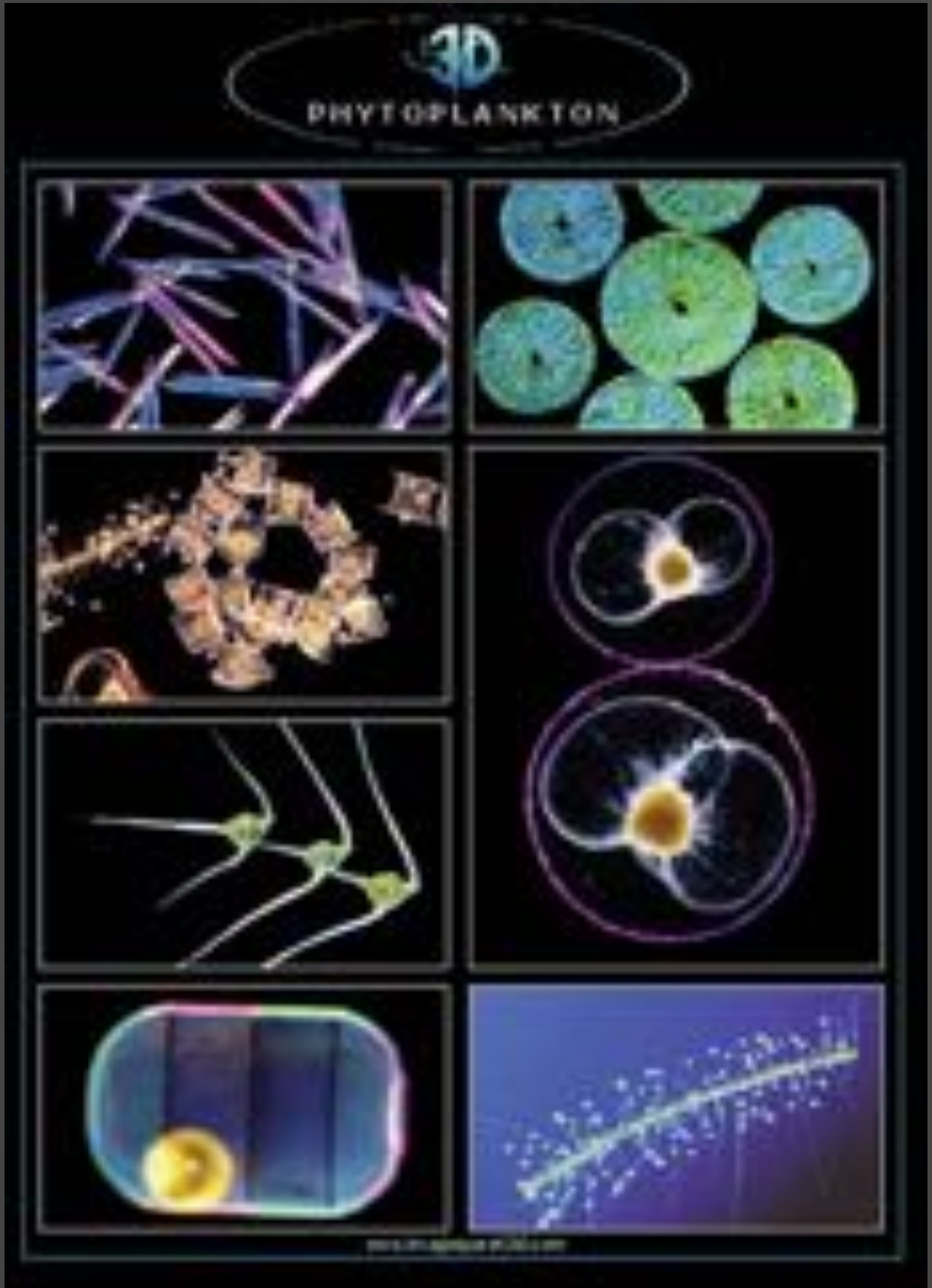
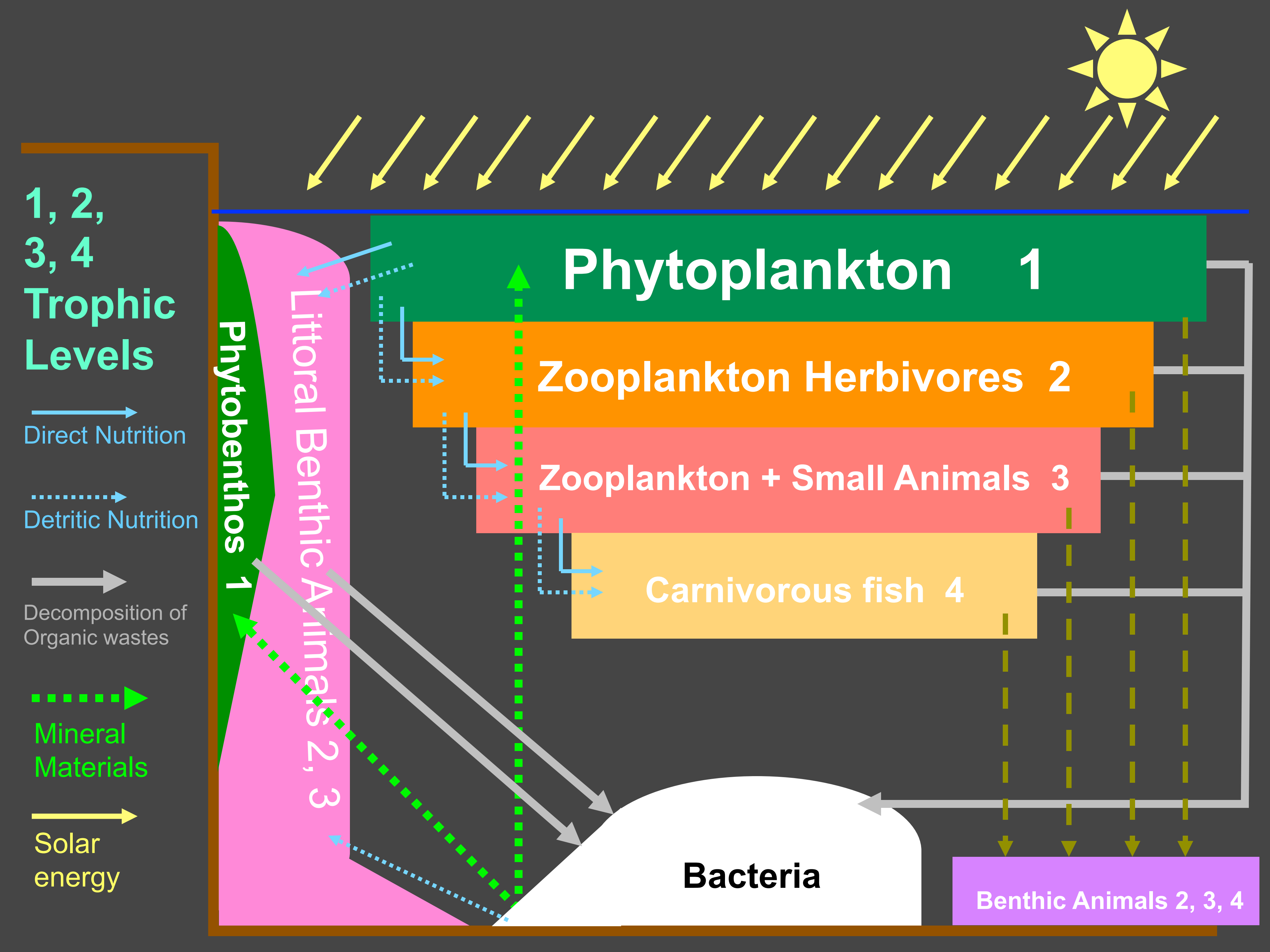
PHYTOPLANKTON ECOLOGY



Phytoplankton: free floating microscopic algal species, with or without motility, without association with submerged substrates

Algal plankton is fundamental in the chain food of aquatic environments


1, 2, 3, 4 Trophic Levels
Direct Nutrition
Detritic Nutrition
Decomposition of Organic wastes
Mineral Materials
Solar energy
Phytobenthos 1
Littoral Benthic Animals 2, 3
Phytoplankton 1
Zooplankton Herbivores 2
Zooplankton + Small Animals 3
Carnivorous fish 4
Bacteria
Benthic Animals 2, 3, 4

ROLE OF EXTERNAL FACTORS ON PHYTOPLANKTON

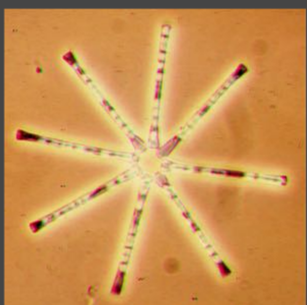
As all living things, plankton algae are affected by physical and chemical factors playing an important role on its development:

- **Temperature**
    - **Geographical distribution**
    - **Seasonal development**
    - **Depth**
- **Light**
    - **Absorption of light**
    - **Vertical distribution of algal plankton**
- **Chemical Composition of the water**
    - **Salinity**
    - **Minerals (N, P, Si)**
    - **Organic Substances**
- **Phytoplankton excretions**

TEMPERATURE

For each species there is a:

-Minimum temperature, below this it cannot exists
-Optimum temperature, reaching maximum development
-Maximum temperature, above it the organism cannot survive



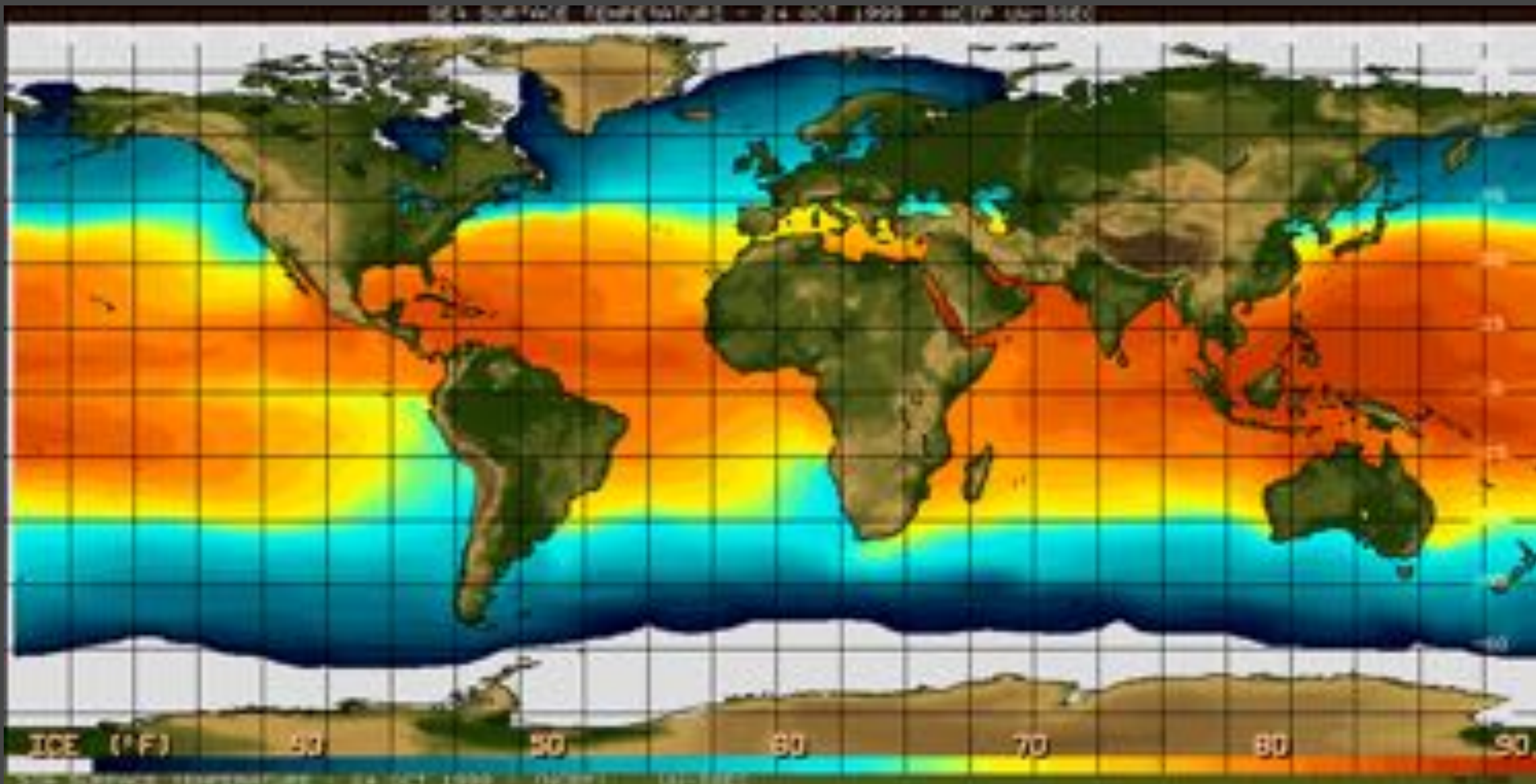
Asterionella formosa, a freshwater diatom, achieves a maximum development at 14^{o}C between 4^{o}C and 18^{o}C

Eurythermal species have a wide range between minimum and maximum temperatures. They are more tolerant to temperature changes

Other are stenothermal, living between a narrow temperature range. These species are very sensitive to temperature changes

Ceratium symmetricum
eurythermal BZ-FL

Distribution of ocean temperatures



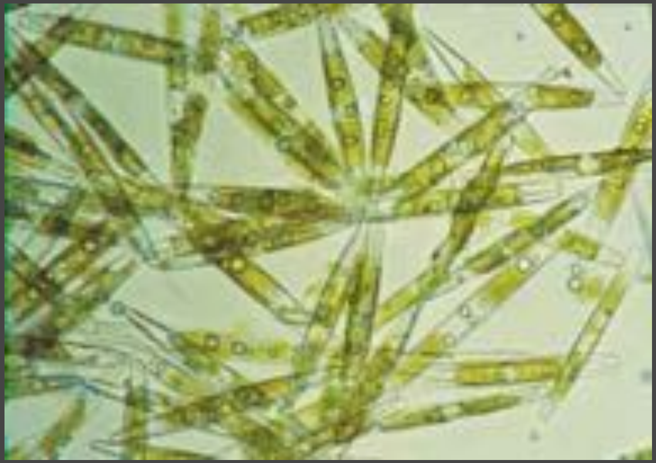
Temperature and geographic distribution of algae

In open aquatic environments (oceans) this factor confine each species to geographic areas compatible with their thermal restriction

Therefore the floristic composition of the plankton algae varies in the same ocean from the equator to the poles

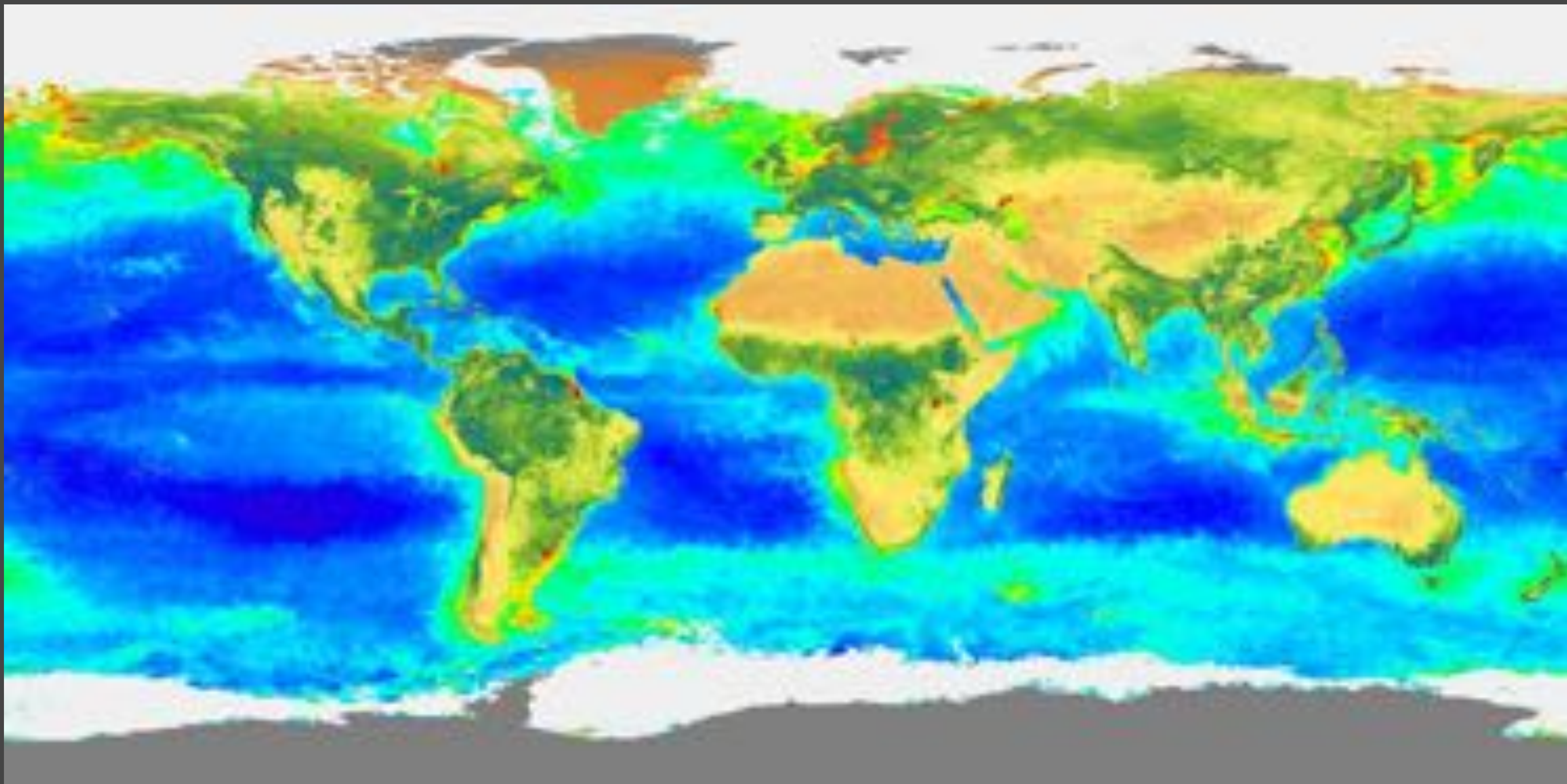
Some species are characteristic of the north Atlantic and other characterize the tropical Atlantic or the temperate Atlantic

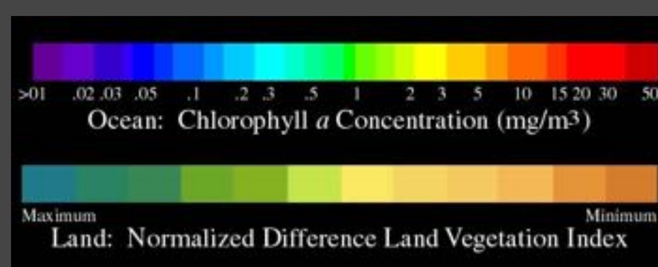
Chaetoceros coarctatus
Atlantic tropical to subtropical



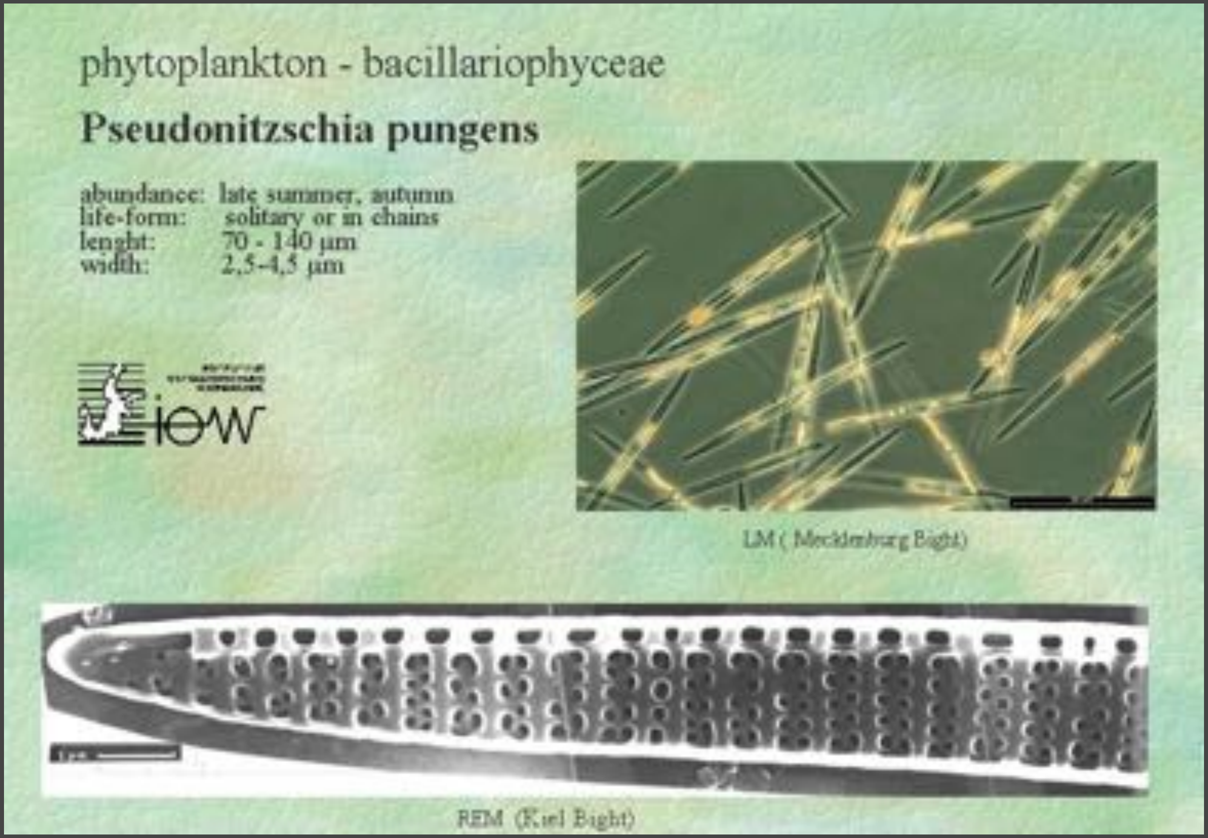
Nitzchia stellata
Antarctic common sea-ice diatom

Map showing distribution of the ocean productivity



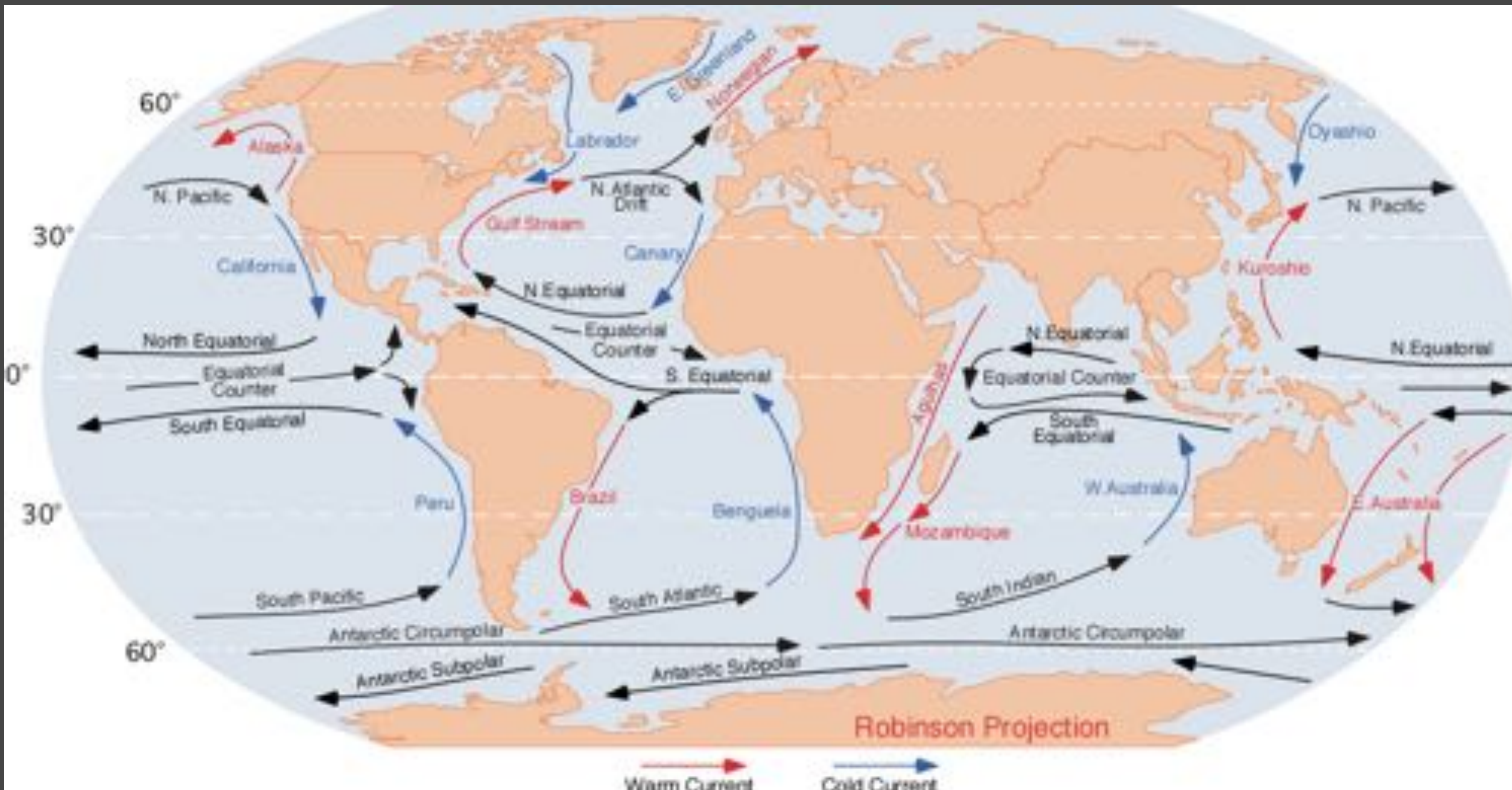


Some species, in particular the most eurythermal algae can be found in several geographic areas, they are *cosmopolitans*



Pseudonitzchia pungens
a marine diatom found worldwide

In oceans with important currents, there is a parallelism between the configuration of the currents and the phytoplankton, where its floristic composition is very different from surrounded areas



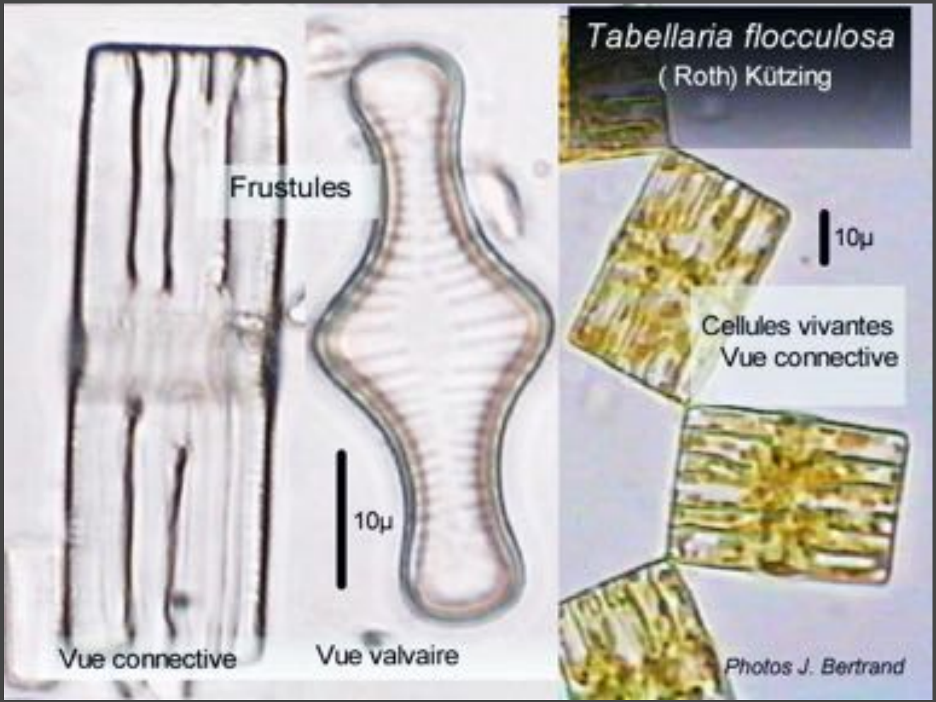
Temperature is responsible for certain winter species in the Mediterranean to be found during summer in the temperate Atlantic

Other species which are abundant in winter in the subtropical Atlantic ocean are found in summer in the Mediterranean sea

Temperature and seasonal development

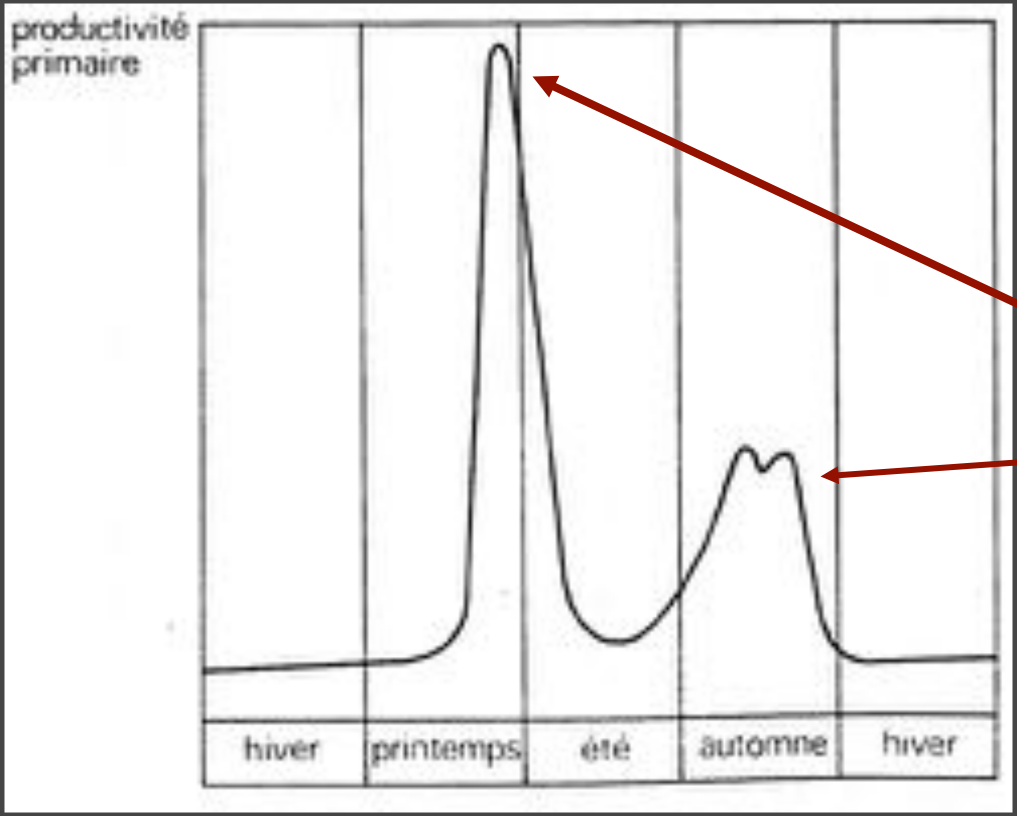
Temperature is one of the important factors that allow to one species to appear, reach a maximum development, and disappear during well defined seasons along the year

Tabellaria flocculosa, a freshwater diatom, its development increase from January to July and decrease from September to December



The graphs of variation in development and that of the temperature in the aquatic environment will overlap

The floristic composition of the phytoplankton from a particular ocean or freshwater lake varies with the season, the temperature plays an important role in these variations

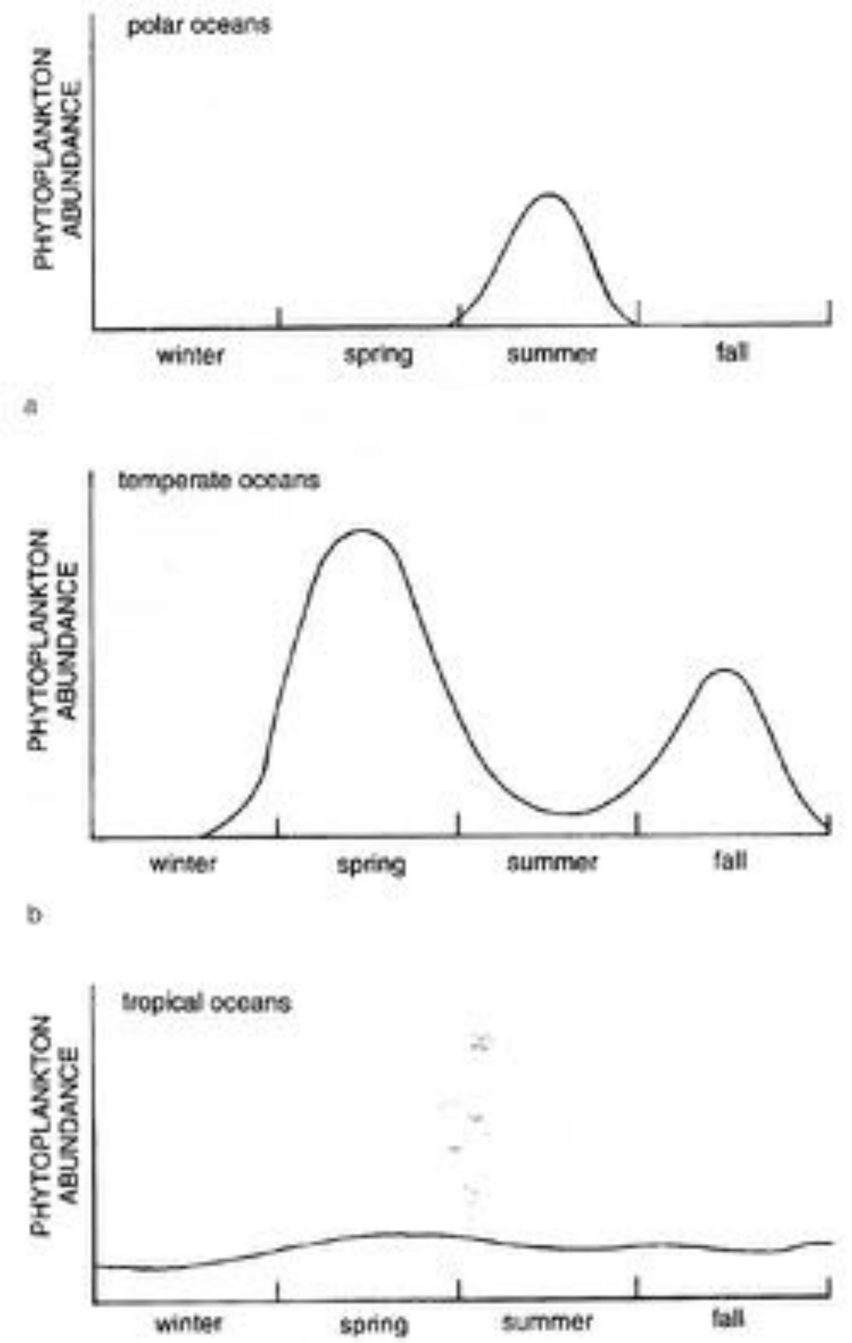


Quantitatively, there is a peak of phytoplankton in Spring, and a second (lower) in fall

Primary Productivity = $mgC/m^2/day$

In freshwater habitats of temperate regions there is a spring bloom of Diatoms and certain Chlorophyceans. During fall there is a great increase of thermophile Chlorophyceans and especially Cyanobacteria

Is this pattern the same all over our planet, from the equator to the poles?



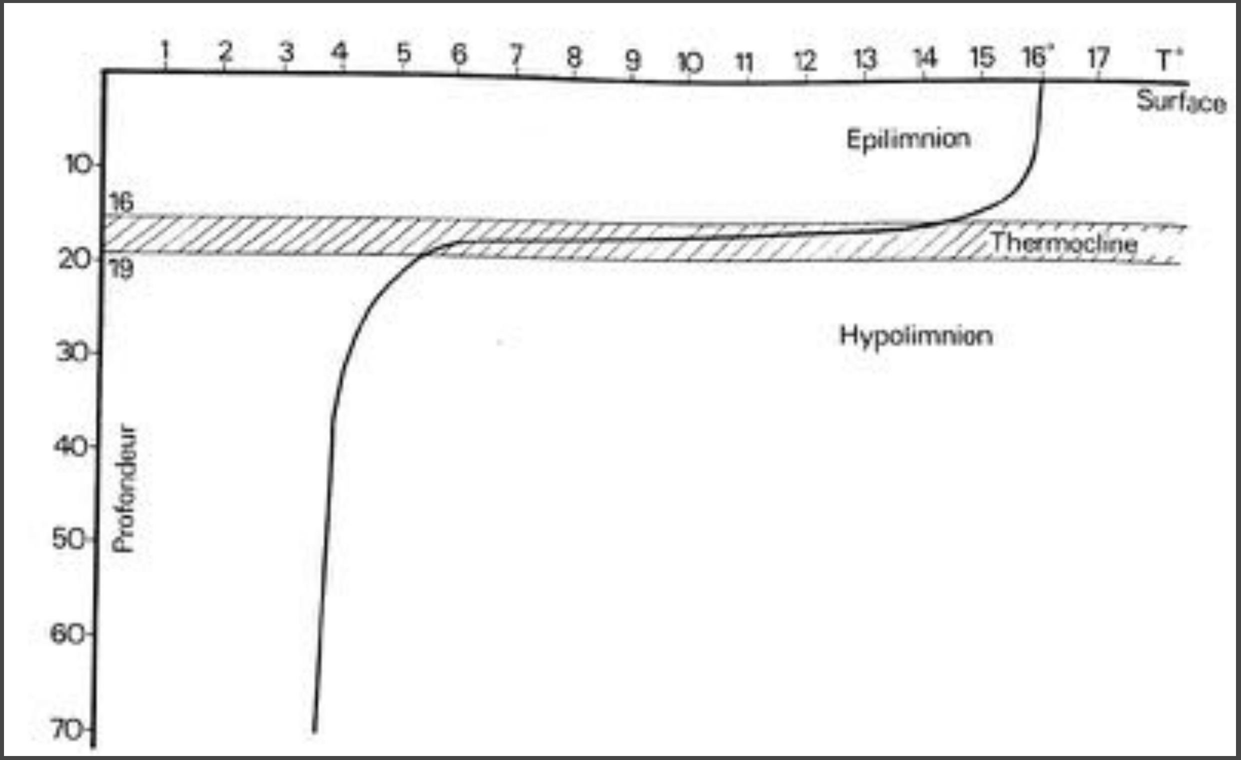
Seasonal patterns of phytoplankton abundance from the equator to the poles

Temperature and depth distribution of algae

Temperature determine the location of the phytoplankton along the water column

Warm, upper layer

Cold, deeper layer

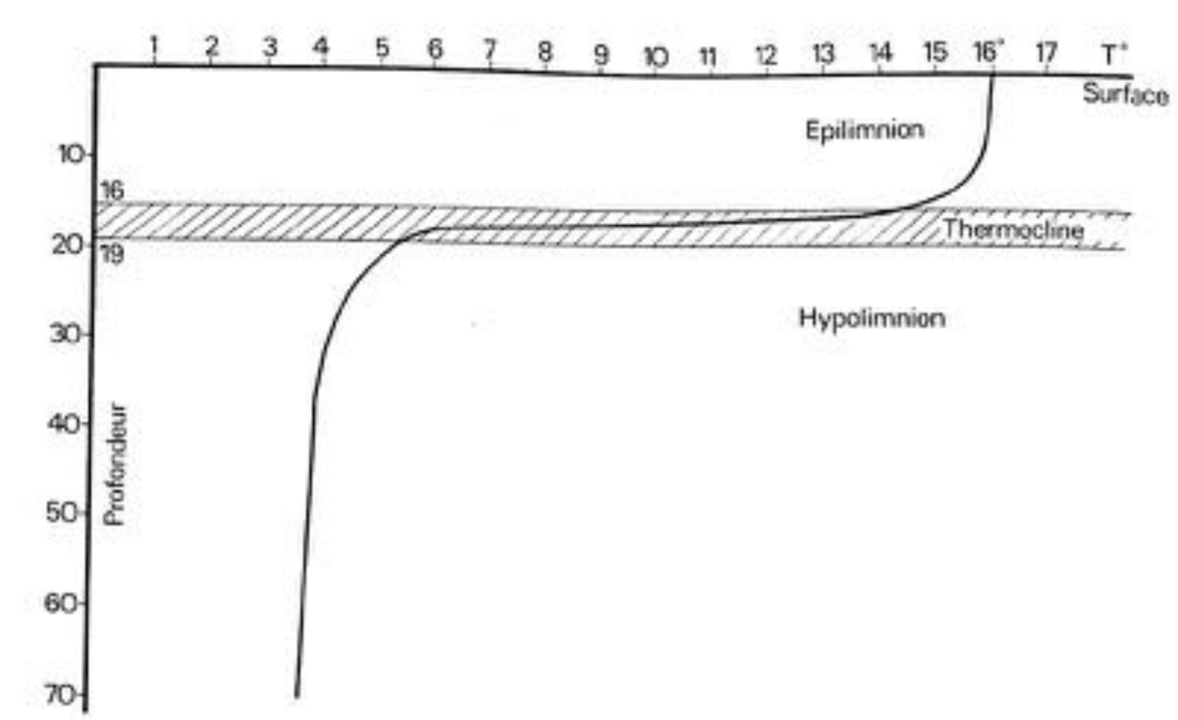


In lakes and oceans there is a period, in temperate regions, where a thermal stratification is established

A special layer is present, the *thermocline*, where temperature decreases rapidly in a few meters in depth

This layer or thermocline separates a warmer superficial region or *epilimnion* with temperature +/- homogenous from a colder and deeper layer or *hypolimnion* with temperatures also +/- constant

Certain species are incapable to cross this barrier, and they are trapped in that region, either epi- or hypolimnion



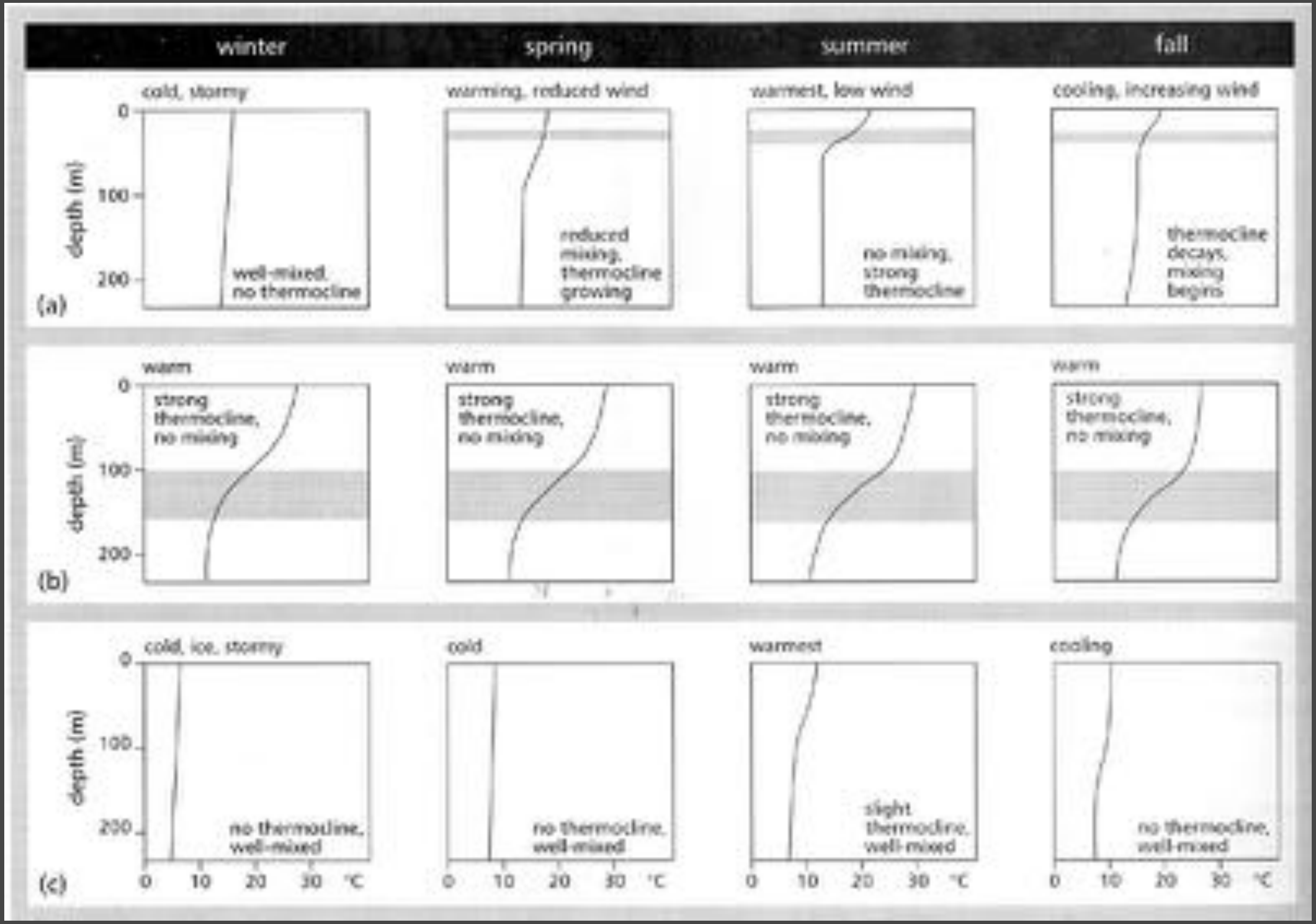
Would you expect this ecological feature to be present all over our planet, from the equator to the poles?

Thermoclynes from the equator to the poles:

Temperate

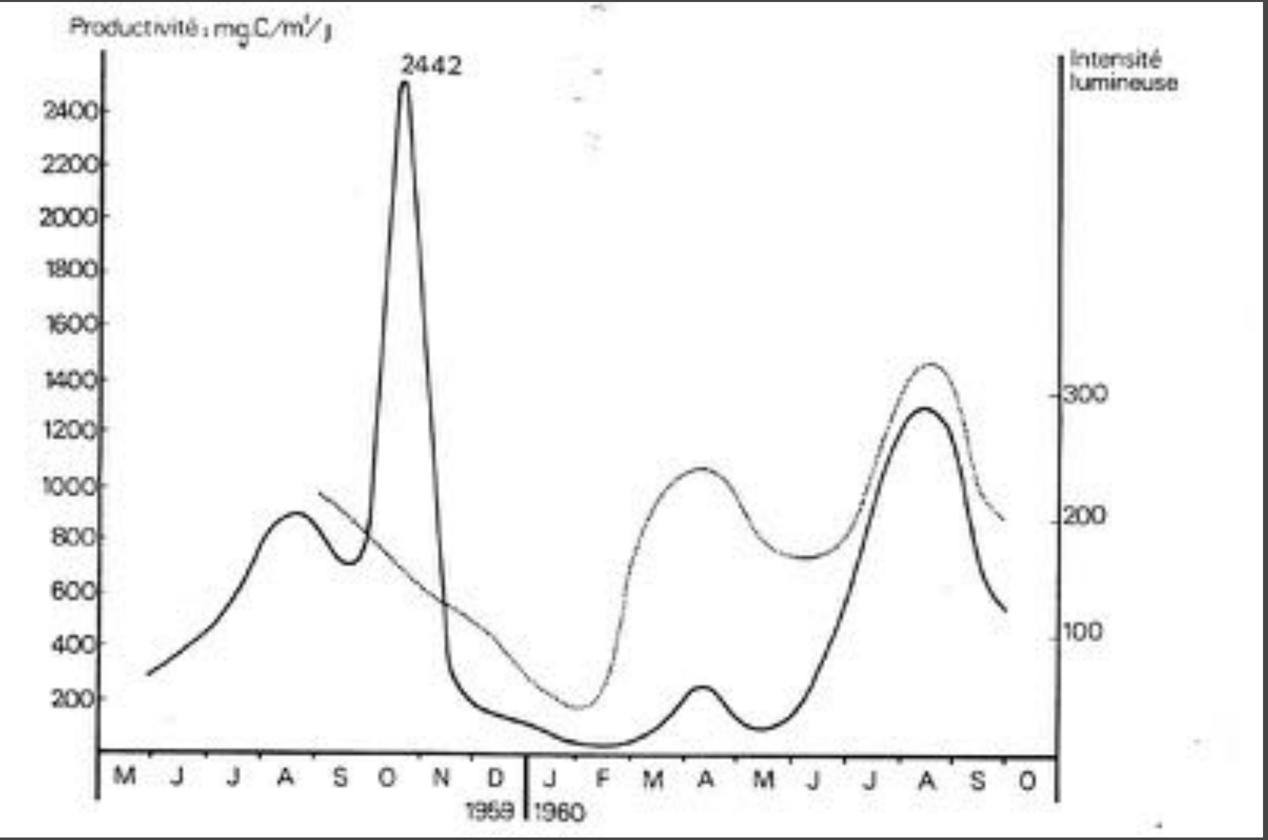
Tropical

Polar



LIGHT

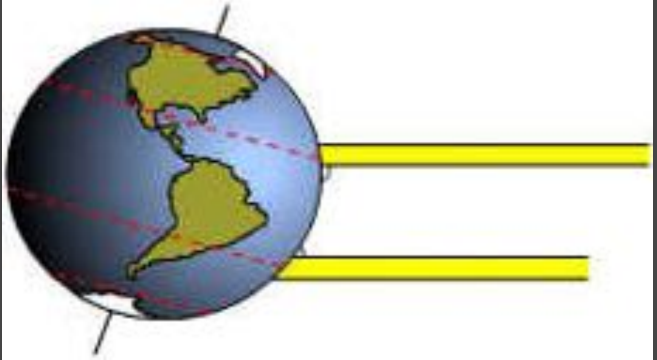
Important factor on phytoplankton because of its effect on photosynthesis

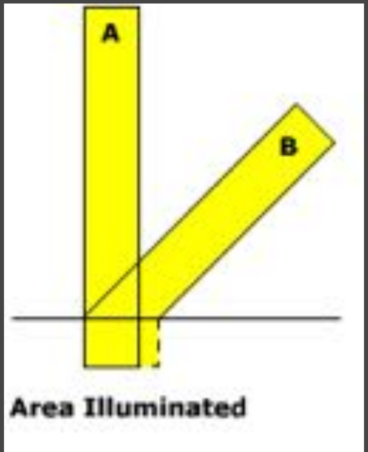


Correlation between annual variation of light intensity and the productivity of phytoplankton in a lake (mg Carbon fixed/surface unit/day

Like other plants, phytoplankton requires a minimum of light intensity to accomplish photosynthesis, an optimum, and a maximum over which the photosynthesis is inhibited by elevated intensities of light (solarization)

Each plankton alga shows different values in their intensity requirements (minimum, optimum, maximum) and these values vary among the algal species

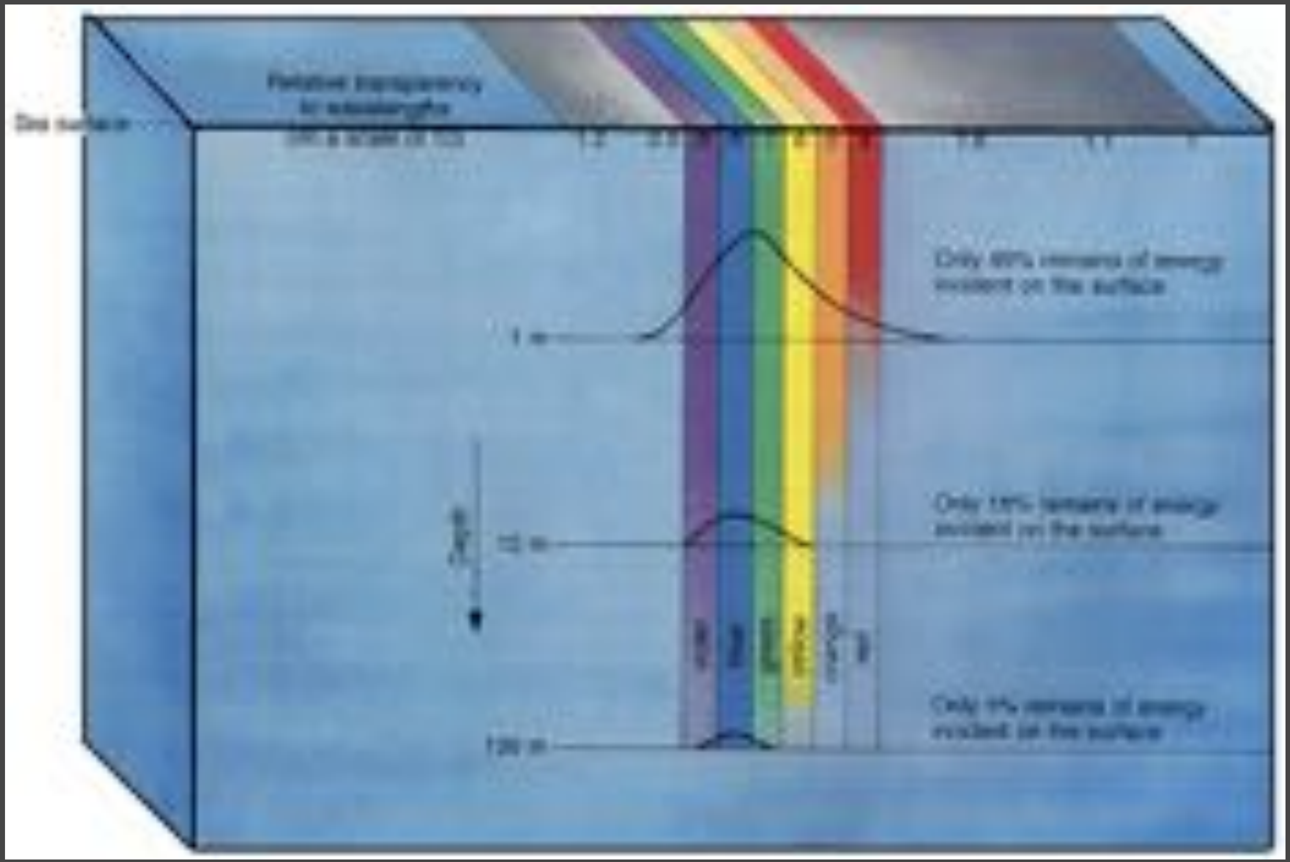




Therefore, light plays an important role on the geographic distribution on the algal plankton by eliminating some of them from areas with a weak intensity (northern regions), particularly those species for which this intensity is below their minimum

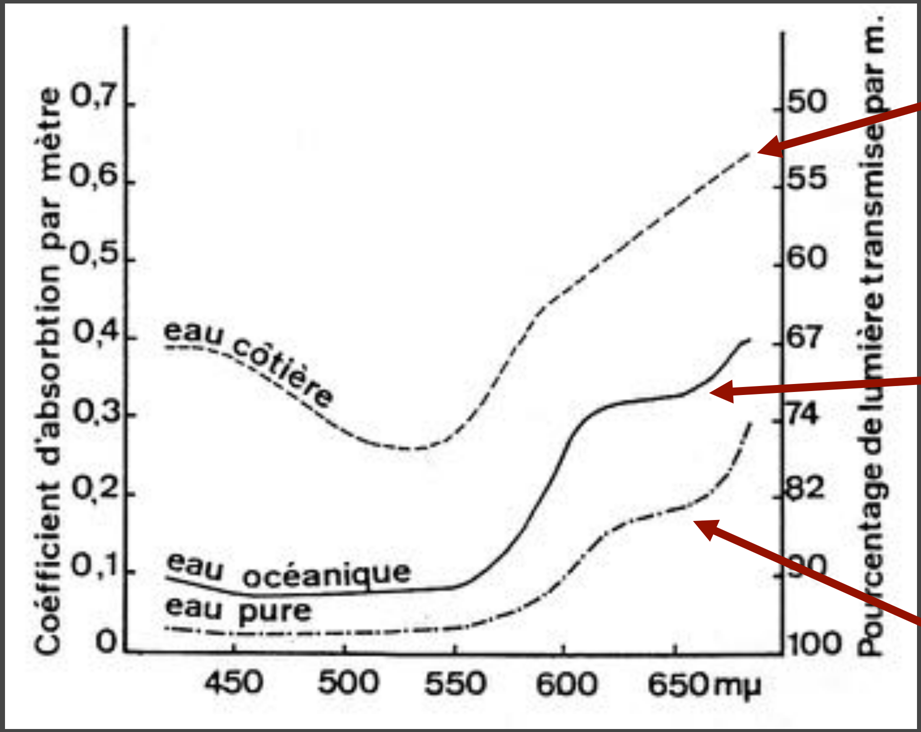
Light and vertical distribution of plankton algae

When the minimum intensity is achieved, the light affect the vertical distribution of phytoplankton because of its absorption along the water column



Light is absorbed by the water and is much more absorbed when the water is less transparent (or more turbid)

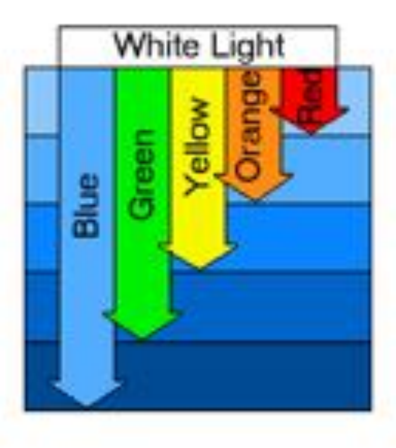
The absorption varies with the wavelength: radiations with longer wavelengths are absorbed faster than shorter wavelengths



Coastal water

Oceanic water

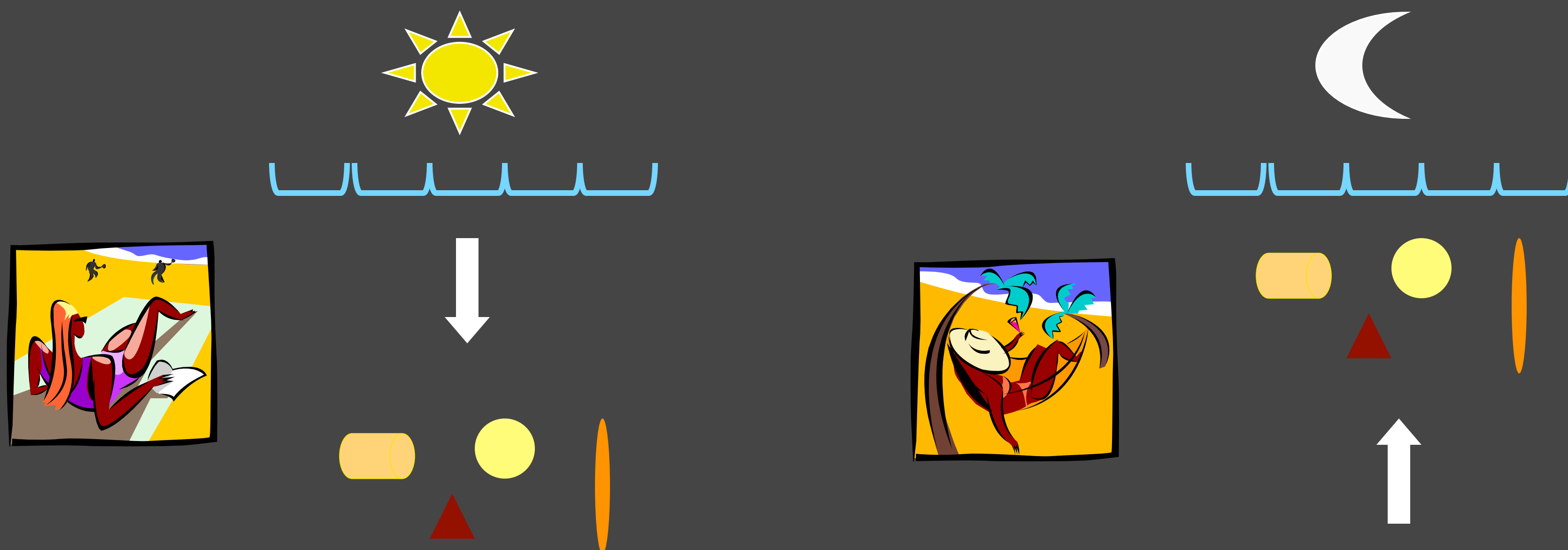
Pure water



Short wavelength radiations (blues and violets) <u>penetrate deeper</u> than longer wavelengths (reds and oranges)

By vertical migration the phytoplankton can find the depth at which its optimum light intensity value is achieved

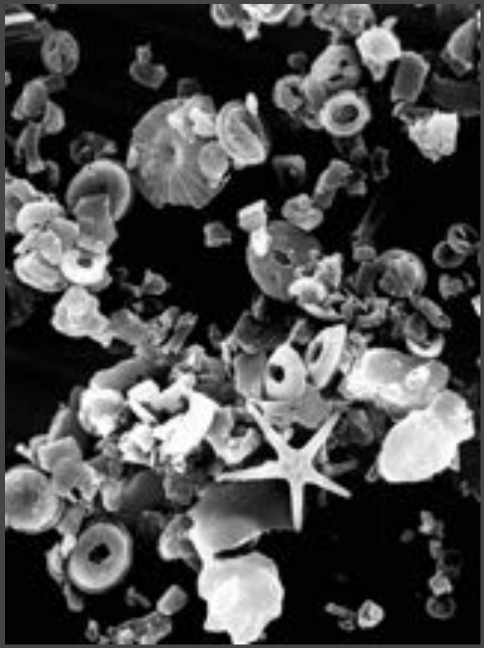
Usually, plankton algae are absent in the immediate vicinity of the water surface, were the light intensity is too strong and extend beyond its maximum requirement. The phytoplankton increases below a certain distance of this surface (some cm or more)



For the same reason phytoplankton species during the day make vertical migrations staying away from the surface during the hours of strong intensity and close to the surface at the end of the day

Selective absorption of wavelengths with the depth can also determine selection of species along the water column

Algal groups with pigment sets requiring radiation of longer wavelength cannot descend beyond the depth in which those radiations cannot penetrate



However the phytoplankton can survive in great depths because even weak light intensities will suffice to certain species

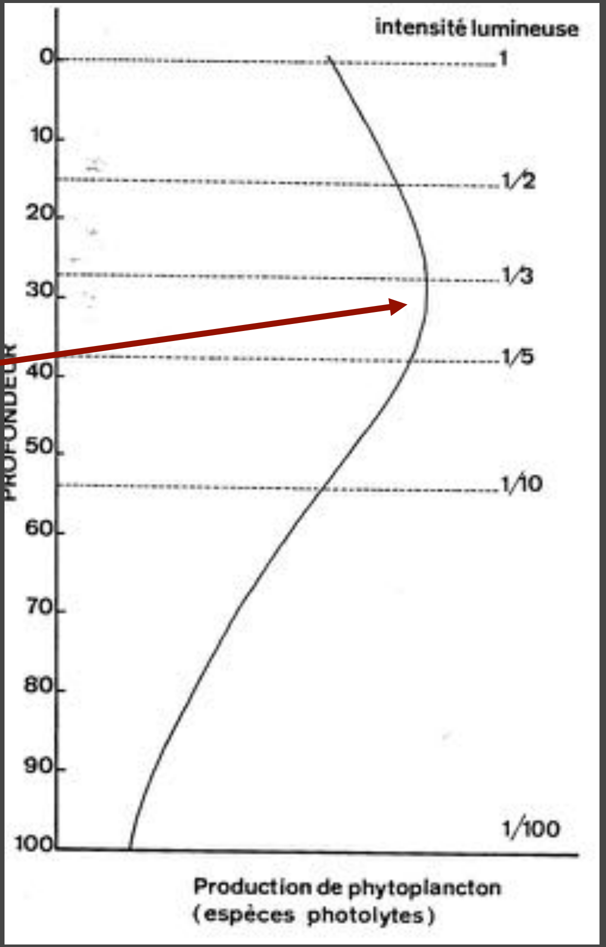
Some nannoplankton (5-60 μ) species can be found even with light intensities less than 0.06-0.07% compared with the water surface

In marine environments, most phytoplankton species can be found in the *euphotic* zone, from the surface down to 50-80 m in depth

Below this region, another zone, named *oligophotic*, extends down to 500 m, where only certain organisms survive, in particular some Coccolithophorids

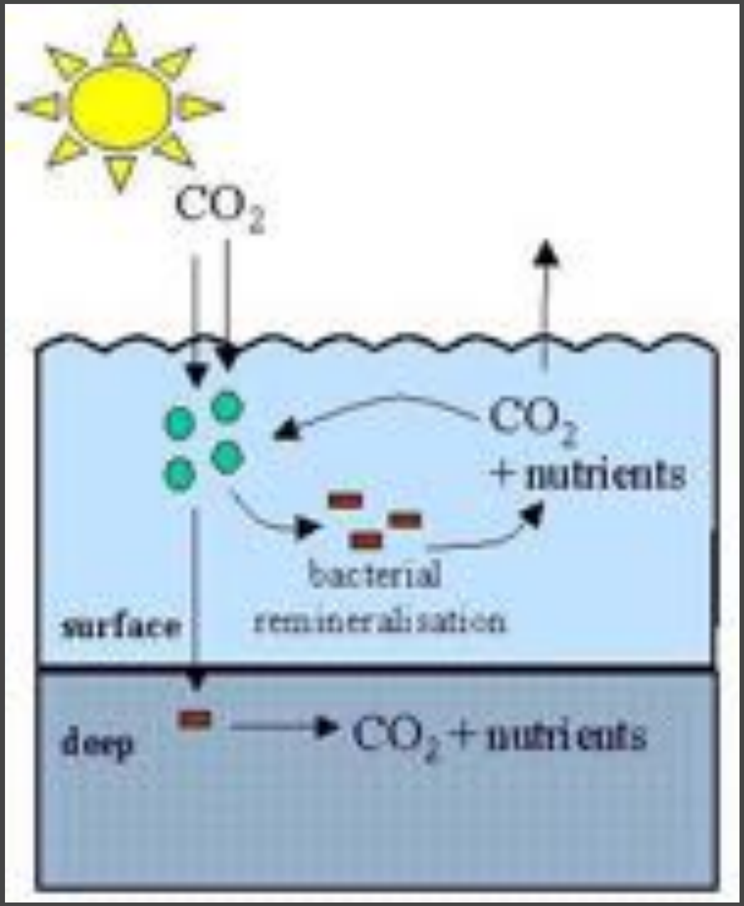
In the euphotic zone, the maximum density of some organisms is located around 20 m in depth for *photophile* species

Around 50 m in depth there is another group of algae, the *sciaphile* species



CHEMICAL COMPOSITION OF THE WATER

Like all autotrophs, the algal plankton depend on the qualitative and quantitative chemical composition of the aquatic environment for the synthesis of organic substances



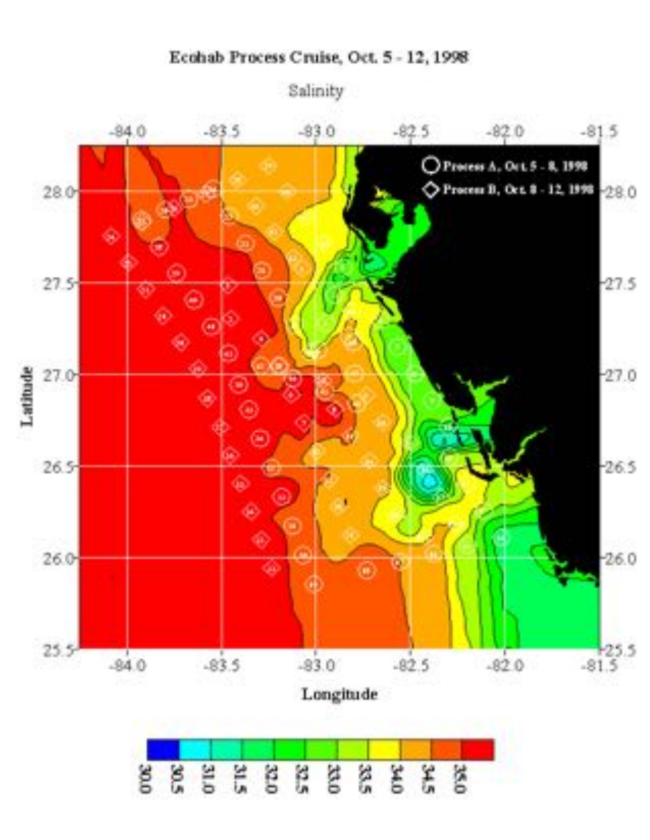
<u>Chemical Composition of the water: Salinity</u>

Salinity is the total content of salts dissolved in the water

Higher salinities in natural waters are due the presence of chlorides, specifically sodium chloride

The content of chlorides is a chemical factor of great importance for algae; when the concentration of chlorides is elevated eliminates the freshwater algae or *oligohalines*

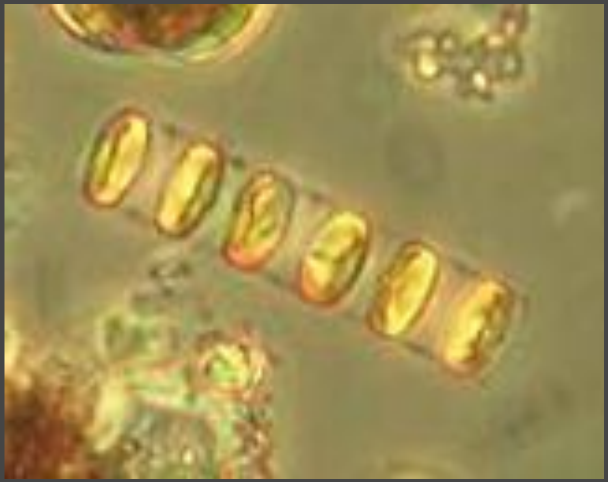
When the salinity is below certain value, eliminates the marine species or *polyhalines*



Coastal salinity fluctuation off Florida

Certain species are very sensitive to salinity variation, they are *stenohalines*; another species stand a variation way below or above their optimum, they are *euryhalines*

Species living in brackish waters are usually euryhalines, either marine species surviving low salinities or freshwater species capable to tolerate higher salinities



Skeletonema costata
Found in salinities between 0 and 20 ppt

It doesn't seem that the Cl^-, Na^+ or K^+ ions requirements determine the presence of algal species because the organisms need these substances in small amounts

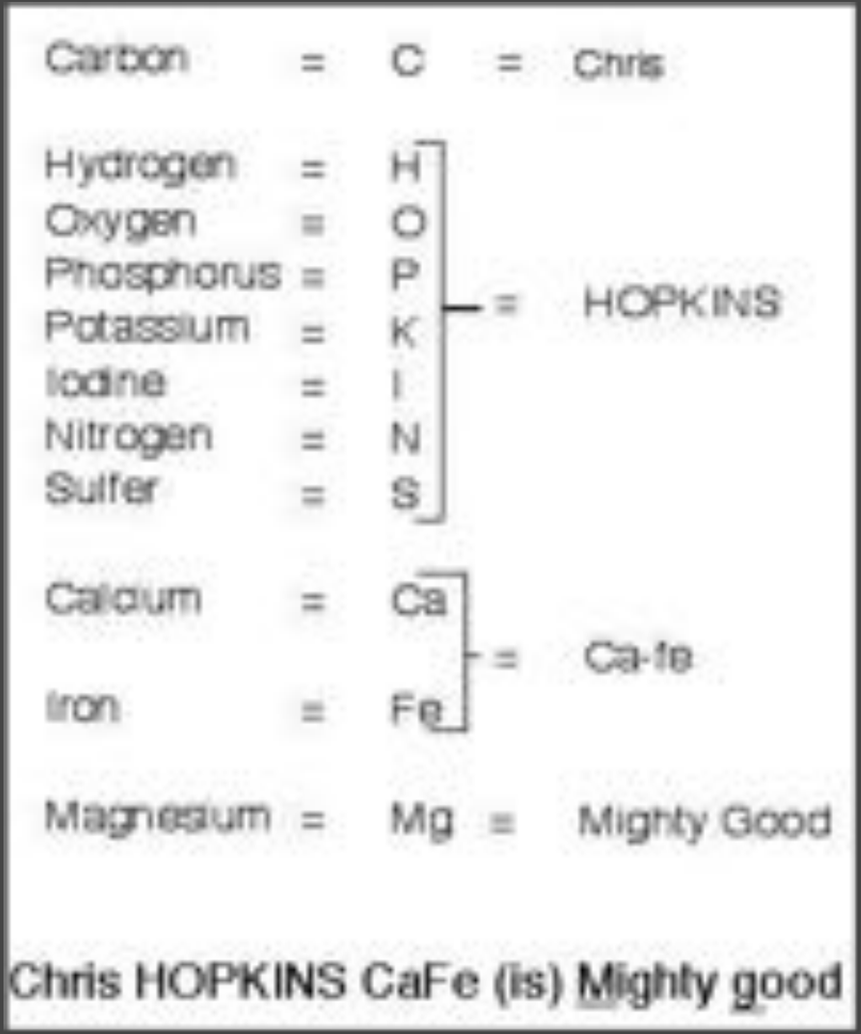
It seems that they affect indirectly by their ionic concentration on the osmotic pressure or the pH

Chemical Composition of the water: Minerals

Like land plants, certain elements are necessary in elevated concentrations, they are the *macroelements*: N, P, S, Ca, Mg, Si, etc

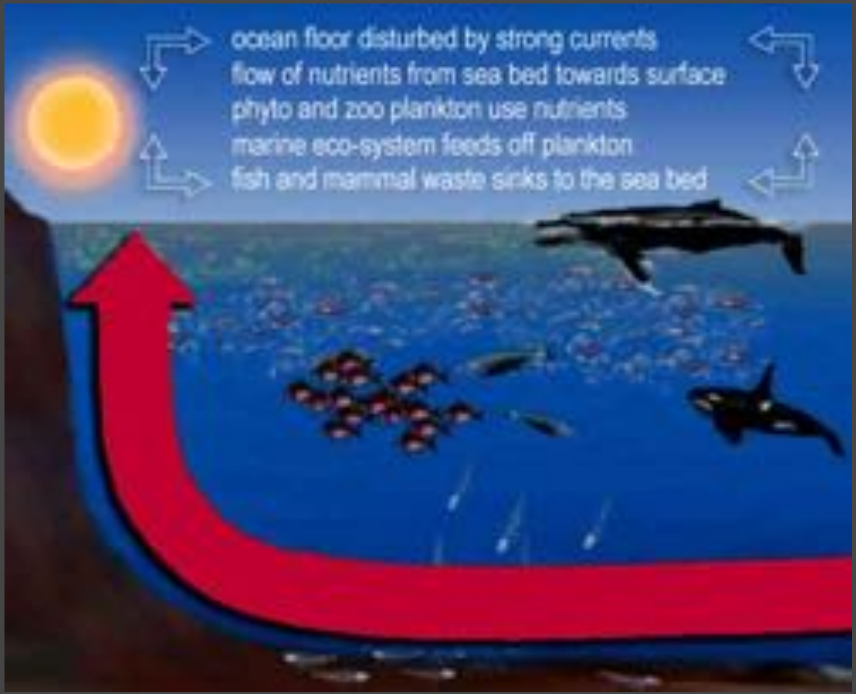
Others play an an important role in weak concentrations, the are the *oligoelements*: Cu, Zn, Mn, Fe, etc

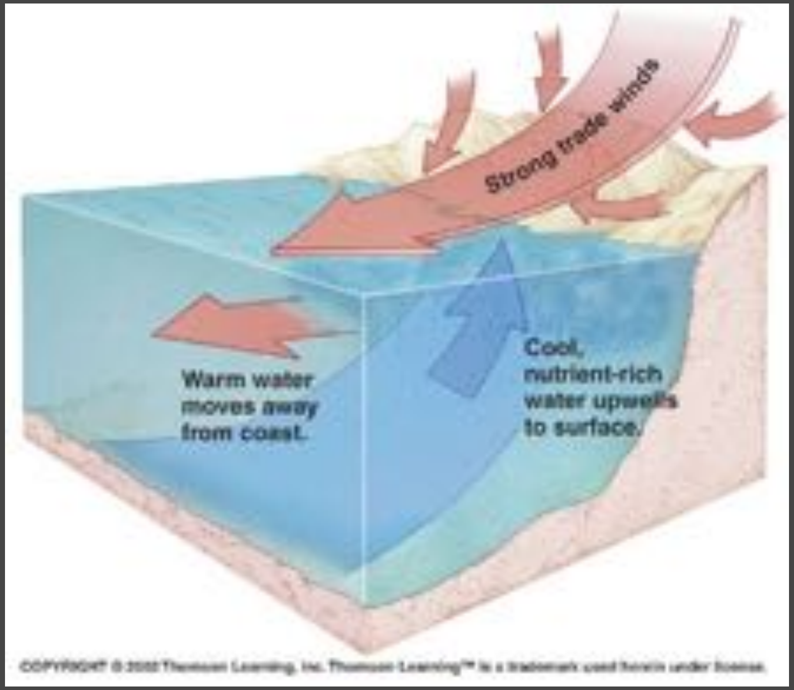
These oligoelements are usually present in enough amounts in the natural environments, however they become inhibitors when they exceed certain values



Seawater has a chemical composition almost constant, the marine organisms are not dependent of environmental fluctuations on the chemical composition.

The macroelements are usually recycled by the action of bacteria on the organic matter that sink to the bottom and they are brought back to the surface either by mixing after the thermal stratification thanks to vertical currents or by upwellings





In brackish and freshwaters where the mineral composition is variable, there is an effect on the diversity of the plankton flora

Waters rich in nitrates, phosphates and calcium (<u>eutrophic</u>) have an abundant flora in which Chlorophyceans and Cyanobacteria are dominant

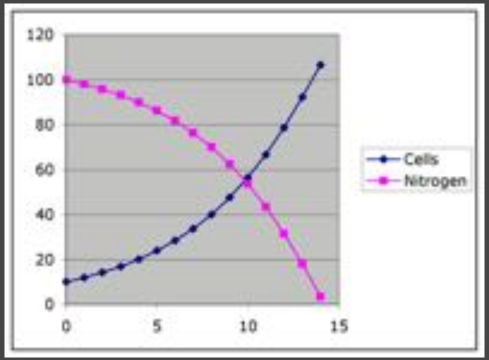
On the contrary, waters low in minerals and weak in calcium (<u>oligotrophic</u>) usually have a poor flora, where Chrysophyceans, diatoms and Desmids are common

Eutrophic lake

Oligotrophic lake FL

Freshwater environments are more contained than marine areas and therefore show more drastic variations in their mineral concentration

The intensive growth of autotrophs in these environments will decrease the mineral content and soon its own development will decrease due to the absence of dissolved nutrients



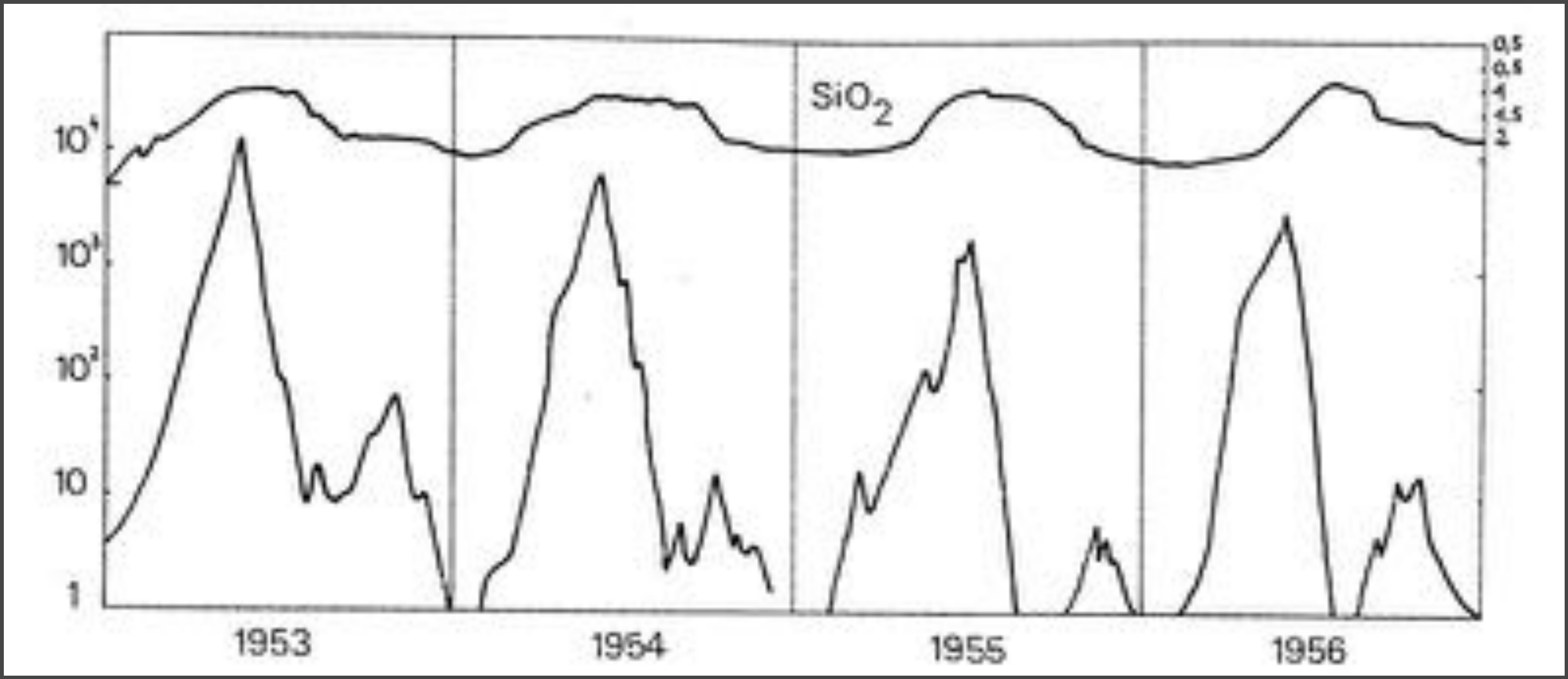
Inversely, an intensive mineralization (due to intensive bacterial activity) will elevate the concentration of certain substances which can play an inhibitive effect on some species

These effects can explain in part the succession of different species during the year

NITROGEN: Algae can utilize nitrates and ammonium salts; some Cyanobacteria fix atmospheric nitrogen; some cyanobacteria and especially Euglenophyceans are capable to use organic nitrogen

PHOSPORUS: Algae use it as orthophosphates, some can take organic phosphate

SILICA: Especially diatoms are correlated to this mineral



Silica and *Asterionella formosa*

In general terms, natural waters contain, in minimal concentrations, the nutritive elements necessary for plankton organisms. However, certain species, especially those with strict requirements are eliminated or reduced when the conditions of the *law of limiting factors* take place:

There is invariably one factor which, when changed, would have the greatest effect on the population (e.g., a resource which is in short supply, which if increased would allow the population to grow)

Temperature, light or chemical elements can play the role of a limiting factor even if all the other factors are favorable for the development of certain plankton alga

Chemical Composition of the water: Organic Substances

It is known from a long time that plankton algae develop weakly in environments with only mineral nutrients and its improved by the addition of soil extracts

This indicates that organic elements are necessary for the growth of algae. Especially vitamins such as B_{12}, thiamine or biotine (auxotrophs)

This confirm the idea that phytoplankton organisms are, in part, under certain conditions, heterotrophs (mixotrophs)

Phytoplankton excretions

Algal excretions are organic products synthesized by the cells and that cross the plasmalemma toward the exterior:

•*Organic acids: lactic, oxalic, tartaric and especially glycolic)*

•*Peptides*

•*Sugars: glucose, xylose, rhamnose, galactose*

Substances with evident biological effects:

•*Inhibiting substances for other individuals or other species*

•*Antibacterial substances*

•*Toxic substances against animals (mollusks or fish) produced by dinoflagellates*

These organic substances have an effect on plankton populations

Some of them have a positive effect (synergism), and others have a negative effect (antagonism)

Chrysophyceans → Organic acids → Lower pH → Minerals release → More Chrysos

Dinoflagellates → Saxitoxins →

Finfish

Seabirds

Marine Mammals

Humans

The study of phytoplankton, its diversity, ecological interactions, distributions and applications is FUN!