Marine Microbiology in the Oligotrophic Ocean

SMILE High School Teacher Workshop
Giovannoni Lab
August 5th, 2019

Oregon State University

Expected Learning Outcomes

- The ocean is the largest biome on Earth and it is full of life.
- Microorganisms are the most abundant and important inhabitants of the ocean.
- Microbes are diverse (size, shape, and function)
- Microbes form ecosystems where their interactions impact global processes, including the carbon cycle.
- We can use models to study and conduct experiments on global processes such as the carbon cycle.

Outline of Lesson

- Marine Microbiology and Carbon Cycle introduction presentation
- Expert Groups
- Modeling presentation
- Explain *Oligotrophic* Simulation
- *Oligotrophic* Simulation 1, 2, and 3
- Conclusions


Arctic Ocean
Greenland Sea
Kara Sea
Laptev Sea
Beaufort Sea
Baffin Bay
Barents Sea
East Siberian Sea
Norwegian Sea
Hudson Bay
Labrador Sea
Gulf of Alaska
North Sea
Sea of Okhotsk
Bering Sea
North Pacific Ocean
North Atlantic Ocean
Med. Sea
North Pacific Ocean
East China Sea
Gulf of Mexico
Caribbean Sea
Bay of Bengal
South China Sea
Arabian Sea
Coral Sea
South Atlantic Ocean
Indian Ocean
South Pacific Ocean
Tasman Sea
© 2007 Geology.com


Arctic Ocean
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Kara Sea
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Norwegian Sea
Hudson Bay
Labrador Sea
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Sea of Okhotsk
Bering Sea
Is the Earth BLUE or GREEN?
North Pacific Ocean
North Atlantic Ocean
Med. Sea
East China Sea
North Pacific Ocean
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Caribbean Sea
Arabian Sea
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South China Sea
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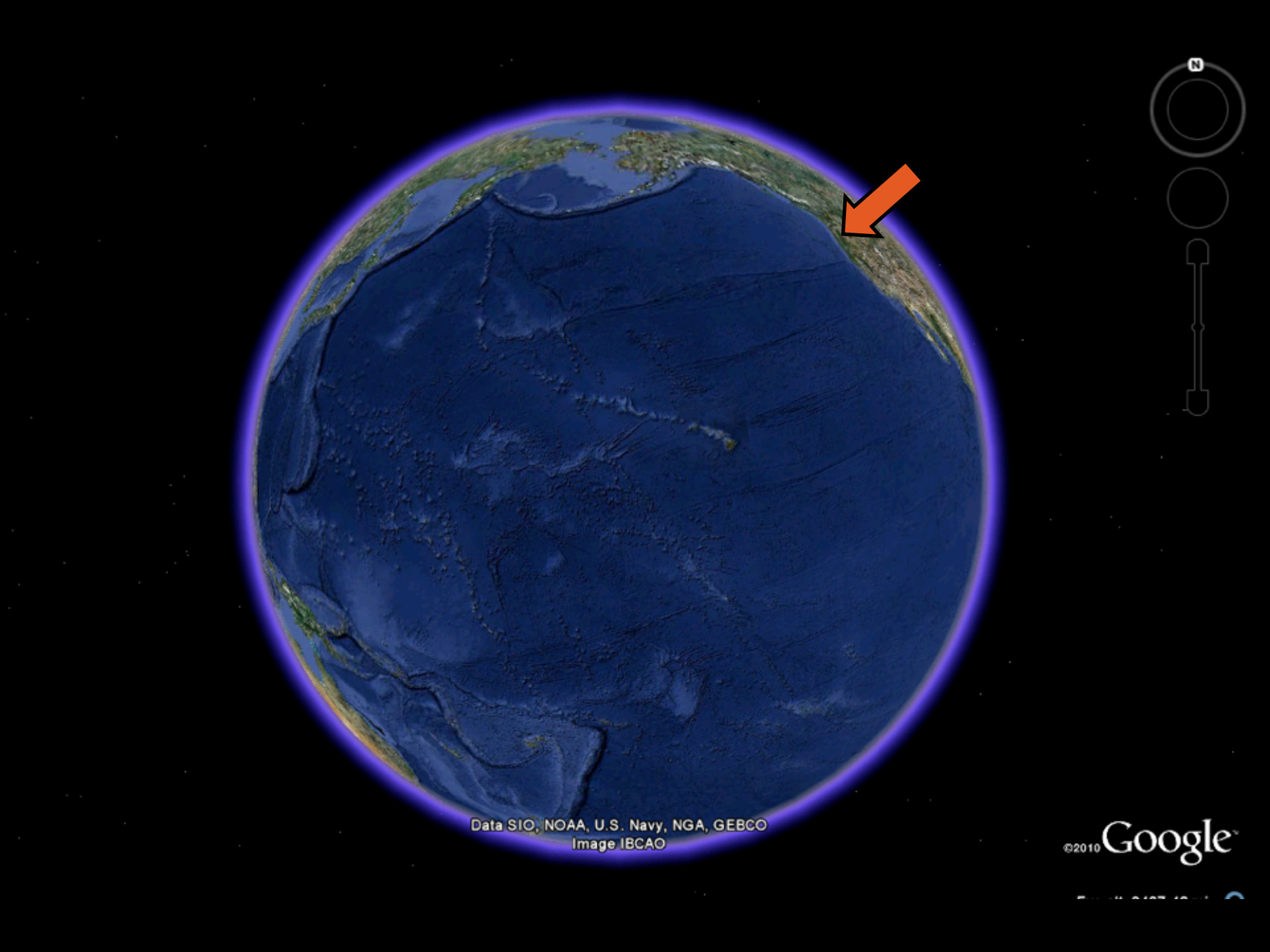
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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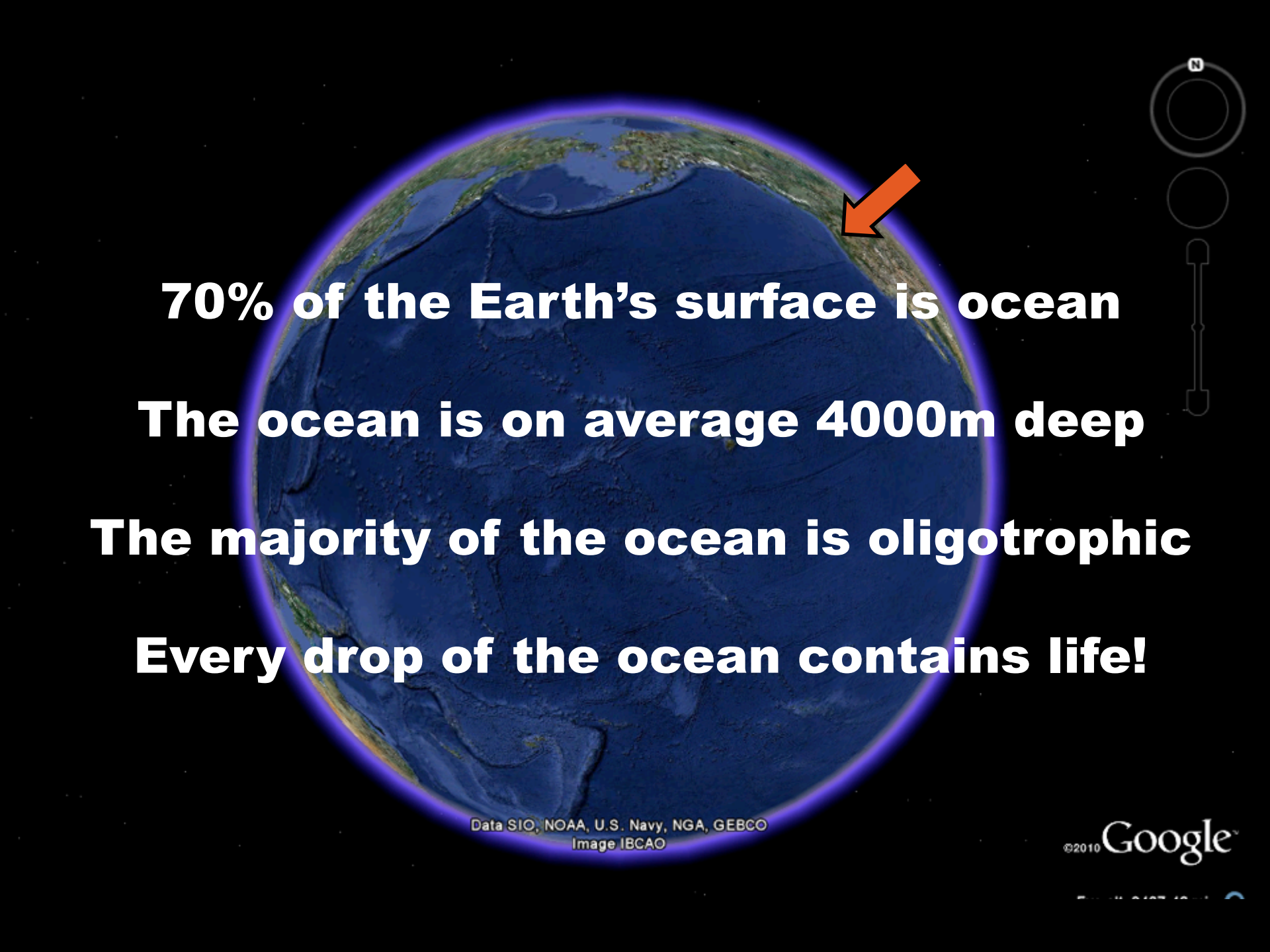
70% of the Earth's surface is ocean
The ocean is on average 4000m deep
The majority of the ocean is oligotrophic
Every drop of the ocean contains life!
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
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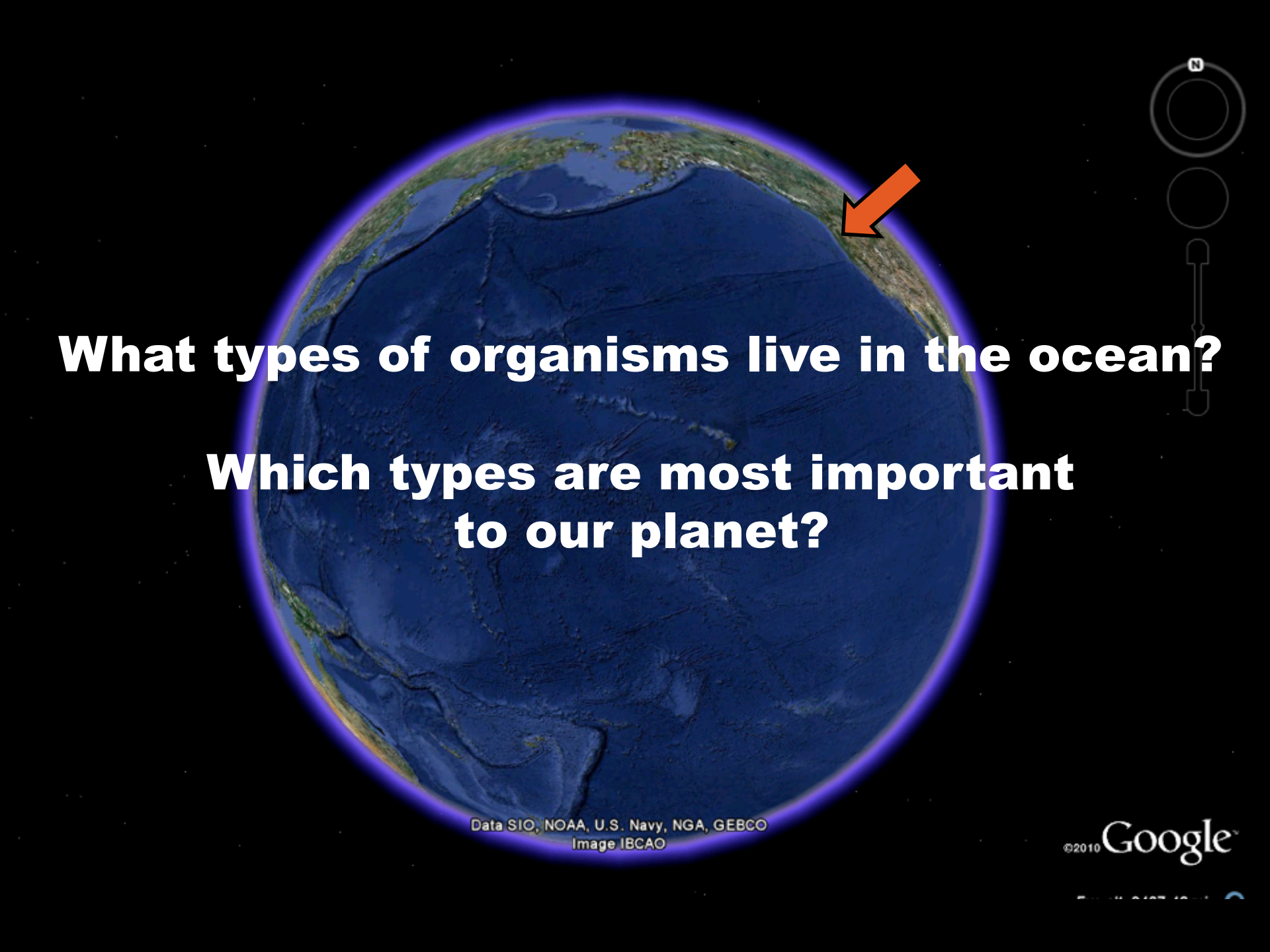
What types of organisms live in the ocean?
Which types are most important to our planet?
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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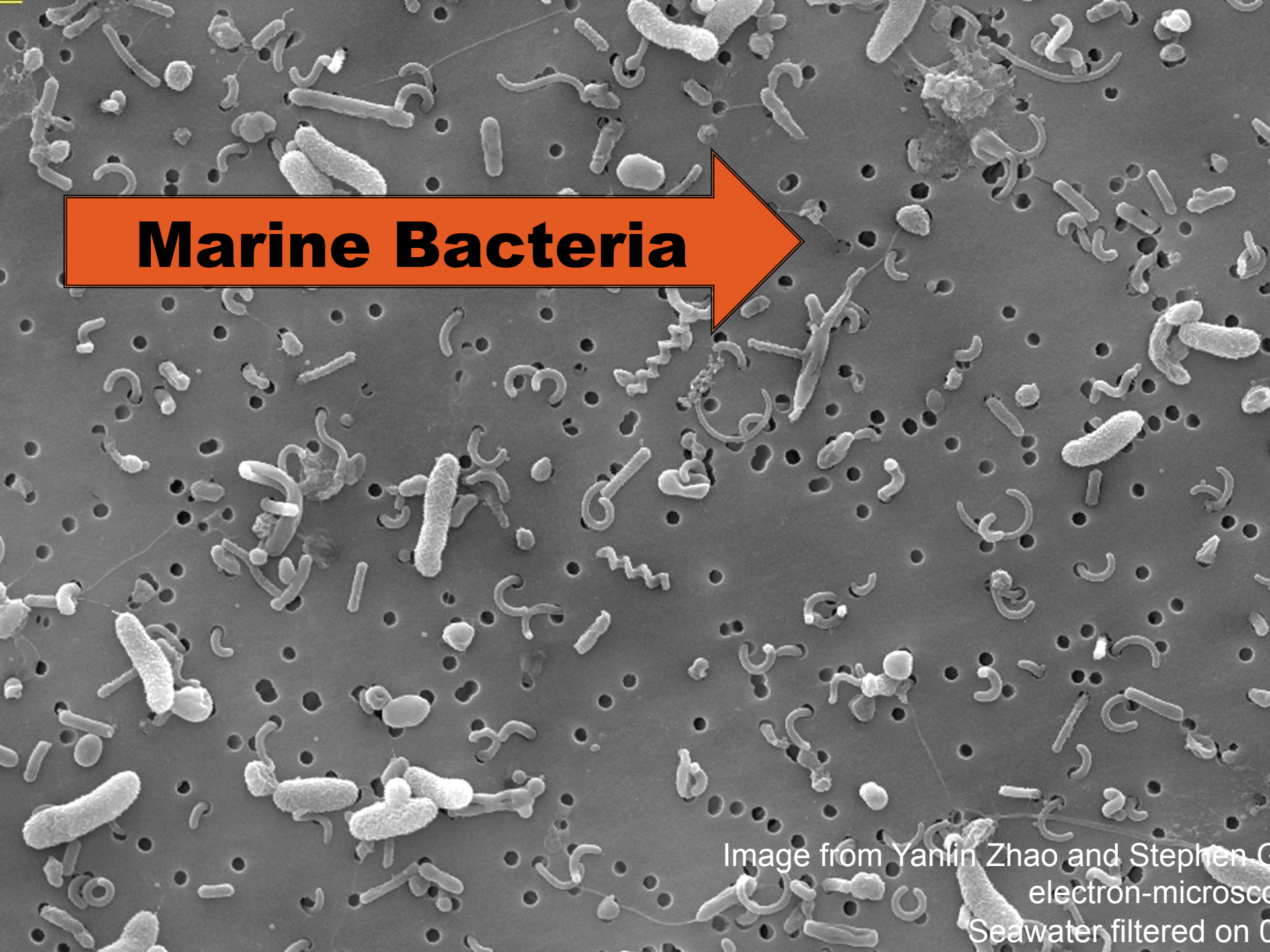
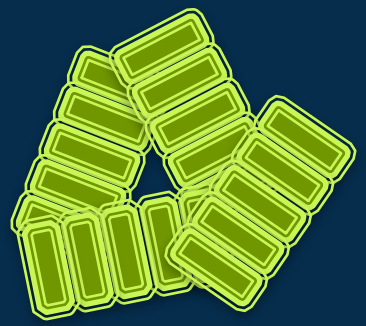


Image from Yanlin Zhao and Stephen C
electron-microsco
Seawater filtered on 0

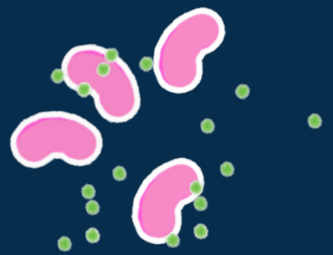
Fun Fact:
In 1 drop of seawater there are *1 million* bacteria!

Marine Microbial Vocab!

Oligotrophic: an area of the ocean with low nutrient concentrations



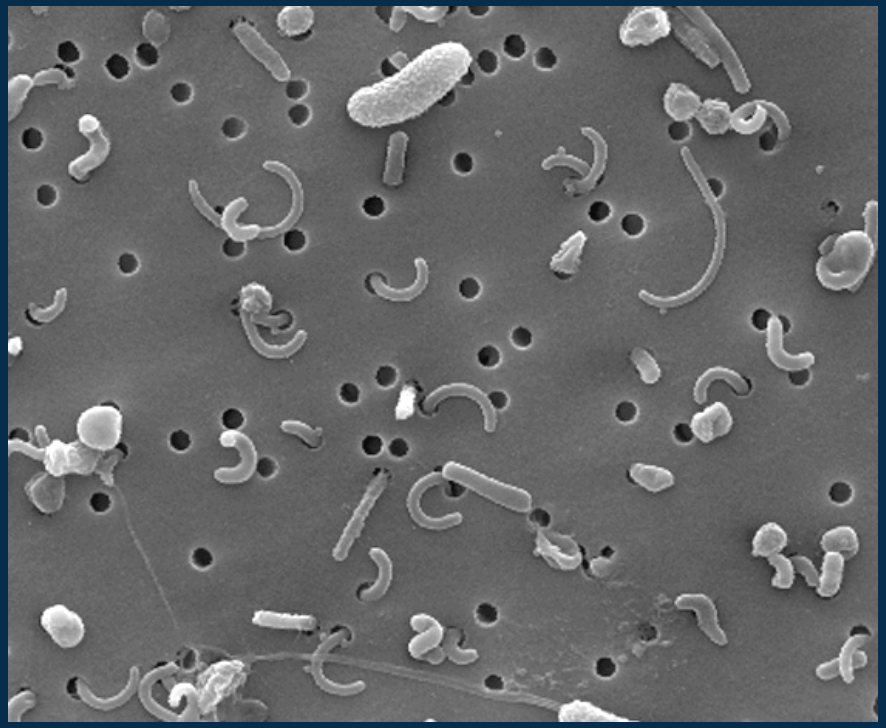
Phytoplankton:
-Create biomass from the sun (like plants)
-example: *Prochlorococcus*

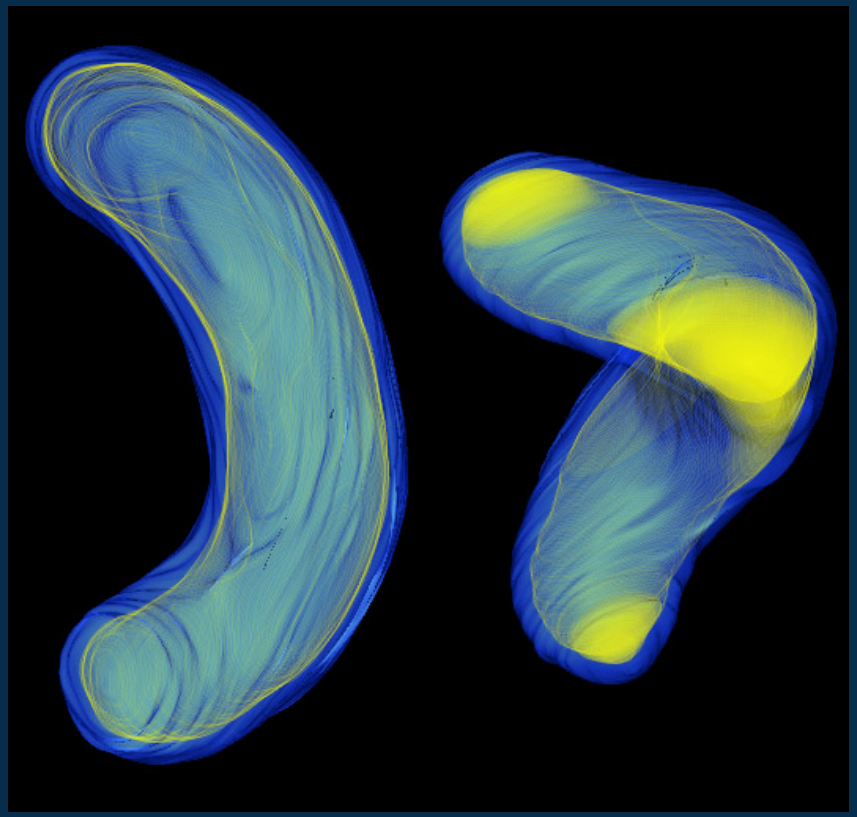


Bacterioplankton:
-Use biomass produced by phytoplankton to survive
-example: SAR11

Zooplankton:
-Consume both phytoplankton and bacterioplankton
-example: copepod

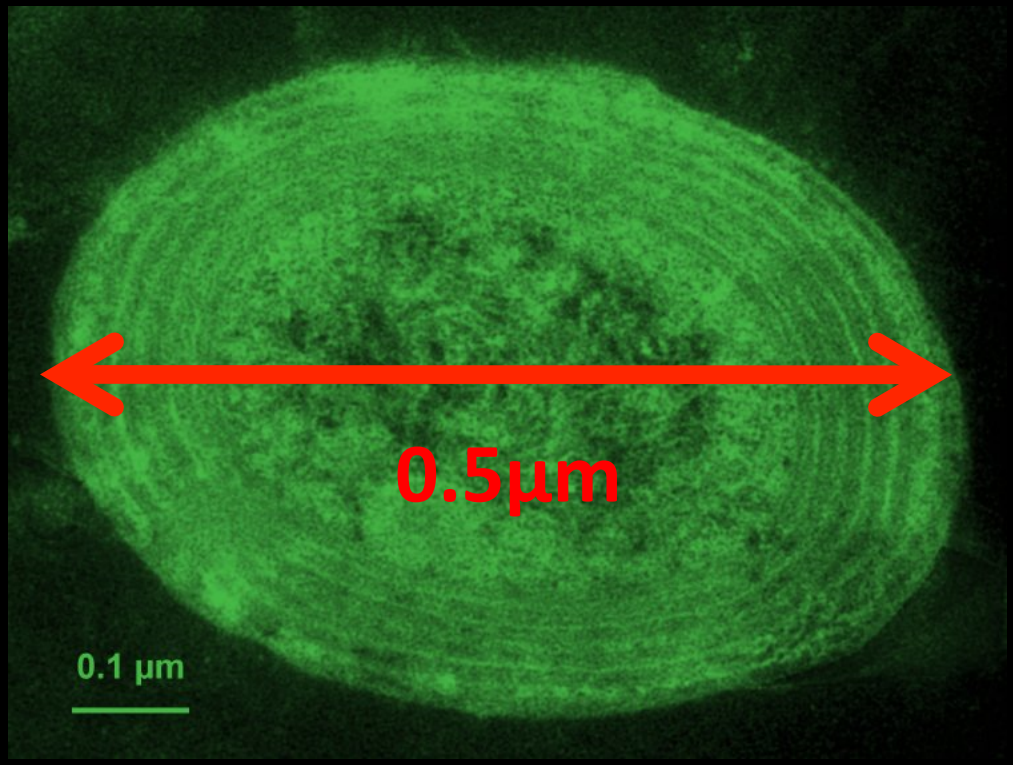
SAR11 is the most abundant bacterioplankton



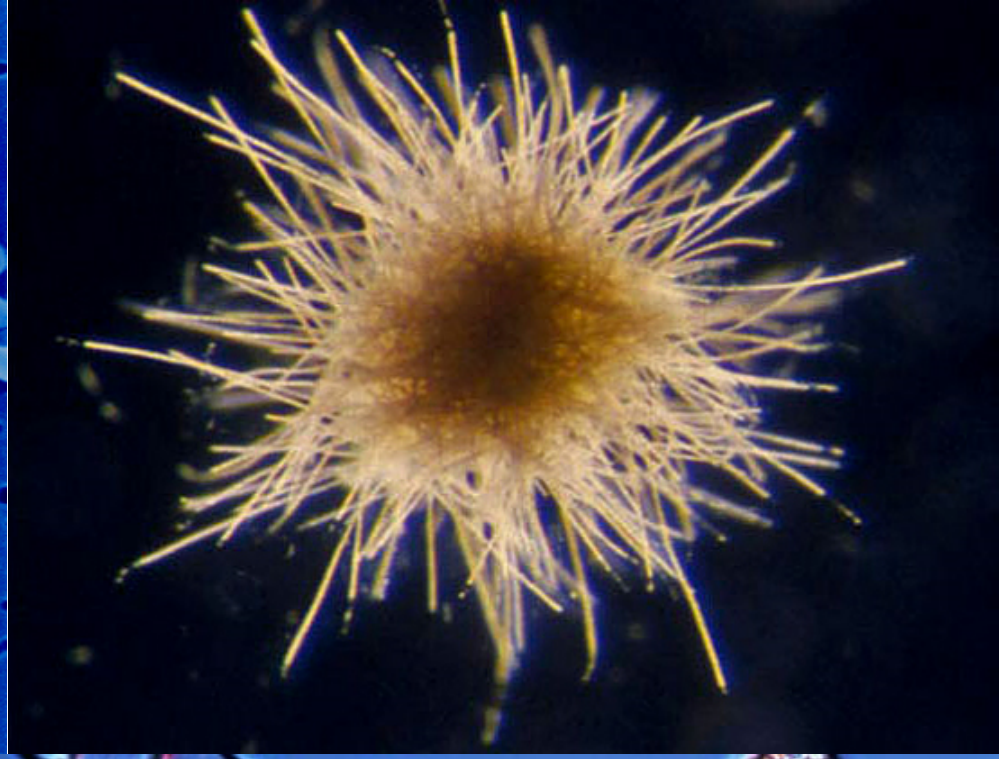


Discovered in the Giovannoni Lab at OSU

Prochlorococcus is an important phytoplankton



200 in a row = 1 human hair!



Marine microbes are small and diverse

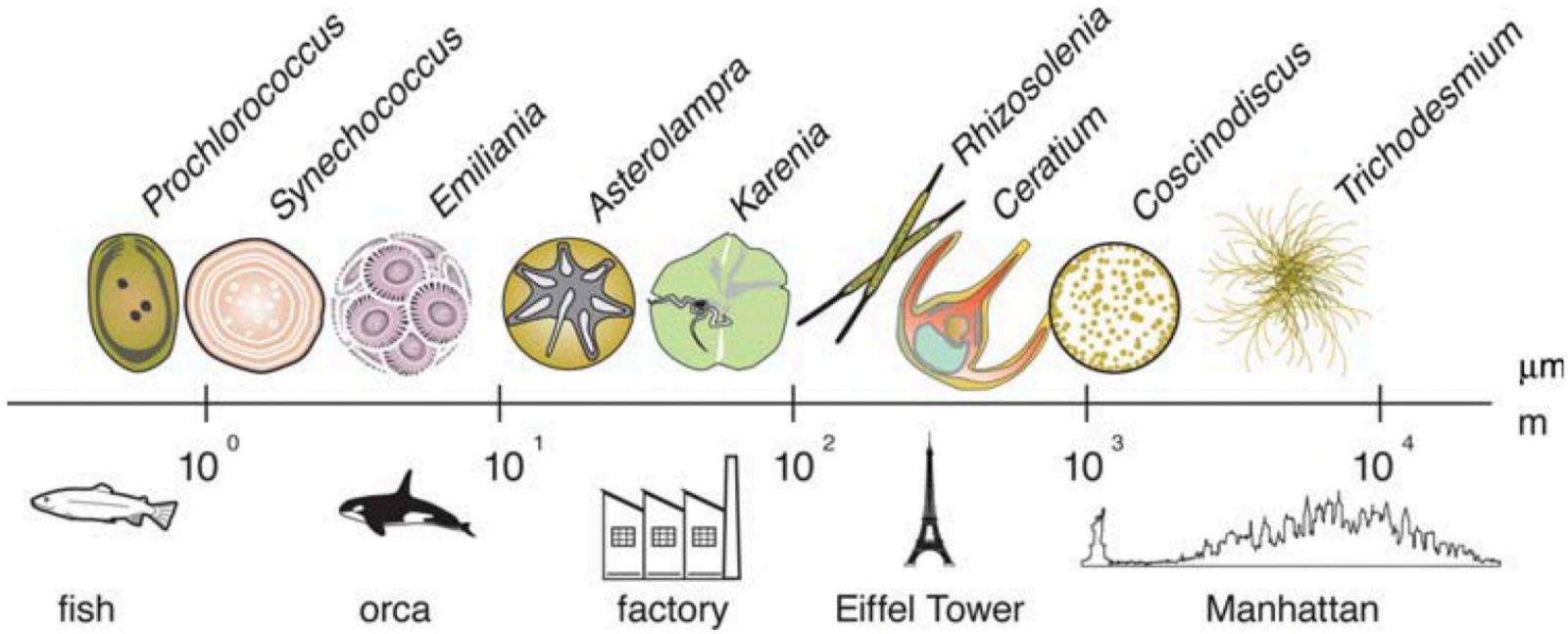
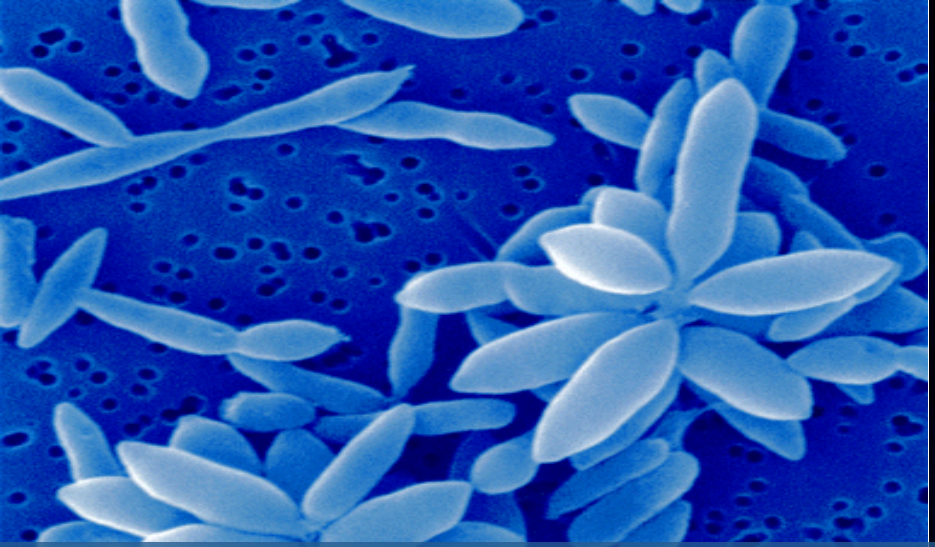


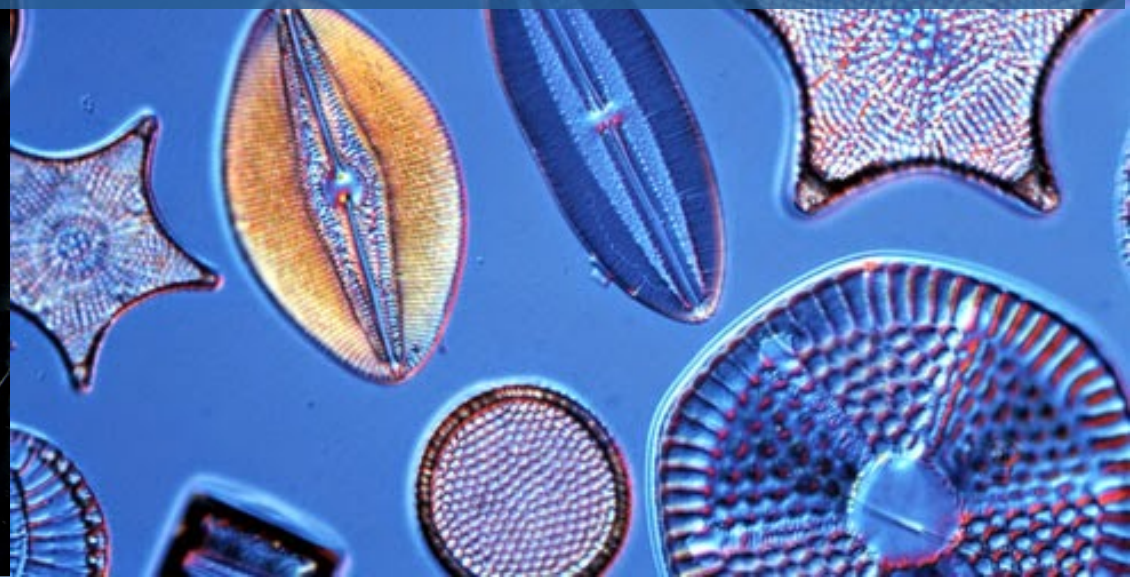
Fig. 2. A comparison of the size range (maximum linear dimension) of phytoplankton relative to macroscopic objects.

Finkel et al., 2010

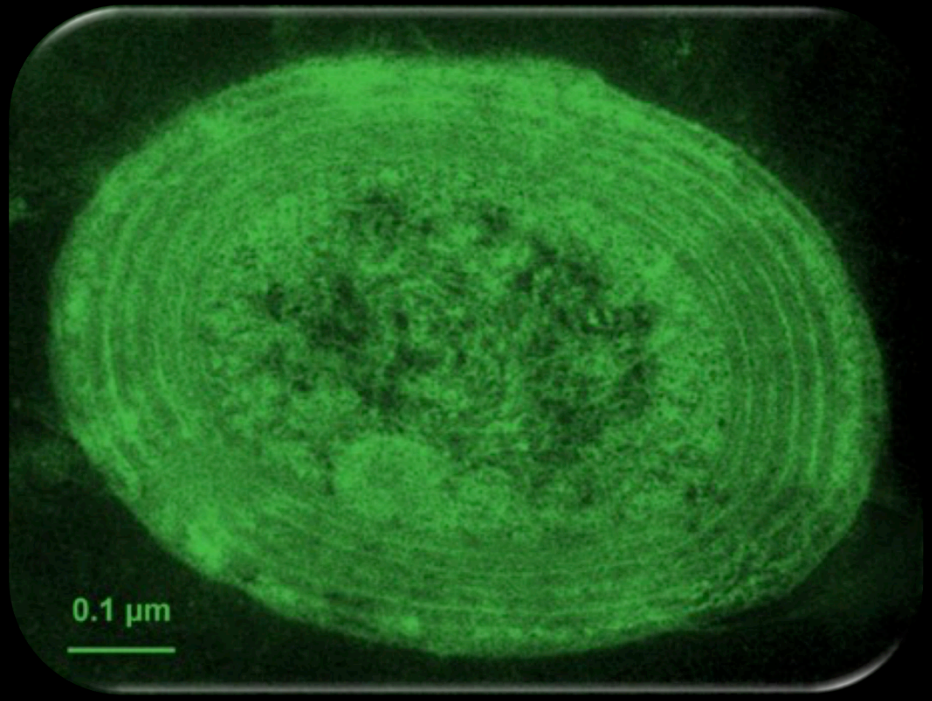


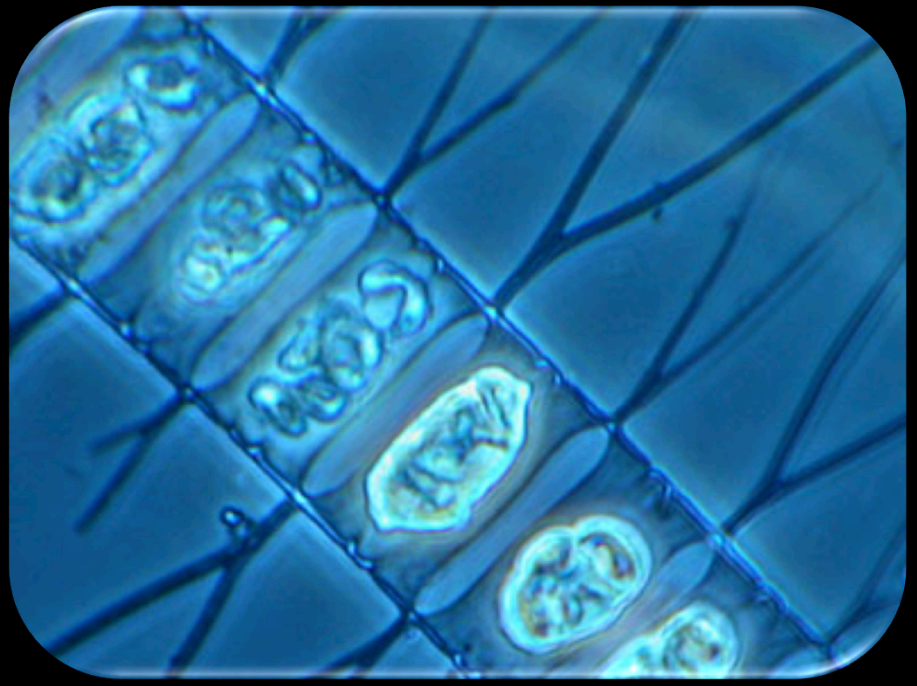
What are these marine microbes doing?

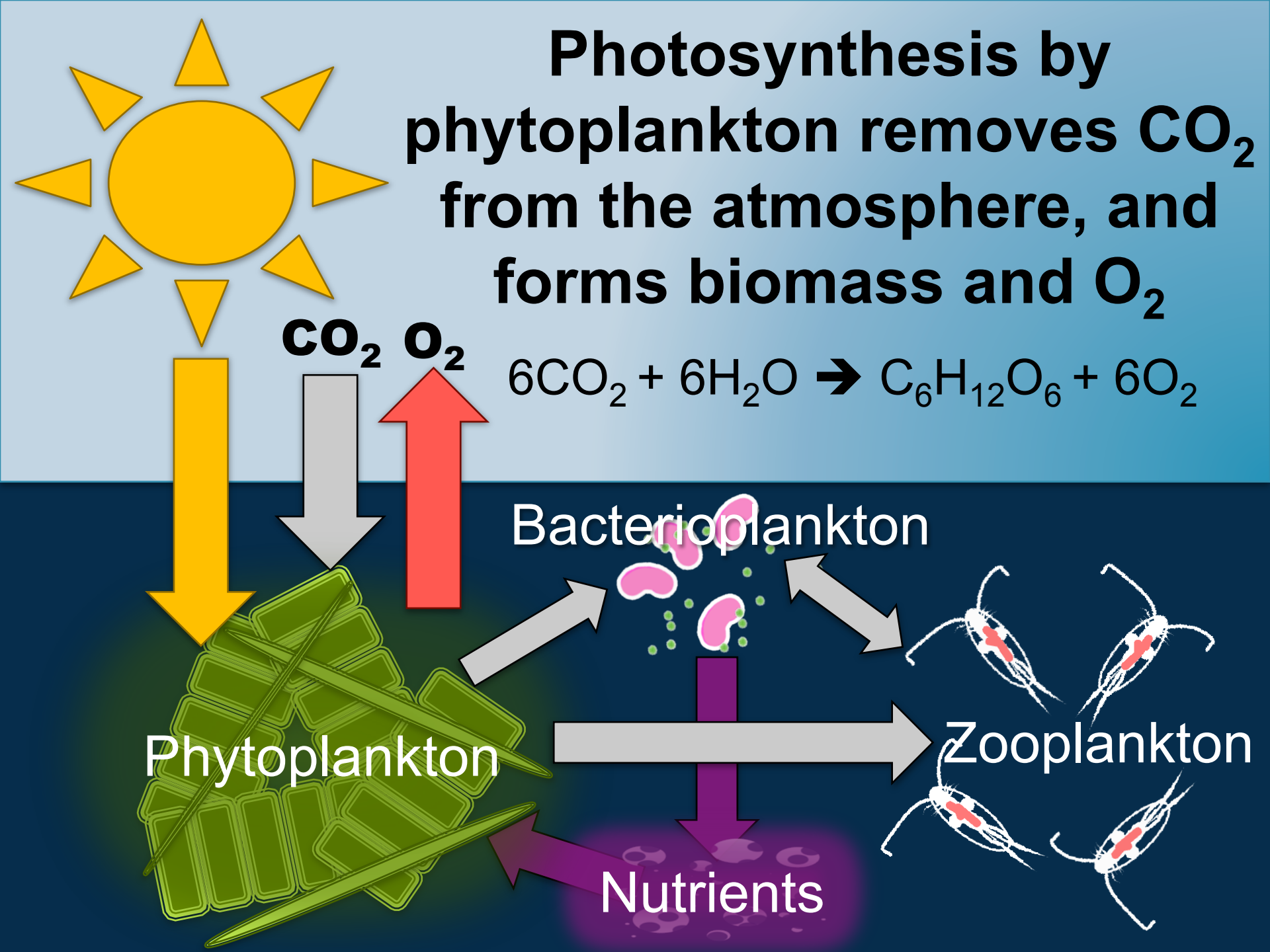
Why should we care about them?



50% of all oxygen we breathe is produced by microbes in the ocean!!

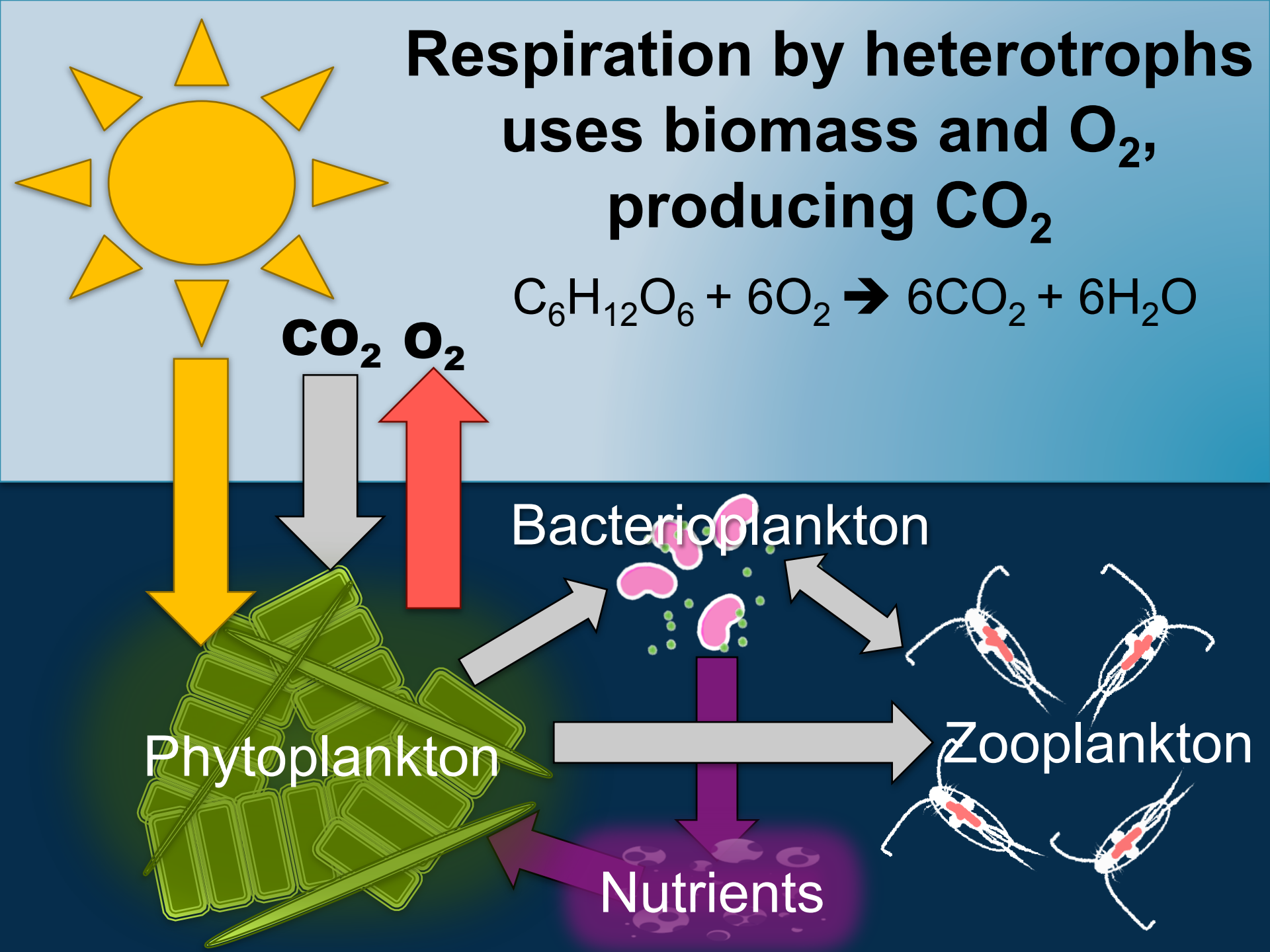





Photosynthesis by phytoplankton removes CO_2 from the atmosphere, and forms biomass and O_2
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
CO_2 O_2
Bacterioplankton
Phytoplankton
Zooplankton
Nutrients

Respiration by heterotrophs uses biomass and O_2, producing CO_2

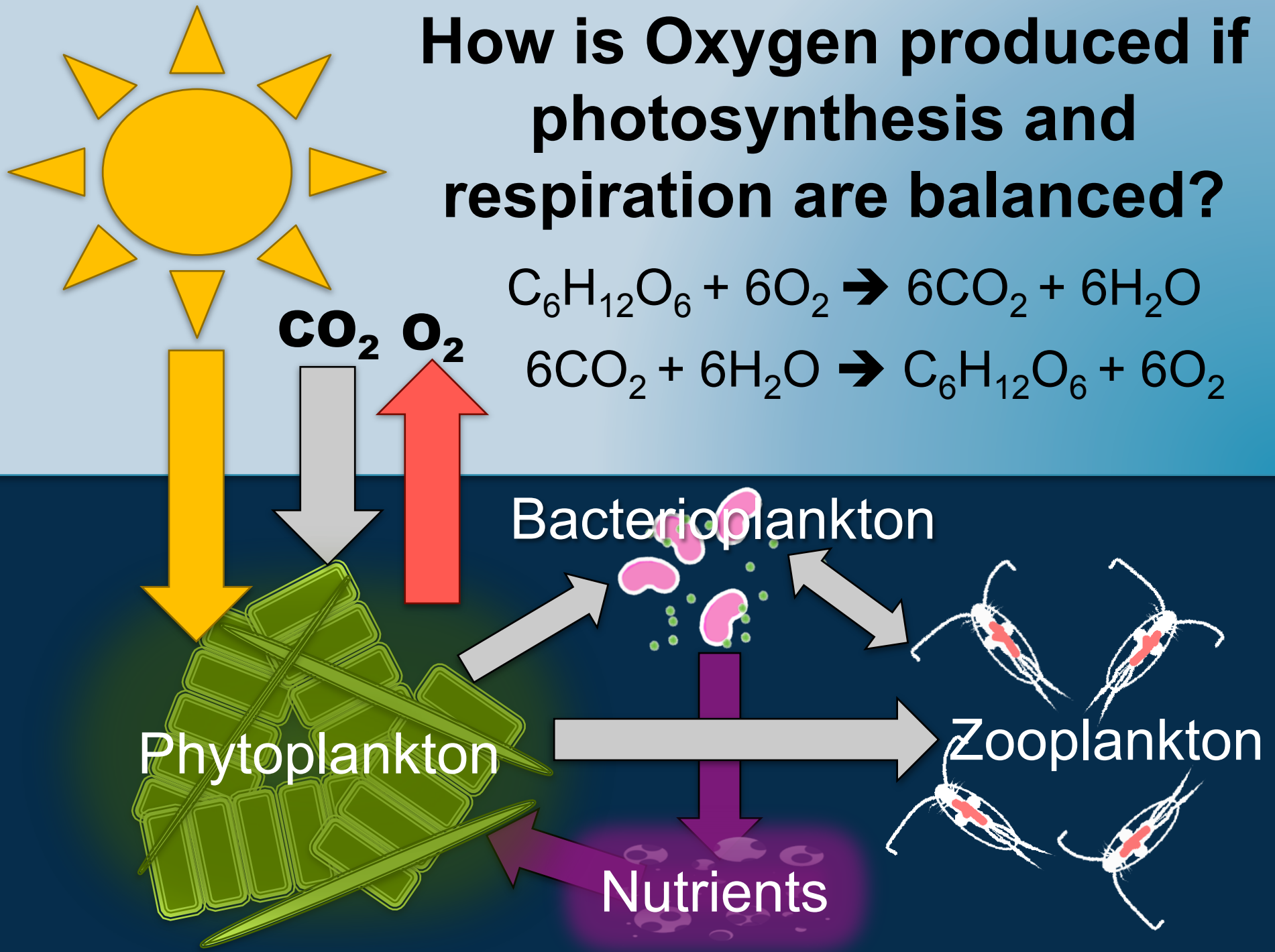
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

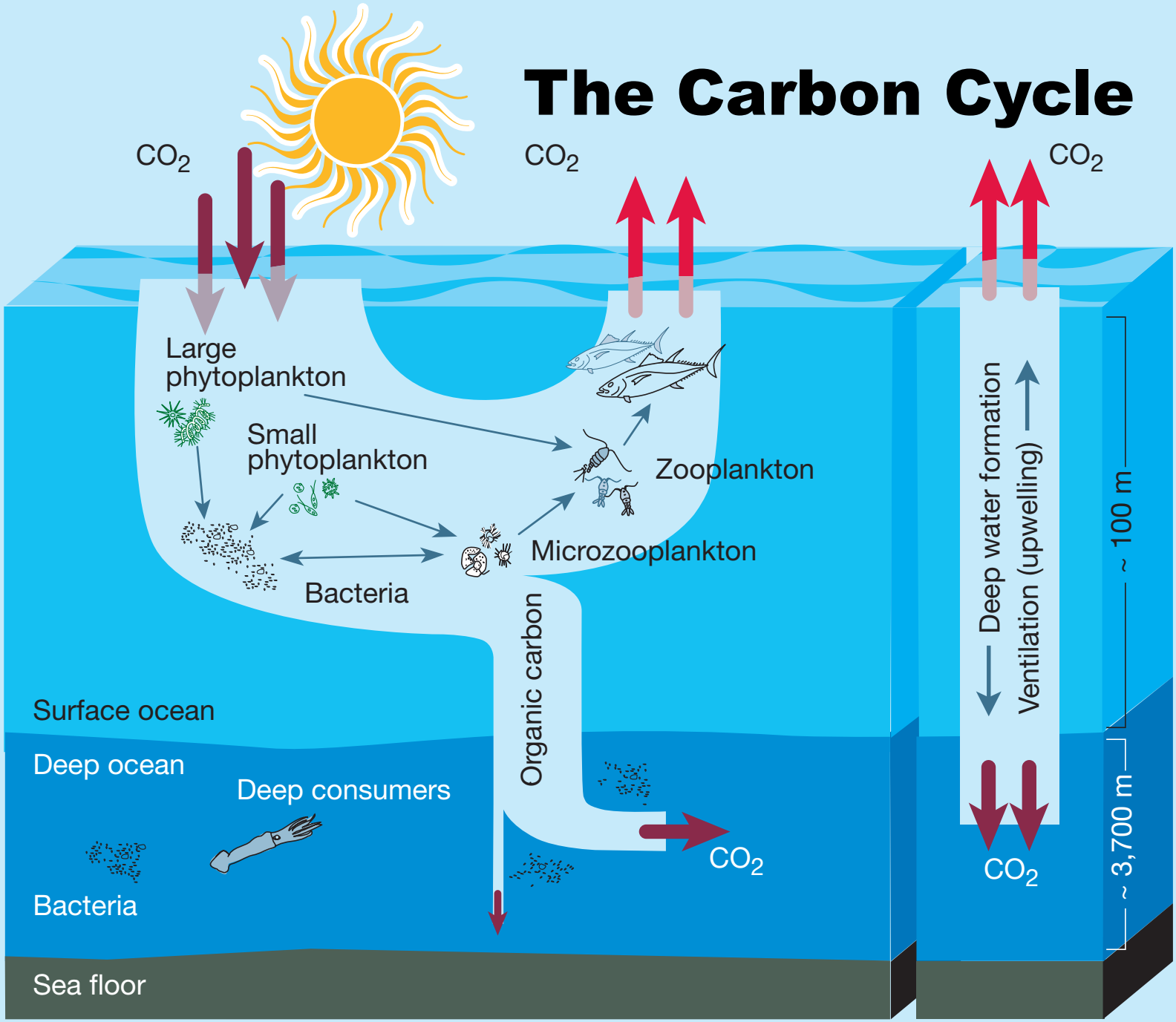


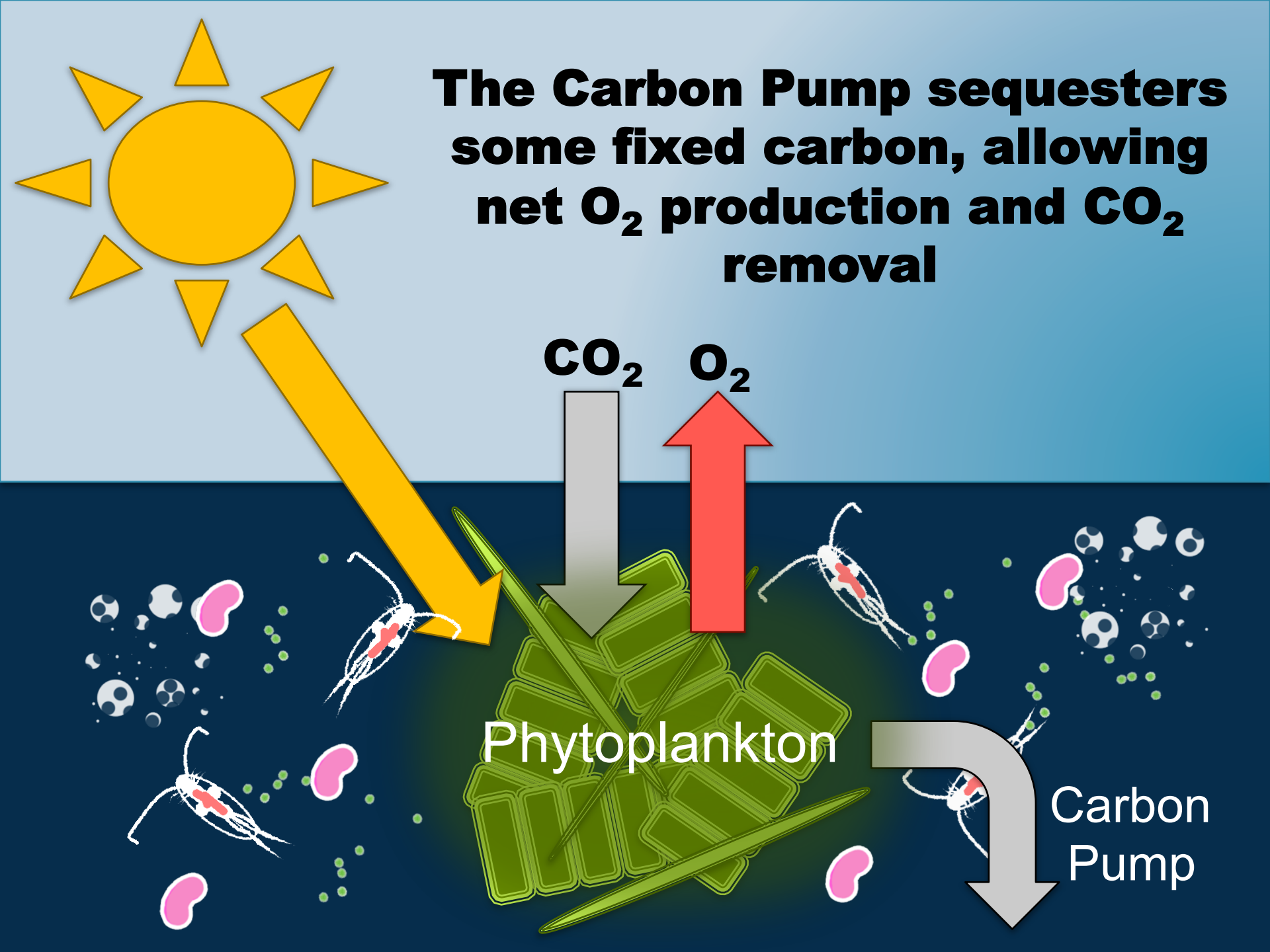
How is Oxygen produced if photosynthesis and respiration are balanced?

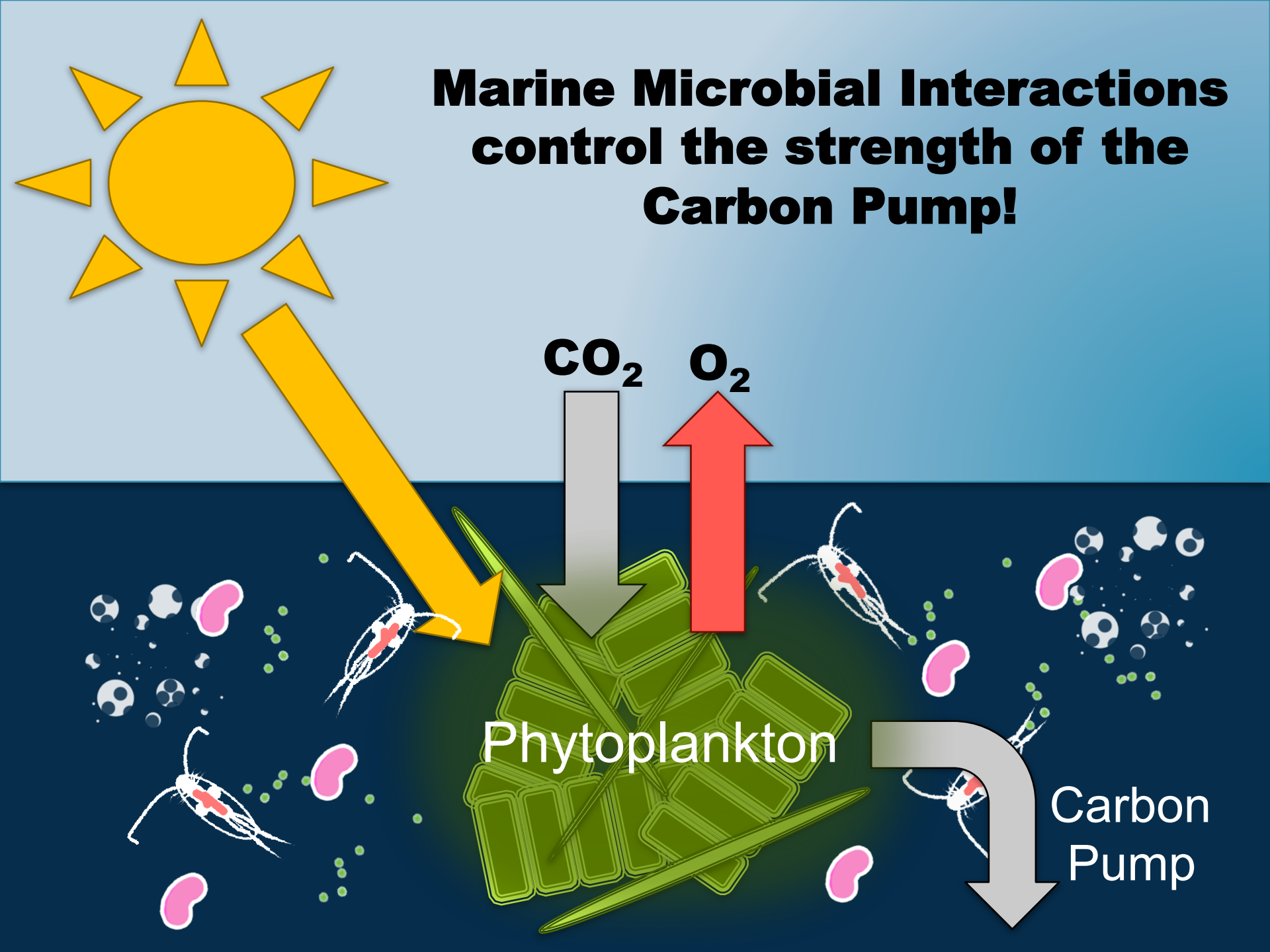
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$




The Carbon Cycle
CO_2
CO_2
CO_2
Large phytoplankton
Small phytoplankton
Zooplankton
Microzooplankton
Bacteria
Organic carbon
Deep water formation
Ventilation (upwelling)
~ 100 m
~ 3,700 m
Surface ocean
Deep ocean
Deep consumers
Bacteria
Sea floor
CO_2
CO_2


The Carbon Pump sequesters some fixed carbon, allowing net O_2 production and CO_2 removal
CO_2
O_2
Phytoplankton
Carbon Pump

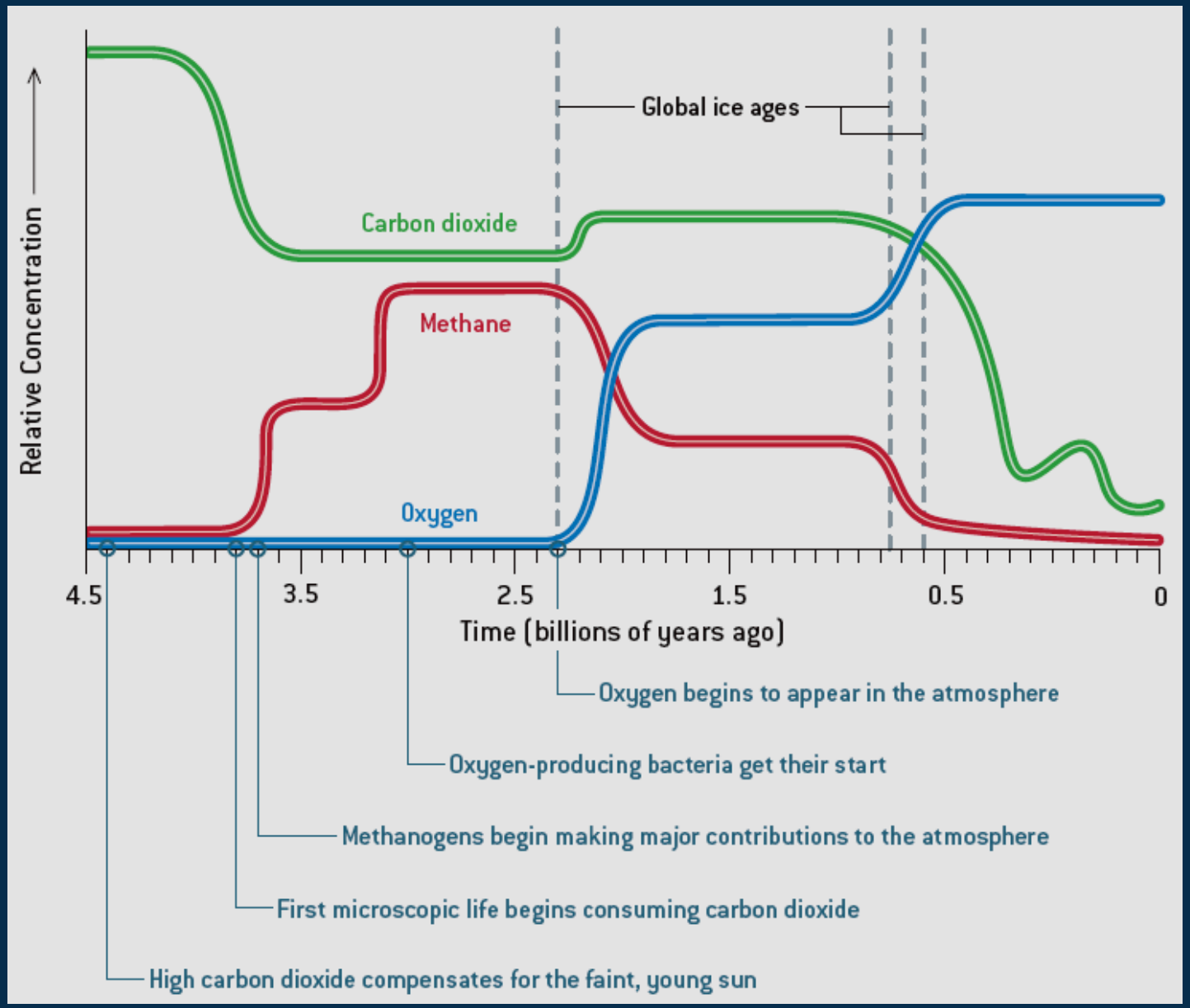

Marine Microbial Interactions control the strength of the Carbon Pump!
CO_2
O_2
Phytoplankton
Carbon Pump

Why is there so much more O_2 in the atmosphere than CO_2?

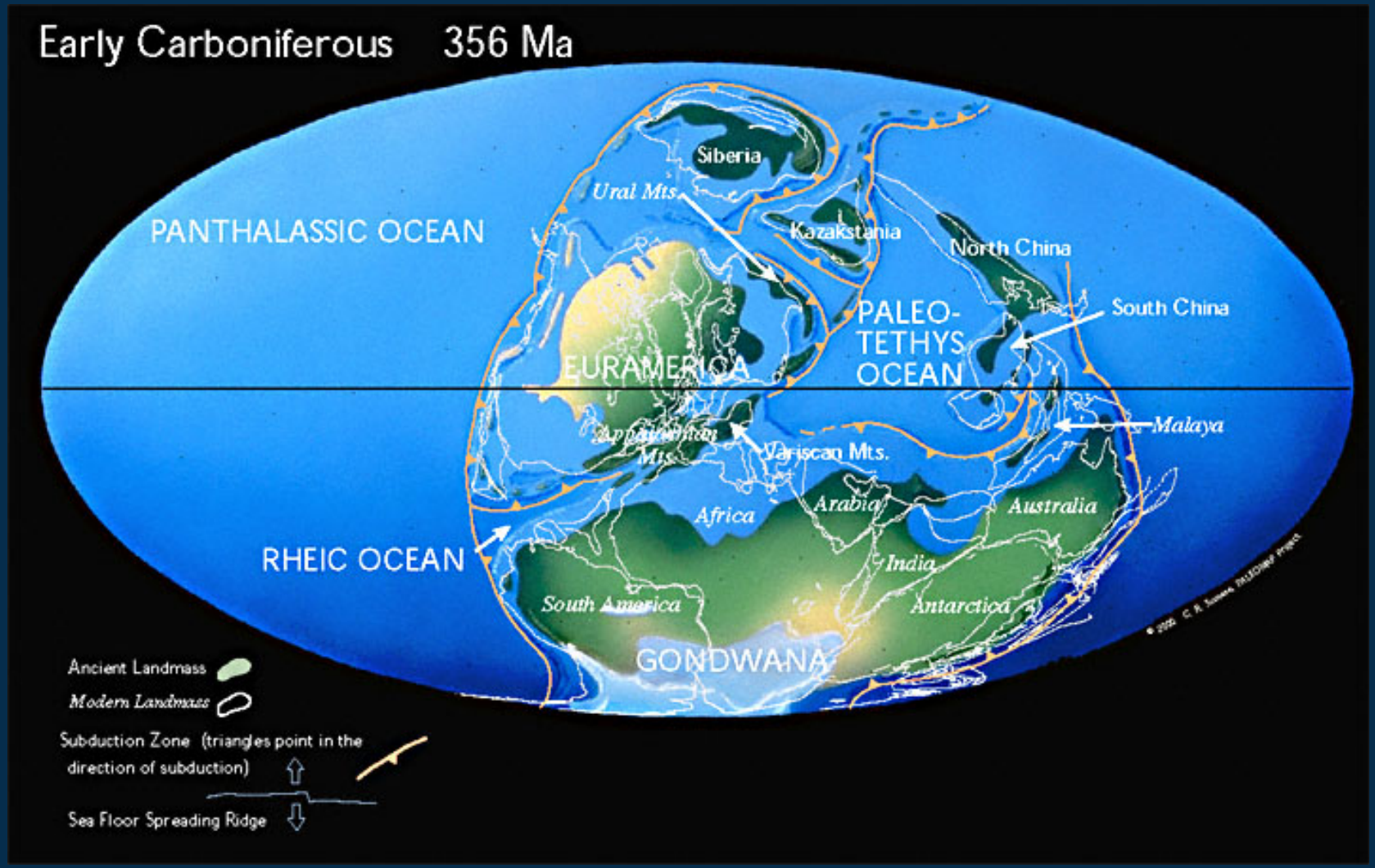
Where do fossil fuels come from?

How is all of this related to global climate change?

The Great Oxidation Event



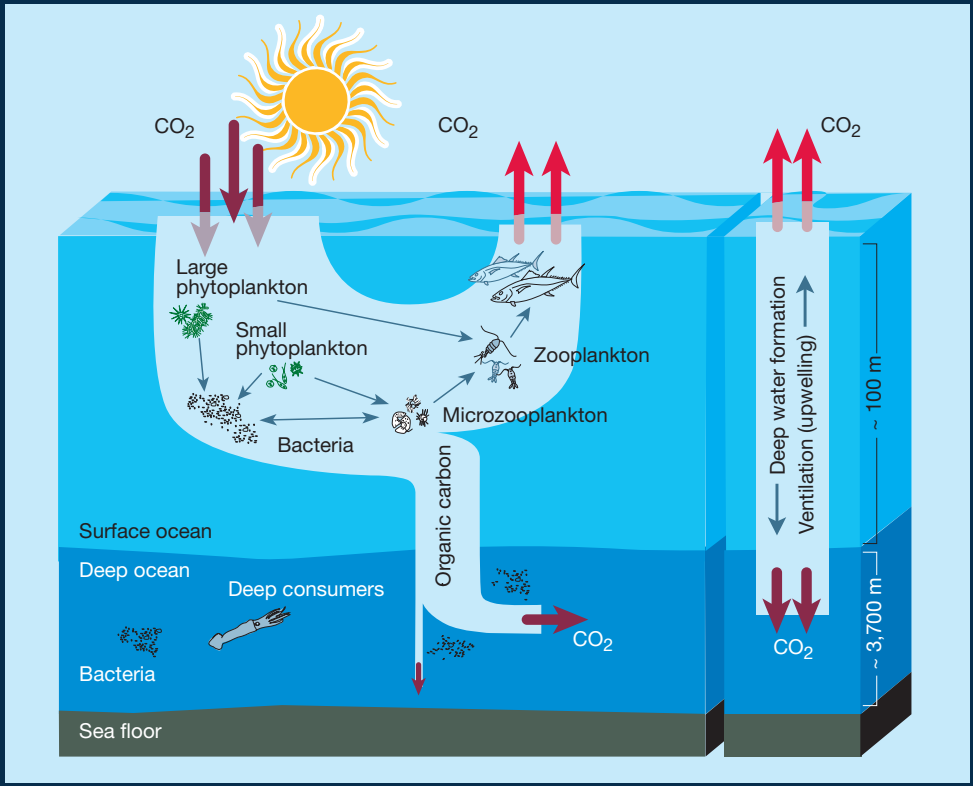
Effect of plate tectonics - productive areas in the tropics and shallow seas

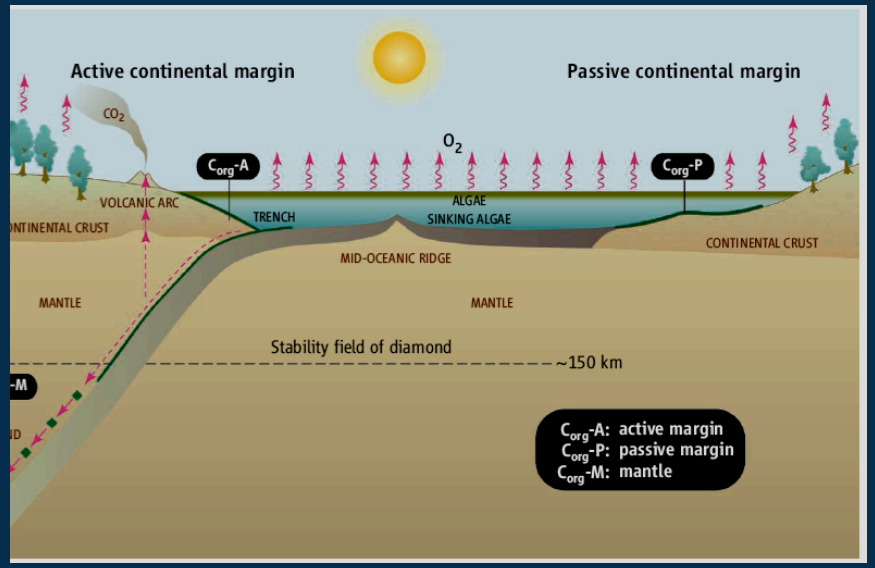


Mass carbon burial hypotheses

- This hypothesizes the locking up of more organic matter in sediments before they had a chance to decay.
- Prevalence of shallow seas in the Carboniferous Period
- Geological viewpoint – production of clays able to absorb organic matter and preserve it between the seafloor and the assembly of a supercontinent whose weathering could stimulate ocean life by adding nutrients.
- Biological viewpoint - arrival of lichens on land (also increasing weathering and the levels of nutrients in the ocean).

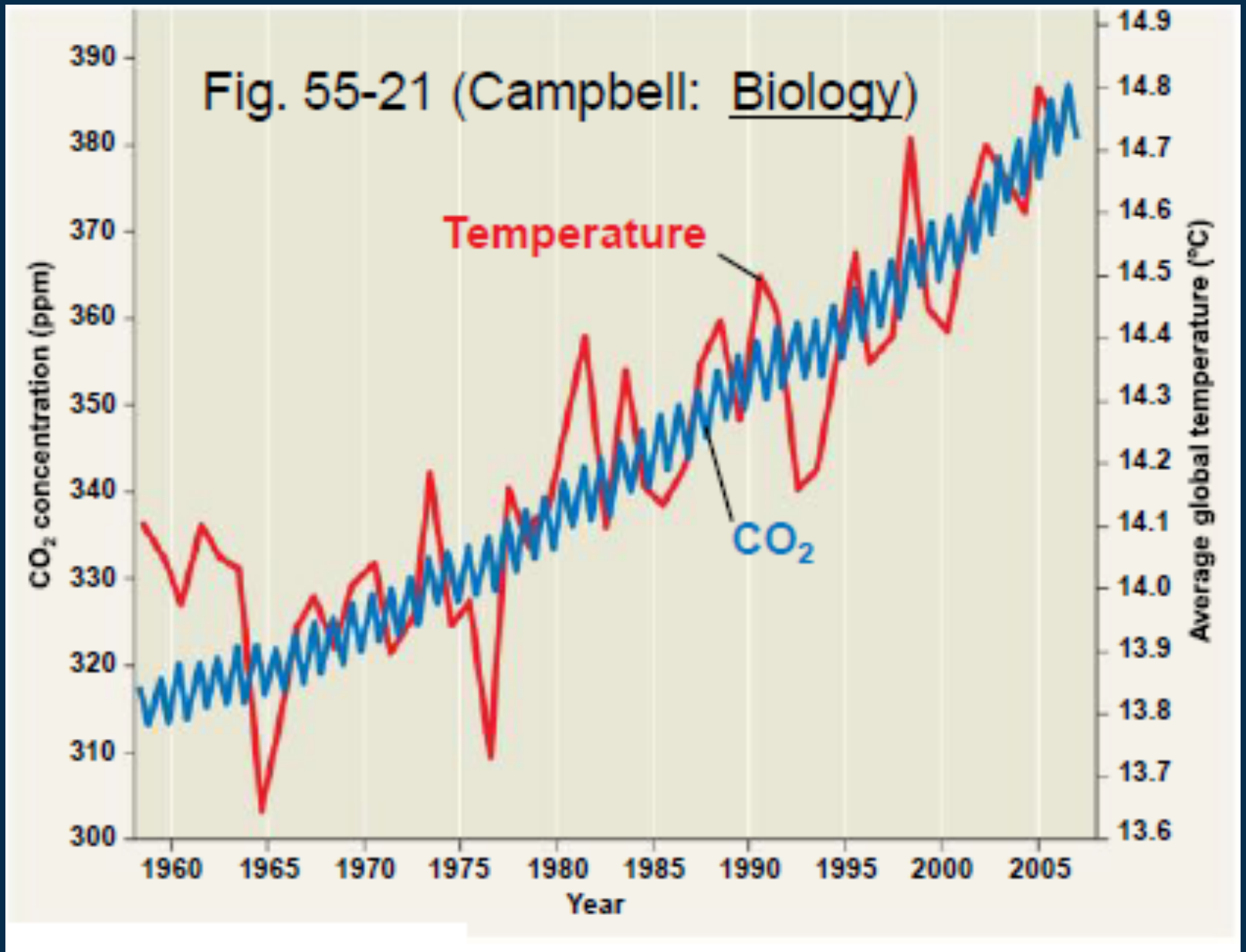
Shallow seas mean sinking carbon is buried faster, so less is respired during the sinking process





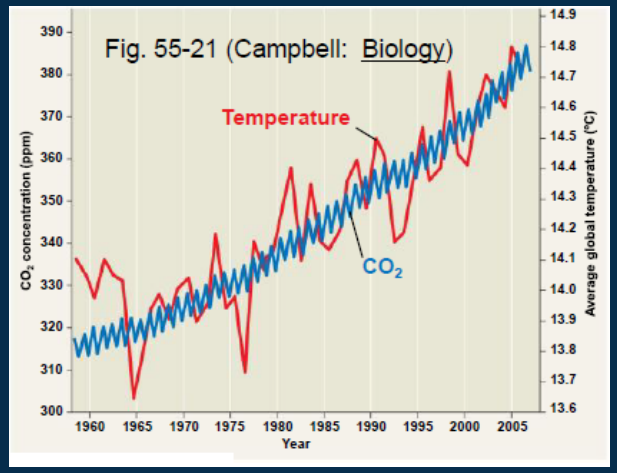
Over 100s of million years, buried carbon becomes fossil fuels!

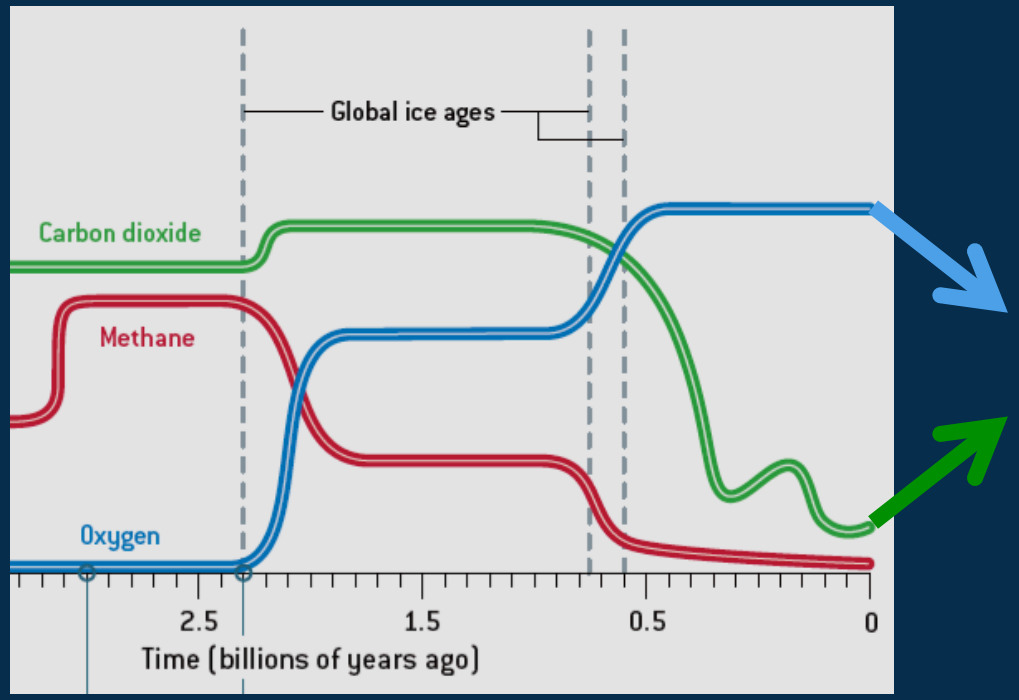
Burning fossil fuels releases CO_2 from buried carbon, causing Atmospheric CO_2 Concentrations to Increase

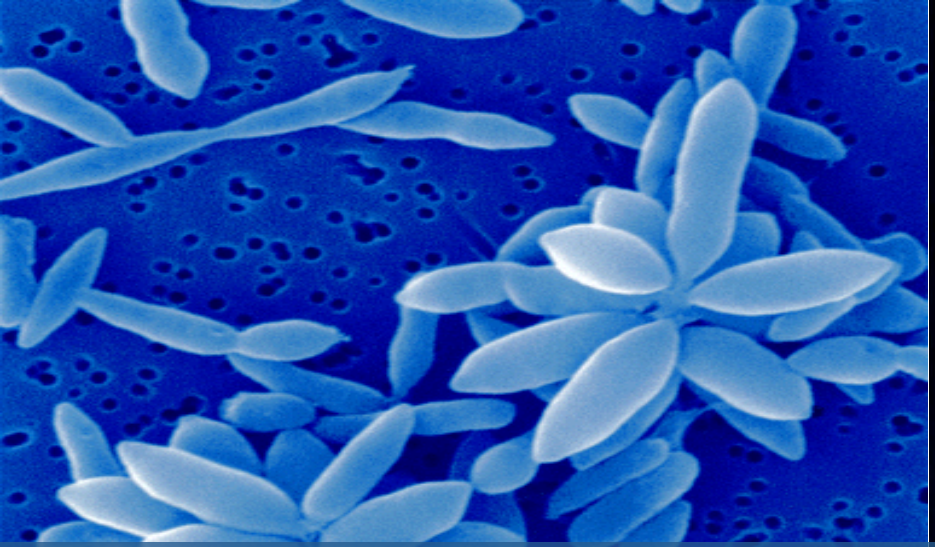


Burning Buried Sunshine

Today's average US gallon of gasoline requires approximately 90 metric tons of ancient plant matter as precursor material







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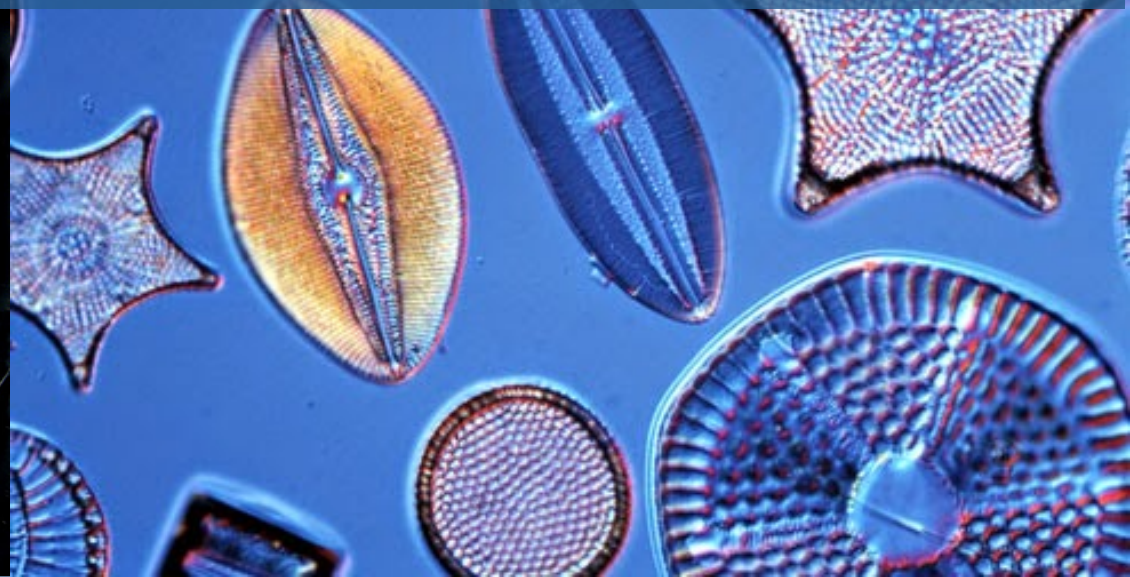

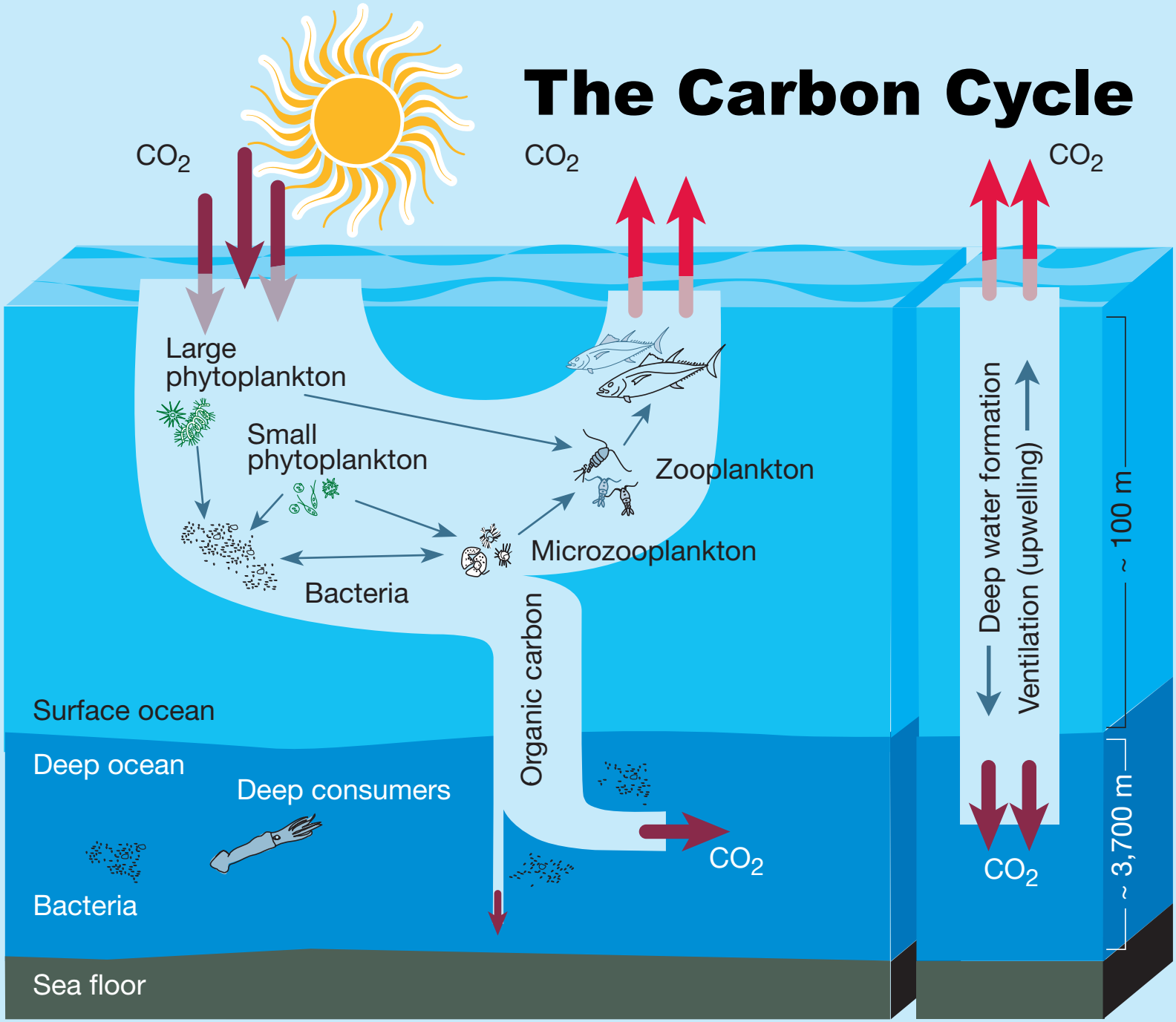
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CO_2
Large phytoplankton
Small phytoplankton
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Deep water formation
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Sea floor
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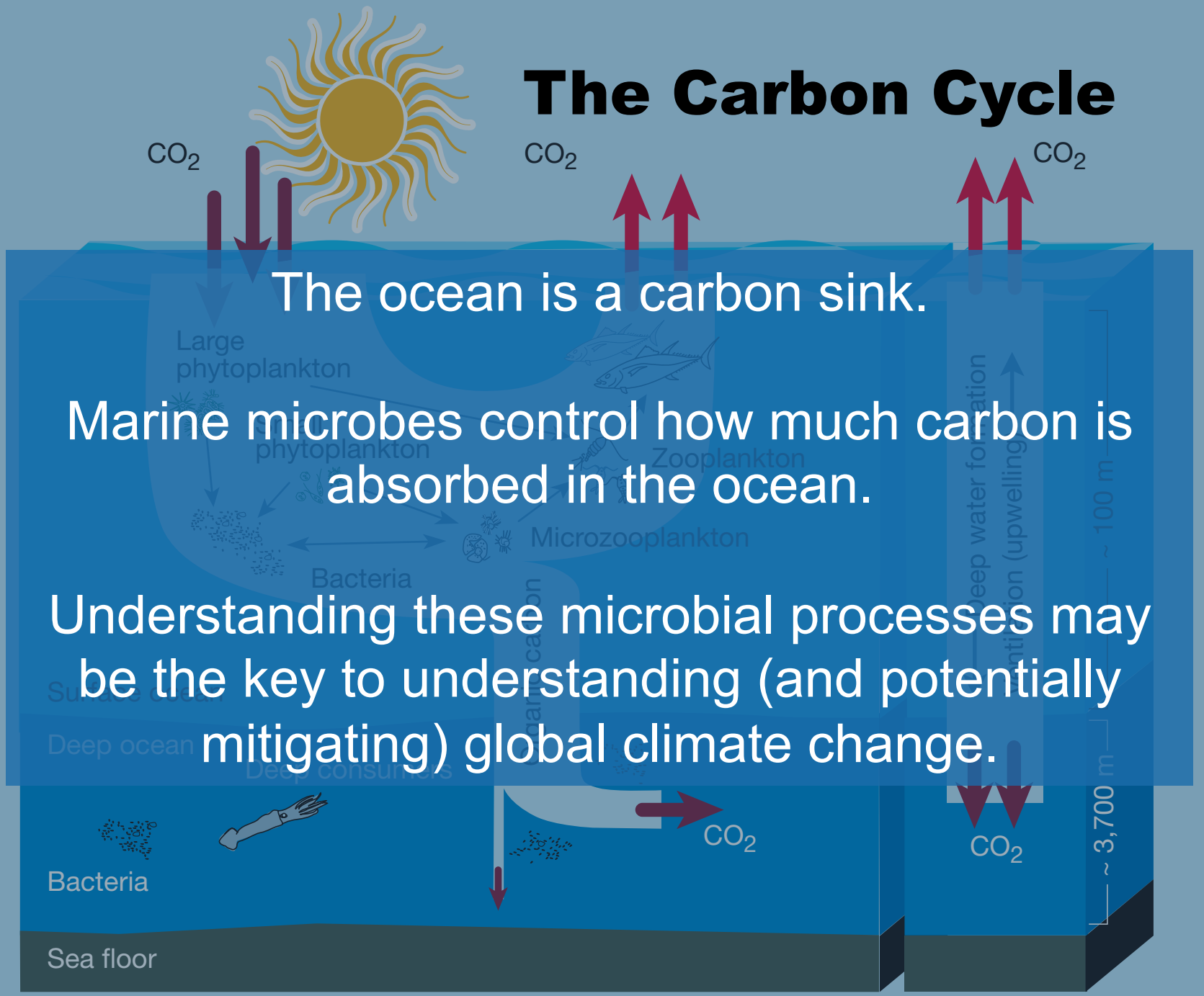
CO_2

The Carbon Cycle

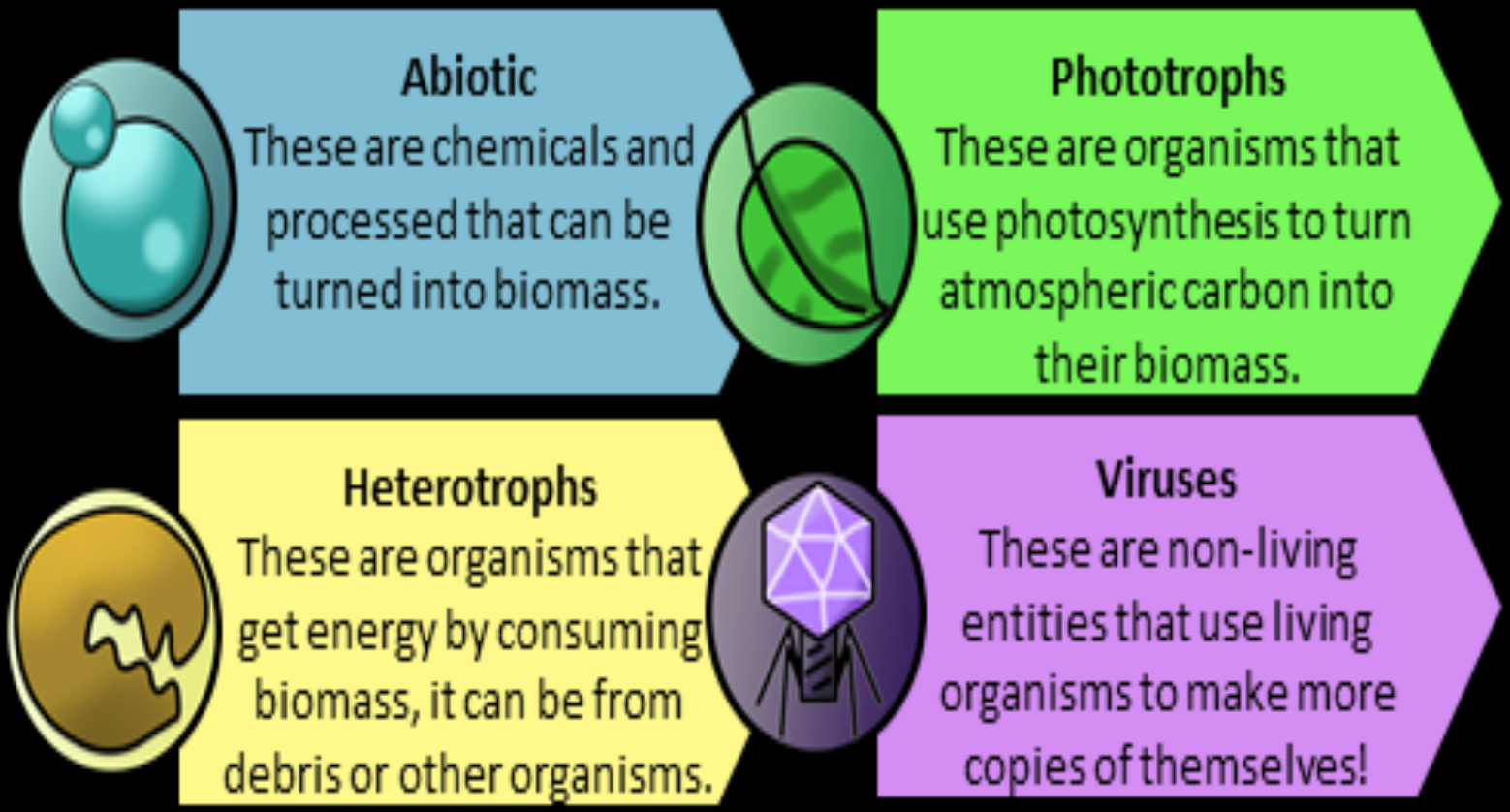


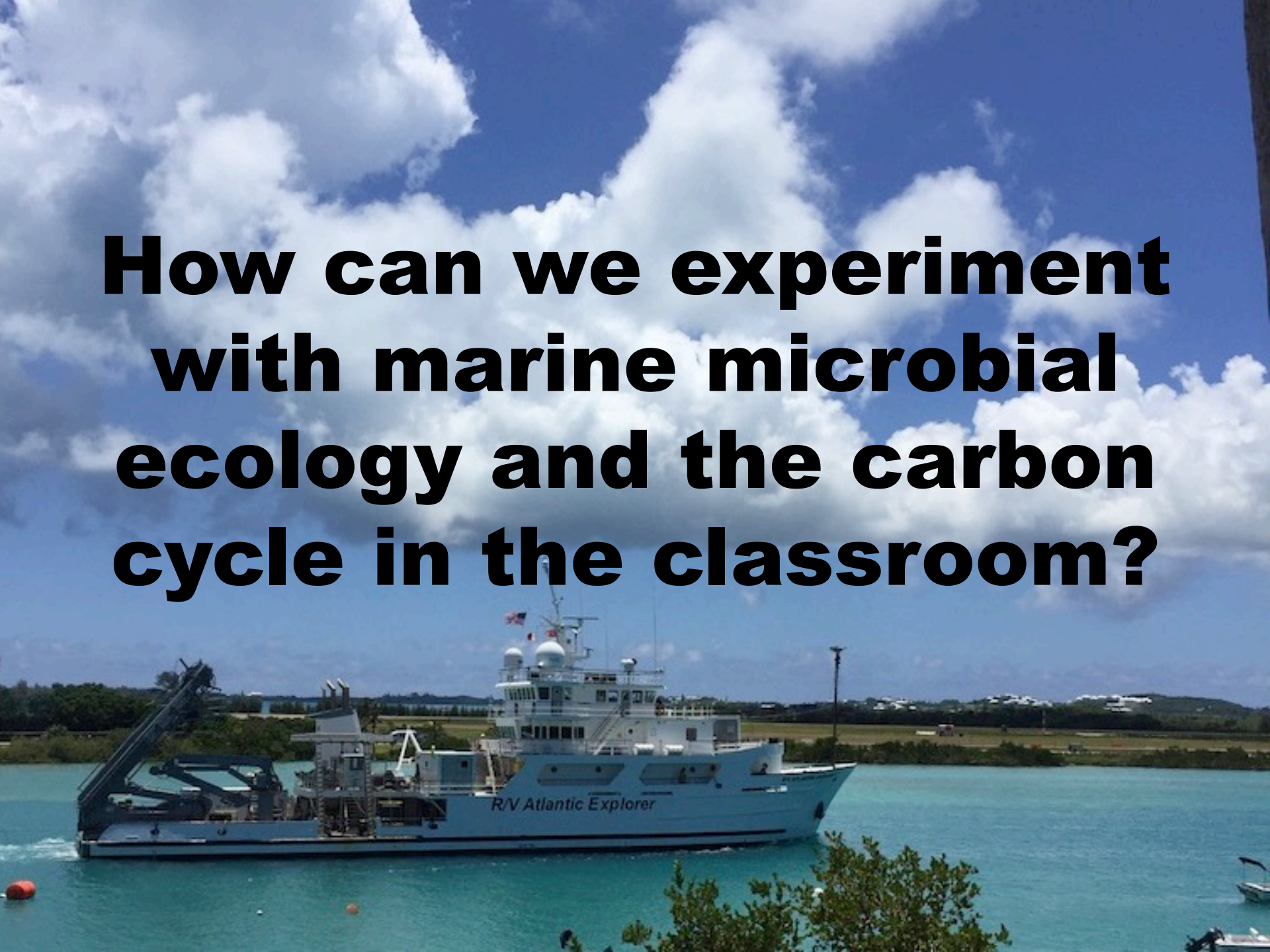
The ocean is a carbon sink.

Marine microbes control how much carbon is absorbed in the ocean.

Understanding these microbial processes may be the key to understanding (and potentially mitigating) global climate change.

Marine Microbe and Carbon Cycle Expert Groups





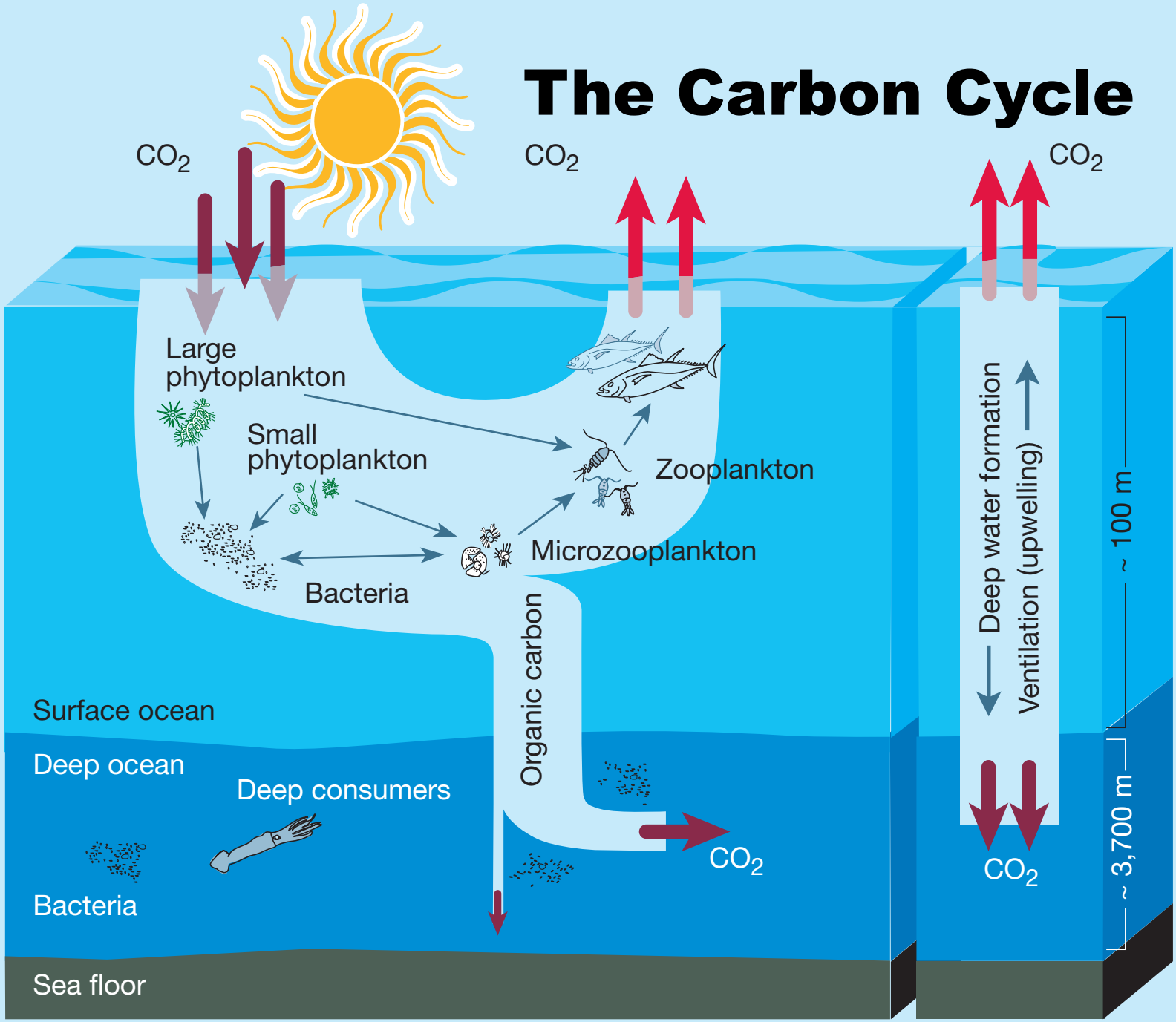
How can we experiment with marine microbial ecology and the carbon cycle in the classroom?

How can we study racecars in the classroom?

Models can be used to study systems

Models use data to recreate actual systems


Models can be used to study the ocean!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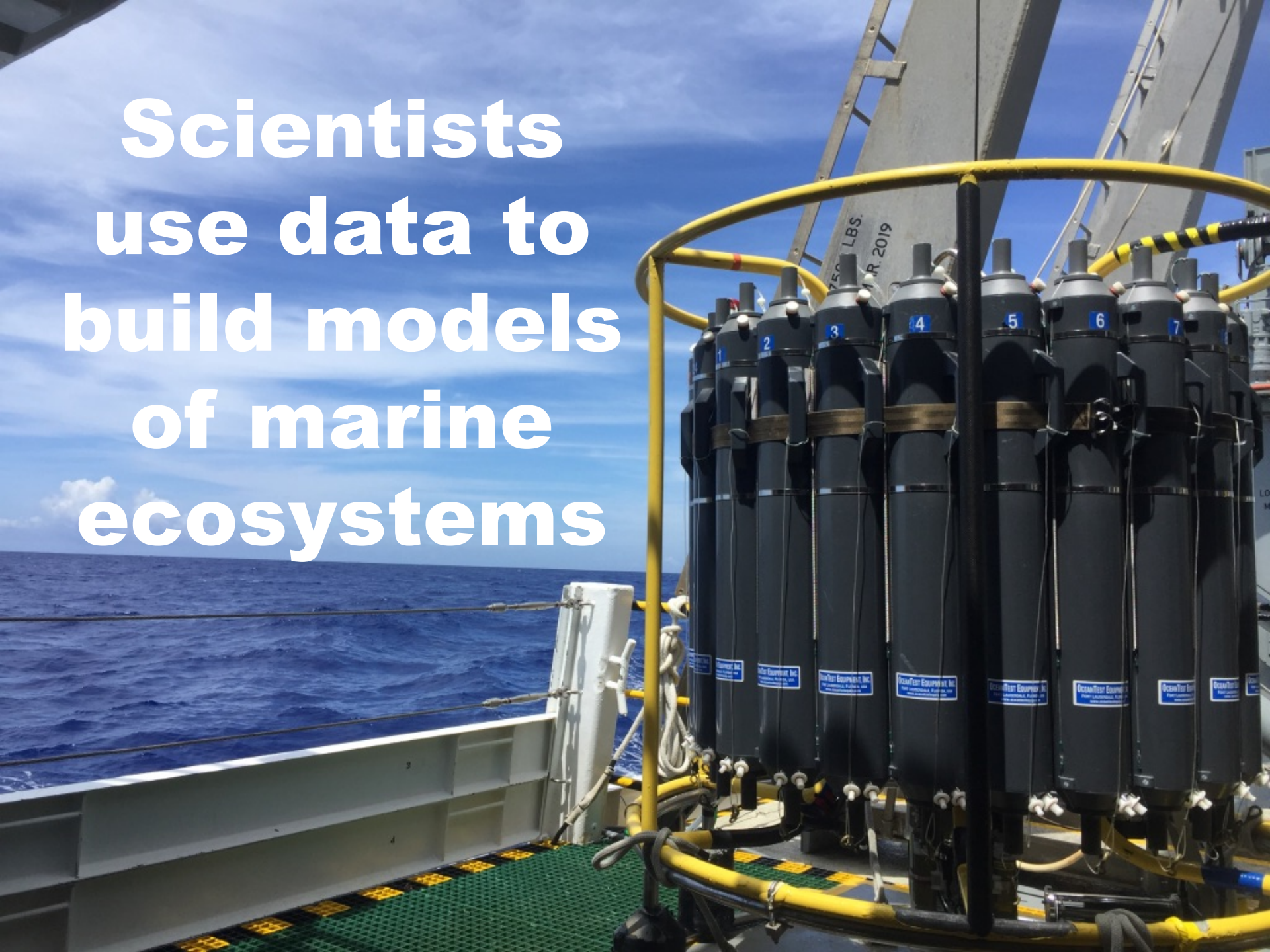
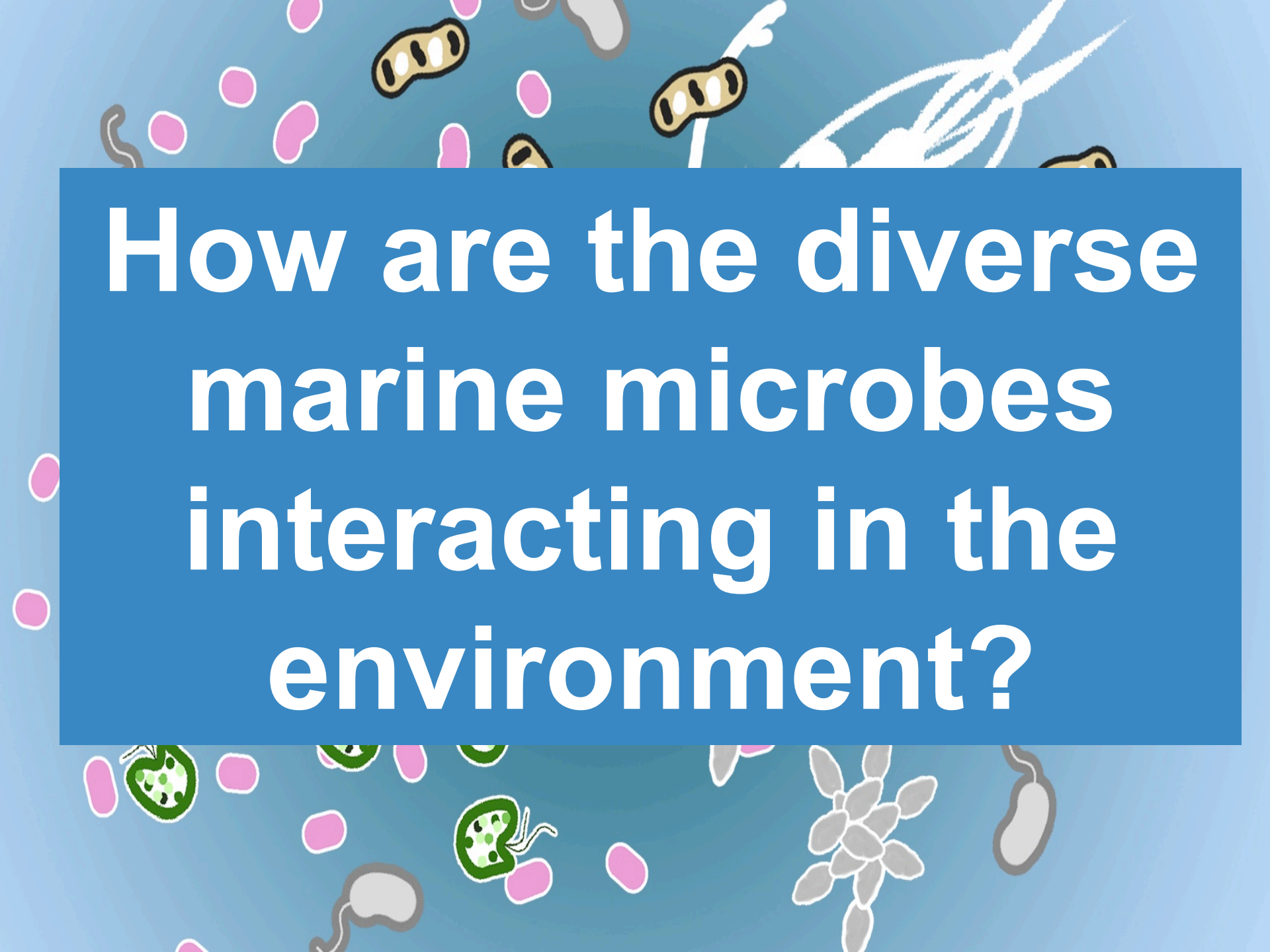
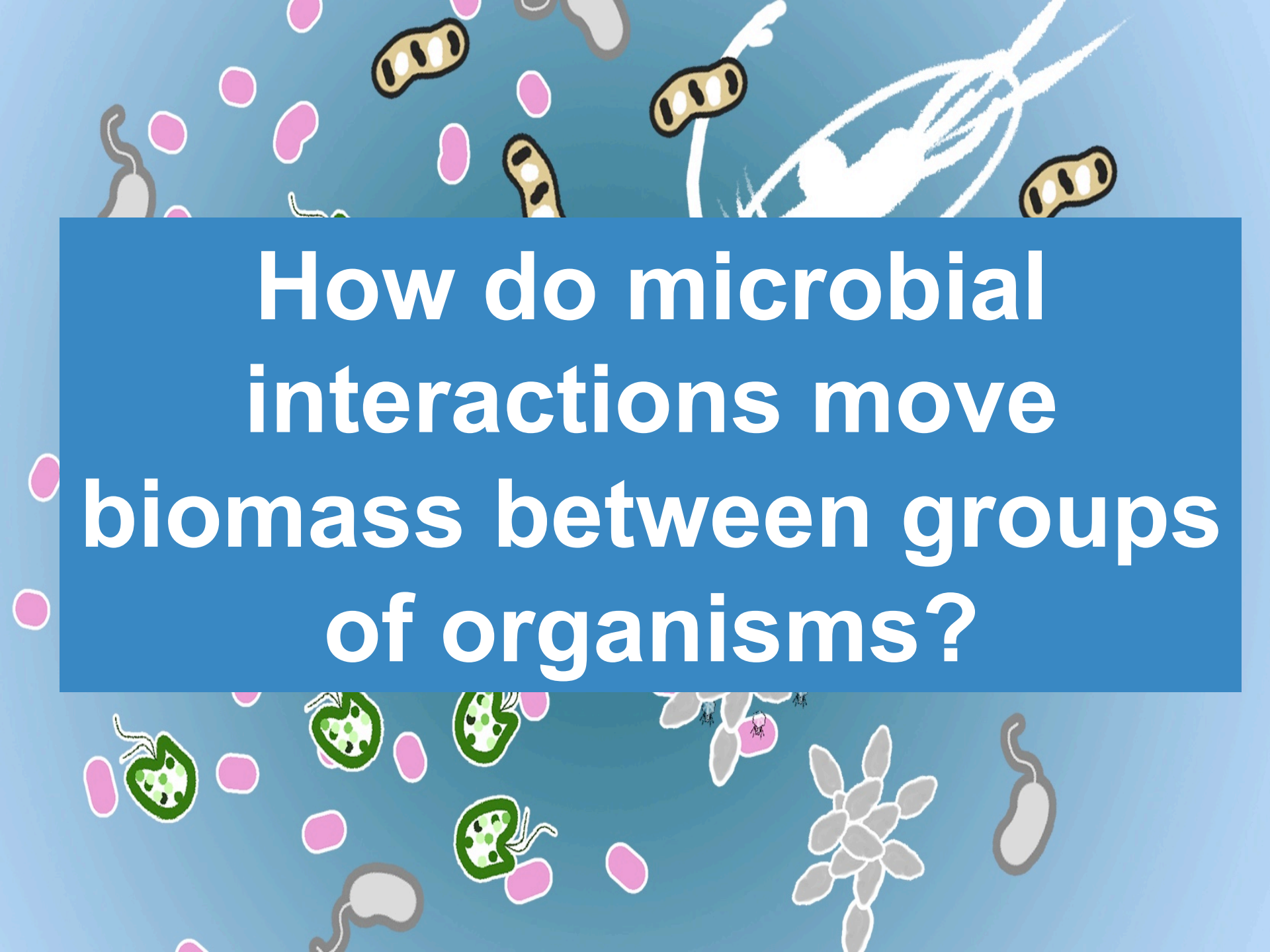

Scientists use data to build models of marine ecosystems


Microbial Ecology Model
Oligotrophic

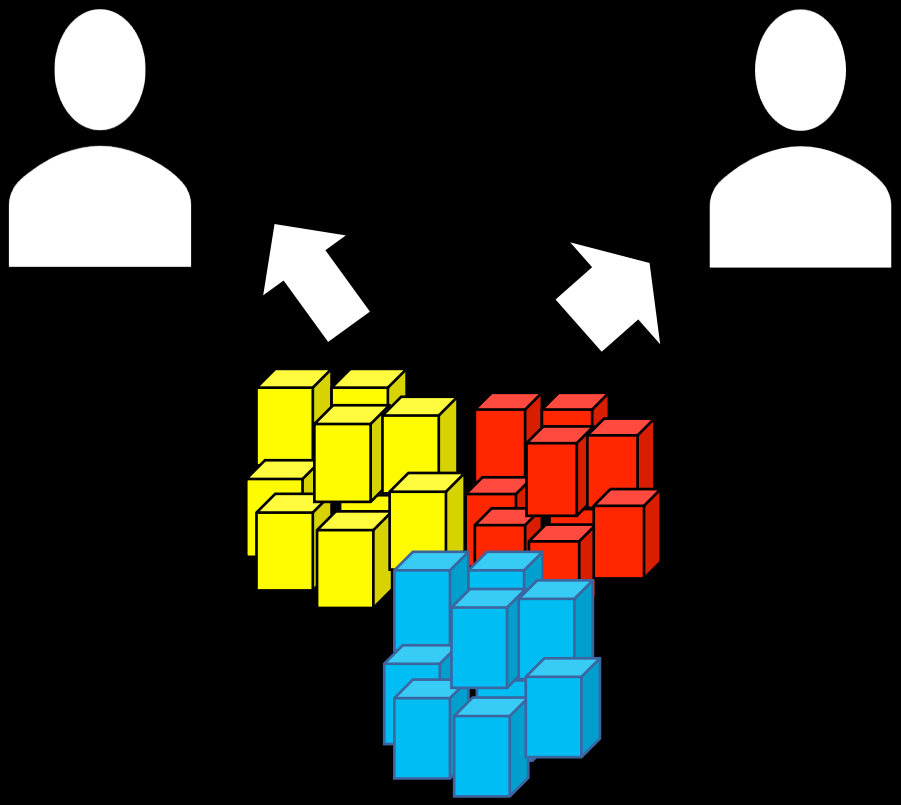

How are the diverse marine microbes interacting in the environment?


How do microbial interactions move biomass between groups of organisms?

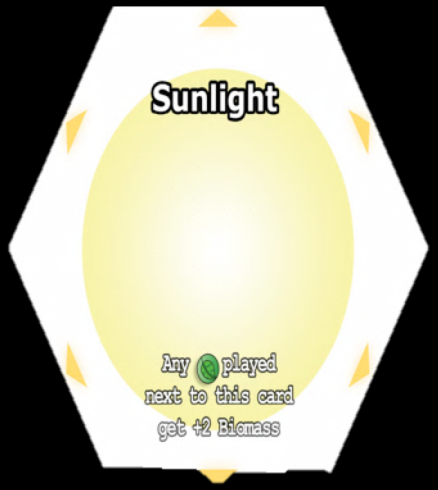

How to play:
Oligotrophic

Set up

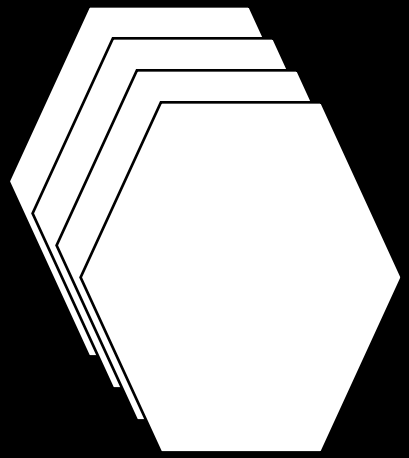
Give 20 cubes to each player of a single color



Pull out the sunlight

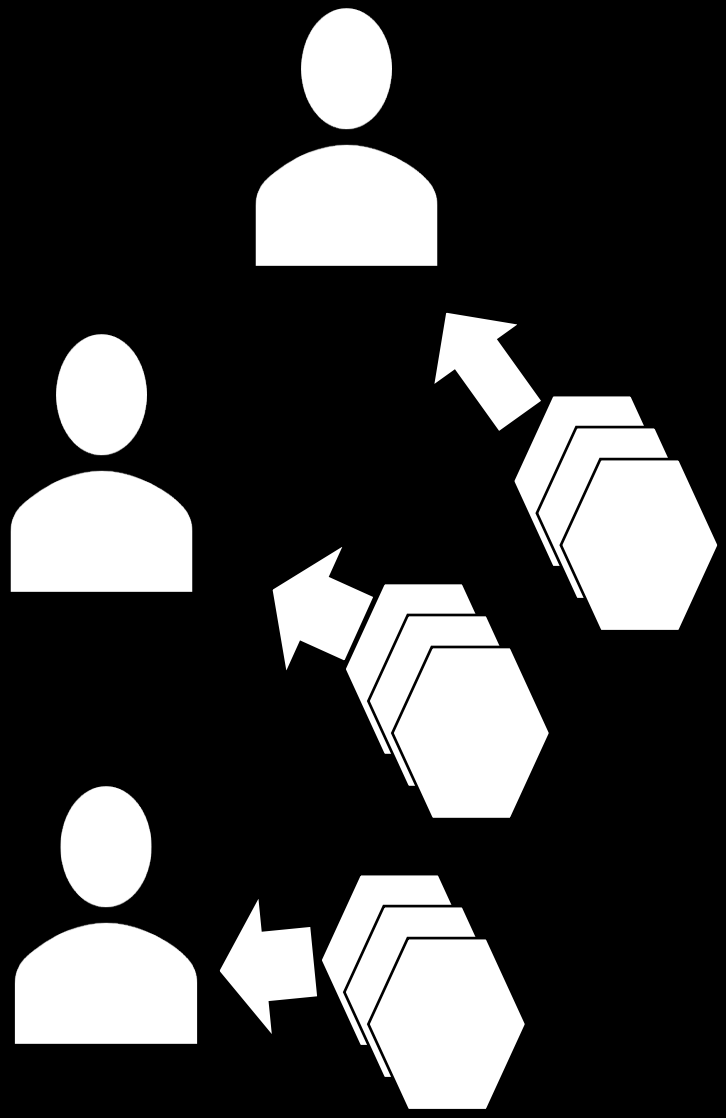


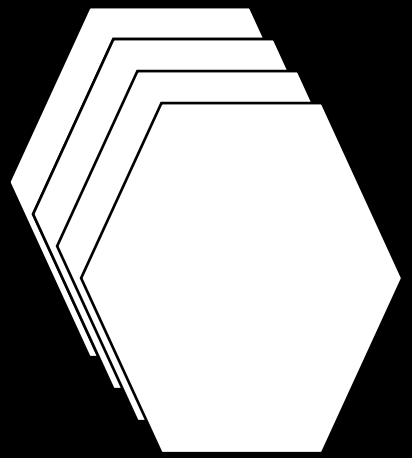
Shuffle all of the other cards together



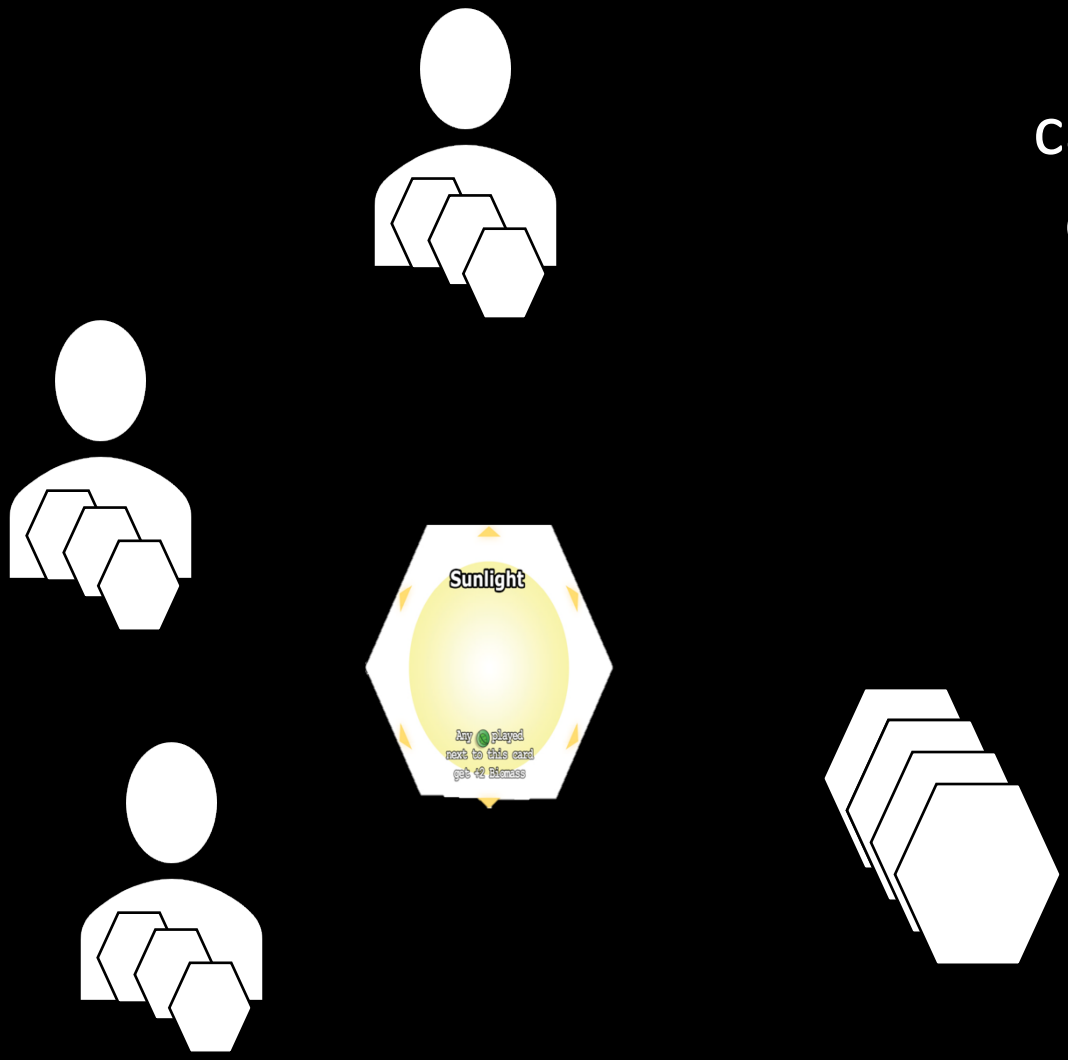
Set up

Give each player
3 cards

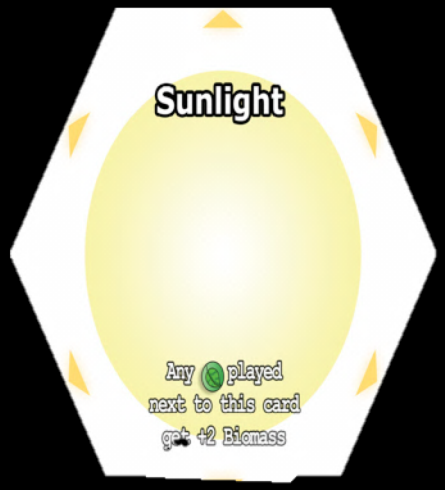




Set up



Put the sunlight card in the center of the play area



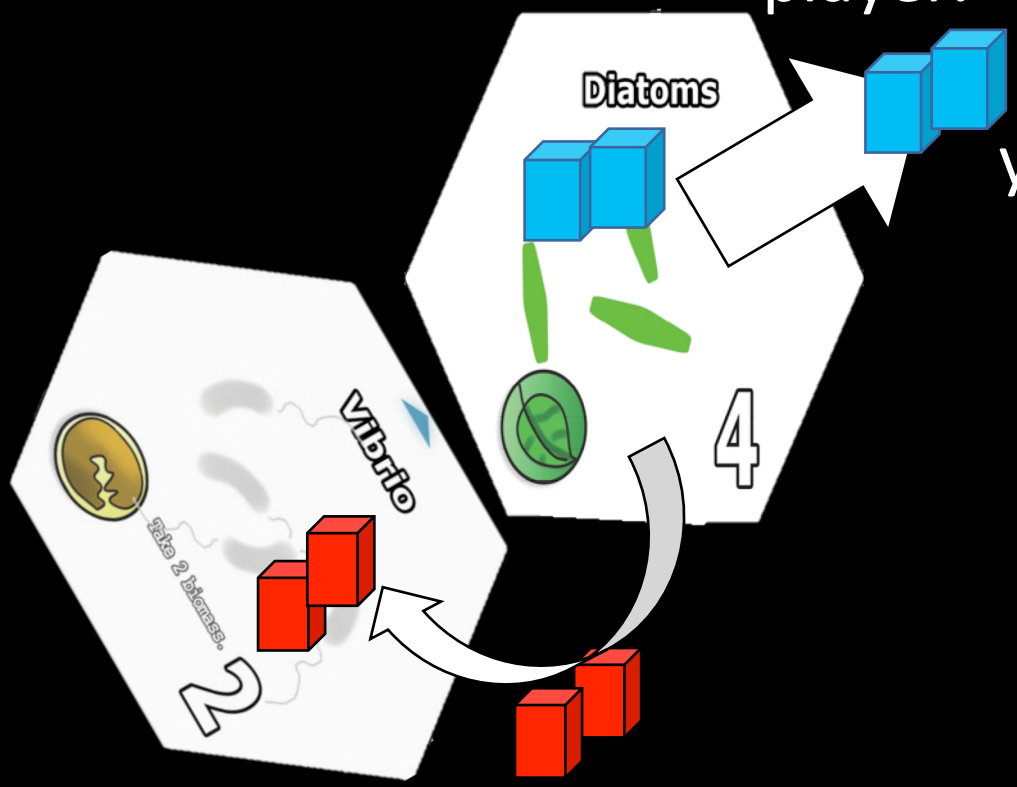
You are now ready to play!

How to play:

Each turn, play 1 card from your hand so it connects to at least one other card.
Put cubes of your color equal to the number on the card

If you play a Phototroph by the sun, add 2 more cubes

When you play a card:



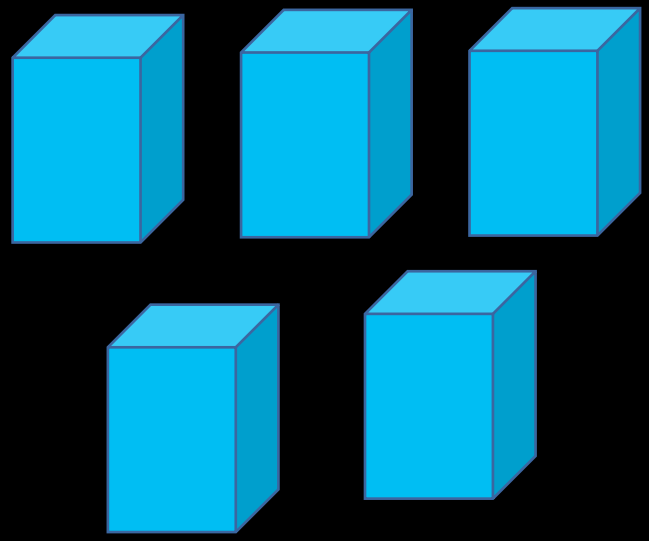
Return to player.

The arrow points to the cards that it effects.

Take: Switch the cubes to you color and move it to you card.
(Remember some can only take from certain others!)

Return: Give the cubes on the indicated card back to their player.

To win, start your turn with 5 or less biomass (cubes).



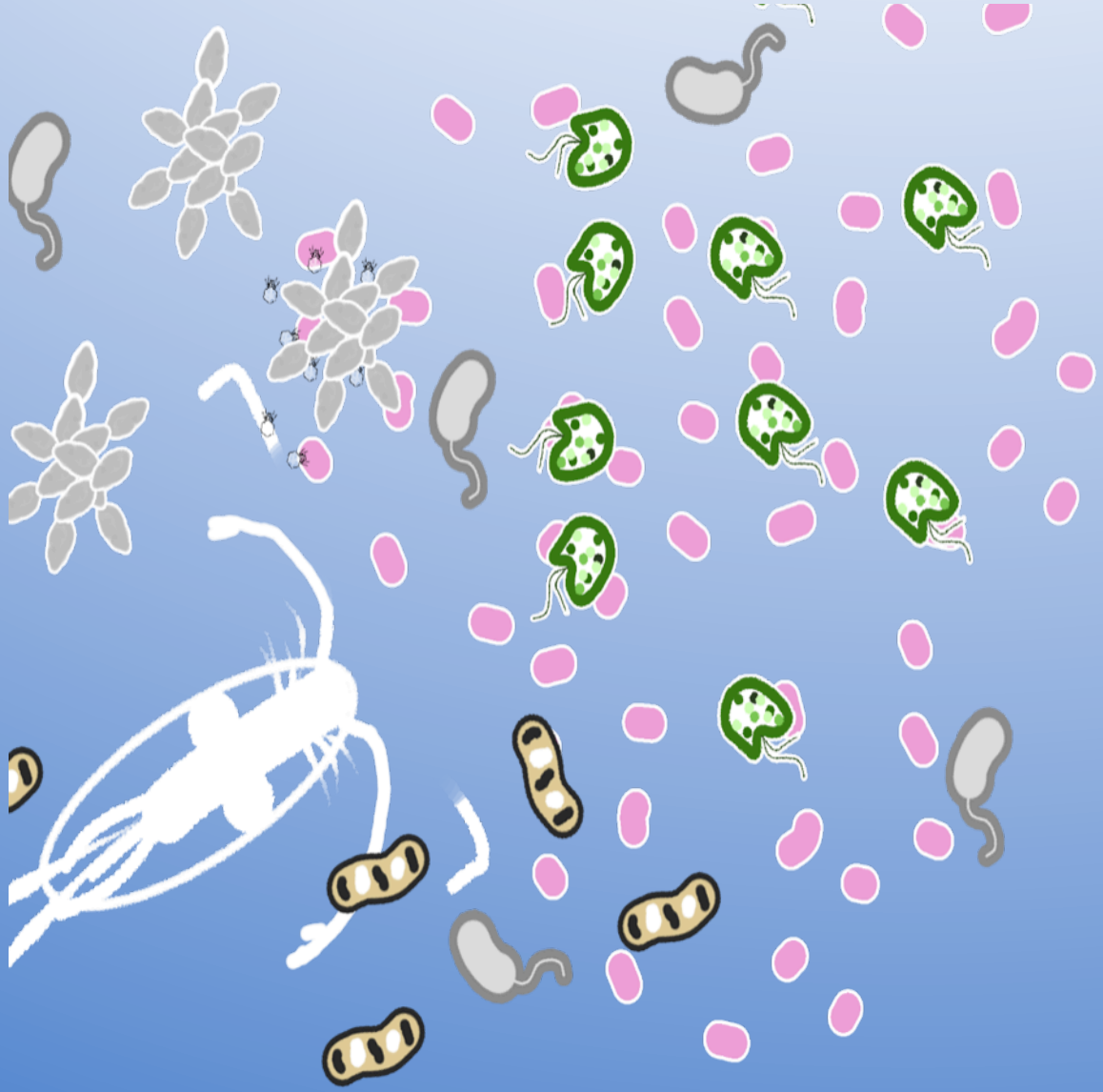
Thank You

Questions?

Feel free to email your questions to
Chris Suffridge suffridc@oregonstate.edu

Oregon State University

Oligotrophic



Available now!

Oligotrophic is a fast-to-learn, strategic tile placement game where players compete to place biomass the fastest. In the game players will select and play hexagonal cards based on actual microorganisms to accumulate biomass, often getting bonuses, hurting, or taking biomass from the other organisms they encounter.

Use it as a fun way to teach about the ecology of globally significant marine microorganism!

Free to download at:
https://boardgamegeek.com/boardgame/269171/oligotrophic
Coming to the Game Crafter soon!
https://www.thegamecrafter.com/