BIOS Explorer

Too Much of a Good Thing

Objectives:

- Students will test the effect of nutrients on algae growth in water.
- Students will learn the major nutrients that are required by photosynthesizing organisms.
- Students will learn how nutrient amounts vary throughout the ocean and how this affects marine ecosystems.

Materials:

- Water (tap water will do, but you can also experiment with water collected from local freshwater ponds)
- Petri dishes or test tubes (flower / rose vials work well)
- Parafilm or plastic wrap
- Incubator (or location with constant temp around 25 degrees C like sunny windowsill)
- Copper Sulfate (available at fish and pet stores)
- Miracle Gro or other sources of nutrients
- Ammonia (NH_3/NH_4^+) Test strips
- Nitrite (NO_2) test strips

Procedure:

Preparation: Students should read the background information (below) and visit websites (links provided) to learn about nutrients in the ocean.

1. Whole group activity: "**<u>KWL</u>**" – Students share what they **<u>K</u>**now and what they **<u>W</u>**ant to know about nutrients in water-based systems (and later will share what they have **<u>L</u>**earned). Students then write up ideas for possible experiments. For example:
   "What fertilizer makes algae grow faster?"
   "Does fresh water or saltwater algae grow faster?"
   "How much copper will kill marine plants?"

2. Inquiry Activity / Scientific Method: In small groups, students choose 1 question to investigate, and will write an experimental procedure, using correct scientific language including the terms; "control", "variable", "hypothesis", "method" etc.
   Possible variables to test (ideas to help them get creative!) include the amount of fertilizer added, amount of trace metals added (copper, iron), pH of the water, temperature of the water, type of algae added.

3. Standard (model) procedure:
    - Fill 5 test tubes with sample water (tap or pond water)
    - Label each test tube 1-5: one should be the "control".
    - Using a clean pipette, add increasing amounts of Miracle Gro or other fertilizer to test (i.e. tube 2 gets 1 drop, tube 3 gets 3 drops, tube 4 gets 10 drops)
    - Incubate the test tubes or leave them on a sunny windowsill. Students should make daily observations and record their observations in science journals.
    - After one or two weeks (or when algal growth is obvious) make qualitative observations of the level of growth in each test tube.

4. Each group presents their results as a scientific paper, poster or online journal. Digital pictures of each sample can be used to express qualitative results visually. Included in the presentation should be a discussion that includes:
    i. Was their hypothesis proven?
    ii. Were there any surprise results?
    iii. What would they do to improve accuracy or scientific methodology?
    iv. How do their experiment and results connect with the real world and health of the ocean environment?

Further Discussion Questions:

1. Which tubes exhibited the most growth? The least growth?
2. What affect did the copper sulfate have on algal growth?
3. What are natural sources of nutrients in ocean water?
4. Where do we find naturally nutrient poor ecosystems? Why?
5. Where do we find naturally nutrient rich ecosystems? Why?
6. What are the manmade sources of nutrients as nitrogen, phosphorous or copper in ocean water? Do you think these greatly affect algal growth in the ocean?
7. How can a large input of nutrients disrupt an ocean ecosystem?
8. How might the availability of nutrients in the ocean affect the global carbon cycle?
9. Will unlimited nutrients lead to unlimited plant growth? Why or why not?

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Background: Too Much of a Good Thing?

Phytoplankton are at the base of what scientists refer to as oceanic biological productivity, the ability of a water body to support life such as plants, fish, and wildlife.

Phytoplankton, like all plants, photosynthesize; they use **energy from the sun** to convert **carbon dioxide** and **nutrients** into complex organic compounds, which form new plant material. In the process of photosynthesis, phytoplankton release **oxygen** into the water. Half of the world's oxygen is produced via phytoplankton photosynthesis. The other half is produced by terrestrial plants such as trees and grasses.

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

The overall equation for photosynthesis is deceptively simple. In fact, a complex set of physical and chemical reactions must occur in a coordinated manner for the synthesis of carbohydrates, which is beyond the scope of this lab.

Plants are able to utilize the energy from the sun due in part to the presence of **chlorophyll** in their systems. Chlorophyll is a **pigment** found in almost all plants, algae, and cyanobacteria. A pigment is any substance that absorbs light, and thus chlorophyll is the molecule that absorbs light from the sun and uses the light's energy to synthesize carbohydrates from carbon dioxide and water in the photosynthetic process. The color of the pigment comes from the wavelengths of light reflected (in other words, those not absorbed). Thus, chlorophyll, the green pigment common to all photosynthetic cells, absorbs all wavelengths of visible light except green.

All organisms require some combination of **nutrients**, or nourishing substances, in on order to survive or grow. For plants, there are 17 essential nutrients:

- 3 primary macronutrients: nitrogen, phosphorus, and potassium.
- 3 secondary macronutrients calcium(Ca), sulphur(S), magnesium (Mg).
- the macronutrient Silicon (Si),
- and micronutrients or trace minerals: boron (B), chlorine (Cl), manganese (Mn), iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), nickel (Ni), selenium (Se), and sodium (Na).

A nutrient is considered essential if it is able to limit plant growth according to **Liebig's law of the minimum**, which states that growth is controlled not by the total of resources available, but by the scarcest resource or **limiting factor**.

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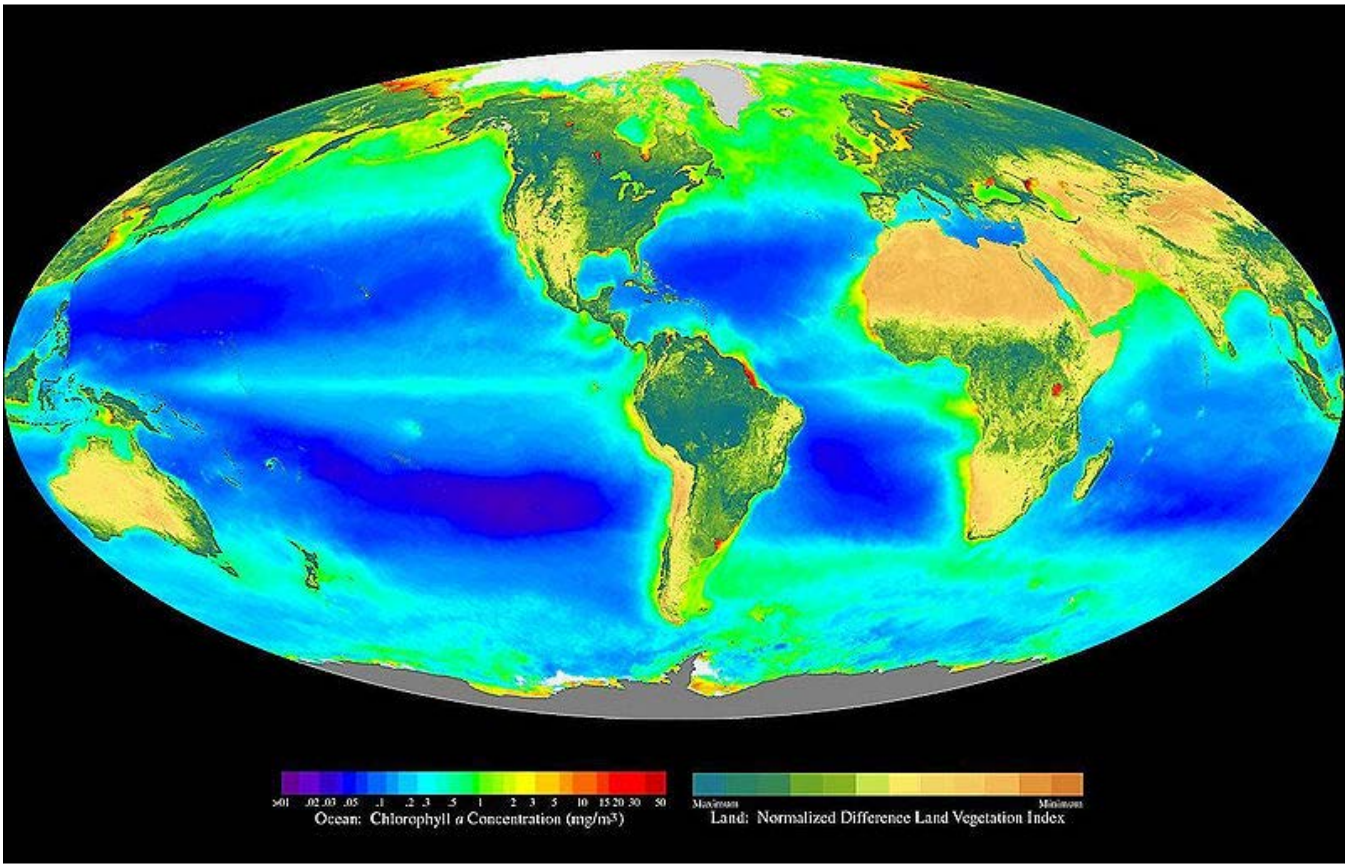
In coastal waters two nutrients, nitrogen and phosphorus, are typically present in such low concentrations that they prevent full growth and thus are the limiting factor. In the remote open ocean iron and other trace metals can also be scarce. Cold waters are richer in nutrients than warmer waters because the water molecules move more slowly than they do in warmer waters, allowing more dissolved gases to stay dissolved. Warmer waters, like the waters immediately around Bermuda thus tend to be the 'deserts' of the sea; few nutrients means little plant and thus animal life. This lack of nutrients and life does , however, mean there is little in the water to 'block the view' and therefore clearer waters.



Lack of nutrients in plants can cause condition known as **chlorosis**, the inability to produce enough chlorophyll. Without enough chlorophyll, the affected plant is often unable to manufacture carbohydrates (its food) through photosynthesis and may die. Chlorosis has been seen to occur in plants that are not receiving enough nutrients including iron, copper, and nitrogen.

Eutrophication is the process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates. These typically promote excessive growth of plant life, especially algae. As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen (make it **anoxic**), causing the death of other organisms, such as fish. For a marine ecosystem, the rapid growth of plant populations can also cloud the water and limit light penetration, thus affecting photosynthesizing populations below them and possibly changing water temperatures. Eutrophication takes place in all marine and aquatic ecosystems and is responsible for green scummy layers of algae that you see covering ponds and streams.

One of the most dramatic effects of these population explosions due to excess nutrient input occurs in coastal waters. When an upwelling (cold water rising from the seafloor) or land runoff (such as water containing agricultural fertilizers) causes an increase in nutrient levels in the coastal waters, it triggers a 'bloom" of the photosynthetic plankton called dinoflagellates. The pigments in the these plankton make the water appear golden or red, and thus we call these events a **'red tide.'** Some of the species of dinoflagellates produce toxins, and when these toxic species are in bloom conditions they can cause mass mortalities in a variety of marine organisms. The toxins also can be quickly carried up the food chain and indirectly passed onto humans via fish and shellfish consumption, sometimes resulting in gastrointestinal illness, permanent neurological damage, or even death

Coral reefs have evolved in the lowest nutrient environment in the world, where plant life often consume all available nitrogen and phosphorus, at which point new growth is limited to rates at which these elements are provided by decomposition of dead organisms. Tiny increases in nutrients above this low level are probably beneficial to corals, but it takes only very small increases for the effect to turn negative. This is not because high nutrients harm corals directly, but because corals are quickly smothered by much faster growing algae which need higher nutrient levels than corals.

In this lab, we will be testing the impact of several nutrients on algae growth in water.

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Cambridge Standards

Year 5:

Scientific Enquiry

Ideas and Evidence in Science

5Si1 Scientists have combined evidence with creative thinking to suggest new ideas and explanations for phenomena

Plan Experimental Work

5Sp2 Use knowledge and understanding to plan how to carry out a fair test or how to collect sufficient evidence to test an idea

5Sp3 Identify factors that need to be taken into account in different contexts

Obtain and Present Evidence

5So1 Make relevant observations

Consider Evidence and Evaluate

5Sc1 Decide whether results support predictions

5Sc3 Recognize and make predictions from patterns in data and suggest explanations using scientific knowledge and understanding

5Sc4 Interpret data and think whether it is sufficient to draw conclusions

5Sc5 Draw conclusions indicating whether these match any prediction made

Biology

Plants

5Bp1 Plants reproduce

Year 6:

Scientific Enquiry

Ideas and Evidence in Planning

6Si1 Consider how scientists have combined evidence from observation and measurement with creative thinking to suggest new ideas and explanations for phenomena

Plan Experimental Work

6Sp1 Decide how to turn ideas into a form that can be tested

6Sp2 Make predictions using scientific knowledge and understanding

6Sp3 Identify factors that are relevant to a particular situation

6Sp4 Choose what evidence to collect to investigate a question, ensuring that the evidence is sufficient

Obtain and Present Evidence

6So1 Make a variety of relevant observations and measurements using simple apparatus correctly

Consider Evidence and Evaluate

6Sc1 Make comparisons

6Sc3 Identify patterns in results and results that do not appear to fit the pattern

6Sc4 Use results to draw conclusions and to make further predictions

6Sc5 Suggest and evaluate explanations for predictions using scientific knowledge and understanding

6Sc6 Say whether the evidence supports any prediction made

Biology

Ecosystems/Environment

6Be1 Food chains can be used to represent feeding relationships in a habitat

6Be2 Food chains begin with a plant (the producer)

Year 7:

Scientific Enquiry

- Suggest ideas that may be tested.
- Outline plans to carry out suitable investigations, including a fair test.
- Make predictions using previous knowledge.
- Identify things to be measured, choose appropriate apparatus and use it correctly.
- Make careful observations.
- Make conclusions from collected data.
- Recognise results and observations that do not fit into a pattern.

Cells and Organisms

- Identify the structures present in plant and animal cells as seen with a simple light microscope. Bc2
- Compare the structure of plant and animal cells. Bc2
- Relate the structure of some common cells to their functions. Bc2

Ecosystems

- Describe how organisms are adapted to their habitat. Be1
- Draw simple food chains. Be2

States of Matter and Physical Change

- Recognize a mixture and a solution. Cm3 Cs3

Materials

- Distinguish between metals and non-metals. Cm4

Physics

Measurement and Properties of Matter

- Choose the appropriate apparatus for measurement. Pp1
- Use apparatus carefully and accurately. Pp1

Year 8:

Scientific Enquiry

- Select ideas that can be tested.
- Plan investigations to test these ideas.
- Make predictions using scientific knowledge.
- Identify important variables and choose which variables to vary.
- Take accurate measurements.
- Identify trends and patterns in results.

- Compare results with predictions.
- Identify anomalous results and suggest improvements to investigations.
- Interpret qualitative data from secondary sources.

Chemistry

Materials

- Describe and explain the differences between metals and non-metals. Cm4
- Describe chemical reactions which are not useful e.g. rusting. Cc2

Year 9:

Scientific Enquiry

- Choose ideas and produce plans for testing based on previous knowledge and research.
- Use preliminary work to decide how to carry out an investigation.
- Decide which measurements and observations are necessary.
- Use appropriate sampling techniques where required.
- Choose the best way to present results.
- Describe patterns seen in results.
- Interpret results using scientific knowledge and understanding.
- Evaluate the methods used and use this to refine methods for further investigations.
- Compare methods and results used by others.
- Look critically at sources of secondary data.

Biology

Plants

- Explain the process of photosynthesis. Bp2
- Understand the importance of water and mineral salts to plant growth. Bp3

Ecosystems

- Explain ways in which living things are adapted to their habitats. Be1
- Explain food chains, food webs and energy flow. Be2
- Describe factors affecting the size of populations. Be3
- Describe some effects of human influences on the environment. Be4