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Studying Plankton Adaptations to Different Marine Environments

Solange Duhamel and Andrew Juhl

Lamont-Doherty Earth Observatory
Columbia University | Earth Institute

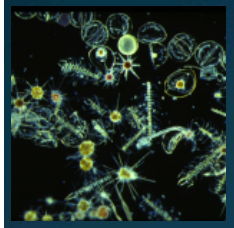
sduhamel@ldeo.columbia.edu
andyjuhl@ldeo.columbia.edu

What's the plan?

- Solange: Plankton adaptations to the subtropical nutrient poor (oligotrophic) ocean
  - Background information
  - The Oligotrophy to UlTra-oligotrophy PACific Experiment (OUTPACE)
    - Goals and sampling strategy
    - Video: onboard the research vessel L'Atalante

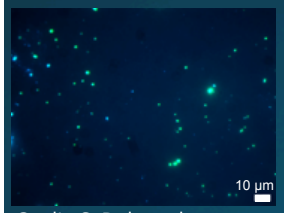
Plankton adaptations to the subtropical nutrient poor (oligotrophic) ocean

- Plankton: organisms living water but that cannot swim against a current. They provide a crucial source of food to larger aquatic organisms



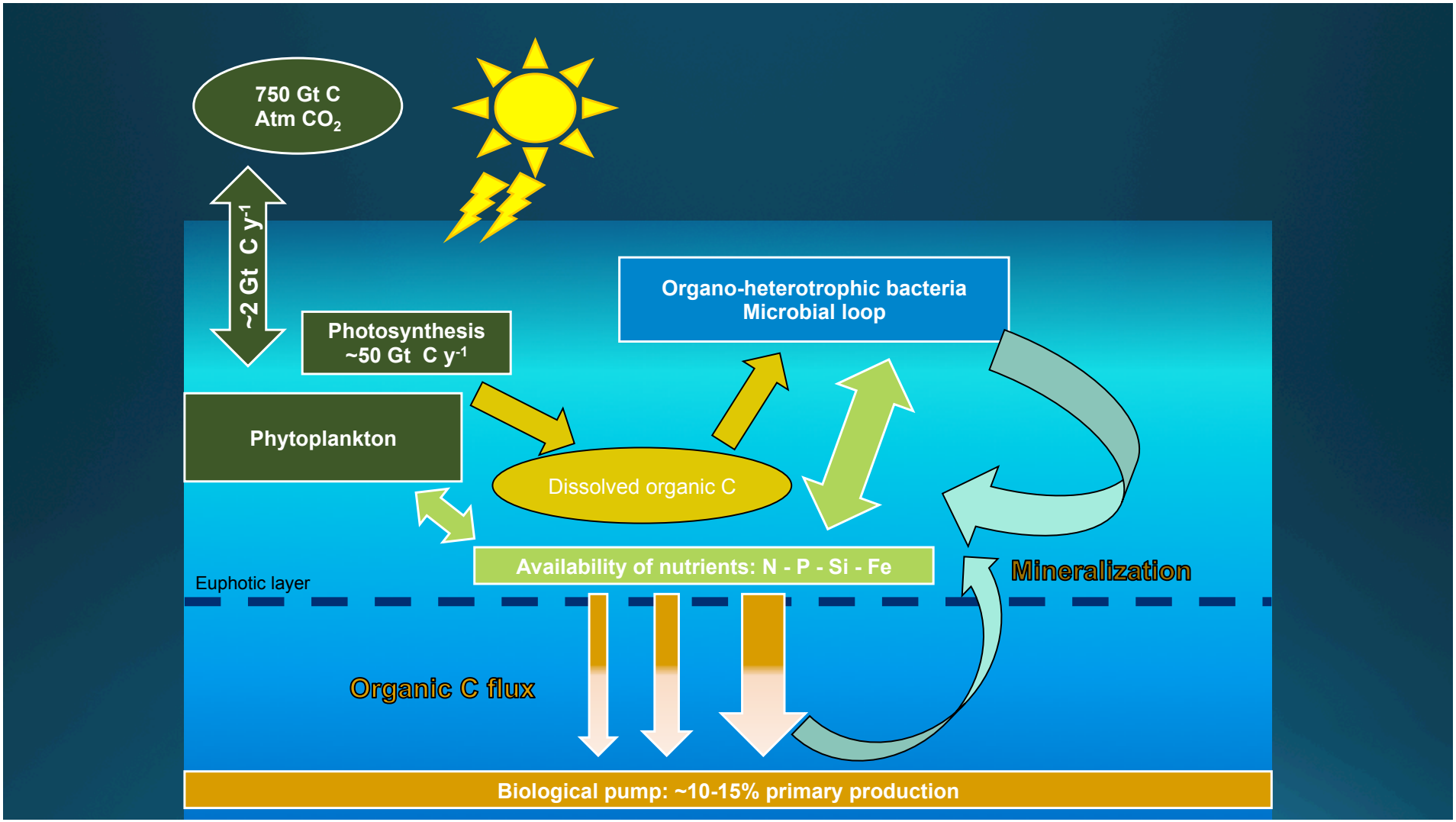
Source: marinephytoplankton.org/

- Phytoplankton: autotrophic plankton: need light and inorganic carbon and nutrient to grow

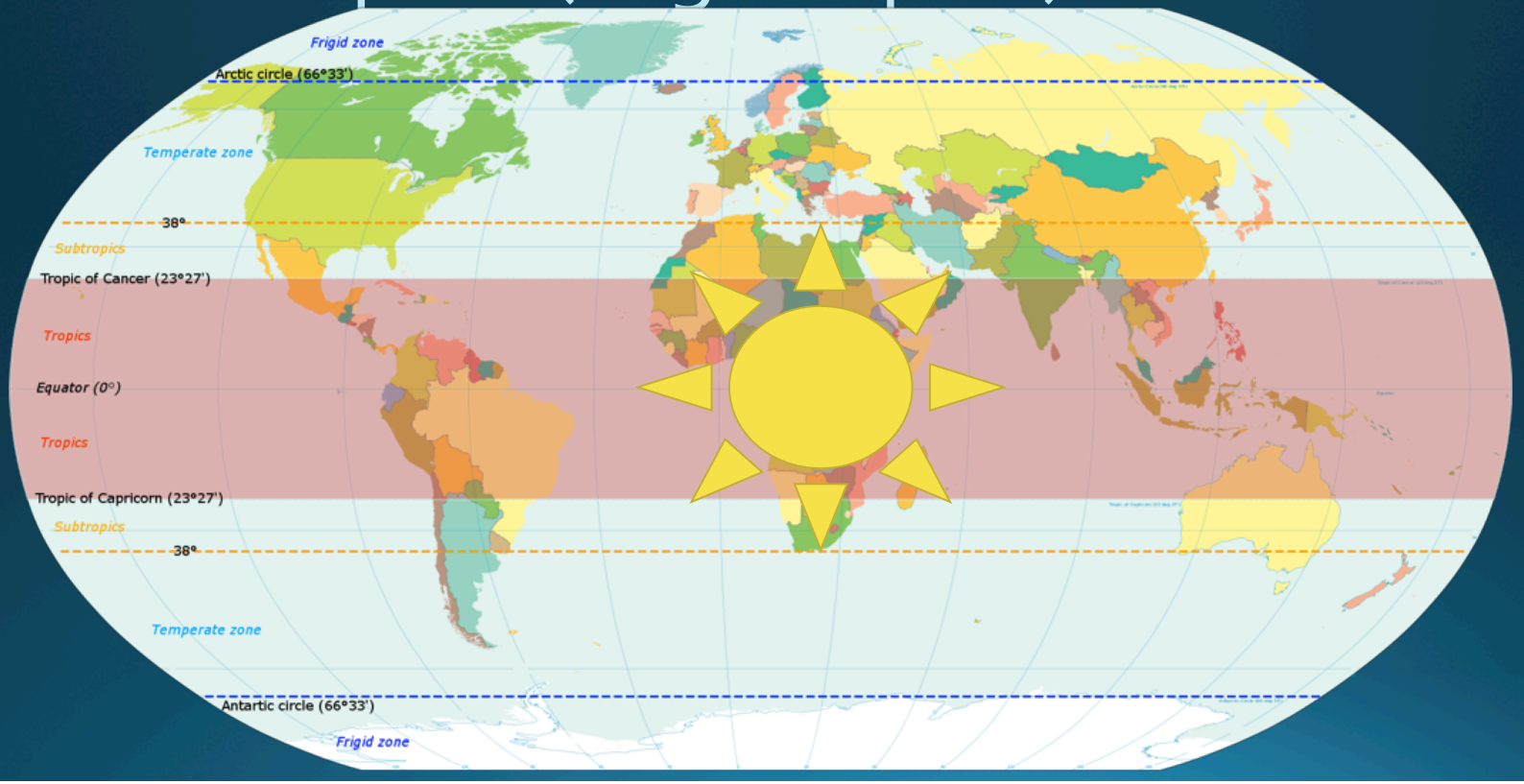


Credit: S. Duhamel

- Bacterioplankton: heterotrophic microorganisms: need organic carbon and nutrients to grow


750 Gt C
Atm CO_2
~2 Gt C y^{-1}
Photosynthesis
~50 Gt C y^{-1}
Organo-heterotrophic bacteria
Microbial loop
Phytoplankton
Dissolved organic C
Availability of nutrients: N - P - Si - Fe
Mineralization
Euphotic layer
Organic C flux
Biological pump: ~10-15% primary production

Plankton adaptations to the subtropical nutrient poor (oligotrophic) ocean



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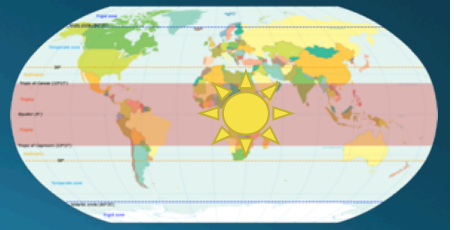
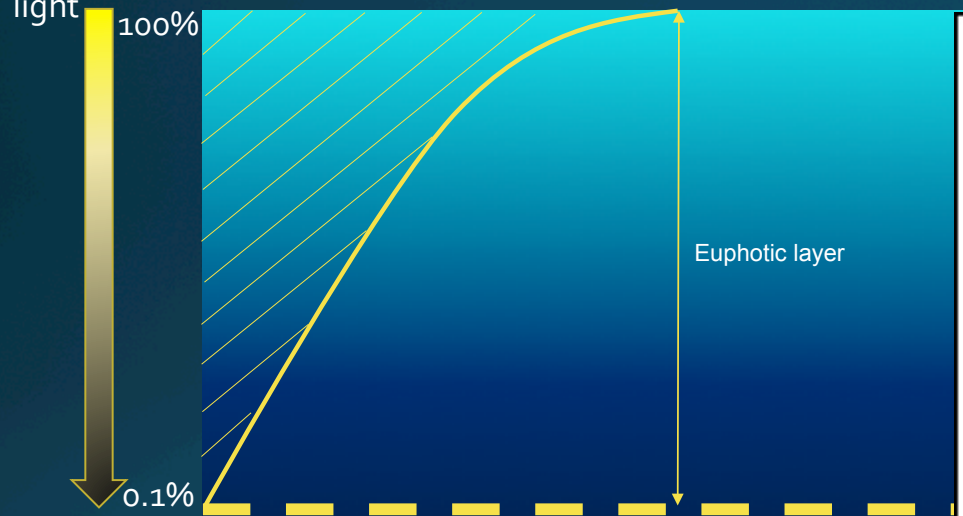


Euphotic zone = layer of water where the sunlight penetrate

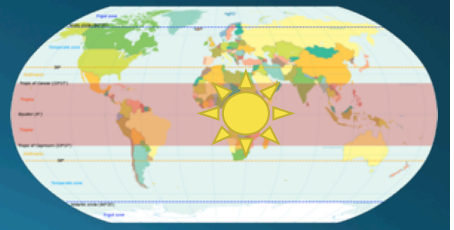


http://www.icanteachmychild.com/make-ocean-zones-jar/

<u>Going from the bottom to the top:</u>
Trench Zone (Hadalpelagic Zone)**:** Corn Syrup (tinted black)
Abyss (Abyssopelagic Zone)**:** Dish soap (tinted purple)
Midnight Zone (Bathypelagic Zone): Water (tinted dark green)
Twilight Zone (Mesopelagic Zone): Oil (tinted dark blue)
Sunlight Zone (Epipelagic Zone): Rubbing Alcohol (tinted light blue)

Plankton adaptations to the subtropical nutrient poor (oligotrophic) ocean

- Plankton: organisms living water but that cannot swim against a current. They provide a crucial source of food to larger aquatic organisms
  - Phytoplankton: autotrophic plankton: **need light** and inorganic carbon and **nutrients** to grow
  - Bacterioplankton: heterotrophic microorganisms: need organic carbon and **nutrients** to grow



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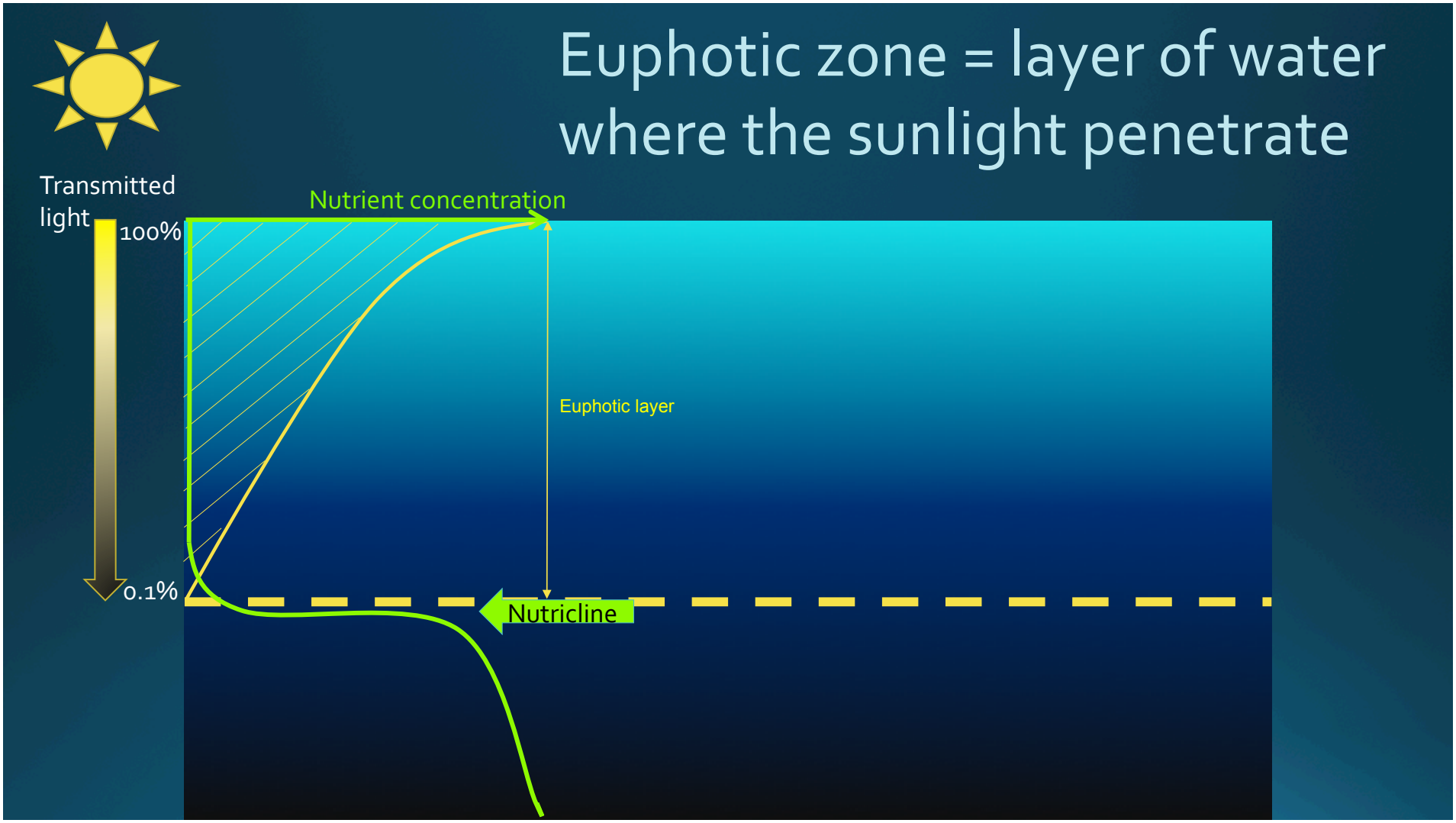
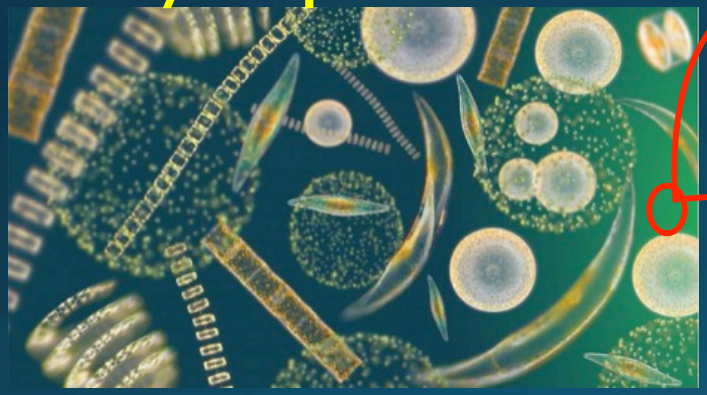


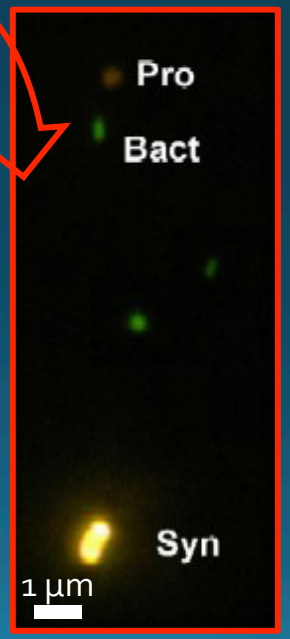
Plankton adaptations to the subtropical oligotrophic ocean

Phytoplankton



From Richard Kirby.

Small cyanobacteria are the most abundant photosynthetic microbes in the ocean



Prochlorococcus

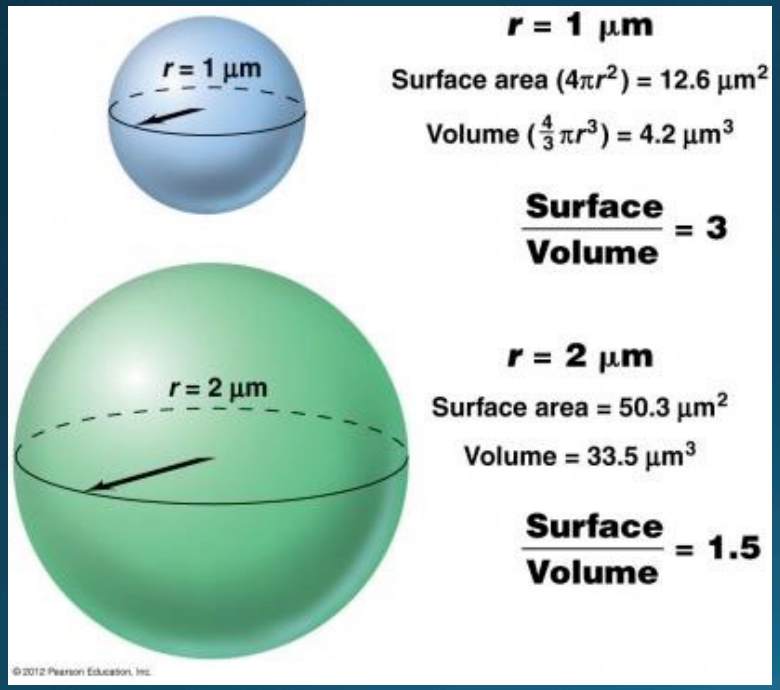
Non-pigmented bacteria

Synechococcus

Using epifluoresence microscopy.
From Dr. Frank J. Jochem

The smaller, the better?

The smaller, the better?



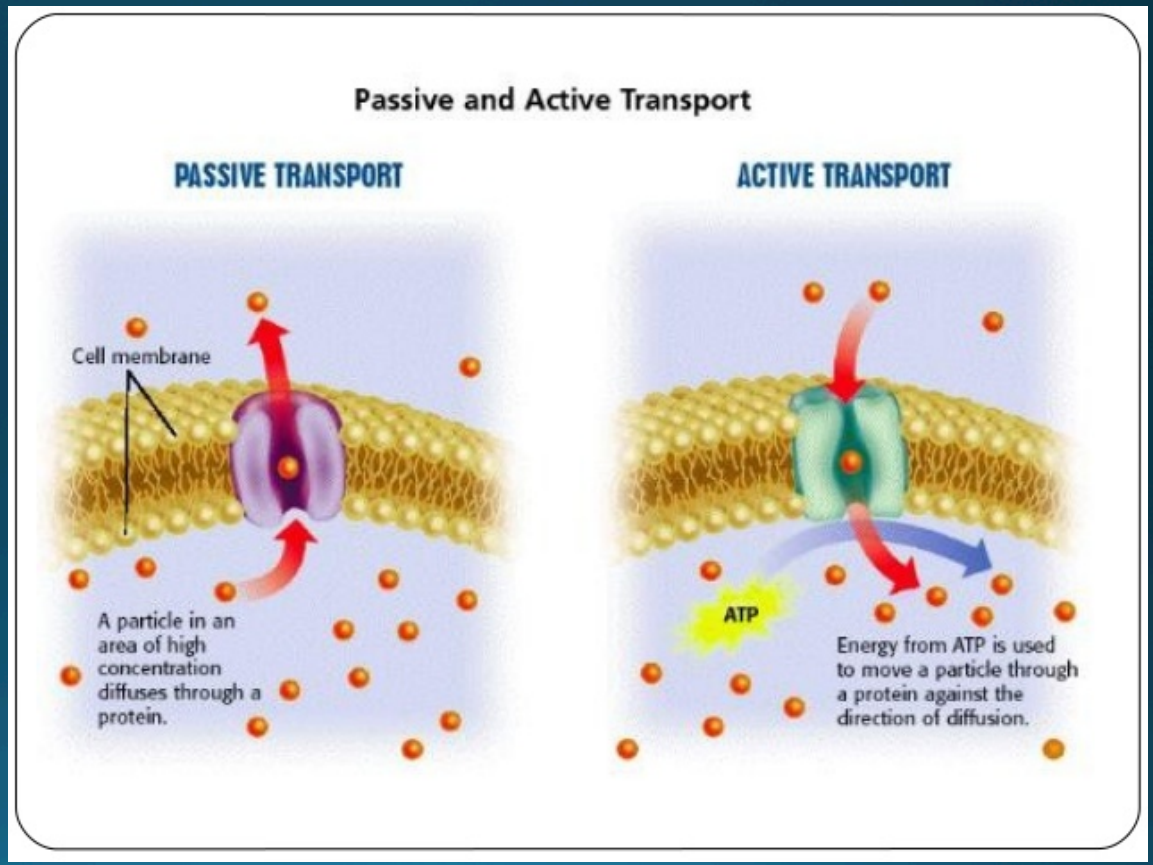
Why are larger cells less competitive than smaller cells in low nutrient environments?

As a cell increases in size, its S/V ratio decreases.

The **higher Surface/Volume ratio of smaller cells supports a faster rate of nutrient exchange per unit of cell volume** compared with that of larger cells.

Expression of high affinity nutrient transporters

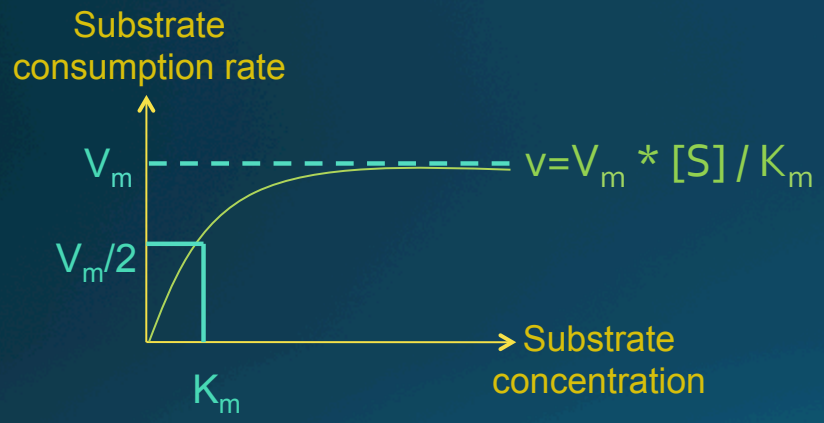
Nutrient transporters are a wide group of membrane proteins that facilitate the transport of nutrients through cell membrane.



Source: www.slideshare.net

How do we know if microorganisms are expressing high affinity nutrient transporters?

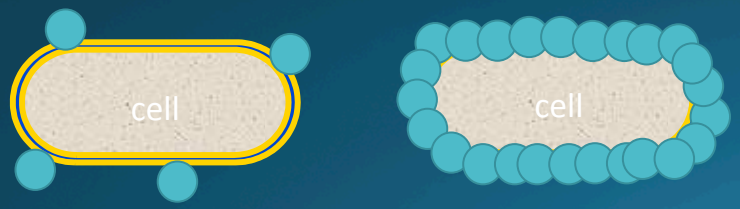
Michaelis-Menten kinetics



The abilities of organisms to sequester substrate are described by kinetic constants:

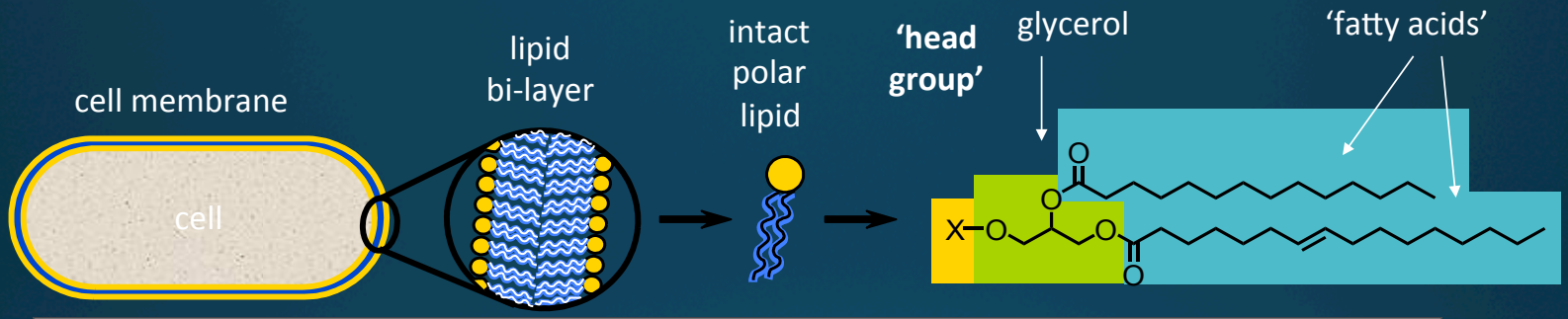
- maximal substrate consumption rate (V_m),
- substrate concentration at which the substrate consumption rate is at half-maximum (K_m)

A low Km value suggests a high affinity



Increase cell efficiency at assimilating nutrient present in low concentration

Membrane lipids substitution



Vol 458|5 March 2009|doi:10.1038/nature07659 nature

LETTERS

Phytoplankton in the ocean use non-phosphorus lipids in response to phosphorus scarcity

Benjamin A. S. Van Mooy[1], Helen F. Fredricks[1], Byron E. Pedler[1]†, Sonya T. Dyhrman[2], David M. Karl[3], Michal Koblížek[4,5], Michael W. Lomas[6], Tracy J. Mincer[1], Lisa R. Moore[7], Thierry Moutin[8], Michael S. Rappé[9] & Eric A. Webb[10]

Mixotrophy

- A mixotroph is an organism that can use a mix of different sources of energy and carbon, instead of having a single trophic mode on the continuum from complete autotrophy at one end to heterotrophy at the other.

Photoheterotrophy

Greek: photo = light, hetero = (an)other, troph = nourishment

Photoheterotrophs are heterotrophic phototrophs—that is, they are organisms that use light for energy to use carbon dioxide and inorganic nutrients but can additionally use organic compounds from the environment to satisfy their carbon and nutrient requirements

OUTPACE: Oligotrophy to UlTra-oligotrophy PACific Experiment

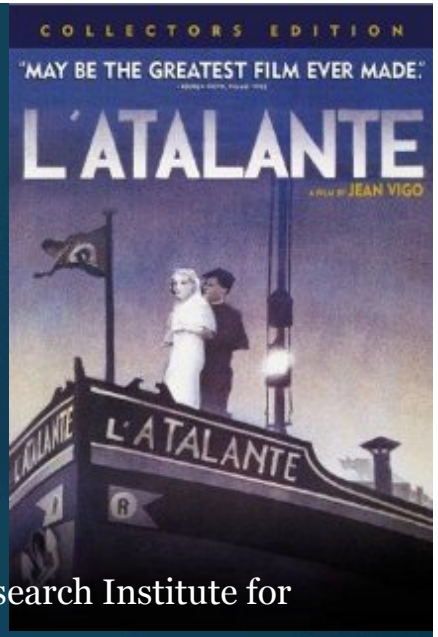
OUTPACE group picture

- Goals:
  - OUTPACE: This project aims to give a zonal description of the biogeochemical functioning and biological diversity of the South West Pacific toward a gradient of nutrients availability, and produce a detailed study of the biological production and its subsequent fate in contrasting sites, with a specific emphasis on the production sustained by nitrogen fixation.

  - Solange: My project aims to investigate the role of light in uptake of organic substrates (carbon and nutrients) by unicellular cyanobacteria and elucidate the importance of photoheterotrophy.

OUTPACE: 45 days on board the Research Vessel l'Atalante

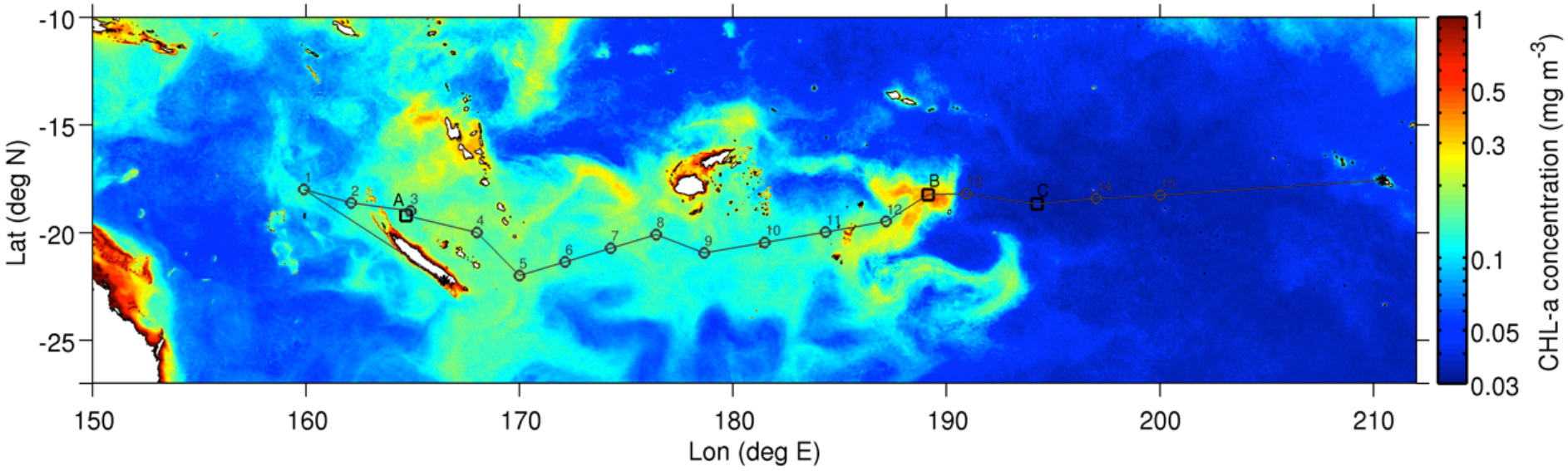
R/V L'Atalante



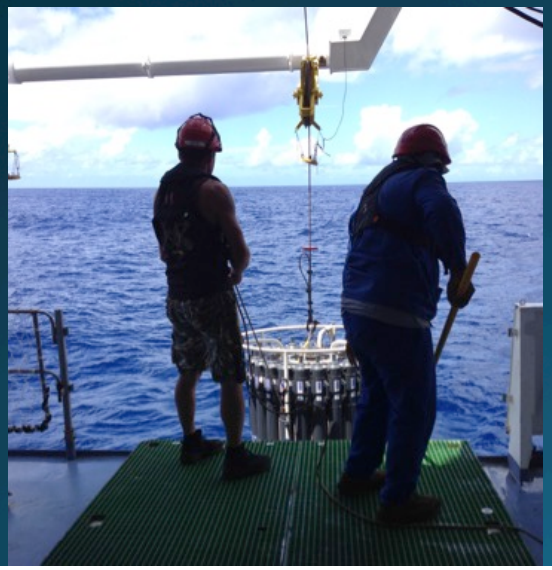
RV L 'Atalante
Operator: Ifremer - French Research Institute for Exploitation of the Sea
Country: Global
Website: http://www.ifremer.fr/flotte/navires/hauturiers/atalante/index.htm
Vessel Type: Multipurpose Research Vessel
Vessel Class: Global
Operational Area: All oceans, except polar regions
Endurance: 40 days
Scientist berths: 30
Length: 85m

Sampling strategy

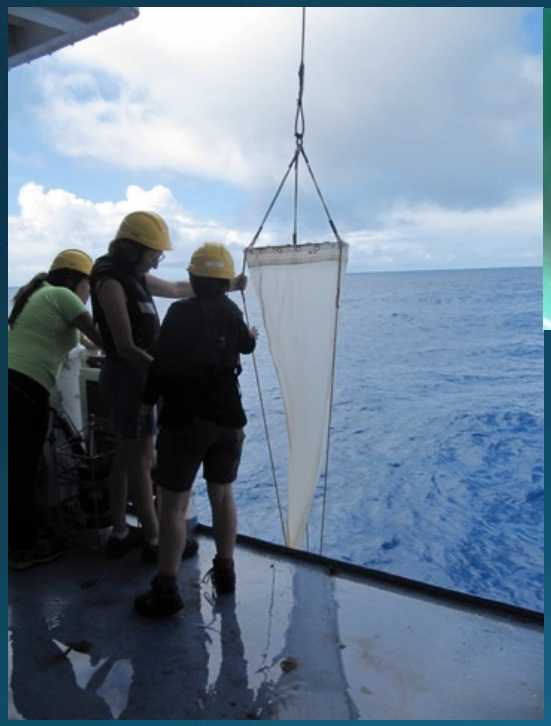
- 15 Short stations: Stop the ship for 8 hours and characterize the water column
- 3 Long stations (A, B, C): Let the ship "drift" to follow the same water mass (i.e. body of ocean water with a distinctive narrow range of temperature and salinity and a particular density resulting from these two parameters) and characterize it over 6 days



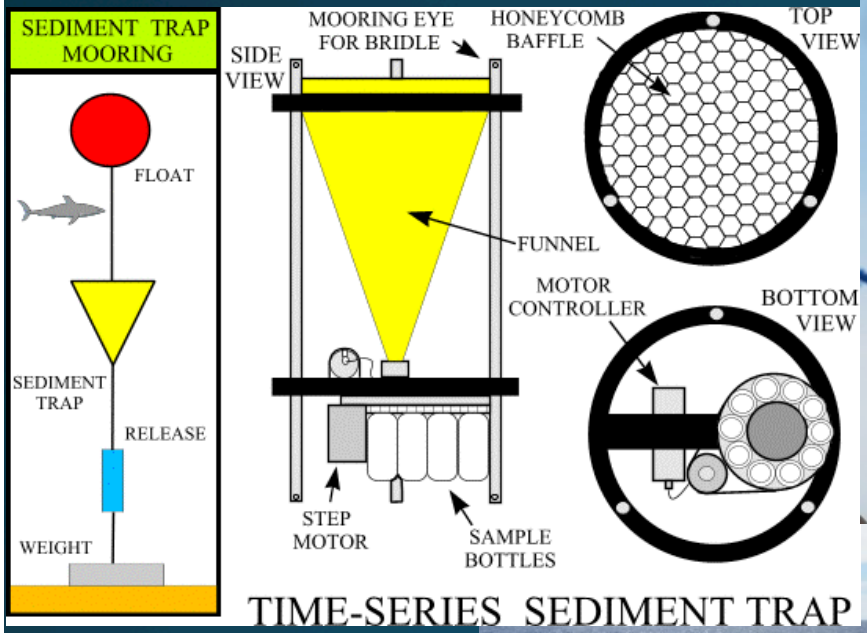
Sampling strategy: rosette



Sampling strategy: plankton net



Sampling strategy: sediment traps

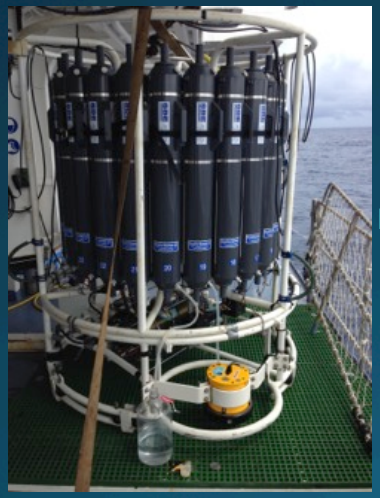


Source: www.bowdoin.edu

Educational ressource: http://www.whoi.edu/instruments/viewInstrument.do?id=10286

Interrogating cyanobacterial photoheterotrophy

- Use radioactive substrates to trace the incorporation of organic carbon and nutrients inside the cells
- Learning resource: http://study.com/academy/lesson/how-radioactive-isotopes-track-biological-molecules.html



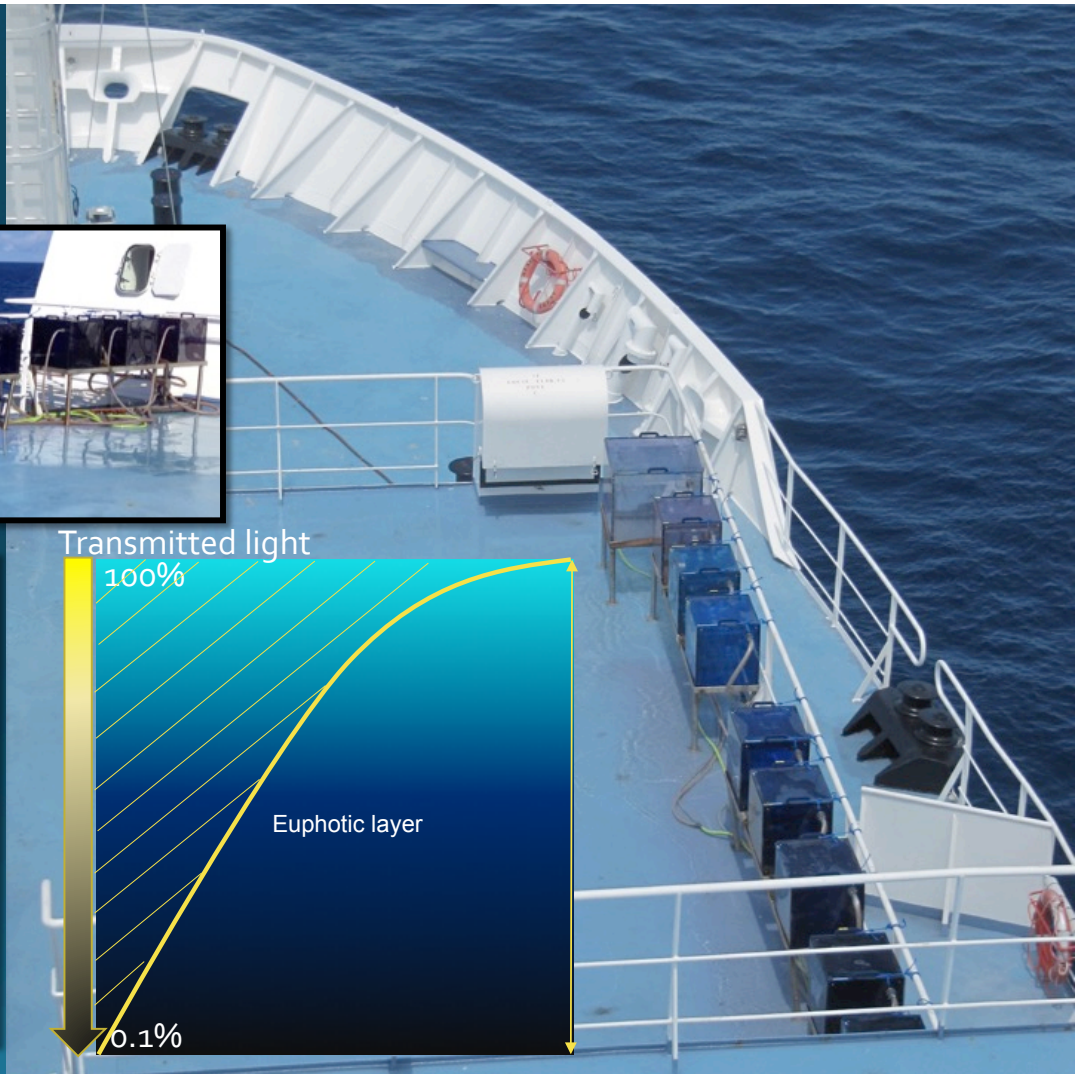
Incubation

Rad van laboratory

Loading the UNOLS rad lab van on board the RV L'Atalante

Keeping busy inside the rad lab van

On-deck incubators



Video

- https://youtu.be/pT-SiEy9khQ

Acknowledgements

- Thanks to my students and collaborators (alphabetic order): Kimberley Popendorf, Moira Dion, Ana Camila Gonzales, Sarah Raney, O. Roger Anderson, Mar Benavides, Karin Björkman, Sophie Bonnet, David Karl, Eunsoo Kim, Thierry Moutin, Sophie Rabouille, Mariona Segura, Alan Steinman, France Van Wambeke and many others
- Thanks to the crew of the RV L'Atalante
- Funding: NSF OCE 1434916 (Duhamel)

OUTPACE group picture

Duhamel Lab group picture

For more information:
http://solangeduhamel.wix.com/duhamellab

https://outpace.mio.univ-amu.fr/

https://www.ird.fr/toute-l-actualite/science-en-direct/outpace-2015/a-bord-de-l-atalante

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