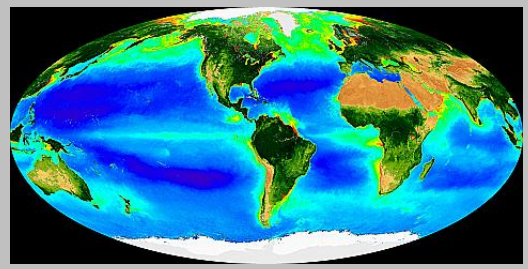
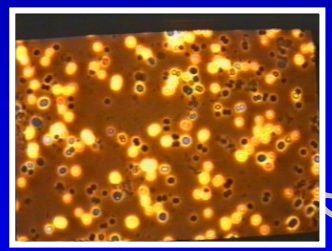
# Planet of the Prokaryotes



## or



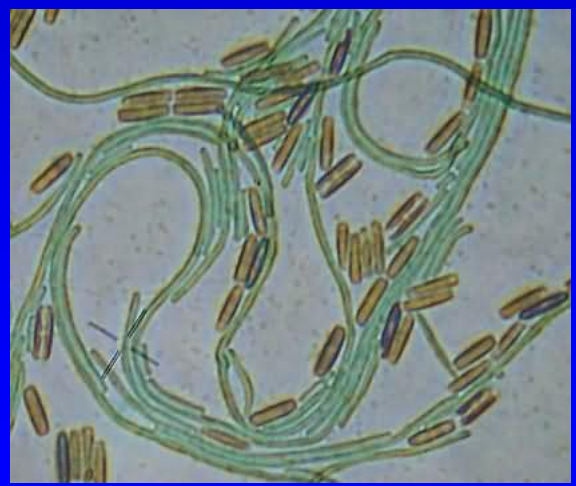
## On the importance of being little

*(with apologies to Oscar Wilde)*

*Doug Capone*
*USC*

# *Main Points*

- Microbes dominate life in the Oceans and on Earth
- They are crucial in the production of organic matter and in global elemental cycles



USC Wrigley Institute for Environmental Studies

NSF

# Two Fundamental Life Forms on Earth

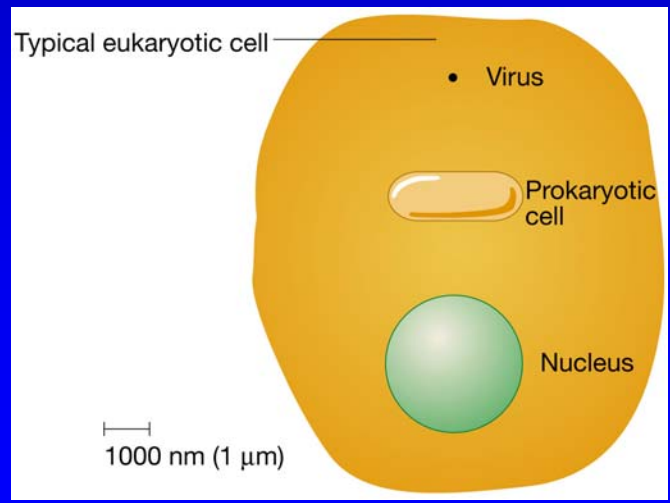
Men & Women ?

***NOT!***

***Prokaryotes***

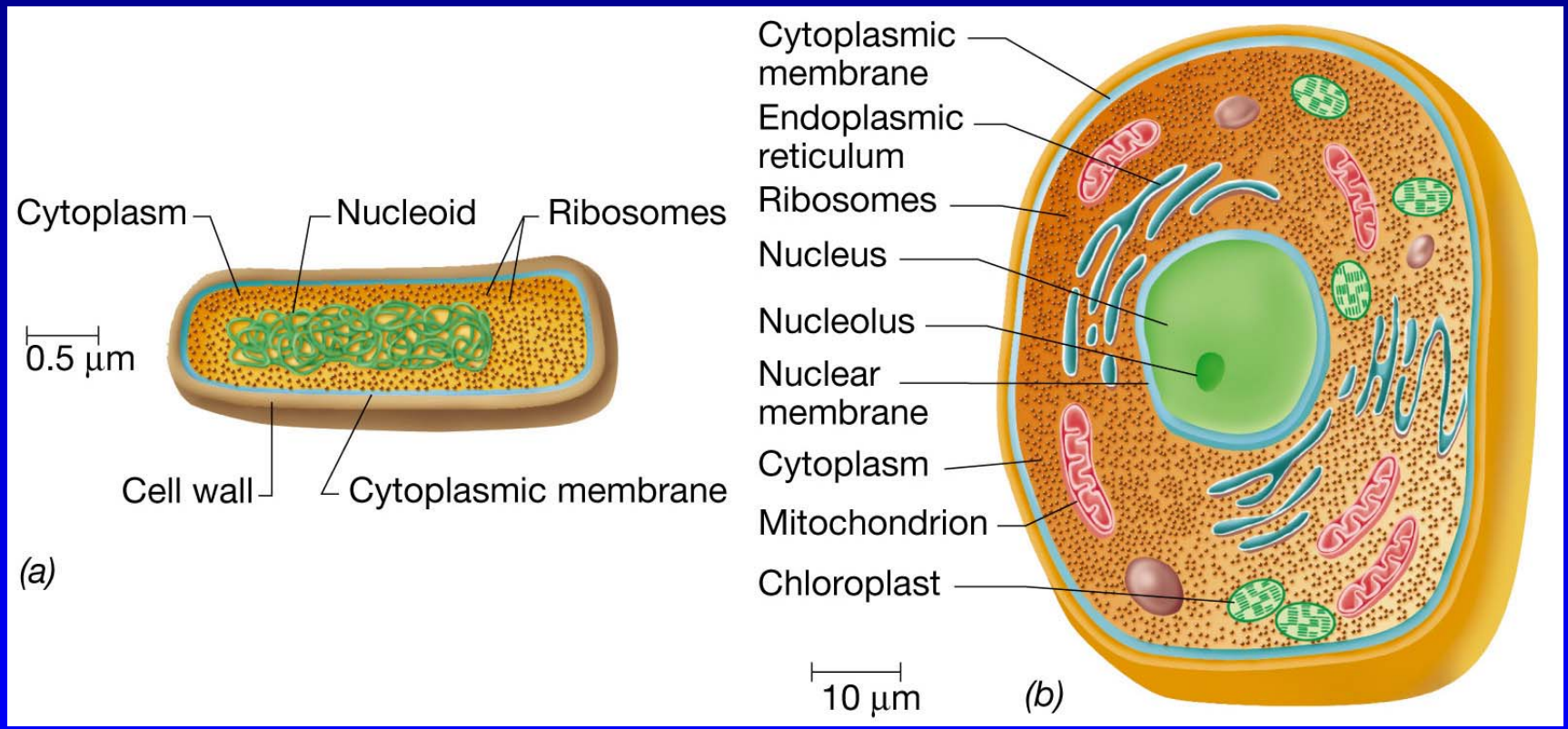
***and***

***Eukaryotes***



**Prokaryotes: Bacteria & Archaea**

**Eukaryotes: protists (inc microalgae), fungi, plants & animals**

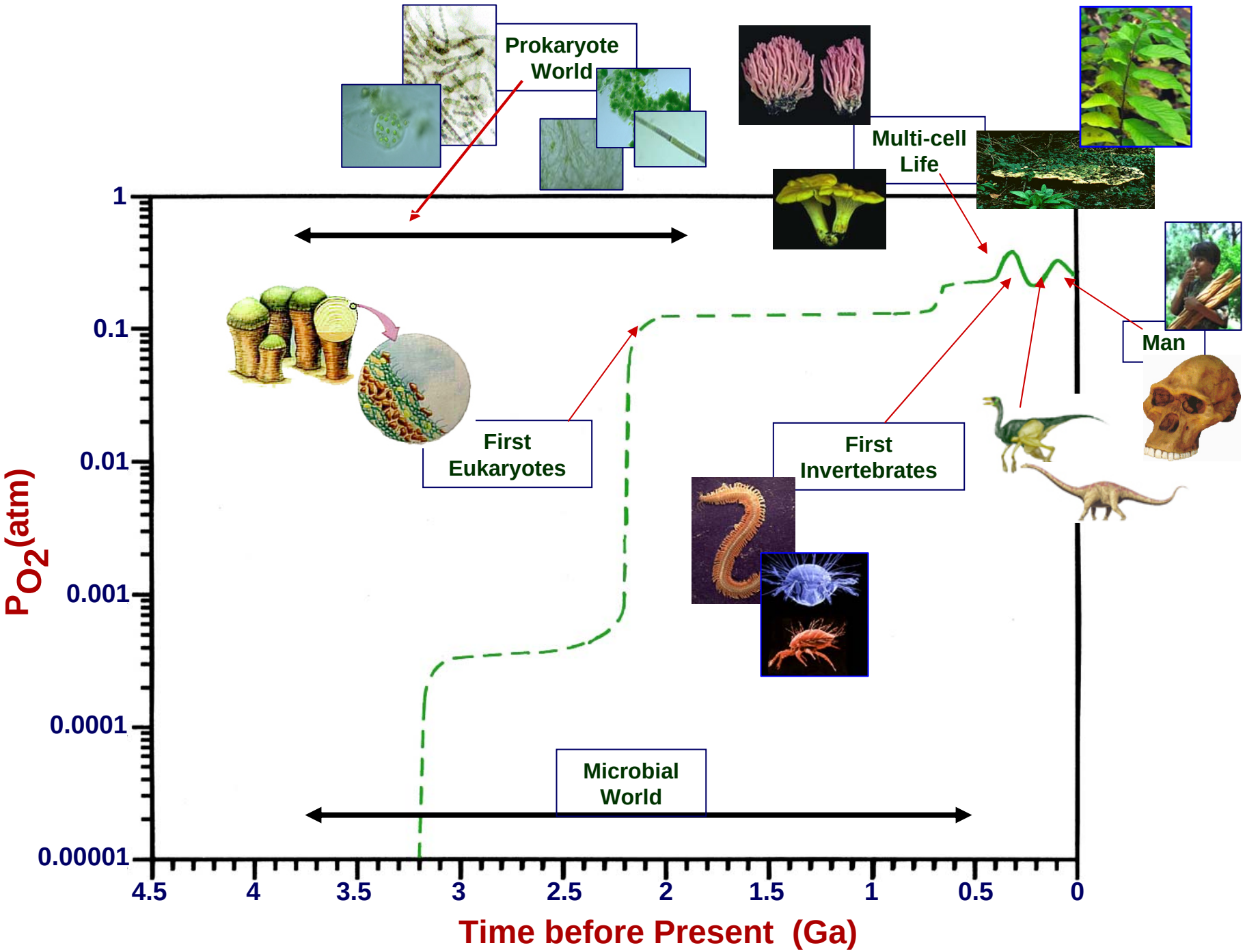



Metabolically diverse

Metabolically limited

# Prokaryote Characteristics Three points ...

- Durability
  - they've been around a while (> 3.5 billion years)
- Diversity
  - there's lots of different ones
  - Phylogenetically and metabolically
- Density
  - there's lots in the environment


Prokaryote World
Multi-cell Life
Man
First Eukaryotes
First Invertebrates
Microbial World
1
0.1
0.01
0.001
0.0001
0.00001
$P_{O_2}$(atm)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Time before Present (Ga)

# Classical View of BioDiversity & Taxonomy

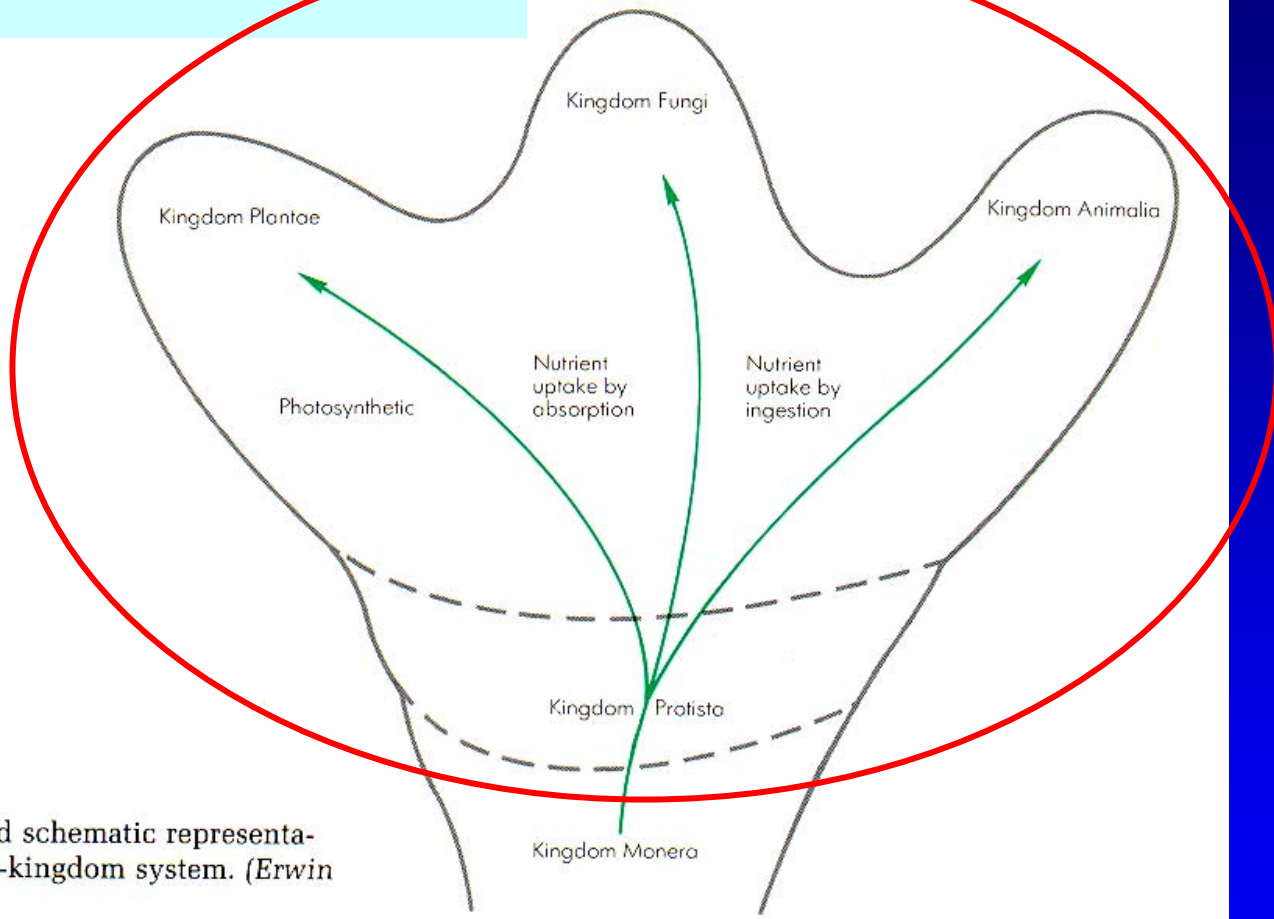
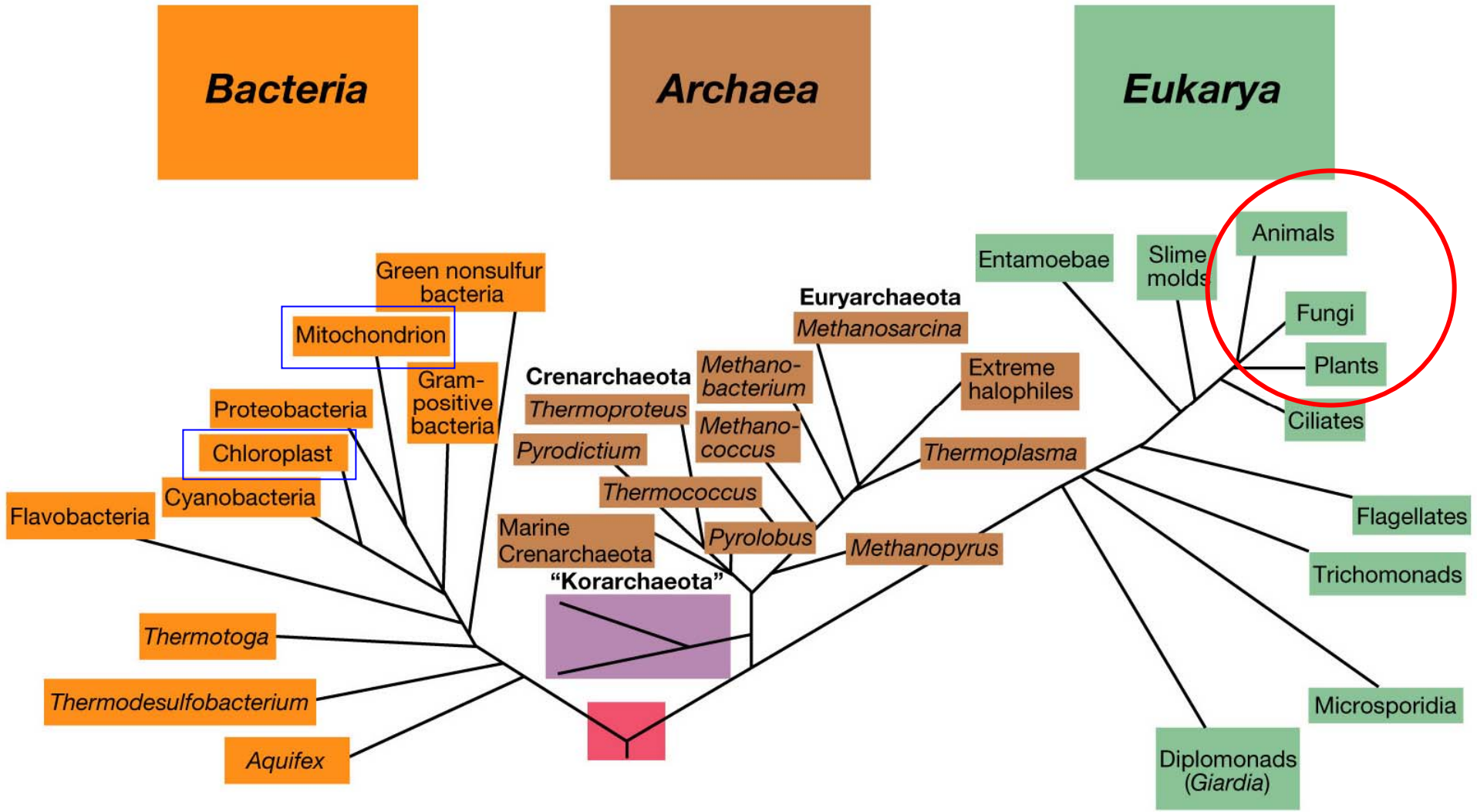



**Figure 1-6.** A simplified schematic representation of Whittaker's five-kingdom system. *(Erwin F. Lessel, illustrator.)*

**Relationships inferred by subjective criteria: comparative morphology, function & metabolism**

# Things Have Changed Radically!
# Recasting the Tree of Life – Where's the Diversity?



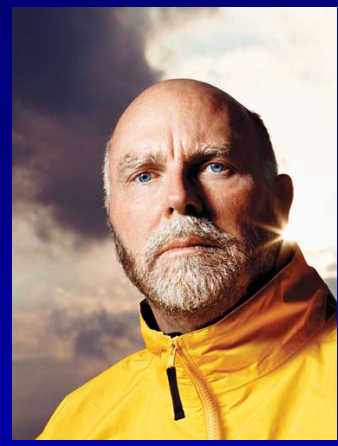

## Modern Phylogeny: DNA based

# Species Diversity

| Group | # Species (described) | Total # Species (estimated) | % Known |
|---|---|---|---|
| Microbes | | | |
| Bacteria | 5,000 | (10,000,000) ? | ~ 0.04 |
| Archaea | < 100 | ? | ? |
| Algae | 40,000 | 400,000 | 10 |
| Protozoa | 40,000 | 200,000 | 20 |
| Plants | 270,000 | 320,000 | 84 |
| Animals | | | |
| Insects | 950,000 | 8,000,000 | 12 |
| Vertebrates | 45,000 | 50,000 | 90 |

# Sorcerer II- Craig Venter

*the human genome guy*



Probing the true microbial biodiversity of the sea - metagenomics

# Microbes have adapted to a wide range of conditions

- Oxygen
- Temperature
- Salt –Extremes of pH
- Extremes of pressure
- Combinations of the above!

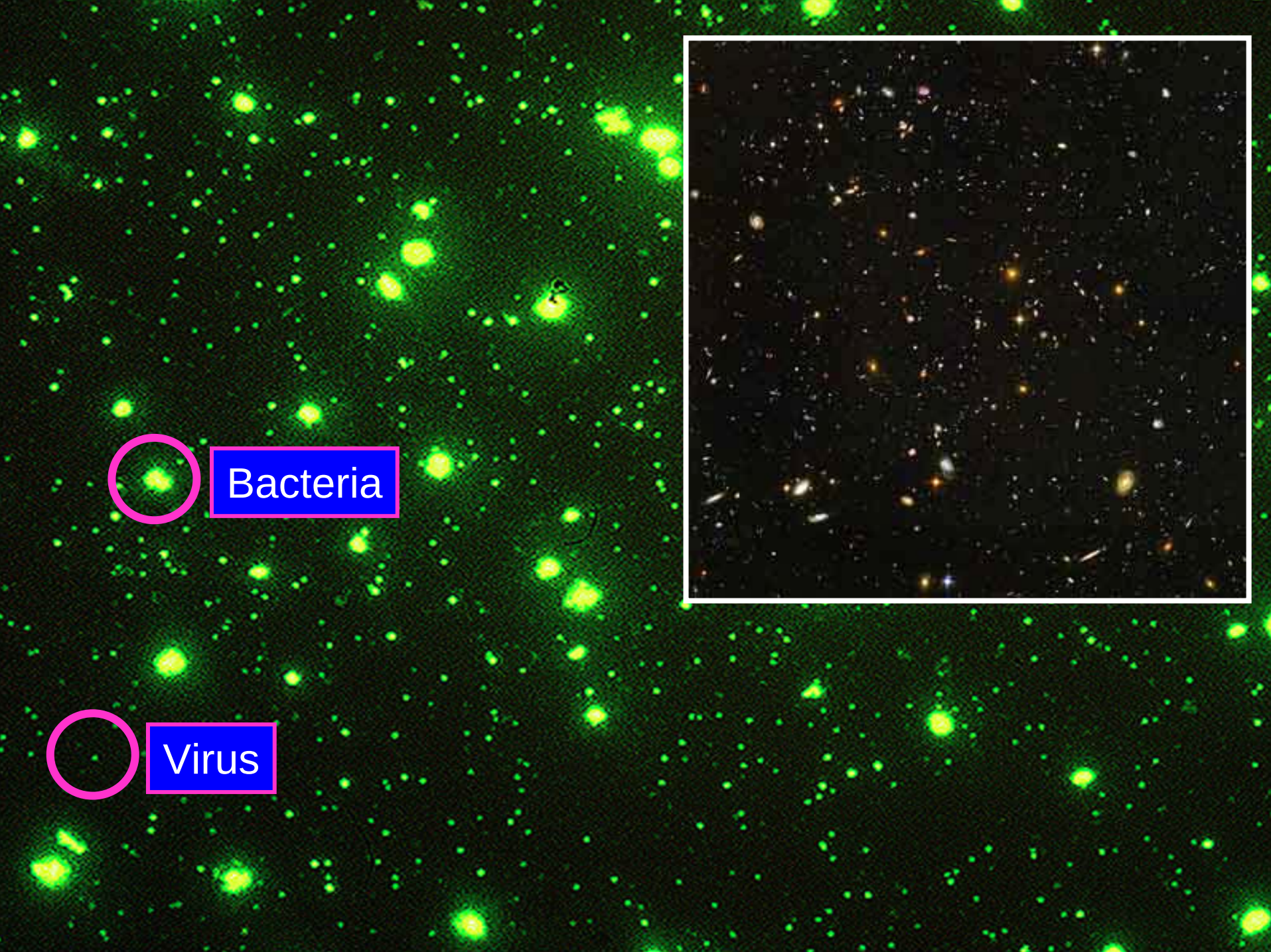
# Microbes are found everywhere!

- Terrestrial
  - Soils
  - Aquifers
  - On and in rocks
  - Lakes
    - High & low pH
    - High salt

- Ocean
  - Plankton
  - Benthos (sediments)
    - Coral reefs
    - Deep sea
    - Hot vents
  - Symbioses

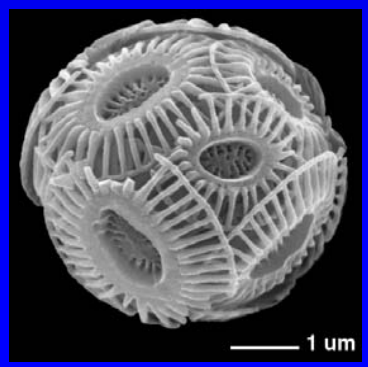
# Microbe Densities in Seawater

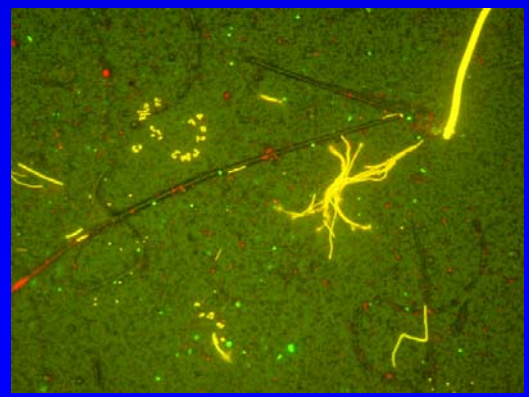
| *Critter* | *Cell densities in Seawater* |
|---|---|
| Viruses | ~10,000,000 per ml |
| Bacteria/ Archaea | ~1,000,000 per ml |
| Microalgae | ~1,000 –100,000 per ml |
| Heterotrophic Protists | ~1,000 per ml |
| Zooplankton | ~1-10 per L |
| Jelly plankton | ~1 per $m^3$ |


Bacteria
Virus

# Microbes and Biogeochemistry

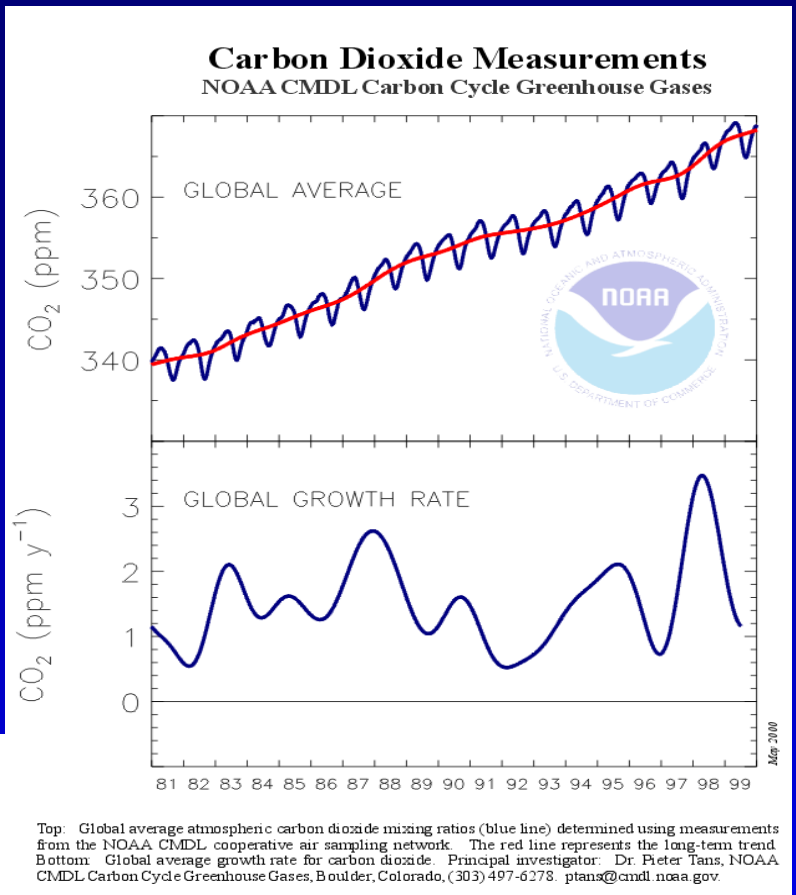
- The earth and its microbial populations have “co-evolved” over 3.6 BY
- The major biogeochemical cycles of carbon and nitrogen were “invented” by microbes as they innovated new modes of metabolism
- Until the arrival of Humans, microbes have dominated biogeochemical cycles



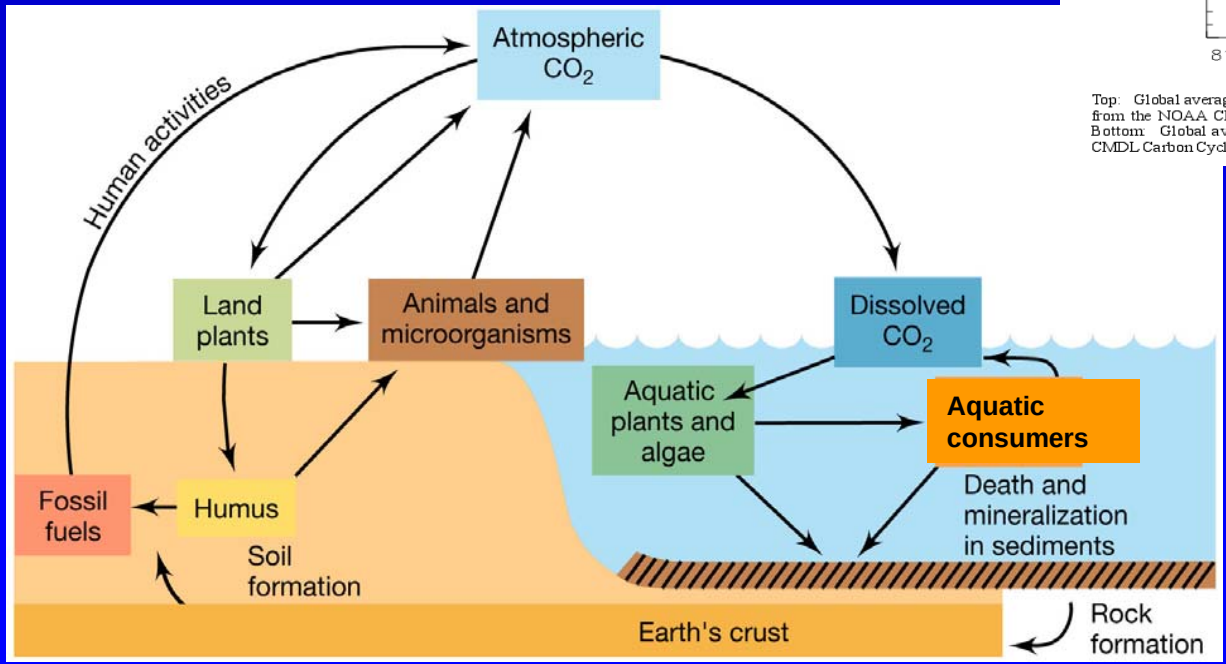



# The Carbon Cycle

- Two main forms
  - Inorganic ($CO_2$)
  - Organic
- $CO_2$ in the Atmosphere: a rising concern
- Increase of ~ 0.4%/ y or about 3.4 billion tons




Top: Global average atmospheric carbon dioxide mixing ratios (blue line) determined using measurements from the NOAA CMDL cooperative air sampling network. The red line represents the long-term trend. Bottom: Global average growth rate for carbon dioxide. Principal investigator: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6278. ptans@cmdl.noaa.gov.



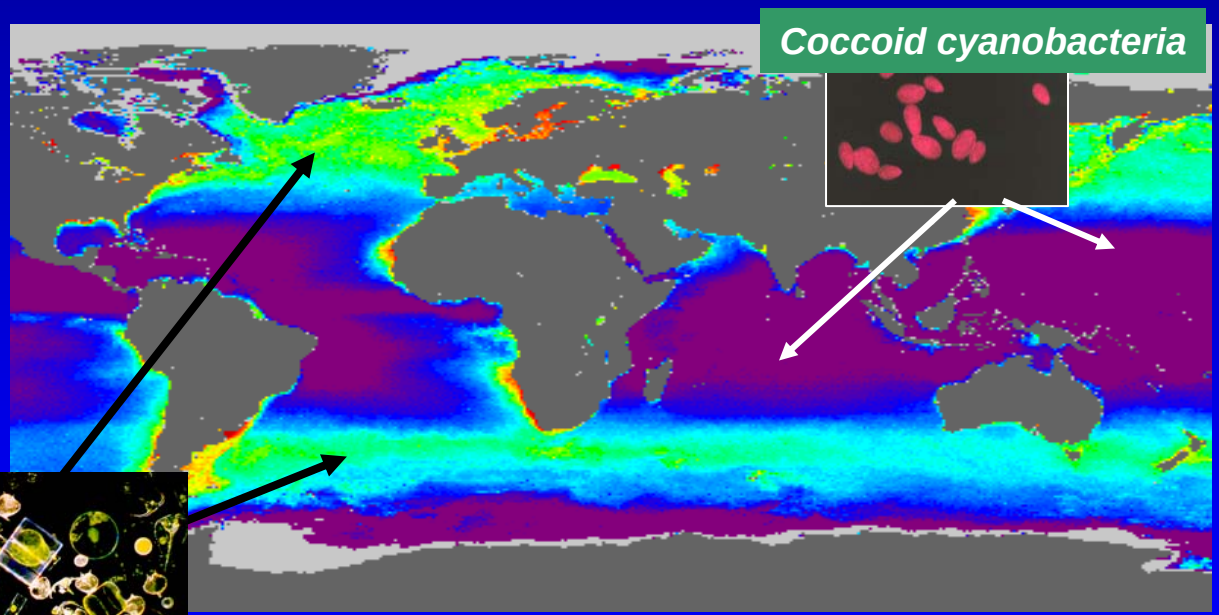

About 50% of fossil fuel emission not accounted for in atmosphere

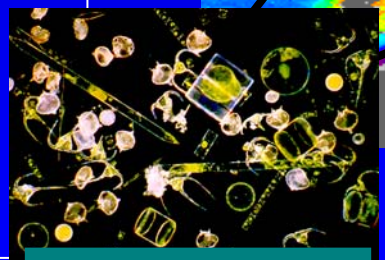
# The Open Ocean

## Microbially dominated

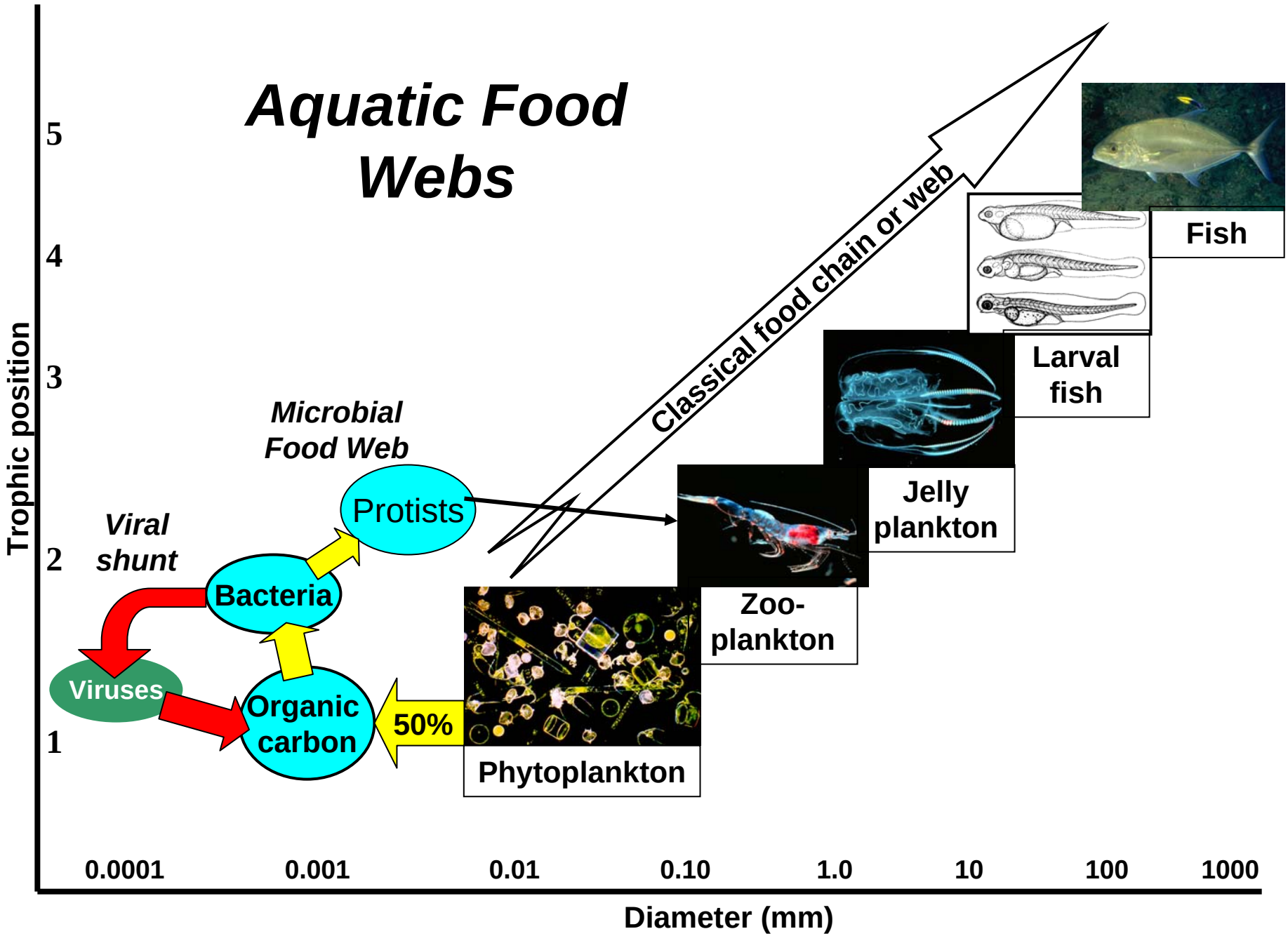
***Intense production of organic matter by microalgae in mid to high latitudes where nutrients are often abundant***

C Fixation/ Primary Production

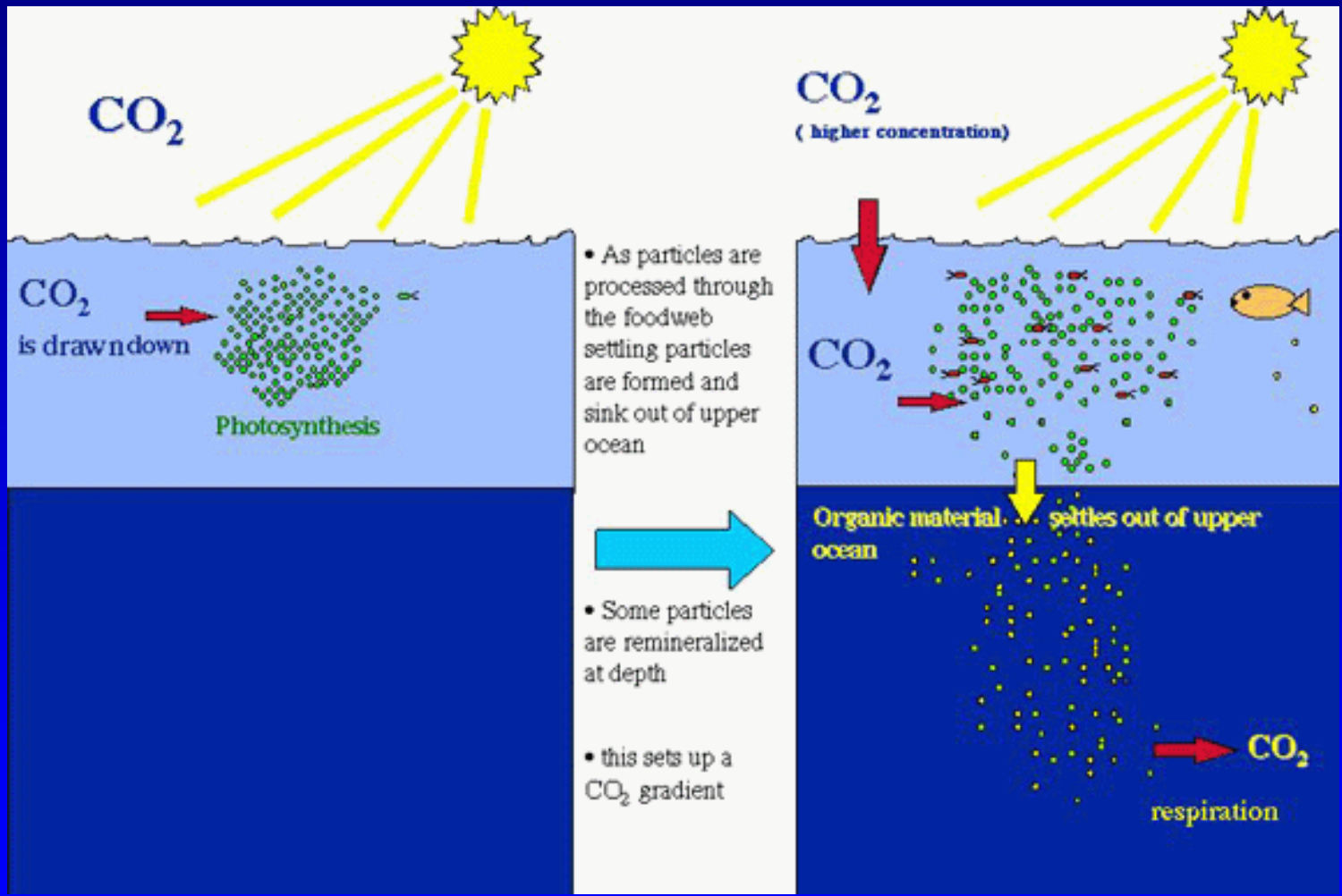


***Diatoms***
***Dinoflagellates***


Aquatic Food Webs
Trophic position
5
4
3
2
1
Classical food chain or web
Microbial Food Web
Viral shunt
Protists
Bacteria
Viruses
Organic carbon
50%
Phytoplankton
Zoo-plankton
Jelly plankton
Larval fish
Fish
0.0001
0.001
0.01
0.10
1.0
10
100
1000
Diameter (mm)

# How Important is the Ocean in C Uptake? "The Biological Pump"

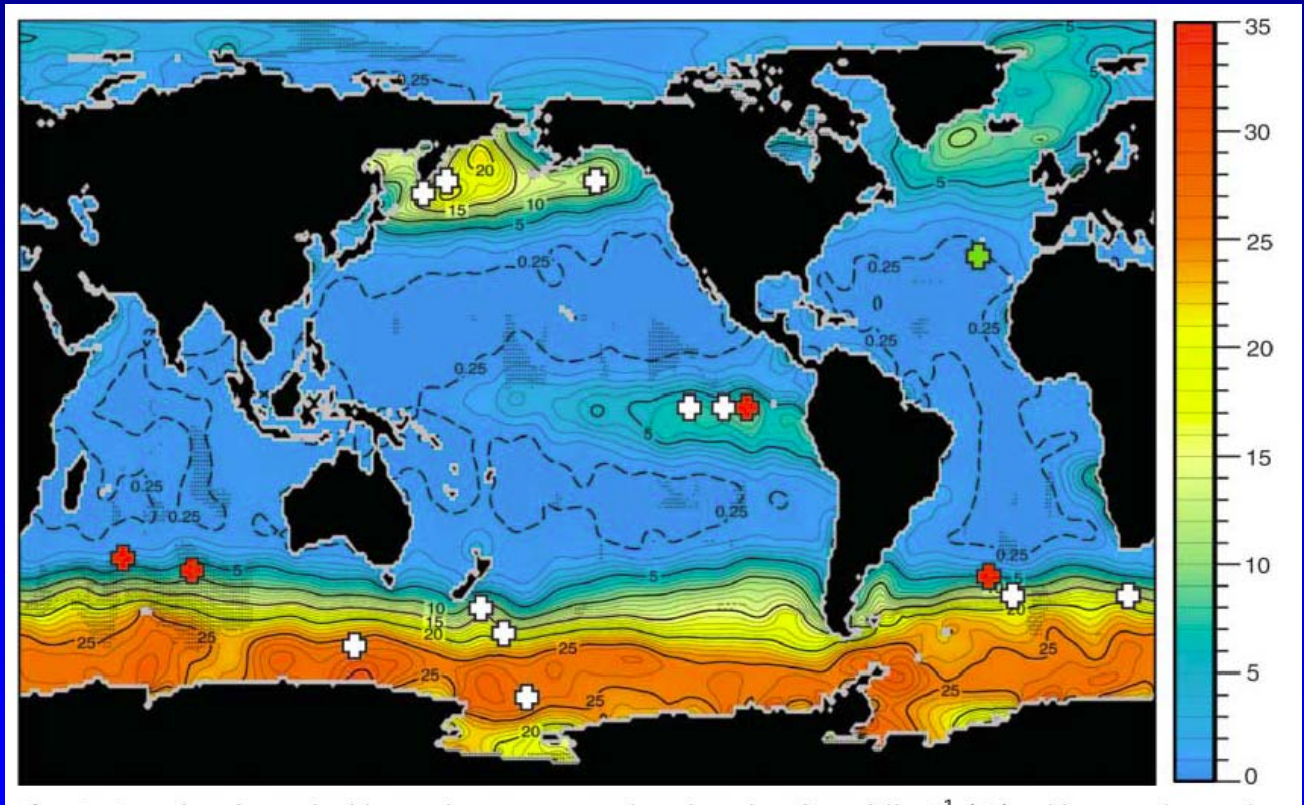


# Ocean Fertilization for C Sequestration

**In addition to $CO_2$, phytoplankton Need other nutrients N, P, S, Fe**

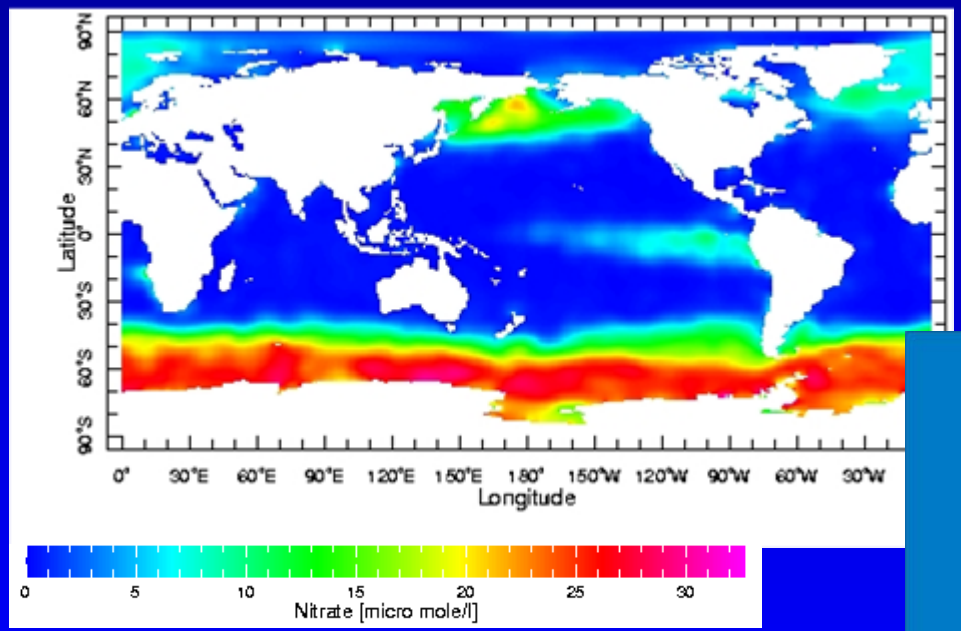
**Some areas of the ocean- iron is in short supply**

**Iron fertilization zones**



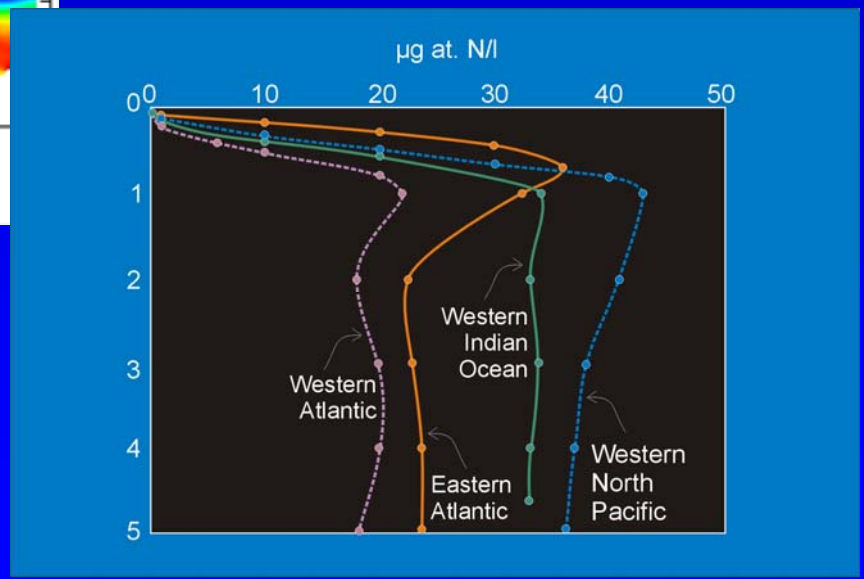
# The Nitrogen and Carbon cycles are closely linked

## The formation of new organic matter in the Ocean is largely limited by nitrogen availability

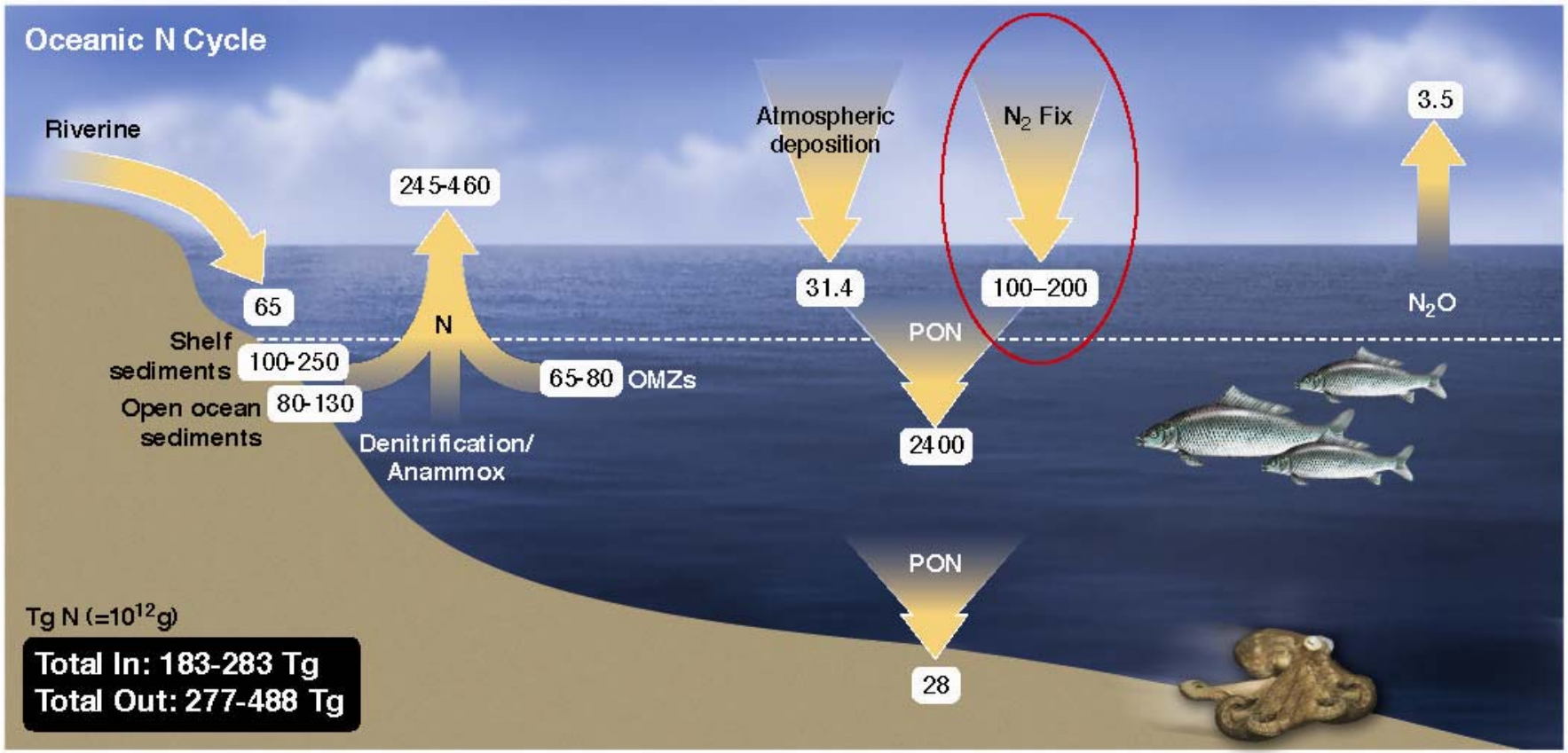



- Phytoplankton need nitrogen to grow

(like your garden)



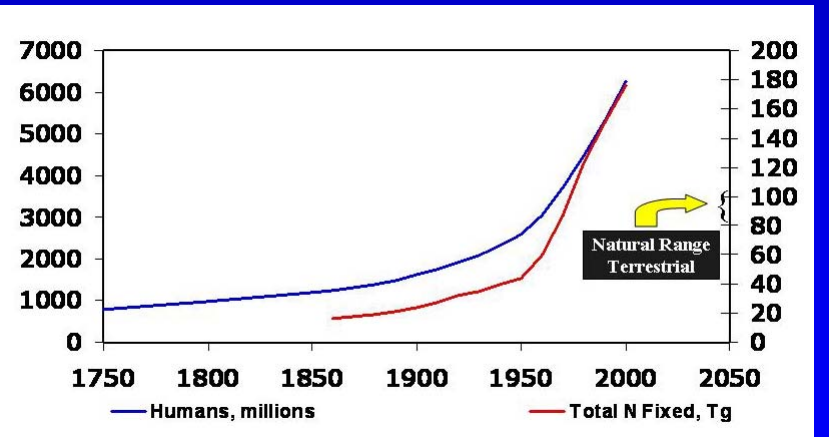
# Fluxes of N in and out of the Ocean



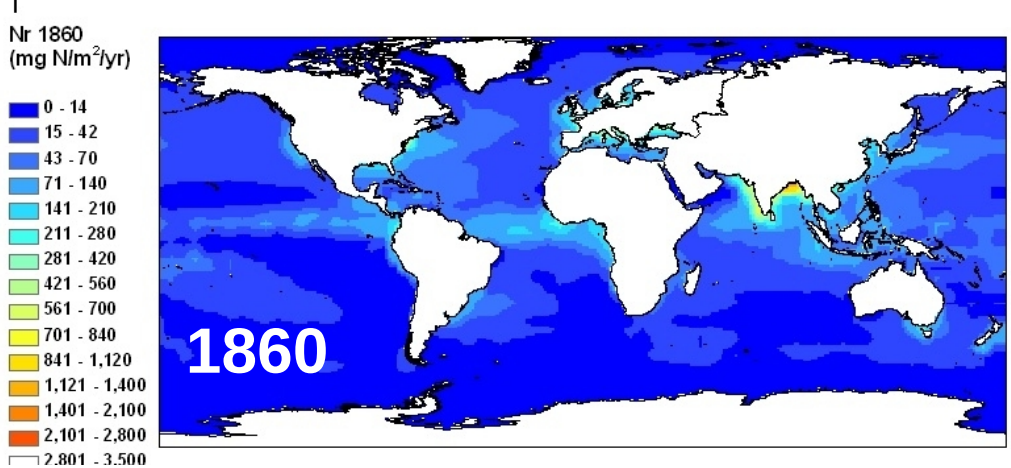
Why worry?

Major Nitrogen Cycle Perturbation Is underway

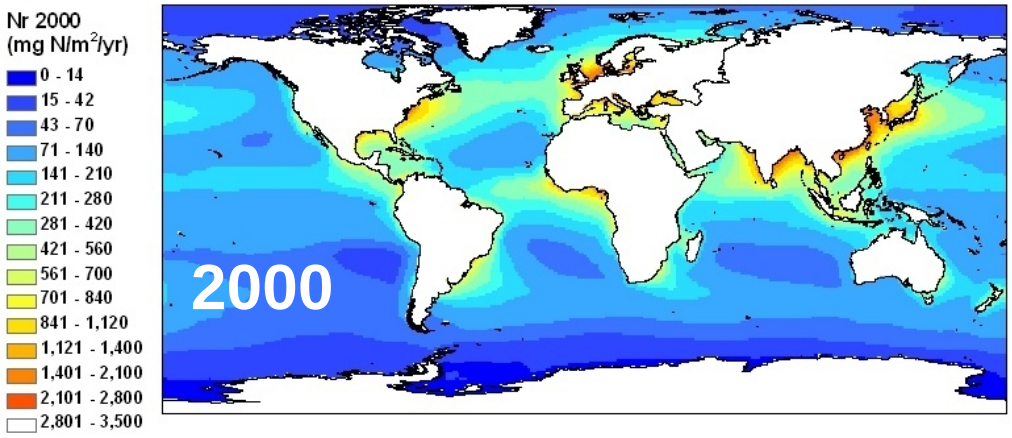
Human Fertilizer production

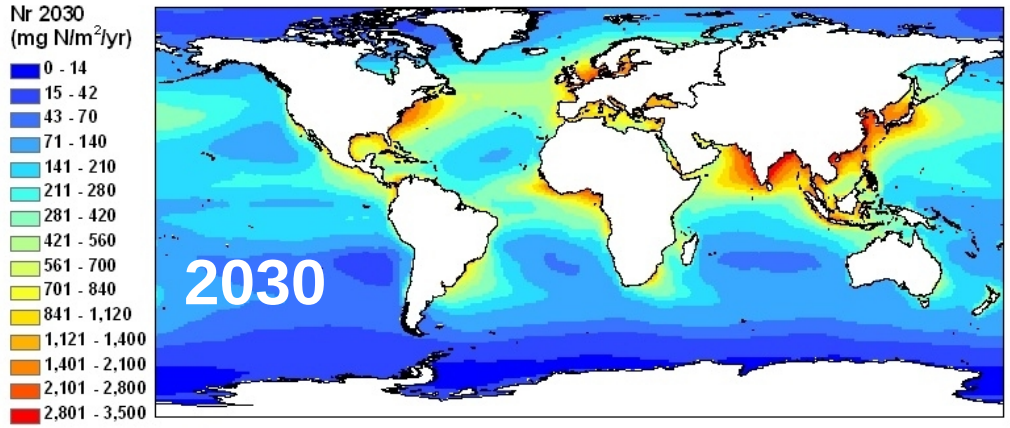



i




ii



# Some take home messages…

- Three domains of life on Earth
  - Bacteria, Archaea & Eukaryotes
  - Extreme diversity in the prokaryotes
- You can find them just about everywhere
- They are the dominant biota and control the major biogeochemical cycles on Earth
- They are responsible for most of the organic production in the oceans

***Microbes: you might not like living with them but we wouldn't survive without them***