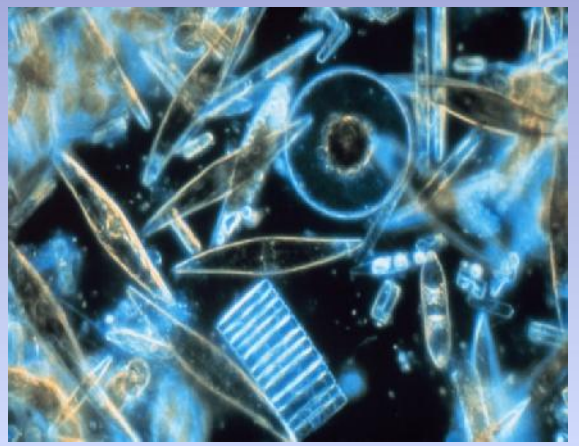

Marine Life
Plankton and Primary Production

Marine Plankton – Key Ideas

- ✓ Drifting, floating and weakly swimming plants and animals - mainly in sunlit portion of ocean
- ✓ Plankton make up more well over 90% of total biomass in ocean; form base of the food web
- ✓ Three types of plankton: Phytoplankton; zooplankton; and bacterioplankton
- ✓ Phytoplankton are photosynthezing plankton that produce food and oxygen
- ✓ Phytoplankton live where there is sufficient sunlight and nutrients
- ✓ Zooplankton are tiny animals that eat phytoplankton – they stay close to the phytoplankton
- ✓ Bacterioplankton decompose dead tissue and fecal matter into recycled nutrients
- ✓ All three types form "Marine Biological Pump"

Phytoplankton



Ocean Plankton Video

Zooplankton

Main *Concepts:* *the* *Marine Plankton*

- *Marine plankton are* marine organisms that, drift, float or weakly swim.
- Plankton live in all parts of water column, but mostly in euphotic zone
- **Plankton include over 90% the ocean's biomass** = most important
- **Availability of sunlight and nutrients control amount of plankton**
- Plankton can be divided into three ***trophic*** categories:

Phytopankton = ***producer*** **Zooplankton =** ***consumer*** **Baterioplankton =** ***recycler***

- **Phytoplankton include diatoms, dinoflagellates, coccolithophores, and silioflagellates; also picoplankton (cyanobacteria)**
- **Phytoplankton are eaten by the zooplankton**
- **Zooplankton include foraminifera, radiolarians, copepods, krill, jellies, and wide variety of larval-stage animals**
- **Plankton can be divided into two life-history categories:**

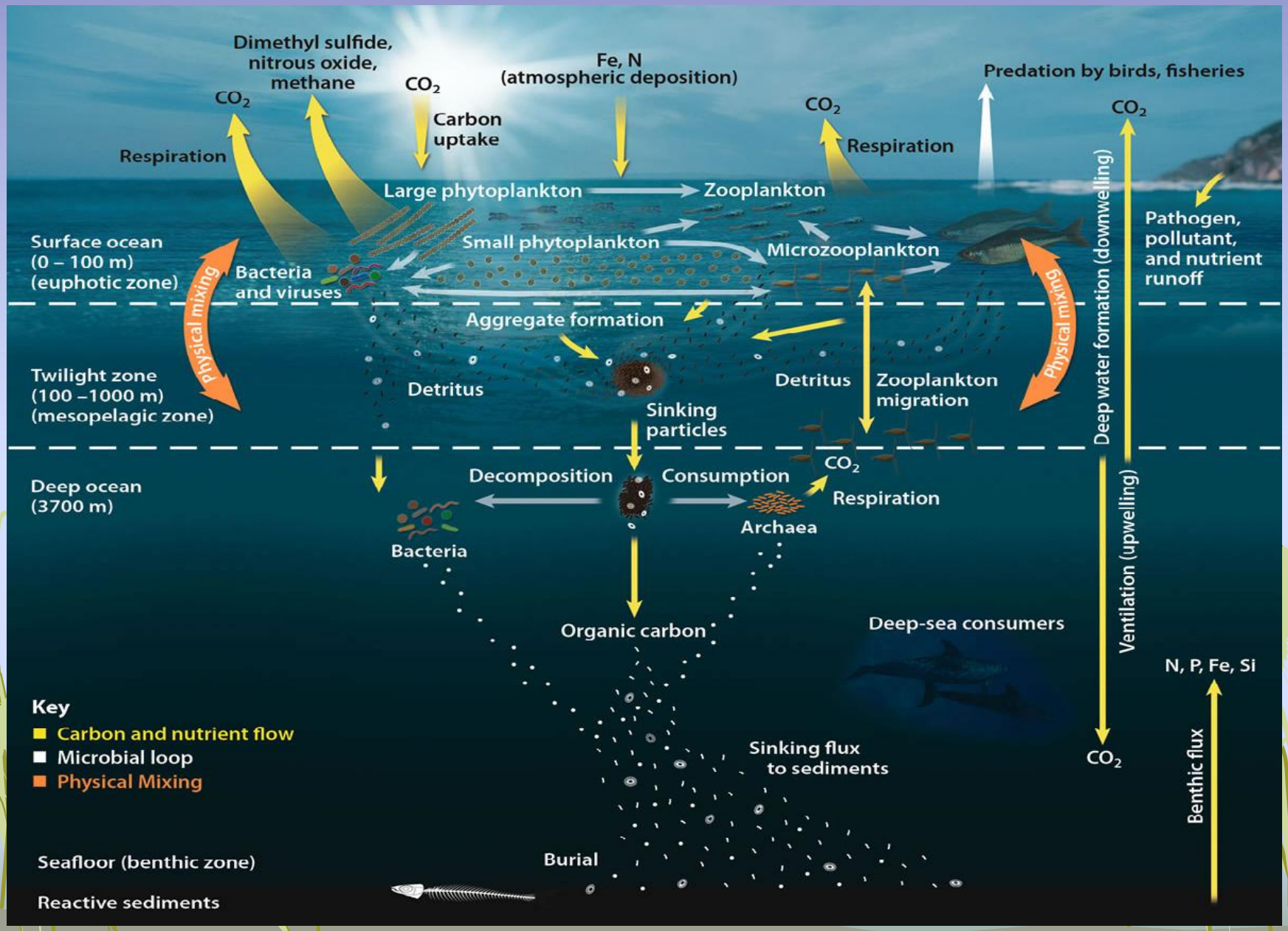
Holoopankton ***= entire life as plankton*** **Meroplankton** = ***larval stage as plankton***

- **Bacterioplankton decompose dead plankton and fecal matter into recycled nutrients; Three types planktons form Ocean Biological Pump**

Main Concepts: *Primary Productivity*

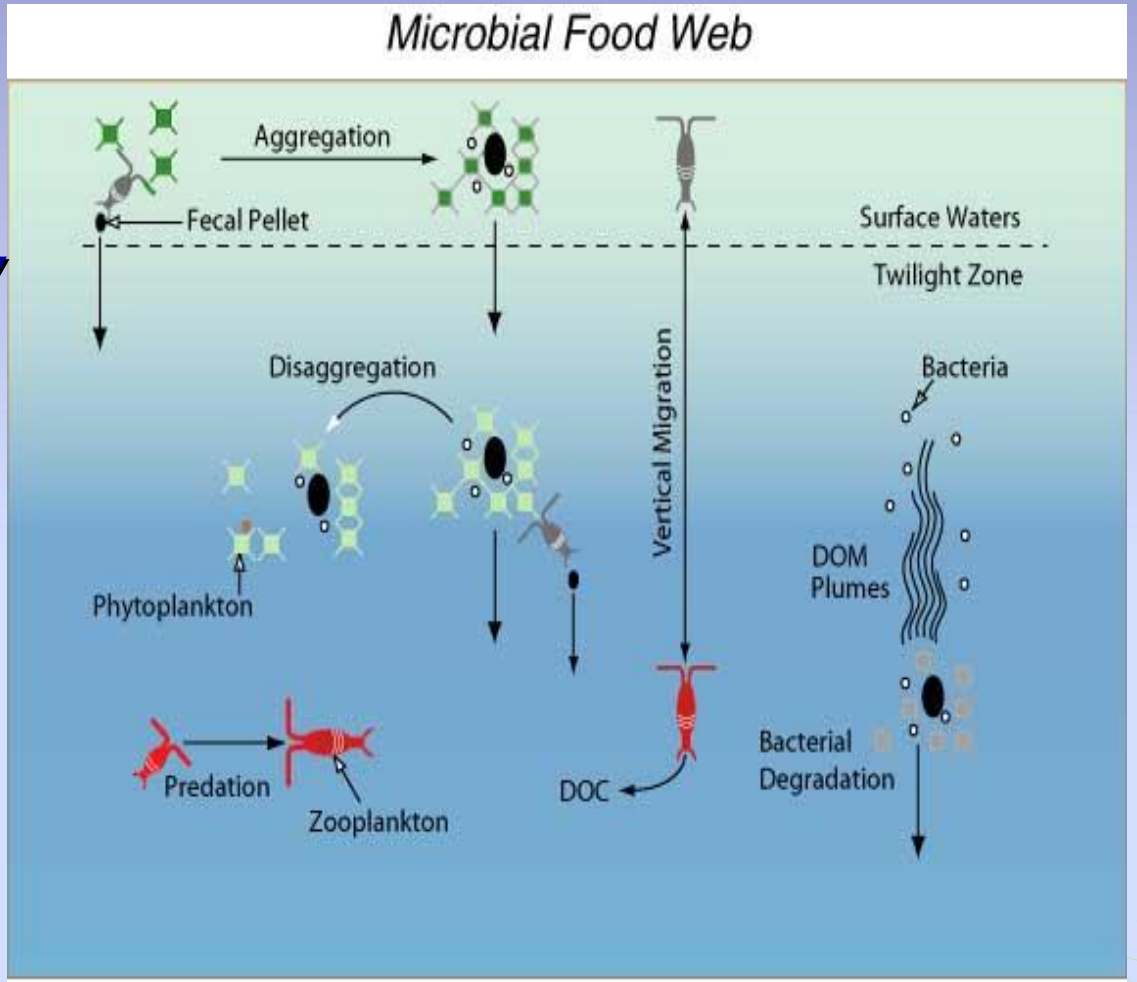
- ***Primary production*** **is the conversion of nutrients with sunlight or chemical energy into carbohydrates by certain organisms**
- **Photosynthesizing organisms are primary producers, or autotrophs**
- **Primary producers form a critical link between the living and nonliving worlds and form the base of all marine communities**
- **Types of primary producers include *microalgae*, *cyanobacteria*, and the *macroalgae* –- collected using nets and water filtration methods**
- **Microalgae (called phytoplankton) include diatoms, dinoflagellates, coccolithophores, and silioflagellates; also picoplankton (bacteria)**
- **Phytoplankton responsible for 50% of global productivity and oxygen**
- **Primary productivity is measured using 1) dark-light bottle, carbon-14 "tagging", and 2) chlorophyll levels.**
- **Two limiting factors of productivity are availability of light and nutrients**
- **Phytoplankton eaten by assortment of small animals called zooplankton**
- **Macro-algae - the kelp and seaweeds – take a minor role in productivity**

Paramount World of Marine Plankton



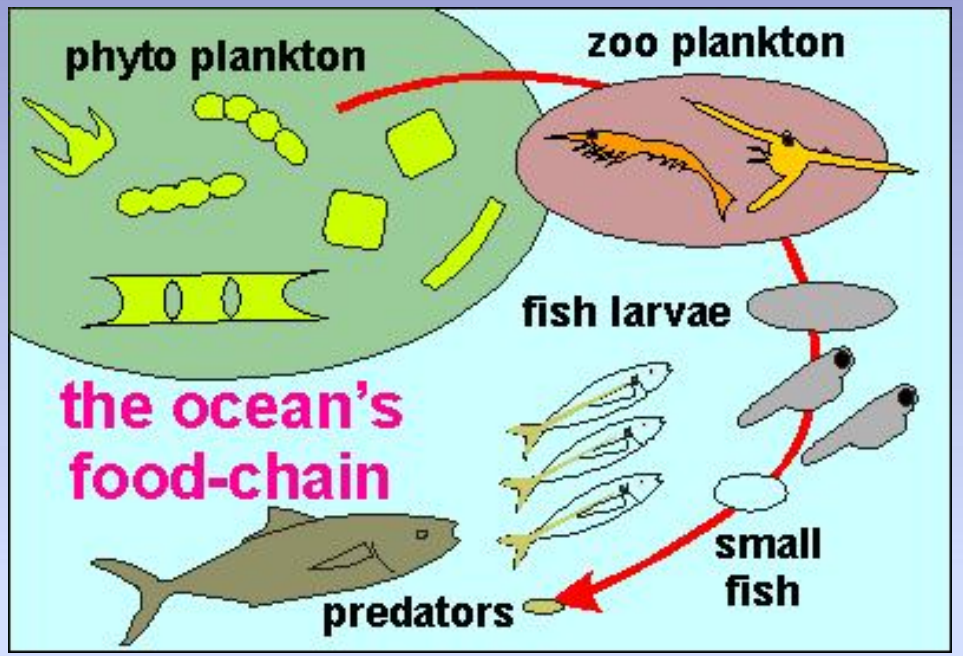
The Ocean's Microbial Food Chain

- The **most important** biological activity in the ocean occurs at the microbial level = ***the tiny planktonic organisms***
- The players include the ***phytoplankton***, the ***zooplankton***, and the ***decomposer bacteria***
- All three players are critical to the entire marine food web and the nutrient cycles



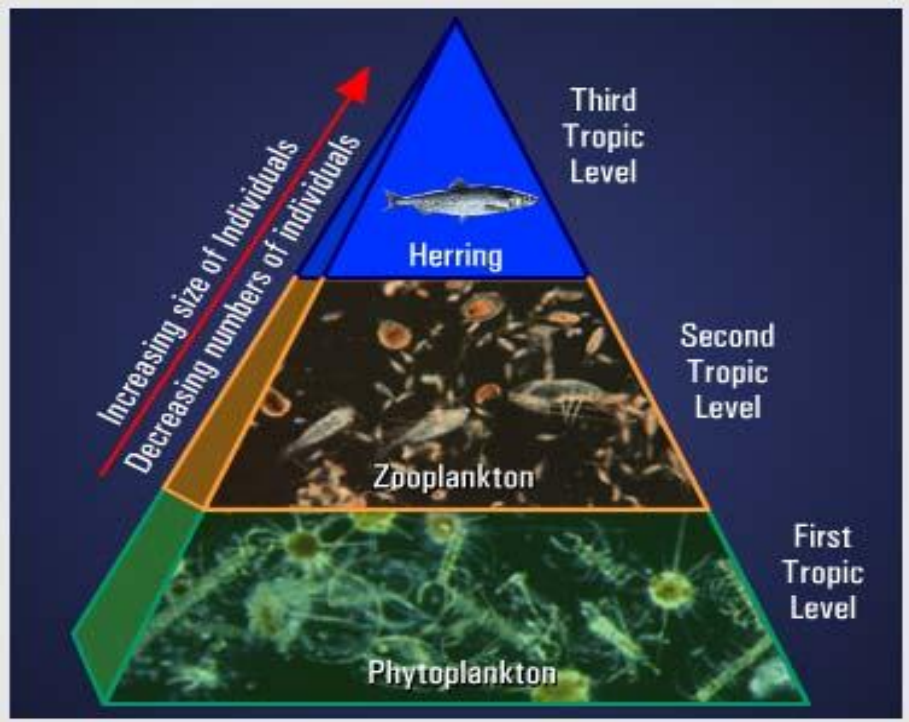
The Ocean's Food Chain

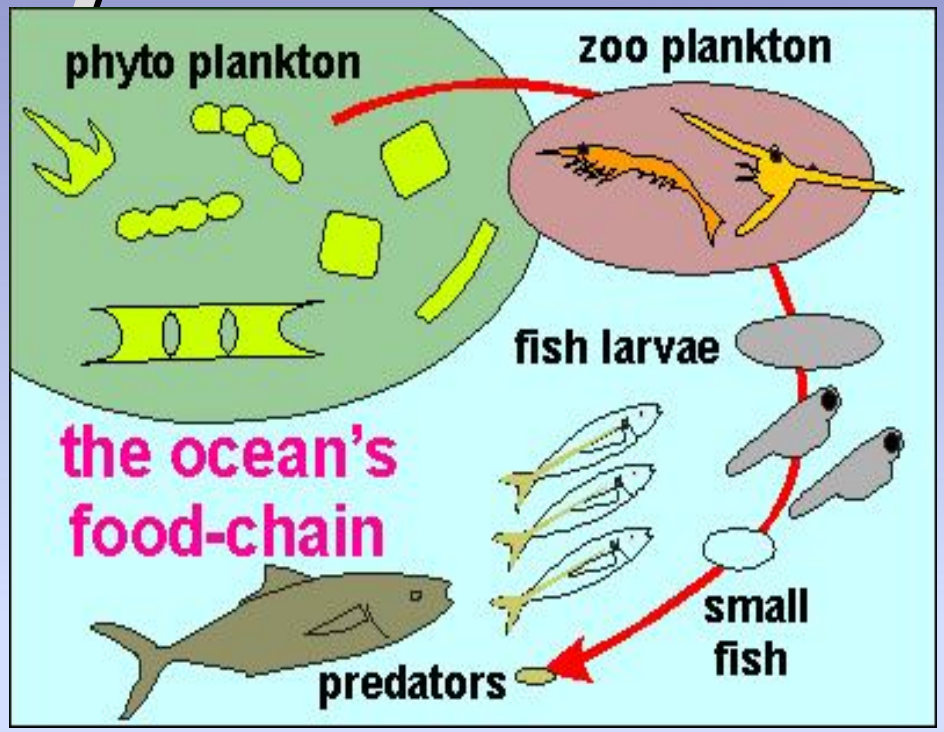
- Phytoplankton are autotrophs; they are eaten by the primary consumers or hetrotrophs, called zooplankton
- Zooplankton are eaten by secondary consumers, such as tiny fish, jellyfish, anemones and mollusks
- Tiny fish, jellies and other secondary consumers are eaten by bigger fish, birds, sea turtles, and sea mammals



- It takes roughly 10 grams of phytoplankton to make 1 gram of zooplankton, and 10 grams of zooplankton to make 1 gram of tiny fish....and on up the food chain

The Ocean's Tropic Levels

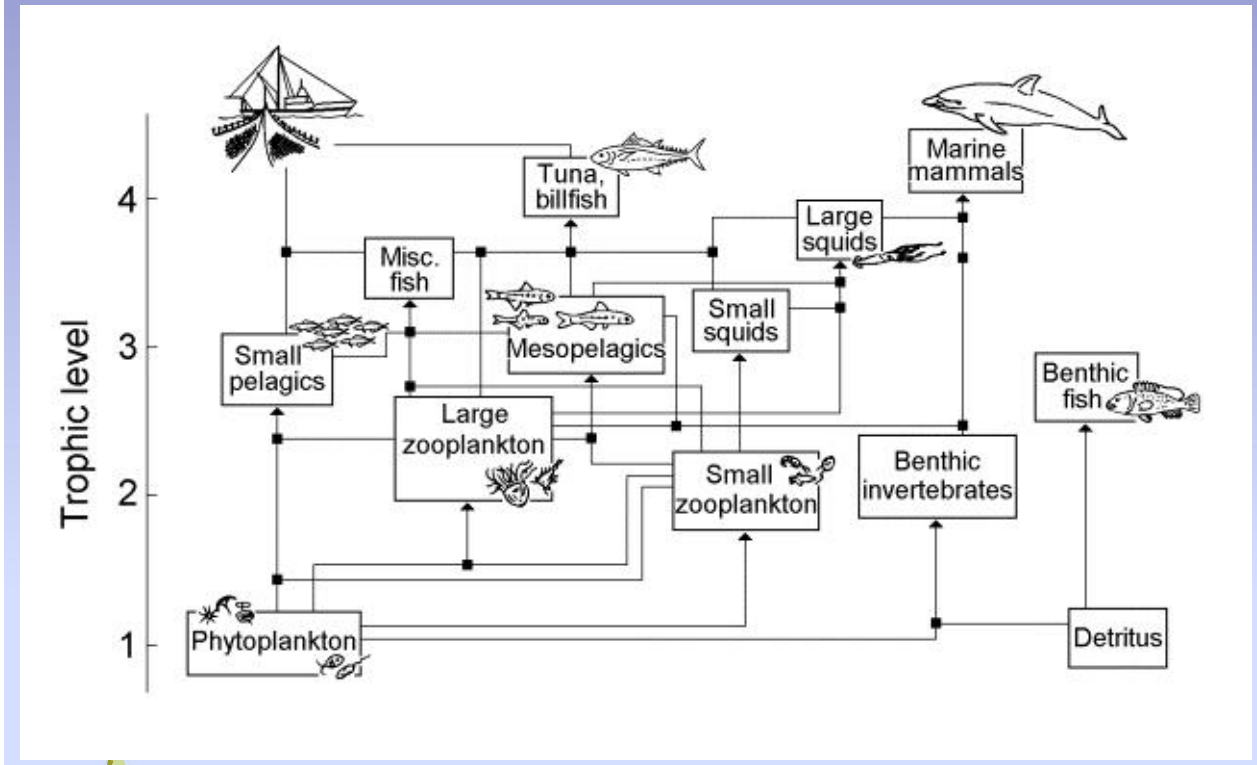


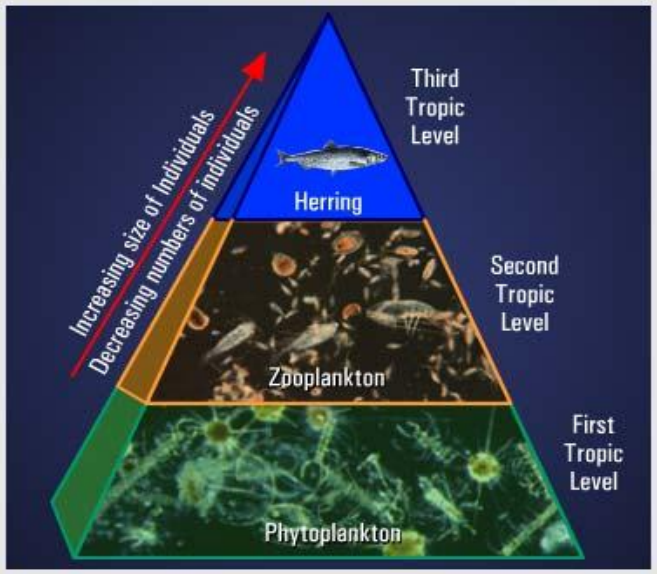


❖ Marine food chains are arranged into tropic levels with the phytoplankton at the bottom (first tropic level), which has the greatest numbers of individuals and greatest total biomass - more than all the other tropic levels put together.

❖ It takes roughly 10 grams of phytoplankton to make 1 gram of zooplankton, and 10 grams of zooplankton to make 1 gram of tiny fish…and so on up the food chain.

The Marine Food Web

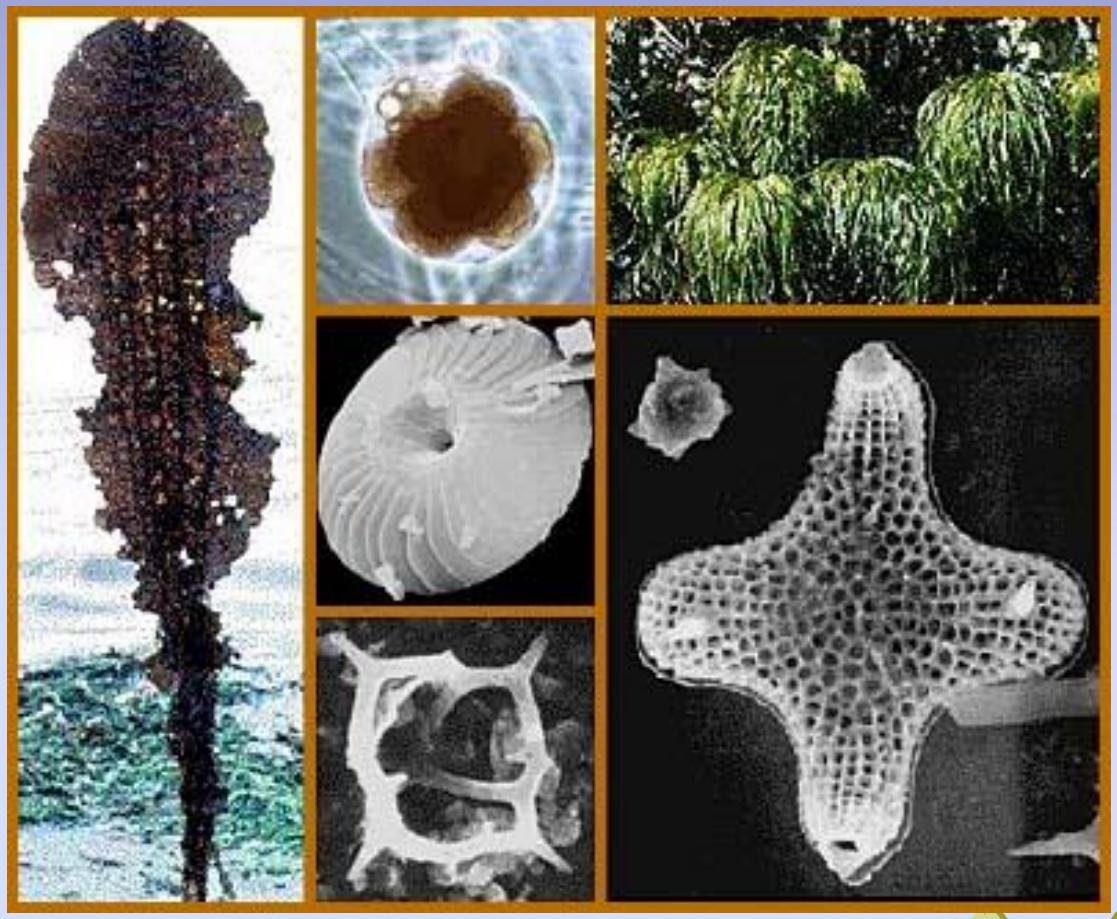




Multiple marine food chains form larger, more complex ***food*** webs that *connect all organisms within a community together – directly or indirectly*

The Marine Photosynthesizers

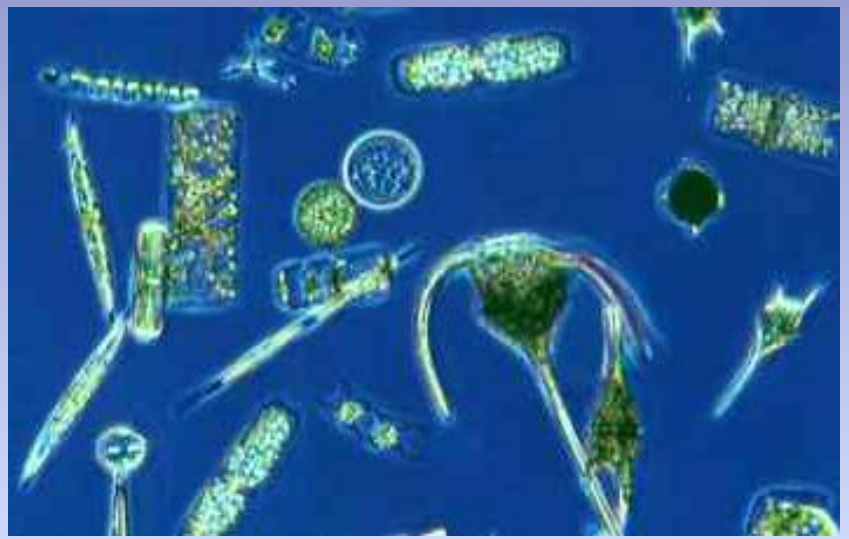
- ✓ **Cyanobacteria**
  - Blugreen Algae
- ✓ **Micro-Algae**
  - *Diatoms*
  - *Dinoflagelletes*
  - *Cocolithophores*
  - *Silicoflagelletes*
- ✓ **Macro-Algae**
  - *Kelp*
  - *Seaweed*
- ✓ **Vascular Plants**
  - *Sea Grasses*
  - *Mangrove*

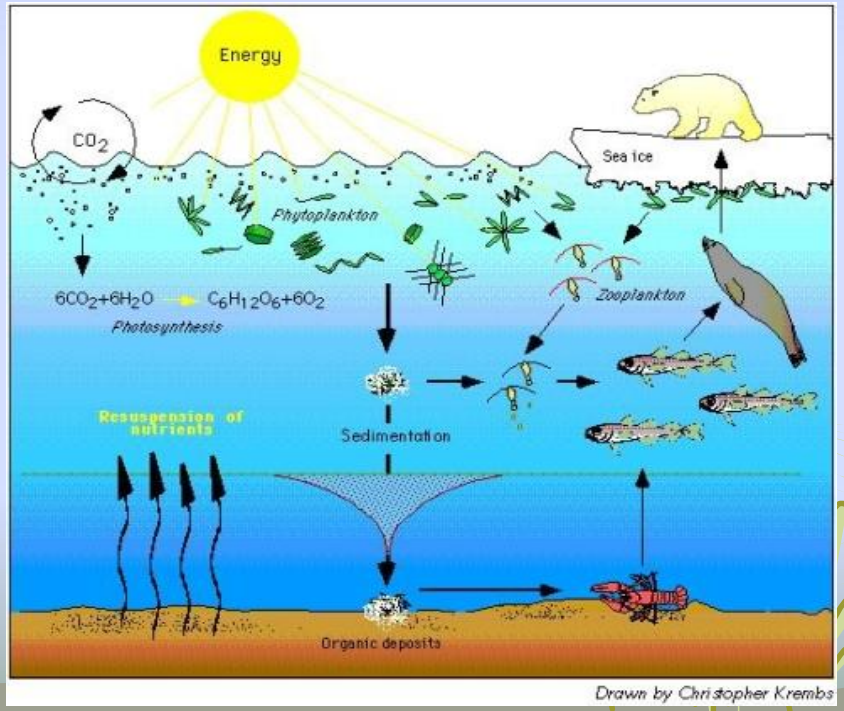


https://vimeo.com/84872751

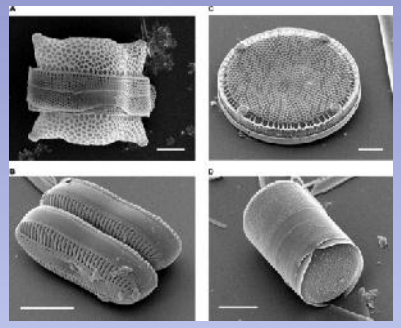
Importance of Phytoplankton

- Marine phytoplankton play a crucial central role in the ocean's ecosystem.
- Marine phytoplankton form the base of the food web in virtually every marine community.
- Marine phytoplankton are the makers of nearly half the world's free oxygen supply.
- Marine phytoplankton have an intimate relationship with the zooplankton and the decomposer bacteria in a micro-food web called the *ocean biological pump.*



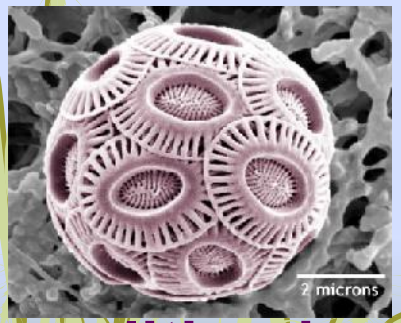


Types of Phytoplankton

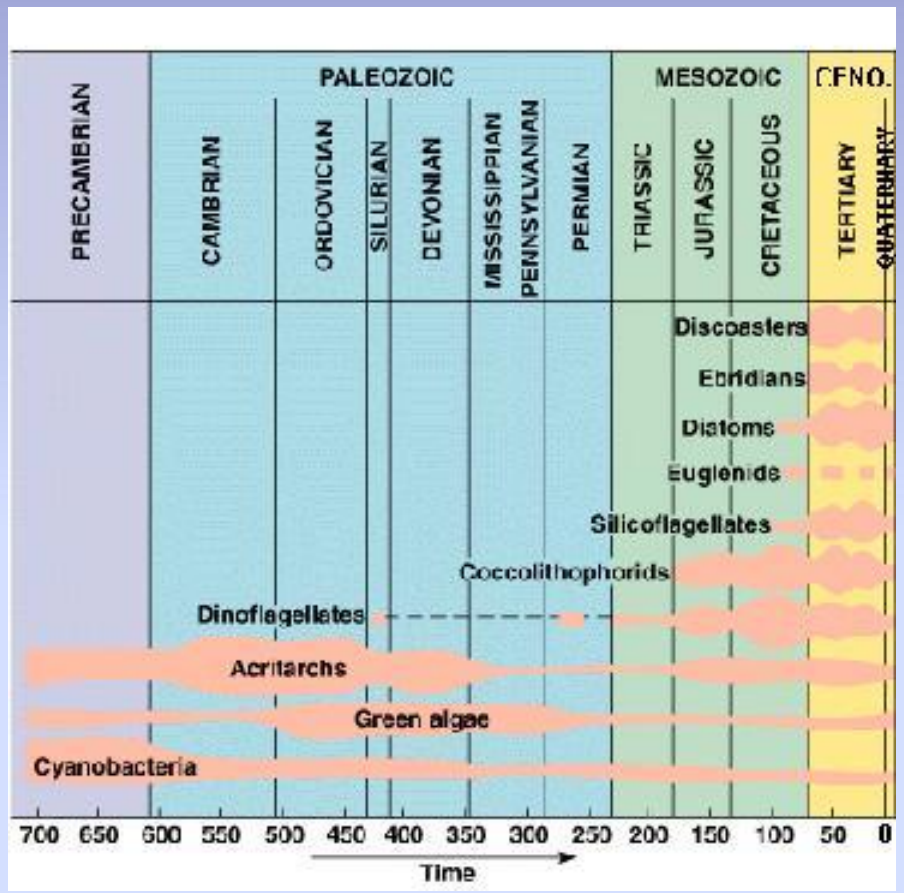


Diatoms

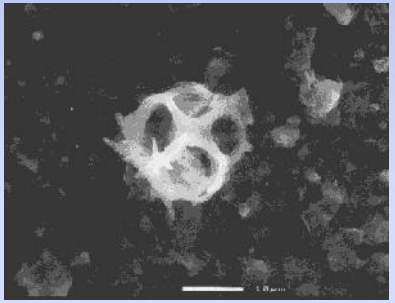
Dinoflagelletes



Cocolithophores



Cyanobacteria



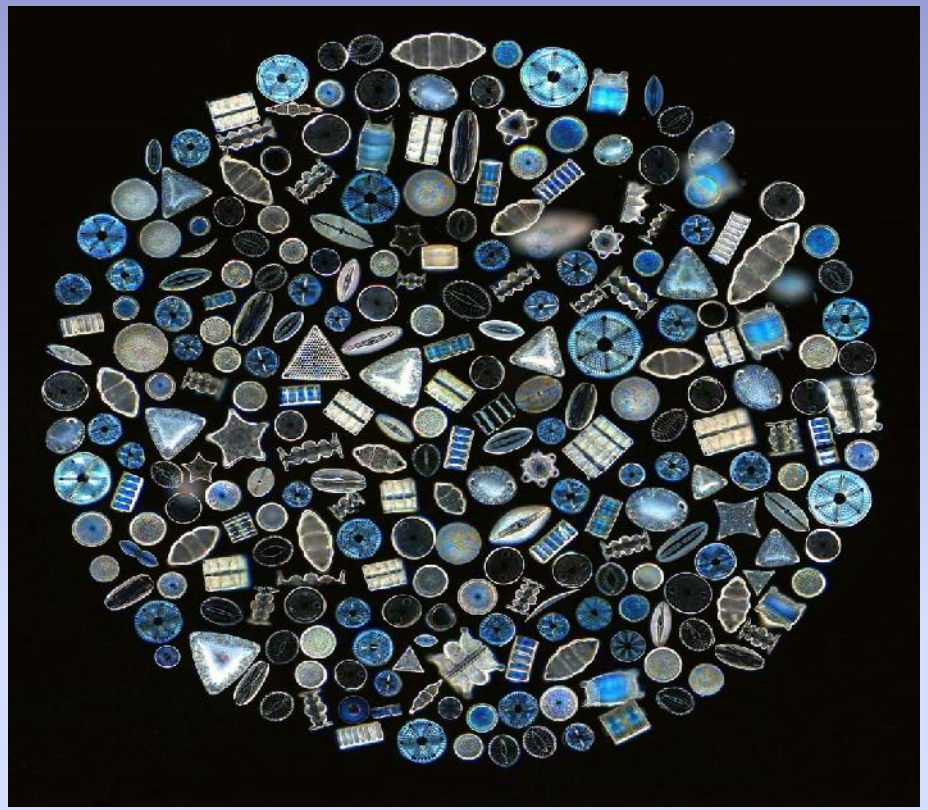
Silicoflagelletes

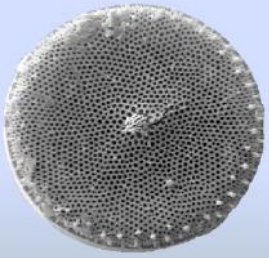
Green Algae

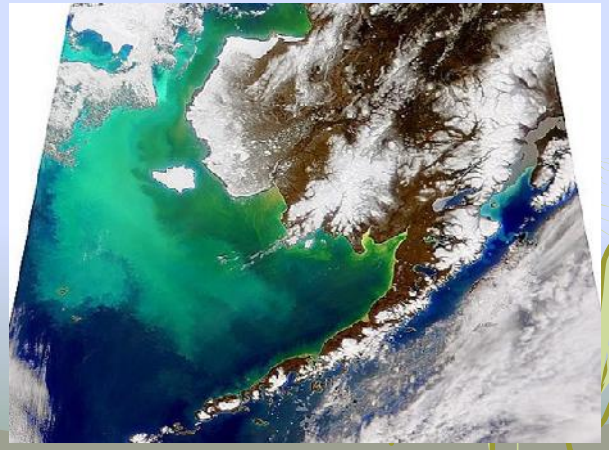
Diatoms

Characteristics

- ✓ *Photosynthesizing, unicellular, microscopic-algae (type of protista)*
- ✓ *Currently the most successful phytoplankter*
- ✓ 100,000 species
- ✓ *Most abundant in temperate and polar waters*
- ✓ *Characterized by a dual-valve silica shell (frustule)*
- ✓ *Forms silica oozes*
- ✓ *Typically forms brown- to green-colored blooms.*







Dinoflagellates

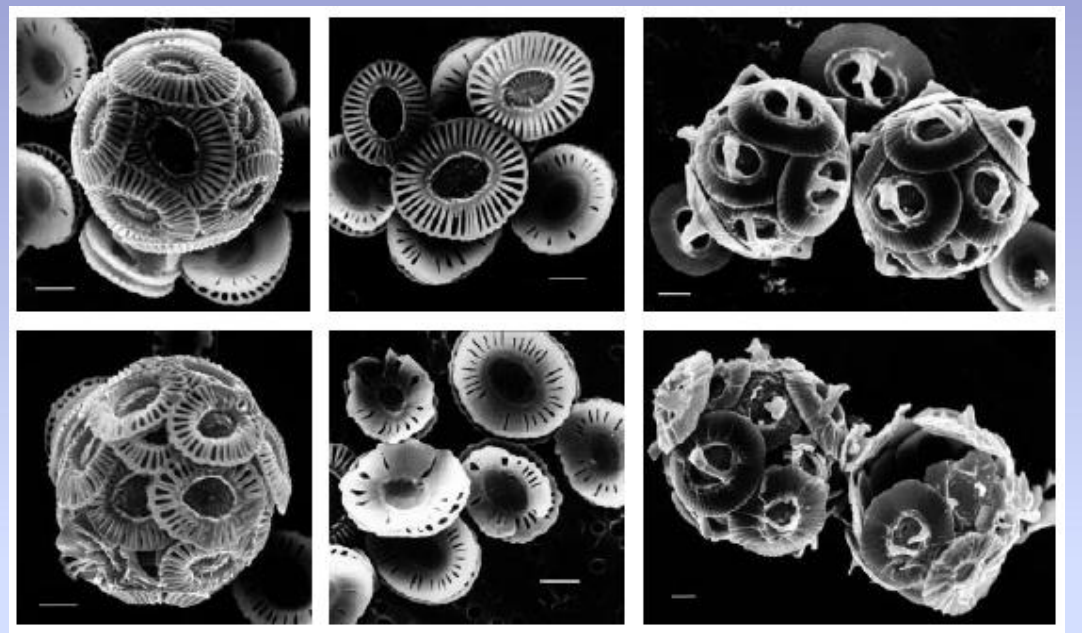
Characteristics

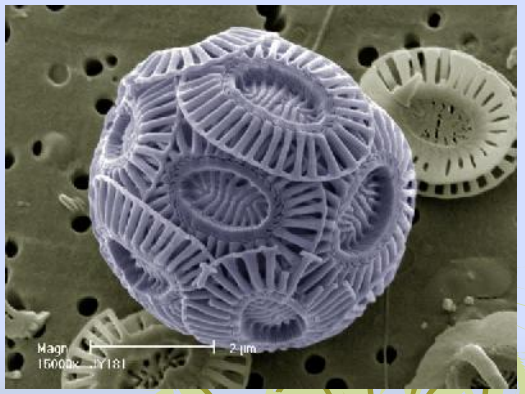
- ✓ *Photosynthesizing, uni-cellular, microscopic-algae (type of protista)*
- ✓ *Currently second most successful phytoplankter*
- ✓ 2,000 species
- ✓ *Covered by hard cellulose plates (amphiesma), and have two whip-like flagella*
- ✓ Some are poisonous; others are bioluminescent
- ✓ Include the zoozanthalae
- ✓ *Typically forms brown- to red-colored blooms.*

Coccolithophores

Characteristics

- ✓ *Photosynthesizing, unicellular, microscopic-algae (type of protista)*
- ✓ *Important phytoplankter found in all sunlit oceans*
- ✓ *Covered by hard calcium carbonate plates (coccoliths)*
- ✓ *Form calcareous oozes*
- ✓ *Typically forms milky-colored blooms.*



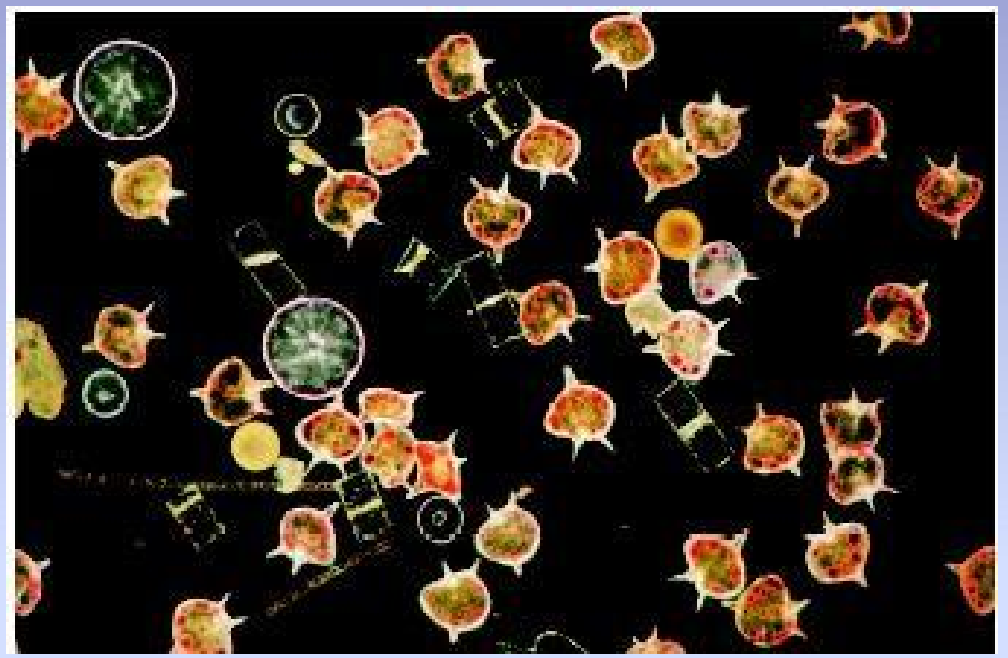


Emiliania huxleyi

Silicoflagellates

Characteristics

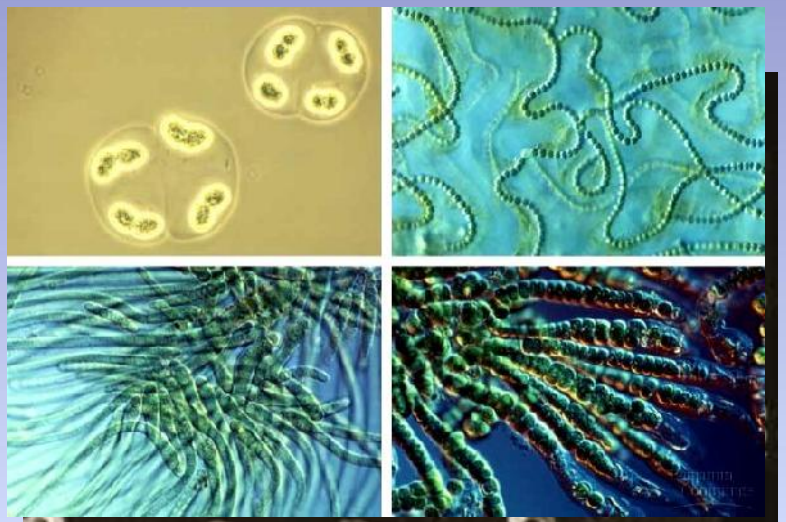
- ✓ *Photosynthesizing, unicellular, microscopic-algae (type of protista)*
- ✓ *Important phytoplankter*
- ✓ *Characterized by a ornate silica shell having a whip-like flagellum*
- ✓ *Contribute to silica oozes*
- ✓ *Typically forms brown- to red-colored blooms.*

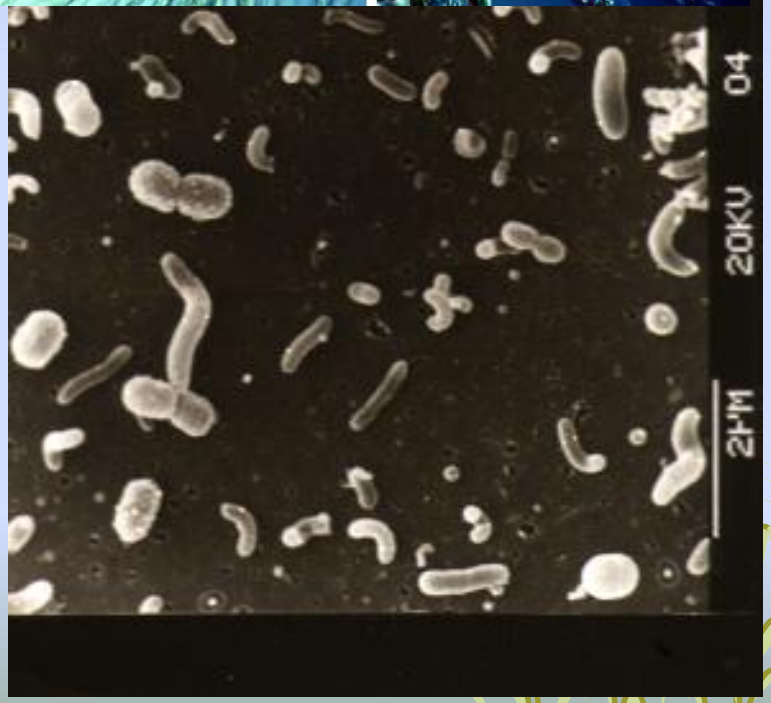


Photosynthesizing Bacteria

Characteristics

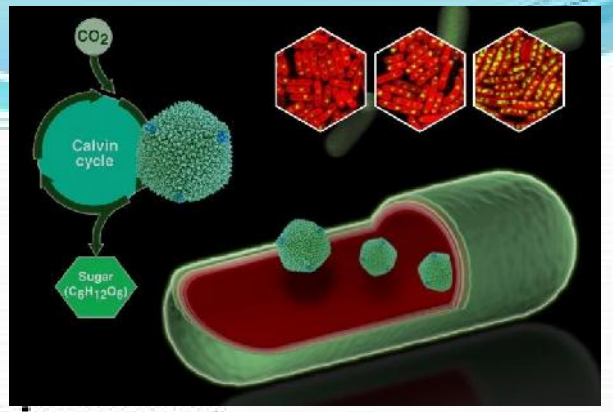
- ✓ *Photosynthesizing marine bacteria known as cyanobacteria or blue-green algae*
- ✓ *Extremely microscopic*
- ✓ *Possibly of greater mass than the micro algae*
- ✓ *Typically forms green-colored blooms.*





"Green Slime" Blooms

Cyanobacteria



- Photosynthetic- contain chlorophyll pigment
- Found in ocean and on land
- Thick cell wall and no flagella
- Commonly called blue-green algae
- Considered the ancestors of present day chloroplasts
- Grow in colonies
- Can manufacture their own food through photosynthesis

Cyanobacteria

40 μm

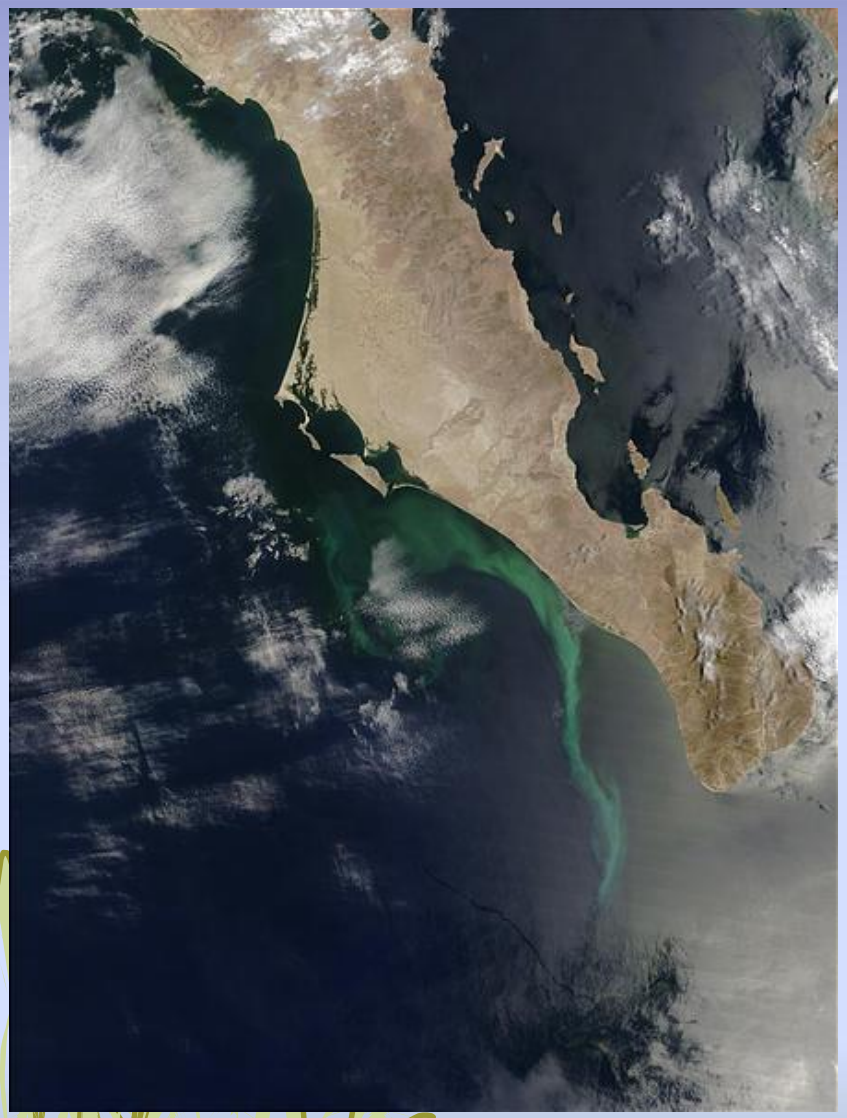
Phytoplankton Blooms

Waiheke Islands

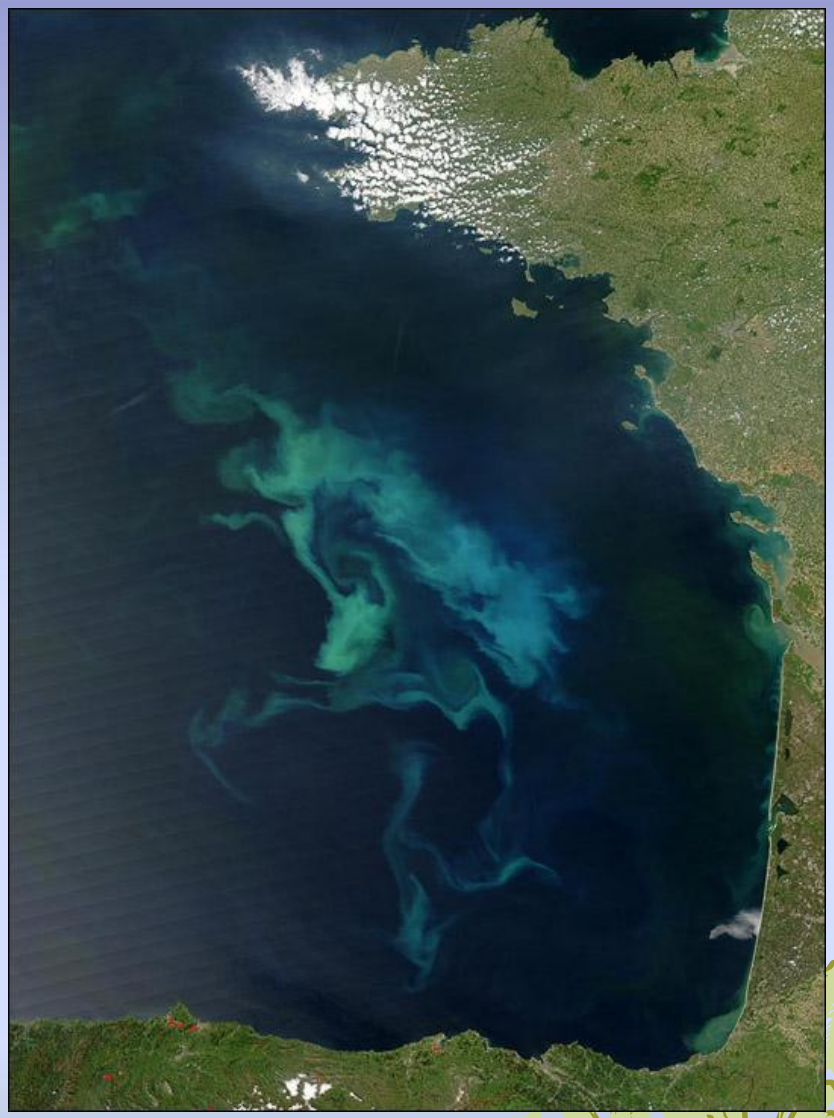
Red tides = dynaflagellates

Green tides = diatoms and/or coccolithophores

Phytoplankton Blooms

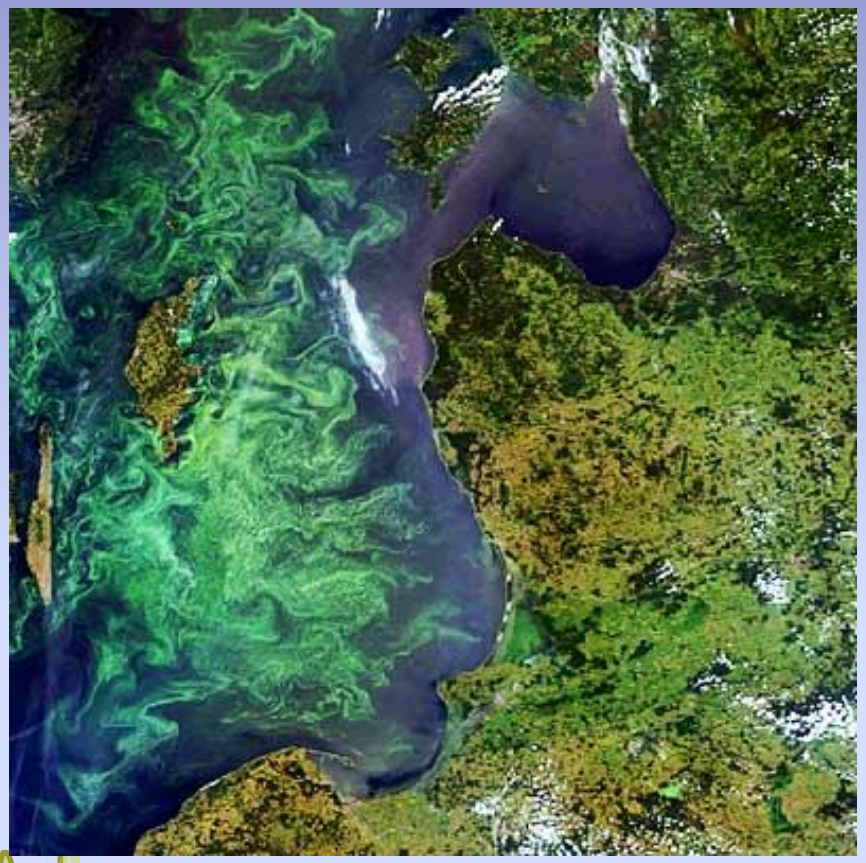


Southern Baja

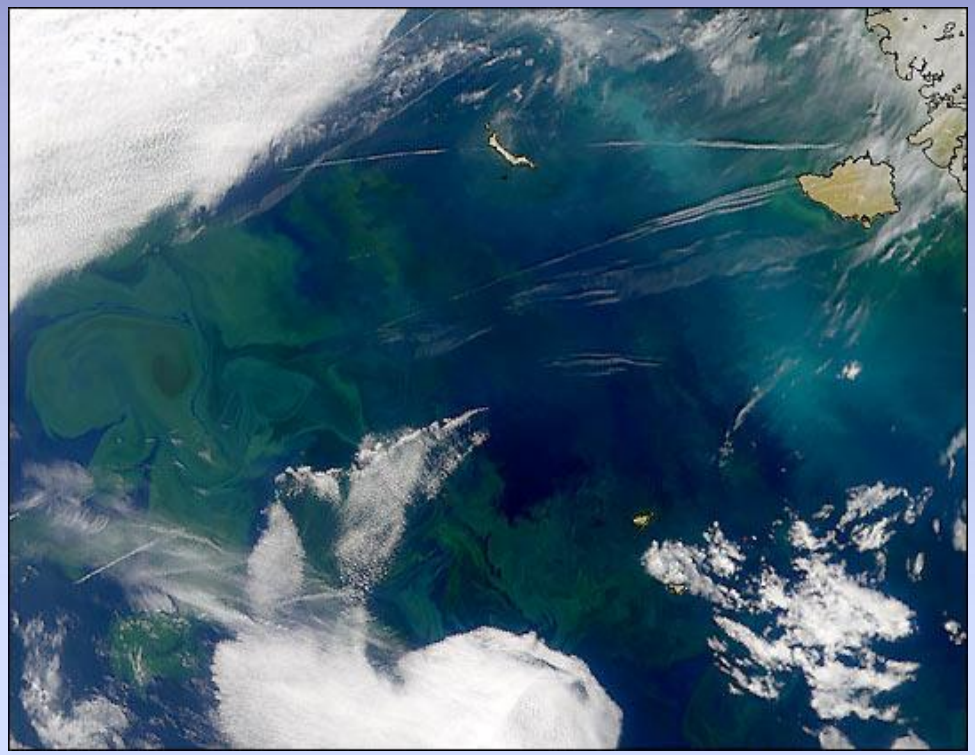


Bay of Biscay

Phytoplankton Blooms

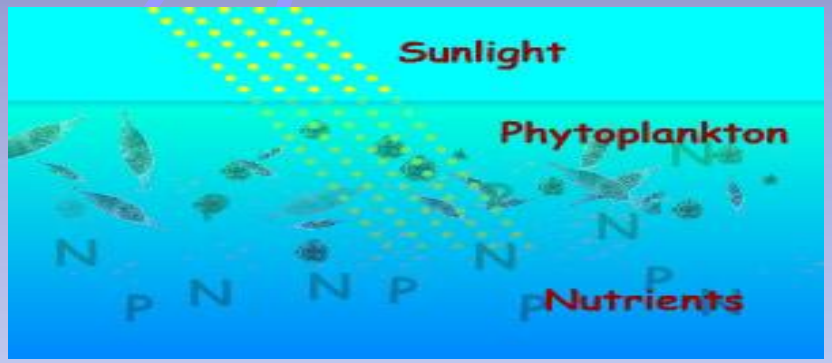


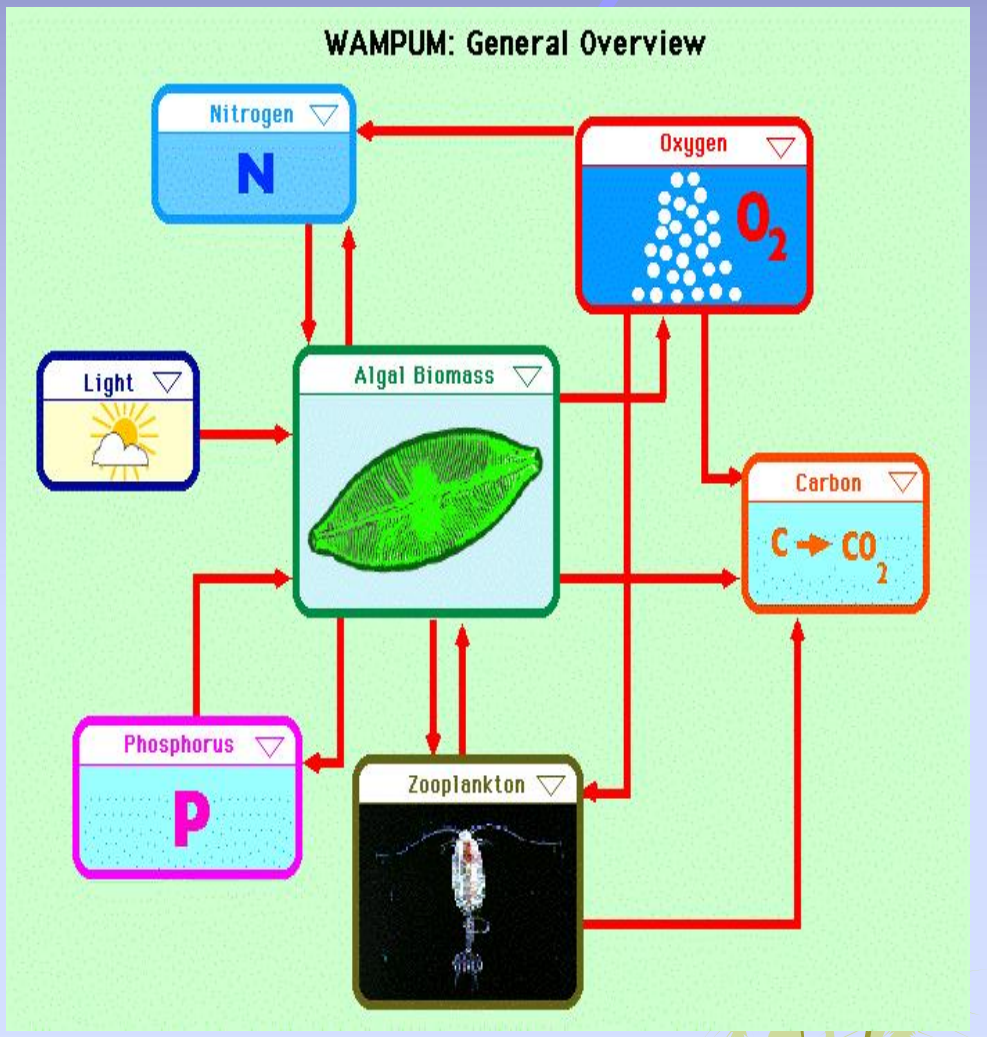
Chile



Bering Sea

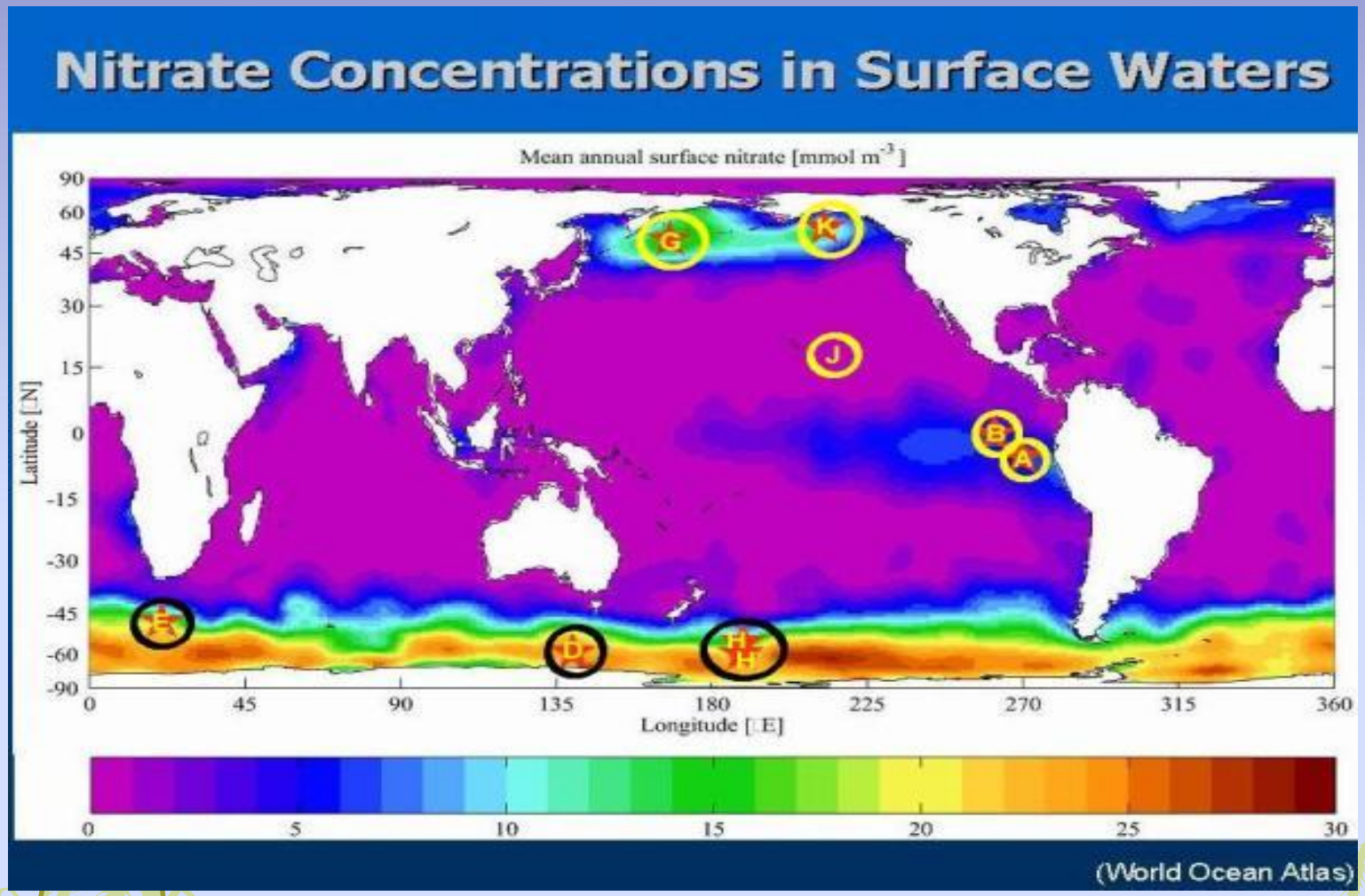
Phytoplankton and the Nutrient Cycles





- The phytoplankton play a central role in the ocean's ecosystems - driving nutrient cycles, making food & oxygen
- Nutrients are a limiting factor in ocean productivity
- Decomposer bacteria and zooplankton play key roles in recycling nutrients

Phytoplankton and Nitrate Availability



- Phytoplankton abundance is closely proportional to the concentration of nitrate nutrients in the surface waters

Primary Productivity

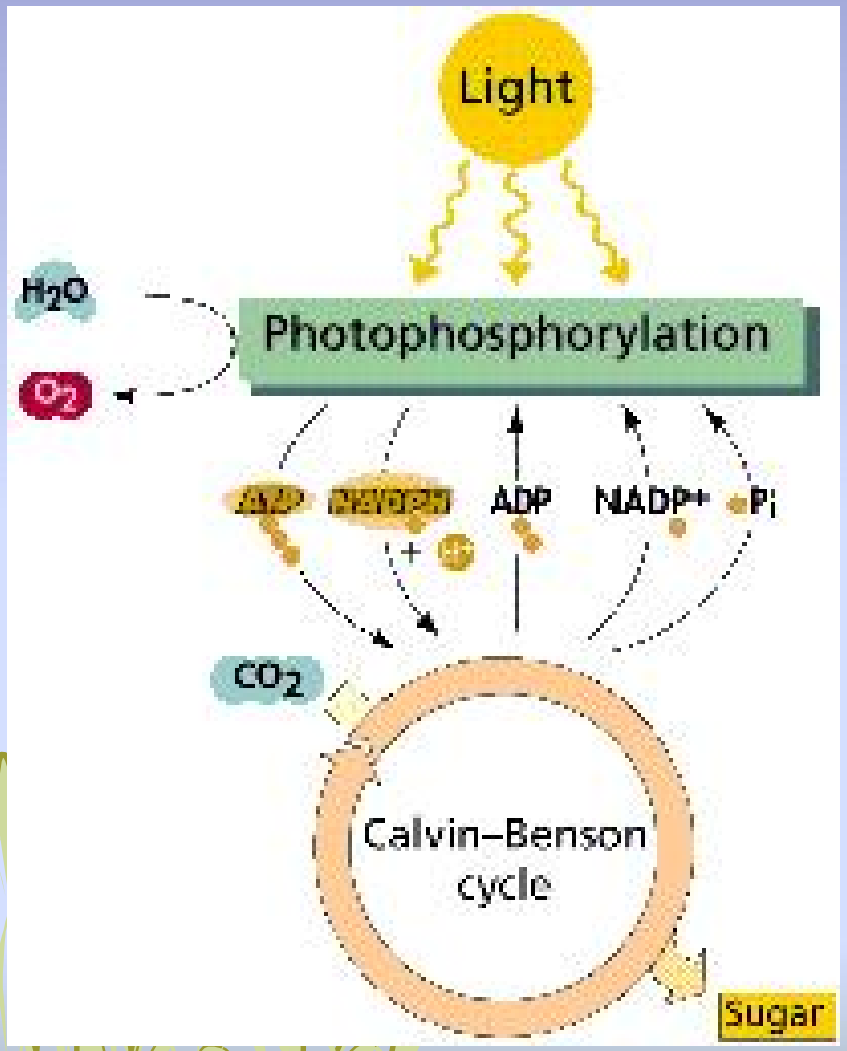
Defined

The sum of all photosynthetic rates within an ecosystem or the rate of carbon fixation as the direct result of photosynthesis in C/m²/day

(C = organic carbon in carbohydrates, m = meters)

- ✓ *Plays an essential role in the global carbon cycle*
- ✓ *Phytoplankton comprise less than 1% of total plant biomass*
- ✓ *Phytoplankton account for 40% of global carbon fixation and free-oxygen production*
- ✓ *Forms the base of the food web in the ocean*
- ✓ *Drives the "Marine Biological Pump"*

Primary Productivity = Photosynthesis

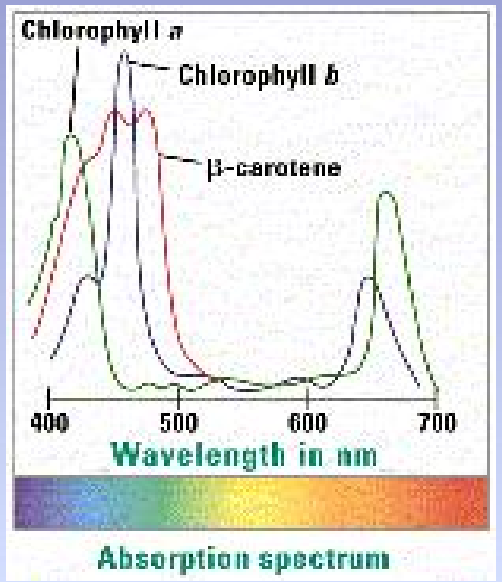


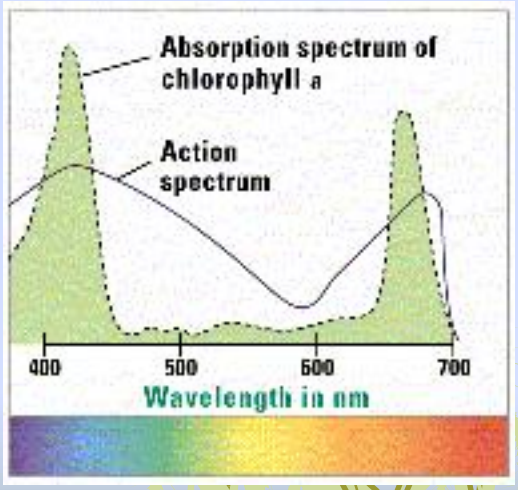
Photosynthesis

- The formation of organic matter from inorganic carbon (CO_2) with light as the primary energy source
- 6 carbon dioxide + 6 water = 1 glucose + 6 oxygen
  $6\ CO_2 + 6\ H_20 = C_6H_{12}O_6 + 6\ O$
- Two reaction steps:
  1. Light reaction: photophosphorylation: production of O_2 and energy from H_2O
     (Where does the O_2 come from?, H_2O / CO_2?)
  2. Dark reaction: carbon fixation: CO_2 to glucose

Primary Producers and Sunlight

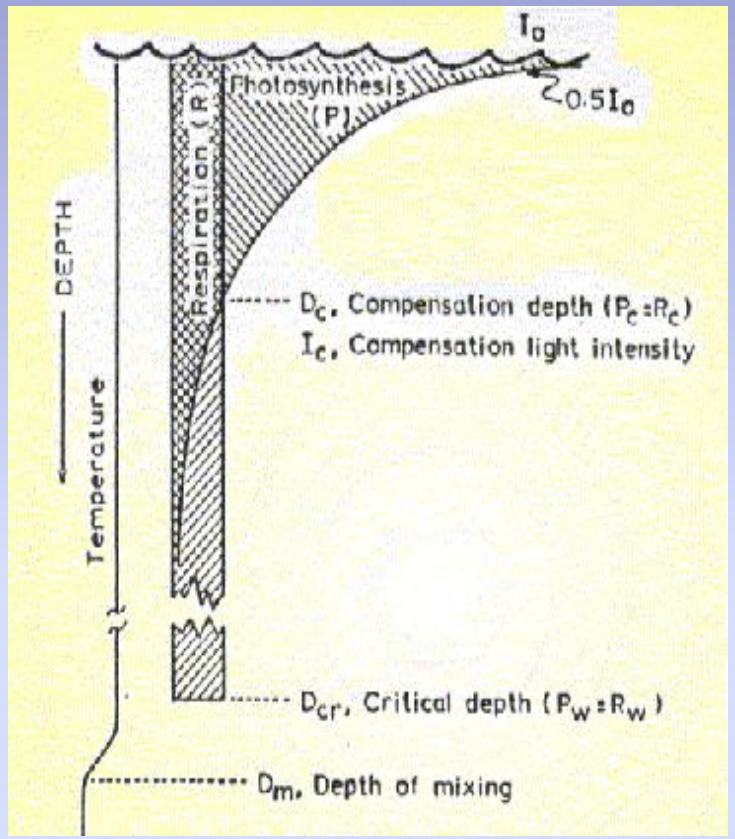
- Phytoplankton and plant photosynthesis = primary production
- Organisms that perform photosynthesis = primary producers or autotrophic organisms
- All phototrophic organisms possess chlorophyll *a* and several accessory pigments (chlorophyll *b, c,* carotenoids*)*, which serve as antenna pigments to capture light energy and transfer electrons to the photosynthetic reaction center
- Each pigment has a distinct absorption spectrum
- Photosynthesis most efficient in blue and red light, according to absorption maximum of chlorophyll (action spectrum)





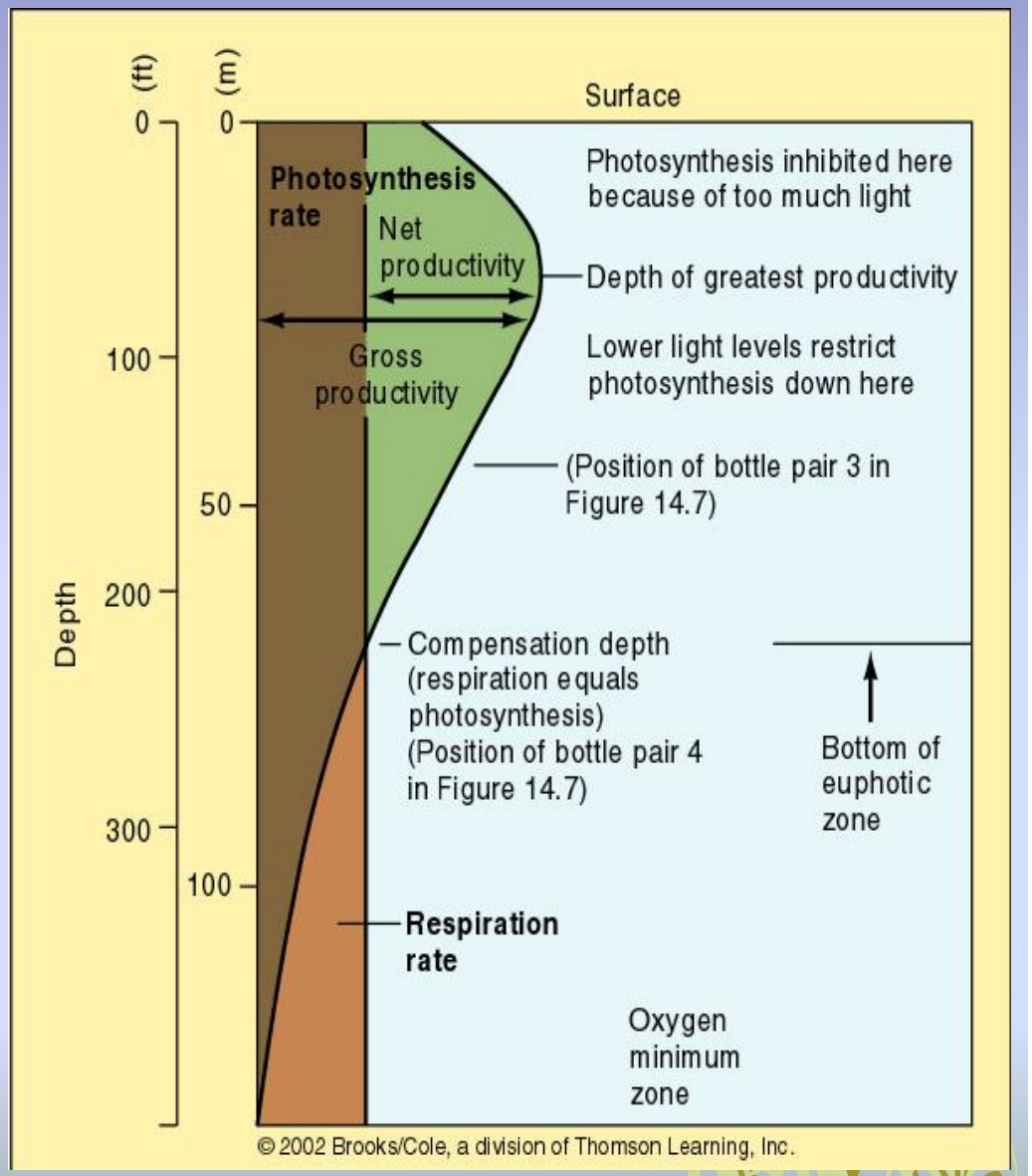
Primary Producers and Sunlight

- **Photosynthesis** decreases exponentially with depth due to decrease in light availability
- **Respiration** is unaffected by light and remains constant with depth
- **Phytoplankton** are mixed by turbulence and experiences different light intensities over time, sometimes above and sometimes below the *Compensation depth*
- Critical Depth is the depth at which total phytoplankton production is exactly balanced by phytoplankton losses (respiration and grazing)



Primary Productivity Compensation Depth

- Primary productivity varies as a function of water depth and nutrient levels
- Maximum production at 25 meters depth
- Compensation depth varies across the ocean
- Difference between gross and net productivity is the energy used for respiration



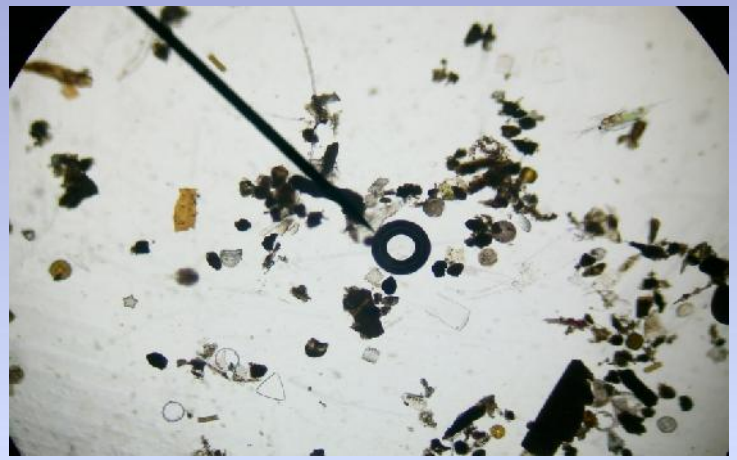
Plankton Collection Techniques

--- Netting Method ---

- Collection by dragging a net behind a slow moving vessel.
- Conical-shaped net with a collection canister at end.
- Net mesh-size is very fine, and variable, depending on size of target plankton
- Net hauled in after 10's of minutes of drag time.
- Plankton removed from canister and bottled for microscopic examination

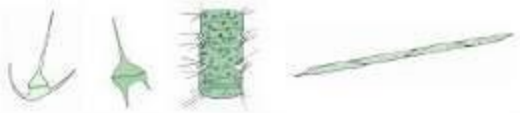
Direct Measurement of Primary Productivity

---Microscopy Counting Method ---



- Data collected by observing and counting plankton under a microscope
- Species type and number count of both phytoplankton and zooplankton are collected
- Data are plotted on graphs to analyze growth and decline curves of plankton
- Typically, the two plankton groups have mirror-like changes in abundance for a given region

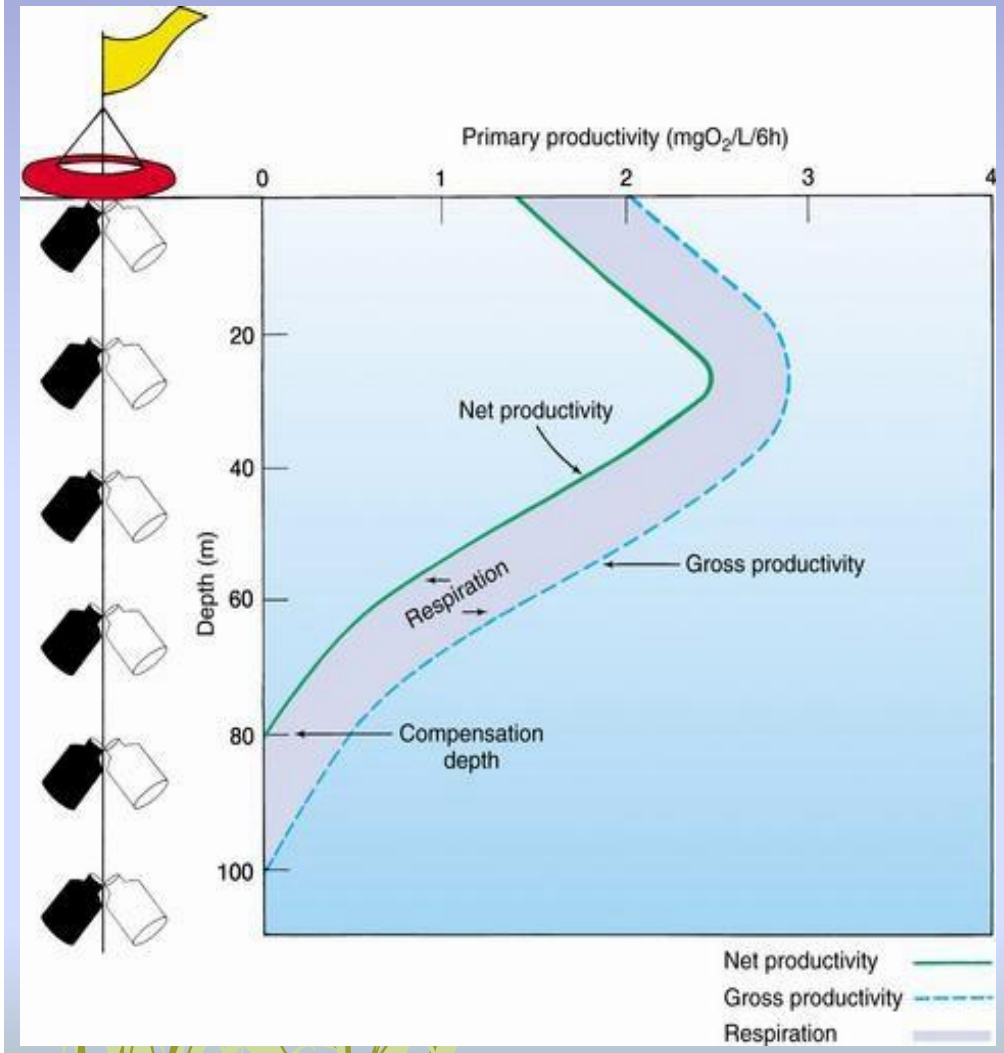
Measuring and Plotting Primary Productivity

Season	Types of phytoplankton
Spring	
Summer	
Autumn	
Winter	

- Most surface waters have seasonal changes in the type and numbers of plankton, which reflect changing oceanographic conditions, such as sunlight, nutrients, temperature, and sea life.
- Data are plotted on graphs to analyze growth and decline curves of plankton over time.
- Typically, the two plankton groups have mirror-like changes in abundance for a given region. Why is this?

Direct Measurement of Primary Productivity

---The Dark-Light Bottle Method ---



- Data collected by using in-situ transparent and opaque incubation bottles strung on a hang line in ocean column
- Measure biological differences between clear and opaque bottles for each sample depth over time
- Use the Carbon14 method to determine precise amount of productivity

Primary Productivity Measuring Technique

The C14 Method

- Simple technique, but problems with radiation safety and waste disposal
- Incubate light and dark bottles with known addition of $H^{14}CO_3$
- Production calculated as:

$P = (R_L - R_D) \times [CO_2] / (R \times t)$

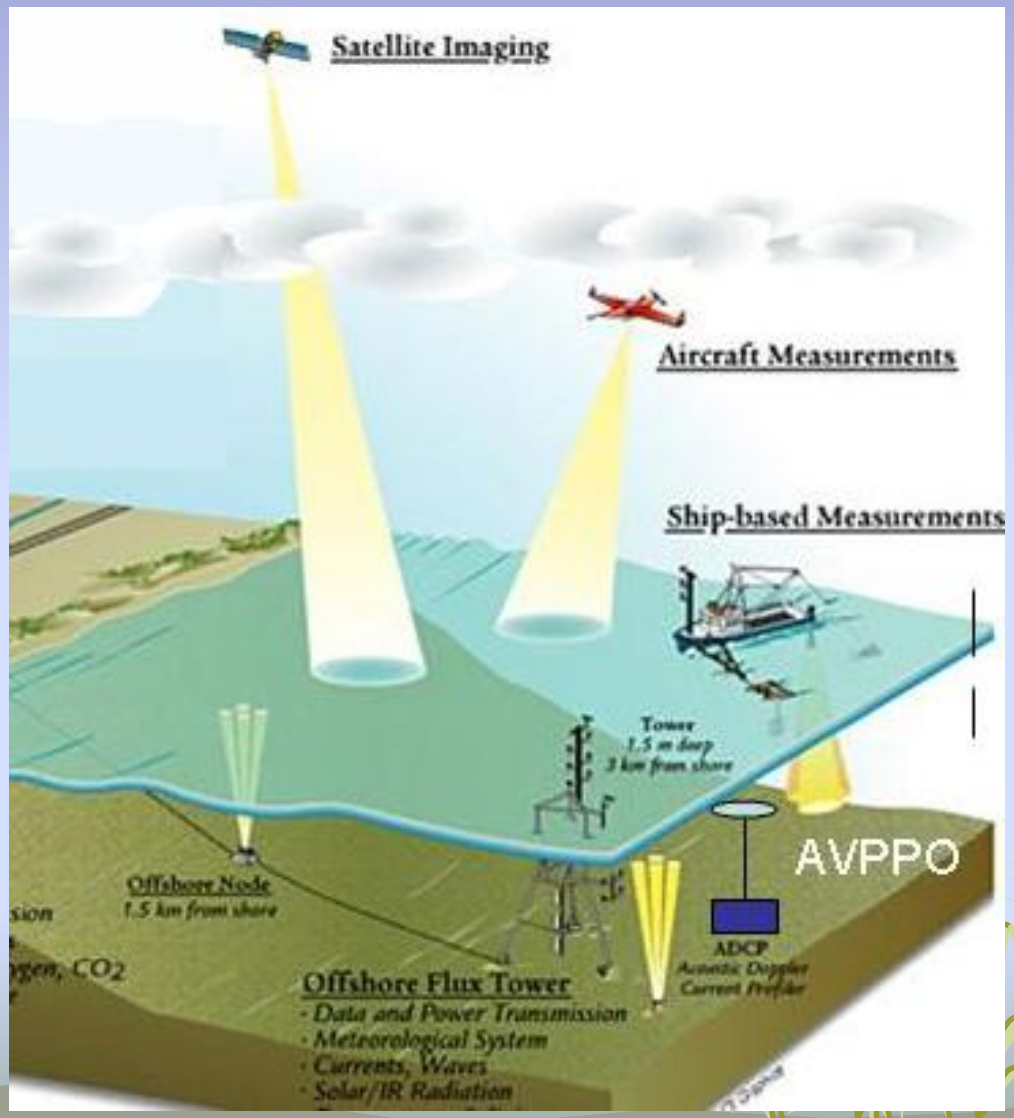
with P = Production; R = added radioactivity; R_L = radioactivity in light bottle after incubation; R_D = radioactivity in dark bottle after incubation; $[CO_2]$ = concentration of total CO_2 in sea water; t = incubation time

- $[CO_2]$ has to be determined separately by titration or from tables (function of salinity)
- P is a measure between gross and net production
- Method cannot account for organic carbon produced and excreted during incubation: exudation
- Long incubations: multiple interaction within microbial food web bias estimates, part of primary production already consumed by small grazers within bottles
- Areas of picoplankton dominance: use small pore filters not to lose too many! (0.2 µm)

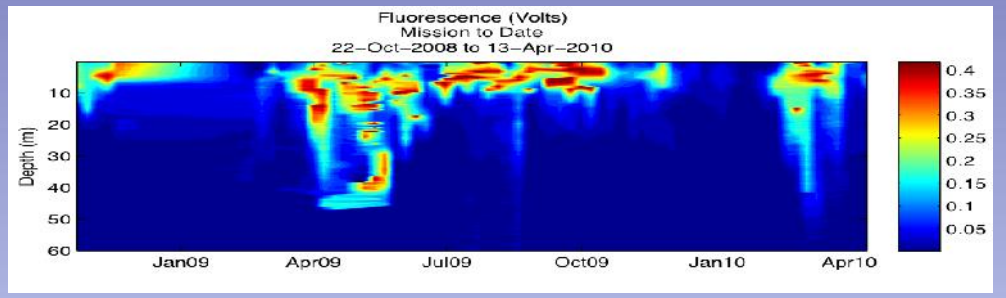
Remote Measuring Primary Productivity

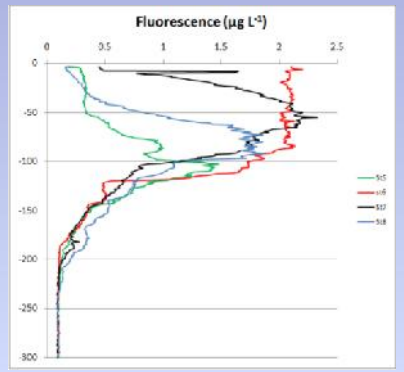
---The Chlorophyll Level Method ---

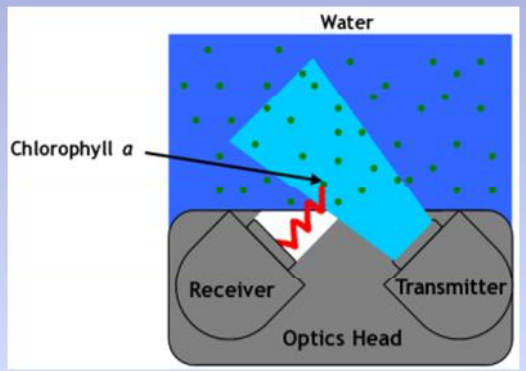
- Remote sensing of phytoplankton abundance by measuring chlorophyll concentrations at ocean surface
- Use of both satellite and aircraft for measuring
- Shipboard measurements help confirm and calibrate data from remote sensing platforms



Measuring Primary Productivity with Fluorescence

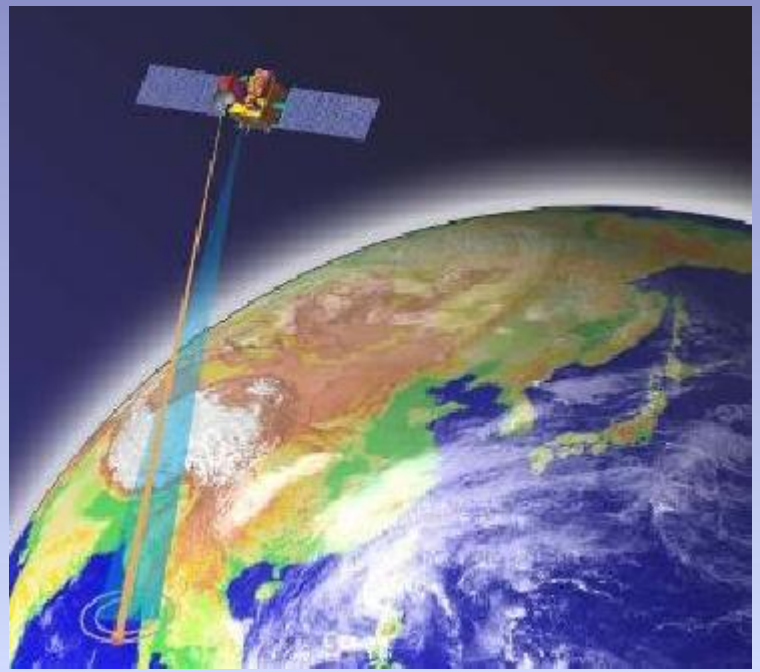




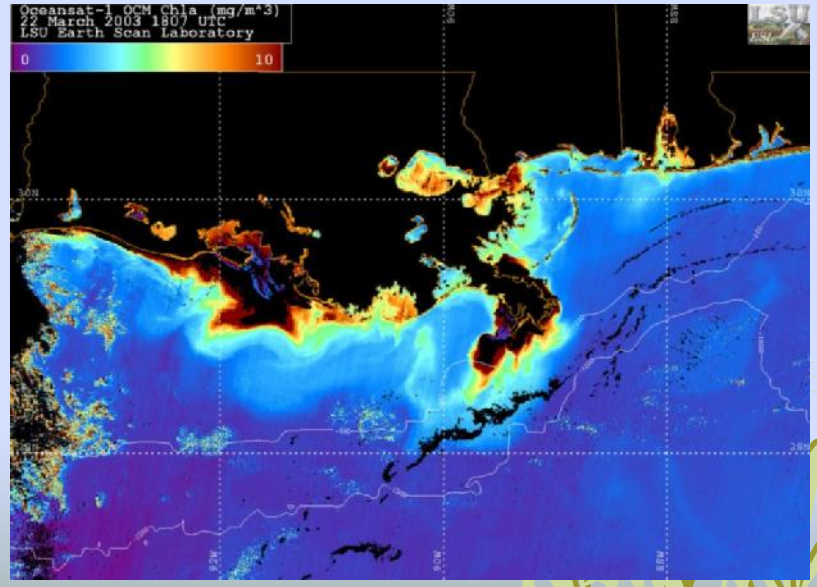


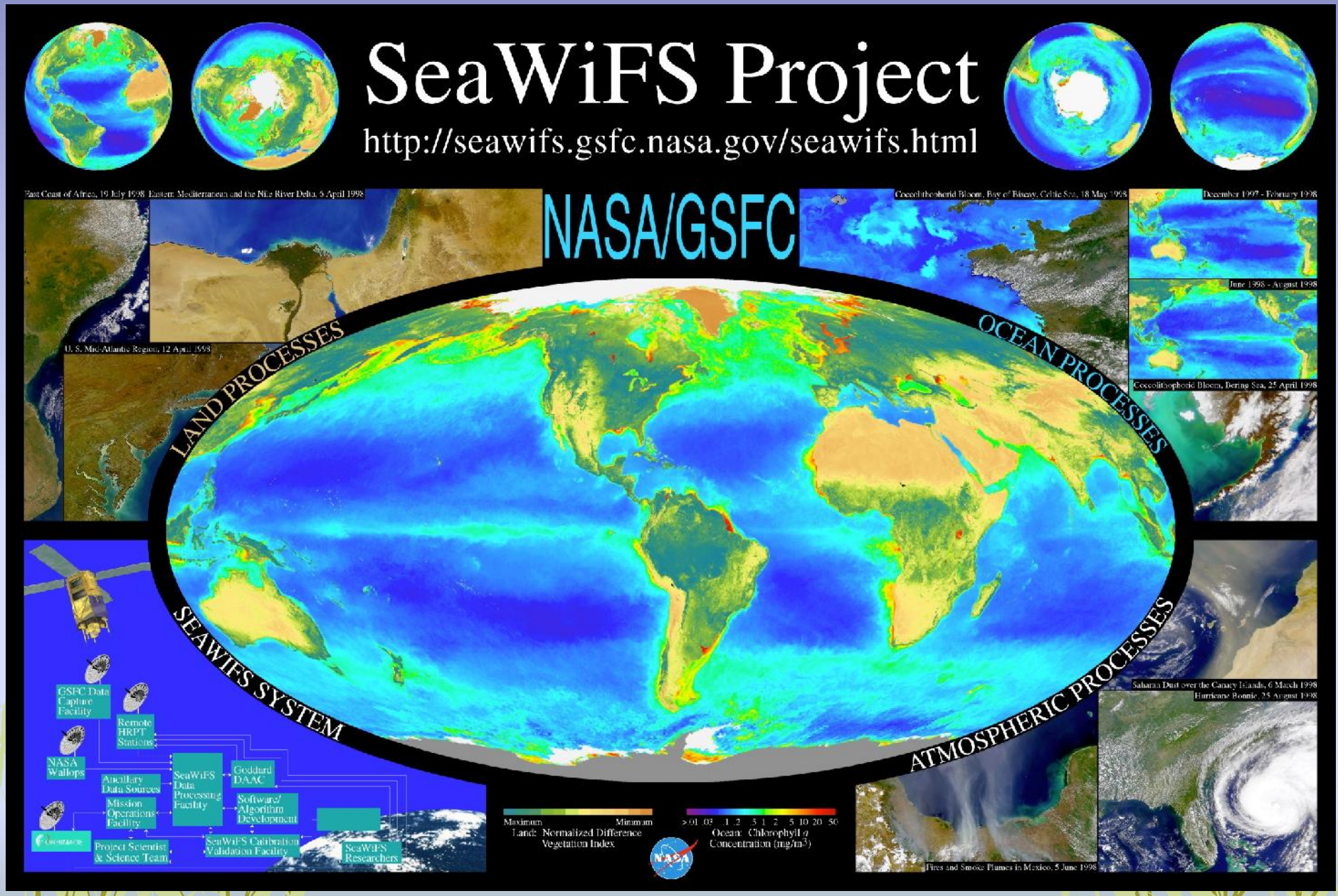
- ***Natural Fluorescence Chemostat*** instrument measures the natural fluorescence of phytoplankton
- Level of fluorescence indicates levels of phytoplankton growth
- Instrument is typically lowered into ocean and can record levels at each given water depth in real time.

Remotely Measured Primary Productivity with Chlorophyll Color

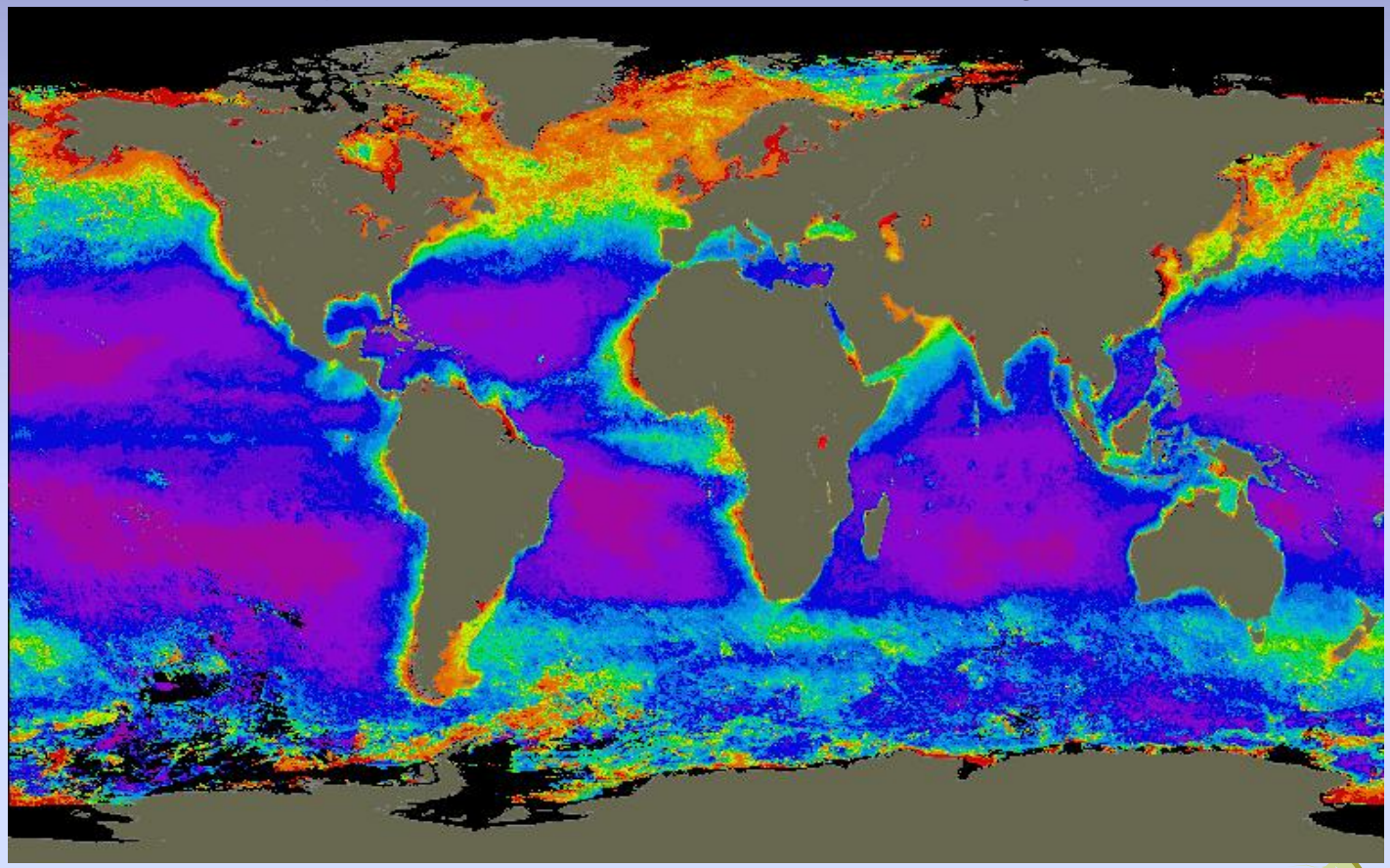


- **Concentration of chlorophyll at ocean surface indicates levels of phytoplankton growth**
- **Chlorophyll give off specific color signatures in ocean water**
- **Ocean Color Monitor (OCM) data collected via India's Oceansat satellite**
- **Chlorophyll levels lowest in much of open ocean**




SeaWiFS Project
http://seawifs.gsfc.nasa.gov/seawifs.html
NASA/GSFC
East Coast of Africa, 19 July 1998
Eastern Mediterranean and the Nile River Delta, 5 April 1998
U. S. Mid-Atlantic Region, 12 April 1998
Coccolithosherid Bloom, Bay of Biscay, Celtic Sea, 18 May 1998
December 1997 - February 1998
June 1998 - August 1998
Coccolithophoric Bloom, Bering Sea, 25 April 1998
LAND PROCESSES
OCEAN PROCESSES
ATMOSPHERIC PROCESSES
SEAWIFS SYSTEM
GSFC Data Capture Facility
Remote HRPT Stations
NASA Wallops
Ancillary Data Sources
Mission Operations Facility
SeaWiFS Data Processing Facility
Goddard DAAC
Software/ Algorithm Development
Project Scientist & Science Team
SeaWiFS Calibration/ Validation Facility
SeaWiFS Researchers
Maximum
Minimum
Land: Normalized Difference Vegetation Index
>.01 .03 .1 .2 .5 1 2 5 10 20 50
Ocean: Chlorophyll a Concentration (mg/m3)
Saharan Dust over the Canary Islands, 6 March 1998
Hurricane Bonnie, 25 August 1998
Fires and Smoke Plumes in Mexico, 5 June 1998

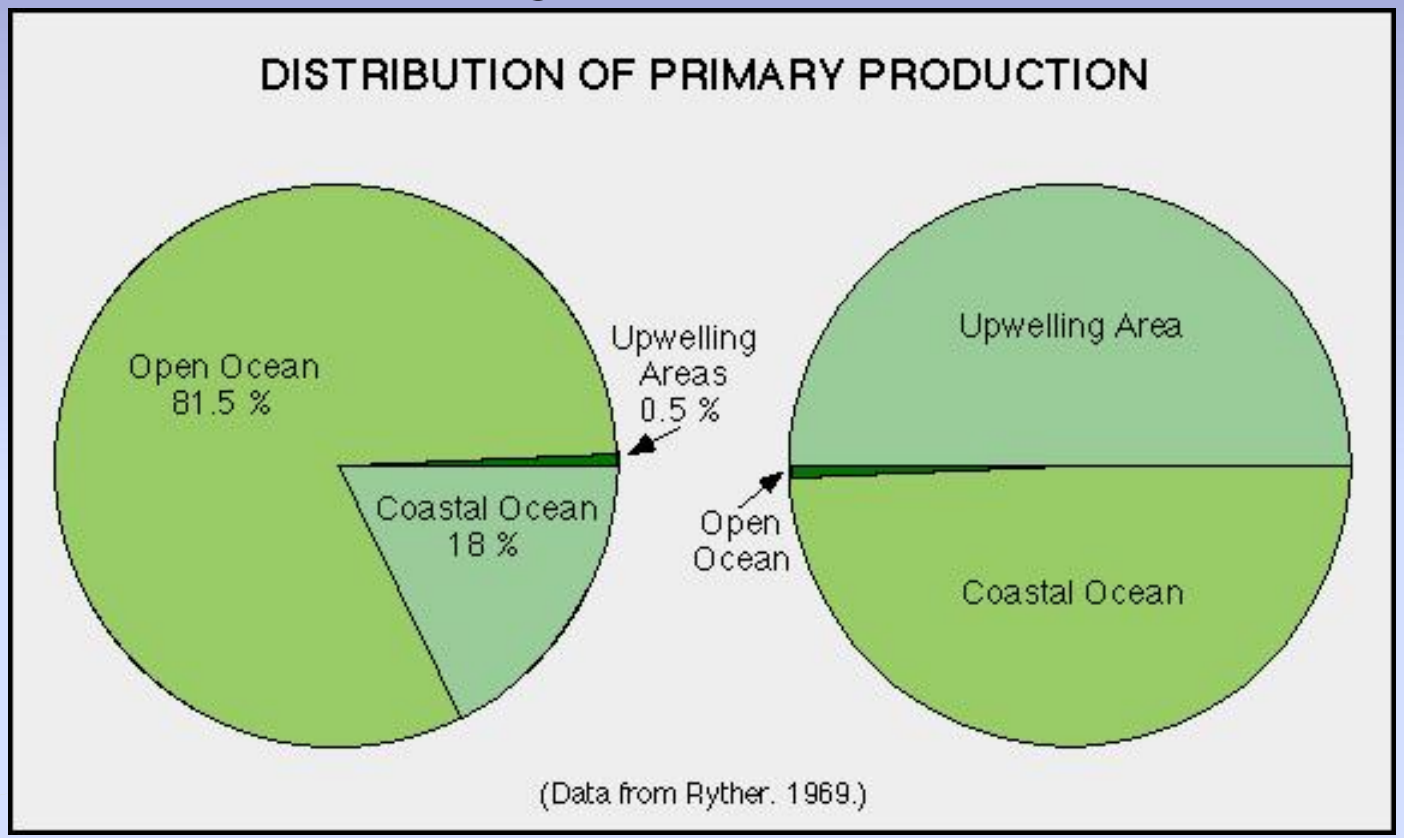
Tracking Global-scale Seasonal Changes in Productivity



Question:

Can you tell which time of the year this image was taken by plankton distribution?

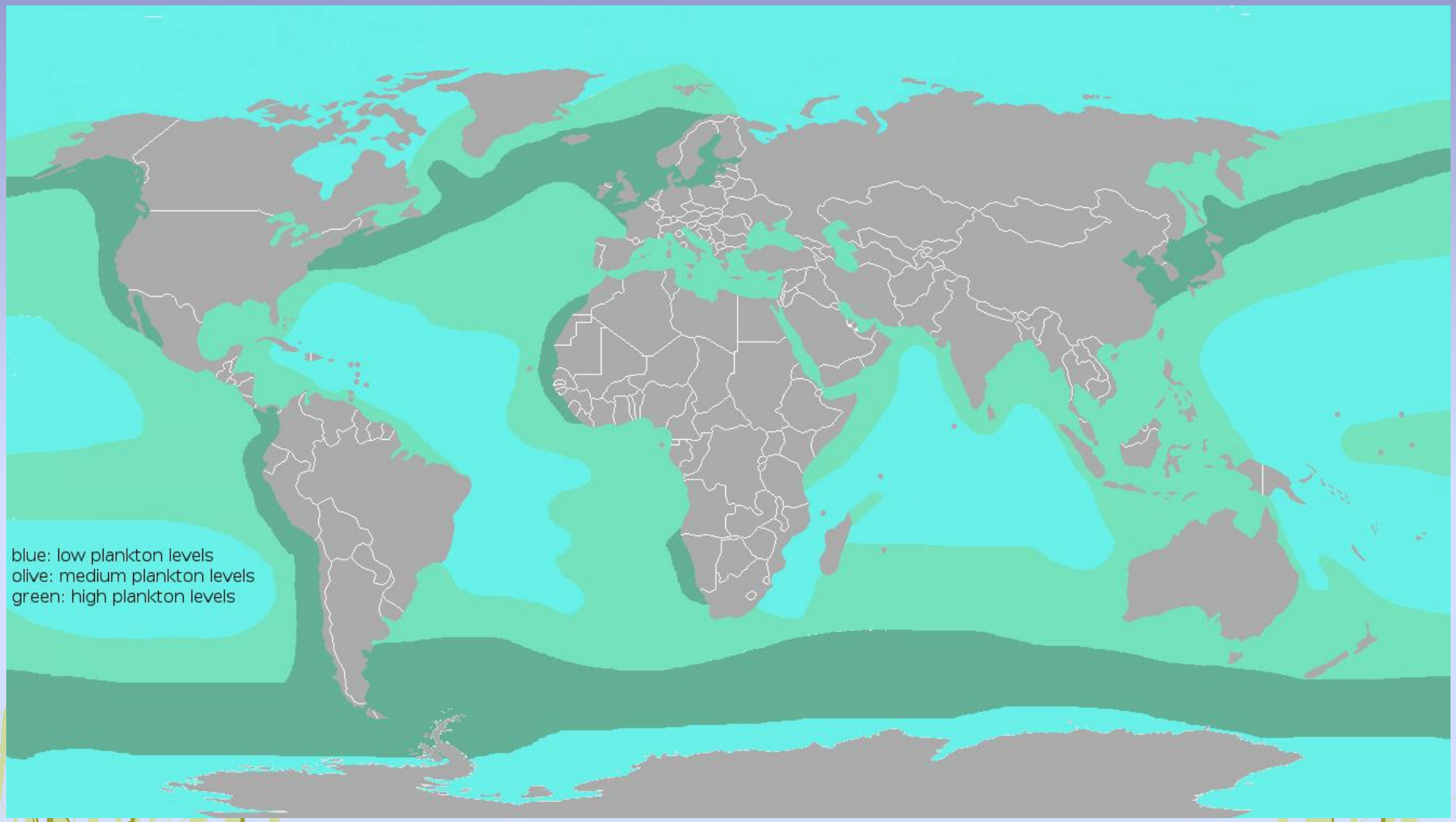
Ocean Surface Area Versus Primary Production



Ocean Surface Distribution

Primary Production Distribution

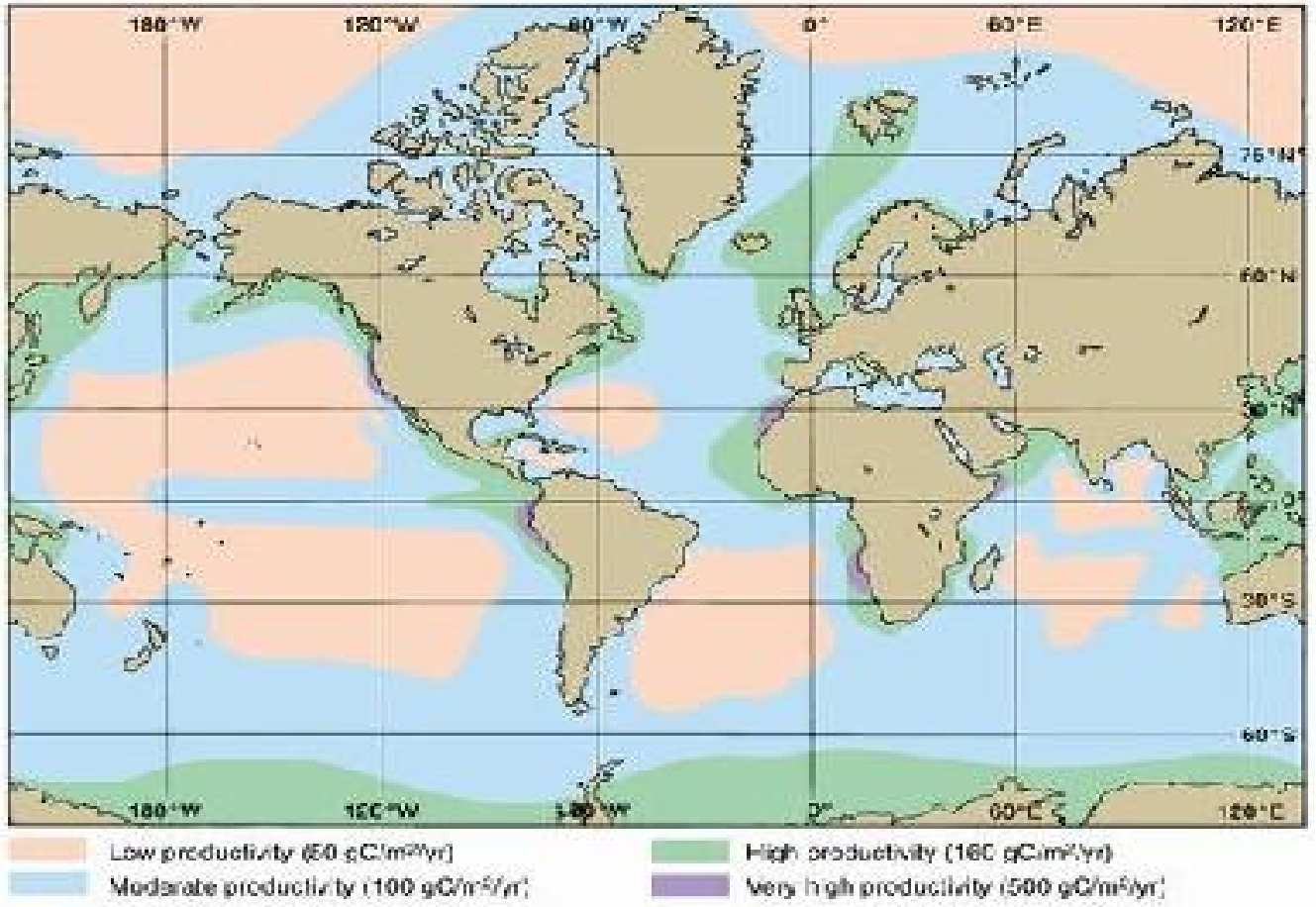
Regional Variations in Primary Productivity



Regional Variation:

Blue: *Low*
Olive: *Moderate*
Green: *High*

Regional Variations in Primary Productivity



Peach: *Low*

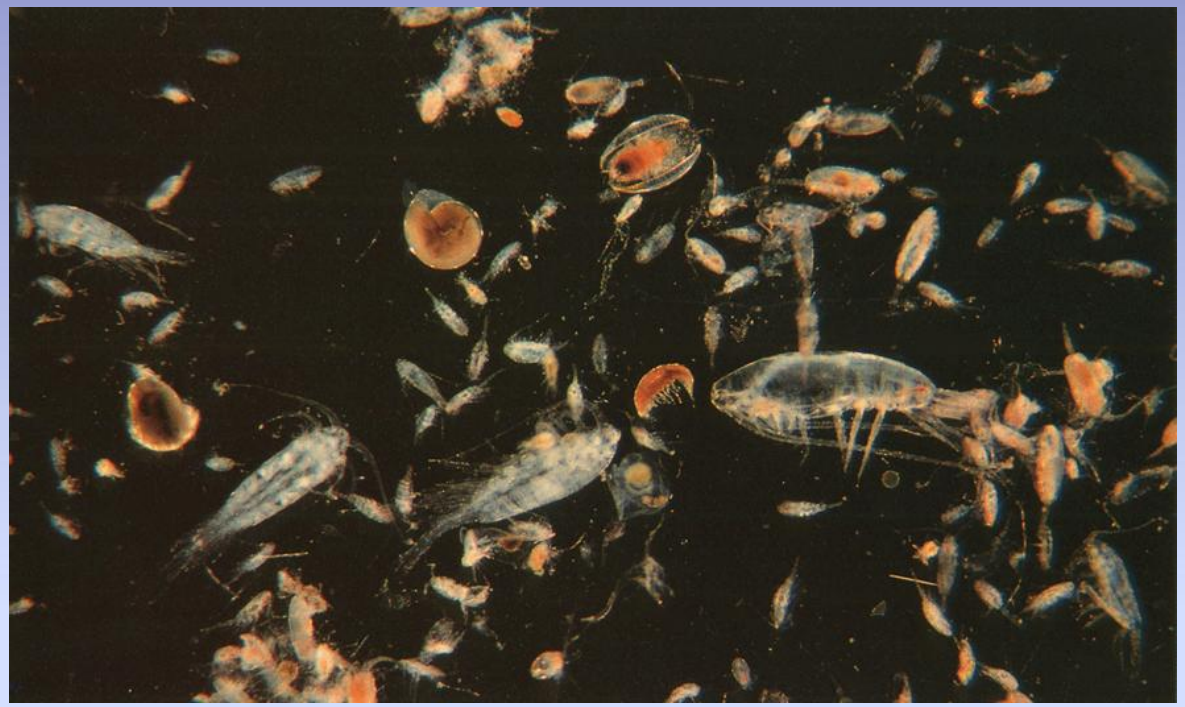
Olive: *Moderate*

Green: *High*

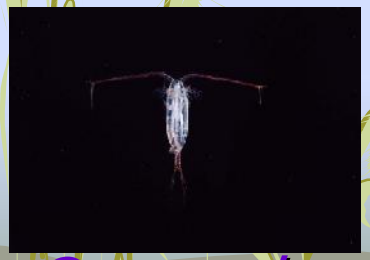
Purple: *Very High*

Zooplankton – The Sea Grazers

1) Copepods
2) Krill
3) Fish Larvae
4) Jellies
5) Radiolarians
6) Foraminifers



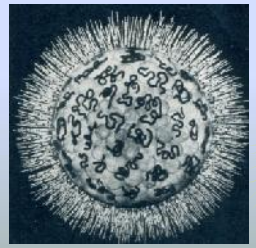
Zooplankton are a diverse group of tiny protozoans and larger metazoans that form the second level of the trophic pyramid: they feed on the primary producers – the phytoplankton



Copepod

Krill

Tiny Jellies



Rads

Forams

Zooplankton – The Sea Grazers

(**A**) Copepods,

(**B**) *Centropages*

(**C**) Harpacticoida

(**D**) Poecilostomatoida

(**E**) *Temora*

(**F**) *Oithona*

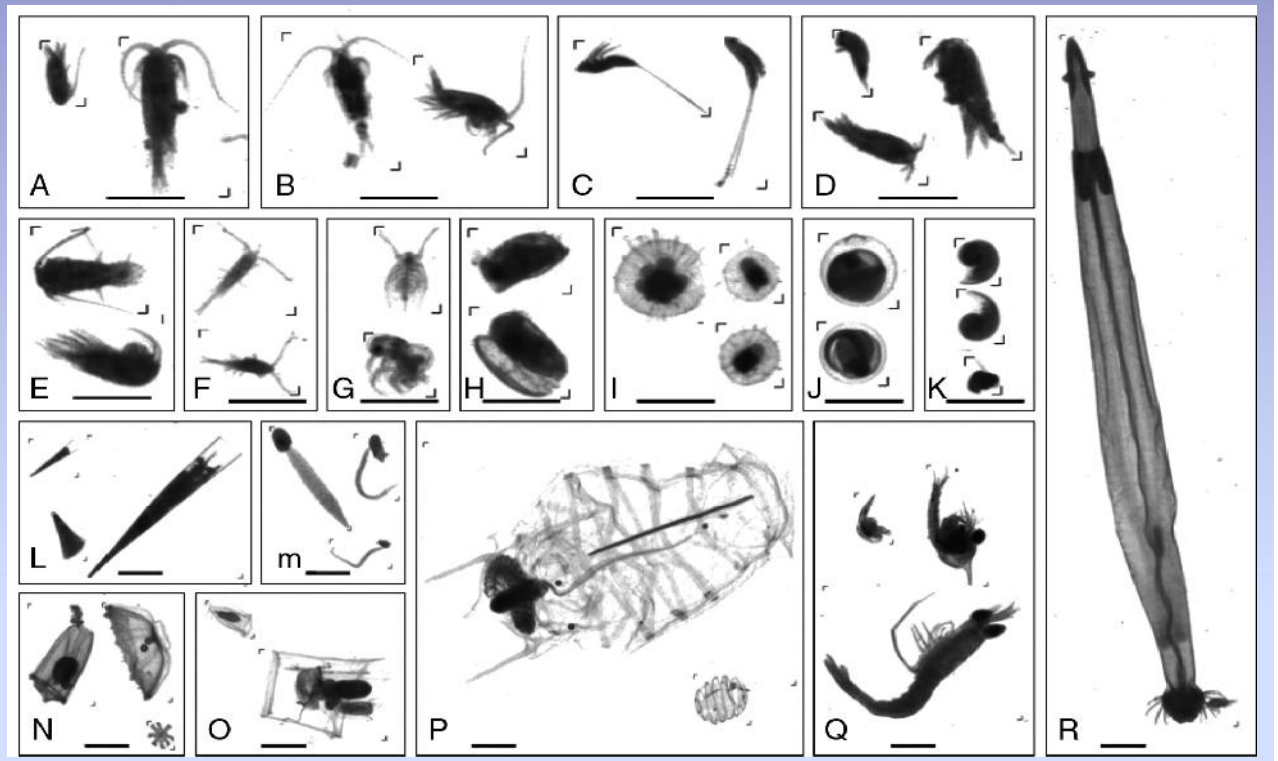
(**G**) Cladocera

(**H**) Ostracoda

(**I**) Radiolaria

(**J**) Eggs

(**K**) *Limacina*



(scale bar = 1 mm).

(**L**) Pteropoda

(**M**) Appendicularia

(**N**) Medusae

(**O**) Siphonophora

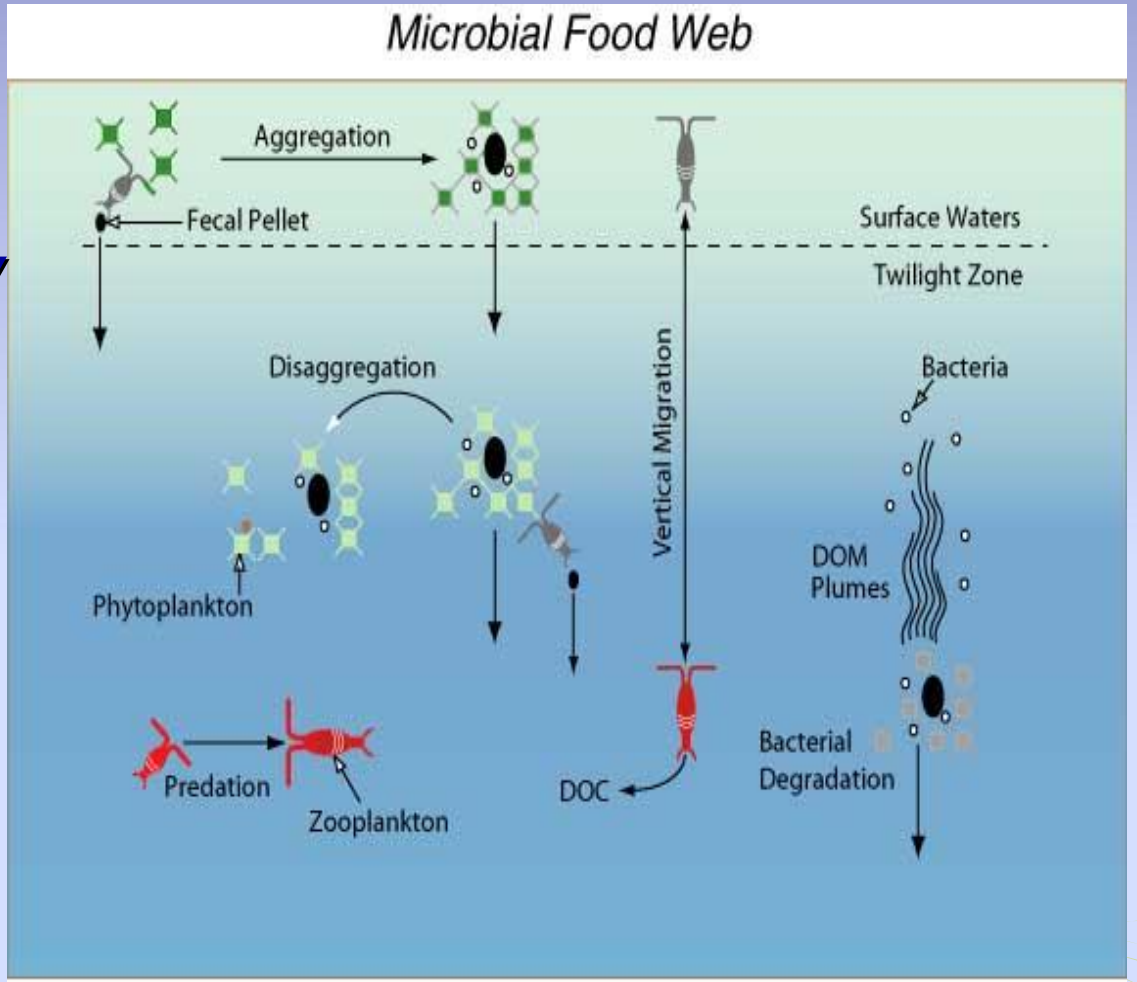
(**P**) Thaliacea

(**Q**) Decapoda

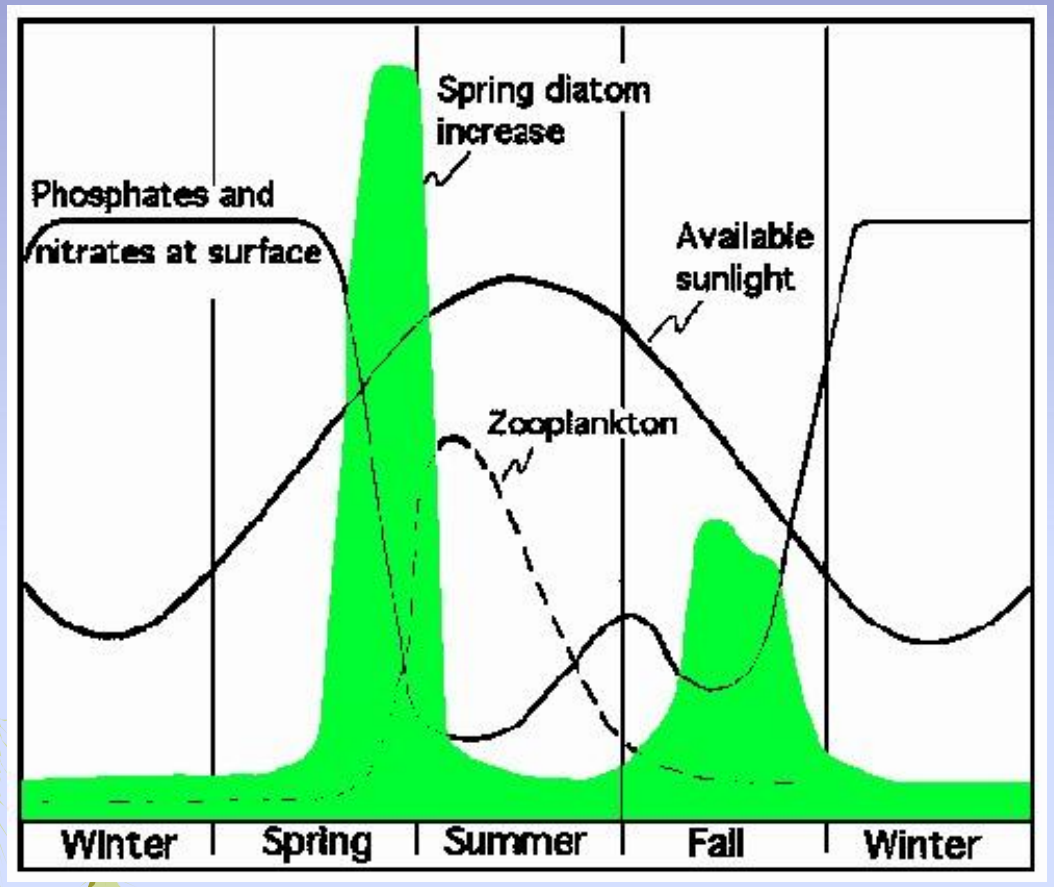
(**R**) Chaetognatha

The Ocean's Microbial Food Chain

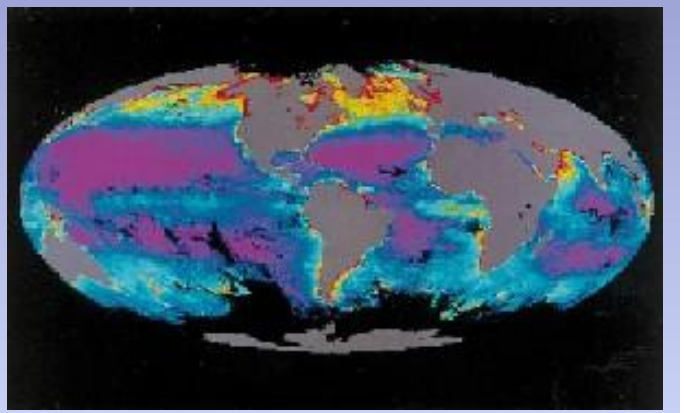
- The **most important** biological activity in the ocean occurs at the microbial level = ***the tiny planktonic organisms***
- The players include the ***phytoplankton***, the ***zooplankton***, and the ***decomposer bacteria***
- All three players are critical to the entire marine food web and the nutrient cycles



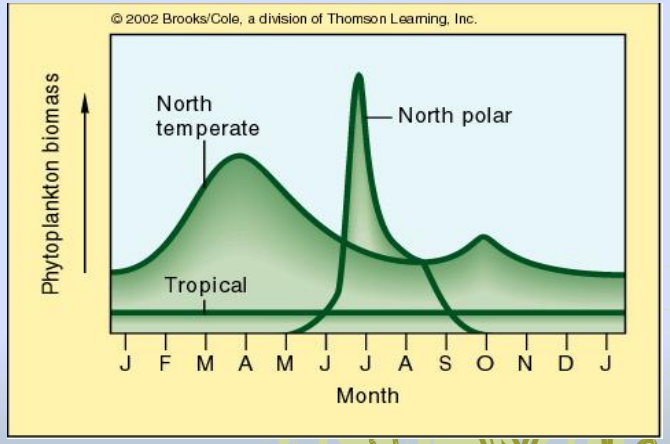
Seasonal Variations in Primary Productivity



Seasonal Variation

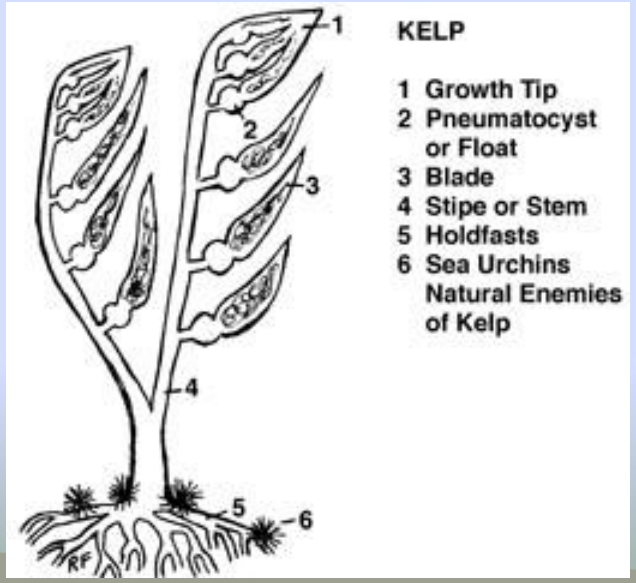


Northern Hemi Variation



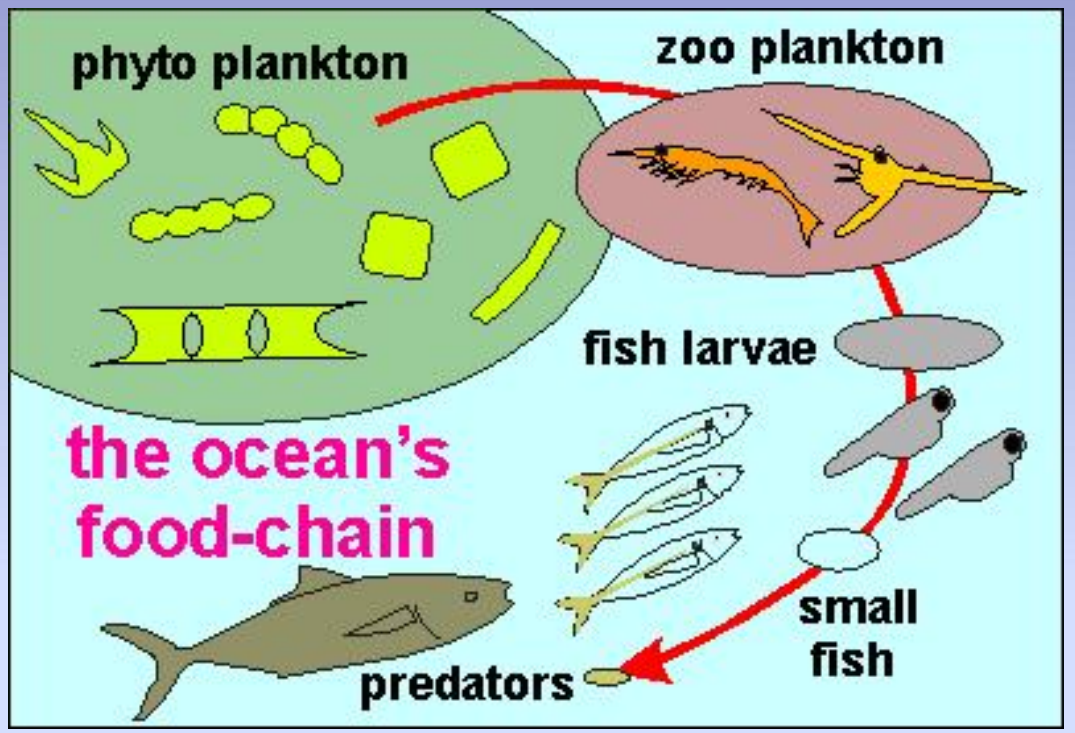
Macro-Algae - Kelp and Seaweed

https://vimeo.com/67962861



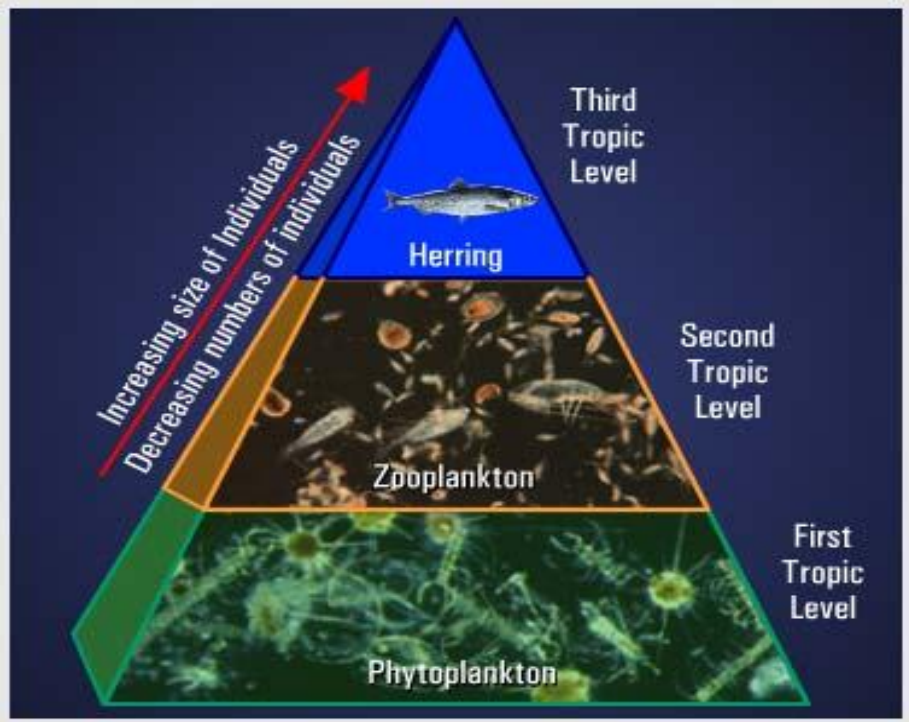
The Ocean's Food Chain

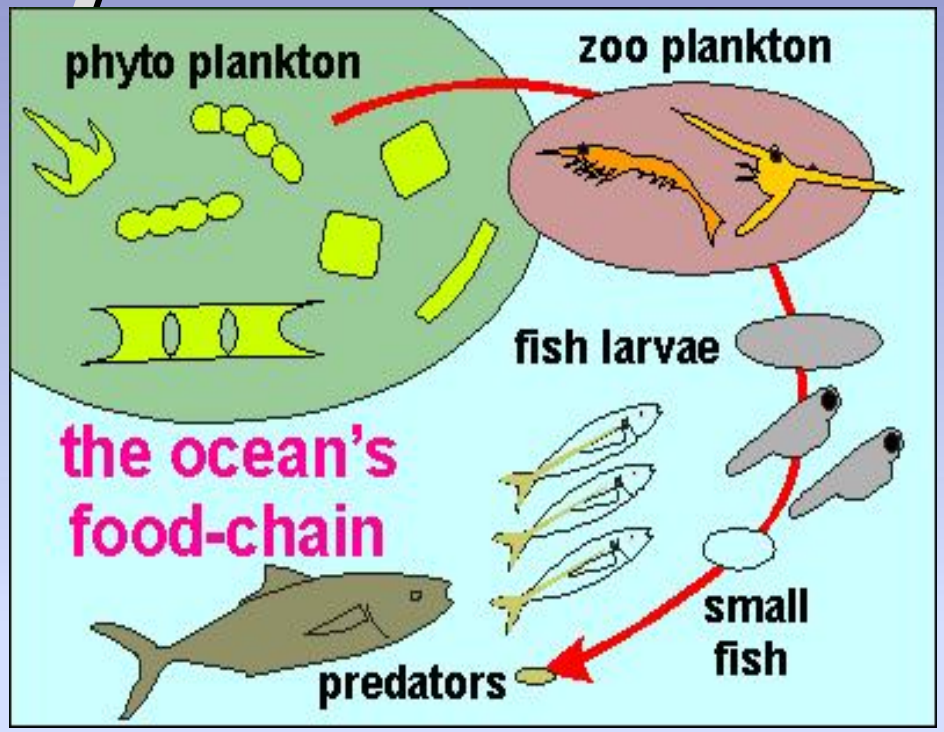
- Phytoplankton are eaten by the primary consumers, called zooplankton
- Zooplankton are eaten by secondary consumers, such as tiny fish, jellyfish, anemones and mollusks
- Tiny fish, jellies and other secondary consumers are eaten by bigger fish, birds, sea turtles, and sea mammals



- It takes roughly 10 grams of phytoplankton to make 1 gram of zooplankton, and 10 grams of zooplankton to make 1 gram of tiny fish....and on up the food chain

The Ocean's Tropic Levels

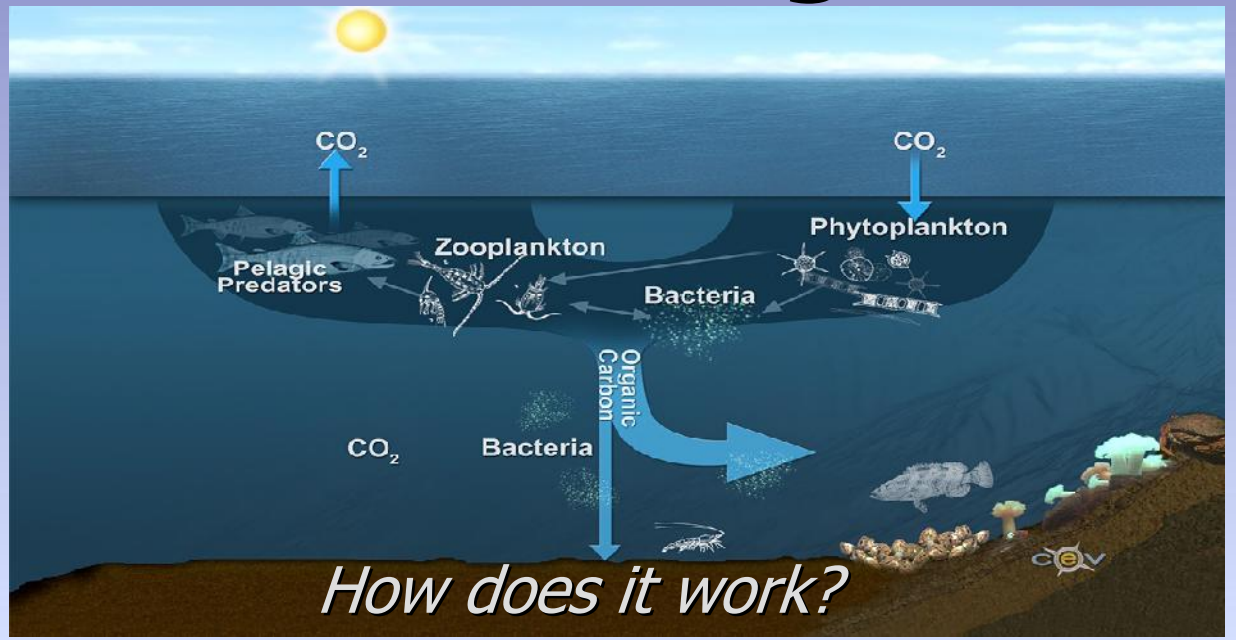




❖ Marine food chains are arranged into tropic levels with the phytoplankton at the bottom (first tropic level), which has the greatest numbers of individuals and greatest total biomass - more than all the other tropic levels put together.

❖ It takes roughly 10 grams of phytoplankton to make 1 gram of zooplankton, and 10 grams of zooplankton to make 1 gram of tiny fish…and so on up the food chain.

The Ocean's Biological Pump



1) *Starts with photosynthesizing phytoplankton: converting seawater, nutrients and sun energy into food and oxygen in the euphotic zone*
2) *Zooplankton consume the phytoplankton*
3) *Sinking dead plankton and fecal matter is decomposed by pelagic bacteria and turned into more simple organic carbon and nutrient matter.*
4) *Part of decomposed material gets recycled back up into the euphotic zone by upwelling for reuse by phytoplankton*
5) *The remaining organic material slowly sinks to sea bottom to become part of the pelagic sediment – a process called sequestration*

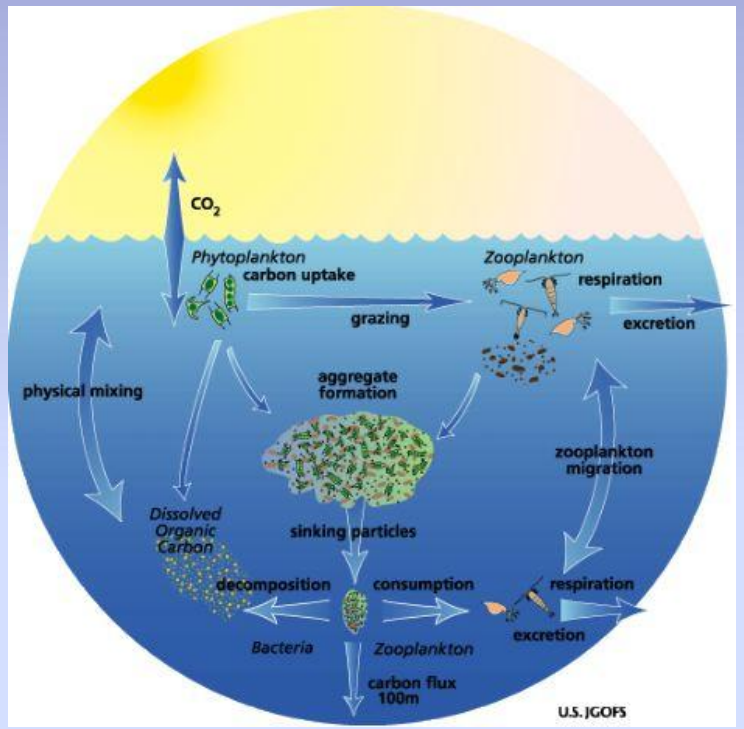
Importance of the Oceanic Biological Pump

1) The oceanic "biological pump" is the primary component in most marine food webs and is critical in driving the marine nutrient cycles such as nitrates and phosphates

2) Living and nonliving components make up the biological pump

3) Oceanic biological pump is crucial for the sustaining of global-scale production of food and oxygen

4) Oceanic biological pump is crucial for moving and storing vast amounts of organic carbon into the seabottom



Review Main *Concepts:* *the* *Marine Plankton*

- ***Marine plankton are*** **marine organisms that, drift, float or weakly swim.**
- **Plankton live in all parts of water column, but mostly in euphotic zone**
- **Plankton include over 90% the ocean's biomass** = most important
- **Availability of sunlight and nutrients control amount of plankton**
- **Plankton can be divided into three *trophic* categories:**

Phytopankton = ***producer*** **Zooplankton =** ***consumer*** **Baterioplankton =** ***recycler***

- **Phytoplankton include diatoms, dinoflagellates, coccolithophores, and silioflagellates; also picoplankton (cyanobacteria)**
- **Phytoplankton are eaten by the zooplankton**
- **Zooplankton include foraminifera, radiolarians, copepods, krill, jellies, and wide variety of larval-stage animals**
- **Plankton can be divided into two life-history categories:**

Holoopankton = ***entire life as plankton*** **Meroplankton** = ***larval stage as plankton***

- **Bacterioplankton decompose dead plankton and fecal matter into recycled nutrients; Three types planktons form Ocean Biological Pump**

Discussion