2. Plankton Diversity

Phytoplankton

- Phytoplankton are plankton that photosynthesize. They are essentially free-floating, water-dwelling plant life.
- Like most plant life, phytoplankton absorb atmospheric carbon dioxide and produce oxygen.
- Phytoplankton are thought to produce about 98 percent of the oxygen in the atmosphere.
- Because phytoplankton need light, they only live in the well-lit surface layers of the ocean. This is known as the euphotic layer.
- They also produce dimethyl sulfide (DMS) which is converted to sulfate in the atmosphere, where it reflects solar radiation and acts as condensation nuclei for cloud formation.

Phytoplankton nutrients

- As well as sunlight, phytoplankton also need carbon dioxide and nutrients, such as iron, to grow.
- Large quantities of carbon dioxide from the atmosphere diffuse into the oceans at the ocean surface.
- Carbon is locked into the bodies of phytoplankton, which sink to the bottom of the ocean when they die.
- Up to 90 percent of the world’s carbon is thought to be locked in ocean-floor sediments formed mostly from the bodies of phytoplankton.
- Other nutrients are brought to the surface by upwellings. Where upwellings fail, phytoplankton levels crash and the rest of the food chain starves.

Phytoplankton are classified into taxonomic groups based on the combinations of their photosynthetic pigments, as well as other characteristics such as the way in which they store energy (lipid or carbohydrate) and the structure of their cell walls. Other distinguishing features include:

- The presence or absence of flagella
- The structure of the flagella
- The pattern and course of mitosis and cytokinesis (cell division)
- Other morphological attributes such as symmetry and size.

Many of these groups are represented in the microplankton (20–200 µm), the nanoplankton (2–20 µm) and the picoplankton (0.2–2 µm) – with some occurring in all three size classes. In temperate coastal waters, the nanoplankton can account for 80% of the total phytoplankton biomass, while in tropical waters the picoplankton can account for 80% of the total phytoplankton biomass. Picoplankton are represented by the cyanobacteria and chrysophytes.

In the following sections we will discuss the major groups of phytoplankton and give a brief description of each group:
Diatoms
Class Bacillariophyceae.
Phylum Chrysophyta.

- Diatoms are one of the most important groups of producer organisms in the marine ecosystem.
- Dominate the phytoplankton in waters from the temperate to the polar zones
- They form the base of the food chain in most ocean waters.
- Some species are solitary, others like *Chaetoceros* form long chains.

**Figure**  Diatoms, (a) a typical chain of *Chaetoceros laciniosus*, (b) *C. laciniosus* chain with resting spores; (c) *Nitzschia pungens* chain of dividing cells; (d) *Thalassiosira gravida* chain; (e) *Coscinodiscus* showing the two valves of the frustule; (f) *Coscinodiscus wailesii*, lateral view; (g) *Chaetoceros socialis* chains in a gelatinous colony formation; (h) a chain of *Asterionella japonica*, and (i) *Skeletonema costatum*. (scales in mm)
• They range in size from 2 µm to 1000 µm.
• Their name is derived from the Greek words *dia* and *temnein*, literally *cut in half*. This refers to the fact that diatoms are encased in a *silica* shell of two halves (valves) that fit together much like that of a laboratory petri dish and split across the middle and separate from each other during reproduction.
• The shell may be covered with spines, or it may be ornamented with a complex series of pores and ridges. The pores are the only connection between the cell and the external environment.
• Diatom taxonomy is based on pores in frustule.
• Two types of diatoms are recognized: the *pennate* and *centric* forms. Pennate diatoms have elongate shapes and are mostly benthic, but the few planktonic genera such as *Nitzschia* (Figure c) may be abundant in some regions. Centric diatoms have valves that are arranged radially or concentrically around a point, and they are much more common in the plankton, with somewhat over 1000 species. *Chaetoceros, Skeletonema,* and *Thalassiosira* are all common centric genera, some of which are illustrated in the previous Figure .
• Planktonic diatoms do not have any locomotor structures and are usually incapable of independent movement. Because it is essential for diatoms and other phytoplankton to remain in lighted surface waters in order to carry out photosynthesis, these algae exhibit a variety of mechanisms which retard sinking. These include their small size and general morphology. Colony or chain formation also increases surface area and slows sinking. Most species carry out ionic regulation, in which the internal concentration of ions is reduced relative to their concentration in seawater. Diatoms also produce and store oil, and this metabolic by-product further reduces cell density. In experimental conditions, living cells tend to sink at rates ranging from 0 to 30 m day⁻¹ but dead cells may sink more than twice as fast. In nature, turbulence of surface waters is also important in maintaining phytoplankton near the surface where they receive abundant sunlight.
• The usual method of reproduction in diatoms is by a *simple asexual division* in which the cell forms two nuclei, the two halves of the frustule separate, and each resulting daughter cell grows a new inner valve of the frustule (Figure ). This can result in the two new cells being of slightly unequal size, the one receiving the inner half of the original frustule being slightly smaller than the cell formed from the outer valve. Asexual division can lead to very rapid population growth under optimal conditions. However, with repeated divisions, there may be a diminution in size of some of the progeny. When a diatom reaches a certain critical minimal size, it undergoes sexual reproduction by forming a cell that lacks a siliceous skeleton and contains only half of the genetic material. Such cells fuse to form a zygote, and this swells to produce an *auxospore*. Subsequently, a larger cell is formed that ultimately produces a frustule of the normal shape and size. Sexual reproduction in diatoms does not necessarily require a reduction in size of the cell, however. Some diatoms, particularly neritic species living in relatively shallow water, produce *resting spores* under adverse environmental...
conditions. These form when the protoplasm of a normal cell becomes concentrated and surrounded by a hard shell. This heavy spore sinks to the bottom and remains dormant until favorable conditions are restored, in which case it is capable of becoming a normal planktonic cell.

- Because of their asexual mode of reproduction, diatoms can increase in population size rapidly, with doubling rates on the order of 0.5-6 per day.
- Over geological time, sedimented frustules have formed seafloor deposits called diatomaceous ooze.
- Diatoms produce large quantities of mucus when nutrient stressed, causing them to coagulate and sink into the deep ocean.
- Diatoms are one of the major producers of omega-3 fatty acids, which are now widely reputed as being beneficial for human health.

**Dinoflagellates**

- The second most abundant phytoplankton group following the diatoms
- Mostly unicellular forms, but some form chains.
- They have two flagella and range in size range from 2-200 µm.
- Dinoflagellates are so-called because of the way that they ‘whirl’ or corkscrew through the water (Gk. Dinos; whirling).
- Can be autotrophic (phototrophic), but 50% of dinoflagellates are strict heterotrophs (they lack chloroplasts and are incapable of carrying out photosynthesis; these species form part of the zooplankton); some chlorophyll-carrying species complement nutrition by phagotrophy (mixotrophic); others are parasitic or symbiotic.
• There are an estimated 1500 to 1800 species of free-living, planktonic dinoflagellates.

• The organism is generally covered with a series of contiguous cellulose plates or theca, whose pattern is usually diagnostic of the species. Naked dinoflagellates (without theca) are also known.

• Taxonomically, the dinoflagellates are separated into the Desmophyceae and the Dinophyceae. The former is a small group in which the species are characterized by having both flagella arising from the anterior end of the cell (Figure a, b). The cell wall is composed of two longitudinal valves that separate during asexual division to form two new cells of equal size (Figure c).

![Figure Desmophyceae Dinoflagellates. (a) Two views of Prorocentrum marinum, (b) Prorocentrum micans, (c) P. micans dividing. (scale bars represent 0.02 mm)](image)

• The majority of planktonic dinoflagellate species form the Dinophyceae (Figure ), and the majority of these are thecate. In all of them, the cell is divided into an anterior (epithea) and posterior half (hypotheca) by a transverse groove known as a girdle or cingulum. The flagella are so arranged that one extends posteriorly from the cell, and the other wraps transversely around the cell in the girdle region. In those species with a theca, the cell wall is divided into a number of separate cellulose plates that are ornamented with pores and/or small spines. Common thecate genera include Ceratium, Protoperidinium, Gonyaulax, and Dinophysys. Gymnodinium is a common naked form belonging to the Dinophyceae.

• Reproduction in dinoflagellates is normally by simple asexual division and they have the capacity to reproduce up to several times per day, with the cell dividing obliquely to form two cells of equal size. The theca may divide, with each new cell forming a new half, or the theca may be lost before division, in which case each new cell forms an entirely new cell wall.

• Asexual division can lead to rapid population development when conditions favour these algae.

• Dinoflagellates often become abundant in summer or autumn, following blooms of diatoms, as they are better adapted at living under lower light
conditions and in nutrient-impoverished water. This is partly because dinoflagellates are capable of moving vertically in the water column; during the day they can carry out photosynthesis in sunlit surface waters and at night they may move deeper to take advantage of higher nutrient concentrations. For the same reason, dinoflagellates are usually the most numerous of the phytoplankton in stratified, nutrient-poor tropical and subtropical waters.

- Sexual reproduction also occurs in at least some species of dinoflagellates. This may lead to the formation of thick-walled, dormant cysts that settle on the seafloor, where they can survive for years. When triggered by environmental change, the cysts germinate to produce swimming cells.

- Several species of dinoflagellates are bioluminescent, and the gentle flickering of shallow waters is often due to luminescence by Noctiluca. Bioluminescence is frequently observed by SCUBA- (Self Contained Breathing Apparatus) divers at night when they turn off their torches and disturb the water with hands.

- Some dinoflagellates, such as the genera Alexandrium, Pyrodinium and Gymnodinium are known to be the organisms involved in red tides. Owing to their production of the deadly neurotoxins such as saxitoxin and brevetoxin, these can cause serious harm if they enter the human food chain. For this reason, monitoring programmes exist to ensure that the fish and shellfish that we consume are safe.

- The origin of red tides, like many other sudden blooms of phytoplankton, is an incompletely explained phenomenon. Red tides are often associated with sudden influxes of nutrients or washout of nutrients from land sources into the sea. Storms may remobilize populations of cysts buried in the bottom sediment, setting the stage for red tides.

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**Fig.** Dinoflagellates. (e) Gymnodinium abbreviatum, (f) Dinophysys acuta, and (g) Gonyaulax fragilis. (All scale bars represent 0.02 mm)
Coccolithophores
Phylum Chrysophyta (golden-brown algae)

- Coccolithophores are unicellular and usually nannoplanktonic (mostly <20 µm).
- They are nearly spherical and are covered with a series of calcium carbonate (calcite) plates, or coccoliths. Also in this group are a large number of naked forms.
- The shape and arrangement of the coccoliths can be used to identify species. The coccoliths accumulate in bottom sediments which often blanket the deep seabed.
- The exact function of the coccoliths is unknown. The coccoliths have been suggested to serve as a grazing deterrent, to help maintain buoyancy and to act as an ultra-violet radiation filter.
- Coccolithophorids possess two flagella, although they may have a life cycle which includes an alternation with a non-motile stage lacking flagella.
- Coccolithophorids can be found in neritic as well as in oceanic waters, and at times are near the surface, the majority of species occur in warmer seas and thrive in reduced light intensities; some species reach maximum abundance at depths of about 100 m in clear, tropical, oceanic water.
- Reproduce by longitudinal cell division, with the shell being divided and afterwards reformed into a whole by each new cell. However, life histories in this group are complex and may involve several different types of stages.
- Certain species produce enormous blooms that are clearly visible from space, causing the water to have a milky-white appearance that fishermen refer to as ‘white water’.
- Emiliania huxleyi is probably the most widespread coccolithophorid in the sea, and it is present in all oceans except the polar seas. Emiliania sometimes forms enormous blooms, one having been measured to cover approximately 1000 km by 500 km of sea surface in the North Atlantic Ocean — or an area roughly the size of Great Britain.
- Emiliania huxleyi produces DMSP (dimethylsulfoniumpropionate); converted to DMS (dimethylsulfide) upon release to air which increases cloud formation; increased clouds and coccoliths increase water albedo, cooling effect
- During dense blooms, foam accumulates on the beaches because wave action destroys the cells and wipes the cells’ proteins to foam
- Toxicity is not reported from such blooms, but fish evades blooms, probably by detection of the DMS in the water
- Fisheries are affected by net clogging
- Oceanic blooms of coccolithophorids DO NOT help decreasing the atmospheric increase in CO2 because algae release acids, which convert HCO3⁻ to CO₂ for carbon uptake; especially important in calcification

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Ca^{2+} + 2 \text{HCO}_3^\text{-} \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2
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Silicoflagellates

**Phylum** Chrysophyta

- Silicoflagellates are **unicellular** and **uniflagellate**.
- They have internal skeleton formed of siliceous spicules.
- Small (10-250 µm) and contain very numerous yellow-brown chloroplasts.
- Silicoflagellate skeletons usually comprise 1-2% of the siliceous component of marine sediments; they are thus much less abundant than diatoms.
- Only a few species of silicoflagellates are known.
- They are widely distributed throughout the world ocean and most abundant in colder waters.

Phaeocystis

**Phylum** Haptophyta

- Phaeocystis is a particularly interesting genus of flagellate.
- Of particular importance is the existence of a complex polymorphic life cycle exhibiting phase alternation between different types of free-living cell (vegetative non motile, vegetative flagellate and microzoospoe) of 3-9 µm in diameter and gelatinous colonies usually reaching several mm up to 3 cm. These colonies, constituted by thousands of cell embedded in a polysaccharidic matrix.
- Gelatinous colonies are known for fouling fishermen’s nets.
- Large blooms of these organisms can be problematic for fish as the gelatinous colonies can clog their gills.
- Phaeocystis blooms can trigger dramatic changes in the structure of marine ecosystems owing to its seemingly unpleasant nature.
- It produces a strong smelling compound called dimethylsulfupropionate (DMSP) which is thought to serve as a grazing deterrent.
- It is also suggested to play a role in climate regulation by stimulating the formation of clouds.
- There is growing concern that the frequency and magnitude of Phaeocystis blooms in coastal waters are increasing as a result of eutrophication.
• **Cyanobacteria**
  **Class** Cyanophyceae
  - Often called blue-green algae, although they are prokaryotic bacteria, not true algae.
  - Occur in and may dominate nearshore waters of restricted circulation, as well as brackish water.
  - Tiny (roughly 1 µm) unicellular forms have been found ubiquitously throughout the ocean and may be the food of smaller zooplankton.
  - Cyanobacteria play a unique role in the nutrient-depleted waters of the open oceans. They are capable of converting inert atmospheric nitrogen (N₂) into organic forms such as nitrate (NO₃⁻) and ammonia (NH₃). This process is known as nitrogen fixation. It provides a valuable source of nitrogen in areas of the oceans where it is otherwise absent.

Recently scientists have discovered even smaller (0.6-0.8 µm diameter) photosynthetic organisms called **prochlorophytes**, which are closely related to the cyanobacteria and occur in both coastal and oceanic waters e.g. *Prochlorococcus*.

• **Green Algae**
  **Class** Chlorophyceae
  **Phylum** Chlorophyta
  - The true green algae are rare in marine waters but can dominate the phytoplankton of enclosed estuaries or enclosed lagoons, especially in late summer and fall.
  - They can be flagellated or nonmotile.
  - Several species cause nuisance phytoplankton blooms associated with coastal pollution.

• **Cryptomonad Flagellates**
  **Class** Cryptophyceae
  **Phylum** Cryptophyta
  - Cryptomonad are a small group of flagellates. They are common in freshwater, and also occur in marine and brackish habitats.
  - They are a group of tiny flagellates, only around 10-20 µm in size and flattened in shape, with an anterior groove or pocket.
  - There are typically two slightly unequal flagella inserting nearly parallel next to the pocket.