Marine Microbial Processes

Cornell University | Oceanography

CORNELL VOTES! EVERY PERSON EVERY VOICE

Outline

1. Historical development of our current understanding of the abundance and function of microbes in marine food webs

2. The role microbial processes play in carbon cycling within marine food webs
   - **The Biological Carbon Pump**

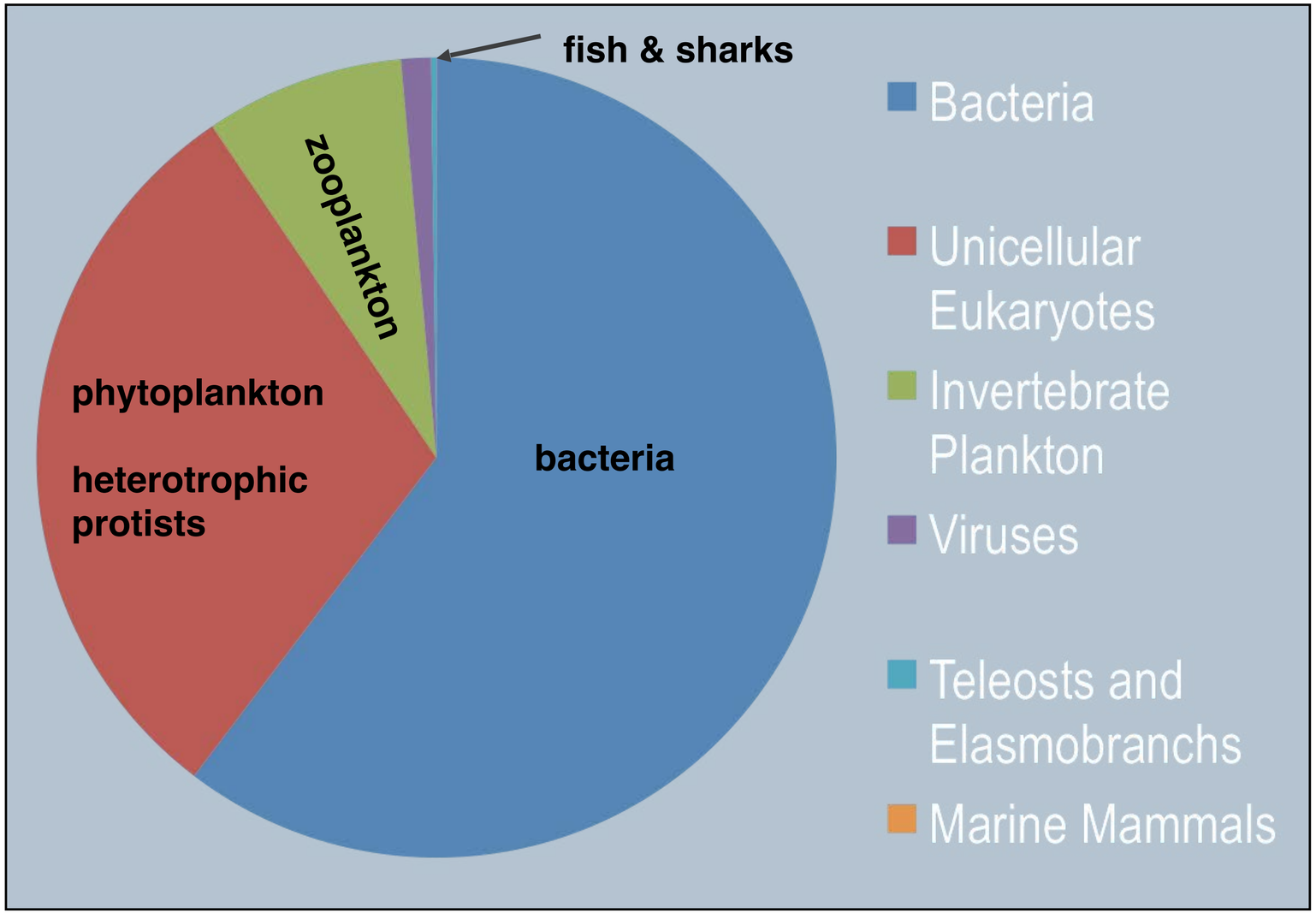
Section 1

Historical development of our current understanding of the abundance and function of microbes in marine food webs

Why Study Marine Microbes?

The vast majority of living biomass in the ocean is in the form of bacteria, phytoplankton/protists and zooplankton.

The smallest stuff is where most of the action takes place!



Proportion of Living Biomass in the Global Ocean

Some Definitions...

Oligotrophic:

Pelagic environment (water column) that has naturally **low** plant nutrient concentrations

- **the vast subtropical gyres are oligotrophic**

Eutrophic:

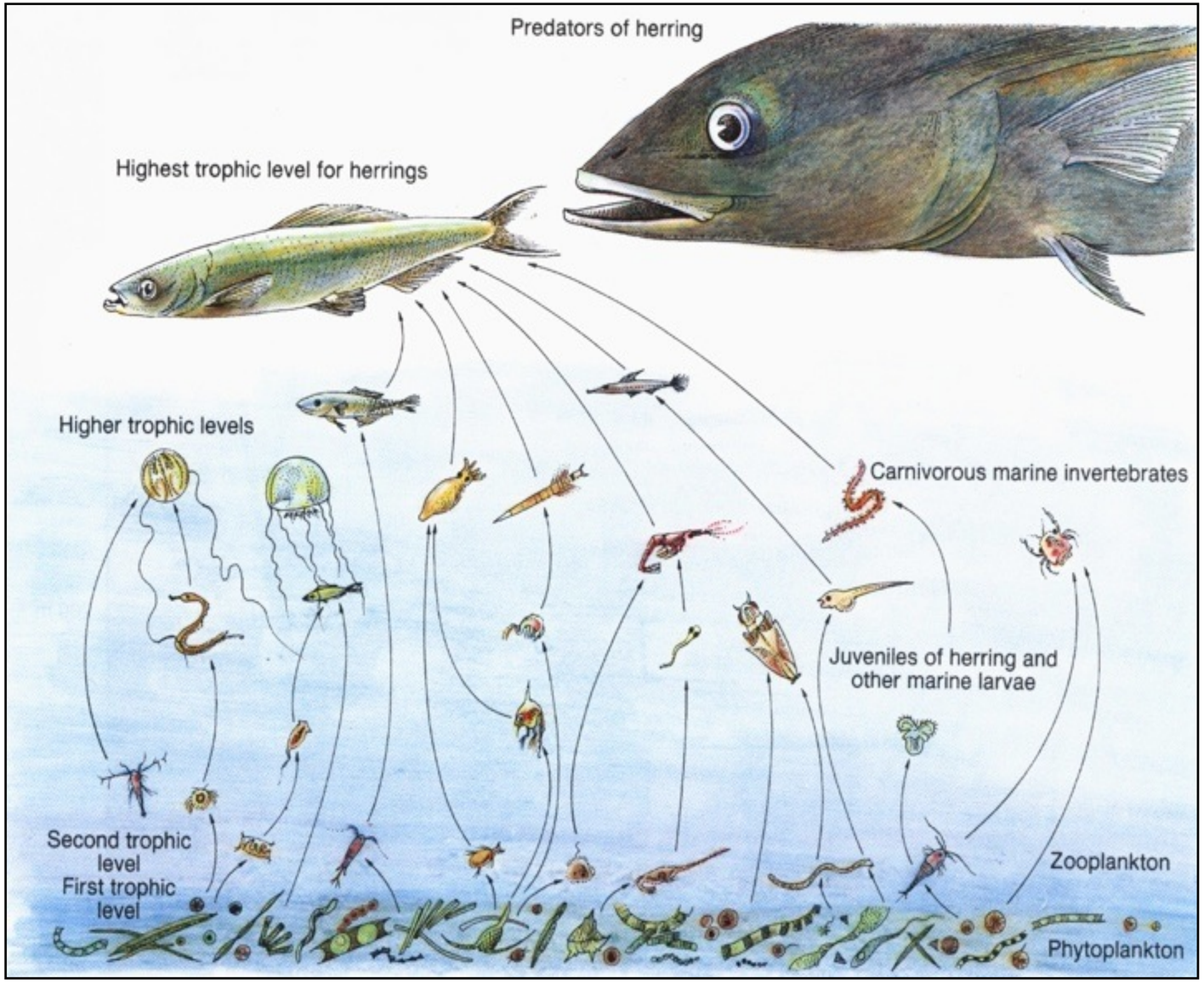
Pelagic environment (water column) that has naturally **high** plant nutrient concentrations

- **coastal upwelling zones are eutrophic**

Recall From the Pelagic Food Web Lecture…

A complex food web can be simplified by classifying organisms into broad categories based on:

1. **presence of chlorophyll**
2. **body size**



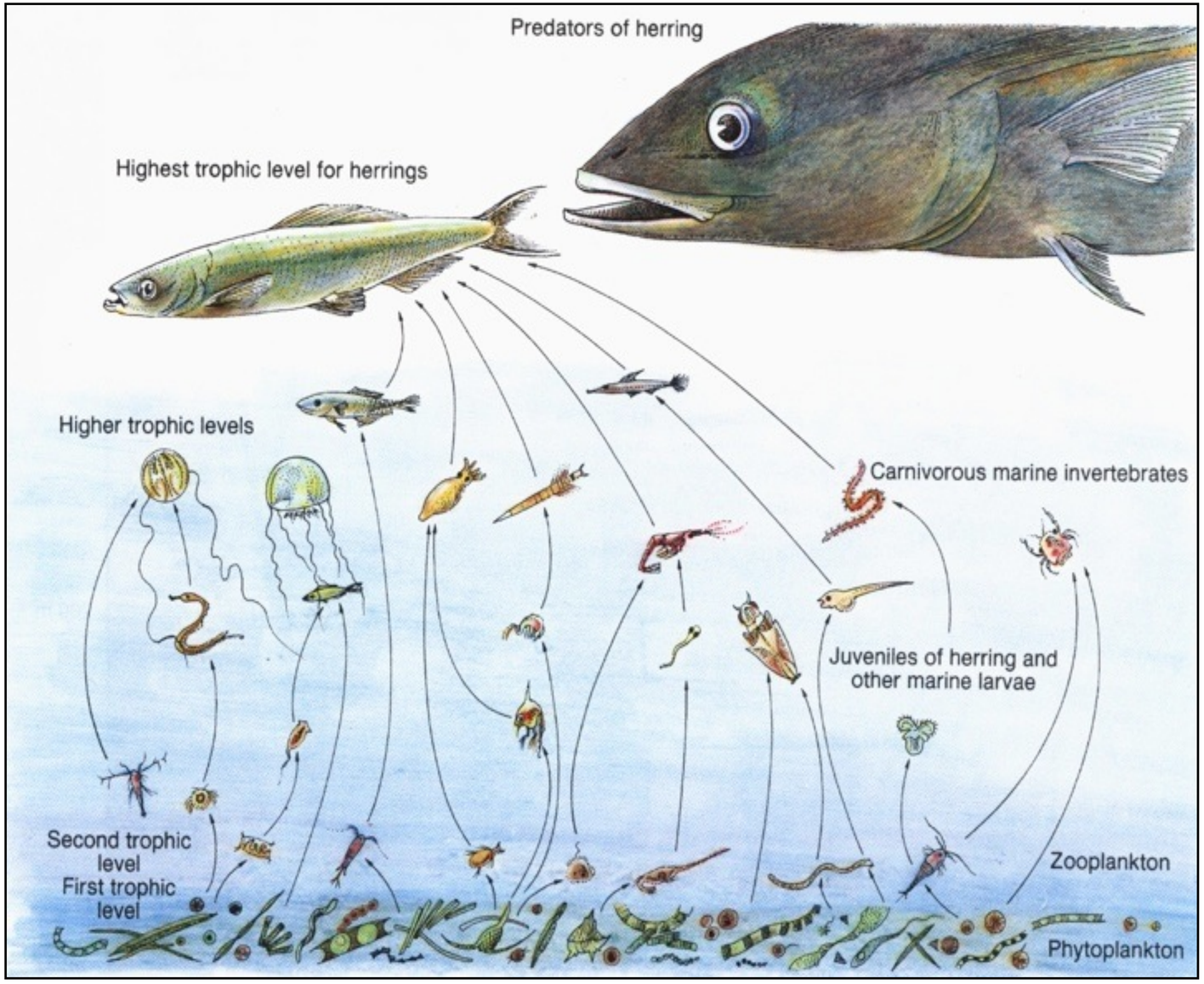
As a general rule, the preferred prey size is approximately *1/10* of the consumer's size

Other than chlorophyll, size determines almost everything about an organism's role in the community of pelagic organisms

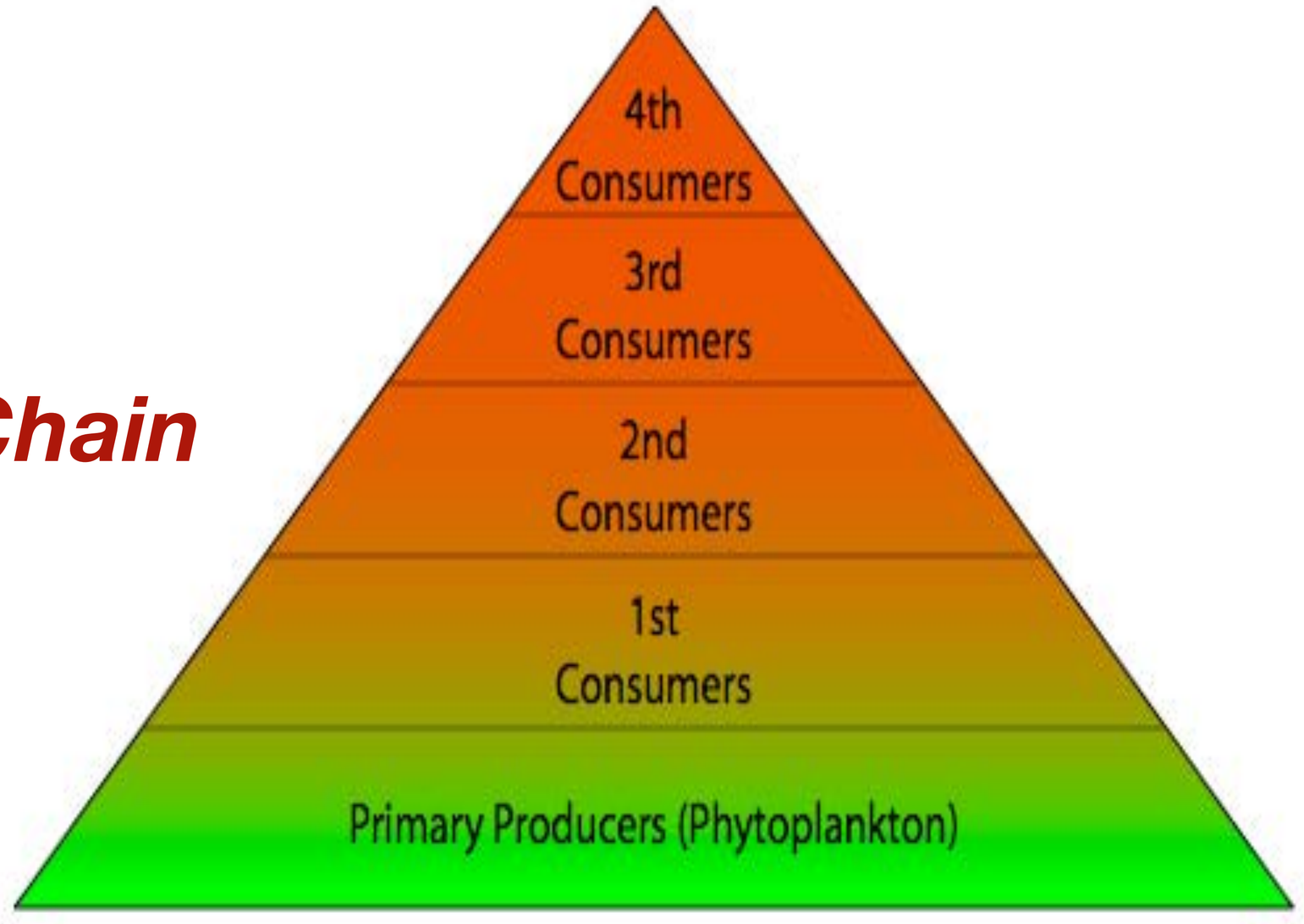
1. It determines who it will eat (all organisms 1/10 its own size)
2. It determines who will eat it (all organisms 10 times bigger than it)

Marine Food Webs are Said to be Strongly Size-Structured!

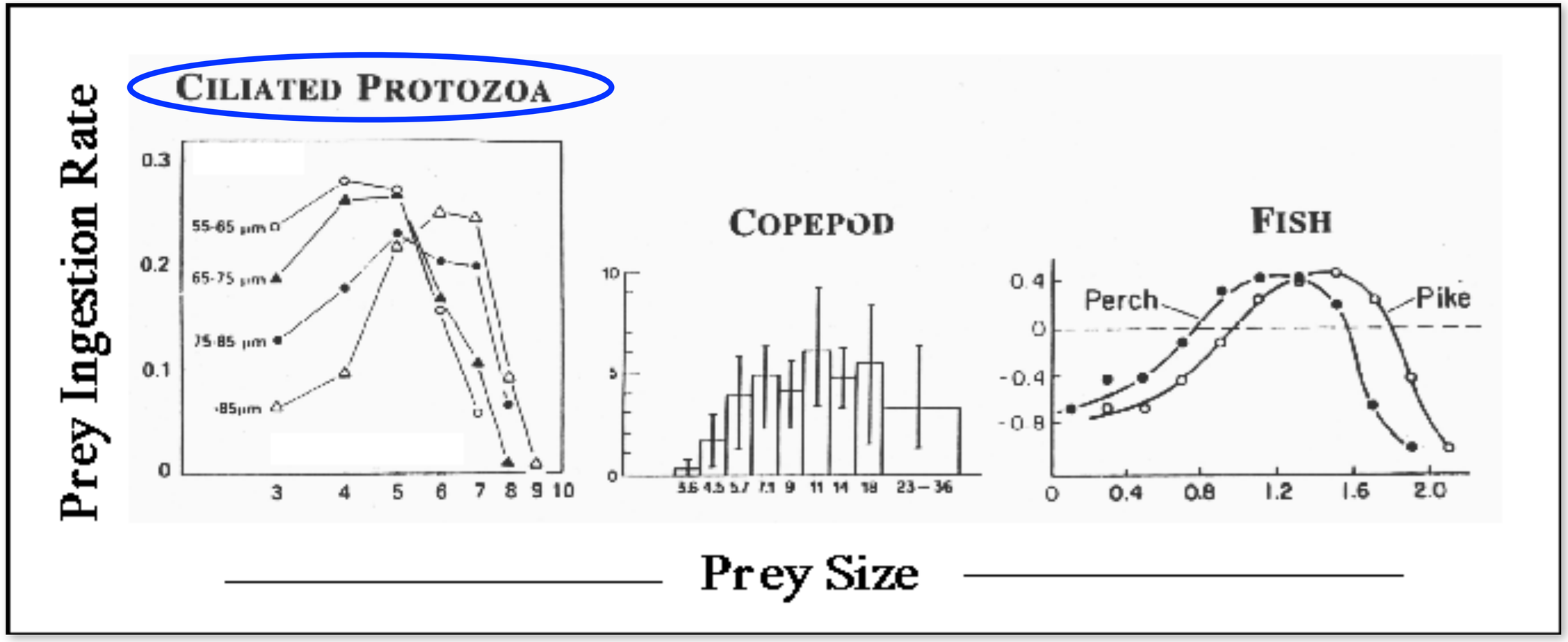
Pelagic Food *Web*



Pelagic Food *Chain*



Optimal Prey Size (1:10) of Pelagic Animals is a Valid General Rule for Even the Smallest Pelagic Organisms (Protozoans and Bacteria)



Traditional Food Chain Concept

early 1970's

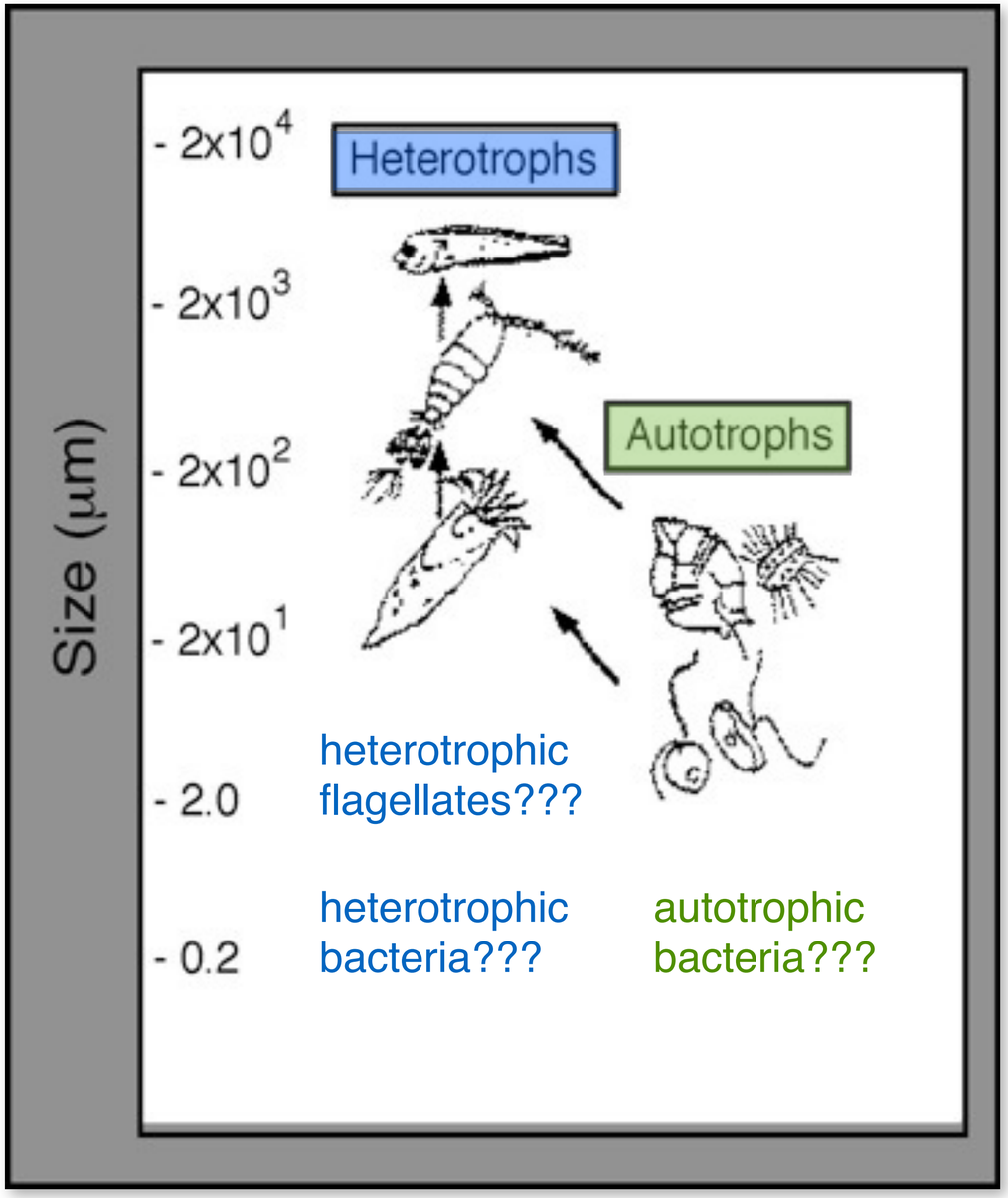
Medium to large phytoplankton are consumed by medium to large zooplankton

Importantly, heterotrophic and autotrophic bacteria and heterotrophic flagellates are omitted at this point in time

Organisms in This Figure are Arranged Based On:

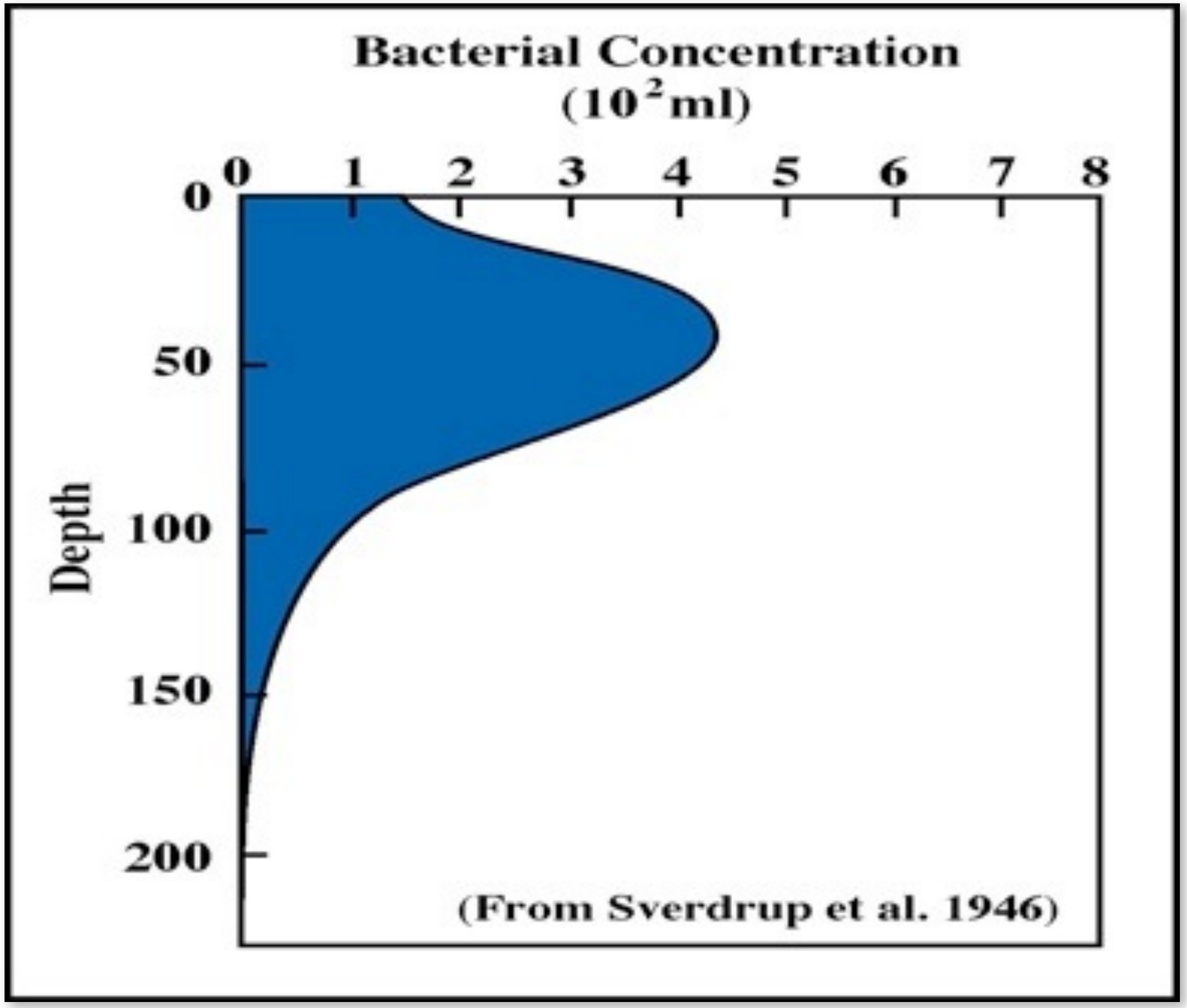
1. Autotroph versus Heterotrophic

2. Organism Size



Traditional Estimates of Bacterial Concentrations

Estimated from Transmission Light Microscopy and Culture-Plate Colony Counts



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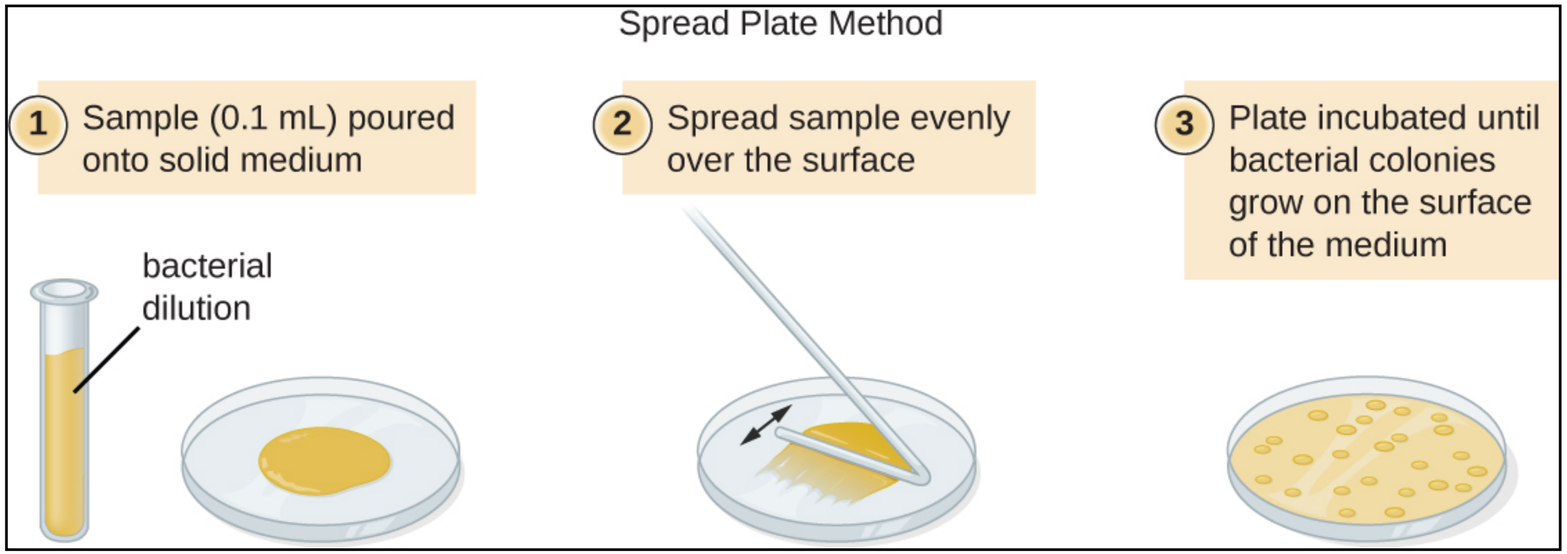
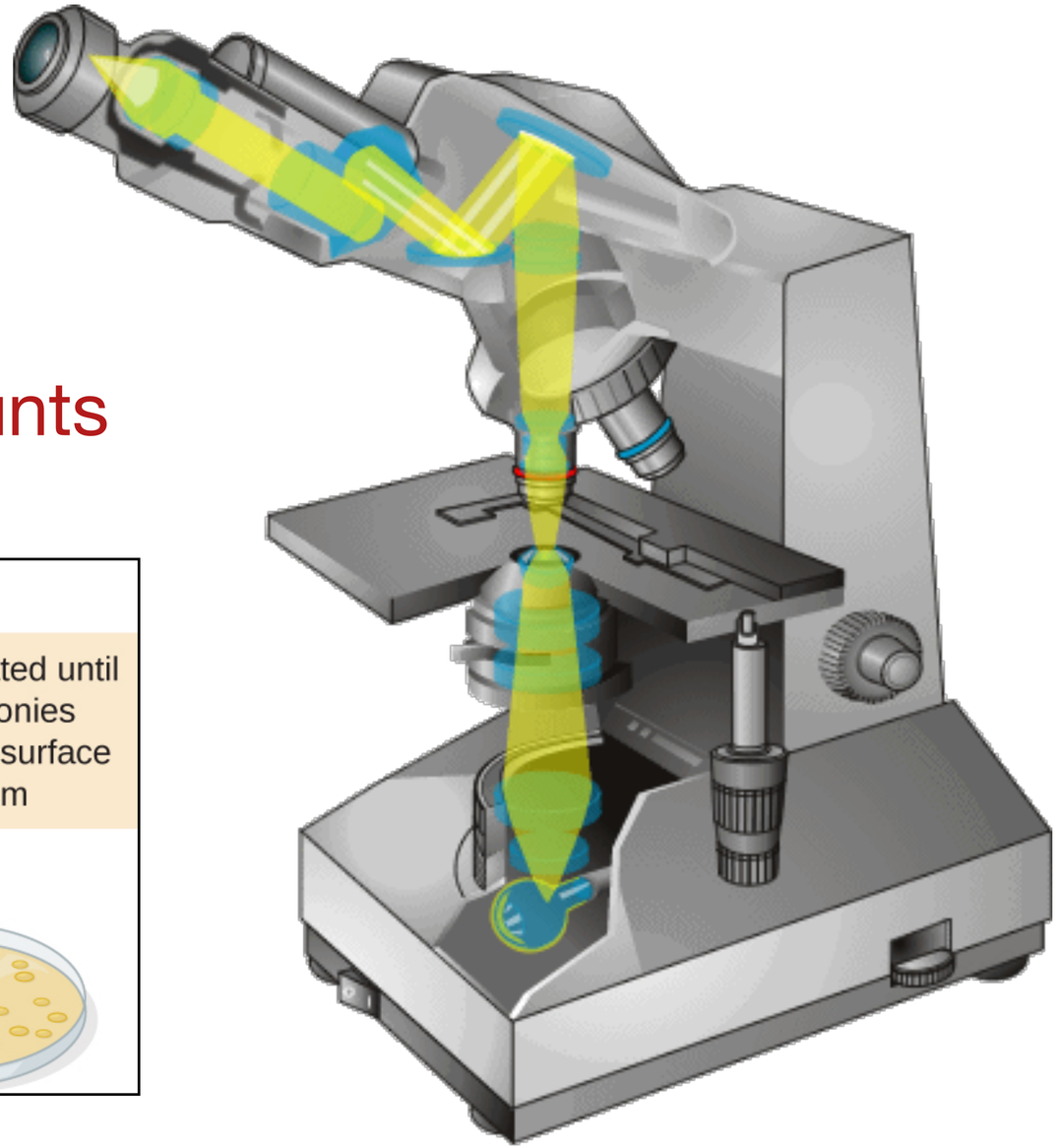
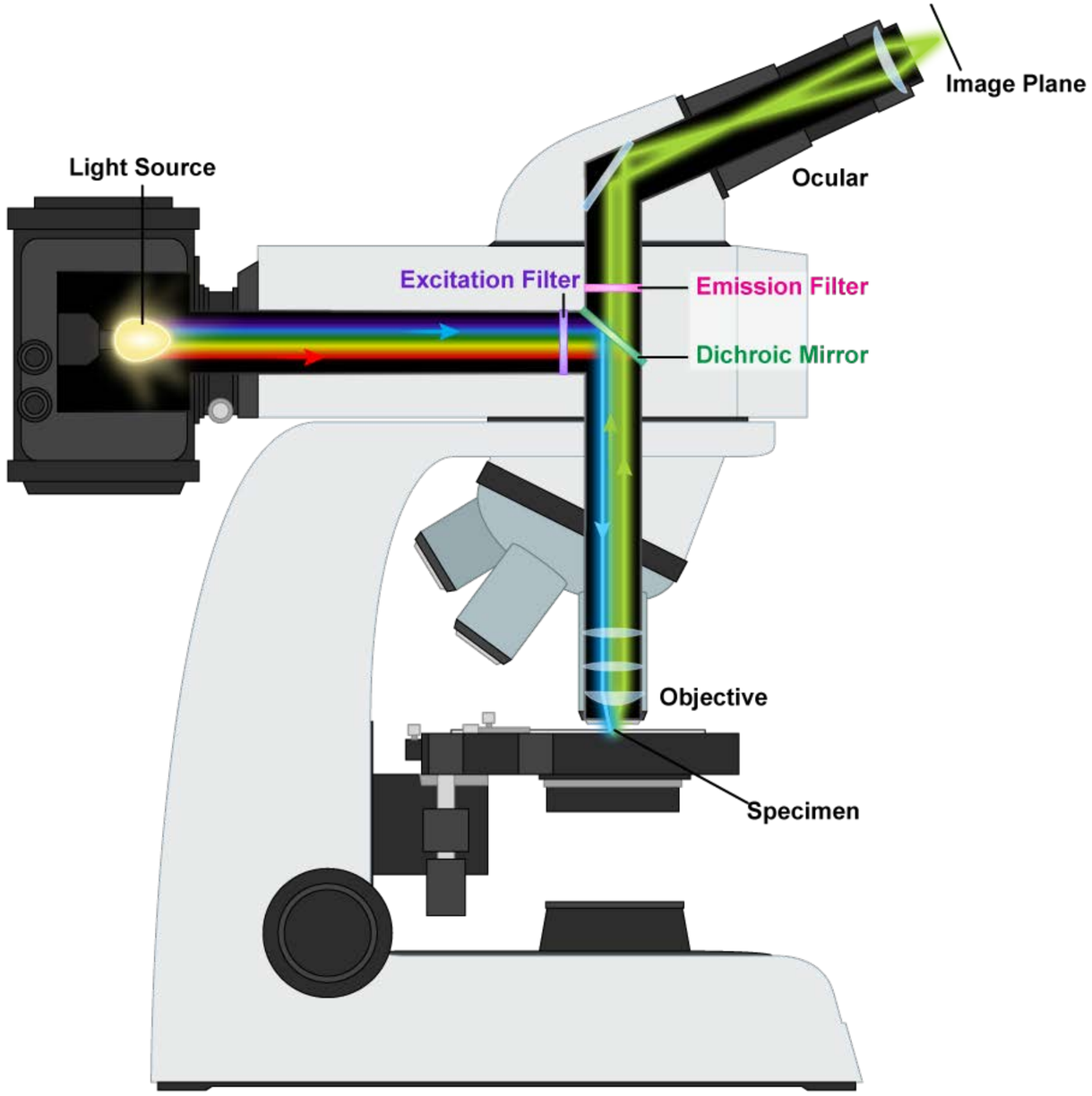




Use of Epifluorescent Microscopy and Fluorescent DNA Stains Became Widespread Between 1975 and 1985

1. Dramatically increased estimates of bacterial abundance in the ocean

2. Also allowed easy distinction between autotrophic and heterotrophic flagellate cells (i.e., chlorophyll containing or chlorophyll lacking)



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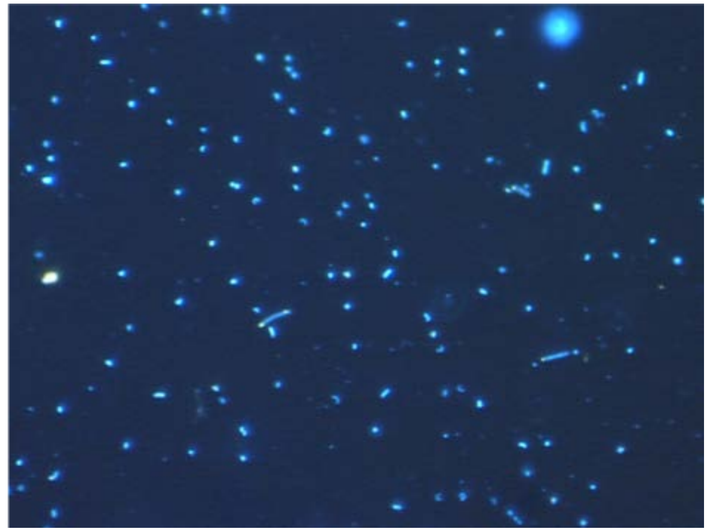
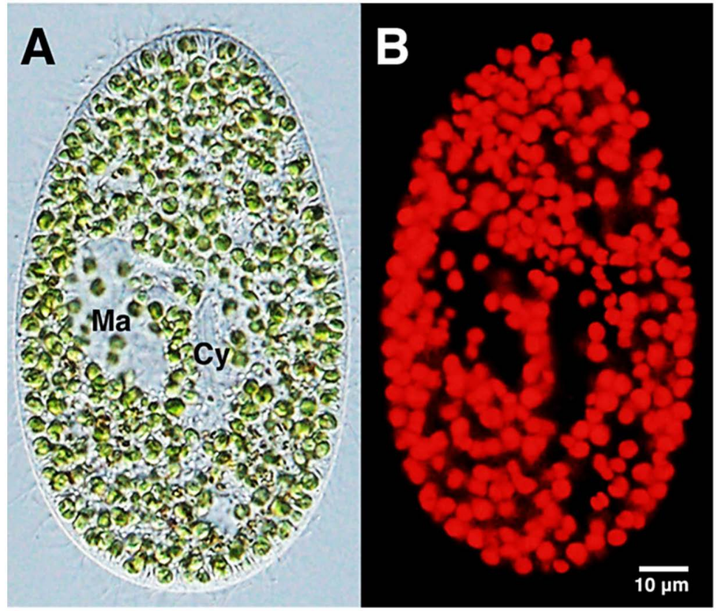
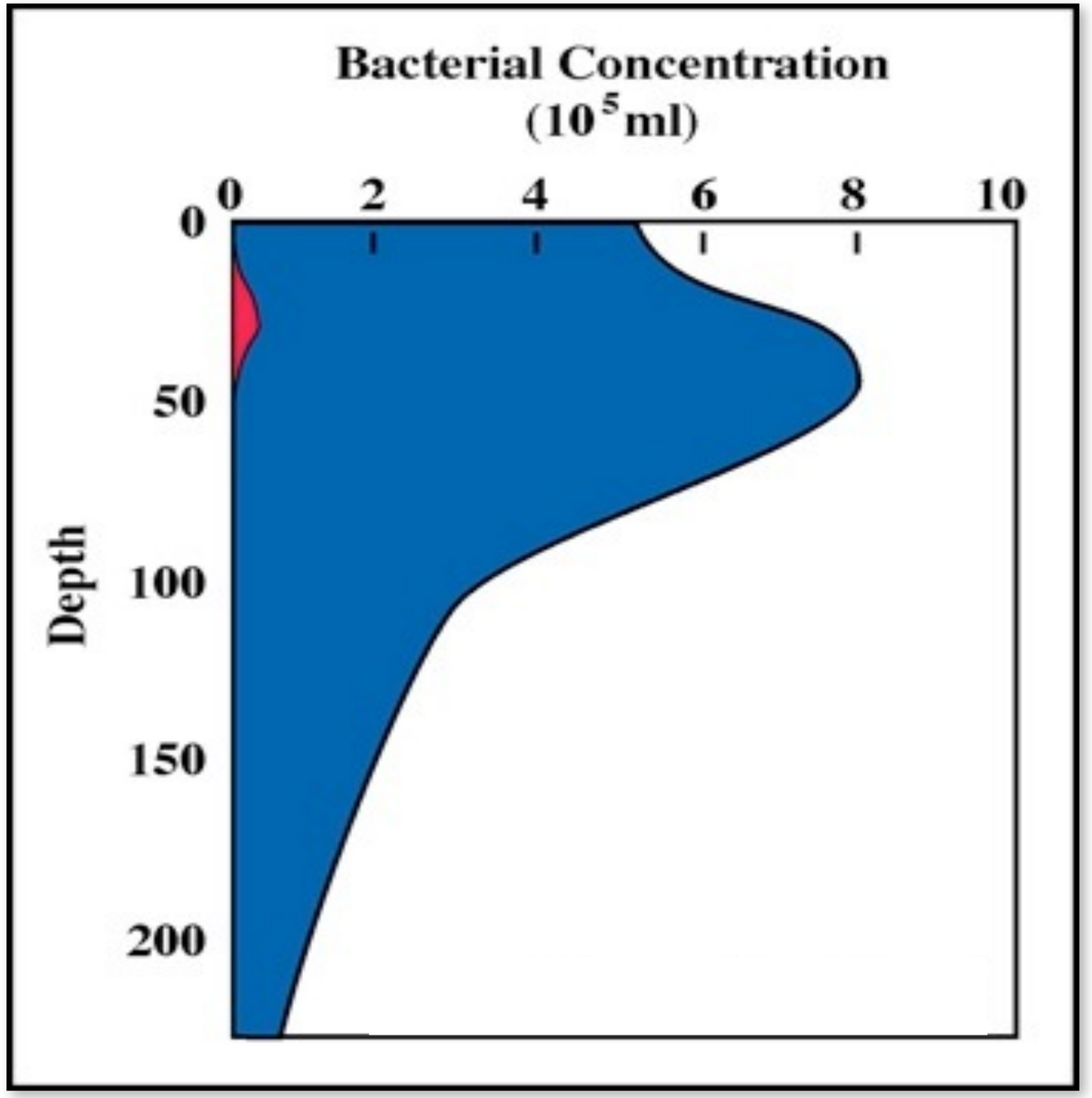




Bacterial Concentrations Before and After the Introduction of Epifluorescent Microscopy



Before (Red Fill)

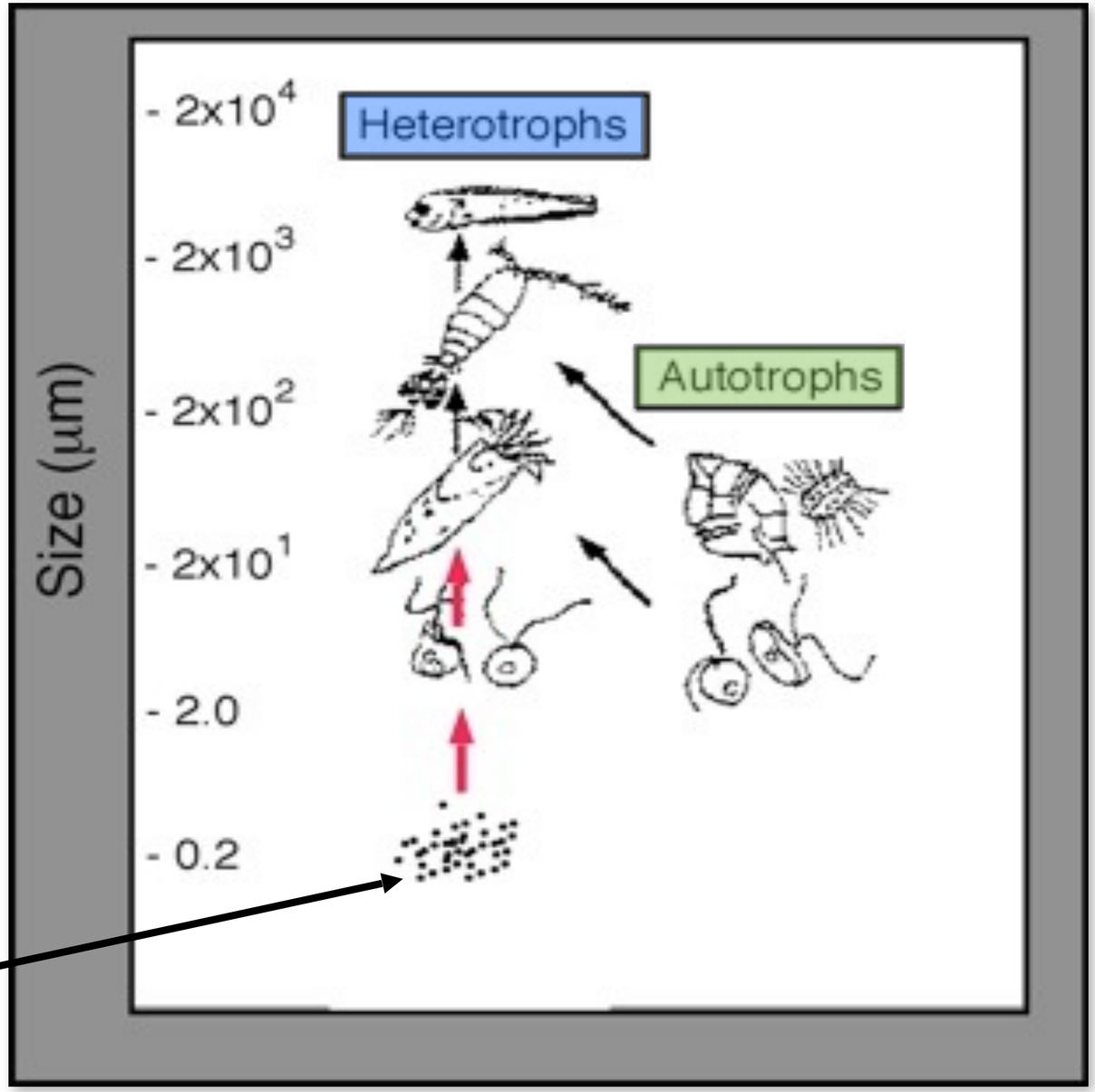
After (Blue Fill)

New View of Marine Food Webs

Recognizes the importance of high **heterotrophic bacterial abundance** and a large fraction of **heterotrophic nanoflagellates** that are the consumers of bacteria

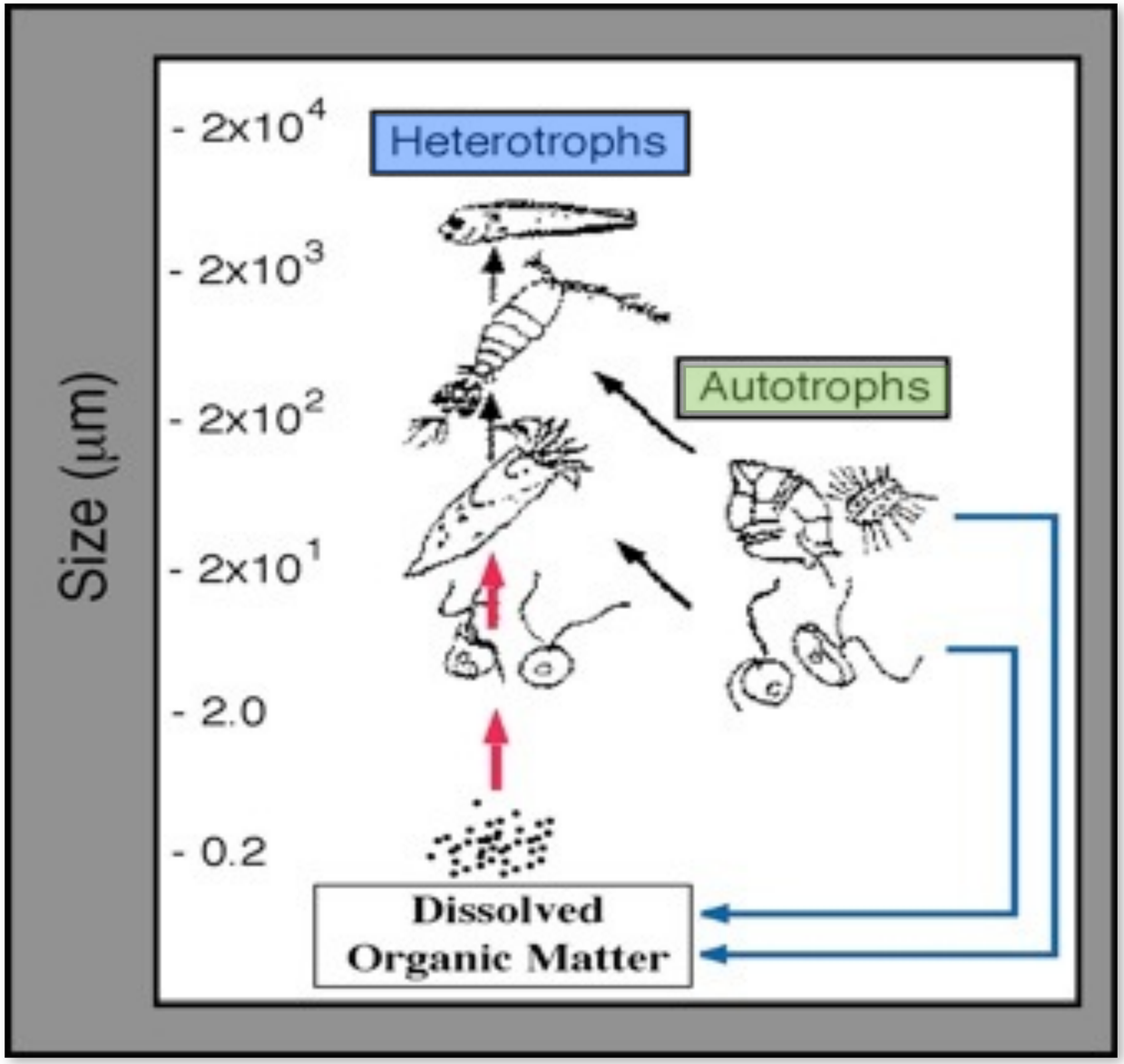
An Unanswered Question…

What is the carbon and energy source for all the newly discovered heterotrophic bacteria?



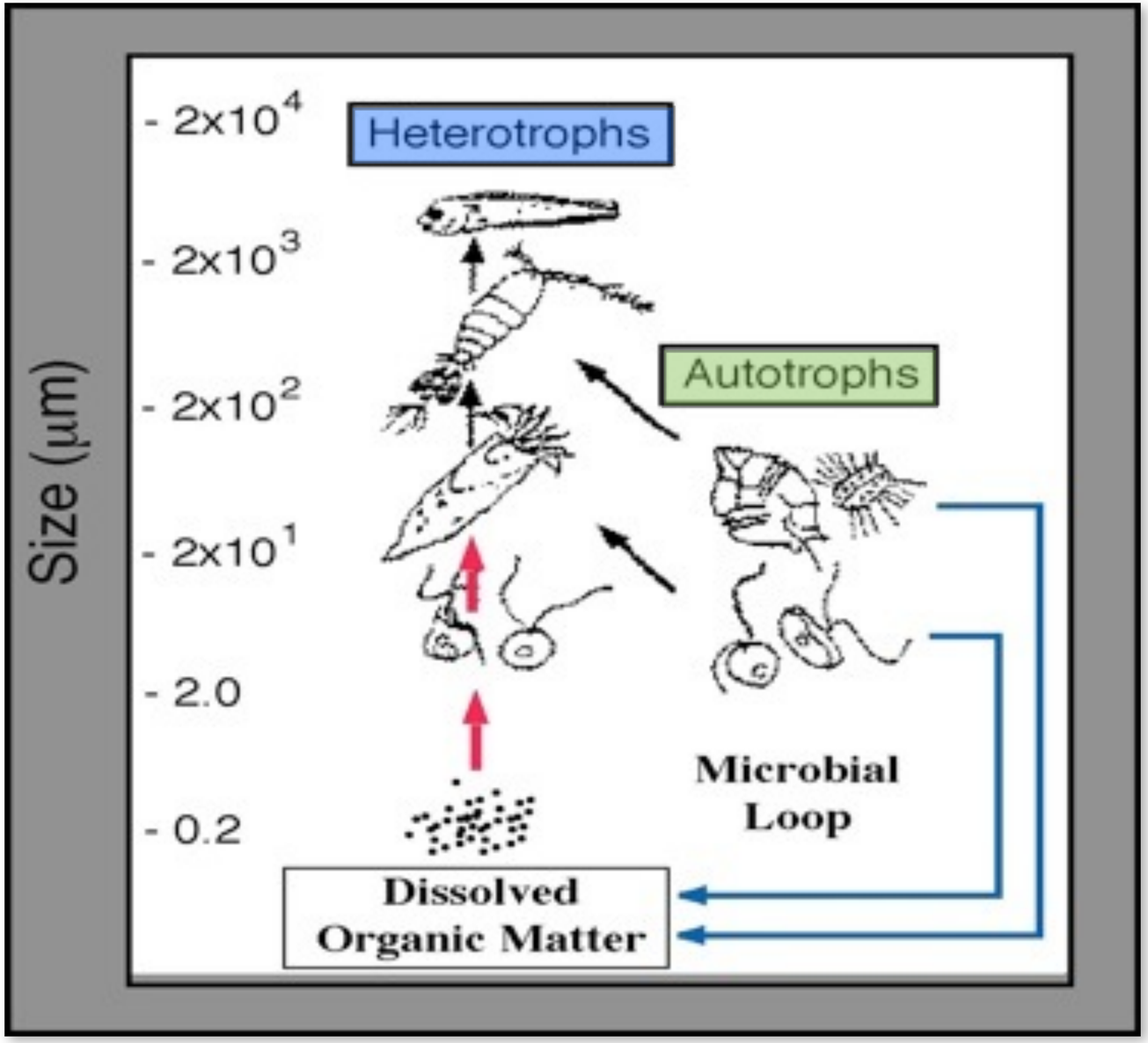
Source of Carbon and Energy for Heterotrophic Bacterial Growth

Heterotrophic bacteria are growing on **dissolved organic matter** (sugars, amino acids etc…) released from phytoplankton by natural leakage, cell senescence or sloppy feeding by large zooplankton

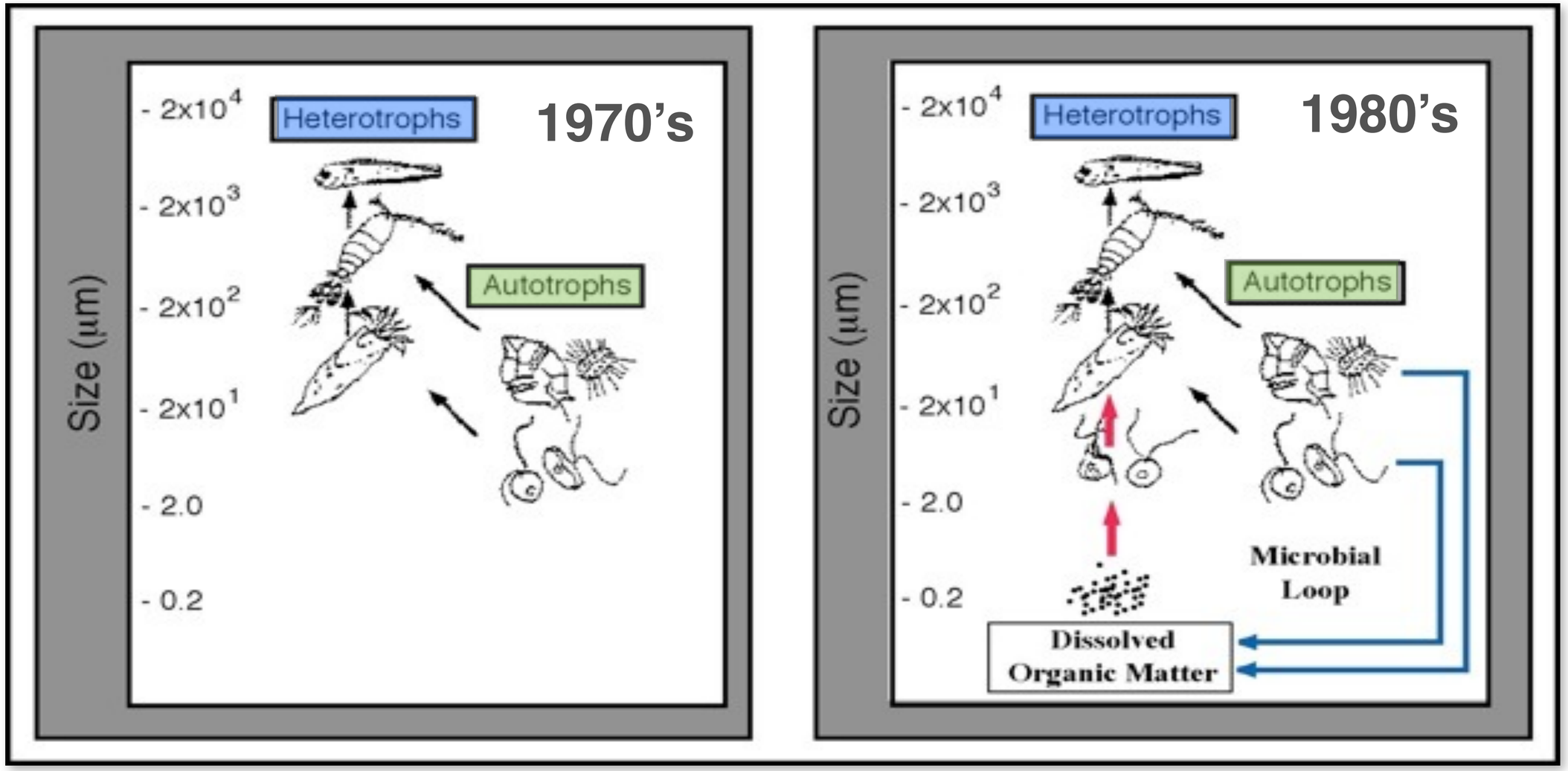


The Microbial Loop

A term coined by Azam et al. in a 1983 scientific publication that described the role microbes play in the marine carbon cycle



Summary: Early 1970's versus Early 1980's



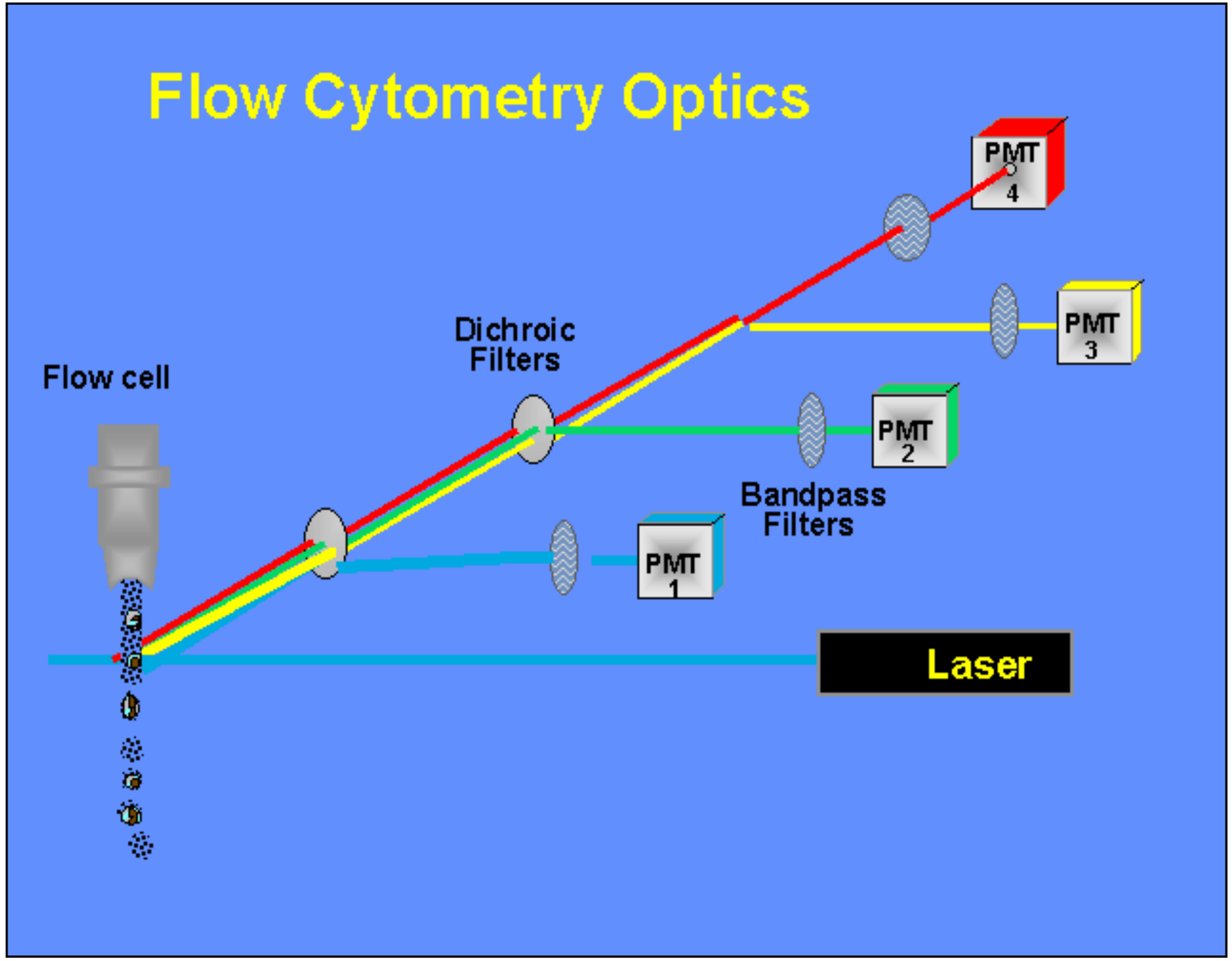
Discovery of an Important New *Bacteria-Sized Autotroph*

In 1988 Sallie Chisholm and others published a paper describing the presence of a **new type of very small autotroph** that is present in high abundance - especially in Oligotrophic Regions

The discovery was made using a new technique called **Analytical Flow Cytometry**

This new organism turned out be a chlorophyll containing *[autotrophic]* bacteria that came to be known as ***Prochlorococcus***

Schematic Diagram of The Flow Cytometric Method



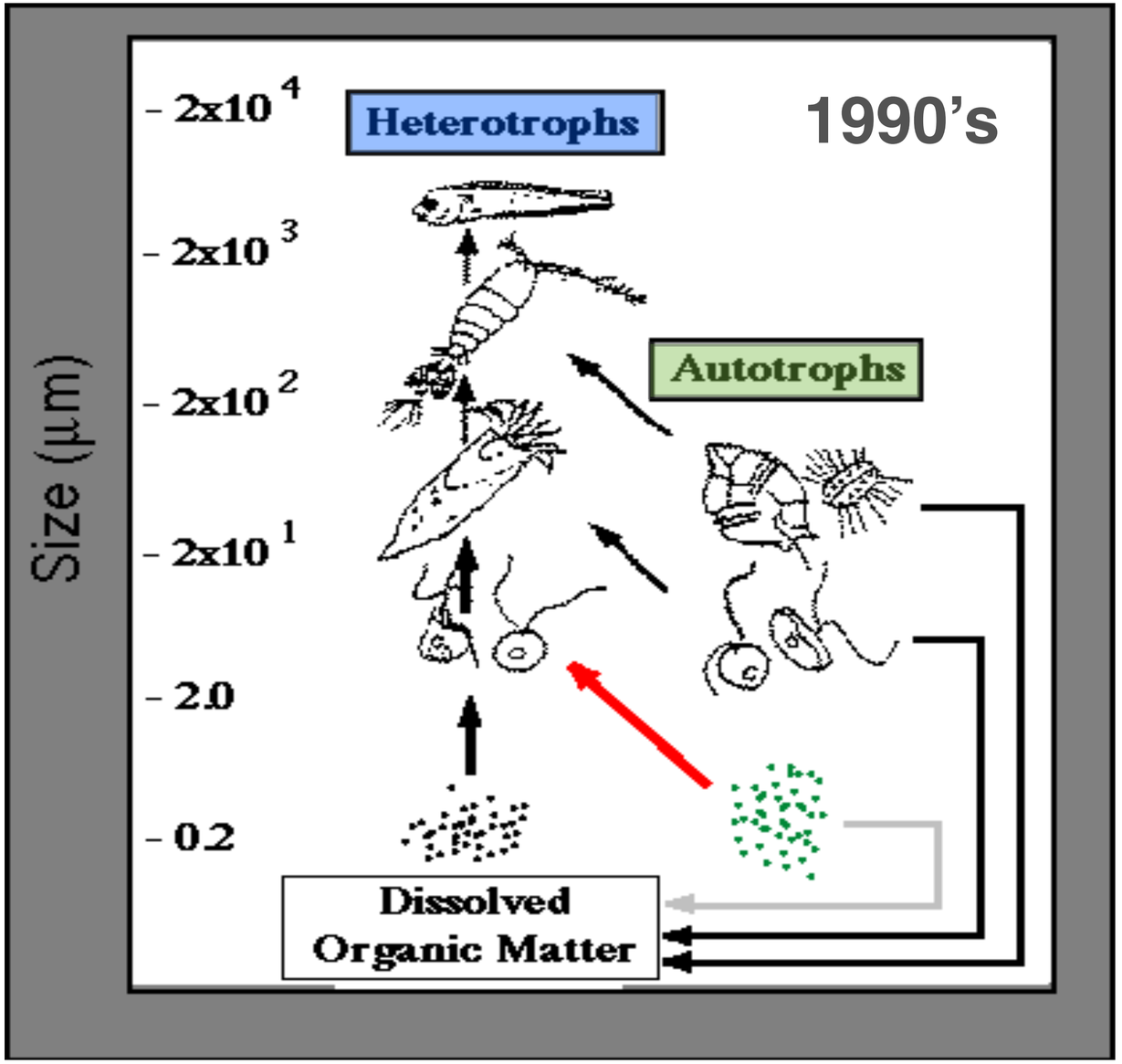
Prochlorococcus Abundance…

1. *Prochlorococcus* abundance in the oligotrophic open-ocean is similar in magnitude to the abundance of heterotrophic bacteria

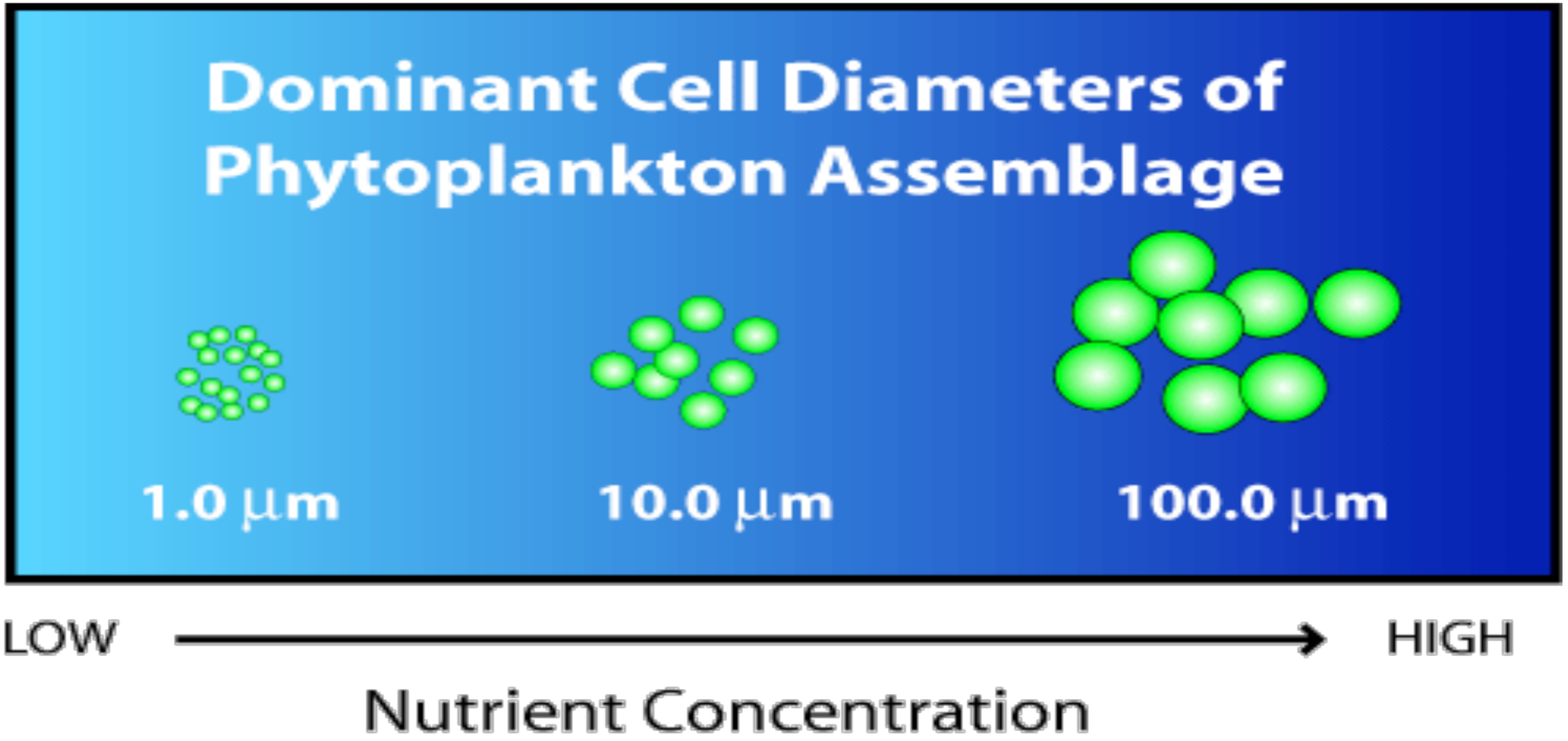
2. Roughly 1/3 of all bacteria in the oligotrophic open-ocean is autotrophic *Prochlorococcus*

New View of Marine Food Webs

Recognizes the Importance of *Prochlorococcus*



Recall: *low nutrient* concentration shifts the growth advantage to *small phytoplankton* cells

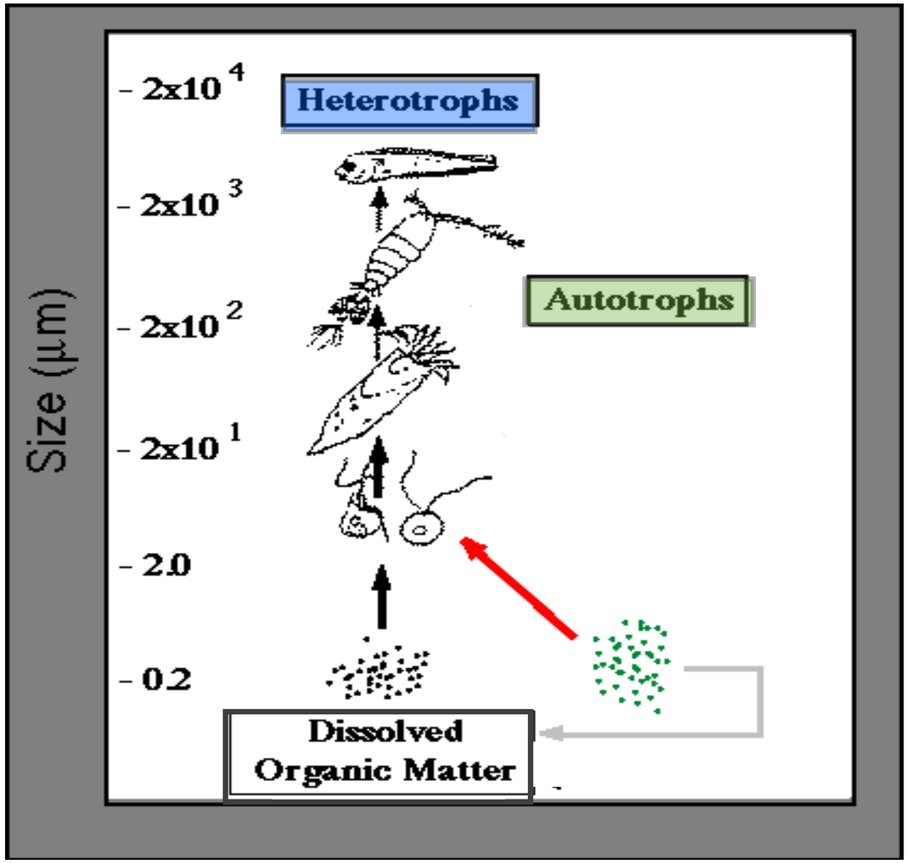


The Global Importance of *Prochlorococcus*

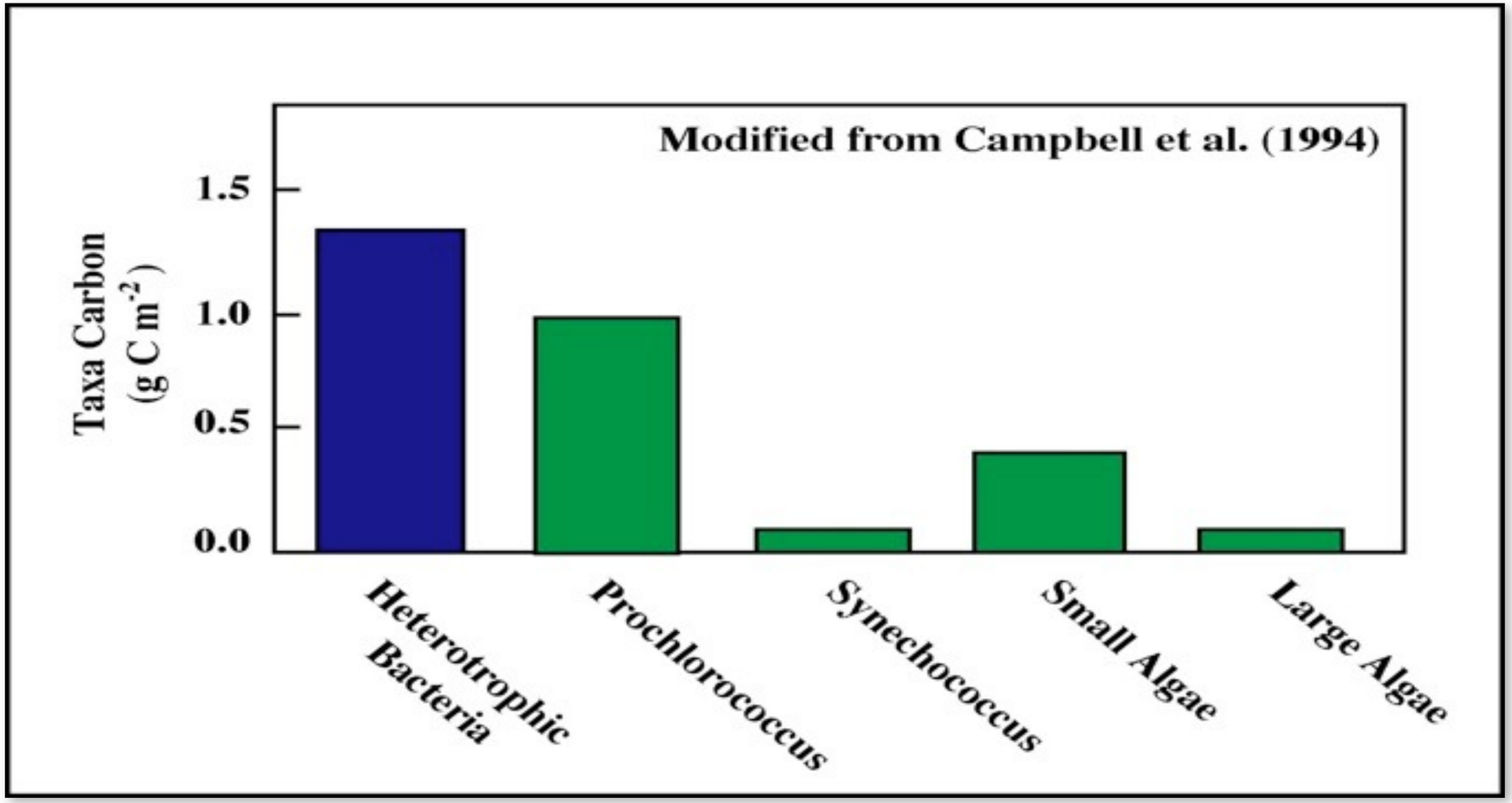
- In the vast **oligotrophic** (low nutrient) open-ocean environment, the growth advantage shifts to the smallest phytoplankton cells which are now recognized to be represented mainly by *Prochlorococcus*.

- *Prochlorococcus* is the **main contributor to primary production** in open-ocean environments.

- Altogether, *Prochlorococcus* single-handedly contributes more than **a quarter of total global ocean primary production** with the remainder being contributed by hundreds of other phytoplankton groups.



Relative Importance of *Prochlorococcus* and Heterotrophic Bacteria in Oligotrophic Systems



Conclusions

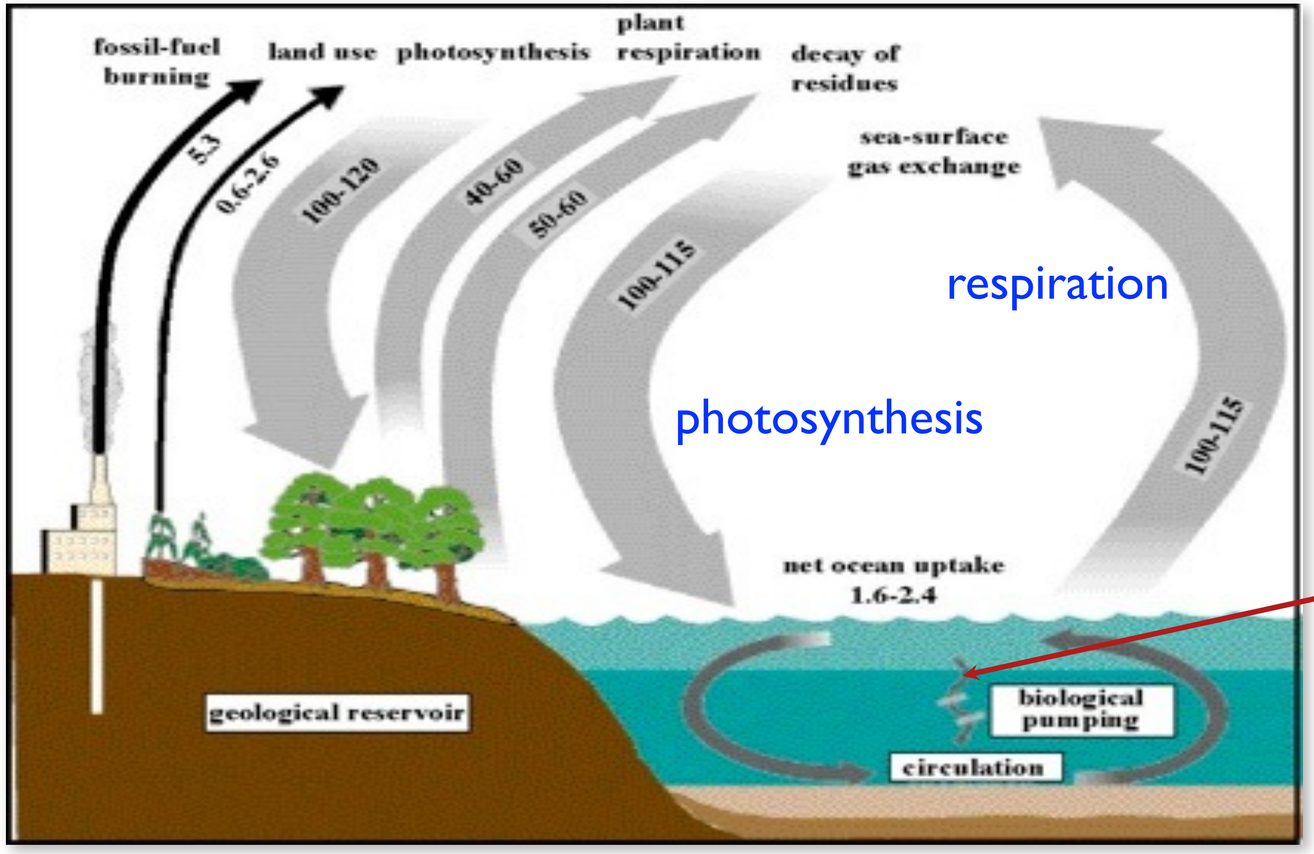
1. ***Heterotrophic Bacteria* are highly abundant in all ocean environments**
   - Dissolved organic carbon that leaks from large phytoplankton cells will be consumed by heterotrophic bacteria and, with the help of protozoans, this organic carbon will eventually be respired back to carbon dioxide.
2. ***Prochlorococcus* is an important autotrophic bacterium** (i.e., bacteria that contains chlorophyll and the smallest type of phytoplankton)
   - It is the main primary producer in oligotrophic (low nutrient) environments
   - It is responsible for more than a quarter of the global ocean primary production
3. **The vast majority of living biomass in the open-ocean is in the form of heterotrophic bacteria and *Prochlorococcus*** and this was only fairly recently discovered.

Section II

The Role of Microbes in Material Flow Through Marine Ecosystems

The Biological Carbon Pump

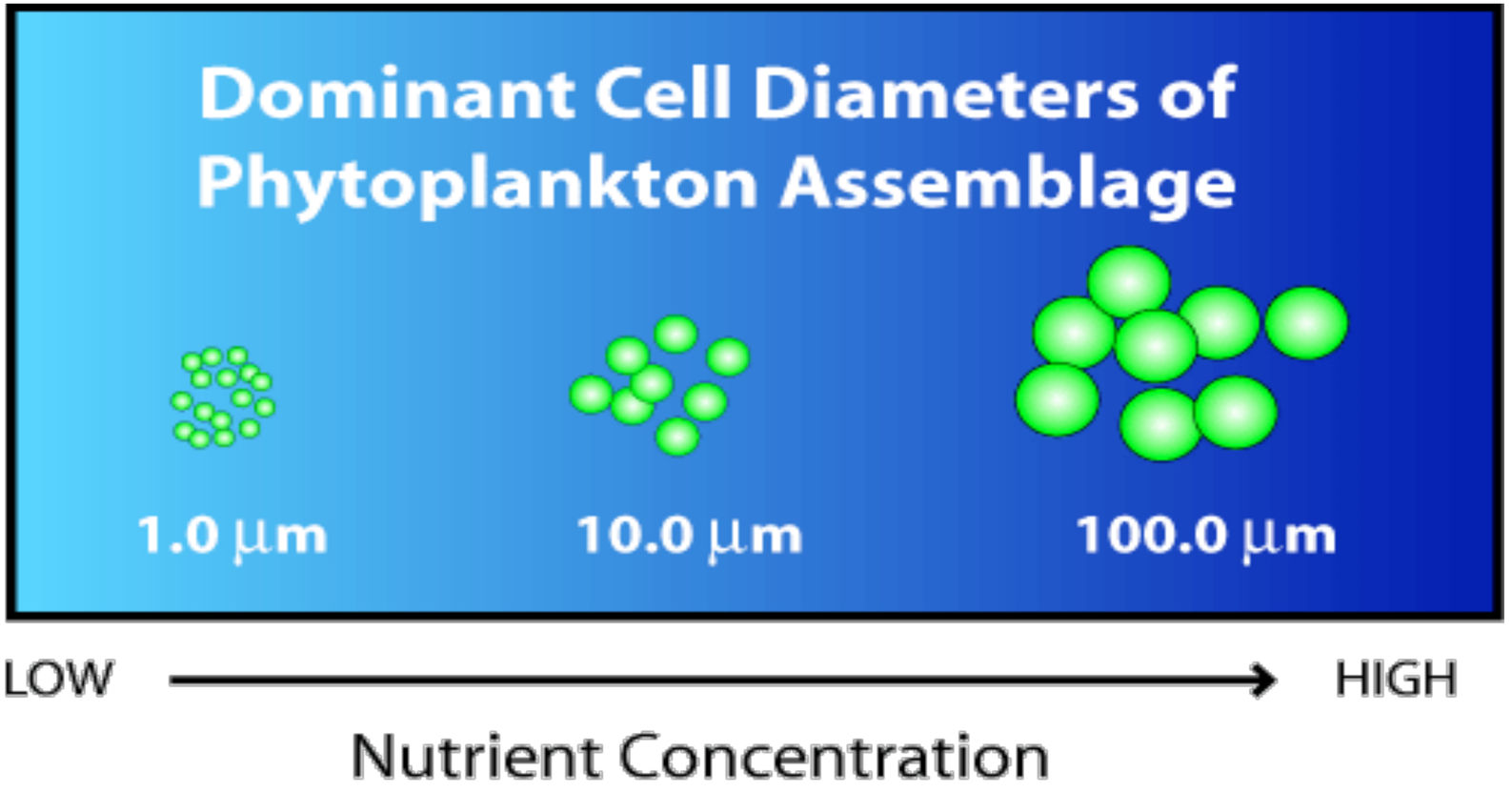
Recall: Global ocean primary production is an important component of the global carbon cycle and an essential element to our overall understanding of global climate change



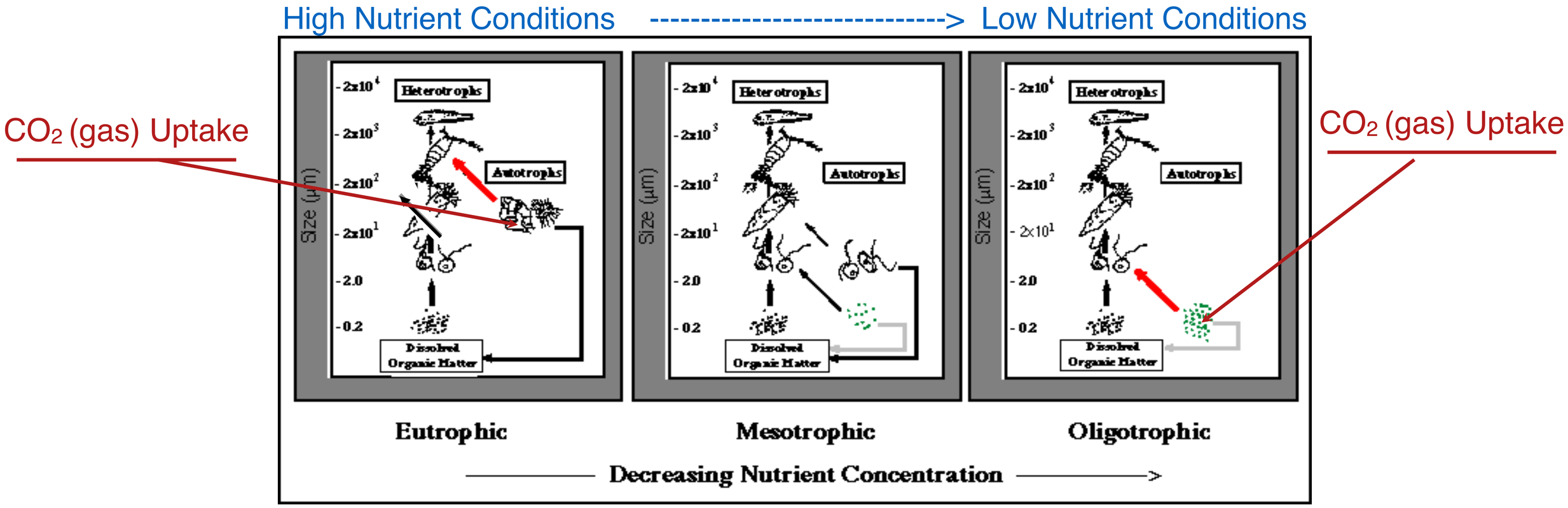
The Biological Carbon Pump

Magnitude of CO_2 flux between Land and Ocean Reservoirs

Recall that low nutrient concentration shifts the growth advantage to small phytoplankton cell (mainly *Prochlorococcus*)



The **pathway** that carbon takes, from CO_2 (gas) to particulate organic carbon (through photosynthesis), and on into particulate organic carbon of higher trophic levels, **varies when nutrient concentration varies**

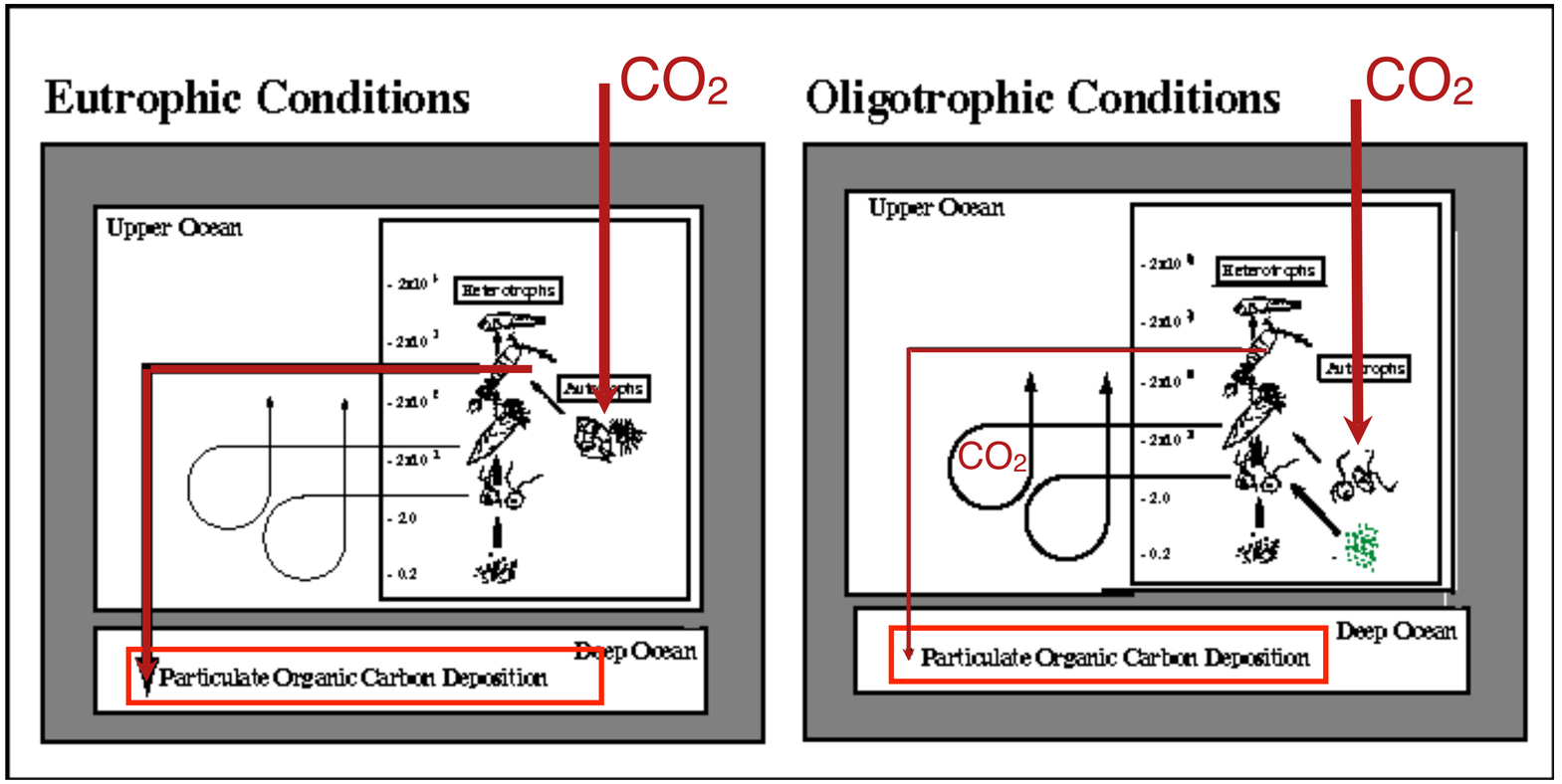


The **Efficiency** of the Biological Carbon Pump

Carbon Cycling and the Biological Carbon Pump

When the dominant phytoplankton cells are large, the dominant grazers are large and their large fecal material easily sinks into the deep ocean taking organic carbon down with it - this forms **an efficient biological carbon pump**.

When the dominant phytoplankton cells are small and grazers are small and fecal material is so small it cannot easily sink and the particulate carbon is instead decomposed by microbes and respired back to CO_2 — **overall the biological pump is inefficient**.



Question

What is the expected efficiency of the Biological Carbon Pump for Coastal Upwelling Zones?

(a) The carbon pump is very efficient in coastal upwelling zones

(b) The carbon pump is *not* very efficient in coastal upwelling zones

Conclusions

- **As nutrient concentration is reduced, the competitive growth advantage shifts to small phytoplankton cells.**

- **Small phytoplankton cells** found at low nutrient concentrations enhances the percentage of organic carbon that is respired back to carbon dioxide gas and, consequently, **carbon is NOT efficiently** pumped into the deep ocean

- **Large phytoplankton cells** found at high nutrient concentrations increases the percentage of organic carbon that is pumped to the deep ocean and, consequently, **carbon is efficiently pumped into the deep ocean**