**Lecture (6)&(7)**

## III- Nutrients

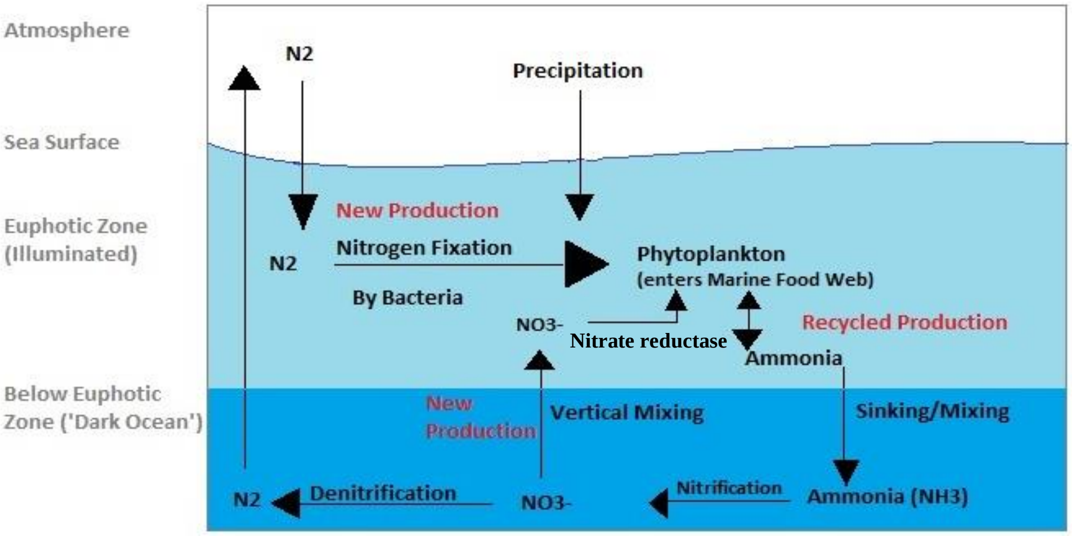
-Phytoplankton require essentially nutrients particularly N and P.

-Nitrate, phosphate, sulphate and chloride are considered as the principal anions, and potassium, calcium, magnesium and sodium as the main cations.

-A correct balance of six elements (N, P, Na, K, Ca and Mg) ensures the best growth of plants. -Small quantities of each element were found in natural waters, causing seasonal changes in phytoplankton. Evidently, the use of artificial fertilizers with crop plants prove the great significance of N and P in influencing phytoplankton growth.

-Although deprivation of other elements present in trace quantities can also be limiting to plant production.

### Nitrogen




-The principal requirement of algae for nitrogen is in the synthesis of amino acids and proteins, wherein it constitutes about one-eighth to one–sixth by weight.

-The potentially available sources of nitrogen for phytoplankton in both sea and freshwater include nitrate, nitrite, ammonium ions as well as certain dissolved organic nitrogenous compounds, such as urea and free amino-acids and peptides in both sea and freshwater.

-Although **nitrate** is an important N source in natural waters and present in much larger quantities, phytoplankton use **ammonium** preferentially to nitrate.

-Utilization of nitrate by phytoplankton involves its conversion ultimately to ammonium before assimilation into cell material, so the direct uptake of ammonium compounds would be advantageous.

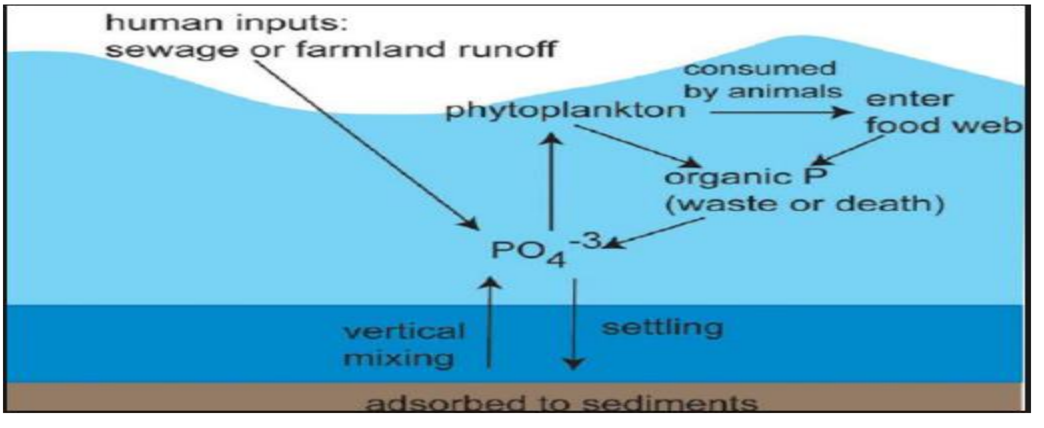
-Nitrate reductase is associated with nitrate utilization in the cells of some phytoplankton. This enzyme cannot be detected during periods of nitrate starvation and when other N sources (ammonia, nitrite) are available.

-In the periods of nitrate starvation, other combined forms of N such as nitrite and organic compounds may well be utilized by some organisms.

-Nitrogen in solution may be used by blue – green algae that are capable of N fixation. Filamentous blue-green algae (e.g. *Calothrix*) growing in salt-marsh and intertidal habitats fix atmospheric nitrogen, contributing to the nitrogen budget.

**Phosphorus**

Phytoplankton need phosphorus to make:- 1) ATP during cellular respiration in the mitochondria. –2) DNA (nucleic acid). 3)- Lipids (phospholipid bilayers of the cell membrane).




In natural waters, phosphorus occurs in both inorganic and organic forms. Orthophosphates is the main sources of phosphorus in both lake and sea. Organic phosphorus compounds occur in the marine and freshwater and may serve as a source of phosphorus for phytoplankton during periods of phosphate deficiency.

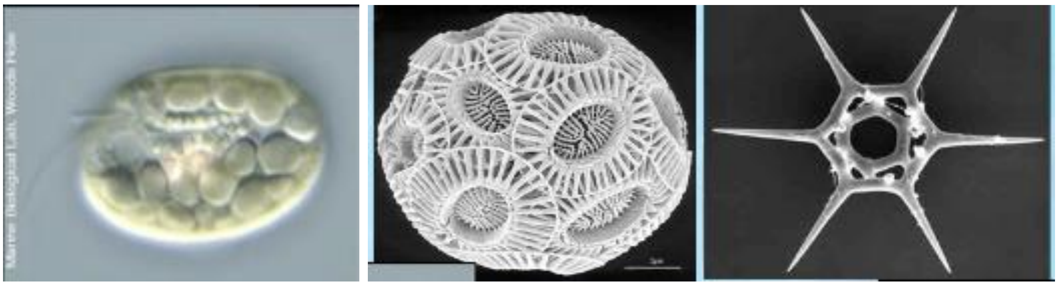
With certain phytoplankton in marine environments, phosphate deficiency is accompanied by increased formation of the enzyme alkaline phosphatase to break down organo-phosphorus compounds, probably after autolysis of phytoplankton cells. The production of this enzyme in the cells falls appreciably when phosphate levels in the external medium are again suitable for growth.

-Availability of organic phosphate compounds in the euphotic zone may be of appreciable ecological significance; because utilization of such compounds would speed up recycling processes without need for total re-mineralization. The excretory products of zooplankton are another important source of recycled phosphorus.

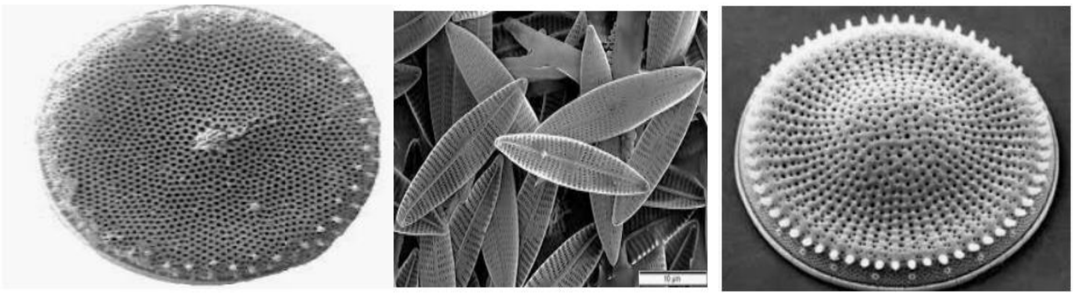
Phytoplankton cells accumulate phosphate reserves in excess when nutrient level are high" luxury consumption" to utilize them during periods of low phosphate concentration in the natural medium for growth. These reserves enable cell growth to continue for some time after the level of nutrient in the water has been significantly reduced.

**Silicon**

The orthosilicic acid is the principal source of silica. Diatoms require silica in soluble form for wall silicification. Likewise, the silicoflagellates are dependent on silica for construction of their tubular skeletons, and their scales.



Silicoflagellates



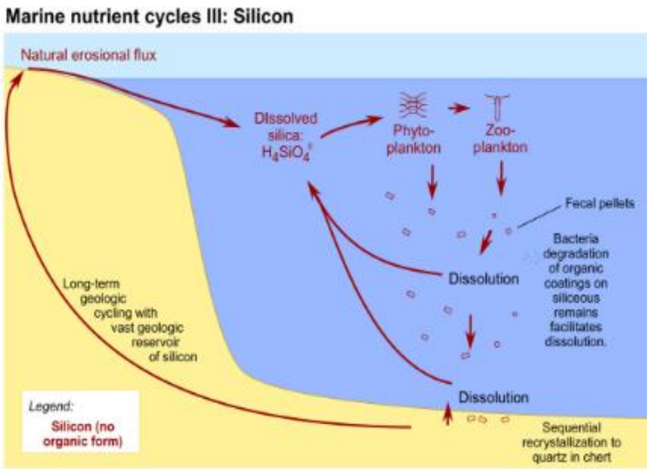
Diatoms

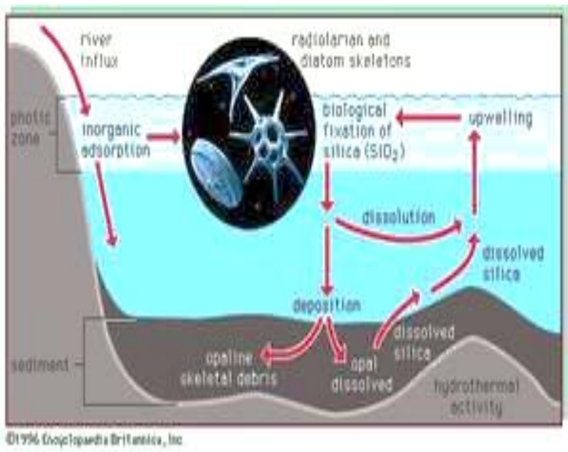
At times of maximum diatom growth, natural waters show a decline in silica content. The silica content in freshwater diatoms vary between 26% and 63% of dry weight, depending on species. Very low concentrations of silica in lake waters (0.5 mg/l $dm^{-3}$) is considered as limiting to continued diatom growth. The marine *Skeletonema costatum* grows in great numbers at the "spring outburst" in some areas with very thin siliceous walls, this may be attributed to the rapid cell proliferation.

Utilization of silica by diatoms is linked with their sulphur metabolism, so the sulphur shortage could indirectly prove limiting.

Recycling of silica in the sea is a fairly rapid process, particularly after breaking down the diatom frustules, during feeding by zooplankton. In freshwater habitats, the rate at which silica can be recycled significantly influences diatom periodicity and varies with the species of diatom dominant. Where rates of solution are very slow, the replacement must come from inflowing tributary streams and rivers if diatom growth is to continue.

During summer stratification, silica is stripped in the epilimnion to below the critical level of 0.5 mg $dm^{-3}$. At such times a sudden rise in silica due to inflowing streams can trigger rapid growth of the diatoms *Tabellaria flocculosa var asterionelloides* and *Fragilaria crotonensis*. Whilst it seems that silica depletion proves limiting to diatom growth in freshwater habitats, this depletion is less significant because some recycling can take place in the sea.

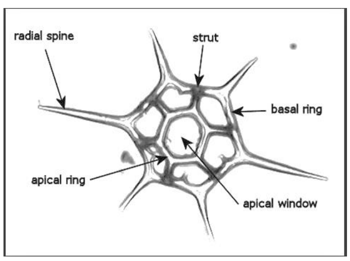



**Other mineral substances**

**Calcium (Ca):**

It is present in sufficient concentrations for phytoplankton requirements in both sea and freshwaters i.e. there is no calcium deficiencies occurring in nature. Certain desmids favour calcareous waters without further calcium requirement. The coccolithophorids require the element for formation of their calcareous scales. Coccolith formation can be inhibited in culture in calcium- deficient media.

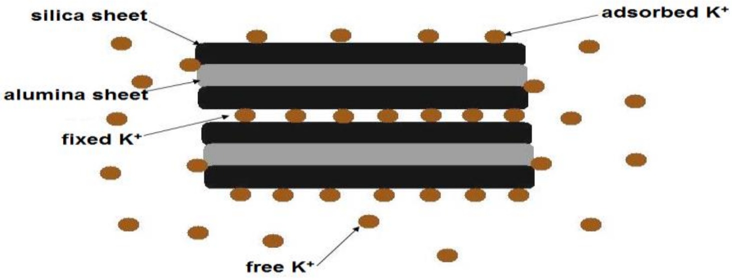



**Magnesium (Mg):**

There is no any clear-cut evidence that magnesium reaches growth – limiting concentrations in nature.

**Potassium (K)**:

It seems rarely to be present in natural waters in concentrations so low that phytoplankton growth is inhibited. The small quantities of K compared with Na in seawater, this is attributed to that K is adsorbed on suspended particulate matter, with subsequent incorporation in bottom deposits.




**Forms of K in the soil in the presence of the clay mineral illite**

**Sulphur (S):**

It is an important element in the silicon metabolism of diatoms; it is present in sufficient quantities as sulphate in natural waters not to prove limiting to phytoplankton growth.

**Traces elements (minor nutrients)**

These are elements required by phytoplankton in very small quantities, but if present in insufficient supply they may limit phytoplankton growth.

**Iron**

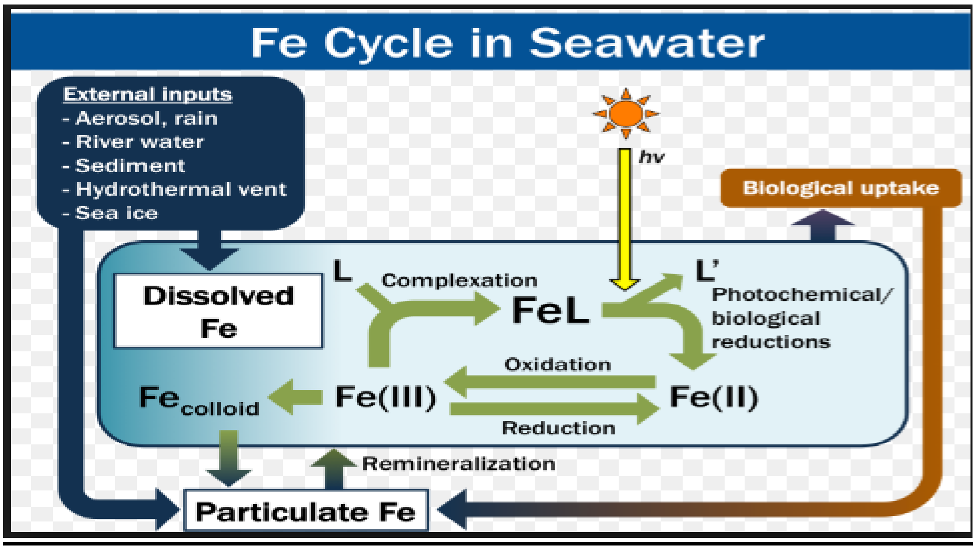
-In freshwater and the sea, iron occurs in solution, particulate and colloidal forms. It is a constituent of vital enzymes systems (such as cytochromes).

-The quantity in solution in natural waters is very small, except under acid or reducing conditions in certain freshwater habitats.

-In the open sea a pH of 8 is usual, with minimal variation. More significant changes in pH occur in localized habitats (some inshore waters and rock pools), but these changes are rarely on the acid side.

Hence in the sea, the quantities of iron in solution will be minimal, and are so small that growth of phytoplankton could not take place without utilization of particulate and colloidal forms of iron.

**In brown water lakes**, iron is present mainly in the ferrous state. The large quantities of organic matter present in some lakes may lead to **complex ion formation** with the element and may bring about its reduction to the ferrous condition.




The diatom cells utilize particulate iron in contact with their siliceous walls, and some marine organisms assimilate insoluble **ferric hydroxide**. The particulate iron is absorbed by the cells where a pH is 6, and is soluble under conditions of little acidity and can be directly used by phytoplanktonic algae after it is reduced in the cytoplasm. The **lack of iron** can prove limiting to photosynthesis of phytoplankton in natural waters.

**Coastal waters** are more richly endowed with iron than the open sea. Sporadic 'blooms' of neritic diatoms in the open sea may be included by localized increases in iron or some other trace element through upwelling.

The spring diatom outbursts are accompanied by **depletion of iron** in inshore waters. The availability of iron significantly influence both **the numbers and species composition** of phytoplankton populations.

**Manganese (Mn):**

Few species have a specific manganese requirement. The manganese content of coastal waters is higher than that of the open sea, and inflows make a major contribution, particularly those from rivers flowing through rich arable land.

The enrichment of media with manganese will appreciably increase the growth of phytoplankton organisms. As with iron, the quantity of Mn in solution is always very small, the particulate form being most common.

**Other minor nutrients**

A number of elements are necessary for the growth of phytoplankton. These include copper, zinc, cobalt and molybdenum.

**Organic substances**

The organic substances in natural waters include carbohydrates, amino-acids, fatty acids, organic acids and vitamins as well as plant growth substances with stimulatory or inhibitory properties.

In ocean waters, there is up to 18 freely amino-acids. Much soluble organic matter comes from **the decomposition** of microscopic and macroscopic organisms, and from excretory products. Also, much soluble organic matter is released into the water by healthy, actively growing phytoplankton cells in the **form of extra-cellular products** which are not to be confused with organic substances released by damaged or dead cells. Sunlight remains the prime factor controlling seasonal change in algal populations.

**Extracellular products**

The quantities of extracellular products excreted have been estimated as equal to 50 % of the fixed carbon during the period of the spring outburst and between 10-70% in the midsummer period when diatom numbers are small. Coastal phytoplankton organisms have been shown to excrete 35% of fixed carbon.

**Glycollic acid**,

It is one of the most extracellular products in natural waters, may enable heterotrophic growth of algae during winter months and support the growth of bacteria which in turn release the extracellular products of their metabolism.

Appreciable quantities of fixed nitrogen are released by blue-green algae. The production of organic substances by phytoplankton organisms and their utilization by others underlines what is now accepted feature of primary production.

**Vitamins**

There are many positive indications ensure the need of algae for certain vitamins. Three vitamins, vitamin $B_{12}$ (called cobalamine), vitamin $B_1$ (thiamine) and biotin, seem to be necessary.

Bacteria are a source of these vitamins in nature but whilst some phytoplankton organisms are dependent on these sources, others seem able to synthesize the vitamins themselves. Vitamin $B_{12}$ and $B_1$ appear to be required more than biotin by photosynthetic algae unable to engulf particulate organic matter.

**The $B_{12}$ content** at coastal waters are invariably richer than the open sea, and near the coast the concentrations (5-10 ng $dm^{-3}$) may be adequate for plant requirements at all times of the year. A **seasonal cycle of $B_{12}$** abundance is high in winter and low in summer in the sea. With certain diatoms, the $B_{12}$ requirement is of greater significance at some stage in their lives (e.g. auxospore formation).

**$B_1$** is also necessary for the growth of some marine phytoplankton organisms and, since it also is more abundant in coastal waters than in the open sea, **lack** of this vitamin might **influence phytoplankton succession in the oceans**.

**Eutrophication**

Eutrophication is defined as "the enrichment of water by nutrients especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned."

**Causes and consequences of the eutrophication:**

When the man use nitrogen and phosphorus containing fertilizers to help grow crops, nitrogen and phosphorus run off abundantly with rain, producing extreme growth of algae (algal blooms), causing eutrophication. This euphotic zone becomes a dead due to lack of $O_2$ and change in pH. The algae become so dense and thick, they block sunlight to reach to plants inhabiting the deeper water and they start to die.

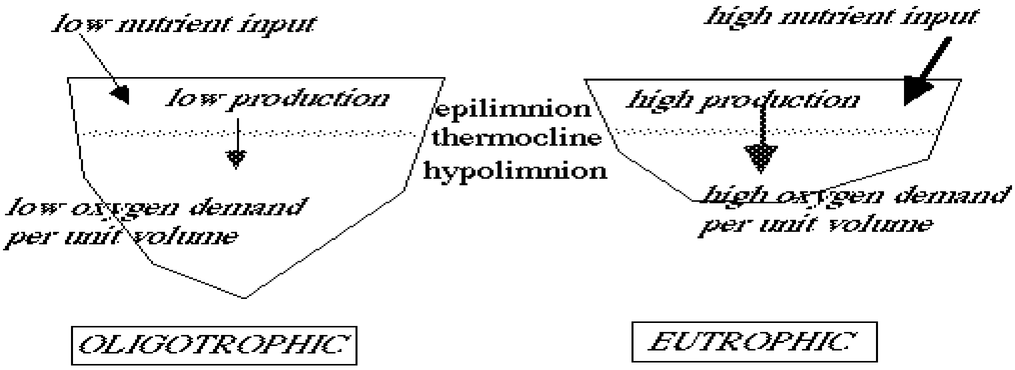
Also, algae themselves will begin to die and bacteria will feed on the dead remains of the algae. Bacteria are using all of the oxygen in the water to breakdown and decompose the algae and other plants so, the water almost becomes void of oxygen (oxygen deficiency). The extreme growth of algae change the pH of the rivers and lakes, then the phosphorus and / or nitrogen cycle become out of balance. Finally, marine life affect adversely

**Eutrophic and oligotrophic lakes**

Based on availability of plant nutrients, lakes are classified into eutrophic lakes and oligotrophic lakes.

**An eutrophic lake**:

It has a good supply of nutrients and potentially a high productivity; these nutrients will support a rich phytoplankton flora and animal population. The process of eutrophication can be a long–term enrichment or ageing process in natural waters. In contrary, artificial (man-made) eutrophication will appreciably speed up this process, sometimes with dramatic side effects. The rich nutrient supply in eutrophic lakes can result in dense growths of phytoplankton which significantly reduce light penetration. Hence a high rate of productivity is restricted to the upper layers. When measured in terms of organic production per unit of surface area the productivity of a eutrophic lake may resemble that of an oligotrophic lake.




**In an oligotrophic lakes**, which have a poor supply of nutrients and less productivity, the less dense plankton will allow light penetration to greater depths. With the deeper photosynthetic zone, **production per unit surface area** of an oligotrophic lake can be similar to a densely populated eutrophic lake. But, because of the lower nutrient levels, the productivity per volume of an oligotrophic lake will always be lower than that of one which is eutrophic.

Another feature relevant at the consumer level is **the ease of capture of food**. A sparse algal population will entail greater energy expenditure by the predator. In dense phytoplankton more than enough food can be filtered with little movement on the part of the animal. **The digestibility of the food** is also important. Even with a dense phytoplankton population in a eutrophic lake it is possible that the larger diatoms will not be acceptable as food for zooplankton.

Subsequently it was hypothesized that lakes evolved from oligotrophic to eutrophic as a result of human activity, in particular the input of sewage, industrial and agricultural nutrients. This was called cultural eutrophication.

Eutrophic freshwaters have consistently higher biomass of (usually) phytoplankton than is found in oligotrophic lakes, and eutrophication is generally the result of addition of phosphate. Cyanobacteria, common in freshwaters, can 'fix' nitrogen.

**Discuss**

1-The importance of N for phytoplankton growth

2- The significance of P for phytoplankton growth

3- The consequence of the luxury of P and N

4- Silica limit the diatom growth in freshwater habitats, in contrary the sea.

5- The importance of S for phytoplankton growth

6-The importance of Fe for phytoplankton growth

5- The importance of vitamins for phytoplankton growth

**Compare between**

1- Oligotrophic and Eutrophic lakes

2- Vitamins types used by phytoplankton

**Complete:-**

1- Coccolith forming species require essentially …………in their media.

2- An important element in the silicon metabolism of diatoms, it is called……

3-Being adsorbed by…….and then ….in deposits, K is in low conc. in natural waters.

4- The main problem of phosphorus luxury is called………………..

**Put (√) or (×)** Magnesium is considered as limiting factor in nature.

**Discuss: consequences using the N and P containing fertilizers**