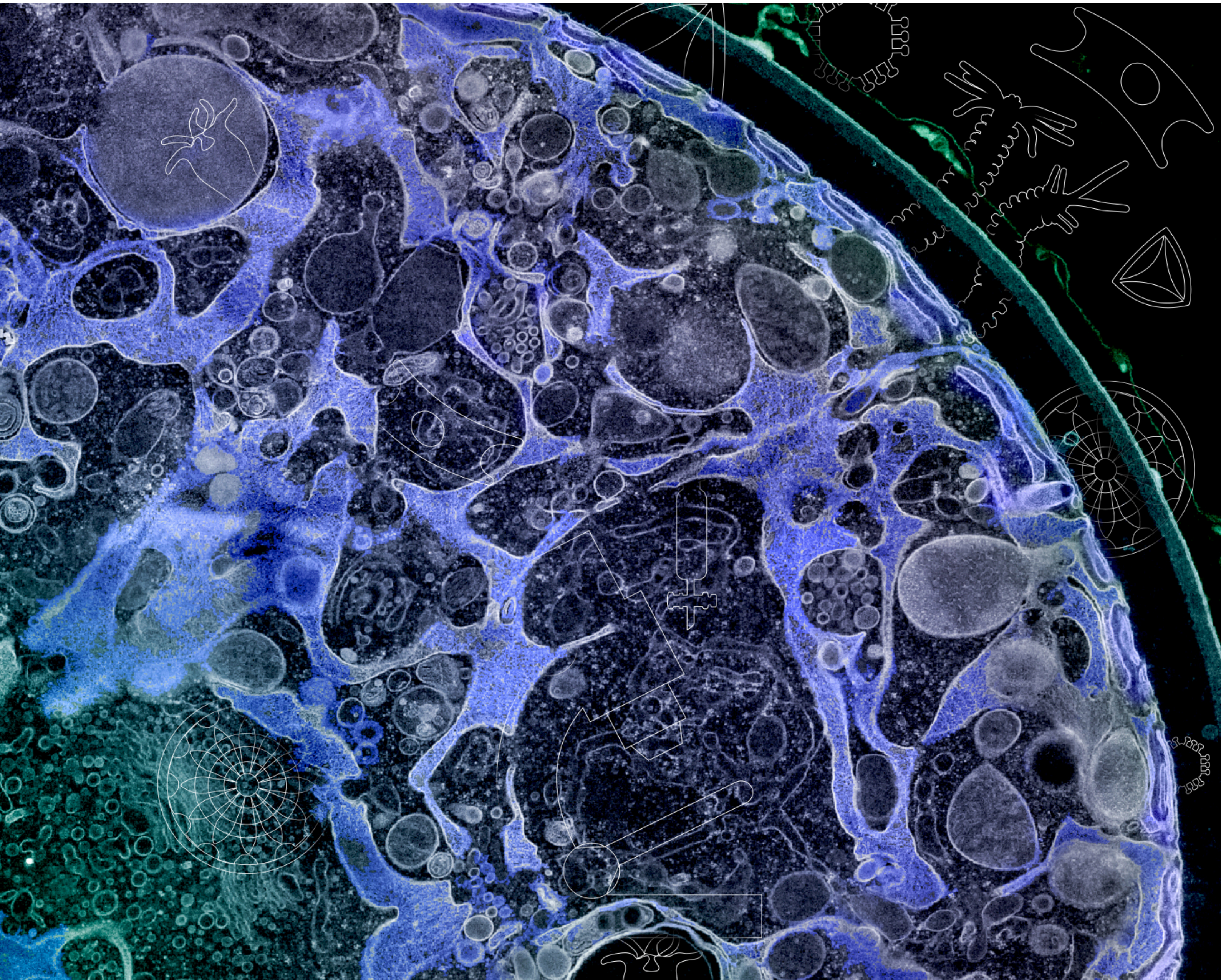
Dive into the world of plankton with the Curiosity Microscope

Worksheet 1 - Observations with the Curiosity Microscope



Sample preparation and observations with the Curiosity microscope

The Curiosity microscope is an optical microscope that uses a small LED as a light source. In contrast to conventional light microscopes, the Curiosity microscope does not have an eyepiece. Instead, there is a camera at the bottom of the microscope, which is used to observe samples. The main part of the microscope is made of wood and environmentally friendly dyes.

Sample preparation

At most 24 hours before your observations:

1. Scoop plankton from the body of water by fully submerging the sieve in the water and following an “infinite” sign eight times.

Note: As more plankton accumulates in the sieve, water will flow through it more slowly. Retrieve the accumulated plankton by pipetting the remaining water from the sieve into a falcon tube. Collect around 20 mL of samples into a container.

2. Now transfer your sample into a Petri dish from the kit using a plastic pipette. You can choose one of the following two alternatives:

    a. Fill the entire petri dish with the sample until you have a convex meniscus on top. Flip the lid of the petri dish over and slowly cover the petri dish.

Note: During this process, some samples will be lost. Keep a tissue around the petri dish to clean the workspace.

    b. Alternatively, cover the bottom of the Petri dish with a thin layer of the water sample you have prepared.

3. Place the petri dish on the sample holder and in between the light source and the camera. Your sample is ready for observation.

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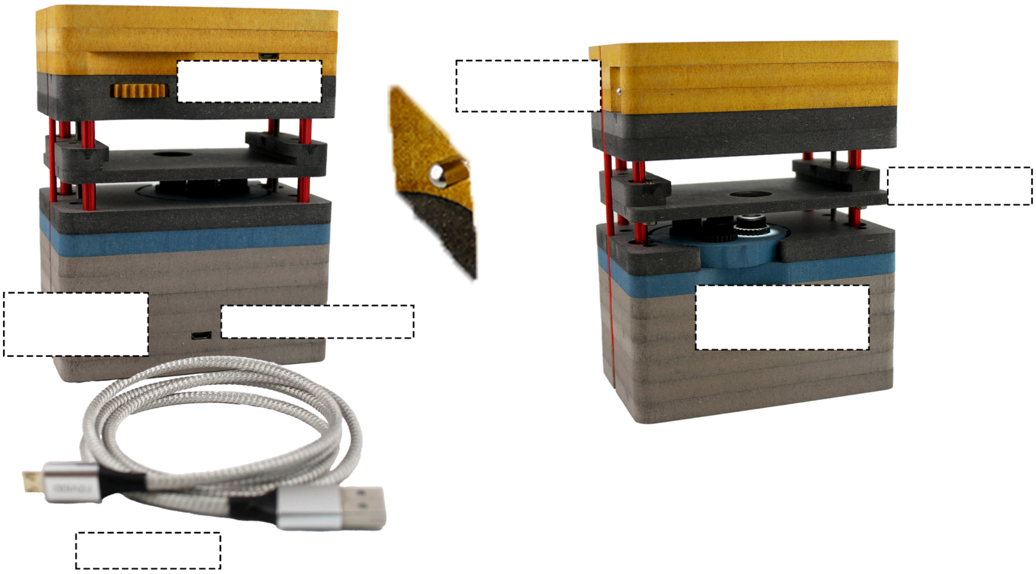
Visualisation under the microscope

Label the parts of the microscope in the following pictures **(5 minutes)**.



Curiosity microscope and its parts. Image by: Noan Le Bescot, Plankton Planet

To use the microscope,

1. Connect the microscope camera to a screen such as your phone, tablet or smartboard using the USB-C cable supplied.
2. Use the camera app on your display device to transfer the camera images to the screen.
3. Switch on the LED light source* with the light switch.
4. *To avoid eye damage, DO NOT look directly at the light source.
5. Place the sample on the sample holder plate.
6. Start your observation with the lowest magnification.
7. Use the objective disc to increase/decrease the magnification.
8. Note your observations in the activity sheet.

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Using the Curiosity microscopes and this educational material, we will explore and identify some of the planktonic organisms we can find in the water. After placing your sample on the sample holder, view it at different magnifications, starting at the lowest magnification and working up to the highest magnification **(30 minutes)**. Use the available space below to insert an image of a plankton species taken with the microscope. Use the magnification at which you can best see the plankton and make a note of the magnification used.

*You can also draw your observations instead of taking pictures.

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1. **Outline** the general characteristics of the plankton you observe by answering the questions below.

    a. Look at your picture and find out whether your observed plankton lives alone or in colonies.

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    b. State the colour of the plankton you observe.

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    c. **Describe** the shape of the plankton.

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2. The word plankton means "drifter" and refers to the fact that they cannot swim against the currents. However, some plankton organisms have body parts that enable them to move in calm water. While some plankton organisms swim around using cilia and/or flagella, others use body parts such as legs to swim. Below are examples of planktonic organisms and the structures they use for swimming (4).

Cilia: numerous whip-shaped extensions

Jointed legs in organisms such as krill and copepods

Figure 1: Plankton can use different structures such as flagella, flagella or jointed legs to swim in water. Ciliated plankton from Phyto'pedia (CC BY-NC-ND 3.0), UBC and the Antarctic krill from Wikipedia (CC BY-SA 3.0)

   a. Identify a moving plankton for observation and capture it in a picture with the microscope. Paste the picture below or draw the plankton in the box.

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b. Describe its movement and note the structure it uses to move OR include a picture of the structure that you took with the microscope (if visible).

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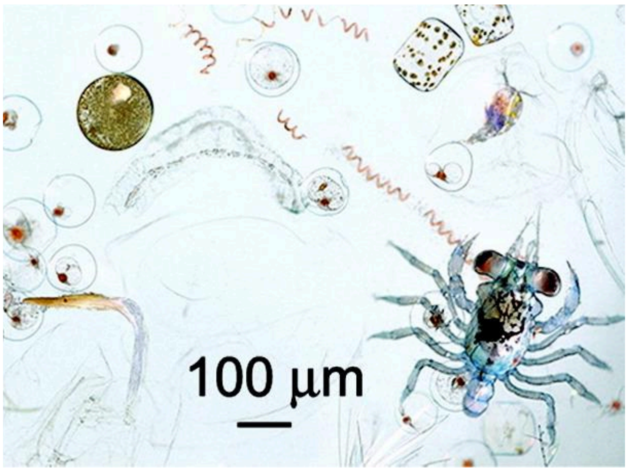
3. While some plankton in the water have an animal-like character (zooplankton), others are more plant-like (phytoplankton). Phytoplankton are the most common life forms in the ocean. Thanks to the green pigment chlorophyll, they utilise sunlight to produce food and grow. Chlorophyll is also found in plants and is the molecule that gives both plants and phytoplankton their green colour. Zooplankton, on the other hand, cannot capture sunlight and have no chlorophyll, so they are not normally green in colour. Zooplankton hunt other organisms like phytoplankton to feed, and therefore may also have small mouths, arms, claws, and in the case of jellyfish, even tentacles with which to capture prey. Below is a group of plankton. Label one that you think is a phytoplankton. Label another one that you think is a zooplankton. Explain your reasoning below.



Marine microplankton photographed aboard the NOAA ship Oscar Elton Sette off Kona, 20 September 2006 by Jay Nadeau and others. CC BY-SA 4.0

4. While looking at the water sample with your microscope, take a picture of a phytoplankton AND a zooplankton and paste them below. Answer the questions.

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a. **Indicate** whether they live alone (solitary) or in colonies.

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b. **Describe** the general appearance of the plankton with reference to the characteristics below.

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i. Colour, shape, visible structures (grooves, symmetrical individual cells)
ii. Presence of claws, spines, eyes, legs and/or mouth
iii. Presence of cilium or flagellum/cilia or flagella

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Worksheet 2 - The role of plankton in ecosystems

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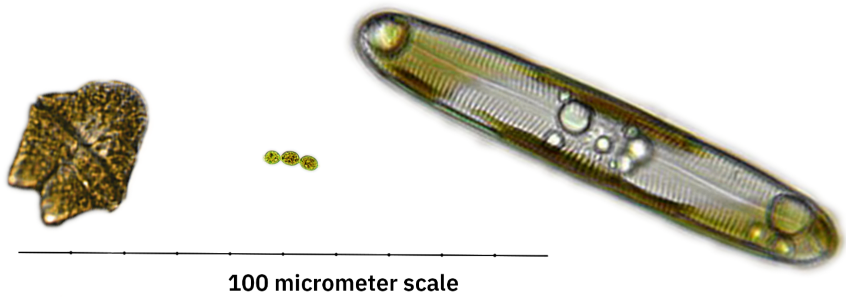
5. Below is a scale comparison of individuals from three different groups of phytoplankton. The scale bar is 100 microns long and divided into 10 micron sections. Refer to the plankton fact sheet and **(5 Minutes)**:

    a. **Identify** the group to which each phytoplankton belongs and label them.

    b. **Estimate** the sizes of the individual cells in each group using the scale bar.

    c. Look at the three types of phytoplankton and **label** the visible parts of their cells that contain chlorophyll. **Explain** your reasoning.



6. Similar to ecosystems on land, ocean ecosystems rely on primary producers such as phytoplankton to sustain other organisms. In the diagram below, identify and label the primary producers and consumers that depend on them **(5 Minutes)**.

7. With reference to Figure 5 of the "Plankton" information sheet, answer the following questions **(10 Minuten)**:

    a. How would the number of sperm whales change if the amount of phytoplankton in the region decreased?

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    b. How would the number of phytoplankton and sperm whales change if the krill population decreased?

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8. Below is a satellite image showing the chlorophyll intensity in parts of the Atlantic Ocean due to plankton growth. Next to the image is a scale that assigns the corresponding chlorophyll intensity to the colours. Answer the following questions **(10 Minutes)**.
    a. **Identify** the colour that shows the highest and lowest chlorophyll concentration in the ocean on the colour scale and label it accordingly.
    b. On the map below, **identify** a region with high and low chlorophyll concentration and label it "high chlorophyll concentration" or "low chlorophyll concentration".
    c. Look at the chlorophyll intensity map and predict, with a reason, in which area of the oceans (labelled B or M on the map) there is more plankton in the water.

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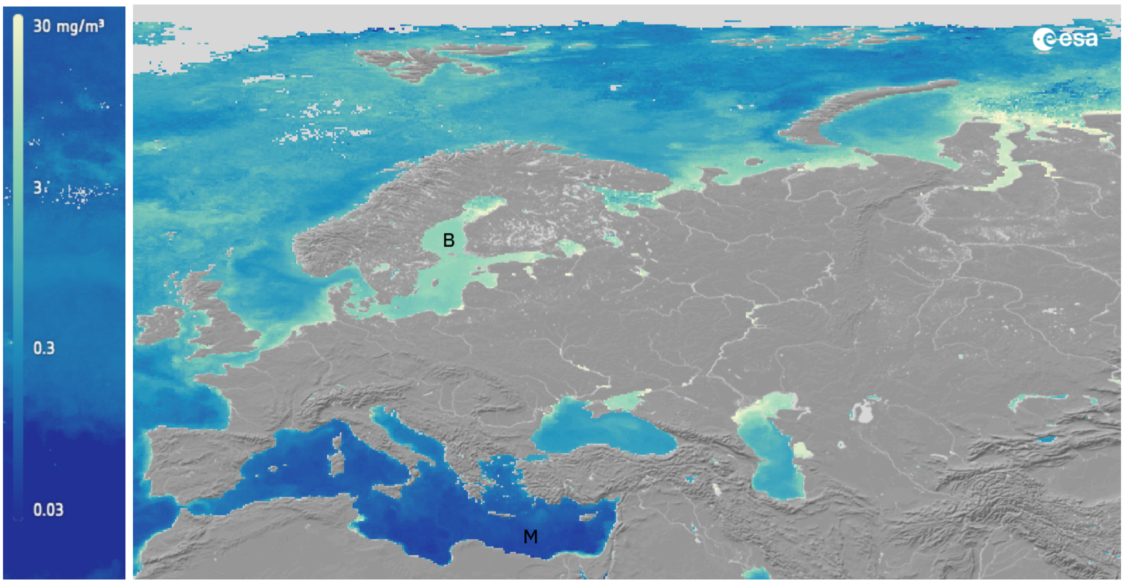

ESA climate from space - concentration of chlorophyll-a

    d. **Explain** which of the two plankton groups (zoo- or phyto) is responsible for this colour change detected by satellites.

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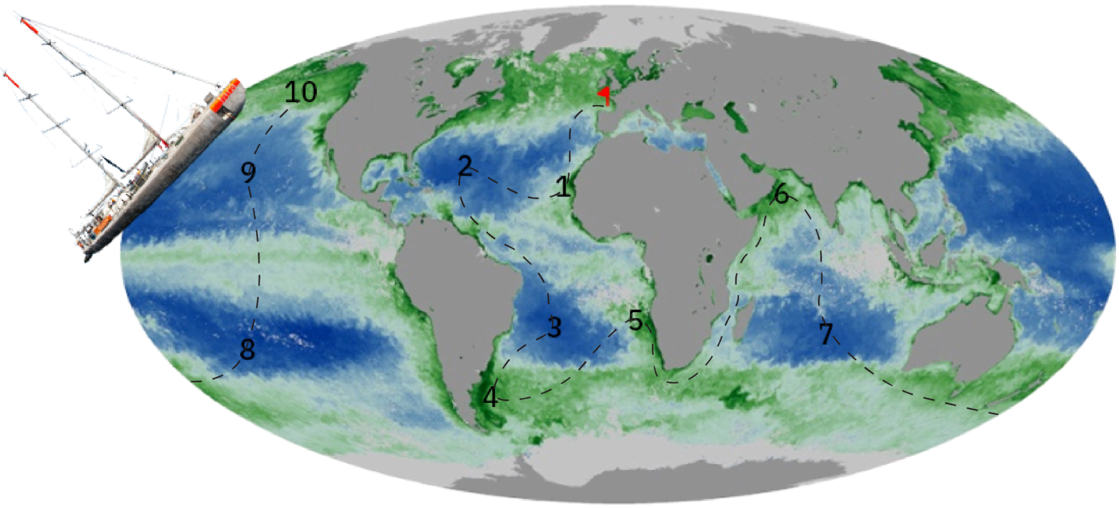
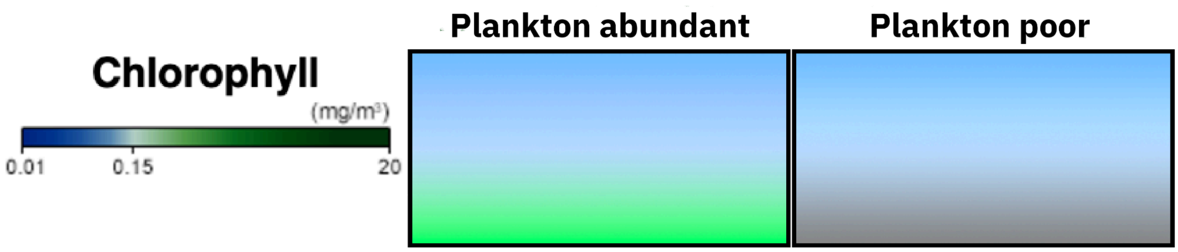
9. Phytoplankton shows an uneven distribution in the world's oceans. Therefore, certain areas of the oceans are rich in phytoplankton, while other areas lack it. Answer the following questions using the corresponding maps **(10 Minutes)**.

   a. The following world map of chlorophyll concentrations shows where phytoplankton is most abundant in the ocean upper layer and the route of the Tara Ocean Foundation's research vessel Tara along which samples were taken (marked by numbers on the map). The route starts at the coast of France (red flag) and ends at location 10. Look at the ocean surface color at each location where samples were taken and **identify** the phytoplankton-rich and -poor parts of the ocean. **Write** them in the individual boxes you see in the diagram below.





The route of the Tara in the world's oceans is shown by dashed lines. Each number represents a sampling point where the scientists in the schooner take water samples from the sea surface to analyse the presence of plankton. Source of the world image: NASA Earth Observatory

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b. The growth of phytoplankton in the ocean depends on factors such as the availability of sunlight and nutrients. On the map below, the regions marked in blue indicate where nutrients rise from the deeper environment to the surface in a process called upwelling. Look at the map and **indicate** whether the phytoplankton-rich regions you listed earlier correspond to the regions of nutrient upwelling.

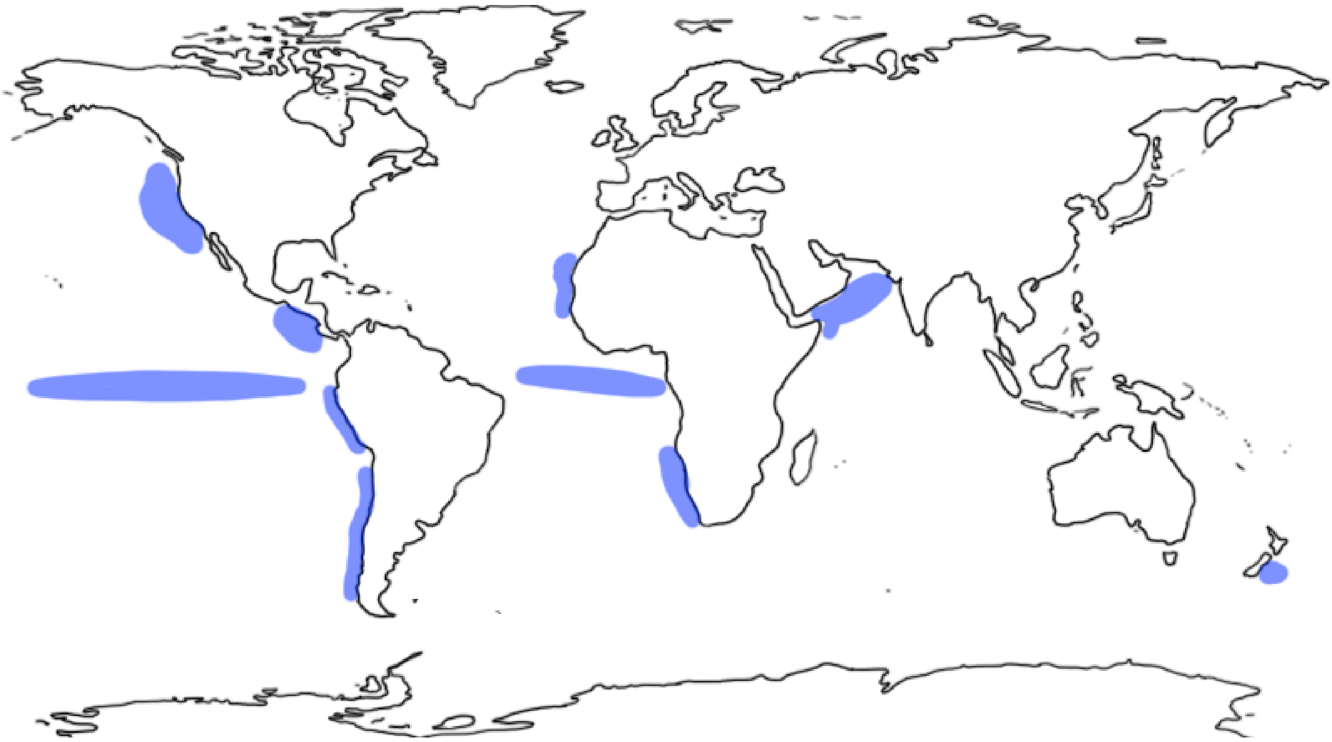

Figure 2: Important areas for nutrient upwelling in the world's oceans (blue).

i. **Briefly outline** how nutrients can contribute to the growth of phytoplankton.

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10. The following map shows where the largest populations of sardines and anchovies live in the ocean. Take a look at the map and answer the questions **(10 Minutes)**.

    a. Using the map, indicate whether the largest fish populations live in regions rich or poor in phytoplankton. Explain your reasoning **(5 Minutes)**.

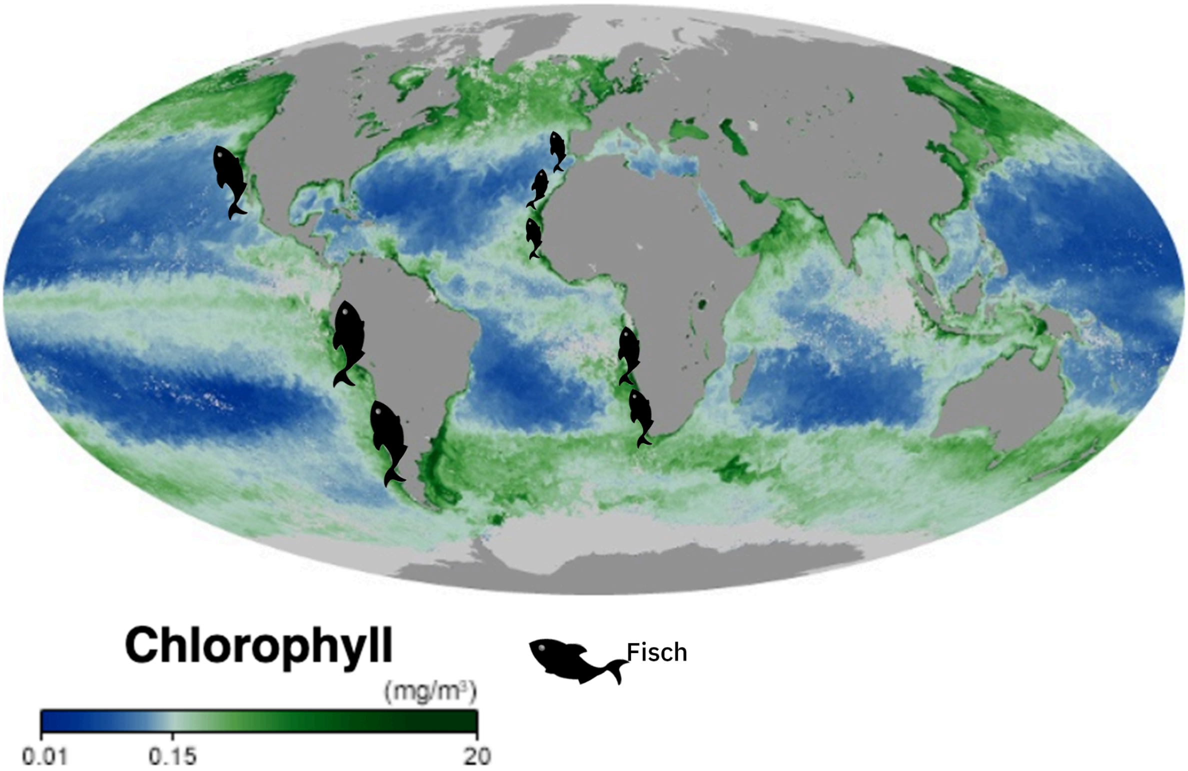

Figure 3: The main areas of upwelling contribute up to 20% of the world's total fish catch (Adapted from Miller S et al., 2022).

    b. **Briefly outline** the role of nutrients in the fish populations of upwelling systems **(5 Minutes)**.

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11. As phytoplankton photosynthesises and grows, it uses the CO_2 diffusing from the atmosphere into the ocean and converts it into organic carbon to produce mass, or in other words, to produce more phytoplankton. While most of this phytoplankton is eaten by marine organisms, the rest sinks to the bottom of the ocean, taking the captured CO_2 from the atmosphere with it. By absorbing CO_2 from the atmosphere with the help of phytoplankton and binding it in its depths, the ocean plays a crucial role in regulating our planet's climate. The extraction of sequestered carbon in the form of fossil fuels and its release into the atmosphere is a major cause of climate change (3).

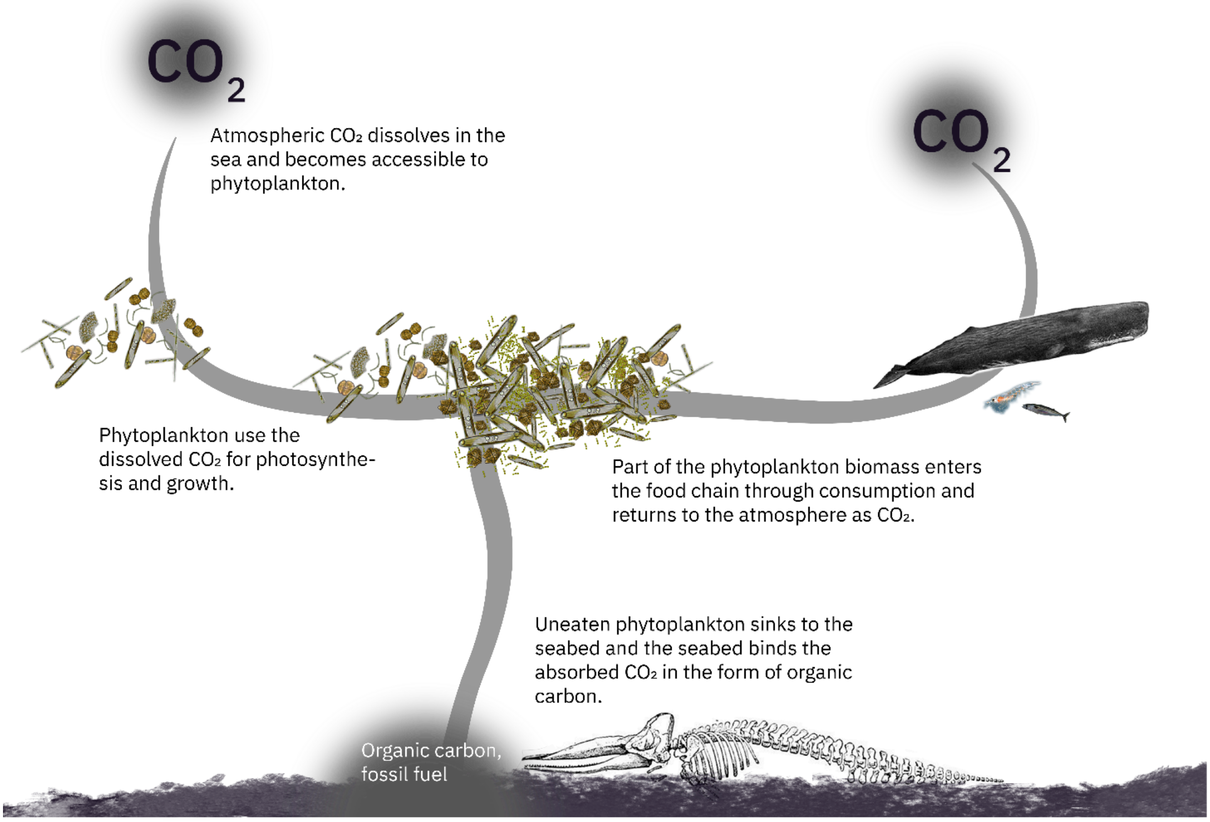

Figure 5: Carbon cycle in the ocean. *Atmospheric CO_2 is dissolved into the seawater and becomes available for phytoplankton to use in photosynthesis and growth. With photosynthesis, inorganic CO_2 from the atmosphere is fixed into phytoplankton in the form of organic molecules such as carbohydrates and proteins. Part of this growing plankton population is consumed by other marine organisms in the food web. Remaining phytoplankton sinks to the bottom of the ocean following their death and becomes part of the ocean sediment that locks the atmospheric CO_2 under the ocean for millenia (7).*

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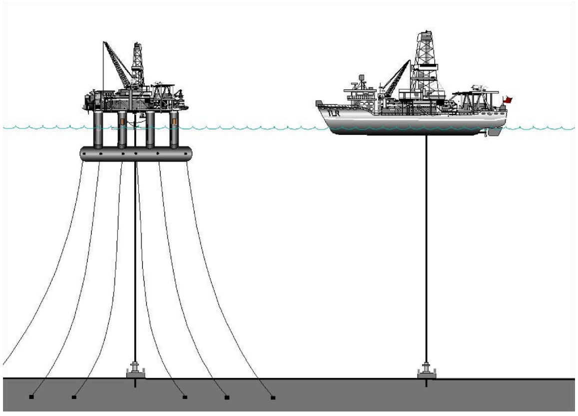
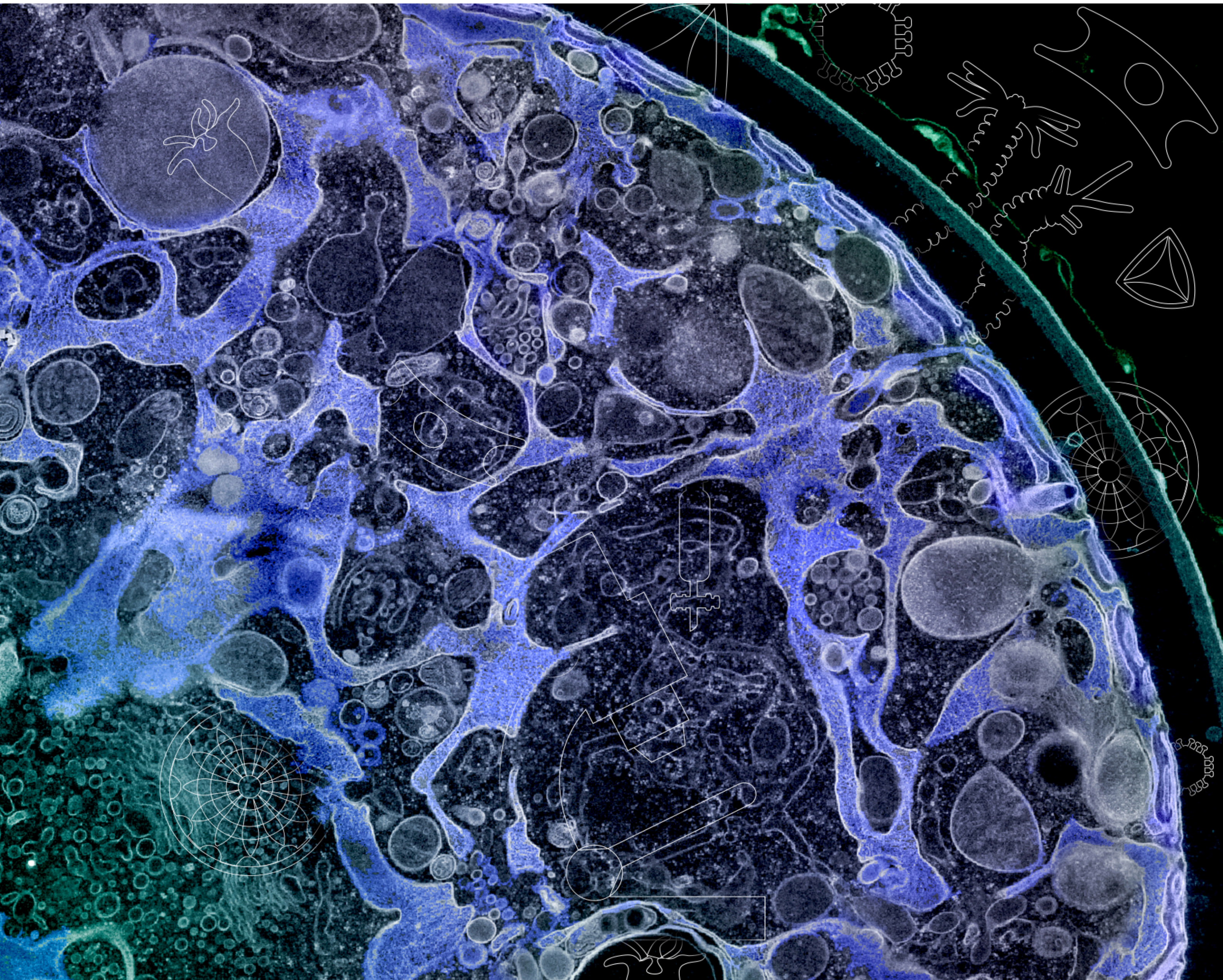
Taking into account the above information, **explain** how offshore drilling as a human activity intervenes in the different stages of the carbon cycle **(10 Minutes)**.

Human activity	Where it disrupts the carbon cycle
Offshore drilling: the process of drilling through the seabed to extract fossil fuels used in industry and transport. 	

Dive into the world of plankton with the Curiosity Microscope

Factsheets



Plankton factsheet

The term plankton refers to aquatic organisms that live in various bodies of water on earth, such as the ocean and freshwater sources like lakes and rivers. The word "plankton" in ancient Greek means "drifter" and describes the fact that these organisms cannot actively swim against water currents, but instead drift with them. Plankton can be as large as jellyfish or as small as cyanobacteria.

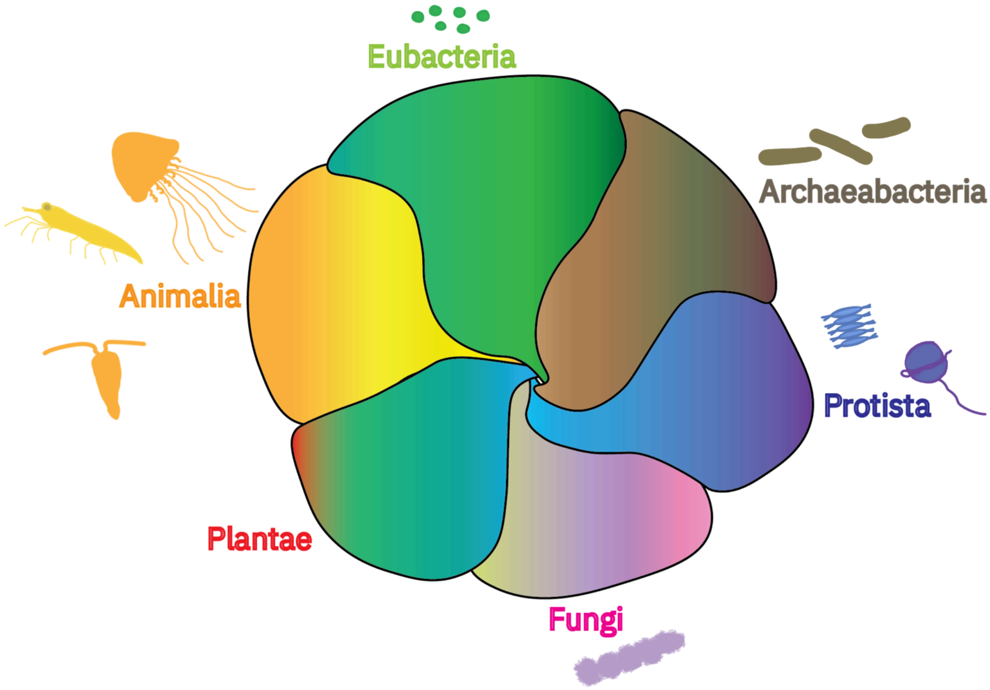


Figure 1: *Plankton refers to a diverse group of organisms. The term plankton does not refer to a scientific classification of organisms according to their evolutionary relationship, but rather to an extensive collection of organisms that have members in all five kingdoms of living organisms except Plantae (plants). They share the common characteristics of living in water and drifting with water currents.*

Depending on their ability to produce their own food through photosynthesis, plankton can be divided into two groups: Phytoplankton and Zooplankton. Phytoplankton can be eukaryotic or prokaryotic and look very different from one another. Although structurally very different, a common characteristic of phytoplankton is the ability to photosynthesise. Phytoplankton can utilise the energy from sunlight, CO_2 and H_2O to produce sugars to feed other organisms and themselves and are called primary producers. The green pigment chlorophyll, which gives them the ability to photosynthesise, also gives them a green colour. Although all members of the phytoplankton have the ability to photosynthesise, they have different cellular characteristics that distinguish them from each other. See Figure 2 below for a comparison between different types of phytoplankton.

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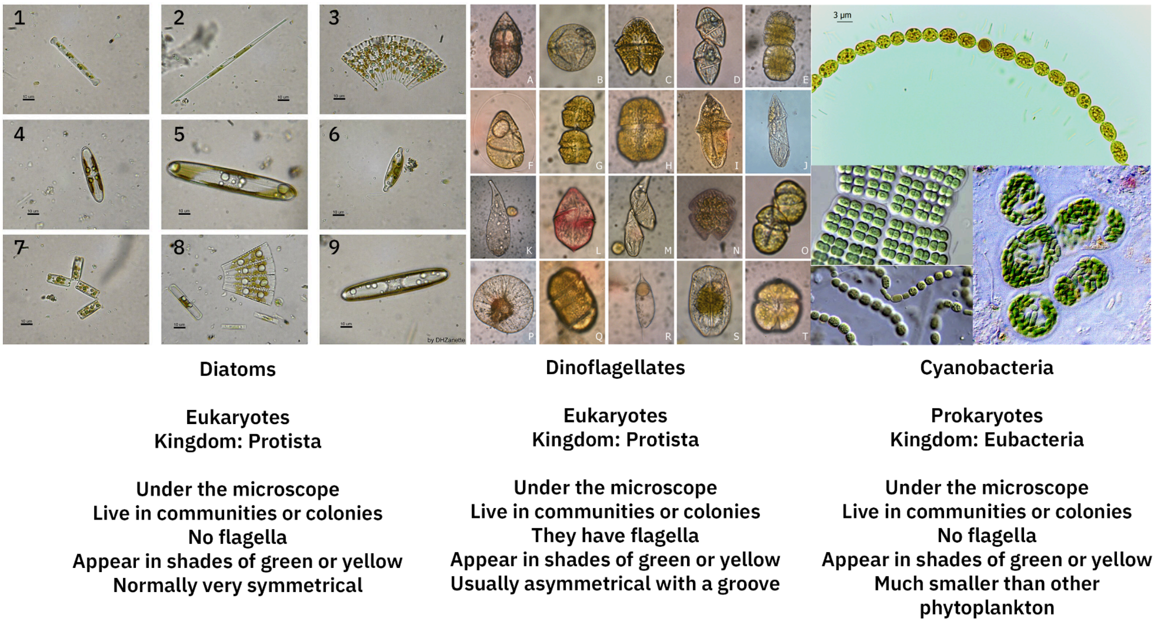

Figure 2: A myriad of phytoplankton. *Phytoplankton are a group of aquatic organisms that can photosynthesise. They can look very different under the microscope. The images of dinoflagellates are from Gárate-Lizárraga, Ismael, et al 2014. All other images are in the public domain.*

Under the microscope you can see that diatoms live alone (or solitary) (see 4, 5, 6 and 9) or form colonies in the form of chains (see 3, 7 and 8). To protect itself, the diatom cell builds a glass envelope of silicon dioxide. Diatoms are generally symmetrical. Dinoflagellates can live solitary (see A, C and T) or form colonies (see D, E and G). To move, they use their flagella, which can be difficult to see under the microscope. In contrast to diatoms, dinoflagellates do not have silica cell envelopes and are usually smaller. Cyanobacteria are prokaryotic organisms. They live in isolation or in colonies (see section Cyanobacteria). They have no flagella. Compared to diatoms and dinoflagellates, cyanobacteria are much smaller: they can be hundreds of times smaller than a diatom. Under the microscope, they usually look like spheres. In Figure 3, the three groups are shown again with some of their characteristic structural features.

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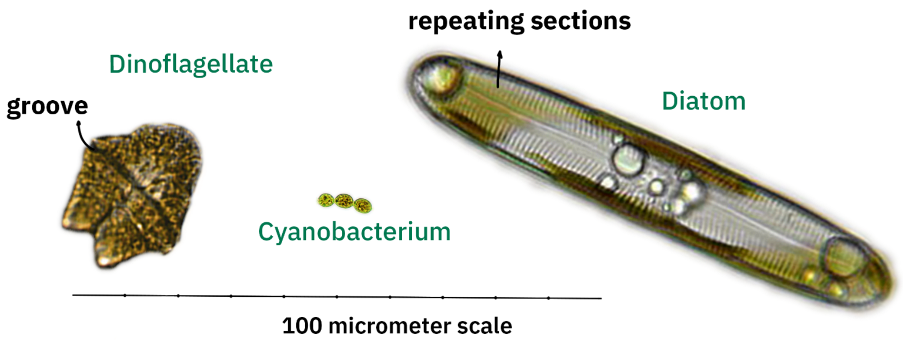

Figure 3: Size and morphological comparison of different types of phytoplankton. *Phytoplankton can be as small as cyanobacteria, which are 2-3 micrometres long, or as large as diatoms, which can be several hundred micrometres long. Diatoms have a silica cell wall with overlapping and repeating geometric shapes and sections. A visible groove running around the cell divides the dinoflagellates into two sections.*

Zooplankton (zoo- means animal-like) are organisms that are unable to utilise sunlight to produce their own food and are therefore dependent on consuming other organisms such as phytoplankton or other zooplankton. The term zooplankton includes both unicellular protists and multicellular organisms such as jellyfish. The group also includes the temporary planktonic larval stages of animals such as sea urchins, octopuses or fish.

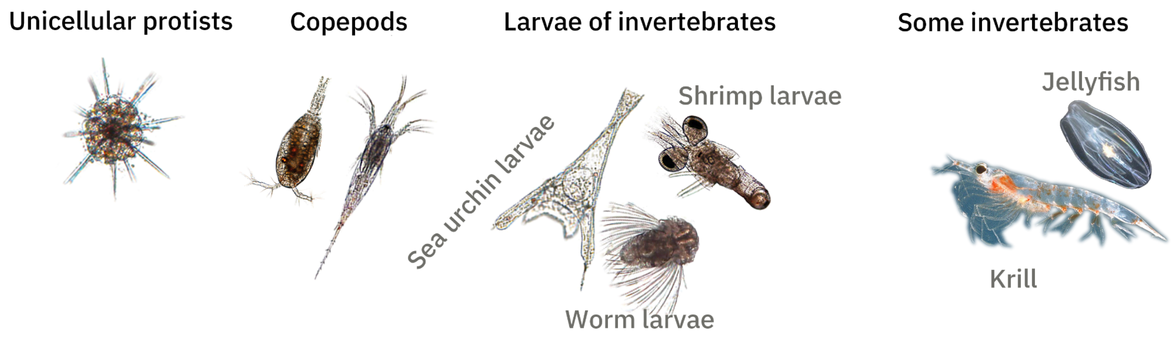

Figure 4: A plethora of zooplankton. *Zooplankton as a group includes different types of organisms such as unicellular protists, multicellular organisms such as copepods, larvae of some animals and adult animals such as jellyfish and krill. Images of protists, copepods and larvae: Noan Le Bescot, Plankton Planet. Jellyfish: Joseph F. Ryan, Wikipedia*

Zooplankton feed on phytoplankton living in the water. The members of this group can use their legs, claws or tentacles to catch prey. The zooplankton is in turn eaten by larger organisms. Jellyfish, for example, feed on floating zooplankton with their tentacles and are themselves eaten by sea turtles. Whales, on the other hand, feed on krill and fish, which feed on planktonic larvae. In this way, the light energy originally captured by phytoplankton is utilised by even the largest marine mammals such as whales for their survival. Both phytoplankton and zooplankton together form the basis of marine food webs.

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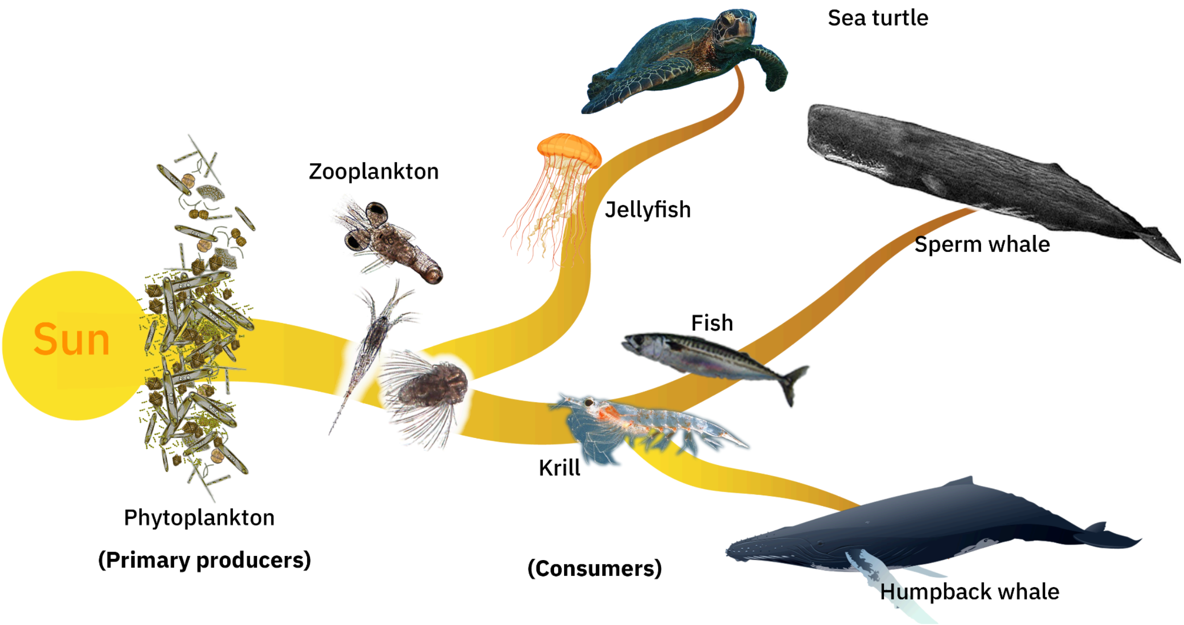

__Figure 5: Phytoplankton form the basis of aquatic food webs and support life in the ocean.__ By converting energy from sunlight into organic matter, phytoplankton become food for zooplankton, which in turn provide food for various other aquatic organisms. Humpback whale and jellyfish (Credits: biorender.com), green sea turtle (Credits: NOAA)

ℹ️Scan the QR code to access plankton images that you can use in your lessons. The images show samples collected along the TREC route. The images can be a great addition to your teaching material to teach students about the biodiversity in the ocean.

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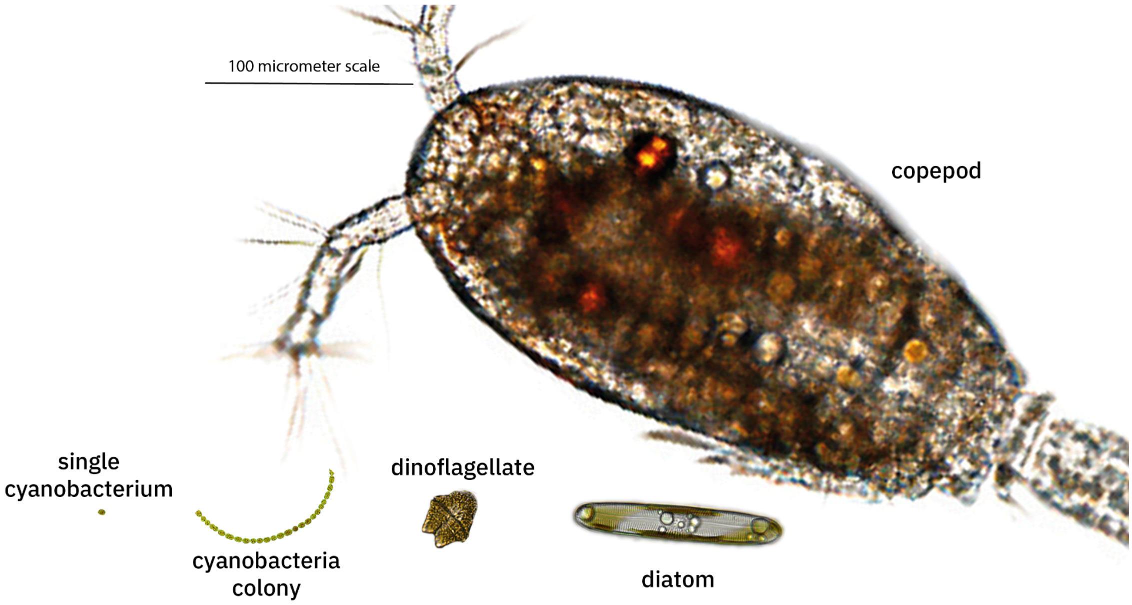
What can you see with the Curiosity microscope?



Here is a to-scale size comparison of different types of plankton that you might see with a Curiosity microscope. With the Curiosity microscope, you can view organisms as small as individual cyanobacteria, which are usually only between 1-3 micrometres in size. Organisms or structures smaller than this are usually difficult to see under this microscope.

Below is a table of organisms and structures that you can view with the Curiosity microscope.

Organismen und Viren	**Können sie mit dem Curiosity Mikroskop betrachtet werden?**
Marine viruses	Not visible under the light microscope
Single cyanobacterium	Visible, but difficult to recognise due to its small size
Cyanobacteria colony	Visible
Dinoflagellates	Visible
Diatoms	Visible
Flagella of dinoflagellates	Visible, but difficult to recognise. Look for a beating hair-like structure
Copepods	Easily visible

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Antennae, legs and claws of zooplankton	Visible

Ocean currents and the growth of plankton

An interesting feature of the oceans is the fact that the water is constantly in motion due to the rotation of the Earth on its own axis and global winds. When the strong winds blow over the surface of the oceans, the surface water moves and creates seasonal and permanent water currents such as upwelling and gyres.

Gyres are large masses of circulating water in the ocean basin.The world ocean has five large gyres whose collective movement transports nutrients across the planet, for example. Below is a world map showing the five major ocean gyres.

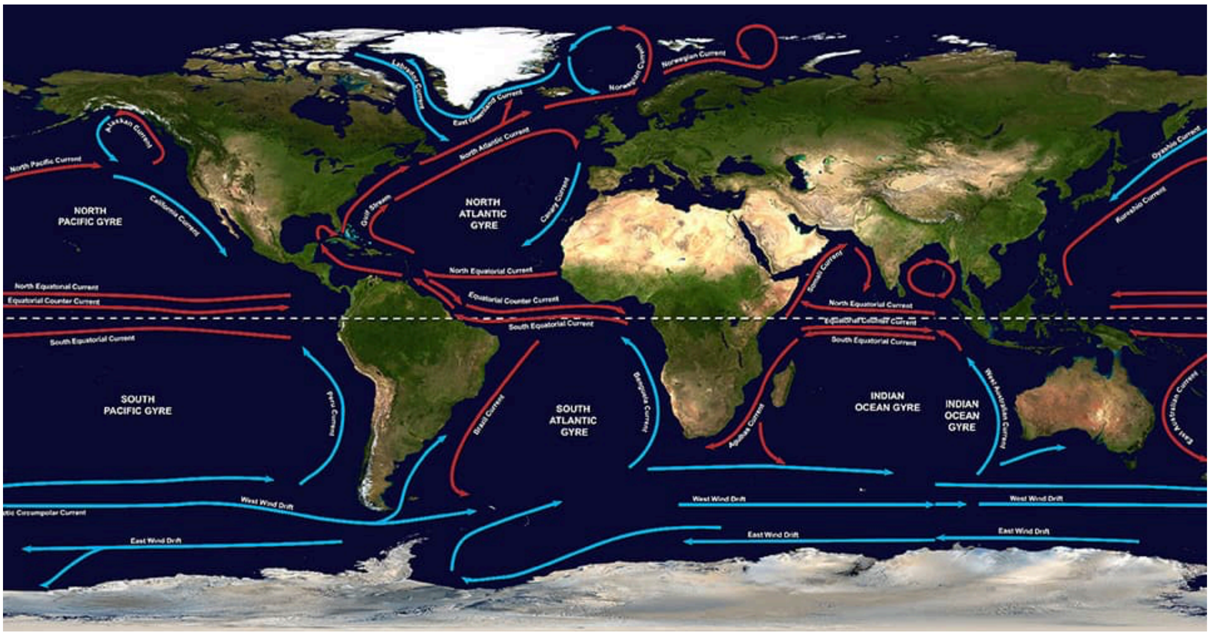

__Figure 1: The surface of the ocean is constantly in motion.__ The surface water of the oceans is in a constant state of flux, triggered by the blowing winds and the rotation of the Earth on its axis. Image credit: NOAA

The North Atlantic Gyre, for example, is made up of westerly and easterly currents that move water, heat and nutrients. These currents are also known as boundary currents. While the western currents (the Gulf Stream and the North Atlantic Current) transport warm water from the south to the north, the Canary Current in the east transports cold water masses from north to south. This eastern current of the North Atlantic Gyre is rich in nutrients compared to the nutrient-poor western current.

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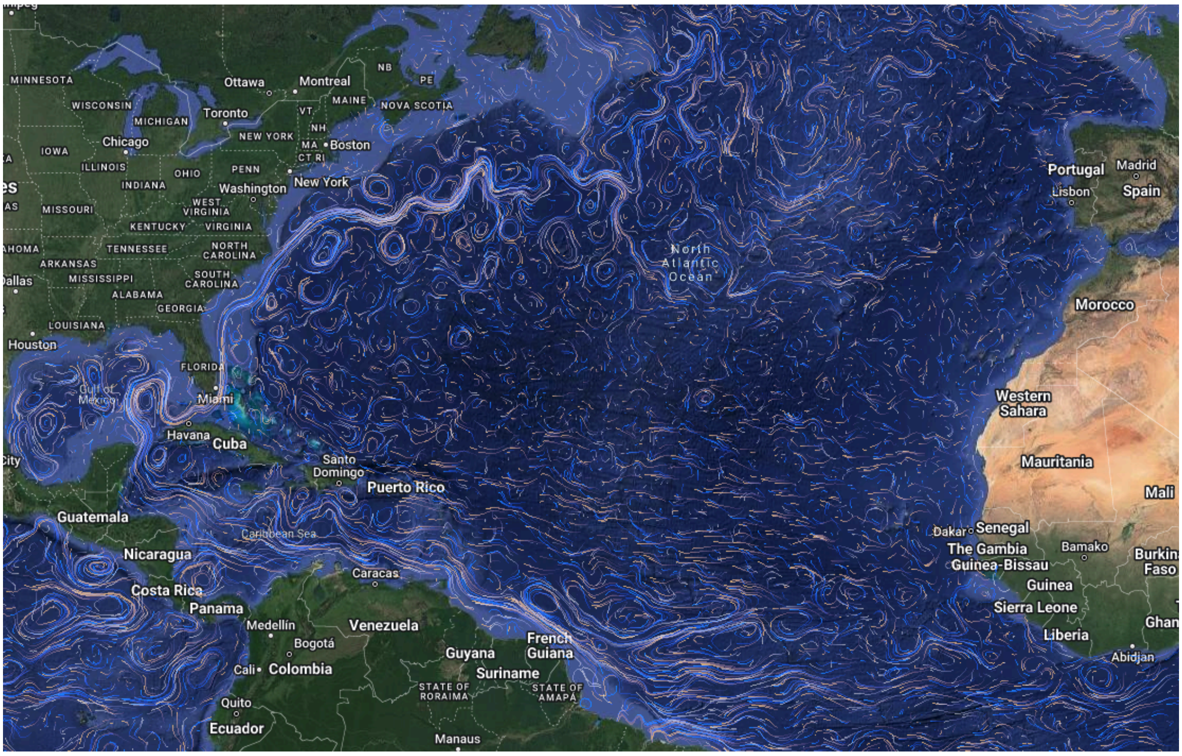

Figure 2: Surface currents in parts of the Atlantic Ocean visualised in ESA's Ocean Virtual Laboratory. *The long westerly current of the North Atlantic Gyre extends from south to north with numerous smaller currents circulating at the surface. Note the many surface currents of different sizes.*

Click on the link here or scan the QR code to see how the ocean's surface currents are actively moving.

When the wind blows across the ocean, it pushes the surface water away. To replace the space left by the water that has been blown away, water from deeper zones of the ocean moves vertically upwards and fills the available space. This process is called upwelling. During upwelling, cold and nutrient-rich water moves from the bottom upwards and transports nutrients from the deep sea to the surface (1).

Once these nutrients are available in the sunlit zone where phytoplankton live, phytoplankton can utilise these nutrients (various nitrogen- and phosphorus-rich compounds) to form other

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organic compounds such as nucleic acids and amino acids, which are crucial building blocks for the formation of new cells. But to do this, they must first photosynthesise to produce glucose, from which other organic compounds can then be synthesised.

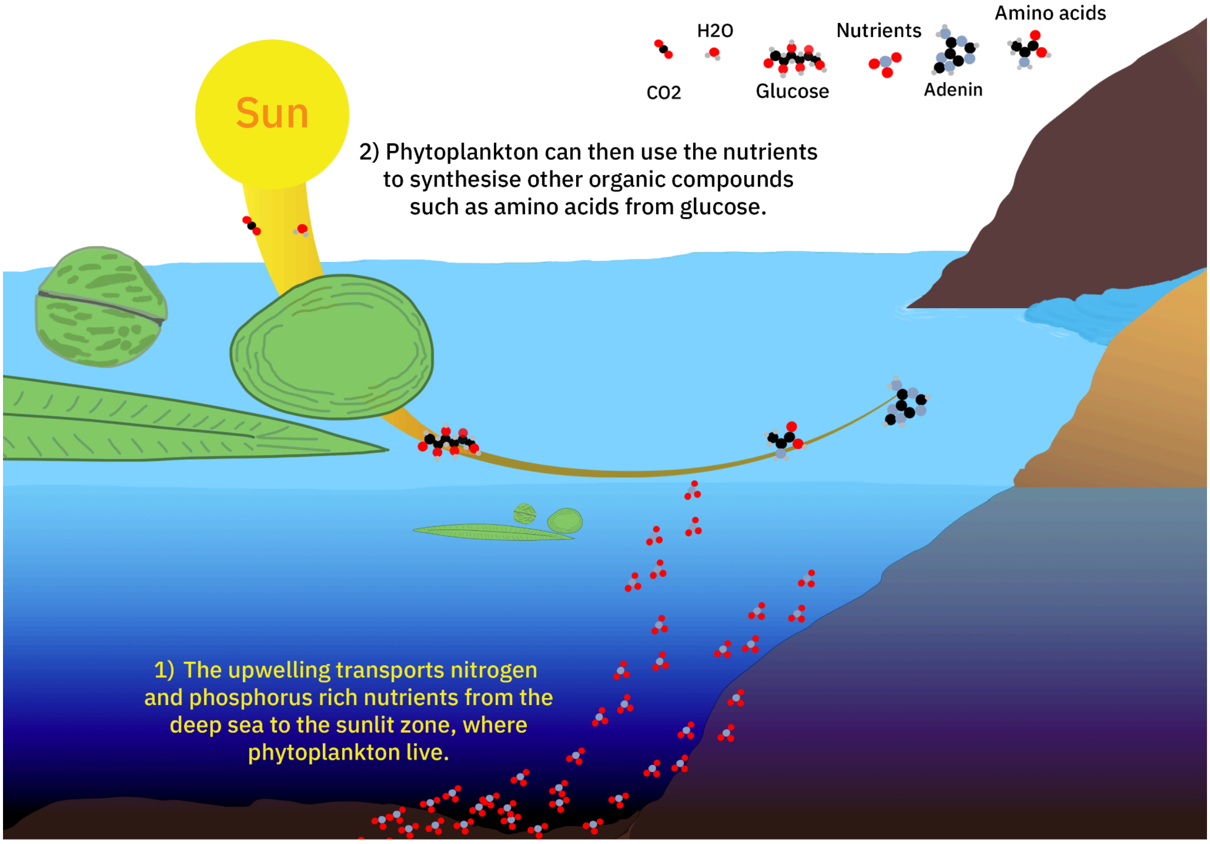

Figure 3: Upwelling transports nutrients from the deep sea to the sunlit surface, where the phytoplankton are found. *Phytoplankton are photoautotrophic and can only exist in the sunlit zone of the ocean where the availability of nutrients is limited. Nutrients are compounds that contain critical elements such as nitrogen (N) and phosphorus (P) for the growth of phytoplankton.*

When phytoplankton in the ocean use sunlight and nutrients to grow, their numbers increase. Sometimes their numbers can become so large that they colour large bodies of water green, which can even be seen from space. This strong growth is known as an (algal) bloom.

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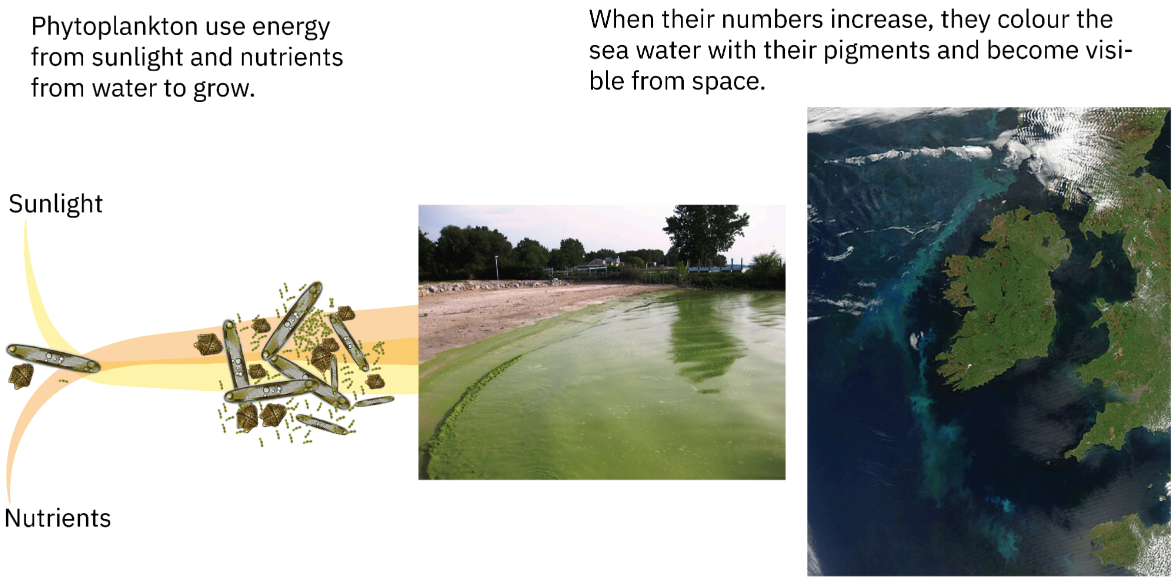

Figure 4: When sufficient light and nutrients are available, phytoplankton blooms. *Phytoplankton growth is limited by access to nutrients and sunlight. The presence of both factors in excess can trigger the growth of phytoplankton populations visible from space. The image on the far right shows a satellite image of blooming phytoplankton near the Republic of Ireland (2).*

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ℹ️To track the growth of phytoplankton in the world's oceans throughout the year, visit the Climate from Space website of the European Space Agency (ESA) at https://cfs.climate.esa.int/index.html#/ and follow the steps below:

- Click on 2D at the bottom right of the web page.
- Select "Ocean Colour" from the "Data Layers" at the top right.
- Use the slider at the bottom to see how the growth of phytoplankton and the colour of the ocean vary over the years and seasons within a year.

Why do we want to track the growth of phytoplankton in the world's oceans? By tracking when and where phytoplankton bloom, we can understand how climate change affects the biology of these organisms and how other organisms that rely on phytoplankton may be affected by these changes in the long term. In addition, phytoplankton is the producer in aquatic food webs and provides food for other organisms. However, certain types of phytoplankton can also be toxic to larger organisms such as marine mammals and humans. Knowing where these organisms bloom can therefore be helpful in preventing humans from being poisoned.

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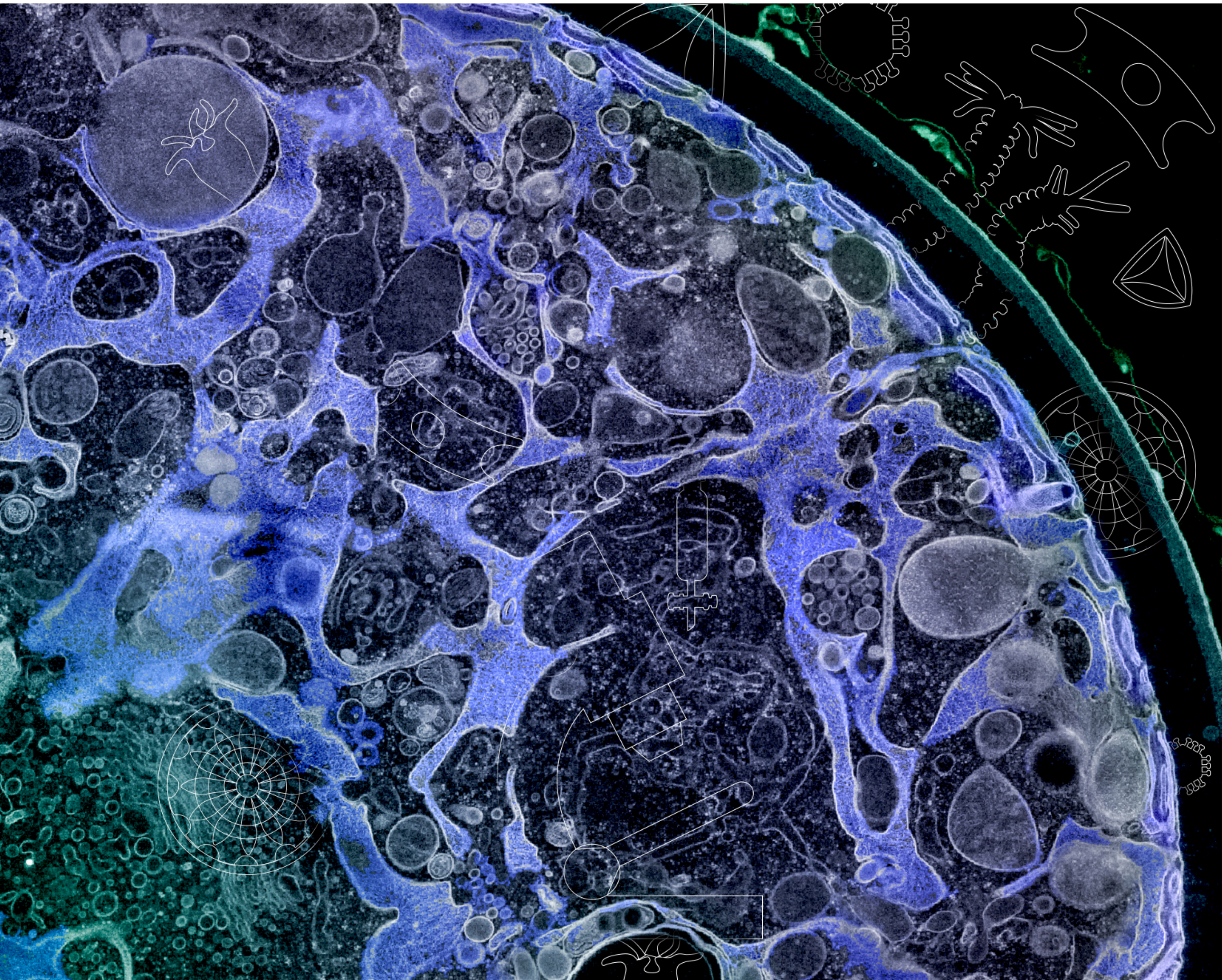
EMBL BIOcean5D

Dive into the world of plankton with the Curiosity Microscope

Teachers guide

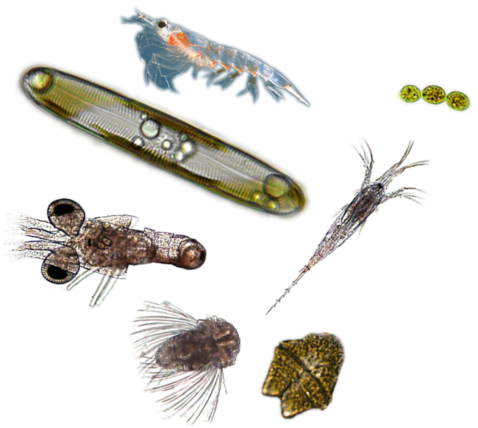


Example lesson plan

Lesson 1 - Before the lesson

Students review the plankton information sheet and answer the following questions.

1. **Define** the term 'plankton'.
2. **Give** two examples of planktonic organisms from the information sheet.
3. With reference to Figure 2 in the plankton factsheet, **state** the phytoplankton group(s) that store their DNA in the cell nucleus.
4. **Categorise** the plankton samples below into phytoplankton and zooplankton.



5. Below you can see a larva of a marine worm. Refer to the food web and indicate which organism the larva depends on to survive and which organism in turn depends on the larva.

Lesson 1 - In class (45 minutes)

Begin the lesson by asking some of the above questions to check that the concepts outlined on the plankton information sheet have been understood and repeat as necessary (10 minutes).

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Give a brief introduction to the microscope and its components (5 minutes).

Hand out the worksheet "Observations of plankton under the microscope" and the information sheet "What can you see with a Curiosity microscope" to the pupils and complete the worksheet by starting with the observations* with the microscope (30 minutes). Depending on class size, you can also form groups of two or three students and assign them to a station.

*Depending on the time available, the teacher can either have the students collect their own samples from a nearby body of water or bring the water samples to class so that the students can prepare them for microscopy.

Note: Curiosity microscopes are only directly compatible with displays that have a Type-C connector.

Lesson 2 - Before the lesson

The pupils read the information sheet on ocean currents and the flow of nutrients and answer the following questions.

1. Referring to Figure 1 of ocean currents, **state** the name of the ocean gyre closest to where you live.
2. Draw a diagram of the North Atlantic Gyre with its main currents.
3. Sketch the process of upwelling.
4. Below is a diagram showing how solar energy is utilized by phytoplankton. Use the diagram below with your students and have them answer the questions.
    a. **Label** the names of the molecules on the diagram.
    b. **Circle** the part of the diagram that shows the process of photosynthesis.
    c. **Circle** the part of the diagram that shows the synthesis of nucleic acids and amino acids from glucose.
    d. **Add** the missing chemical required for the synthesis of nucleic acids to the diagram.

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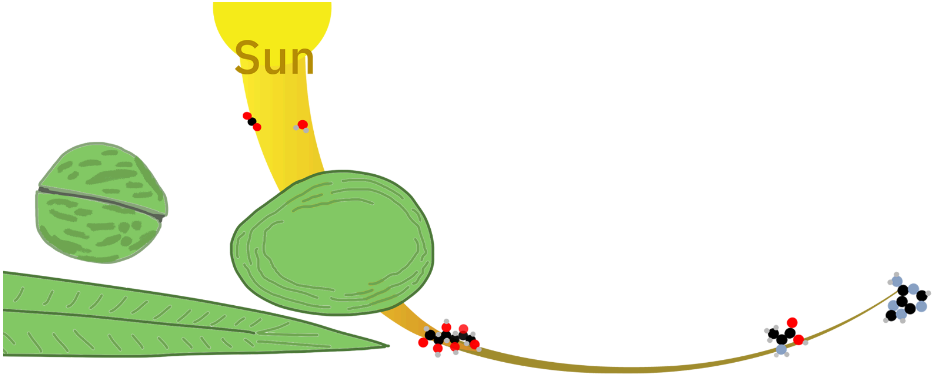

5. **Explain** what satellites detect in the ocean that can be used to assess the growth of phytoplankton.

Lesson 2 - In the classroom

Following their observations of plankton under the microscope, students will deepen their understanding of their biological importance in the context of food webs. Start the lesson by asking some of the questions above to check that the concepts introduced for ocean currents and plankton growth have been understood and repeat them if necessary (10 minutes).

Hand out the 'The role of plankton in ecosystems' section of the worksheet and complete it with the students (35 minutes).

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Further links

Below you will find a collection of materials that you can use to explore further topics in the field of ecology and biodiversity.

Source	Brief description
https://www.embl.org/ells/teachingbase/nexus-island/	The teaching resource "Nexus Island" focuses on the interaction between organisms, non-living environmental factors and humans as well as their interdependencies and adaptation strategies.
https://seos-project.eu/oceancurrents/oceancurrents-c04-p03.html	This website brings marine science closer by focussing on the characteristics of the ocean and its role in sustaining life.
https://naturalhistory.si.edu/sites/default/files/media/file/greatplanktonsinkoff.pdf	Explore the world of plankton organisms and create your own.
https://oceanservice.noaa.gov/facts/plankton.html	This short read introduces you to the world of plankton organisms and explains why they are important.
https://planktonid.geomar.de/en?page=root&extra_args=%7B%7D	A crucial aspect in the research of planktonic organisms is their correct identification. Contribute to planktonic research by playing the linked game.
https://divediscover.whoi.edu/hydrothermal-vents/vent-life-2/	Explore life at hydrothermal vents and discover how communities form deep in the ocean without sunlight.
https://noc.ac.uk/education/educational-resources/online-learning	The National Oceanography Centre offers a variety of resources to learn more about the ocean.

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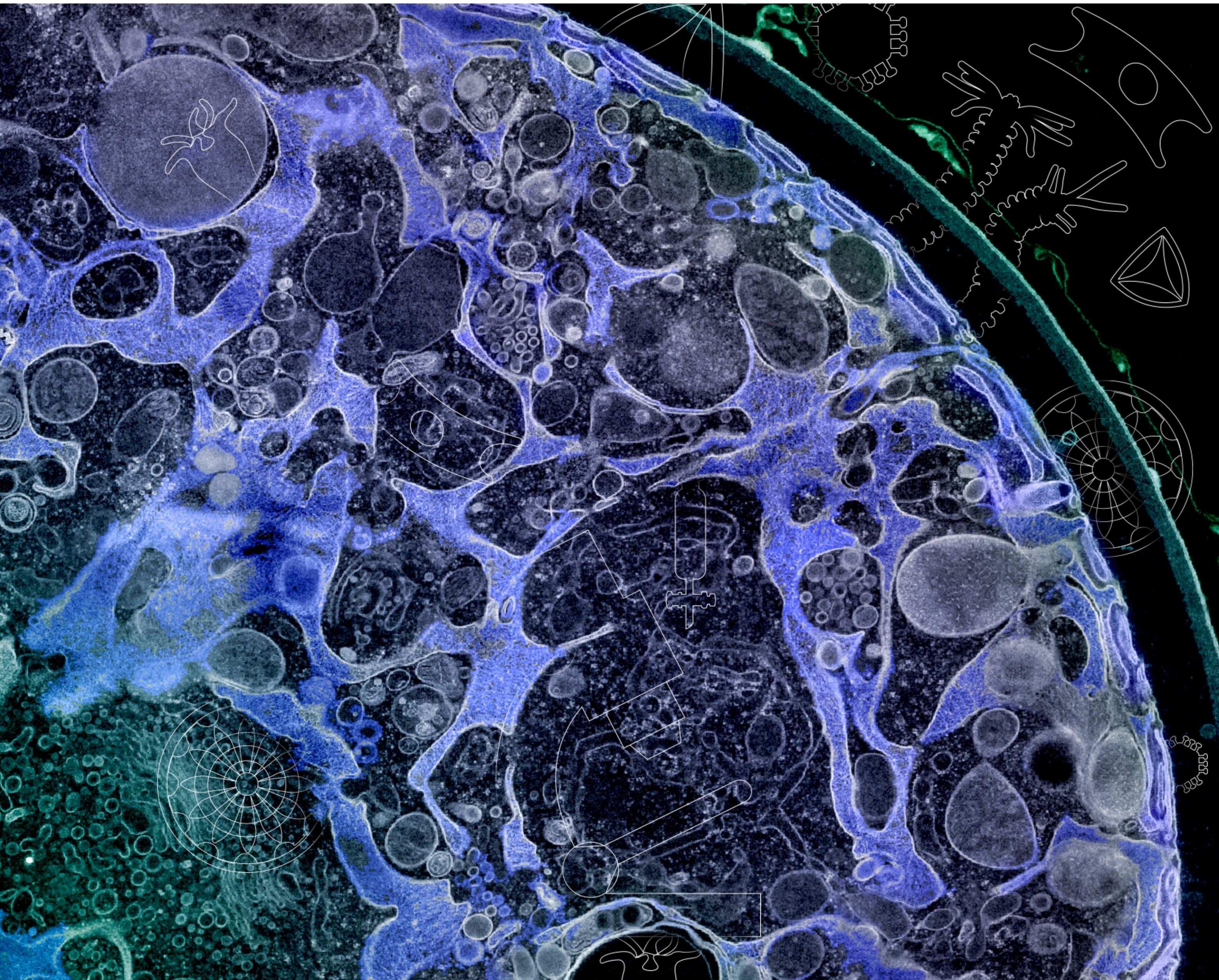
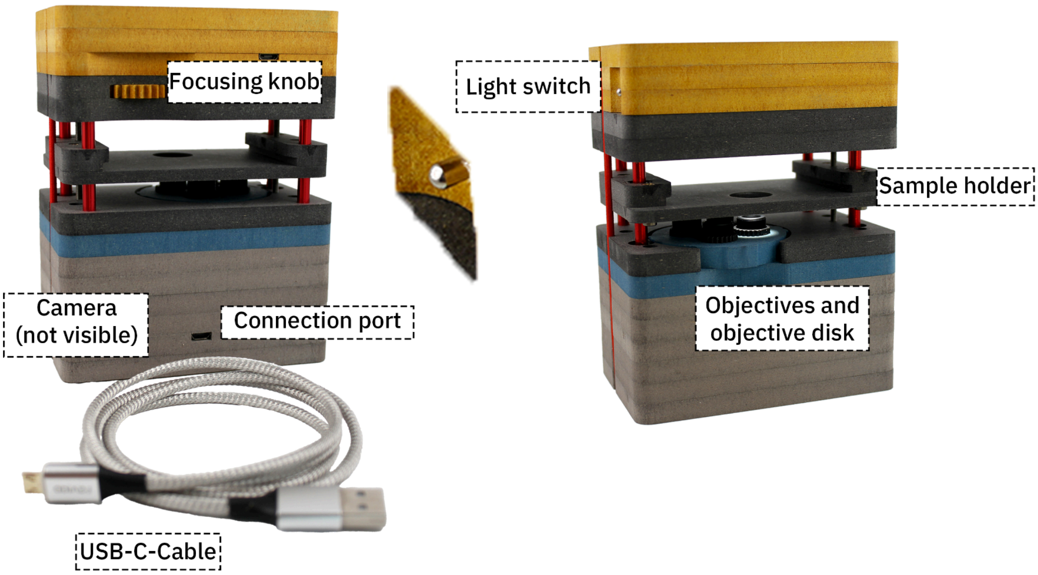
Dive into the world of plankton with the Curiosity Microscope

Answer sheet

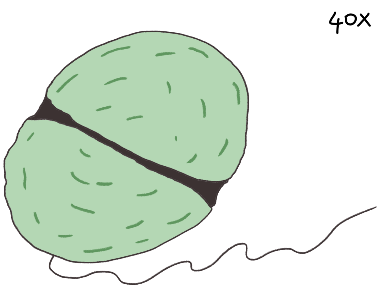


Visualisation under the microscope



Using the Curiosity microscopes and this educational material, we will explore and identify some of the planktonic organisms we can find in the water. After placing your sample on the sample holder, view it at different magnifications, starting at the lowest magnification and working up to the highest magnification **(30 minutes)**. Use the available space below to insert an image of a plankton species taken with the microscope. Use the magnification at which you can best see the plankton and note the magnification used.

*You can also draw your observations instead of taking pictures.



Outline the general characteristics of the plankton you observe by answering the questions below.

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a. Look at your picture and think about whether your observed plankton lives alone or in colonies.
The plankton lives solitarily

b. **State** the colour of the plankton you observe.
Light green

c. Describe the shape of the plankton.
The plankton has an oval and asymmetrical shape. Two parts are separated by a groove that runs along the centre of the plankton. A flagellum can be seen at one end.

The word plankton means "drifter" and refers to the fact that they cannot swim against the currents. However, some plankton organisms have body parts that enable them to move in calm water. While some plankton organisms swim around using cilia and/or flagella, others use body parts such as legs to swim. Below are examples of planktonic organisms and the structures they use for swimming (4).

a. Identify a moving plankton for observation and capture it in a picture with the microscope. Paste the picture below or draw the plankton in the box.

b. Describe its movement and note the structure it uses to move OR include a picture of the structure that you took with the microscope (if visible).

Pupils may be able to observe a directional movement of the plankton. Their cilia or flagella are used for this, and the movement can be described as follows:

The plankton moves continuously in a certain direction until it encounters a barrier and changes direction. After changing direction, the plankton continues to swim uninterrupted.

Alternatively, the students can also record the movement of copepods, which show short jumps when swimming, whereby the description could be as follows:

The plankton moves through the water with jumps / periodic strokes using its legs. After each jump, the plankton stops and continues its movement by repeating the same motion.

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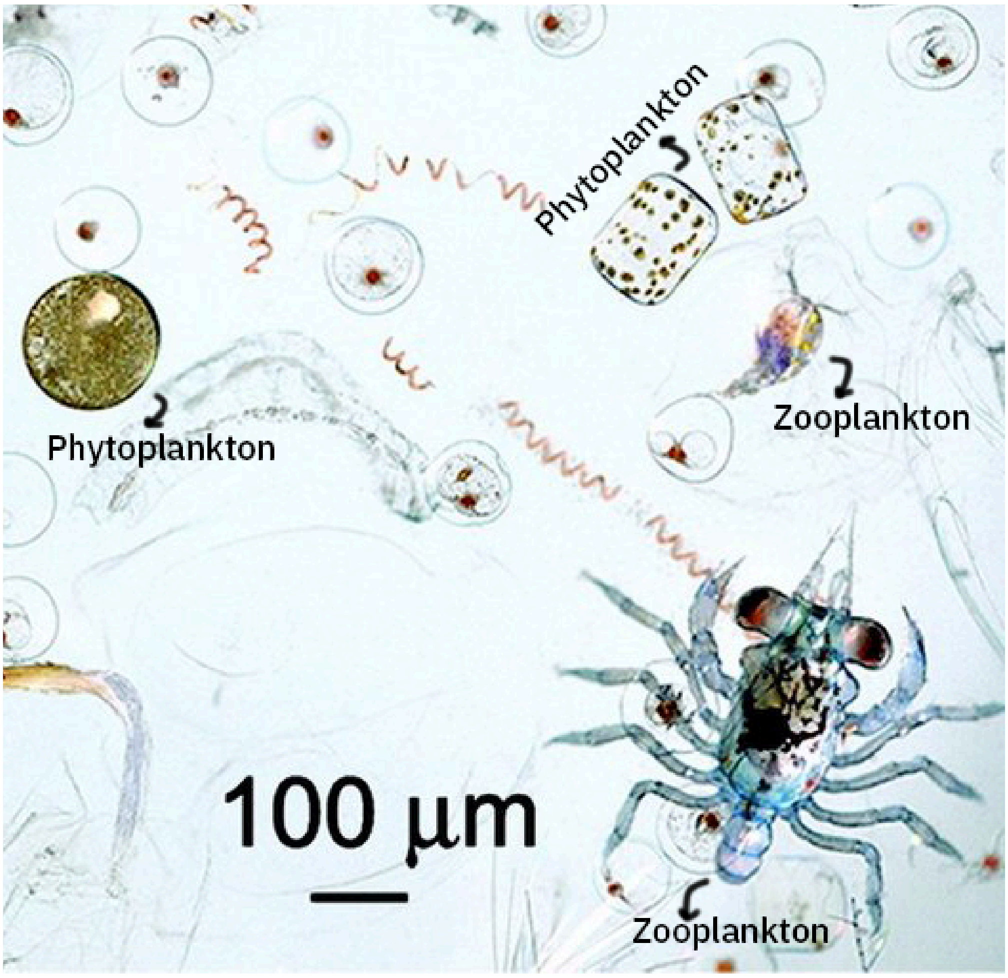
While some plankton organisms in the water have an animal-like character (zooplankton), others are more plant-like (phytoplankton). Phytoplankton are the most common life forms in the ocean. Thanks to the green pigment chlorophyll, they utilise sunlight to produce food and grow. Chlorophyll is also found in plants and is the molecule that gives both plants and phytoplankton their green colour. Zooplankton, on the other hand, cannot capture sunlight and have no chlorophyll, so they are not normally green in colour. Zooplankton hunt other organisms like phytoplankton to feed, and therefore may also have small mouths, arms, claws, and in the case of jellyfish, even tentacles with which to capture prey. Below is a group of plankton organisms. Label one that you think is a phytoplankton. Label another one that you think is a zooplankton. Explain your reasoning below.



Phytoplankton are photosynthetic organisms that contain chlorophyll, which gives them their green colour. Therefore, organisms with green pigmentation could be phytoplankton. Zooplankton are organisms that feed on other organisms and do not contain chlorophyll. As they rely on hunting other organisms to feed, they may have eyes, claws and legs that can

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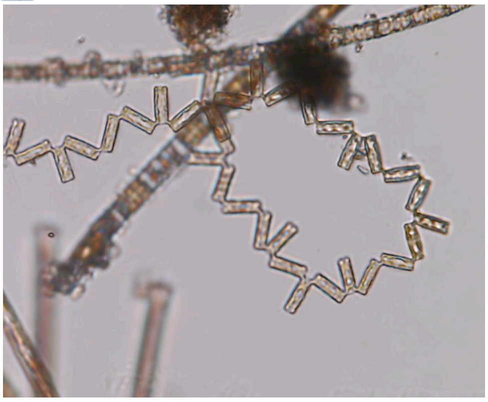
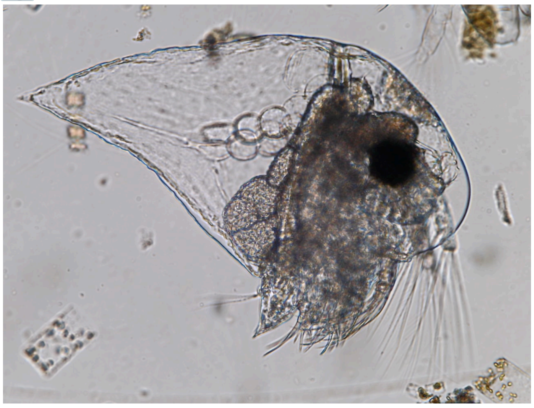
help them recognise and capture prey. The shrimp larva in the corner, for example, has claws, legs and eyes.

While looking at the water sample with your microscope, take a picture of a phytoplankton AND a zooplankton and paste them below. Answer the questions.

📷



📷



a. **Indicate** whether they live alone (solitary) or in colonies.

Phytoplankton: Colony

Zooplankton: Alone

b. **Describe** the general appearance of the plankton with reference to the characteristics below.
   i. Colour, shape, visible structures (grooves, symmetrical individual cells)
   ii. Presence of claws, spines, eyes, legs and/or mouth
   iii. Presence of flagellum/s

The phytoplankton colony has a pale yellow to greenish colour. The individual cells appear to be connected to each other at the corners, forming a chain-like structure. Individual cells are symmetrical and look like rectangles.

The zooplankton has a transparent and colourless body with visible outlines. There are legs and hair-like structures on the body. A dark black spot is also visible above the legs, which could represent an eye of the zooplankton.

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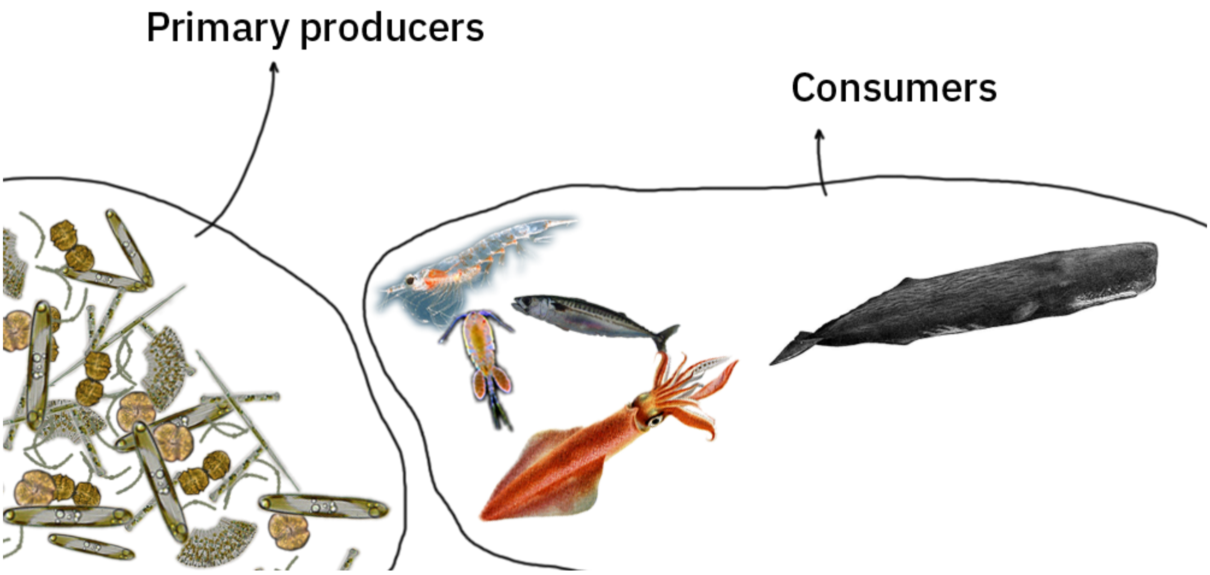
Below is a scale comparison of individuals from three different groups of phytoplankton. The scale bar is 100 microns long and divided into 10 micron sections. Refer to the plankton fact sheet and **(5 minutes)**:

a. **Identify** the group to which each phytoplankton belongs and **label** them.
b. **Estimate** the sizes of the individual cells in each group using the scale bar.
c. Look at the three types of phytoplankton and **label** the visible parts of their cells that contain chlorophyll. **Explain** your reasoning.

The chlorophyll pigment has a green colour. The presence of chlorophyll in cells and tissues therefore also makes these structures appear green in colour. Similar to plants, phytoplankton also contain chlorophyll in their cells (especially in chloroplasts in eukaryotes), which appears green or various shades of green under the microscope. Therefore, parts of the cell that appear green may contain chlorophyll.

Similar to ecosystems on land, ocean ecosystems rely on primary producers such as phytoplankton to sustain other organisms. In the diagram below, identify and label the primary producers and consumers that depend on them **(5 minutes)**.



Referring to Figure 5 of the "Plankton" information sheet, answer the following questions **(10 minutes)**:

How would the number of sperm whales change if the amount of phytoplankton in the region decreased?

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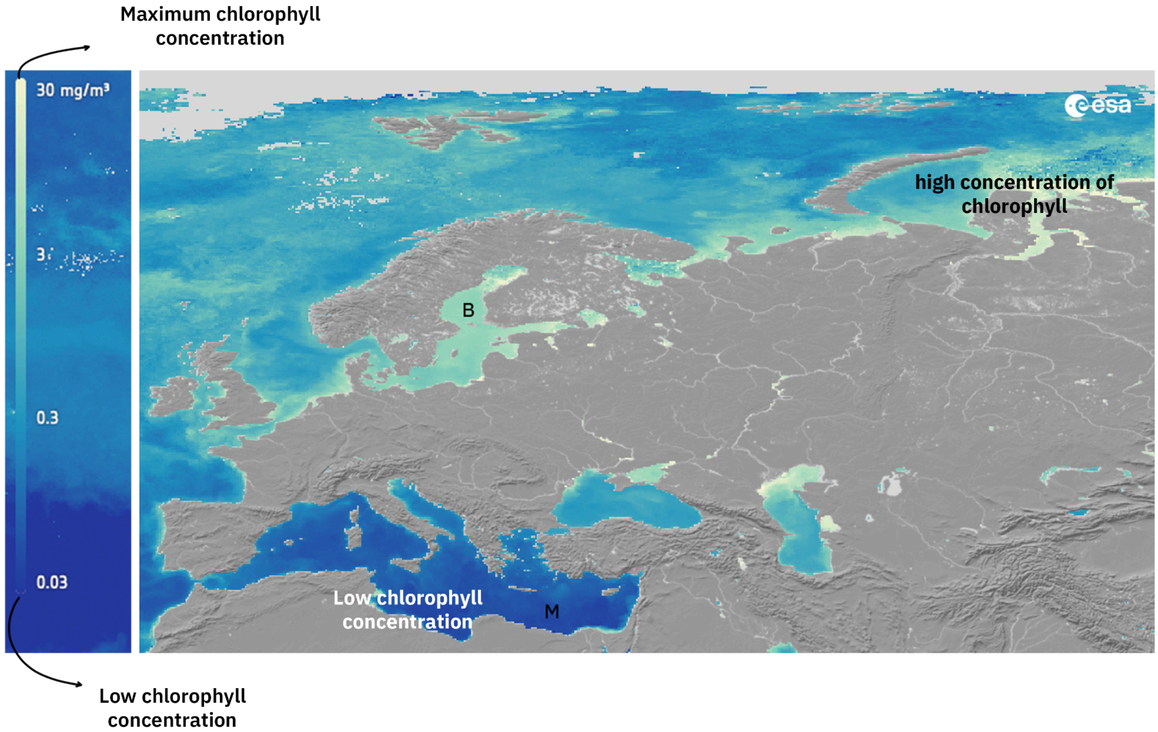
A decline in phytoplankton numbers would lead to a decline in the total number of zooplankton that depend on them. A decline in zooplankton numbers would also lead to a decline in the number of organisms (such as whales) that feed on them.

How would the number of phytoplankton and sperm whales change if the krill population decreased?

A decline in the number of krill would mean that there are fewer consumers who feed on phytoplankton. Unconsumed, the numbers of phytoplankton would increase. The same decline in the krill population would also lead to a decline in the number of whales.

Below is a satellite image showing the chlorophyll intensity in parts of the Atlantic Ocean due to plankton growth. Next to the image is a scale that assigns the corresponding chlorophyll intensity to the colours. Answer the following questions **(10 minutes)**.

a. **Identify** the colour that shows the highest and lowest chlorophyll concentration in the ocean on the colour scale and **label** it accordingly.
b. **Identify** a region of high and low chlorophyll concentration on the map below and **label** it "high chlorophyll concentration" or "low chlorophyll concentration".
c. Look at the chlorophyll intensity map and **predict** which area of the oceans (labelled B or M on the map) contains more plankton in the water.



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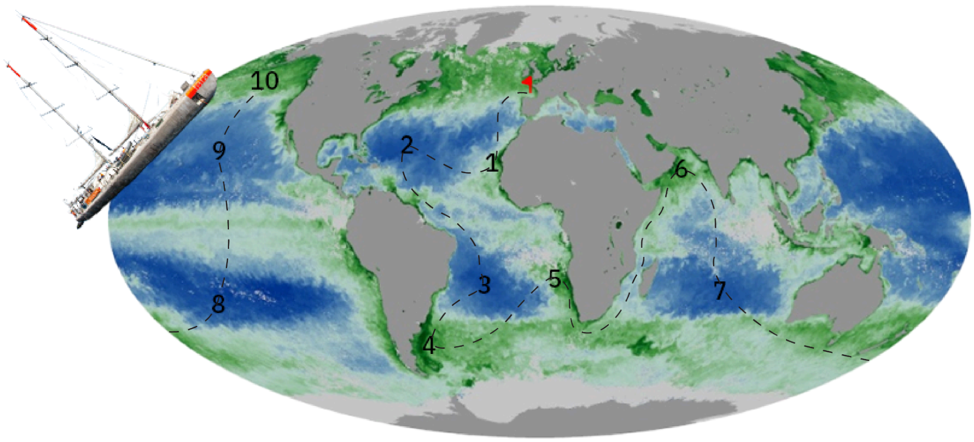
The greenish colouring on the map represents the amount of chlorophyll and therefore the abundance of phytoplankton in the region. When looking at the map, the Baltic Sea region labelled B has more phytoplankton in the sea, which can also feed other plankton species such as zooplankton. Therefore, the area of the ocean labelled B contains more plankton.

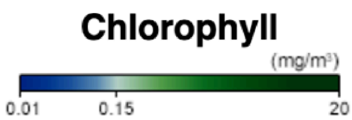
Explain which of the two plankton groups (zoo- or phyto) is responsible for this colour change detected by satellites.

The colour detected by satellites comes from the chlorophyll pigment of the phytoplankton. The presence of large quantities of green phytoplankton colours the sea greenish. Phytoplankton organisms are therefore directly responsible for the colour change.

Phytoplankton shows an uneven distribution in the world's oceans. Therefore, certain areas of the oceans are rich in phytoplankton, while other areas lack it. Answer the following questions using the corresponding maps **(10 minutes)**.

a. The following world map of chlorophyll concentrations shows where phytoplankton is most abundant and the route of the Tara Ocean Foundation research vessel Tara along which samples were taken (marked by numbers on the map). The route starts at the coast of France (red flag) and ends at location 10. Look at the ocean colour at each location where samples were taken and identify the phytoplankton-rich and -poor parts of the ocean. Write them in the individual boxes you see in the diagram below.





Plankton rich	Plankton poor
1,4,5,6 & 10	2,3,7,8 & 9

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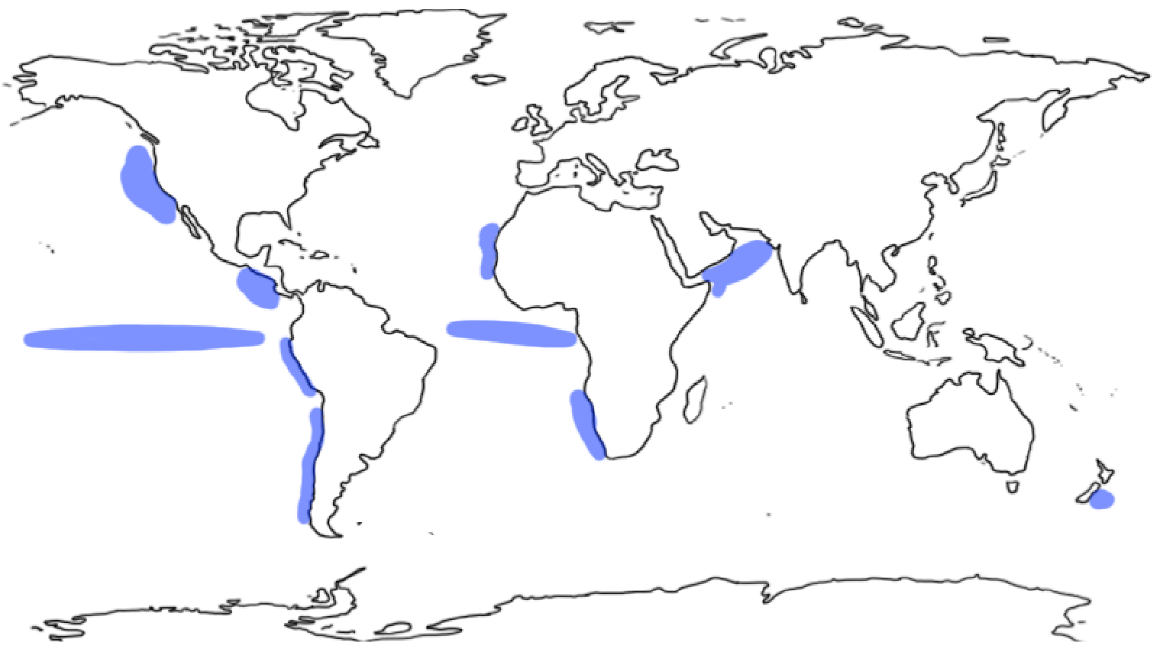
d. The growth of phytoplankton in the ocean depends on factors such as the availability of sunlight and nutrients. On the map below, the regions marked in blue indicate where nutrients rise from the deeper environment to the surface in a process called upwelling. Look at the map and indicate whether the phytoplankton-rich regions you listed earlier correspond to the regions of nutrient upwelling.



Yes, the previously identified phytoplankton-rich regions correspond to the upwelling areas.

Briefly **outline** how nutrients can contribute to the growth of phytoplankton.

Phytoplankton use sunlight, CO_2 and H_2O to produce organic molecules such as sugars ($C_6H_{12}O_6$).

CO_2 and H_2O do not contain elements such as N and P, which are also important for the development of organisms. Phytoplankton use the nutrient-rich compounds of N and P, which are brought to the surface by upwelling, to synthesise other organic compounds such as nucleic acids and amino acids. These in turn are used to synthesise DNA and proteins.

Once these organic compounds are synthesised, phytoplankton can reproduce.

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The following map shows where the largest populations of sardines and anchovies live in the ocean. Look at the map and answer the questions (10 minutes).

a. Using the map, indicate whether the largest fish populations live in regions rich or poor in phytoplankton. Explain your reasoning **(5 minutes)**.

The largest fish populations overlap with the phytoplankton-rich regions. As producers in the ocean, phytoplankton forms the basis of the food web. Waters with abundant phytoplankton also support the growth of other types of plankton such as zooplankton, which feed on phytoplankton. The presence of zooplankton attracts larger animals such as fish, birds and marine mammals to the same areas to feed on them.

b. Briefly **outline** the role of nutrients in the fish populations of upwelling systems **(5 minutes)**.

Upwelled nutrients provide the necessary compounds that phytoplankton use to synthesise proteins and DNA molecules and help these organisms to reproduce. An increase in the number of phytoplankton leads to an increased presence of consumer organisms such as fish, which are dependent on them.

As phytoplankton photosynthesises and grows, it uses the CO_2 diffusing from the atmosphere into the ocean and converts it into organic carbon to produce mass, or in other words, to produce more phytoplankton. While most of this phytoplankton is eaten by marine organisms, the rest sinks to the bottom of the ocean, taking the captured CO_2 from the atmosphere with it. By absorbing CO_2 from the atmosphere with the help of phytoplankton and binding it in its depths, the ocean plays a crucial role in regulating our planet's climate. The extraction of sequestered carbon in the form of fossil fuels and its release into the atmosphere is a major cause of climate change (3).

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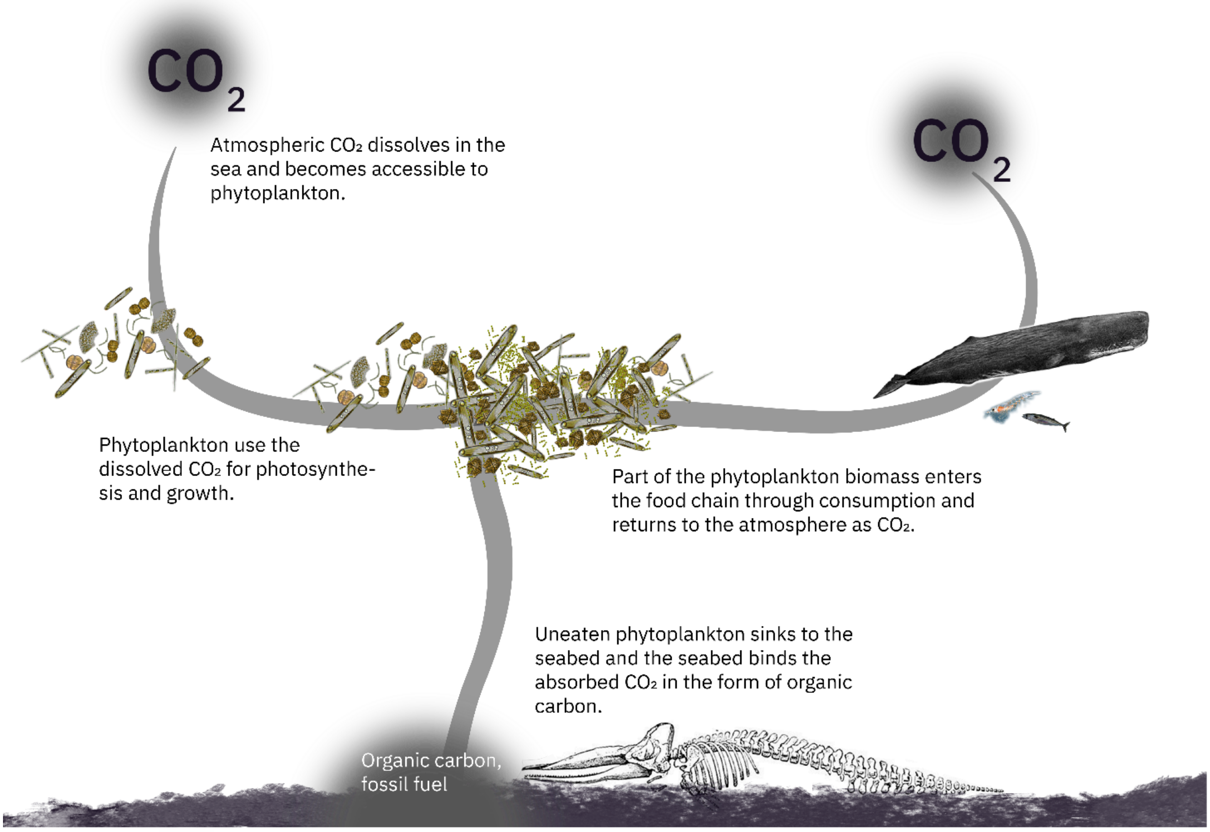

Using the above information, **explain** how offshore drilling as a human activity interferes with the different stages of the carbon cycle **(10 minutes)**.

Human activity	Where it disrupts the carbon cycle
Offshore drilling: the process of drilling through the seabed to extract fossil fuels used in industry and transport.	Offshore drilling and fossil fuel extraction remove organic carbon from the seabed, which prevents the CO2 absorbed by phytoplankton from remaining in the depths of the ocean. The extracted organic carbon (fossil fuels) can then be utilised by humans.

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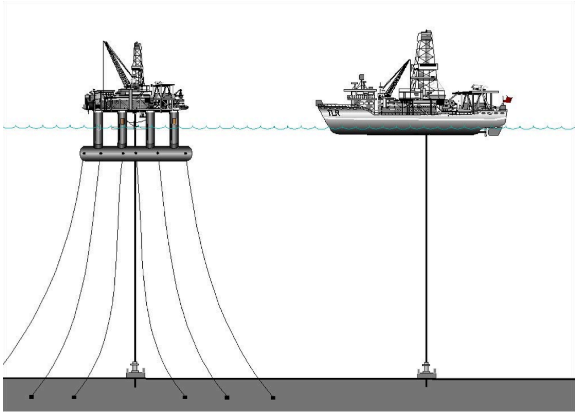

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