Nutrients Reading

OCN201L

Phytoplankton are microscopic plants that inhabit the surface waters of the ocean. Much like plants on land, these organisms require specific nutrients and light to grow. The **essential nutrients** are carbon, nitrogen and phosphorous, and all three of these nutrients must be present for plants to grow. This is because carbon, nitrogen, and phosphorous are all required to build the soft tissues of all plants and animals. Because they are all required, if one is absent it is called the **limiting nutrient**. This is because its absence prevents (limits) further phytoplankton growth from taking place in that area. These nutrients are rapidly consumed by phytoplankton, and therefore only small quantities exist in regions of the ocean where phytoplankton are present.

Table 1. List of nutrients.

Element	**Form in Ocean**
	Essential Nutrients
Carbon	bicarbonate (HCO_3^-) from carbon dioxide
Nitrogen	nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+)
Phosphorous	phosphate (PO_4^{3-})
	Optional elements (building skeletons)
Calcium	Ca^{2+}
Silicon	$Si(OH)_4$
	Micronutrients
Magnesium	Mg^{2+}, used in chlorophyll
Iron	Fe^{3+}, used in converting sunlight into energy

Another set of chemicals are required for building the **skeletons** of organisms. They are used in fairly large quantities but are not required by all organisms. For example, calcium (Ca^{2+}) is used by organisms that build shells out of calcium carbonate, like coccolithophores. Silica ($Si(OH)_4$) is used by organisms that have siliceous skeletons, like diatoms. (We saw examples of animals that build shells from these chemicals a few weeks ago. Remember the foraminifera and radiolarian tests from the ooze?) Keep in mind that not all phytoplankton build skeletons, and therefore these chemicals are not required by all organisms.

There is also a third group of chemicals, required in very low concentrations, known as **micronutrients**. Magnesium (Mg^{2+}) is required by all plankton that photosynthesize because it is at the heart of every chlorophyll molecule. Chlorophyll is the essential compound for trapping light energy to permit organic matter to be made from carbon dioxide. In the case of magnesium, there is no shortage since it is one of the major ions in sea water. Iron (Fe) is also needed within the chemical system of phytoplankton for the conversion of light energy into chemical energy. In certain regions of the ocean micronutrients are known to limit the growth of phytoplankton.

In addition to nutrients, plants need light to survive. The depth to which phytoplankton grow depends on how deeply the sunlight can penetrate into the water. This is determined by the strength of the sun (summer/winter or time of day) and by the amount of particulate material in the water. (Particles in the water scatter the incoming sunlight and prevent it from penetrating deeper.) Phytoplankton can only function down to about the **1% light level**, the depth at which 1% of surface light is present. Below this depth light, rather than nutrients, becomes the factor limiting plankton grown. Scientists have discovered that when sunlight is available, phytoplankton remove nutrients from the water until one becomes limiting. Below the 1% light level, nutrients like phosphate and nitrate become plentiful! If phytoplankton are constantly growing and using up nutrients from the water, how are the nutrients replaced so that growth can continue?

Recycling and removal

Phytoplankton are capable of removing the nutrients phosphate and nitrate to almost zero in most surface waters (except when one of the micronutrients is limiting). That means there must be some delivery mechanism that brings the nutrients from deep water, where the phytoplankton cannot live due to light limitation, up to the surface ocean. Without this process the phytoplankton would run out of nutrients (food), and then there would be nothing for the zooplankton, fish, and large mammals to live on. Part of the answer is that much of the material from the phytoplankton is immediately recycled in the photic zone, where light is available. The rest is recycled deeper in the ocean and must somehow make its way up to the surface. The physical process responsible for moving nutrients from the deep ocean to surface waters is called **upwelling**. Understanding how this process works requires some basic ocean physics concepts.

Basic Ocean Physics

First, you need to understand that the ocean, just like the earth itself, is composed of many layers organized by **density**. Recall that density is mass divided by volume, and more dense things are heavier than less dense things. When two materials are put together, the denser one sinks and the other sits above. Think about the density stratified layers of the earth. The core is most dense, followed by the mantle, crust, ocean and last the atmosphere. The ocean too is organized according to density, with less dense waters at the surface, and more dense ones at the bottom. We will go into the details of how the ocean is stratified in a later lab.

Coriolis Force

The second concept we need to understand is the Coriolis Force, which arises because the Earth is rotating and results in winds and currents moving to the right in the Northern Hemisphere and the left in the Southern Hemisphere. Back in 1893, a Norwegian scientist and explorer Fridtjof Nansen decided to freeze a vessel into the Arctic ice and allowed the boat and ice to drift for a year. What he noticed was that the ship did not move parallel to the direction of the wind, which you would think it would, but rather it moved to an angle of 20-40 degrees to the right of the wind. Nansen presented the problem to V. Wilfrid Ekman who determined why wind-driven currents were deflected to the right, and so they named it Ekman Currents. It’s hard to imagine the Coriolis Force, but the bottom line is that in the Northern Hemisphere, the **Coriolis Force** “pushes” objects to the right, and in the Southern Hemisphere the Coriolis Force “pushes” objects to the left. This force is related to the Earth’s rotation, and only works on large-scale systems, like ocean basins and the atmosphere. The direction water swirls as it goes down a sink is not influenced by the Coriolis Force. Since the Earth rotates eastward, anything moving in the Northern Hemisphere is deflected to the right, and in the Southern Hemisphere it is deflected to the left.

Wind Force

Wind is an integral part of maintaining many global processes, from heat transport to air and water motion. Think about waves!! How does the wind interact with water? Imagine you are sitting on a sandy beach with a flat surface. You run your hand over the very surface of the sand. Friction is created between your hand and the sand, and the sand grains move as your hand pushes them along. If you repeat this motion in the same spot, you will develop a pile of sand in one spot and a hole in another. When wind passes over water friction occurs, just like with your hand on the sand, and the wind is able to push the water. This pushing by the wind also stacks water up in one location and leaves a hole in another. The hole does not remain for long, as water from other areas rushes in to fill it.

Mass Water Transport

The overall movement of water depends on: 1) the hemisphere, 2) the wind direction, and 3) the Coriolis Force. The figure below shows a picture off the west coast of South America. The wind (pink arrow) is blowing to the north, and due to the Coriolis Force the mass water transport (blue arrow) is to the left, or in this case to the west. The opposite occurs off the California coast, where the wind blows to the south, and water moves to the right. In both of these situations, water is being pushed away from the coast which creates **upwelling**. Would you expect there to be more or less phytoplankton in these regions of the ocean? Why?