

PLANKTON

- Term actually defined by Professor Victor Hensen (Kiel Univ., 1887), comes from the Greek "planktos" to wander or drift
- Ernst Haeckel (1890) critically defined the term 'plankton' to encompass all drifting organisms including:
 - i) plants phytoplankton
 - ii) animals zooplankton
 - iii) bacteria bacterioplankton
 - iv) temporary meroplankton (only part of organism's life cycle)

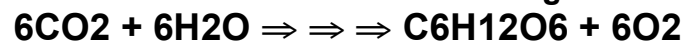
PHYTOPLANKTON

Photosynthetic marine organisms, as the primary producers of the marine ecosystem, are the first link in the marine food web. They convert solar energy to an energy form usable by themselves and, in turn, by other marine consumers. Their importance to the biological economy of the sea cannot be overstressed. The most significant contribution to the primary productivity of the world oceans does not come from the obvious macroscopic attached plants that occupy the fringes of the continental masses. Rather, it is the microscopic, free-floating forms, collectively called **phytoplankton**, that are the dominant primary producers.

- Unicellular (single-cell) plants, microscopic, benthic and pelagic, marine/fresh. Can form colonies (filaments, chains). Members include **3** kingdoms:
 - i) Monera
 - ii) Protista
 - iii) Plantae
- Present in all lighted areas of the sea (including under ice)
- Dominant plants in the sea - hence role in marine food chain very important called the "grasses of the sea"
- If large enough to be caught in a fine-mesh net - net or macroplankton (> 200 µm) If too small to be caught in a net - microplankton (< 200 µm) traditionally called microplankton. Smallest plankton by this classification would be picoplankton.
- All phytoplankton are **autotrophs** (i.e., self-feeding), manufacturing their own food, in their case by the process of **photosynthesis**- hence are **photoautotrophs** and thus also considered **primary producers**.

PHOTOSYNTHESIS

Biological process of creating high-energy organic material from carbon dioxide, water and other essential nutrients utilizing the sun's energy



- Other forms of autotrophy include the use of inorganic materials such as iron, methane, or sulfur—these organisms would be called **chemo-autotrophs** because they don't use sunlight.
- Many phytoplankton are really **osmotrophs** because they require vitamins synthesized by other organisms (bacteria), and absorb these compounds across the cell membrane. Osmotrophy refers to uptake by absorption of organic compounds, such as urea, vitamins, etc.
- Some phytoplankton are also **heterotrophs** because they can consume organic particles. If they are capable of switching back and forth between heterotrophy and phototrophy, they are called **mixotrophs**. If they cannot photosynthesize, they would be considered **obligate heterotrophs**. Another term for a mixotroph is a **facultative heterotroph**, meaning it can switch back and forth.
- Although we will focus on phytoplankton in this class, other organisms also photosynthesize. The purple sulfur bacteria and green bacteria only have part of the photosystem (they have PS I but not PS II—we'll come to that later in the quarter), so while they use sunlight, they do not produce oxygen. Similarly, a newly discovered type of "photosynthesis" uses a rhodopsin molecule (similar to the cones in your eye), and is found in some oceanic bacteria.

Major Groups of Phytoplankton

DIATOMS

- belong to the Phylum (division) **Bacillariophyta**, class **Bacillariophyceae**
- most important and often most dominant (numerous) phytoplankters in temperate and high latitudes of the ocean (particularly upwelling areas)—these were the first studied, and are responsible for the Spring Bloom in the North Atlantic
- occur singularly, or in chains, or in loose formations
- most cells range in size from ~ 50 to 500 μm (millionth of a meter), range from 2 μm to 2000 μm (=2 mm)
- chains and other aggregates held together by mucilagenous threads or SPINES
- All species have a distinctive, rigid, external skeleton (cell wall) called a frustule or test

FRUSTULE (TEST)

- composed of (> 95%) of **SILICA** (4-50 % dry weight of cell)
- gives structural strength, but allows cytoplasm outside contact with the aquatic environment
- frustule is sculptured into patterns of spines, pores, channels, ribs
- frustules fundamentally composed of two valves: smaller fitting into larger like a Petri dish

Outer - **Epitheca**

Inner – **Hypotheca**

Note **Silicon** is the element, Si. **Silica** is short for silicon dioxide (SiO_2), in all crystalline, amorphous, & hydrated or hydroxylated forms, **Silicate** is ionized from of monosilicic acid (Si(OH)_4), aqueous (dissolved) silicate at the pH of seawater forms **silicic acid**

- diatoms have been abundant since at least the Cretaceous Period (135 million yrs)
 - first fossils from Jurassic period (191-205 million years ago)
 - (diatomaceous ooze or sediments)

Two major types of diatoms based on cell shape (many varieties)

CENTRIC diatoms:

- round, pill-box shaped
- two equal halves
- **> 1500 spp**
- radially or concentrically symmetrical (from end view), all non-motile

PENNATE diatoms:

- elongated shapes
- primarily benthic, but some are pelagic (e.g., *Nitzschia*)

DINOFLAGELLATES

- Belong to Phylum **Pyrrophyta** (Dinophyta),
 - class **Dinophyceae**
 - This is a large group - 1,500 to 1,800 free-living species
 - class **Desmophyceae**
 - smaller group, two flagella at anterior end
- Second most abundant phytoplankton group, cell size 10 to 1,000 μm
- Most exist singularly, some species (spp) form chains
- Possess two **flagella** (whiplike appendages, flagellum singular) - so **MOTILE (capable of movement)**
- Different species utilize different energy sources:
 - i) **Autotrophic** - building organic materials & obtaining energy from photosynthesis
 - ii) **Heterotrophic** - meet energy needs by feeding on phytos & small zooplankton (hence often also referred to as zooplankton) ~ 50 % of dinoflagellates are strict heterotrophs (no chloroplasts)
 - iii) **Mixotrophic** capable of both autotrophic and heterotrophic production (others are parasitic or symbiotic)
- Dinoflagellates are divided into two general categories, on the basis of possession of a relatively thick cellulose wall called a **THECA**.
- **THECATE** forms (majority), and **NAKED** forms (no theca) are a minority
- Cell divided into anterior and posterior half by transverse groove – **GIRDLE flagella arranged such that one extends posteriorly from the cell and the other wraps transversely around cell in girdle region**
- In thecate spp, the cell wall is divided into a number of separate cellulose plates ornamented with pores and/or small spines
- common thecate genera include Ceratium and Lingulodinium
- A genus of dinoflagellates called **Symbiodinium** are the organisms that form a symbiotic relationship with coral—they are also referred to as **zooxanthellae**
 - The coral keeps the dinoflagellate in an unbalanced state of growth, which favors consumption of urea and carbon dioxide (waste products from the coral) and production of sugars, which are used by the coral

CYANOBACTERIA

(also known as blue-green bacteria, or as blue-green algae)

- belong to the phylum (division) **Cyanophyta** - class **Cyanophyceae**
 - the 'typical' cyanobacterium, approx. 150 genera, 2000 species
 - recently **Prochlorophytes** have been added to the Cyanophyta (based on molecular evidence, previously they were their own division) - 3 genera
- Prokaryotic cells - lacking complex organelles
- no chloroplasts, nuclear envelope, mitochondria, Golgi bodies, endoplasmic reticula, etc. They do have thylacoids, ribosomes (protein production sites) are the smaller (70s) typical of bacteria
- first algae to evolve (filamentous fossils found from 3.5 billion yr.)

Pigmentation

- Typical - chlorophyll a, phycobiliproteins (phycocyanin gives distinctive blue-green color)
- Prochlorophytes - divinyl chlorophyll a, chl b, (c), no phycobilins.

Note: a phycobiliprotein is several phycobilins tightly bound to a protein)

- Storage product: cyanophycean starch
- Cells walls: peptidoglycan wall of amino sugars and amino acids, similar to that of gram-negative bacteria, often surrounded by mucilage polysaccharide sheath
- Reproduction is asexual, no sexual reproduction, in contrast to other algae
- Wide-spread distribution - freshwater, marine, terrestrial and symbiotic relationships
- No flagellated cells, two main groupings based on filamentous nature, which is further divided by the presence or absence of akinetes & heterocysts:
 - Akinetes:** - larger, thick-celled vegetative cells, dormant (for many years) (resting spores) - develop during, and are very resistant to, unfavorable conditions
 - have only 10% of normal photosynthetic and respiratory capability
 - Heterocysts:** larger, specialized cells for N -fixation (appear empty, limited life)
 - establishes an oxygen-free micro-environment, necessary for the functioning of the nitrogenase enzyme used to fix N₂
- Many (but not all) cyanobacteria are **Nitrogen Fixers** (in nitrogen fixation, gaseous N₂ from the atmosphere which is dissolved in water is converted into ammonium, which is then incorporated into amino acids). The most common cyanobacteria in the marine environment, *Synnechococcus* and *Prochlorococcus*, do NOT fix N₂

PICOPLANKTON (includes cyanobacteria)

- Diverse group, includes both **prokaryotes** and **eukaryotes**
 - Prokaryotes (also known as cyanobacteria):
 - Synechococcus spp. (blue-green algae)
 - includes colonial form **Trichodesmium**, which is extremely important to the world's oceans because it can fix nitrogen and photosynthesize simultaneously
 - Prochlorococcus spp. (red-fluorescing picoplankton)
 - some of the smallest algae known
 - not discovered until the 1980's
 - Eukaryotes
 - 'Picoeukaryotes'
 - not well defined...most of these haven't been identified yet
 - generally identified by their molecular signature, rather than by traditional methods, such as shape, color, size, etc.
- Picoplankton can account for most of the biomass in nutrient depleted areas such as the open-ocean gyres. They are very common worldwide, but we are still learning about them. The 'discovery' and measurement of picoplankton was made possible through the use of two techniques:
- Epifluorescence microscopy
 - Flow-cell cytometry