

Chemistry Connection

Created by Sara Heintzelman, Interdepartmental Graduate Program in Marine Science
University of California Santa Barbara

Supported by:

The Santa Barbara Coastal Long Term Ecological Research Project (SBC-LTER)
funded by the National Science Foundation OCE-9982105
and the
The Marine Science Institute,
University of California Santa Barbara



Santa Barbara Coastal Long Term Ecological Research Project



The National Science Foundation



California Department of Education Science Standards

6th Grade

- Ecology (Life Science)
 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.
 - a. Students know energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs.
 - b. Students know matter is transferred over time from one organism to others in the food web and between organisms and the physical environment.
- Investigation and Experimentation
 7. Scientific progress is made by asking meaningful questions and conducting careful investigations.
 - a. Develop a hypothesis.
 - b. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
 - d. Communicate the steps and results from an investigation in written reports and oral presentations.

7th Grade

- Investigation and Experimentation
 7. Scientific progress is made by asking meaningful questions and conducting careful investigations.
 - a. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
 - b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.
 - c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
 - d. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge.
 - e. Communicate the steps and results from an investigation in written reports and oral presentations.

8th Grade

- Structure of Matter
 3. Each of the more than 100 elements of matter has distinct properties and a distinct atomic structure.
 - a. Students know the structure of the atom and know it is composed of protons, neutrons, and electrons.

- b. Students know that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements.
 - f. Students know how to use the periodic table to identify elements in simple compounds.
- Chemistry of Living Systems (Life Science)
 - 6. Principles of chemistry underlie the functioning of biological systems.
 - a. Students know that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.
 - b. Students know that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.
 - c. Students know that living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.
- Periodic Table
 - 7. The organization of the periodic table is based on the properties of the elements and reflects the structure of atoms.
 - b. Students know each element has a specific number of protons in the nucleus (the atomic number) and each isotope of the element has a different but specific number of neutrons in the nucleus.
- Investigation and Experimentation
 - 9. Scientific progress is made by asking meaningful questions and conducting careful investigations.
 - a. Plan and conduct a scientific investigation to test a hypothesis.

Chemistry Connection Instructions

In this lesson the students will learn how and what algae “eat”. This hands-on lab activity has four stations (Adsorption, Passive Transport, Facilitated Diffusion, and Active Transport) each focusing on one way that algae obtain the nutrients they need to survive. Students have guiding questions to help them focus as they work their way through this fun and messy lab. The students will not only learn the four transport mechanisms, they will actually experience them; allowing them to see the important connections between chemistry and biology.

Objectives:

* The students will learn the basic nutrient requirements of algae including types of nutrients and uptake methods.

* The students will learn fundamental chemistry principles as they relate to algal biology.

Specifications:

- The students will learn which macronutrients and micronutrients algae require for growth.
- The students will learn the basic concept of an atom, the parts of an atom, and the idea of ions (both anions and cations).
- The students will be able to calculate the charge on an atom when given the number of neutrons, electrons and protons.
- The students will learn the 4 main methods of nutrient transport into an algal cell: adsorption, passive transport, facilitated diffusion, and active transport.

Materials: Chemistry Connection Worksheet (1 copy per student), soap and newspaper (newspaper not supplied, but it is highly recommended to cover tables with newspaper before lab activity as it gets messy!)

- Station 1: Adsorption:* 3 pairs of magnets (1 pair at each station) with + and – charges labeled (** Please remind students to be gentle with the magnets; they are ceramic and will break if students are rough with them**).
- Station 2: Passive Transport:* 3 plastic containers, 1 at each station (1 small Rubbermaid and 2 large plastic containers- box 1 and box 2 which normally hold supplies), and 3 small food coloring bottles (1 at each station).
- Station 3: Facilitated Diffusion:* 6 plastic bottles (2 at each station- 1 filled with vegetable oil and 1 filled with water with food coloring added), 3 small Tupperware containers (1 at each station and fill about halfway with water), and 3 straws (1 at each station).
- Station 4: Active Transport:* 1 balloon for each student.

Activity: (approximate time: 50 minutes)

- Have the students read the 1st 2 pages of the Chemistry Connection Worksheet and answer the questions on those pages prior to the lab activity (either as homework or in class the day before). If your students don't read the 1st 2 pages previous to the lab activity, the activity will take longer than 50 minutes.

- In class before beginning the lab activity, assign each group to a station and have them read the directions for that activity and report back to the rest of the class on what to do at that station. Alternatively, you could go over the directions for all 4 stations as a group.
- There are enough supplies to set up 3 copies of each of the 4 stations (12 in total). Depending on the number of students in your class you may choose to set up all 3 copies of each or less depending on your needs. Decide how your students will rotate through the stations (it is recommended that they work in groups of 3-4).
- It is highly recommended that you cover the tables/countertops where lab activities will be taking place with newspaper (the vegetable oil gets messy). Soap is provided in the kits for students to get oil off of their hands (you may want to ask them why the oil won't come off with just water to get them thinking more about hydrophobic substances).
- Station 4: Active Transport uses balloons. It may be best to not set up this station and instead have the students rotate through stations 1-3 and then all do station 4 as a class (students seem to get very excited about balloons!).

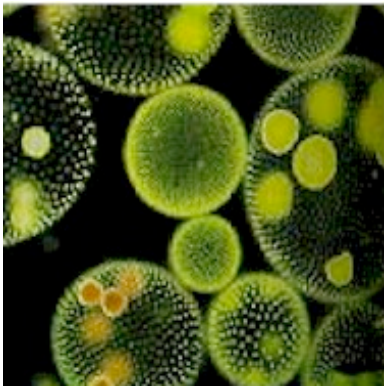
Name _____ Period _____

Chemistry Connection Worksheet

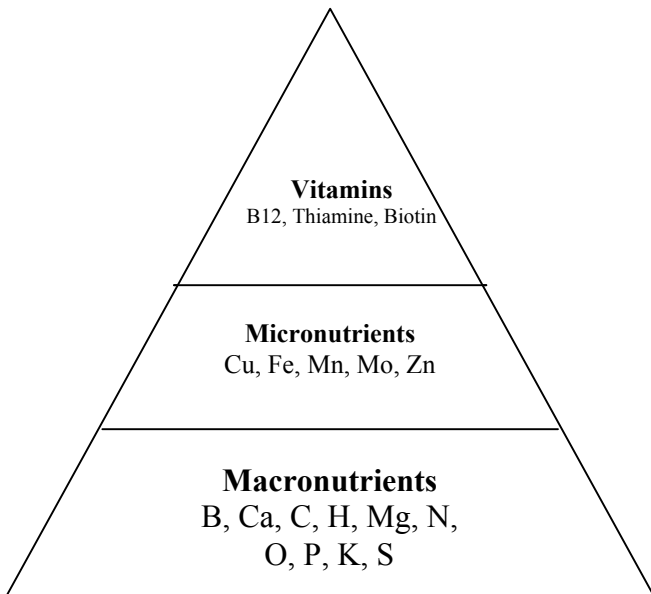
Nutrients

Every living organism needs to eat to stay alive, what they eat and how they eat it is going to vary a lot though! I'm sure that all of your parents have encouraged you to eat more fruits, veggies, and "healthy" food instead of eating junk food like candy and desserts. You are also probably familiar with the food pyramid, describing how many servings of each food group you should eat every day. Algae have their own food pyramid, and while they aren't eating sandwiches and fruit, they do have their own nutrition requirements. Food for algae falls into two major categories: macronutrients and micronutrients. Macronutrients are the "food" that the algae need a lot of while they tend to need less of the micronutrients.

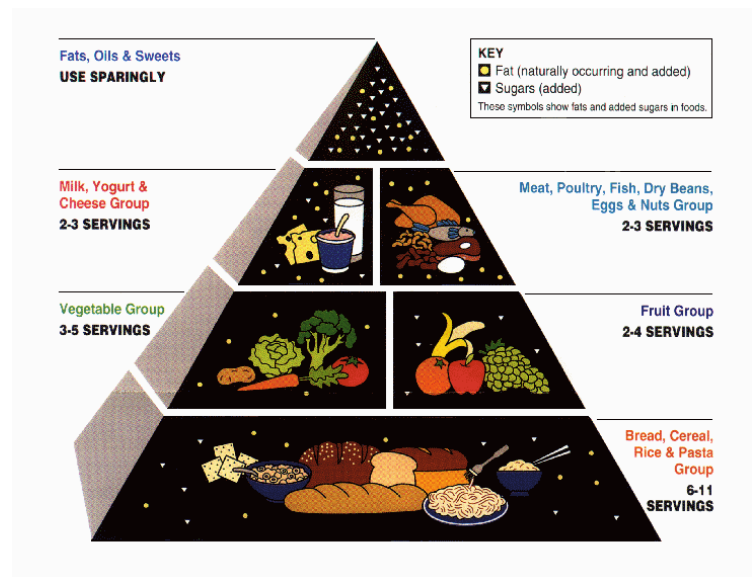
Algae Nutrients



Macronutrients	Micronutrients
Boron (B)	Copper (Cu)
Calcium (Ca)	Iron (Fe)
Carbon (C)	Manganese (Mn)
Hydrogen (H)	Molybdenum (Mo)
Nitrogen (N)	
Oxygen (O)	Vitamins
Phosphorus (P)	B12
Potassium (K)	Thiamine
Sulfur (S)	Biotin



The Algae Food Pyramid



The Human Food Pyramid

Limiting Nutrients

Do you remember when we talked about limiting factors? We defined limiting factors as any abiotic or biotic factor that restricts the number of individuals in a population. An example is houses. If there are no more houses for sale and no land to build more houses on in a town; the population of that town cannot increase. In this case, housing would be a limiting factor. Nutrients can be a limiting factor as well. If you didn't have food to eat, you wouldn't be able to grow- in fact it could lead to death. In this case, nutrients would be the limiting factor, limiting your growth.

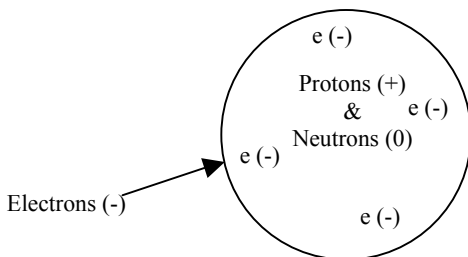
Algae frequently face a problem of having limited nutrients. Nitrogen (N), phosphorus (P), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), and carbon (C) have all been shown to limit algae growth in different situations. The first two nutrients, nitrogen and phosphorus, limit algae growth most regularly.

Do you remember any products that might put these nutrients (nitrogen and phosphorus) into the aquatic environment? Write your answer below:

Car soap, fertilizer, animal waste

Algae food isn't quite like human food....

You may have noticed that the type of food algae eats is really different than what we eat. Instead of eating a nice slice of pizza, algae enjoy some yummy nitrogen! The favorite foods of algae, such as nitrogen and phosphorus, are all elements that you might be familiar with from the periodic table of elements. Each element on the periodic table is made up of three parts: protons, neutrons and electrons. Protons have a positive charge, neutrons have no charge and electrons have a negative charge. Protons and neutrons make up the core of the element and are surrounded by the electrons. Usually the number of electrons is equal to the number of protons so the element has no charge. Sometimes though, an element may either lose or gain electrons and this will give it a charge. When an element has a charge, it is called an ion. It can gain a positive charge, which makes it a cation, or it can gain a negative charge, making it an anion.



Ions

6 protons (+) & 6 electrons (-) = no charge

6 protons (+) & 5 electrons (-) = +1 charge (cation)

6 protons (+) & 7 electrons (-) = -1 charge (anion)

Practice Questions:

1. Nitrogen (N) normally has 7 protons $+$ and 7 electrons $-$. It loses 1 electron, calculate its charge and indicate if it is negative or positive:

positive one

2. Phosphorus (P) normally has 15 protons and 15 electrons. It gains 1 electron, calculate its charge and indicate if it is positive or negative:

negative one

How do Algae “Eat” their Nutrients?

When you need some nutrients, you might make a sandwich or go to the store and get something that is already made. You take bites of it, digest it, and voila: your body gets nutrients! All of the nutrients that algae need are found in the water around them, but how do they “eat” them? How do they get the nutrients from the water into their cells?

There are 4 ways that algae take nutrients into their cells:

1. Adsorption
2. Passive Transport
3. Facilitated Diffusion
4. Active Transport

Activity: You and your group will visit 4 lab stations, at each one there will be an activity and some questions that you need to answer. You will rotate through each station and learn about the 4 ways that algae take nutrients into their cells.

Station 1: Adsorption

Have you ever heard the phrase “opposites attract”? Well that is basically what is happening in the case of adsorption. There are certain negatively charged molecules (such as proteins with sulfate, carboxyl, and phosphate groups) which are found in the cell wall of algae. When a cation (a positively charged ion) tries to enter the cell, it gets trapped by these negatively charged molecules because the negative charge and the positive charges attract one another. One cation that algae needs is the sodium ion (Na^+), it has a charge of +1 and the negatively charged molecules in the cell wall are going to try and grab it and use it to neutralize their charge (+1 and -1 = 0 charge). Most things want to be neutral if they can, that is their most comfortable condition.

Question 1: Do you think 2 positive charges would attract or repel? How about 2 negative charges? Answer below

They would repel because they are both positives or negatives

Activity: See for yourself! Magnets have a positively charged end and a negatively charged end. Using the magnets at your station, what happens when you try to put 2 positively charged ends together? (Please be gentle with the magnets, they break easily!)

They repel

What happens when you try to put 2 negatively charged ends together?

They repel

What happens when you put 1 positively charged end with 1 negatively charged end?

The two ends are attracted to each other and thus come together

Which of these 3 set-ups (2 positive charges, 2 negative charges or 1 positive and 1 negative charge) is most like adsorption? Circle your answer.

Question 2: If you had a sodium ion (Na^+), which of the following would it probably want to combine with?

- a) Carbon (C, charge = 0)
- b) Chlorine (Cl^- , charge = -1)
- c) Oxygen (O, charge = 0)

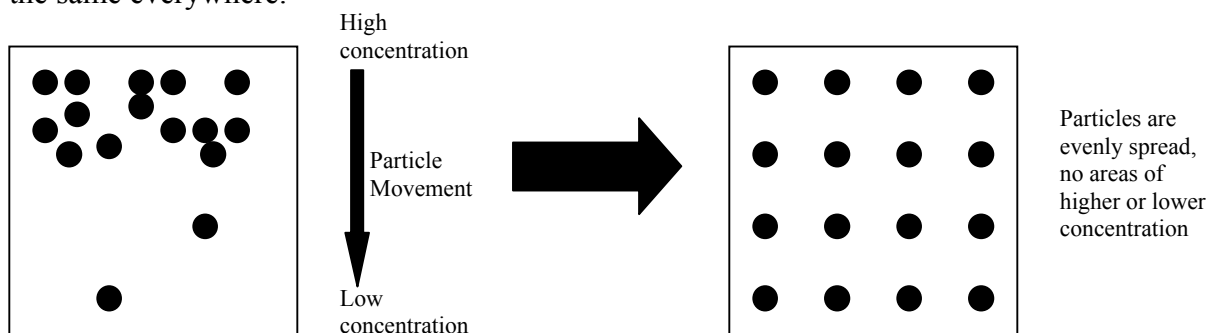
Question 3: Lead (Pb) is often added to aquatic environments as a result of pollution (burning fossil fuels releases lead into the air and it reaches the earth when it rains). Lead is a positively charged metal and is adsorbed by algae cells. Lead can poison humans, what do you think its affect on algae is? Adsorption usually happens quickly, would fast uptake of lead be bad for algae?

The algae would be instantly killed

Station 2: Passive Transport

Have you ever heard the word diffusion before? Diffusion is the tendency for chemicals or elements to spread out from areas of high concentration so that concentration becomes equal over a given area. Chemicals diffuse, so do people! Think about a crowded beach during the summer. A lot of people arrive at the beach at one small area (where there is a parking lot or where a path leads down to the beach); do they all stay clumped together right at the entrance? Not usually, normally they spread out. People want to leave the area where it is really crowded and go to an area where there are less people.

The trend that you see with people and with particles is the same; you see movement from areas of high concentration to areas of low concentration until the concentration is the same everywhere.



Activity: Your group is going to carefully add 5 drops of food coloring to your container of water, make sure to put them all in at the same place. Watch what happens after you add the food coloring and write down any observations.

Slowly spreads, yet does not combine together

Question 1: Where is the concentration of the food coloring the highest when you first added the drops?

The highest concentration is where the color was dropped

Question 2: Does the food coloring stay where you first added it to the water? If not, where does it go?

It tends to move out around itself

What you saw happening was diffusion. Nutrients can diffuse into a cell if the concentration of that nutrient is lower inside of the cell than it is outside of the cell (remember, the nutrients don't like to be crowded!). Waste products from the cell can also diffuse out of the cell.

Question 3: Do you think it would be easier for a particle with a neutral charge or a particle with a positive or negative charge to diffuse in or out of a cell? Why?

Neutral because it is the most comfortable condition

Station 3: Facilitated Diffusion

This is the same idea as the diffusion that we just talked about, the main difference is that facilitated diffusion is faster than the diffusion we talked about at Station 2.

Fill in the blanks: Diffusion is movement from areas of high concentrations to areas of low concentration.

Sometimes nutrients need a little help to diffuse into the cell, when they get this help it is called facilitated diffusion. The cell membranes of algae cells are made up of a lipid bilayer (lipid= fat, bilayer= 2 layers).



This part (the head) is hydrophilic. Hydro = water, philic = love
So hydrophilic = loves water



This part (the tail) is hydrophobic. Hydro = water, phobic = fear
So hydrophobic = afraid of water



The hydrophobic part of this membrane is a barrier for charged nutrients (ions), so how do they get through the membrane and into the cell? They need some help!

Activity 1:

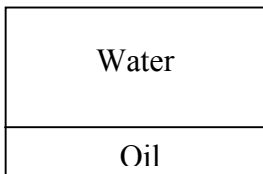
Question 1: Can you think of anything that is hydrophobic (afraid of water)? If you can write your answer here: oil

Question 2: How do you know it is “afraid” of water? What does it do that shows you that? ***The water does not dilute the oil, instead it sits at the surface***

Pour a small amount of oil into your container of water.

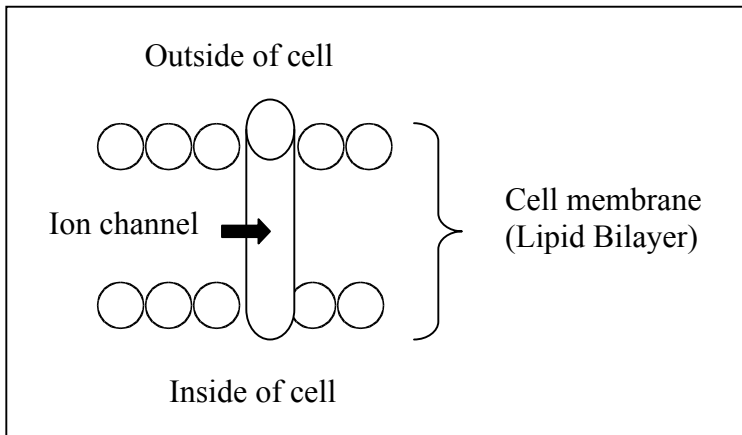
Question 3: What does it do? If you stir the container can you get the oil to mix with the water? Describe what happens: ***the oil went from a big mass into tiny parts***

It would be difficult to get your oil to stay at the bottom of the water:



How would you do this? If you think of the top of the container as the surface of an algae cell, and the bottom of the container as the middle of the algae cell (where it wants to get nutrients), you see the problem the algae face. So how do they do it?

They can get charged molecules (ions) into their cells two different ways which are both considered facilitated diffusion, the two ways may work together (scientists are trying to figure it out). The first way is by having a carrier. The carrier grabs the ion at the cell membrane and helps it to get inside the cell. This would be like trying to get into a very exclusive club and knowing a member who can help you get in. The second way is through something called an ion channel. An ion channel is a protein that goes through the cell membrane (see picture).



Ion channels will allow charged nutrients to get inside of the cell without being stopped by the lipid bilayer. The nutrients are still diffusing into the cell because their concentration is greater outside of the cell than it is inside of the cell—so they are still moving from areas of high concentration to areas of low concentration. A carrier and an ion channel can work together (the carrier would take the charged molecule through the ion channel).

Activity 2: Carefully pour a little of the colored water on top of the oil. Does it mix with the water below the oil or stay on top of the oil? (Circle your answer).

Now, place your straw so that it goes through the layer of oil and into the water below. Pour a small amount of colored water through the straw. Does it get trapped above the oil like before, or does it reach the water? (Circle your answer)

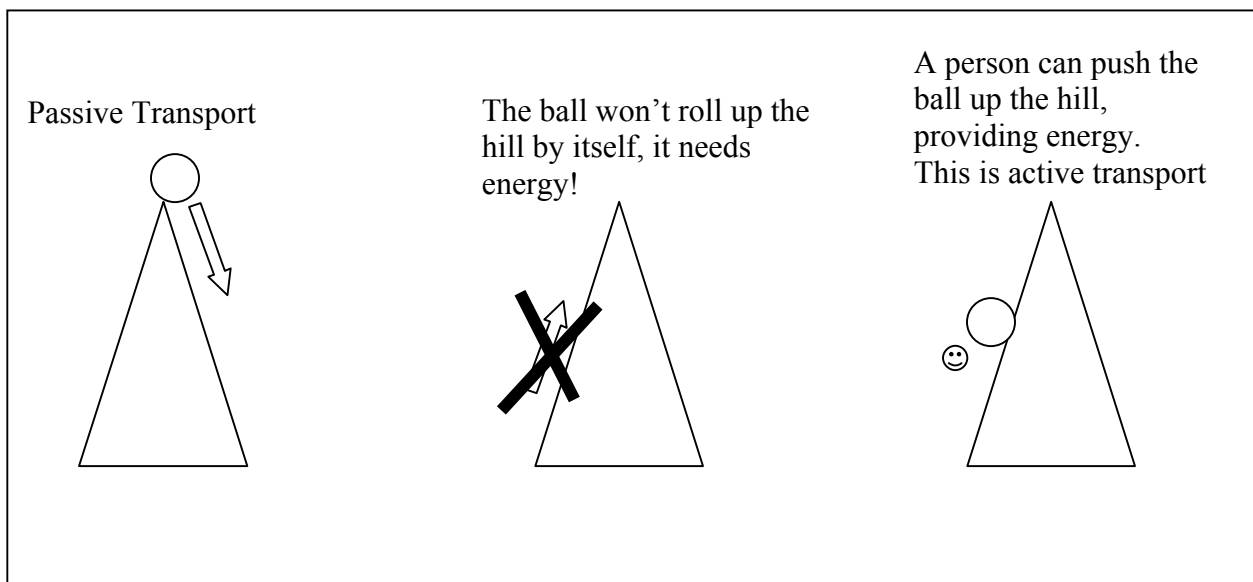
The straw is just like the ion channels, allowing charged nutrients to make it through the membrane and into the cell!

Question 4: What do you think would happen to an alga cell that doesn't have any ion channels? Would it still be able to get the nutrients it needs or would it starve?

The algae would starve or die

Station 4: Active Transport

Active transport is different from the other three methods of nutrient transport because it requires energy in order to get the nutrients into the cell. It forces nutrients from areas of low concentration into areas of high concentration (and remember; nutrients don't like to be crowded!). The other three methods of nutrient transport can be thought of as downhill processes: a ball balancing at the top of a hill is naturally going to roll down the hill, but a ball at the bottom of a hill definitely won't roll up the hill by itself! In this example, active transport is the process of pushing the ball up the hill; it takes energy.



Activity: Your group has several balloons at your station.

Question 1: Do you think the concentration of air is greater inside of the balloon, outside of the balloon or is it equal inside and outside of the balloon? Circle your answer.

Question 2: If you were to blow up the balloon, you would be increasing the concentration of air inside of it. Would this take energy? Yes or No (circle your answer)

Question 3: Does a balloon ever spontaneously fill up with air? Why or why not?

No, because it takes energy to become filled with air

Question 4: If you blow up a balloon and you do not tie the end, does the air want to stay inside of the balloon or does it want to come out? Why?

It wants to come out because of diffusion, meaning the air wants to go to a lower concentrated area

Everyone in your group should take a balloon and blow it up.

Question 5: Is it easier to blow it up when you first start, or when the balloon starts to get very full? Why do you think that is the case? ***It is harder in the end because there is less room***

Carefully (please don't let your balloon go zooming out of control!), let a little air out of the balloon.

Question 6: Is it easier to get the air out of the balloon than it was to put the air into the balloon? Yes or No (circle)

Does it take energy? Yes or No (circle)

Question 7: Which of the 4 transport methods (adsorption, passive transport, facilitated diffusion or active transport) brings the air out of the balloon? Circle your answer.

Question 8: Draw the concentration of air particles (just draw them as dots, lots of dots for high concentration and just a few dots for low concentration) you think are in the balloon and outside of the balloon in each situation below:

Empty Balloon	Inflated Balloon	Balloon Losing Air

Question 9: Zinc (Zn) is a metal and a micronutrient that algae need to survive, however algae only need low concentrations of zinc and if the concentrations get too high, zinc can actually become toxic to the algae and poison them! Zinc is brought into alga cells by active transport. Why do you think algae would continue to bring zinc into their cells when the concentration of it gets high enough to be toxic? Can they control it?

The algae can not control the intake of the zinc, it is just like breathing, it is an involuntary action

Conclusion: Hopefully you have learned something about how another type of organism “eats” their food. Even though algae don't go to the fridge and make a sandwich, they still have to get nutrients everyday just like us! So, the next time you are eating lunch, think about all of the algae “munching” on nitrogen, phosphorus, carbon and all of the other macro and micro nutrients they like so much.

Chemistry Connection References

Images:

All images without a reference are from Microsoft Clipart.

1. Algae: <http://pearl.spatial.maine.edu/pictures/glossary/ALGAE.jpg>
2. Food Pyramid: <http://www.nalusda.gov/fnic/Fpyr/pyramid.gif>
3. Kelp: http://www.vibrantsea.net/kelp33_channel1.htm

Information:

Glencoe Science Voyages: Life and Physical Sciences. 2001. Glencoe/ McGraw-Hill, New York.

Lobban, C.S. and P.J. Harrison. 1997. Seaweed Ecology and Physiology. Cambridge University Press, New York.

Purves, Orians, Heller and Sodava. 1998. Life: The Science of Biology, 5th Edition. Sinaur Associates, Inc. Sunderland, MA.