To fix or not to fix?

What controls Nitrogen Fixation?

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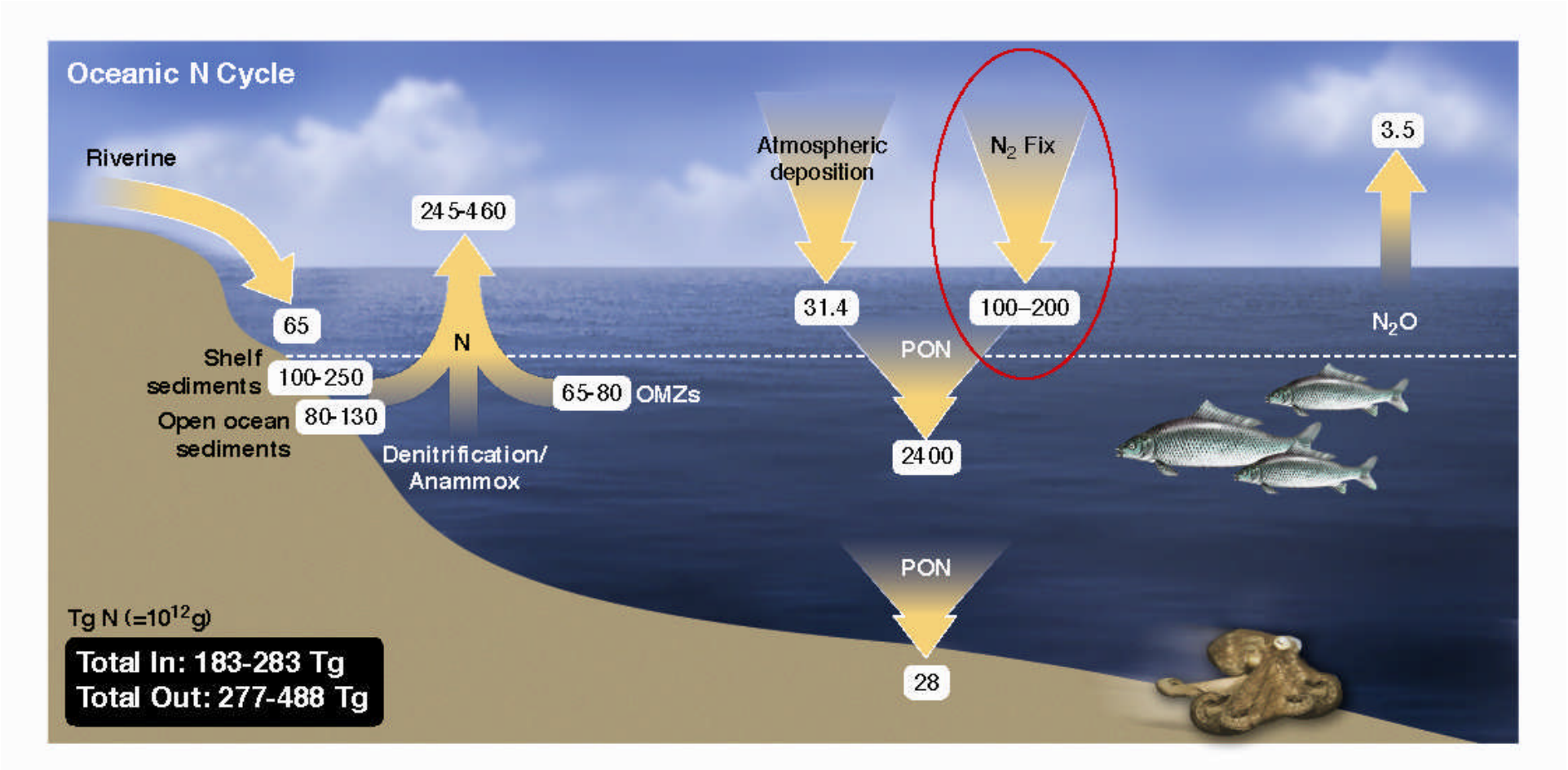
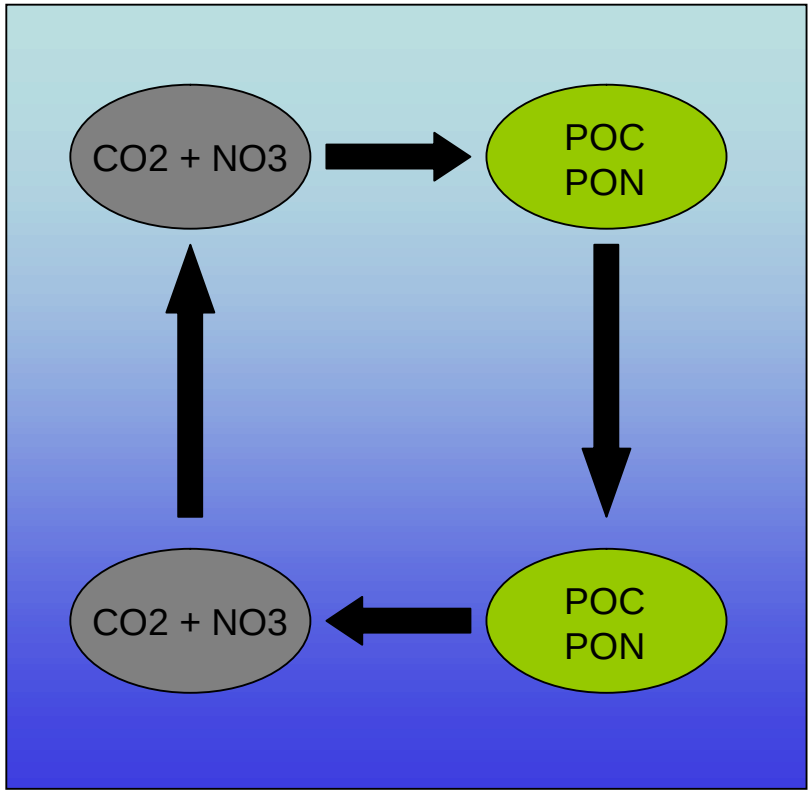
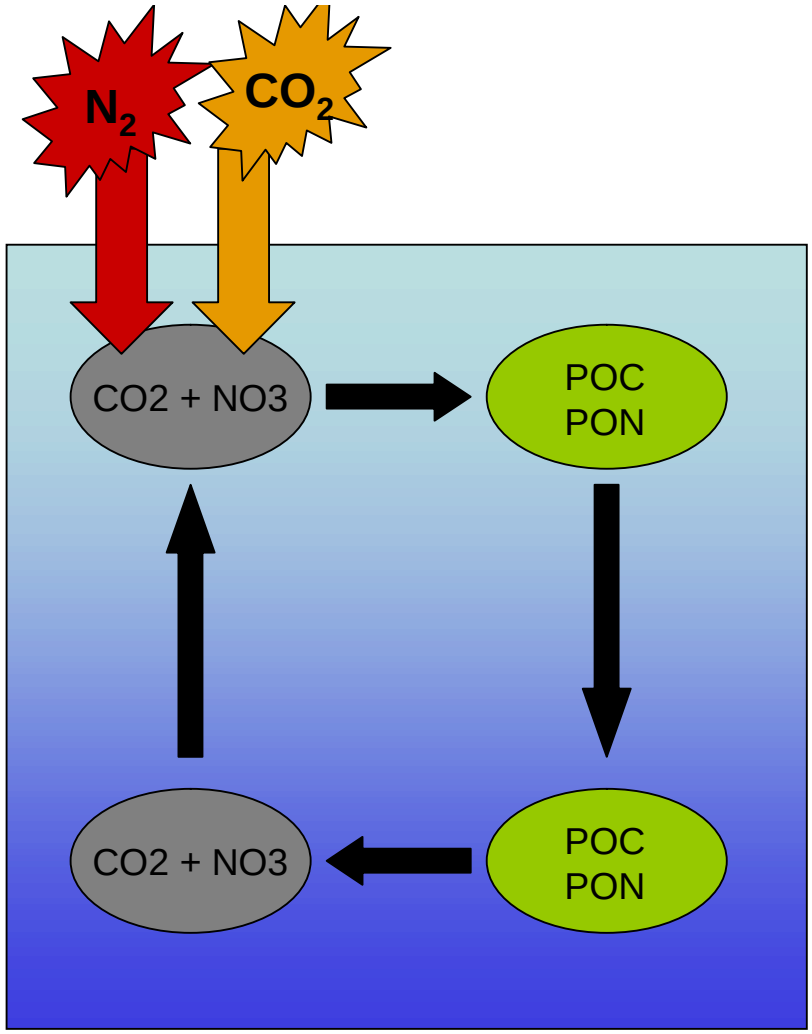
Nitrogen Fixation



Nitrogen fixation provides a source of fixed nitrogen and thereby a path for atmospheric CO_2 uptake in the open ocean



Traditional biological pump:
"new" nitrogen = NO_3 from below photic zone



Biological pump with N_2 fixation:
"new" nitrogen = fixed N + NO_3

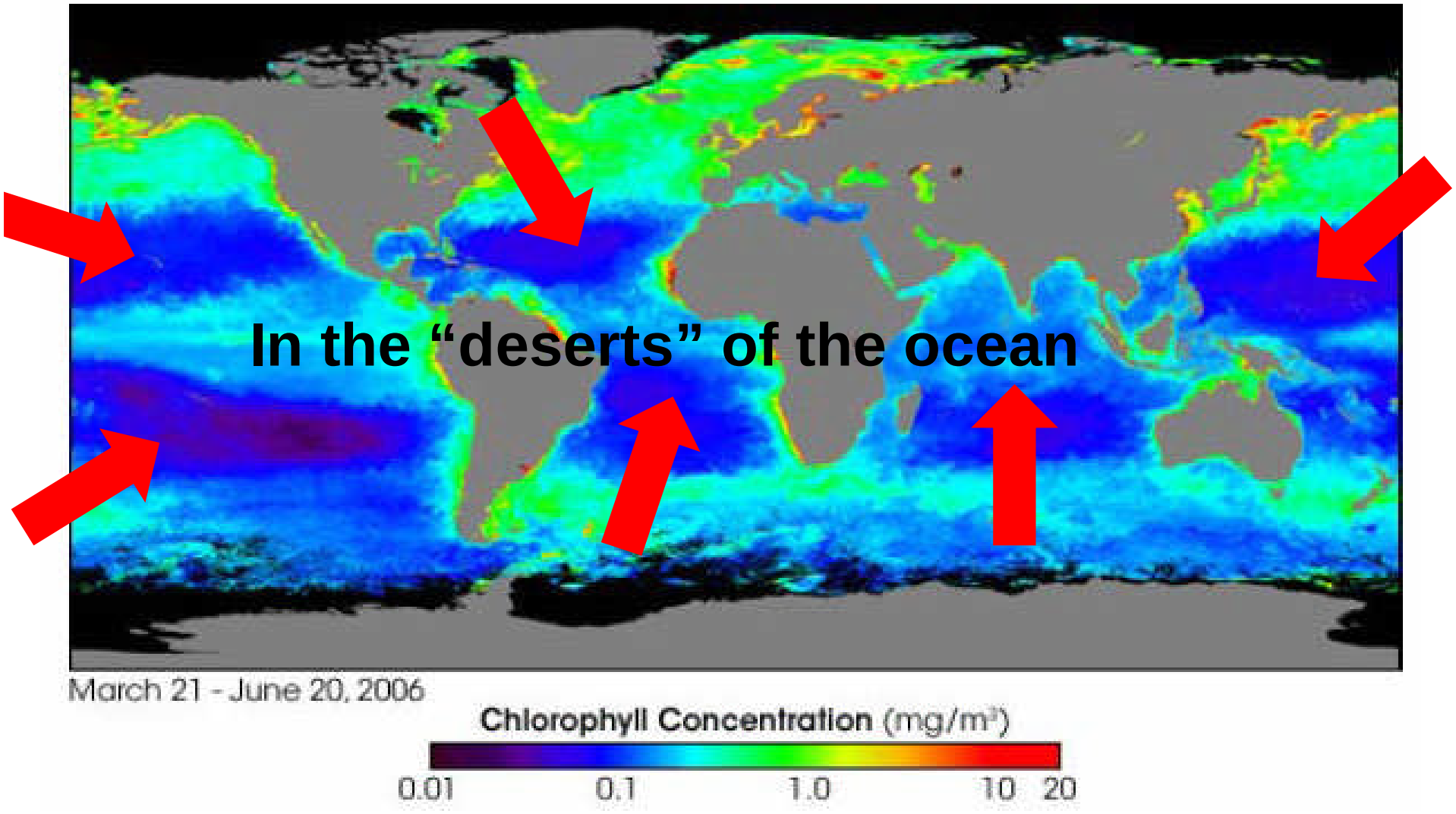
Nitrogen Fixation Background

- Atmosphere is 80% nitrogen gas (N≡N)
  - Unusable/inaccessible form (for most organisms)
- Nitrogen fixers can access this pool!
  - Exclusively prokaryotic (ancient)
  - Primary input of fixed nitrogen to biosphere (before humans)
- Like fertilizer for the ocean

Nitrogen Fixation Background

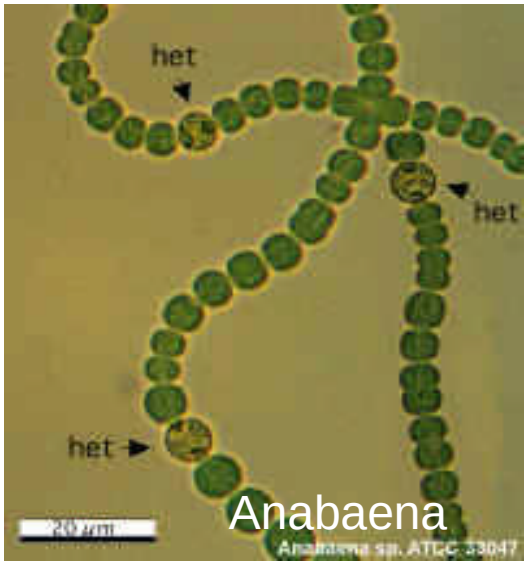
- $N_2 + 8e^- + 8H^+ \rightarrow 2NH_3 + H_2$
  - This process takes energy…
- Enzyme catalyzed reaction (nitrogenase)
  - O_2 sensitive
- Find in nitrogen deficient environments

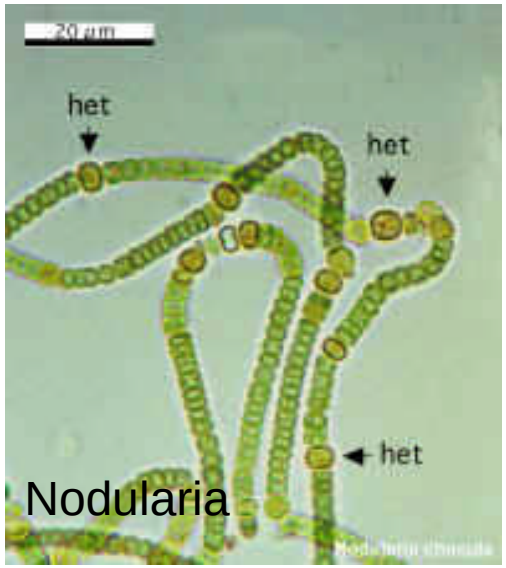
Where?


In the “deserts” of the ocean
March 21 - June 20, 2006
Chlorophyll Concentration (mg/m³)
0.01
0.1
1.0
10
20

Heterocystous

- Differentiated cell for N fixation (fix during the day)
- See in freshwater systems and colder seawater systems (higher nutrients)





Trichodesmium (non-heterocystous)

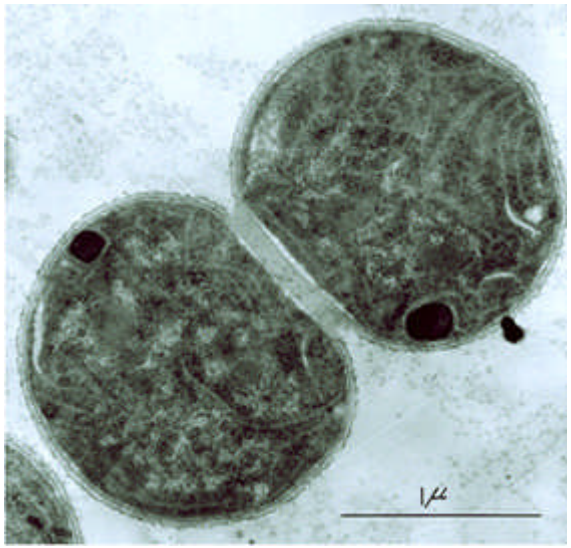
- Colony forming
- No specialized cell for nitrogen fixation, but fix N during the day!
- Tropical and subtropical (low nutrient)

Unicellular cyanobacteria

- Single celled (small - <10μm)
- Fix nitrogen at night (temporal separation)
- Tropical and subtropical

?

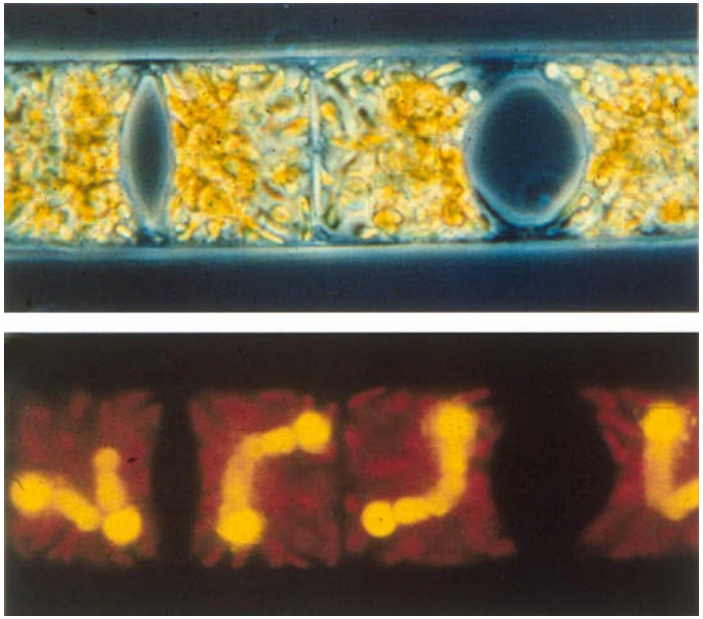
Group A

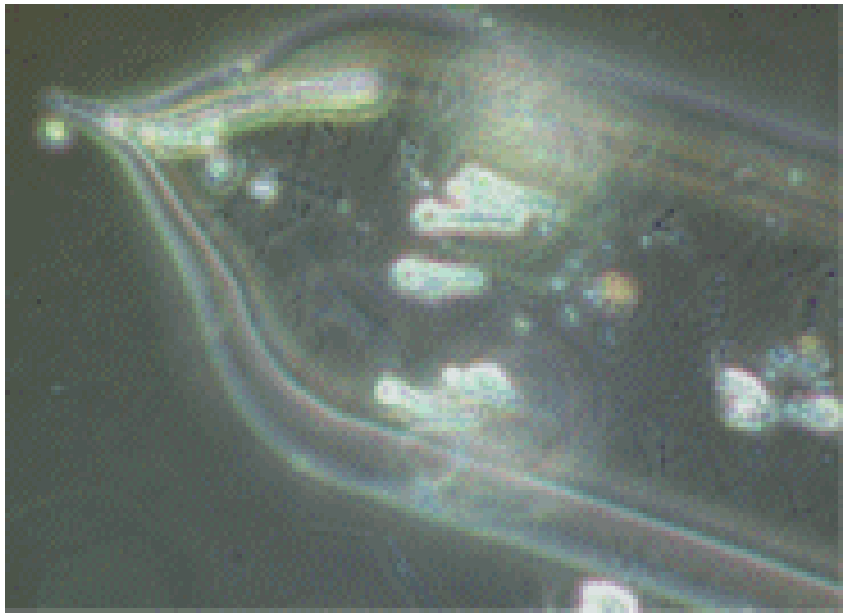


Group B

Diatom-diazotroph assemblages

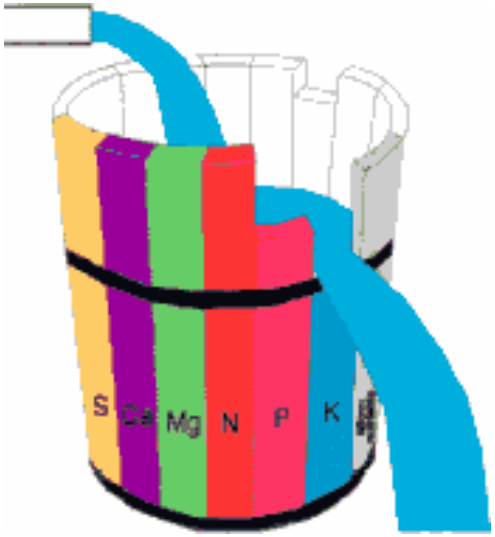
- Symbiont: Richelia – heterocystous
- Host: Hemiaulis, Rhizosolenia
- Tropical and subtropical
  - Need Silica!





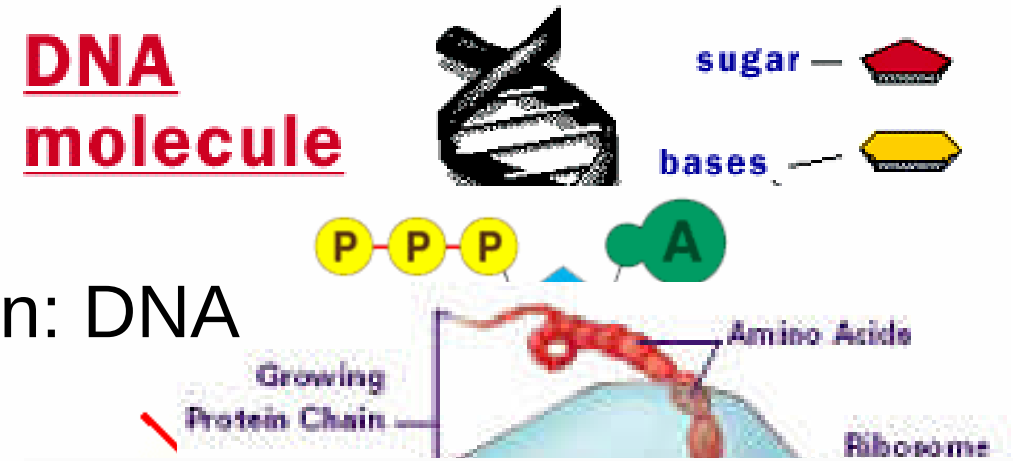
The law of the minimum

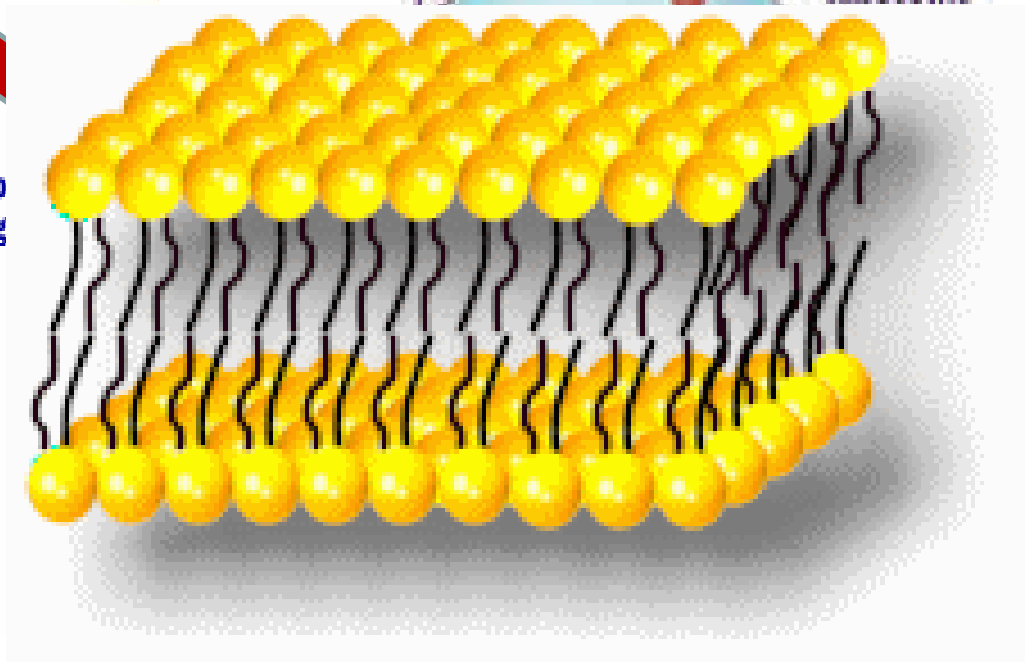
- Nutrient in least supply limits growth
- Ocean is generally considered nitrogen limited
- If nitrogen fixers can make their own nitrogen, what limits them?



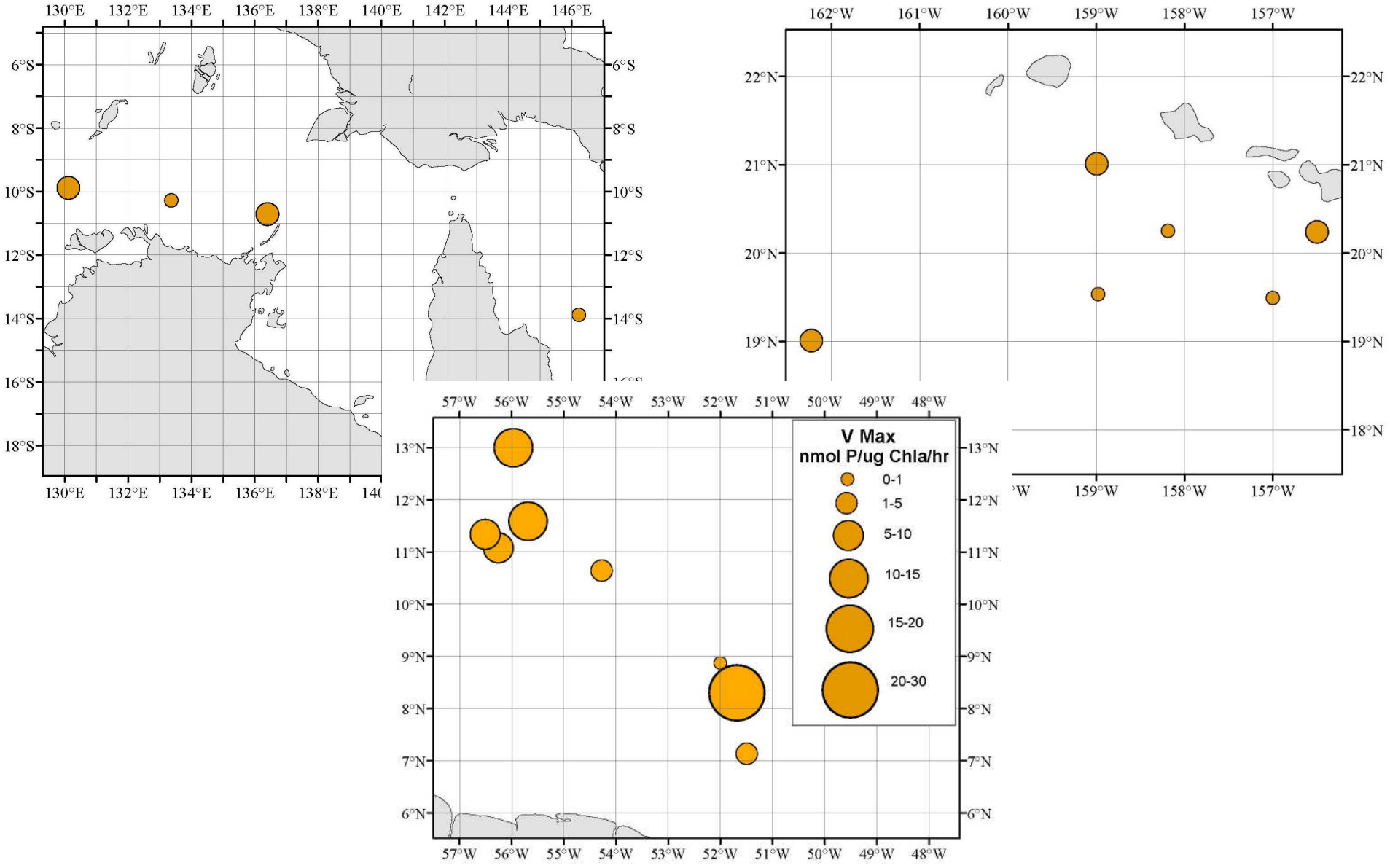
Controls on Nitrogen Fixation

- Phosphorus
- Important for:
  - Genetic information: DNA
  - Energy: ATP
  - Growth: ribosomes
  - Membranes: lipids



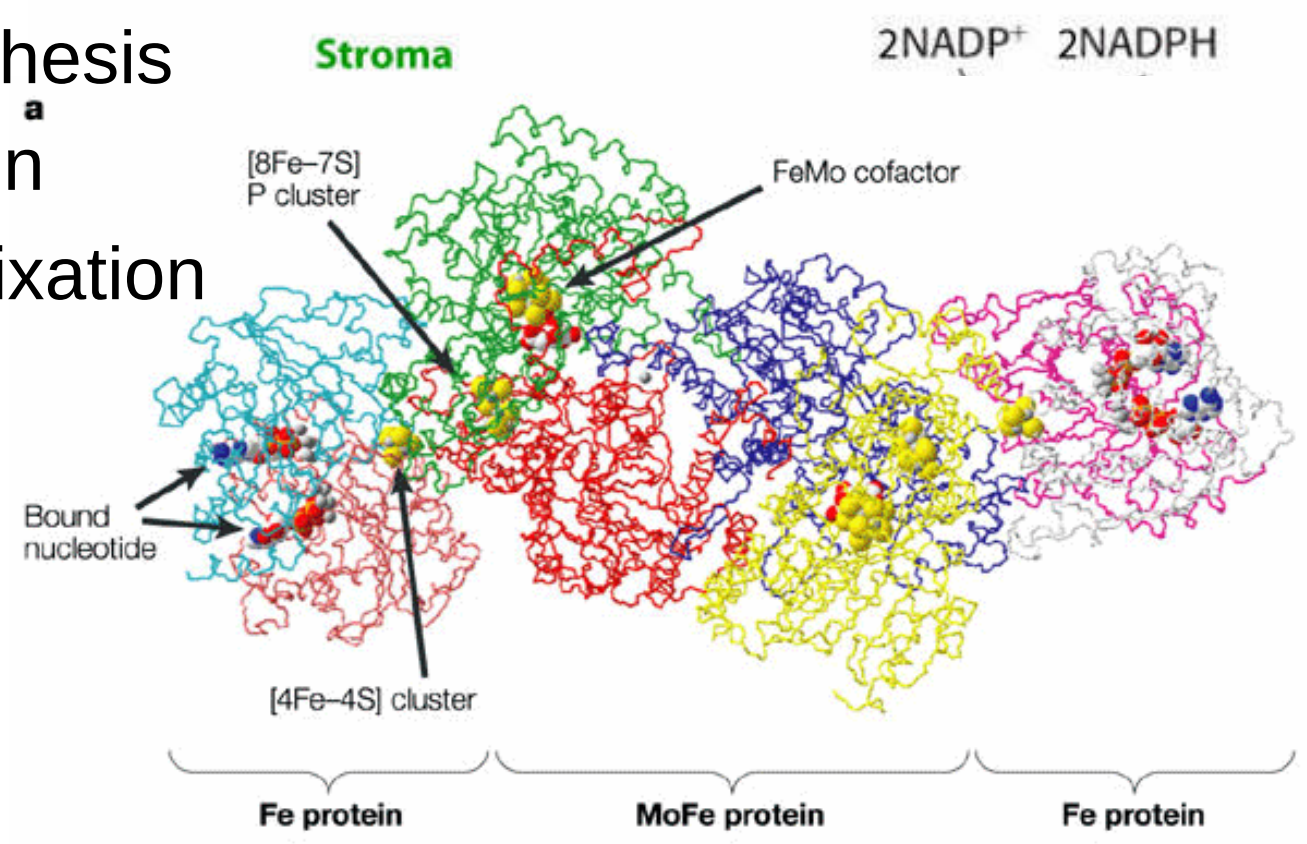


Phosphorus control

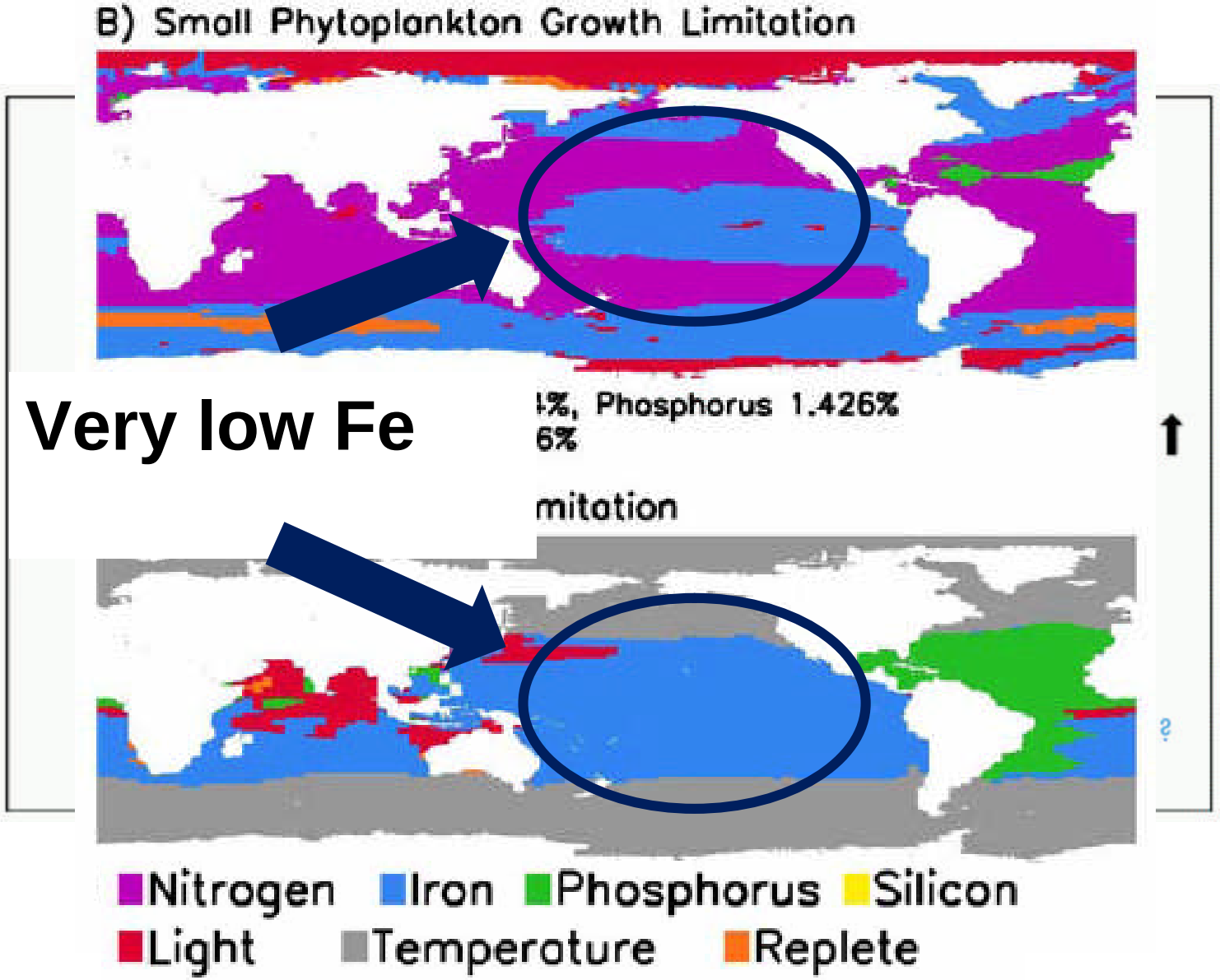


Controls on Nitrogen Fixation

- Iron (Fe)
- Important for:
  - Photosynthesis
  - Respiration
  - Nitrogen fixation

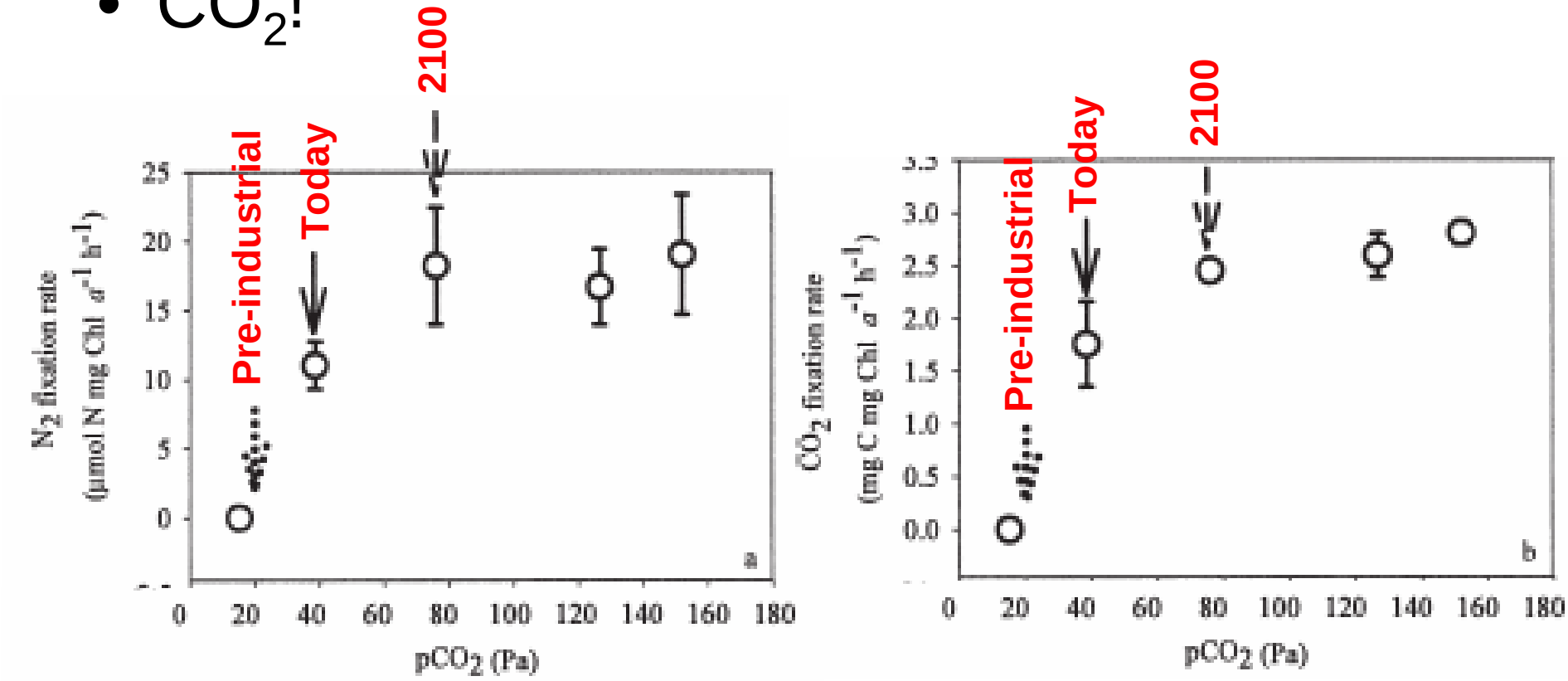


Iron control



Controls on Nitrogen Fixation

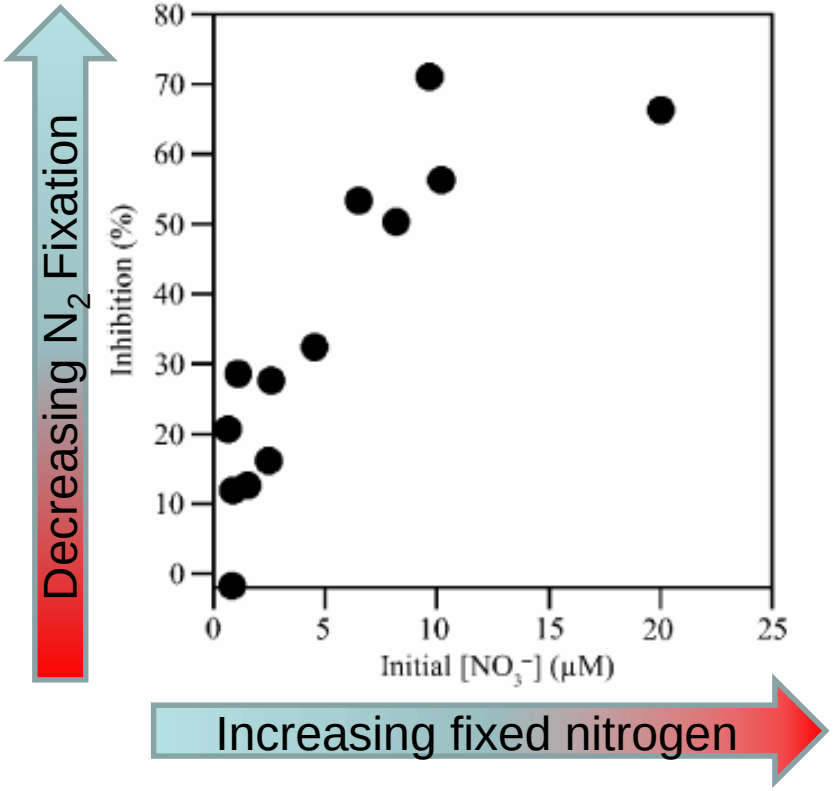
- CO_2!



Why? Increased CO2 makes carbon fixation “easier” – more energy available for nitrogen fixation?

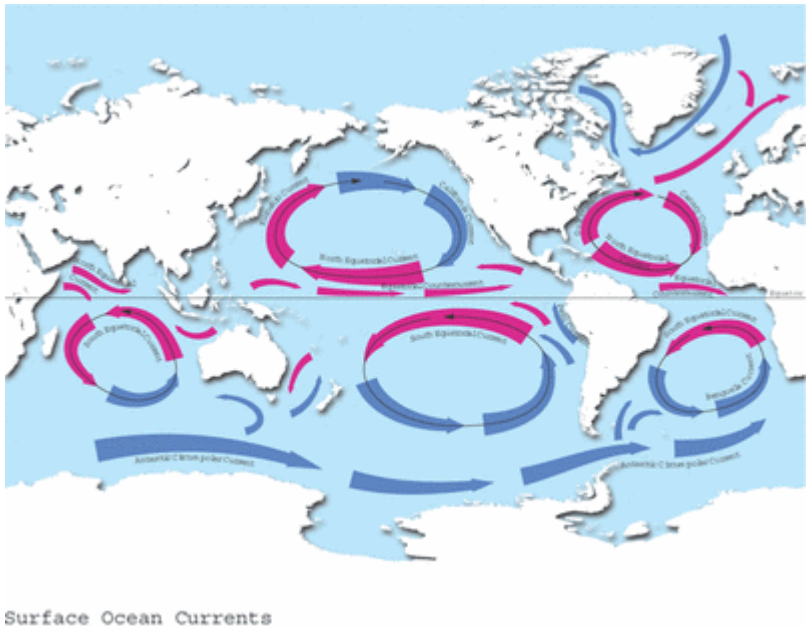
Controls on Nitrogen Fixation

- Nitrogen
  - Nitrogen fixation is expensive!




The Unseen Sea
Why plankton matters

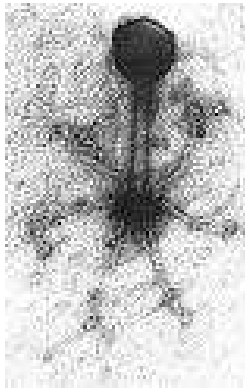
What is plankton?

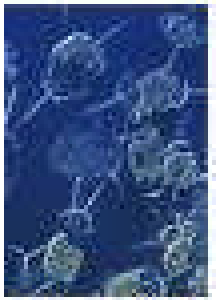


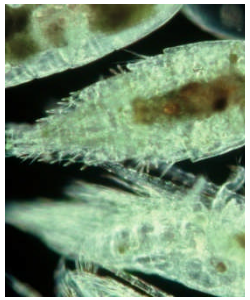
Surface Ocean Currents

- Plankton is a group of organisms that are not big enough or strong enough to swim against ocean currents, or simply can’t swim at all

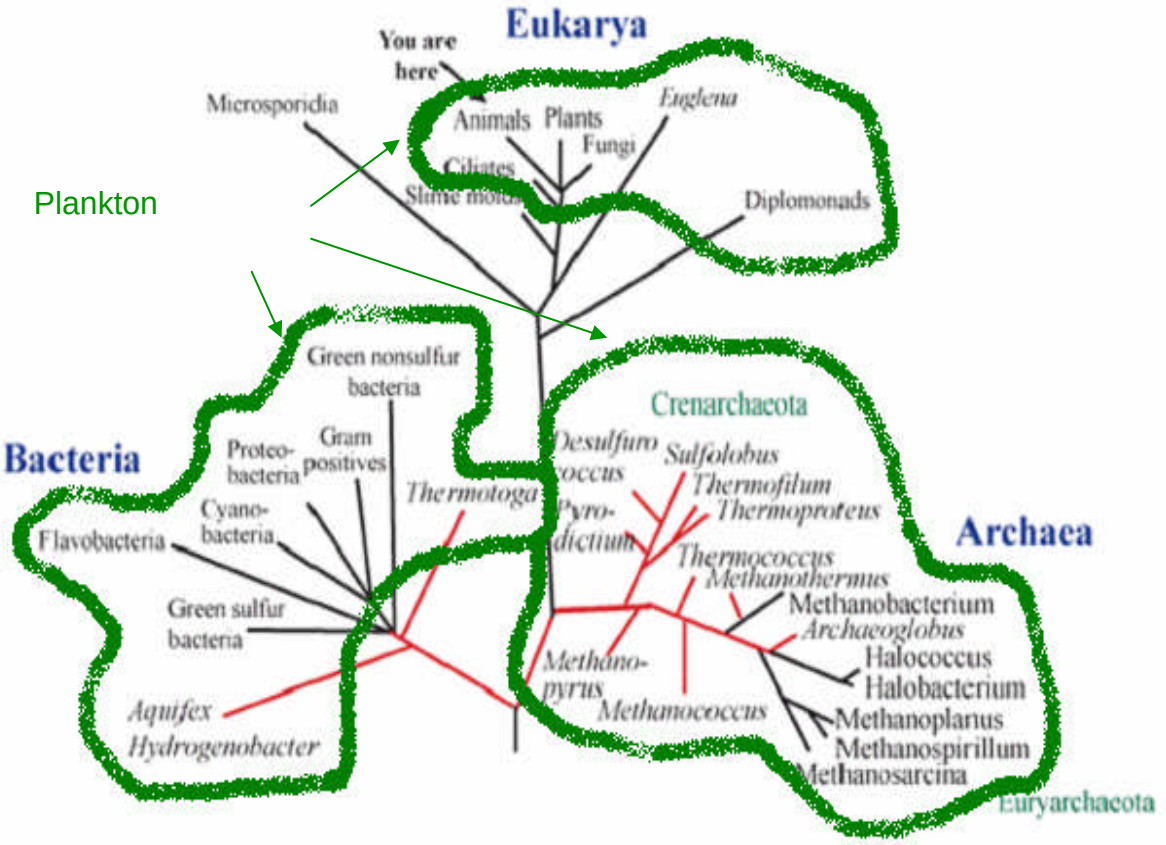
Plankton diversity



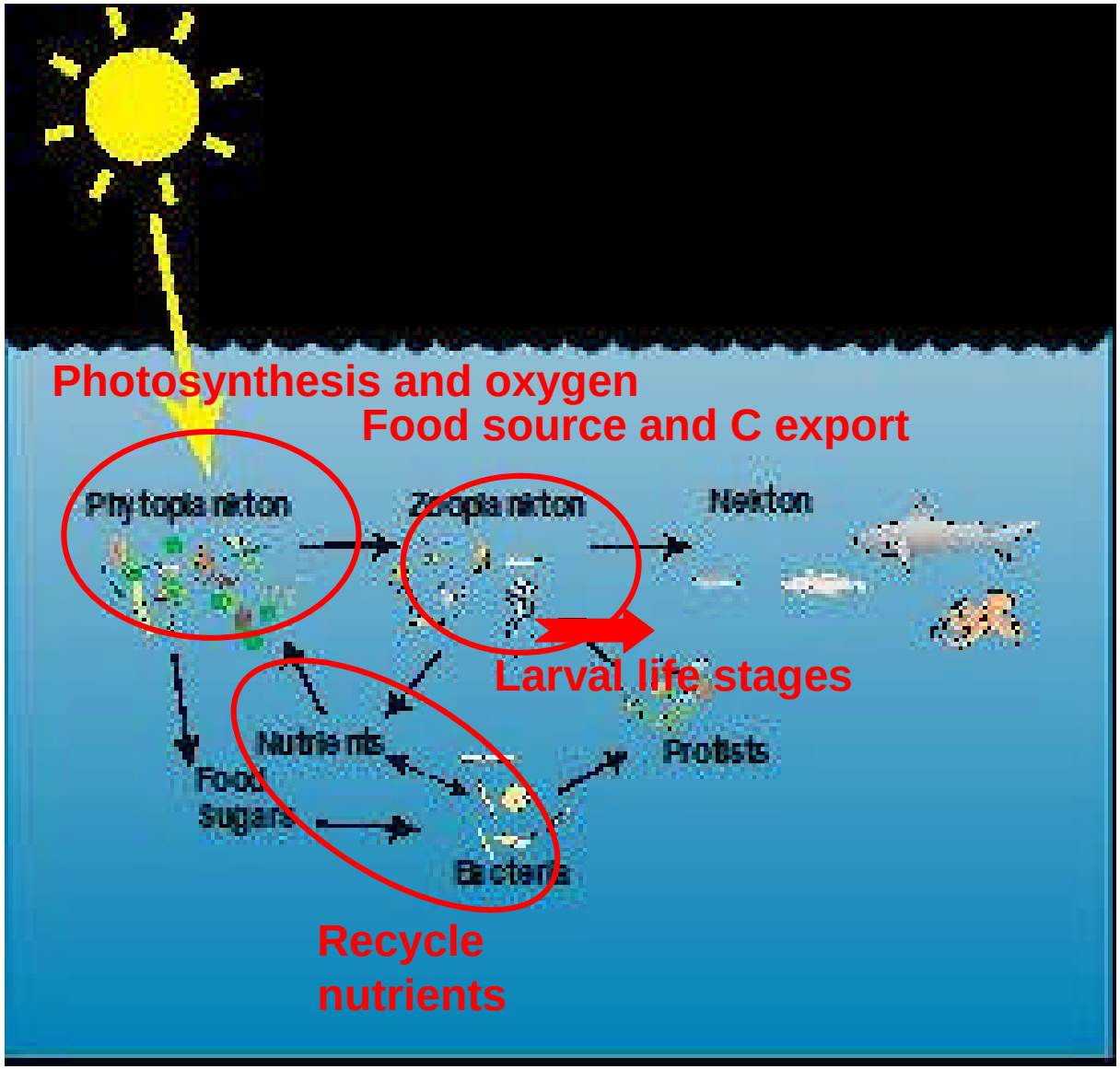




Plankton

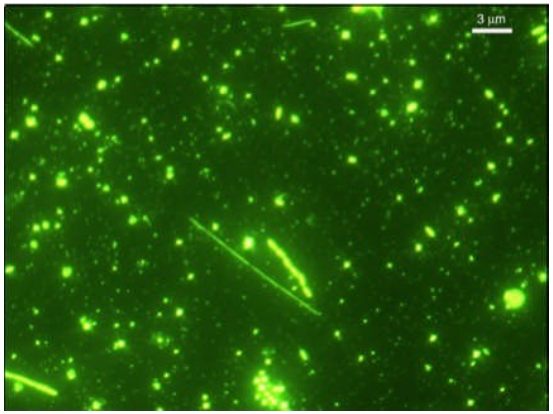


Why do they matter?

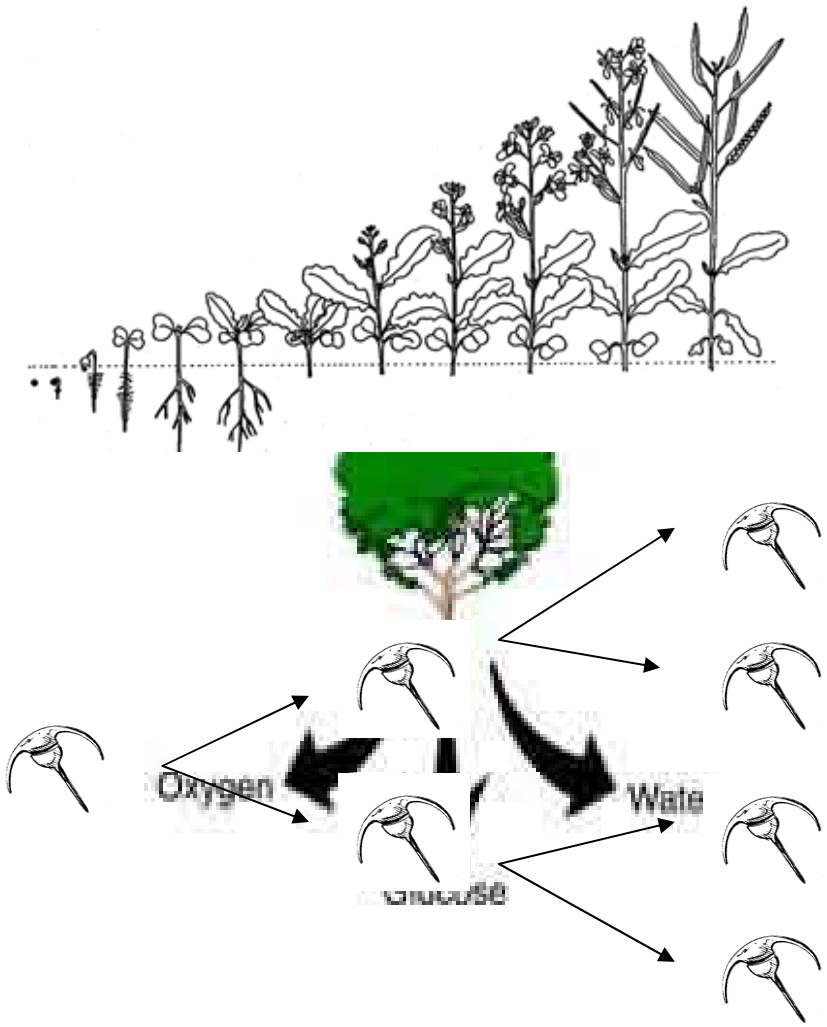


Basic plankton information

- Size: <1 µm to >100ft
  - Vast majority are microscopic
- Abundant
  - In a liter of water:
    - 10,000,000,000 viruses, 1,000,000,000 bacteria, 1,000,000 phytoplankton, 10 copepods
- Total number: 10^{29} bacteria in the ocean



Phytoplankton, photosynthesis and oxygen

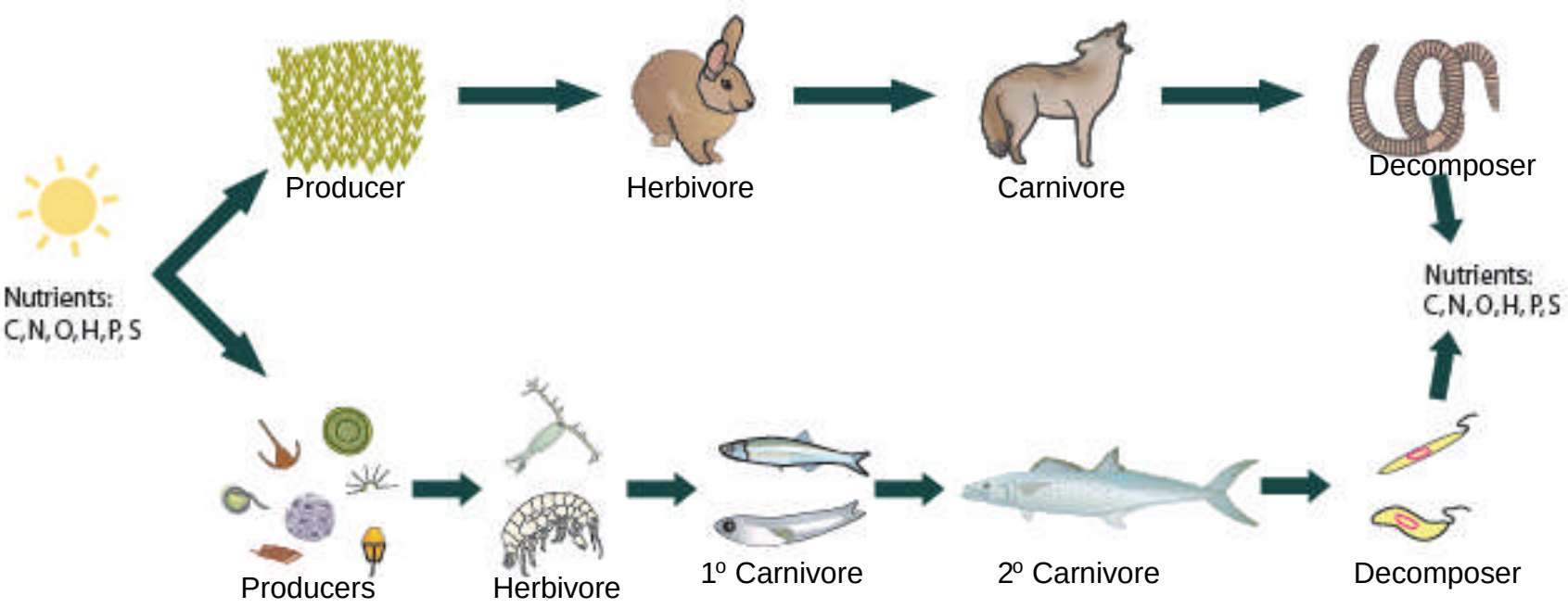


- Phytoplankton are single celled plants
- Plants fix CO_2 from the atmosphere – make oxygen and grow
- Instead of growing larger, phytoplankton divide and increase their number

Phytoplankton, photosynthesis and oxygen

- Animals rely on photosynthesis to harness the energy of the sun and make it “useable”
- This process originated in the ocean
- Phytoplankton are responsible for most of the oxygen in our atmosphere today

Food chains/webs



Food chains/webs

- Some organisms occupy different parts of the chain in different parts of their lives








- Many are important fisheries species

Plankton are important and beautiful!