## Outline for week 10

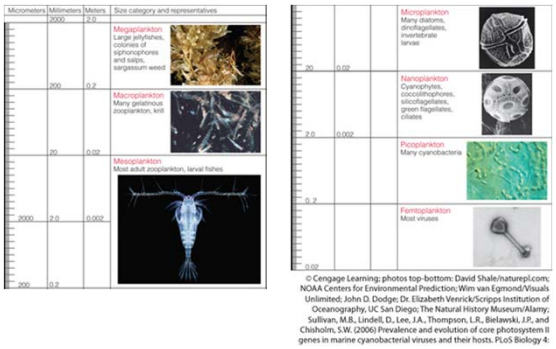
- Sea-level history – moved to week 13
- Constraints in the oceans
- Evolution
- Taxonomy
- Diversity and Mass Extinctions
- The flow of energy and primary production (PP)
- Primary producers
- Factors affecting primary production
- Patterns of primary production

## Classifying organisms

- **Plankton** drifts with ocean currents; unable to move against current flow
- In contrast to **nekton** – active swimming
- **Benthos** – associated with substrate (seabed)

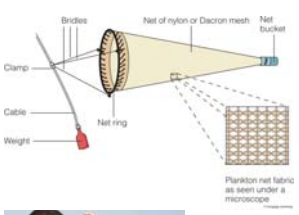
- **Zooplankton** – heterotrophs
- **Phytoplankton** includes photosynthetic plankton species

## Plankton classification by size

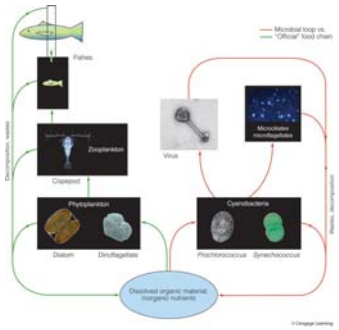





## Plankton Collection Methods Depend on the Organism's Size

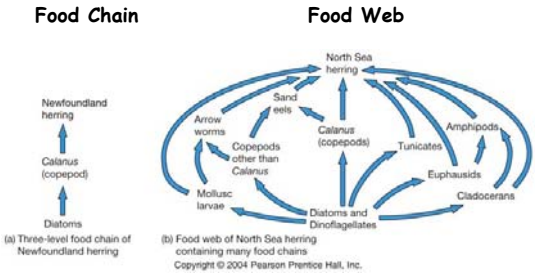



## The "Official" Food Chain





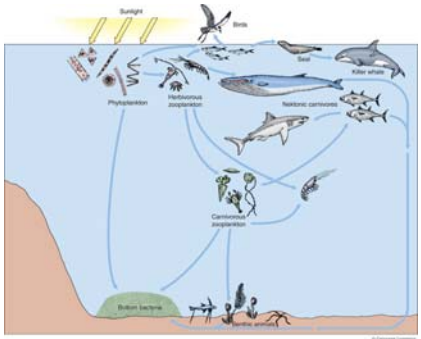

## Feeding Relationships





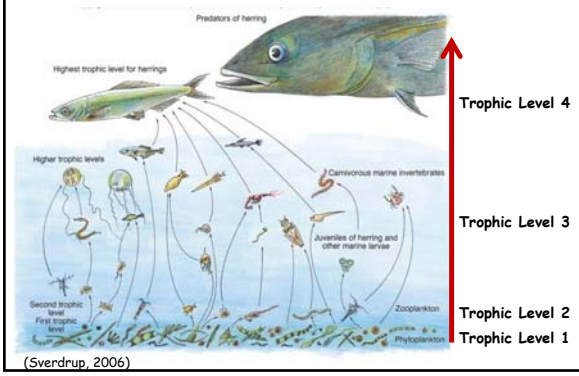

**The arrows show the direction of energy flow**

## A simplified food web



**Energy transfer. Elements cycle between living organisms and their surroundings.**

## Trophic Level



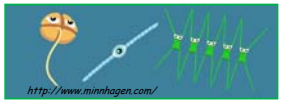

(Sverdrup, 2006)

## A Generalized Trophic Pyramid

Trophic pyramid – feeding hierarchy

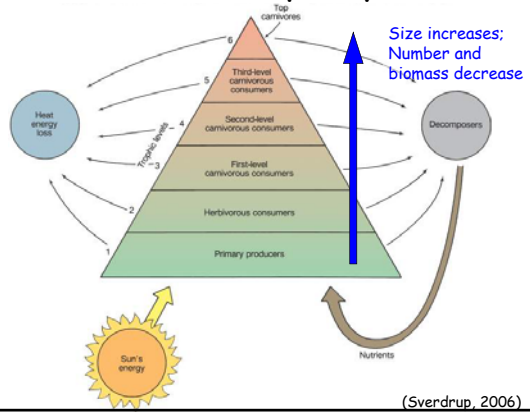
**Autotrophs** – make their own food

**Heterotrophs** – must consume food



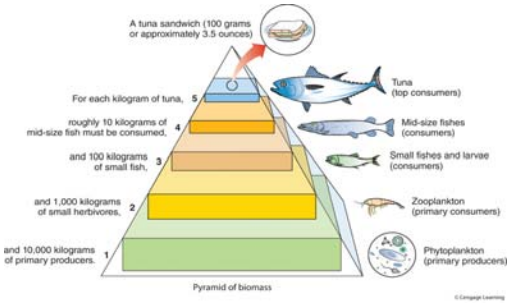

There is much more productivity at the primary producer level in an ecosystem than at the consumer levels, and there is more at the primary consumer levels than at the secondary consumer level.

## A Generalized Trophic Pyramid




(Sverdrup, 2006)

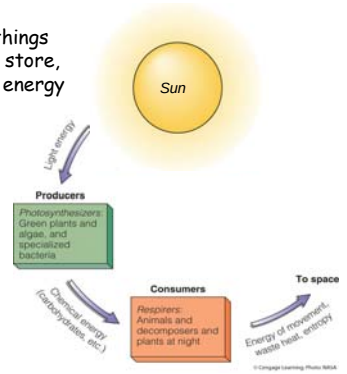
## A Generalized Trophic Pyramid




How much energy or biomass would the top level have given the following energy transfer efficiency? Bioaccumulation.

## The Flow of Energy through Living Systems

Living things capture, store, transmit energy



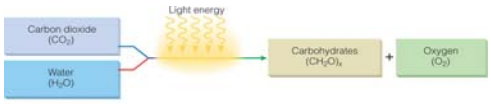
## Primary production

**Amount of carbon fixed by organisms (primary producers) into organic matter** using energy derived from:

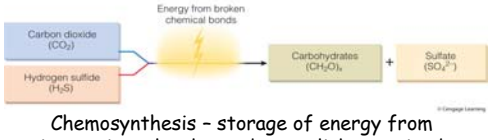
- **sunlight (photosynthesis)**
  - » **Photoautotrophs**
- **chemical reactions (chemosynthesis)**
  - » **Chemoautotrophs**

**Photosynthesis: responsible for most marine primary production (PP).**

## Photosynthesis and Chemosynthesis

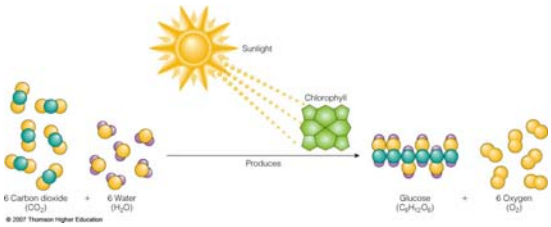



Photosynthesis – storage of solar energy




Chemosynthesis – storage of energy from inorganic molecules and no sunlight required

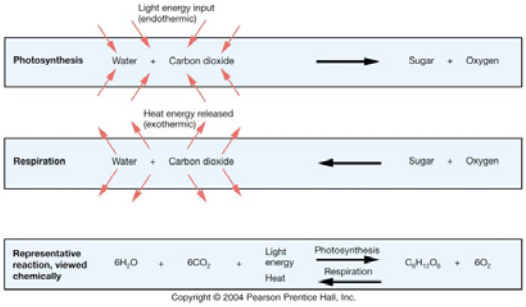
## Photosynthesis




$6CO_2 + 6H_20 +$ light energy $= C_6H_{12}O_6 + 6O_2$

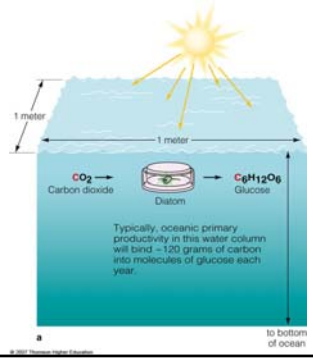
**Gross Primary Production (GPP): Total primary production per time**

## Photosynthesis and Respiration




**Net Primary Production (NPP): GPP – losses to respiration**

## Primary productivity measured in terms of carbon ($gC/m^2/yr$)




## Measuring Primary Productivity

Uptake of $CO_2$ (mainly using $^{14}C$)
Changes in $O_2$

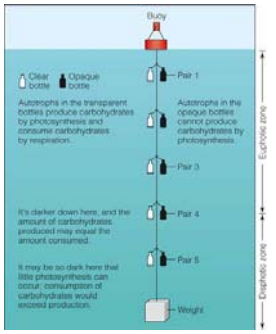
$$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_2O_6 + 6O_2$$

Add labeled $^{14}CO_2$

Measure how much labeled $^{14}C_6H_{12}O_6$ is produced

Incubating seawater samples (with phytoplankton) in light and dark bottles (and at different light intensities) for hours.

## Light-dark bottle technique for estimating marine primary productivity



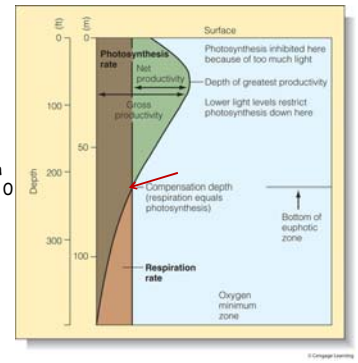

Incubating seawater samples (with phytoplankton) in light and dark bottles (and at different light intensities) for hours.

no light / light

Francoeur et al 2013

## Production Equals Consumption at the Compensation Depth

Compensation Depth: NPP = 0

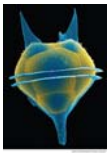



## Photosynthetic marine organisms

- Phytoplankton
- Picophytoplankton (ex. cyanobacteria)
- Benthic algae and flowering plants

Diatoms

Dinoflagellates



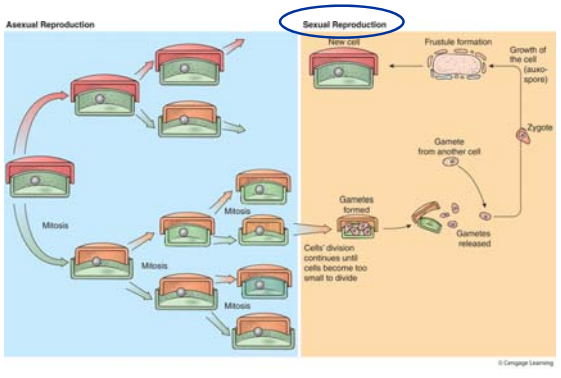
Coccolithophores

**Phytoplankton – responsible for producing 90-96% of the ocean's carbohydrates**

## Diatoms

- Frustule – rigid cell wall of silica ($SiO_2$)
- Some float, others lie on shallow bottoms
- Responsible for 40% of marine primary production
- Primarily in temperate and polar oceans
- Create siliceous ooze

## Diatom reproduction



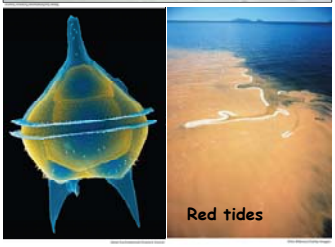

## Diatoms

Very abundant group.
Some diatoms form colonies

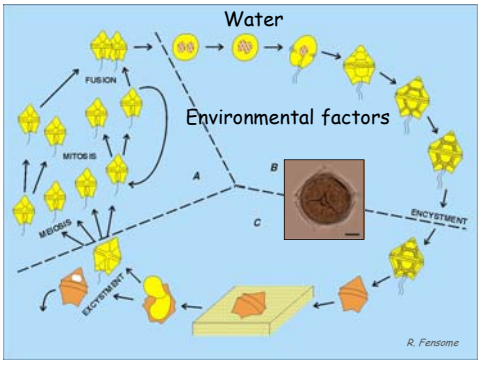
Cadboro Bay, August 2009.

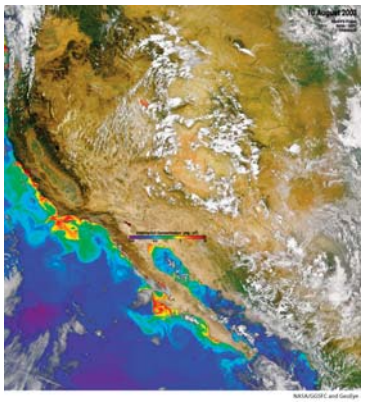
## Dinoflagellates

- Flagella – for movement
- Adapted at living under low light and low nutrient conditions
- Autotrophic / heterotrophic / mixotrophic
- Blooms (Concentrations >3,000 cells/ml constitute a **bloom**.

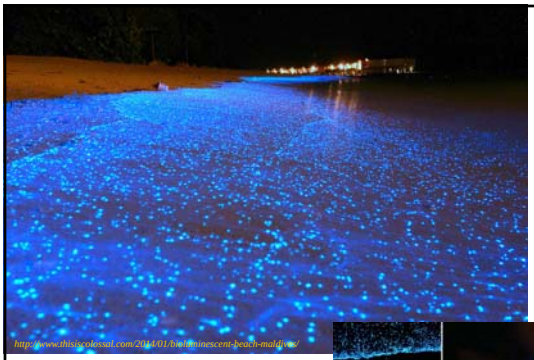


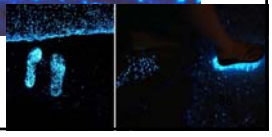

**Dinoflagellate cysts are hypnozygots produced by dinoflagellates, which can be preserved in sediments**



## What is bioluminescence?

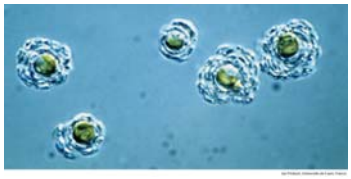



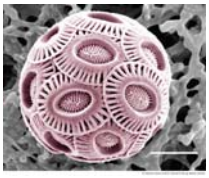



Bioluminescence

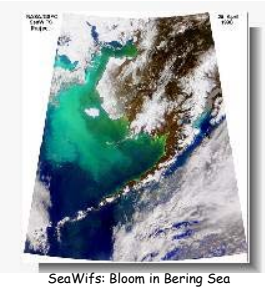
## Coccolithophores

- Shells of calcium carbonate ($CaCO_3$ )
- Milky or chalky water
- Produce ~40% of the ocean's CaCO3
- Calcareous ooze

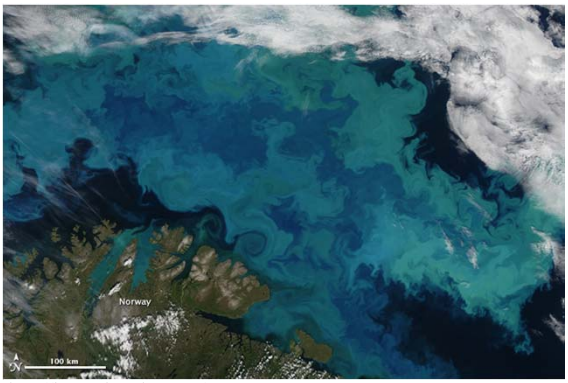




## Blooms are usually in warmer waters



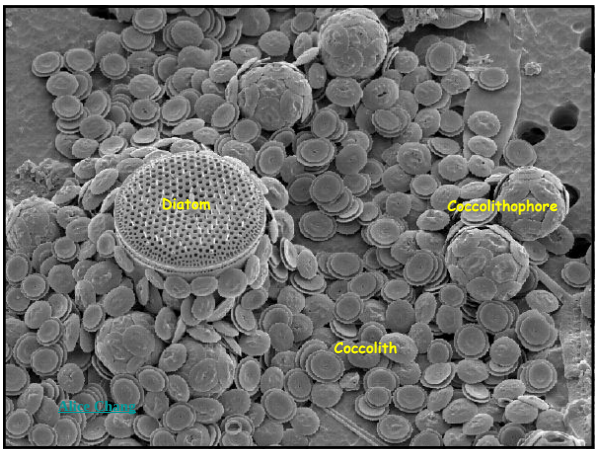
SeaWifs: Bloom in Bering Sea



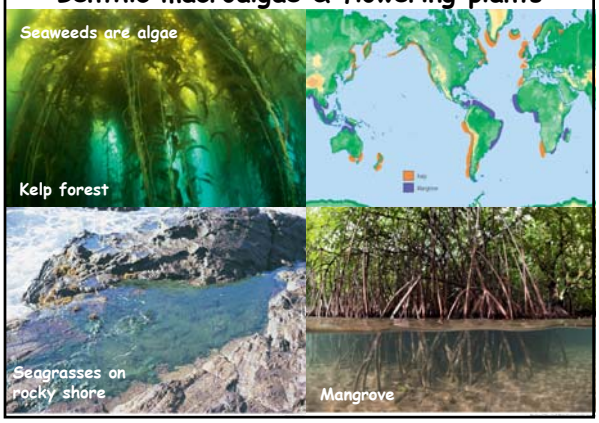

https://lance-modis.eosdis.nasa.gov/

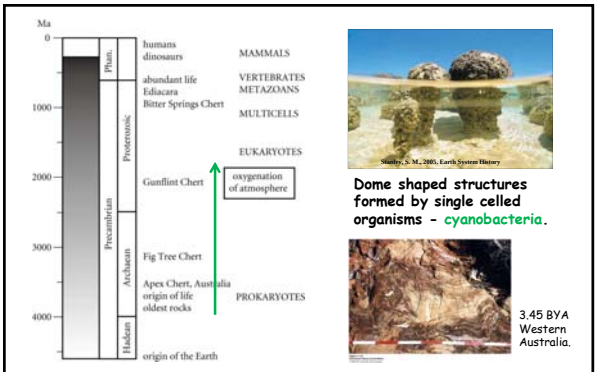


Fell to bottom (remember about CCD!) and produced great chalk deposits - calcareous oozes. K = Cretaceous!




## Benthic macroalgae & flowering plants





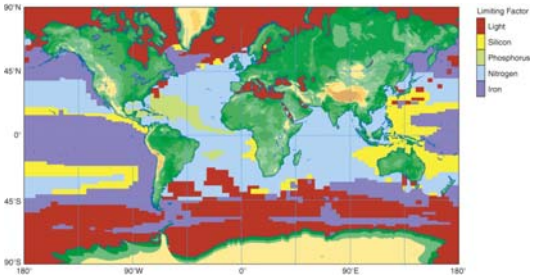

Dome shaped structures formed by single celled organisms - cyanobacteria.



3.45 BYA Western Australia.

Time scale showing major events in the history of the Earth and of life. Most of the time scale is occupied by the Precambrian, whereas the well-known fossil record of the Phanerozoic accounts for only one-seventh of the history of life.

## What limits primary production?




Light, nutrients, (and to a lesser degree temperature)

## Availability of nutrients

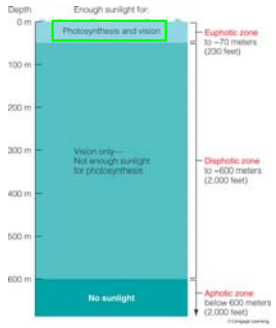
Elements required for algal/plant growth: dissolved in seawater: N, C, P, Si for diatoms.

TABLE 14-1 Major nutrients used by organisms in metabolic processes.

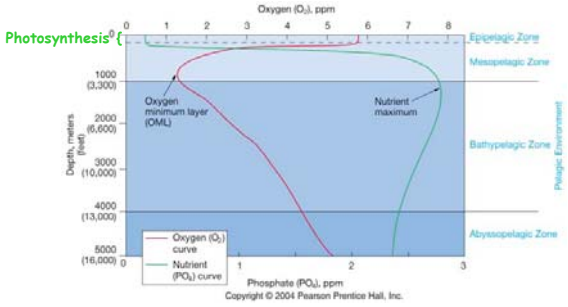
| Nutrient (symbol) | Metabolic use(s) |
|---|---|
| Nitrogen [a] (N) | Production of proteins and nucleic acids |
| Phosphorous (P) | Production of nucleic acids and teeth/bones/shells |
| Sodium (Na) | Body fluids; osmotic regulation |
| Magnesium (Mg) | Osmotic balance; chlorophyll production |
| Sulfur (S) | Production of proteins; cell division |
| Chlorine (Cl) | Nerve discharge; osmotic regulation; ATP formation |
| Potassium (K) | Nerve discharge; osmotic regulation; enzyme activation |
| Calcium (Ca) | Production of shells/bones/coral/teeth |
| Iodine (I) | Production of thyroid hormone |
| Silicon (Si) | Construction of hard supporting structures such as tests |
| Iron (Fe) | Electron transport; nitrogen assimilation |
| Copper (Cu) | Electron transport |
| Zinc (Zn) | Nucleic acid replication and transcription |

[a] Before nitrogen can be assimilated, it must be "fixed" by being converted into nitrate compounds such as ammonia ($NH_4OH$).

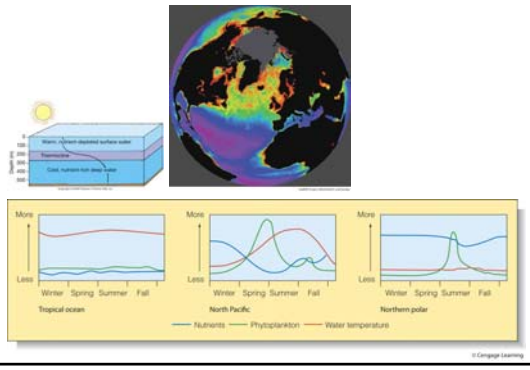
## Availability of solar radiation (light)



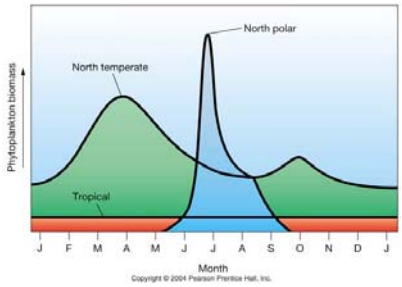

## Vertical profile of oxygen and nutrients




## Phytoplankton Productivity Varies with Local Conditions

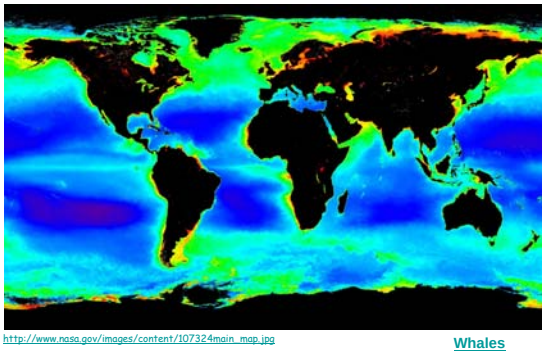



## Phytoplankton Productivity Varies with Local Conditions




Comparison of Productivity in Tropical, Temperate and Polar Oceans (Northern Hemisphere)

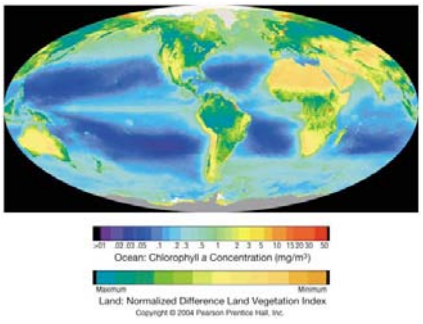
Map showing the spatial distribution of marine annual chlorophyll a concentrations



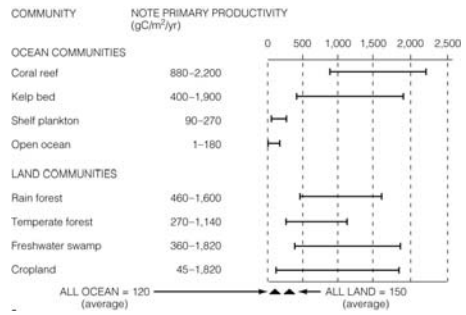
http://www.nasa.gov/images/content/107324main_map.jpg

Whales

**Primary productivity in some marine and terrestrial communities between September 1997 and August 1998**



## Net Annual Primary Productivity in some marine and terrestrial communities




**A much smaller biomass in the ocean produces roughly similar NPP as on land. Marine algae and plants are thus far more efficient !**

## Summary

- All life activity is involved, directly or indirectly, in energy transformation and transfer
- Primary productivity involves the synthesis of organic materials from inorganic substances by photosynthesis or chemosynthesis
- Most primary producers are phytoplankton—organisms that drift (or swim weakly). Phytoplankton are common near the ocean's surface
- Phytoplankton are responsible for most of the ocean's primary productivity (diatoms, dinoflagellates, coccolithophores)
- Not all producers are drifters
  - Attached seaweeds, sea grasses, and mangroves are also important contributors
- Availability of nutrients and light can limit productivity
- Chemosynthetic microbes can live near hydrothermal vents, in seabed sediments, and even in solid rock