ARCTIC PHYTOPLANKTON

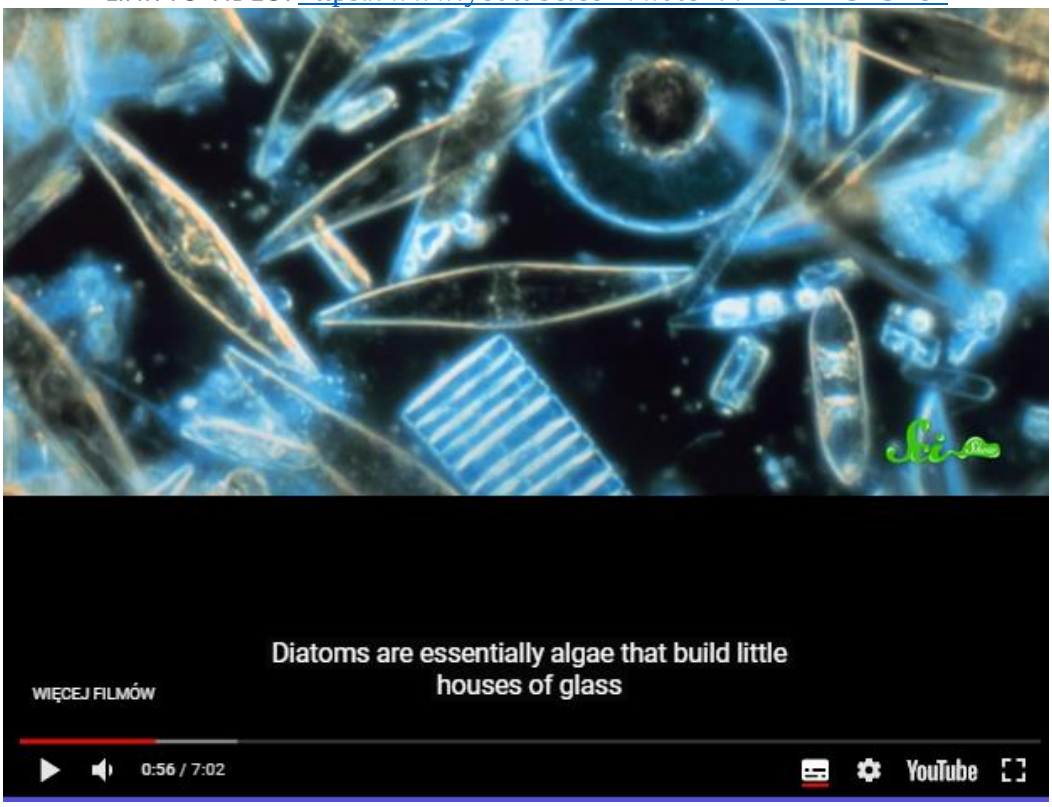
Introduction

Phytoplankton is the base of several aquatic food webs.

It's a group of microorganisms consisting of about 5,000 known species. Most of them are buoyant and float near the surface of the water. The major types of phytoplankton are diatoms, golden-brown algae, blue-green algae, green algae and dinoflagellates. They reside in the euphotic zone of the ocean, which ranges 200 to 300 meters below the surface. These microorganisms are abundant in the ocean, but their presence went unnoticed for a long time. After improvements in technology, however, they were finally made visible in the 1970s.

Is phytoplankton the most important life on Earth? Watch a short video dedicated to PHYTOPLANKTON and answer the questions.

LINK TO VIDEO: https://www.youtube.com/watch?v=fS422O4SLc4



Now, answer the questions regarding the video:

1) what is the process that all the organisms belonging to phytoplankton have in common?

……
……

EDU-ARCTIC 2: from polar research to scientific passion – innovative nature education in Poland and Norway receives a grant of ca. 240 000 EUR received from Iceland, Liechtenstein and Norway under EEA funds. The purpose of the EDU-ARCTIC 2 project is to: enhance the knowledge about nature, geography, natural resources, political specificities concerning polar regions and increase awareness of environmental issues and climate change, increase of interest in pursuing STEM education and careers due to enhancement of knowledge about scientific research, and their place in the modern world, familiarizing young people with scientific career opportunities; introduce innovative tools by way of an e-learning portal and effective methods of teaching science in schools

2) name one famous location (landscape element) built from fossiled phytoplankton

……
……

3) by mass, is there more phytoplankton or land plants?

……
……

4) does phytoplankton consume more or less carbon dioxide than Earth's forests?

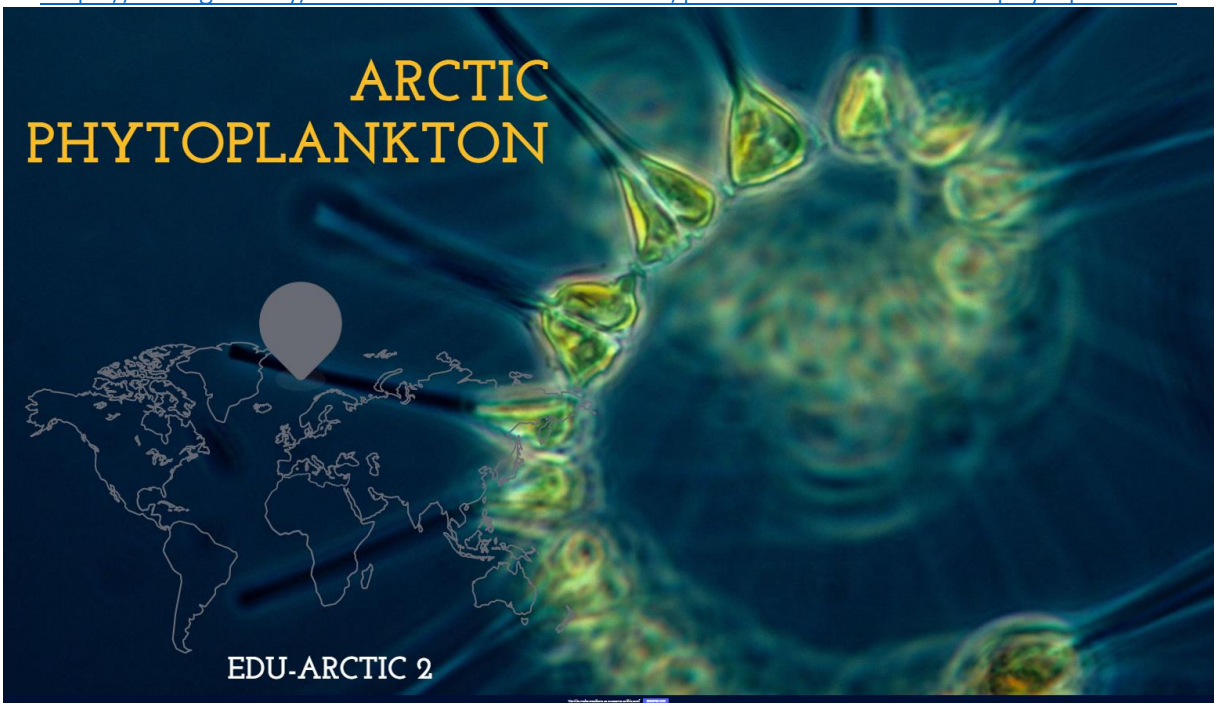
……
……

What, where and how?

What are the conditions in Arctic Ocean? What types of organisms belong to phytoplankton?

LINK TO PRESENTATION ONLINE:

https://view.genial.ly/601eff253668350d0014288d/presentation-intro-arctic-phytoplankton



WHAT IS PLANKTON?

Derived from the Greek words phyto (plant) and plankton (made to wander or drift), phytoplankton are microscopic organisms that live in watery environments, both salty and fresh.

It's group of organisms that live in water, are not attached to the bottom and are carried along by currents without the means to swim against them.

A diverse range of living organisms that spend at least a part of their life cycle suspended in water.

SIZE	TYPE OF ORGANISM	POSITION IN WATER COLUMN	ADULT FORM
nanoplankton	virioplankton	epiplankton	meroplankton
microplankton	phytoplankton	bathyplankton	holoplankton
mesoplankton	zooplankton		
macroplankton			

Arctic Ocean

Arctic Ocean and its constituent seas are rather shallow; make around **3 %** of the total ocean area and only about **1 %** of the volume.

The Arctic Ocean is the shallowest (mean depth 1361 m) ocean and has significantly larger continental shelves than other oceans.

Deep Sea Basin +seas

Conditions in the Arctic Ocean

Cold water- The temperature of the surface of the Arctic Ocean is fairly constant, near the freezing point of seawater. Because the Arctic Ocean consists of saltwater, the temperature must reach –1.8 °C before freezing occurs.

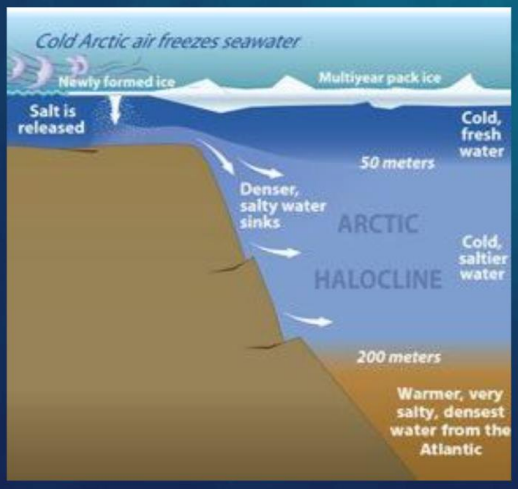
Access to nutrients - depending on mixing of water layers

Limited access to light (Polar NIght above the Arctic Circle, sea ice)

Stratification of water

Stratification

The **stratification** (which means characteristics of layers) in the Arctic Ocean is maintained by the fresh water dynamics.
The major freshwater sources include: rivers (Arctic Ocean receives around 11 % of the global river runoff discharge), precipitation and ice melt.
The low-salinity water from Pacific Ocean inflows via Bering Strait.
The low-saline, cold surface waters occupy the upper ~ **50 m and form PML (Polar Mixed Layer)**
Arctic halocline (a layer of cold water with a steep salinity gradients) forms below PML and limits the exchange between surface and deep ocean water masses.
Deeper water masses are formed by transformed Atlantic waters.

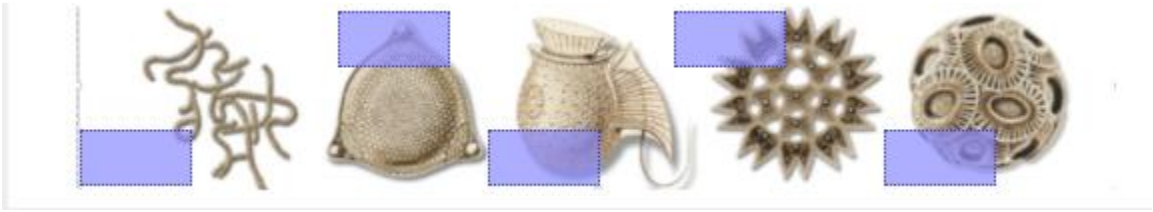


source: https://divediscover.whoi.edu/

Phytoplankton comprise two very different kinds of organisms. The larger category include, single-celled algae known as protists—advanced eukaryotic cells, similar to protozoans. These forms include **diatoms** and are most abundant near coasts.

The other type of phytoplankton cells, more primitive but far more abundant than algae, is photosynthetic bacteria. These tiny cells, some only a micron across, are invisible but present in numbers of hundreds of thousands of cells per tablespoon of ocean water. Too small to be caught in any net, these organisms were unknown until the 1970s, when improved technology made them visible. Scientists now know these bacteria are responsible for **half of the ocean's primary productivity and are the most abundant organisms in the sea**.

The group also includes **cyanobacteria**, which are believed to be among the oldest organisms on Earth and the origin of the photosynthetic organelles in plant cells known as chloroplasts.



green algae | cyanobacteria | dinoflagellate | coccolitophore | diatom

Match names of selected phytoplankton groups with images.

What we know so far?

Solve the short quiz below.

In case of the third question, try to guess which group can be used for which of 3 purposes.

Which of the following statements about phytoplankton is true?

- ○ All phytoplankton are algae
- ○ All phytoplankton are free floating and depend entirely upon water currents for locomotion
- ○ All phytoplankton are green

Phytoplankton provide a main source of food for water-based ecosystems

TRUE FALSE

Which of the following is NOT a common human use of phytoplankton?

- ○ abrasive
- ○ fertilizer
- ○ food supplement
- ○ nuclear waste treatment

.....

.....

NASA quiz – which phytoplankton are you?

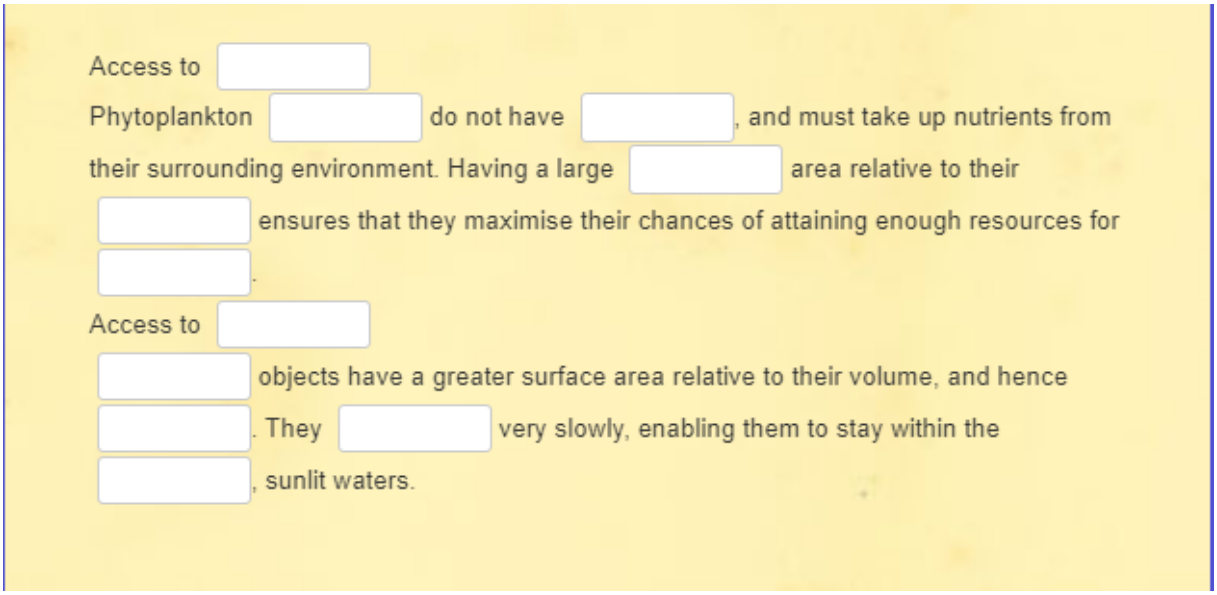
Fun with phytoplankton - NASA quiz! Which phytoplankton are you? Answer four questions to discover which of these diverse organisms is most like you!

LINK TO ONLINE QUIZ: https://pace.oceansciences.org/phyto_quiz.cgi

Inquiry

In many community assemblages, the abundance of organisms is a power-law function of organism size. In phytoplankton communities, changes in size structure associated with increases in resource availability.

Fill in the blanks to learn about advantages of being small!



LINK TO ONLINE EXERCISE: https://learningapps.org/watch?v=peaky39tc21

Biological pump

The biological pump is one process that leads to long term carbon storage in the deep ocean.

The 'biological carbon pump' (BCP) contributes to the ocean's role in taking up and storing carbon dioxide from the atmosphere. The transformation of carbon dioxide and nutrients into organic carbon, its sinking into the in the deep ocean, and its decomposition at depth, is known as the biological carbon pump. It contributes to the ocean's uptake and storage of carbon dioxide and keeps atmospheric CO2 about 200 ppm lower than it would be if the ocean were without life.

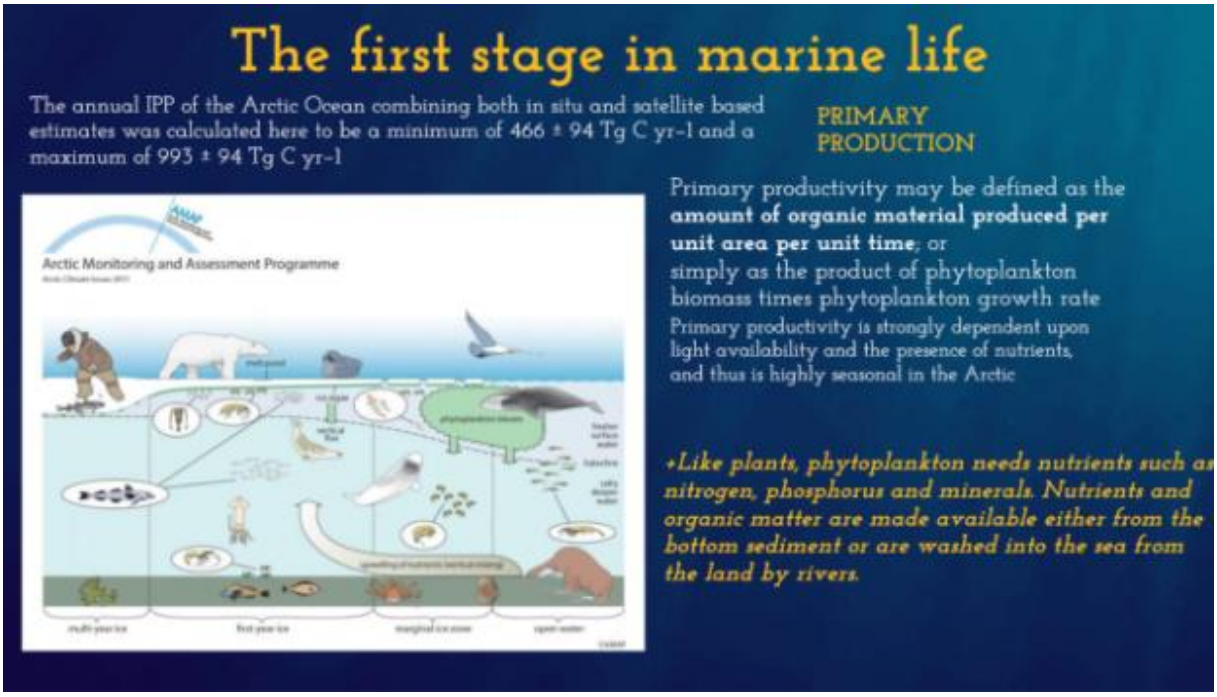
LINK TO VIDEO: https://www.youtube.com/watch?v=U03MUHFuO2o

After watching the video, explain what is the role of PHYTOPLANKTON in BIOLOGICAL PUMP.

……
……
……
……
……

Primary production

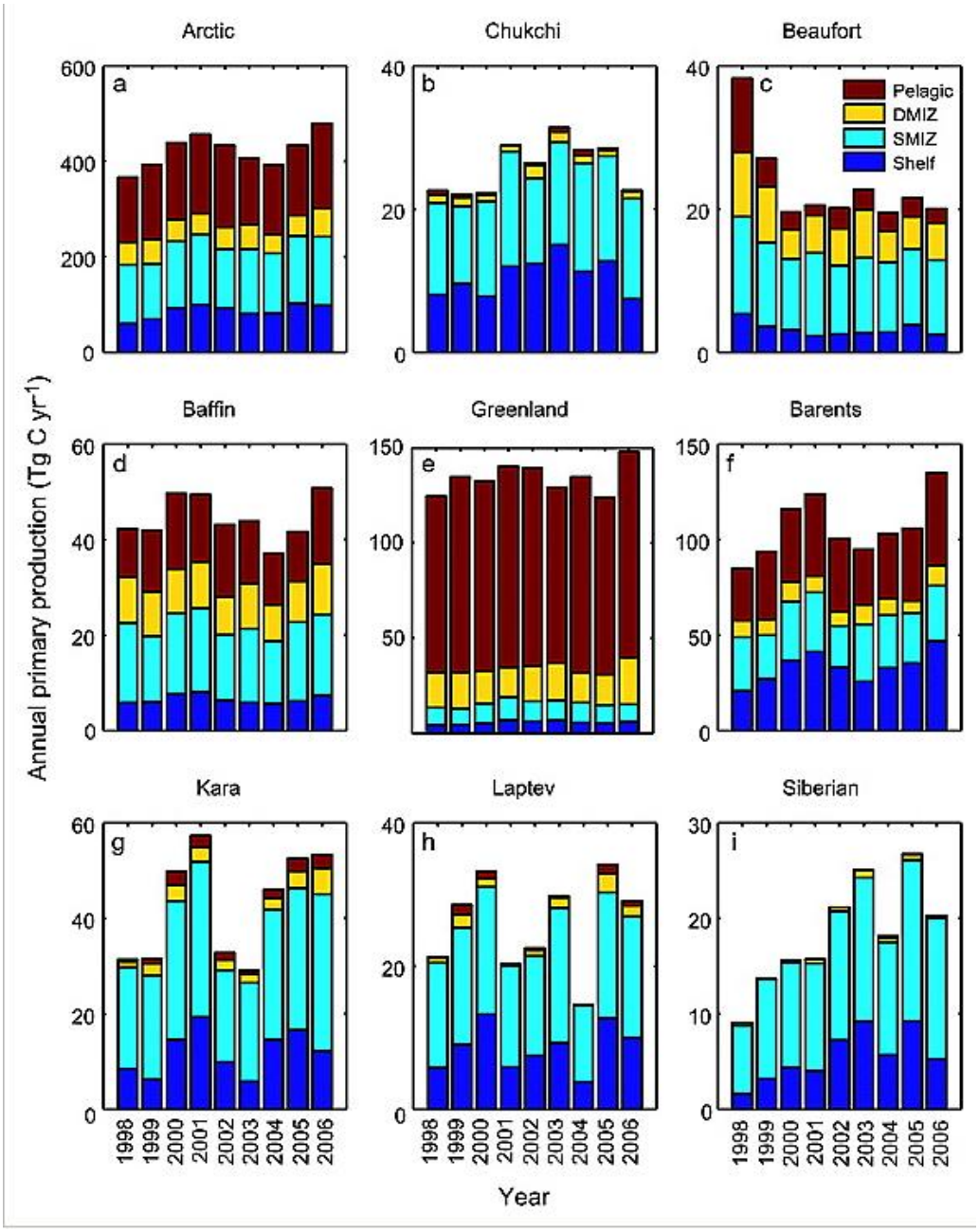
Autotrophic single-celled algae living in sea ice (ice algae) and water column (phytoplankton) are the main primary producers in the Arctic Ocean. Through photosynthesis, they transform dissolved inorganic carbon into organic material. Consequently, primary production provides a key ecosystem service by providing energy to the entire food web in the oceans. Primary productivity is strongly dependent upon light availability and the presence of nutrients, and thus is highly seasonal in the Arctic. In particular, the melting and retreat of sea ice during spring are **strong drivers of primary production in the Arctic Ocean.**



Differences in productivity

Look at the figures, presenting primary production in the Arctic Ocean, 1998–2006, Sudeshna Pabi, Gert L. van Dijken, Kevin R. Arrigo https://doi.org/10.1029/2007JC004578

Note that the scale of the graphs varies.



Different seas,different productivity

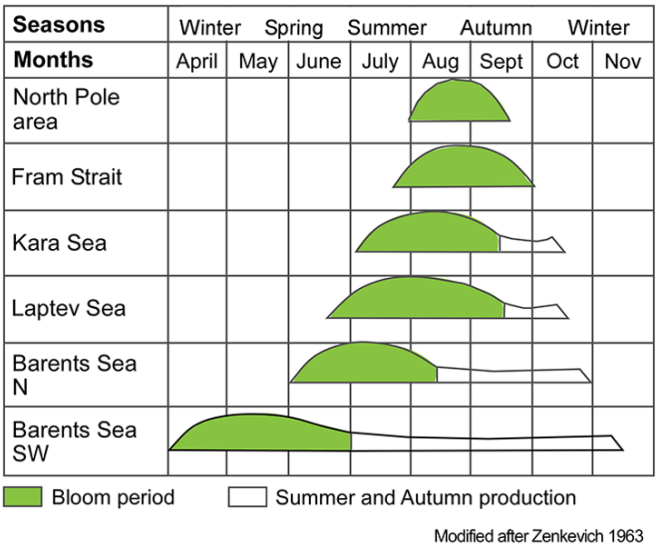
Based on the figures, put names of seas in order from the highest to lowest primary productivity in 2006. Discuss: what can cause differences in productivity in different seas?

>>Laptev<< – >> Barents<< – >>Siberian<< – >>Beaufourt<< - >>Greenland <<– >>Morze Kara<< – >> Baffin<<

LINK TO TASK ONLINE: https://learningapps.org/watch?v=pu5k3o9s321

Annual cycle

Look at the figure presenting seasonality of phytoplankton in the Arctic.



Modified after Zenkevich 1963

Limiting factors

Find names of two factors limiting Arctic phytoplankton growth

e	n	m	o	p	i	u	o
s	u	n	l	i	g	h	t
h	t	d	r	g	m	m	c
x	r	r	f	u	d	a	z
c	i	e	r	p	z	f	x
i	e	p	l	f	h	x	n
y	n	n	z	u	l	s	a
i	t	t	h	l	c	l	c
m	s	k	u	i	n	z	i

1. _____
2. _____

……

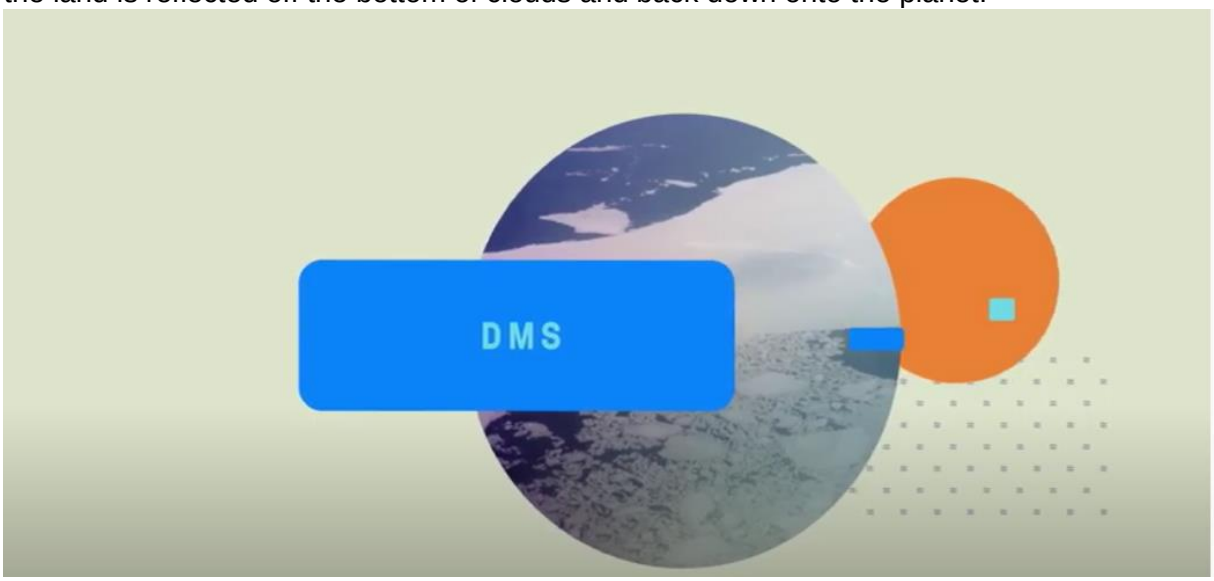
……

Match names with phases and discuss: is Arctic phytoplankton more prolific in spring or summer? Why?

DMS – smell of the sea

DMS stands for dimethylsulfide. At the low concentrations produced by phytoplankton, it's generally harmless. If you've gone to the beach, you've smelled DMS at some point in your life. It's a somewhat disagreeable odor, the same one produced when cooking corn, boiling cabbage, or certain types of seafood. It's a crucial component of the instantly recognizable "smell of the sea." It's produced naturally by certain types of phytoplankton, and so, it's natural to assume that as phytoplankton increase, DMS concentrations increase.

DMS does have some impact on cloud formation. If DMS concentrations in the Arctic continue to increase, it may change cloud patterns in the Arctic. And this is important, because not only do clouds play a crucial role in regulating Earth's climate, clouds and the impact of clouds on Earth's temperature are also one of the least understood aspects of climate change. As far as we understand it, clouds can act to either cool Earth, if sunlight is reflected from the tops of clouds and back into space, or further amplify warming, if heat from the land is reflected off the bottom of clouds and back down onto the planet.



LINK TO VIDEO: https://www.youtube.com/watch?v=2uZNMK10dGc

CLAW –feedback loop?

CLAW hypothesis proposes a negative feedback loop that operates between ocean ecosystems and the Earth's climate. The hypothesis specifically proposes that particular

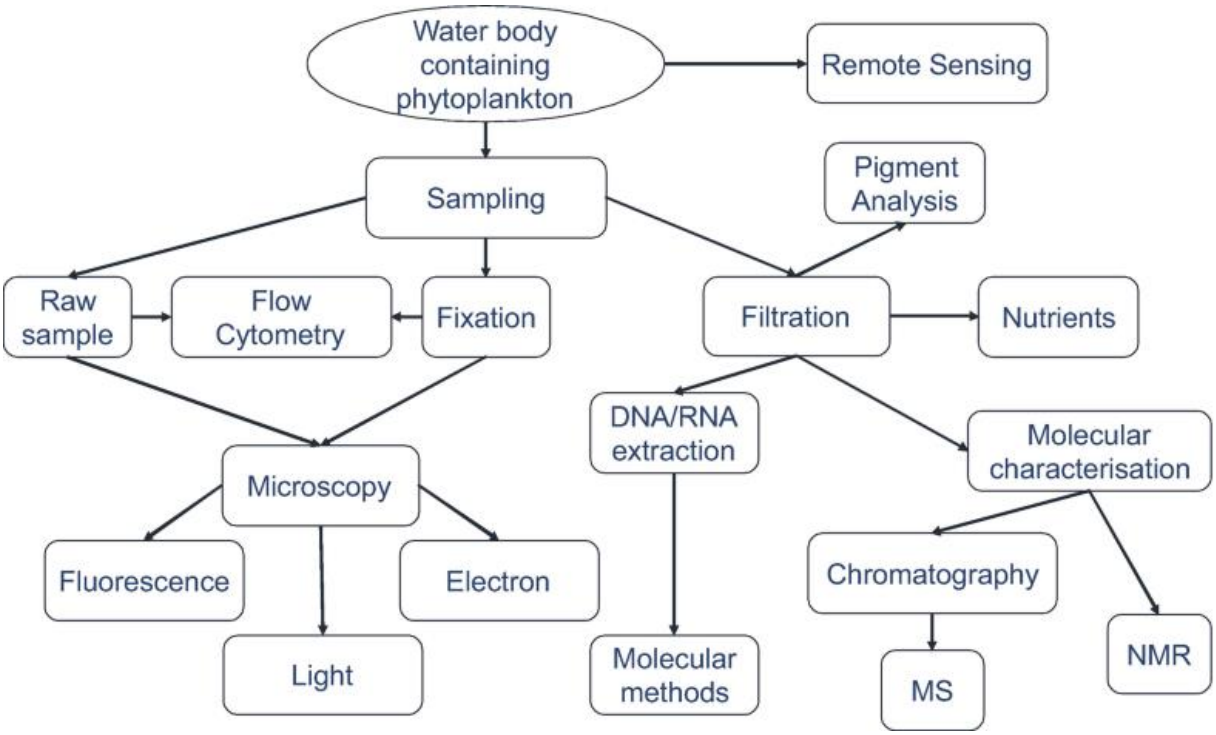
phytoplankton that produce dimethyl sulfide are responsive to variations in climate forcing, and that these responses act to stabilise the temperature of the Earth's atmosphere. The CLAW hypothesis was originally proposed by Robert Jay Charlson, James Lovelock, Meinrat Andreae and Stephen G. Warren, and takes its acronym from the first letter of their surnames.

Now use predefined terms (you can also add your own) to create a feedback loop. DISCUSS: is it a POSITIVE or NEGATIVE feedback loop?

Research

WIde range of methods
Schematic overview of the methods used for phytoplankton studies. Three different possibilities to process the sample are using raw samples, fixation or preservation, and filtration. Since molecular methods, pigment analysis and detection of molecular tracers usually require concentrated cells, filter residues serve for phytoplankton measurements. Molecular characterization and quantification of trace molecules is performed using chromatography, mass spectrometry (MS), and nuclear magnetic resonance (NMR) spectroscopy.

Source: Käse L., Geuer J.K. (2018) Phytoplankton Responses to Marine Climate Change – An Introduction. In: Jungblut S., Liebich V., Bode M. (eds) YOUMARES 8 – Oceans Across Boundaries: Learning from each other. Springer, Cham. https://doi.org/10.1007/978-3-319-93284-2_5

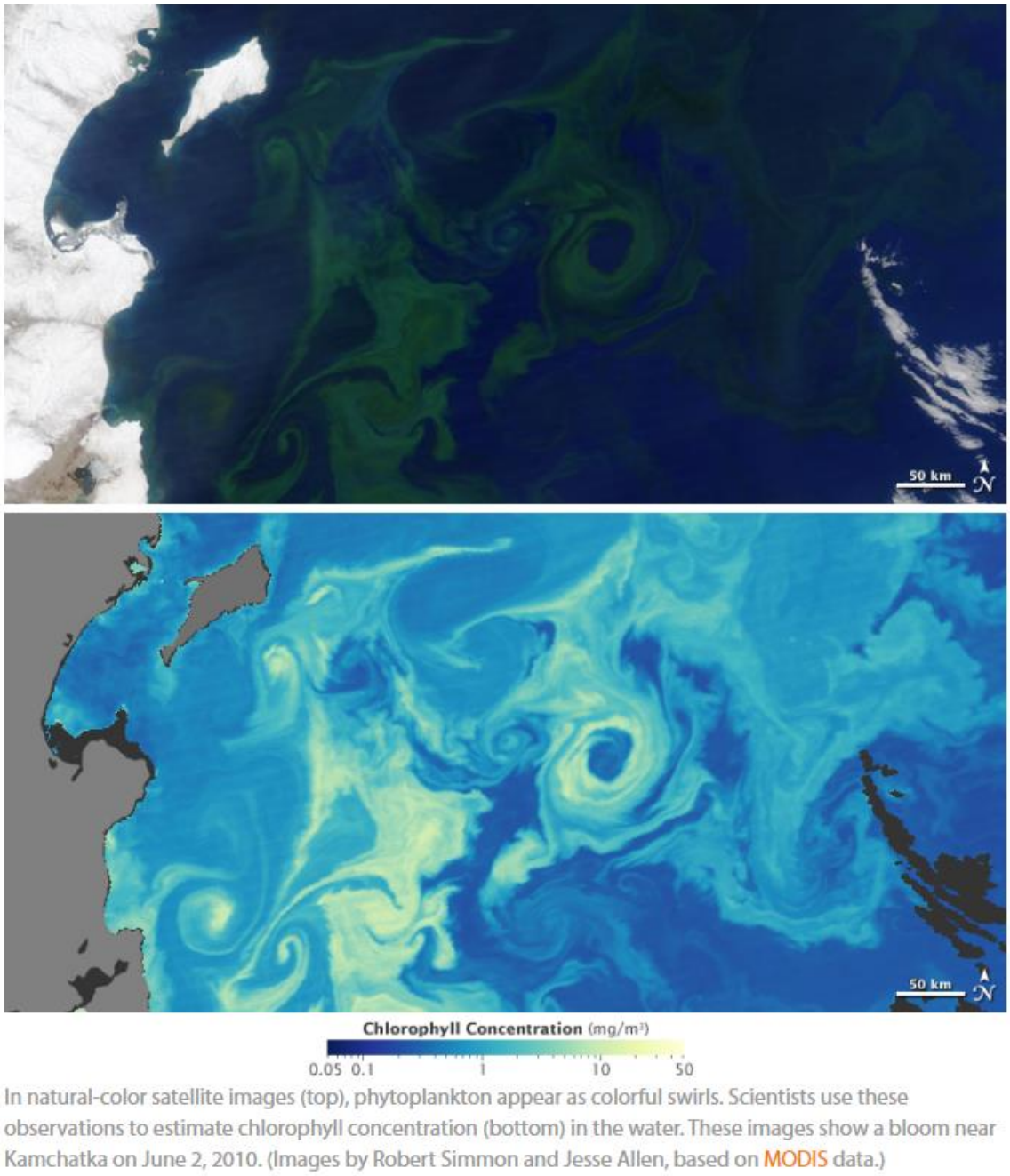


Scientists use satellite-based observations of chlorophyll (the green pigment vital for photosynthesis) as a proxy for phytoplankton productivity.

Chlorophyll-a is an indirect measure of phytoplankton crop, and represents the mass of phytoplankton per unit volume or area of water and should be reported as micrograms per litre (pg.L-1) or milligrams per cubic metre (mg.m-3) or per square metre (mg.m-2).

How is it calculated? Thanks to "chlorophyll algorithms"("chlorophyll_a"), adapted for types of waters and regions. Algorithms are validated against actual results from specific waters.

Although a useful indicator of primary productivity in the Arctic, satellite-observed chlorophyll is an imperfect measurement. It does not measure ice algae, nor does it measure phytoplankton blooms under the sea ice, both of which likely make a significant contribution to the Arctic food web and carbon cycle. Nevertheless, the picture that we can obtain from satellites indicates productivity is increasing in the Arctic’s open water areas in the summer.



In natural-color satellite images (top), phytoplankton appear as colorful swirls. Scientists use these observations to estimate chlorophyll concentration (bottom) in the water. These images show a bloom near Kamchatka on June 2, 2010. (Images by Robert Simmon and Jesse Allen, based on MODIS data.)

Sampling

When it comes to phytoplankton, it is not just the quantity, but also the quality that matters. You may wonder how can researchers sample something that we cannot see that exists in an environment where we cannot be in? How can we catch something that is passively driven by currents and changing all the time? How can we get the insight of the abundance of some particles that are unevenly dispersed in an ocean? Since the discovery of the microscope scientists have been trying to find answers to those questions.

The image belowe show typical phytoplankton samplers (sampling bottles). Sampling nets are also used.

polycarbonate sampling bottle and store the bottle in the closed cooler.

			
Kemmerer Water Sampler	Van Dorn Sampler	Niskin Bottles	Nansen Bottle

Sampling process -matching columns
Match the columns to create sentences describing sampling phytoplankton.

Surface water samples are collected by	between 8.30 and 10.00 a.m. is the preferred time
It is best to sample at particular time each day	there should be minimum disturbance of water to prevent avoidance reaction by plankton
The sampling bottles or water samplers with closing mechanisms are commonly used	for obtaining samples from the desired depths.
The plankton are then concentrated	dipping a well-rinsed bucket or bottle over the side of the boat, let it fill half with water and bring it back into the boat
Irrespective of methods	samples should be preserved soon after collection and where possible, live samples should also be examined
While collecting the water samples	by allowing them to settle, centrifuging or fine filtration

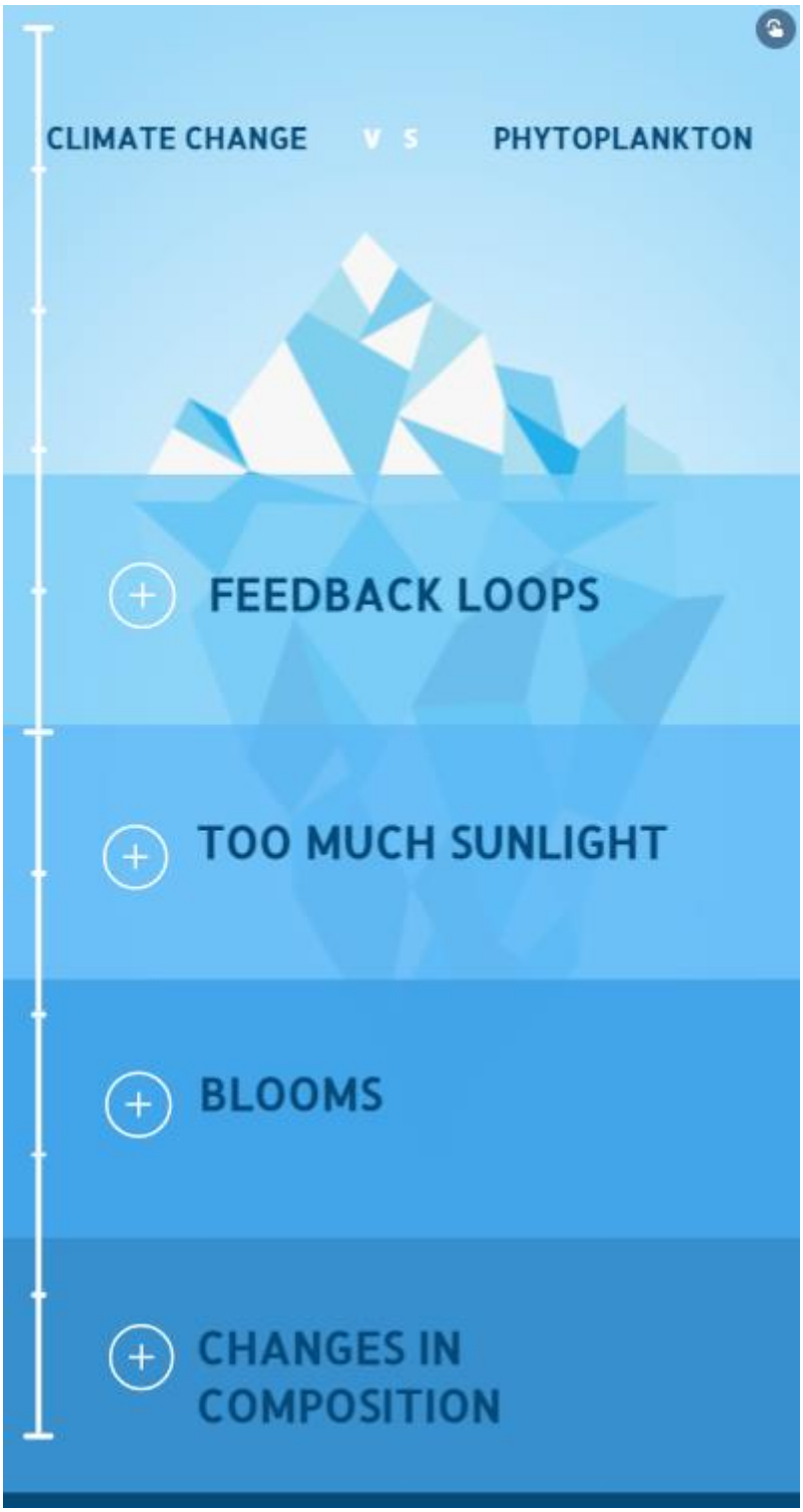
LINK TO EXERCISE ONLINE: https://www.educaplay.com/learning-resources/8326395-sampling_phytoplankton.html

Arctic bloom
Scientists have made a biological discovery in Arctic Ocean waters as dramatic and unexpected as finding a rainforest in the middle of a desert. A NASA-sponsored expedition punched through three-foot thick sea ice to find waters richer in microscopic marine plants, essential to all sea life, than any other ocean region on Earth.

The discovery is the result of an oceanographic expedition called ICESCAPE, or Impacts of Climate on EcoSystems and Chemistry of the Arctic Pacific Environment. The NASA-sponsored mission explored the seas along Alaska's western and northern coasts onboard a U.S. Coast Guard icebreaker during the summers of 2010 and 2011. The finding reveals a new consequence of the Arctic's warming climate and provides an important clue to understanding the impacts of a changing climate and environment on the Arctic Ocean and its ecology.

LINK TO VIDEO: https://www.youtube.com/watch?v=cpUf2EAmHxk

Climate change vs phytoplankton
LINK TO INTERACTIVE IMAGE ONLINE:
https://view.genial.ly/602958b72ea5b30d6689d189/vertical-infographic-list-climate-change-and-phytoplankton


CLIMATE CHANGE
V S
PHYTOPLANKTON
FEEDBACK LOOPS
TOO MUCH SUNLIGHT
BLOOMS
CHANGES IN COMPOSITION

Feedback loops
Chlorophyll and the related pigments in phytoplankton absorb solar radiation and then change sea surface temperature. So plankton blooms cause increase of temperature and more ice melting.

On the other hand, with more phytoplankton,there is more DMS dimethyl sulfide are responsive to variations in climate forcing, and that these responses lead to a negative feedback loop that acts to stabilise the temperature of the Earth's atmosphere.

Too much sunlight
Too rapid sea ice melting in April could expose the ice algae to excessive sunlight, which the researchers found from their trials can kill the algae; at the very least the shock causes the algae to produce less omega-3.

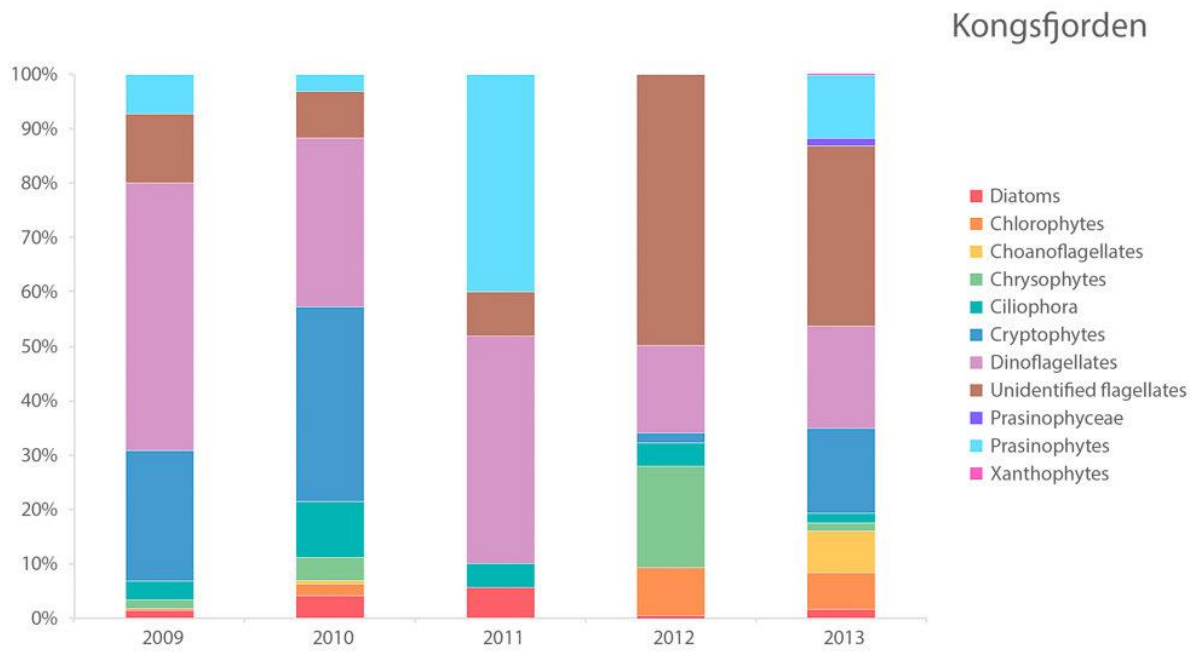
Blooms
Not that long ago, had been believed that the water beneath the ice was far too dark for plants to photosynthesize.
But studies show that Arctic is turning green because massive blooms of plankton can grow beneath the thinning sheets of sea ice,
The phenomenon was first noticed in Summer 2011 and was something of a surprise to NASA that observed it. It was the most intense pytoplankton bloom recorded on Earth in terms of biomass.
Expansion of ice free regions has increased Arctic primary productivity by 30% since 1998

Changes in composition
Environmental changes have led to regional changes in phytoplankton community size structure and diversity, with large phytoplankton being replaced by smaller cells.

Warmer water means limited mixing of layers of water-so phytoplankton is limited to upper layer; smaller cells have the advantage of not sinking easily.

Activities

Phytoplankton composition
Observe data regarding composition of phytoplankton community in Svabard (Kongsfjorden).



Observe the figure and decide which statements are true and which are false.

There were more diatoms than dinoflagellate in 2011

TRUE FALSE

No prasinophytes were recorded in 2012

TRUE FALSE

The share of diatoms in phytoplankton community is constant

TRUE FALSE

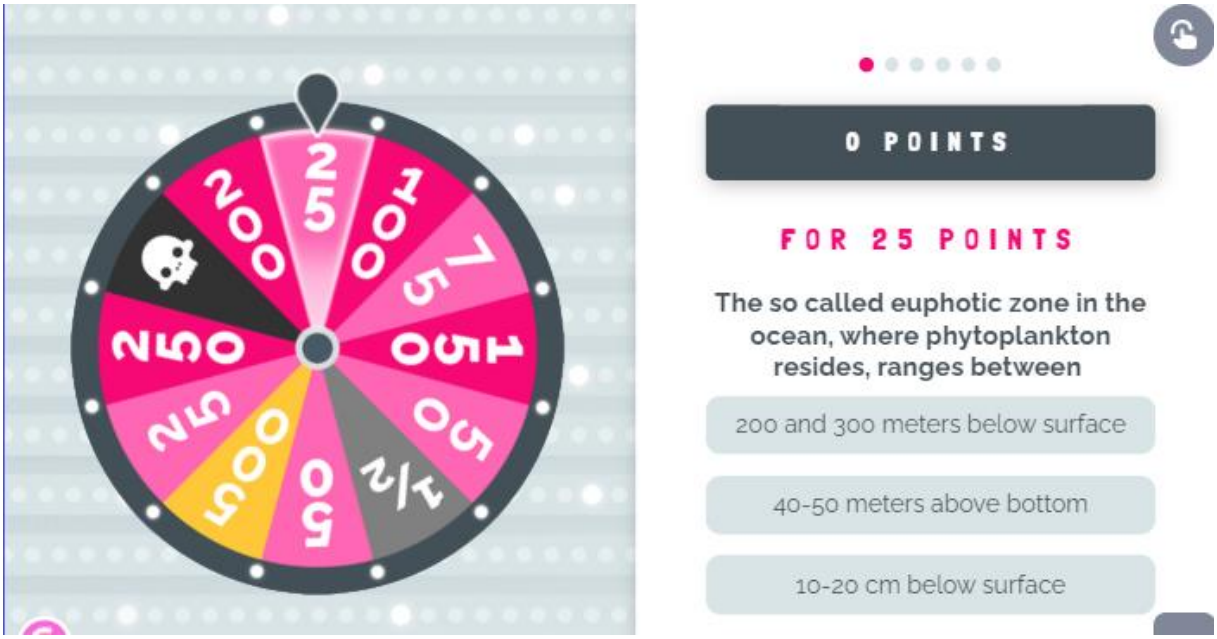
The share of chlorophytes in 2012 is larger than in 2010

TRUE FALSE

Wheeeel ooooff fortune!!!!!

Spin the wheel and answer the questions to win a prize (and check what you know about phytoplankton)!

LINK TO QUIZ ONLINE: https://view.genial.ly/602beb38740fca0db8ff64b4/game-phytoplakton-wheel-of-fortune



25 POINTS

FOR 100 POINTS

Phytoplankton used as abrasives, fertilizer and environmental indicator are

cyanobacteria

ice algae

diatoms

125 POINTS

FOR 75 POINTS

The most intense primary production in Arctic Ocean takes place in

early Autumn

late Summer

late Winter/Springtime

200 POINTS

FOR 250 POINTS

Dimethylsulfide

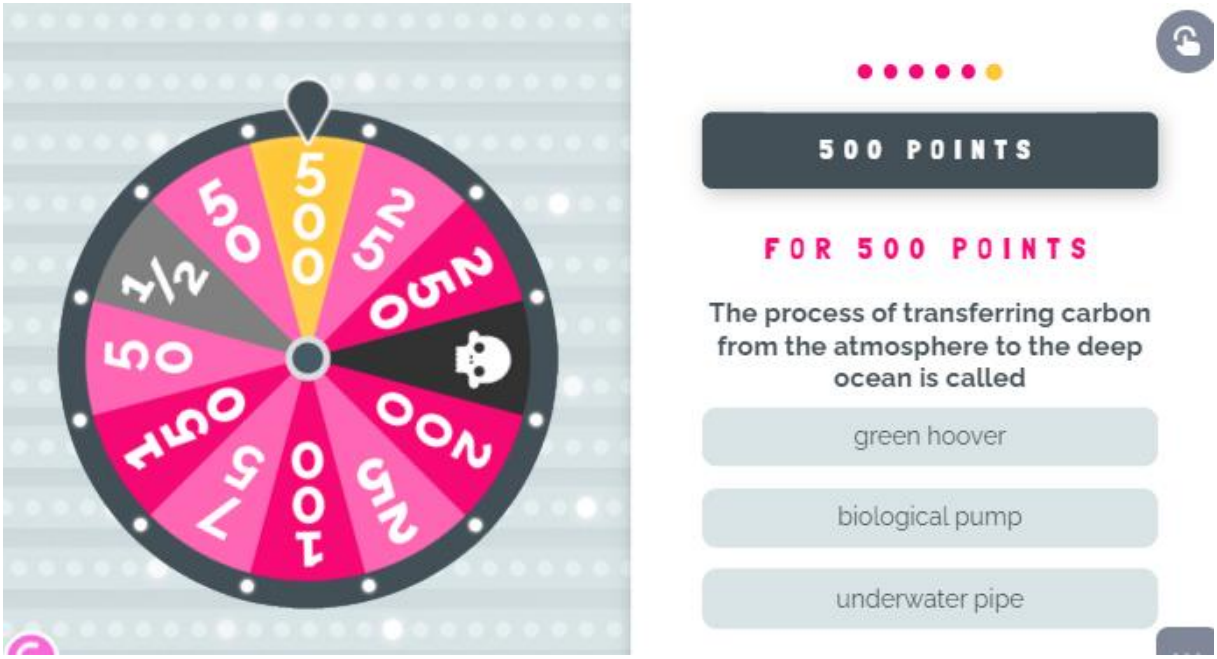
- is a toxin
- faciliates formation of clouds
- is an element of positive feedback loop in climate change

450 POINTS

FOR 50 POINTS

Phytoplankton blooms in the Arctic were first observed thanks to

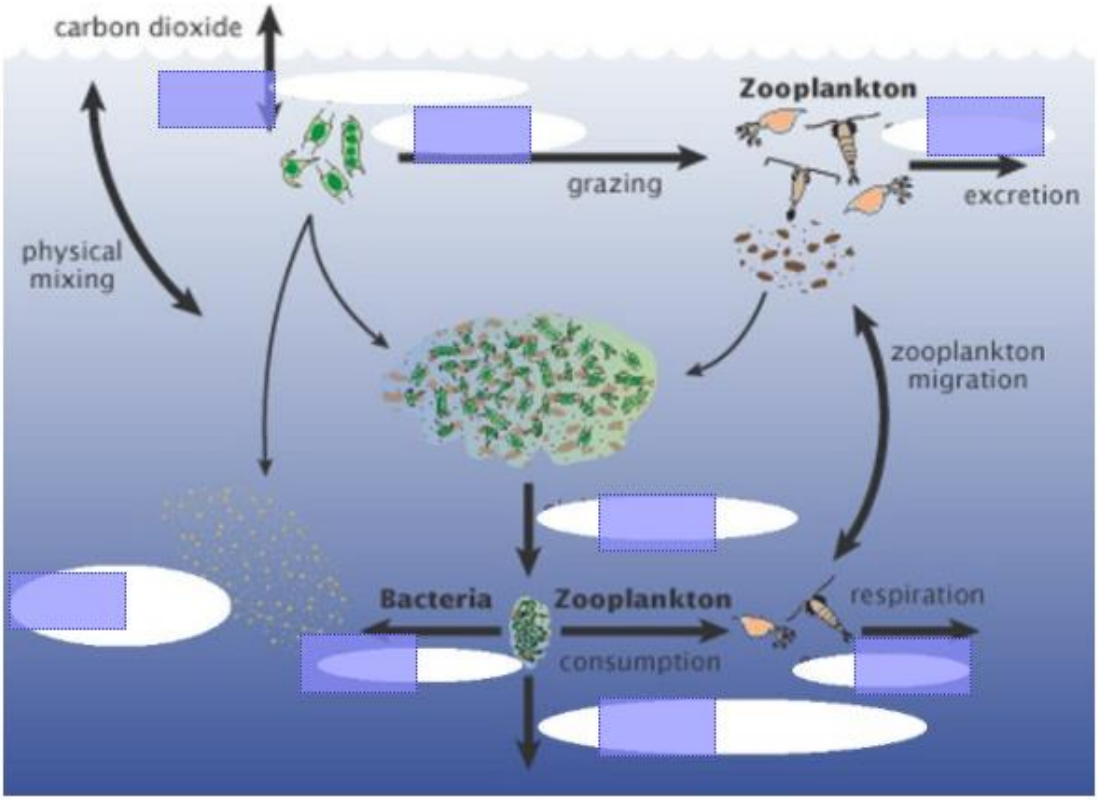
- satellite observations
- sampling with nets
- sampling with bottles



Carbon flux

Do you remember how biological pump works? Revise the video in INQUIRY section, if necessary, and match names with blanks on the scheme.

dissolved organic carbon | phytoplankton | carbon uptake | respiration | deep ocean carbon flux | decomposition | exretion | sinking



What a distracted polar researcher!

You have to help a distracted polar researcher! He was taking samples from the Arctic ocean and kept taking notes, but one days the wind opend the door in his observatory and all the notes got messed up. All we have is his table with observations (not entirely complete) and some loose sheets. Analyse data in table below and solve the puzzle!

Note: PAR stands for photosyntetically active radiation

(adapted from: https://oceanexplorer.noaa.gov/explorations/02arct...)

	ICE COVER (% of surface)	photosynthetically active radiation (% of maximum(	Chlorophyll a (µg/l)	Primary Productivity (mg C/m2/day)
Day 1	0	75	87	9,3
Day 2	50	78	76	4,3
Day 3	20	45	73	5,1
Day 4	10	76	82	3,4
Day 5	0	98	85	4,3
Day 6	70	79	71	3,4
Day 7	100	???	???	???
Day 8	30	82	82	6,5
Day 9	???	10	10	???
Day 10	15	79	79	2,6

Which day is it?
Now read description of sample days and guess which of sample days (from #1 do #10) is described

Attention – these are not consecutive days.

50% of the sea surface is covered with ice, and this limits Primary Productivity to less than half the value on Sample Day #1, even though the PAR level is actually a little bit higher, and there are only slightly fewer algae (as indicated by Chlorophyll a) than on Sample Day #1. Reduction of sunlight by sea ice can be a major limiting factor for primary productivity in the Arctic Ocean

Enter your answer

When would you expect ice to cover 100% of the sea surface? Winter, of course! So, PAR would be zero because night lasts 24 hours in the polar winter. We would expect Chlorophyll a and Primary Produc-tivity to be pretty close to zero as well

Enter your answer

Everything seems favorable here, but Primary Productivity is low. What would be the cause? PAR is almost at maximum), and we may wonder whether there is such a thing as too much light. In the Arctic Ocean, photosynthetic algae can be adapted to rather low light conditions, and it is possible for photosynthesis to be inhibited if these algae are exposed to too much light.

Enter your answer

Primary Productivity again is much lower than on Sample Day #1!!!A combination of ice cover and reduced PAR (yes, it was a cloudy day!) are probably responsible, since Chlorophyll a level is similar to previous days.

Enter your answer

With this much ice you know it's winter, and if it's winter-it's polar night, so PAR is ....

Enter your answer

Wrap-up

What are the 3 main reasons (in your opinion) that make phytoplankton an important part of Earth ecosystem?

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……
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……
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……
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Under the microscope

Let's say you've collected your samples. Observe selected phytoplankton "under the microscope" (zoom in). Which one do you find the most interesting and why? You can search additional information regarding selected species. Please note that not only phytoplankton can be viewed on this website.

LINK:
https://askabiologist.asu.edu/sites/default/files/ZoomifyHTML5/fragilariopsisCylindrusPhytoplankton.html