Solving the Mystery of Lake Nyos

A Case-based Unit for Photosynthesis and Cellular Respiration

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Introduction to Teachers

This unit uses a fictionalized story based on a real incident in Cameroon, West Africa as a means of instruction for photosynthesis and cellular respiration. Eight sequential, inquiry-based, hands-on experiments are provided to build student knowledge of photosynthesis and cellular respiration through discovery. A bank of assessment questions, from which the educator may choose, accompanies the unit as well.

Photosynthesis and cellular respiration are traditionally covered in all High School Biology courses. These are difficult concept for most students to comprehend. The difficulty encountered by students lies in their inability to relate the importance of the chemical reactions of photosynthesis and cellular respiration to living systems. This case "Solving the Mystery of the Killer Lake" uses a fictionalized story, about a real incident in Cameroon, West Africa in 1986 as a vehicle for instruction in these two biochemical pathways. By reading the story then exploring the topic through on-line resources, coupled with hands-on experiments in the laboratory, students should achieved a real-world, concrete understanding of the biological processes of photosynthesis and cellular respiration.

"Solving the Mystery of Killer Lake" is a multidisciplinary unit that covers a variety of topics through out the course of the story. The topics include:

- Photosynthesis
- Cellular Respiration
- Lake Stratification
- Density
- Role of Microorganisms in Carbon cycling
- Volcanism
- Water quality

The eight laboratory experiments provided by this unit utilize these different topics in a logical and sequential nature. Students read the story first to establish some knowledge of the importance of photosynthesis and cellular respiration in the natural environment. Guiding questions are provided to help students stay on task and focus on the pertinent scientific points in the story. Then students should work through all or some of the inquiry based hands-on experiments to build the necessary content knowledge which is linked to the national scientific standards. "Solving the Mystery of Killer Lake" is designed in such a way to allow its implementation to be flexible. The educator may choose to implement all aspects of the unit or just one or two specific concepts, according to her own educational expectations. Additional web sites are provided for students who wish to explore this topic further.

Lake Nyos is undergoing continual study by the scientific community in hopes of preventing another disaster such as the one that occurred in 1986. We believe the study of the unique lake to be an interesting and unique basis for teaching students the importance of photosynthesis and cellular respiration in the natural world.

How To Implement this Unit

Initially, students should read the story, explore the on-line resources, and complete the guided questions on the topics of photosynthesis and cellular respiration. Answering the guided questions helps students stay on task during this exercise and ensures that readers focus on the pertinent scientific points discussed in the story.

The final chapter of the story is password protected. This is to ensure that after students have read about the history of the Lake Nyos incident and some of the findings following the explosion, they have a chance to hypothesize about what caused the disaster. Teachers should encourage students to discuss about what they think occurred to cause this natural disaster using the information provided in the links. Following the discussion students can be provided with the password "nyos" and read the final installment which explains how photosynthesis and cellular respiration functioned in this geologically unique lake to cause an explosion.

Depending on the computer availability in the educators' classroom the following strategies are suggested for the implementation of the story:

- If you have enough computers for groups of 1-3, each student can read the story up until the last frame. As students read the story they should discuss and answer the guided questions in their groups. Have students discuss what they think happened at Lake Nyos before providing them with the password (limnicquake) to read the final installment.

- Jigsaw II Method – Separate students into groups of 4-5 with one computer per group. Each student is assigned a specific role: reader, recorder, computer user, etc. The user logs onto the site, the reader reads the story out loud to the group and the recorder summarizes the pertinent information. Each group is assigned one section of the story and become experts in that section. The groups then reconfigure with one expert in each section assigned to each one of the new groups. The students then piece the story back together and answer the guided questions. From this point on the students may remain in their second groups. The educator then prompts each group to hypothesize as to the cause of the Lake Nyos disaster. As closure for the unit the groups should be given the password to the last frame of the story (limnicquake). Students should read the scientific explanation of the Lake Nyos disaster and write a summary piece that reflectively evaluates their experimental design and results in comparison to the scientific explanation.
- One computer in the classroom – The story will be available on CD in narrated form. Students can watch the story on CD as they would a video

and answer the guided questions individually or the educator may lead a large group discussion. The educator may then divide the students in to cooperative groups. The educator then prompts each cooperative group to hypothesize as to the cause of the Lake Nyos disaster. As closure for the unit the groups should be given the password to the last frame of the story (limnicquake). Students should read the scientific explanation of the Lake Nyos disaster and write a summary piece that reflectively evaluates their hypothesis in comparison to the scientific explanation.

A set of hands-on laboratory experiments is provided in the teacher notes. These experiments afford students the opportunity to explore and discover the necessary content to solve the mystery of Lake Nyos. Educators should feel free to choose a few or all of the experiments provided depending on their own educational focus.

National Science Education Standards

Content Standard A: Science as Inquiry (9-12)

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science (9-12)

- Chemical reactions
- Interactions of energy and matter

Content Standard C: Life Science (9-12)

- Interdependence of organisms
- Matter, energy and organization in living systems

Content Standard D: Earth and Space Science (9-12)

- Energy in the earth system
- Geochemical cycle

Content Standard F: Science in Personal and Social Perspectives (9-12)

- Natural hazards
- Environmental quality

Project 2061 – AAAS Standards

Flow of Matter and Energy – 8th grade

- Food provides molecules that serve as fuel and building material for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately for fuel or materials or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms.
- Over a long time, matter is transferred from one organism to another repeatedly and between organisms and their physical environment. As in all material systems, the total amount of matter remains constant, even though its form and location change.
- Energy can change from one form to another in living things. Animals get energy from oxidizing their food, releasing some of its energy as heat. Almost all food energy comes originally from sunlight.

Flow of Matter and Energy – 12th grade

- At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide.
- The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going.

Diversity of Life – 8th grade

- One of the most general distinctions among organisms is between plants, which use sunlight to make their own food, and animals, which consume energy-rich foods. Some kinds of organisms, many of them microscopic, cannot be neatly classified as either plants or animals.

- All organisms, including the human species, as part of and depend on two main interconnected global food webs. One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them and so forth. The cycles continue indefinitely because organisms decompose after death to return food material to the environment.

Interdependence of Live – 12th grade

- Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.
- Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution
- Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

Guided Questions for "Solving the Mystery of The Killer Lake"

1. What would the climate be like in the area around Lake Nyos?

2. What kind of geography exists around Lake Nyos?

3. What are the names of the three layers that a lake divides into during warm weather? In what layer does photosynthesis take place?

4. What is the element that can cause a lake to become eutrophic? How would you recognize a eutrophic lake?

5. What are three factors necessary for photosynthesis to take place?

6. Why don't most lakes build up an excess amount of Carbon dioxide (CO_2) in the hypolimnion like Lake Nyos does?

Lesson Plan Outline

This unit includes a total of 11 Lesson Plans, each requiring various amounts of time to complete. If all lessons are utilized, this unit could encompass 2-3 weeks of science instruction. Outlines of each lesson follows:

Lessons:	
Graphing Lake Data	Students graph the layers of a lake in summer using light, dissolved oxygen and temperature data to determine the positions of the epilimnion, hypolimnion and thermocline. This activity promotes skills in graphing and data interpretation.
Water Density and Lake Stratification	The density of water changes according to temperature. Students complete an experiment to view how water will divide into layers on the basis of temperature. This activity illustrates how lake waters mix as the seasons change.
Gas Solubility	This is a demonstration to get students thinking about how temperature affects gases dissolved in liquids.
Building a Density Column	Students will build a column to evaluate the densities of a variety of objects. This activity calls for students to be able to determine the relative densities of each object in comparison to one another, using their observations.
Density of Gases	This is a demonstration activity which recreates the incidence at Lake Nyos. Students should understand that the concept of density applies to gases, as well as liquids and solids.
Cellular Respiration: Part I	This experiment calls for students to vary the percentage of sugar used in a cellular respiration experiment. The results generated should illustrate that a higher input of carbon (sugar) into the reaction will yield a higher output of carbon (carbon dioxide gas) out of the reaction .

Cellular Respiration: Part II	This experiment has students vary the percentage of yeast in a cellular respiration experiment. This lab illustrates that a living organism (yeast) is required to perform the biochemical pathway and that the number of organisms present directly affect the efficiency of chemical reaction.
Waste Products of Cellular Respiration	Students perform an experiment to determine if the gases they exhale (carbon dioxide) are the same as released by a burning candle.
Photosynthesis: Part I	In this lab, students vary the growing conditions for seedlings. This lab calls for students to design, implement and analyze a scientific experiment to determine the effect of light on growing plants. This activity is useful in teaching the scientific method.
Photosynthesis: Part II	Students will experiment with adult plants, wrapping paper around leaves to determine the effect light has on chlorophyll production.
Photosynthesis Part III	Students will experiment with a culture of algae, one sample exposed to light, one kept in the dark. Using iodine solution, students will test for the presence of starch to determine which culture is undergoing photosynthesis.
Photosynthesis Part IV	Students will test two geranium plants to conclude which plant has been kept in the dark by determining which plant does not contain starch in the leaves.

Lesson Plan #1: Graphing Lake Data

Length of Lesson: One class period

Scientific Processes Addressed: Observing, Calculating, Graphing

Scientific Concepts Addressed: Light filtration, lake stratification, dissolved oxygen, photosynthesis and cellular respiration.

National Standards Addressed: A, B, C

Objectives: Students will:

1. Produce three graphs in the proper format using Microsoft excel.
2. Will obtain experience using technology to graph data.
3. Graph lake data to understand how lakes stratify into three distinctive layers in the summer months.
4. Describe the products of photosynthesis (O_2 + $C_6H_{12}O_6$) and cellular respiration (CO_2 + H_2O).
5. Develop an understanding of how light determines which pathway (photosynthesis or respiration) will dominate in an ecosystem.

Materials:

Microsoft Excel
Data table (students can generate their own data for this lab)
Graph paper (for those classes which do not have computer access)
Rulers

Introductory Activity: Discuss the terms dissolved oxygen, temperature and light. Ask students to predict what a graph of each of these might look like at different depths in a lake. Have them clarify if seasonal changes would alter the graphs.

Main Activity:

1. Introduce students to the Excel program, if they are not already familiar with it. (step by step instructions for working with Excel are available at the end of this lesson plan).
2. Enter the data into the spreadsheet, copying the from the data table.
3. Generate three graphs, keeping the depth data on the y-axis.

4. Determine three distinct layers of the lake and label them epilimnion, thermocline and hypolimnion.
5. Label where the processes of photosynthesis and respiration are taking place.

Data table:

Depth (m)	Temp (C)	Oxygen (mg/ml)	Light (footcandles)
0	19.1	8	2300
1	19.1	7.9	1100
2	19	7.9	500
3	18.8	7.9	350
4	18.7	7.8	220
5	18.3	7.3	130
6	18.2	7.8	57
7	17.6	7.1	40
8	11.7	0.5	18
9	9.9	0.1	2.4
10	9.1	0.1	0.37
11	8.8	0.1	

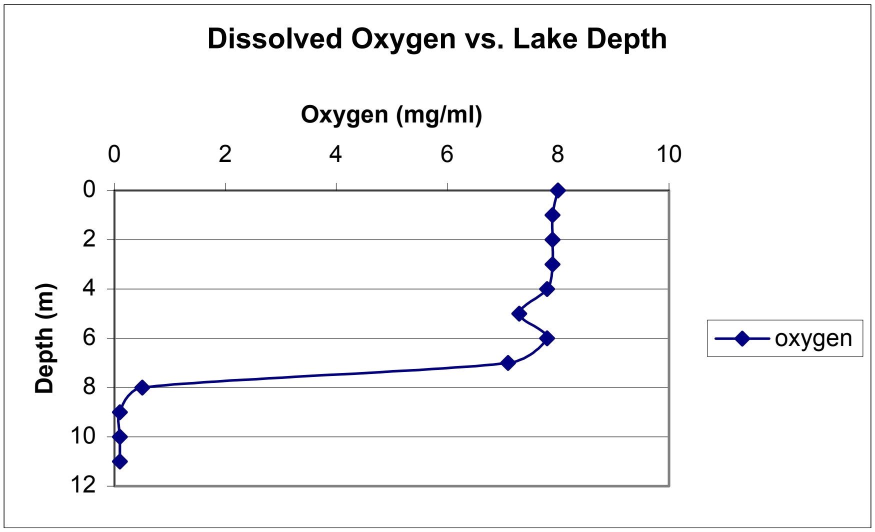
Expected Conclusions: Students should be able to determine the three layers of the lake by generating and observing the three different graphs. They should be able to predict where photosynthesis and cellular respiration are taking place.

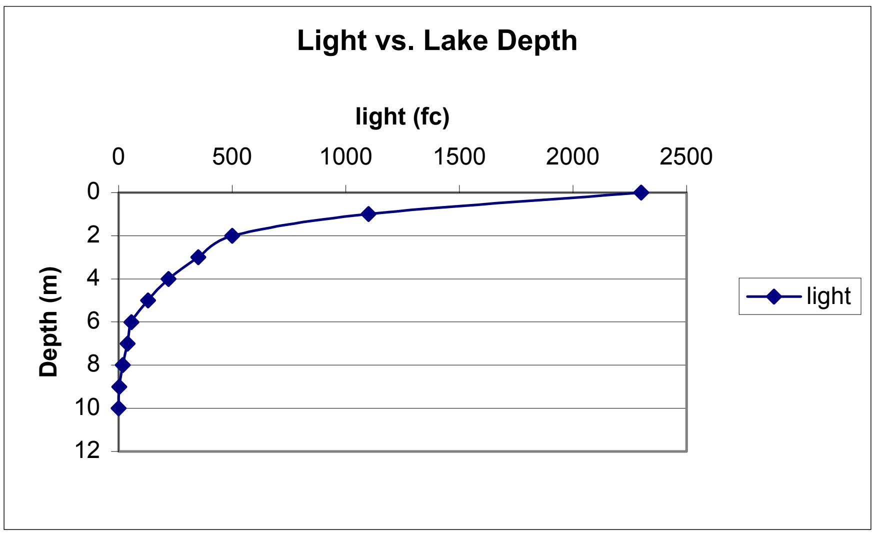
Assessment:

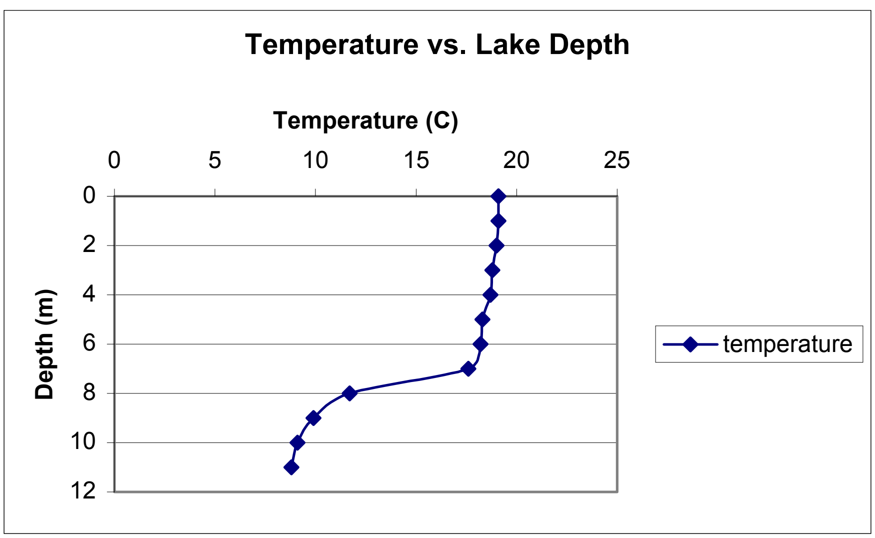
Students should produce three graphs: dissolved oxygen vs. depth, light vs. depth, and temperature vs. depth with estimations for the placement of the epilimnion, thermocline and hypolimnion.

Extension Activities:

Computer skills – Students can explore lake stratification on the web.


Dissolved Oxygen vs. Lake Depth
Oxygen (mg/ml)
0
2
4
6
8
10
Depth (m)
0
2
4
6
8
10
12
oxygen


Light vs. Lake Depth
light (fc)
0
500
1000
1500
2000
2500
Depth (m)
0
2
4
6
8
10
12
light


Temperature vs. Lake Depth
Temperature (C)
0
5
10
15
20
25
Depth (m)
0
2
4
6
8
10
12
temperature

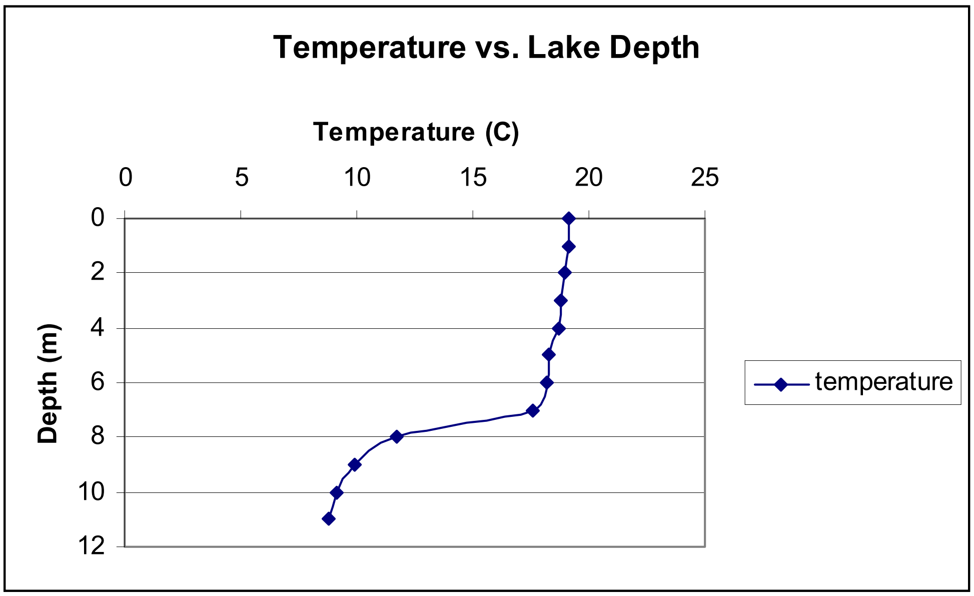
Generating a graph in Excel
Temperature vs. Depth

1. Open the Microsoft excel program. You will be presented with a spreadsheet.
2. Enter your data in columns adjacent to each other. Put labels at the top of the column.

Depth (m)	Temp (C)
0	19.1
1	19.1
2	19
3	18.8
4	18.7
5	18.3
6	18.2
7	17.6
8	11.7
9	9.9
10	9.1
11	8.8

3. Click on the graph icon on the toolbar or click on the *insert* tab and then choose "*Chart*".
4. Choose *XY(scatter)* graph by clicking on the key.
5. Choose the chart of sub type (scatter or connected by lines) by clicking on that choice.
6. Click on the *Series* tab.
7. Press the *Add* button. This will enable you to tell the program which data you want to graph.
8. Enter the name of your graph (temperature) in the name box.
9. Press on the icon next to the *x axis* box. This takes you back to the data table. Highlight the temperature data only, not the chart title. Press the icon box again.
10. Click the data on the icon box for the *y axis*. Highlight the data for the lake depth. Click on the axis box icon to return.
11. Now a graph should show up in the box. Click *next*.
12. Enter titles for the graph and axis.
    a. Title - Temperature vs. Lake Depth
    b. X axis – Temperature ©
    c. Y axis – Depth (m)

13. Choose where to put your graph either in a new sheet or in the data table. Click *Finish*.
14. You can change a number of features of the graph by clicking on the titles and axis. Double click on the *y axis*.
15. Click on *Scale* and enter a check in the box "values in reverse order".
16. Right click on the graph itself. Choose "*format plot area*" and click on '*no fill*' to remove the background.
17. Your graph should look like this.



Lab #2: Water Density and Stratification of Lakes

Length of Lesson: One class period

Scientific Processes Addressed: Observing, Classifying, Predicting

Scientific Concepts Addressed: Water Density, Stratification of lakes

National Standards Addressed: A, B, C

Objectives: Students will be able to:

1. Define density.
2. Describe how temperature affects water density.
3. Explain how mixing of nutrients and oxygen takes place in lakes with seasonal changes in temperatures.

Introductory Activity:

Demonstration – beakers of room temperature water and ice. Ask students what they think density is. Explain the equation for density – mass/volume. Question students - Should a solid have higher density than a liquid. Place the ice cubes in the beaker. Ask students to explain why they float on the top of the water instead of sinking to the bottom. Discuss why water behaves differently in response to temperature than most liquids.

Materials:

Clear plastic shoe box or a large, clear mixing bowl
Food coloring and droppers
Unsweetened Kool Aid
Water density worksheet (1 per student)
Ladle
Water pitcher with cold water
Tray of dark colored ice cubes

Main Activity:

Students can work together in groups of 4-5 for this activity.

1. Place 2-3 inches of very hot water into each clear box. Let settle.

2. Add 10 drops of green or yellow food coloring into 4 cups of very cold water in the pitcher. Have students sit at an eye level with the water. Very slowly pour the cold colored water along the side of the box. Use the ladle if desired so the hot water isn't stirred up.
   (Note: the cold colored water will form a layer across the bottom of the box. This represents temperature stratification that occurs in summer.)

3. Blow on the water (wind) to stir the surface to mix the colors.
   (Note: the water will be colored from surface to bottom. This is what lake temperature gradients look like in fall.)

4. Distribute dark colored ice cubes to each group (Use one package of unsweetened "Kool Aid" per tray). Have students carefully lay ice on the top of the water and observe.
   (Note: As the ice melts and becomes dense (39.2F) it sinks to the bottom and forces the water on the bottom up. Allow the ice to melt. Students may blow across the top again and mix the water from top to bottom. There will be another 'turnover' this time. Diagram the temperature gradient of winter as the situation with ice on top and spring as the turnover.

Expected Conclusions:

Students should gain an understanding of lake mixing with temperature changes affecting water density.

Assessment:

Student worksheets should be filled out and handed in discussion questions answered and with temperature gradients depicting spring, summer, fall and winter.

Extension Activities:

Computer Skills – Have students research lake stratification on the internet.
Language Arts – Have students write an essay on the travels of a water molecule in a lake through the four seasons.

How would life in the lake be affected if water achieved its maximum density at 32F?

What would happen if the lake stayed stratified all year long?

Why is nutrient and oxygen redistribution in spring and fall so important?

Where could you find most living organisms in a winter lake?

References:

Fialkowski, C. Water Density: Its impact on lakes and ponds. The Field Museum. Available on-line May 2001: http://www.mos.org/learn_more/cheapbook/waterdensity/index.html

Lab #3: Solubility of a Gas in Response to Temperature

Length of Demonstration: 5-15 minutes

Scientific Processes Addressed: Observing, Communicating

Science Concepts Addressed: Solubility, Temperature

National Standards Addressed: A, B

Objectives: Students will

1. Observe the differing solubility of Carbon dioxide at various temperatures.
2. Describe how gas molecules are affected by increases in temperature.

Materials

2 Cans of Soda
2 Identical transparent cups
Refrigerator

Procedure: The teacher can perform this demonstration and lead a class discussion about the effects of temperature on gas molecules and the resulting differences in solubility.

Main Activity:

1. Present two cans of identical soda to the class.
2. Tell them one can is at room temperature and one can is cold. You want them to tell you which is which without touching the cans themselves.
3. Open both the cold and warm sodas and pour each soda into a separate cup.
4. Observe the amount of bubbles that leave the warm soda and the cold soda.

Expected Conclusions:

Students should understand that normally, a higher temperature allows for a higher solubility. However, this doesn't hold true for a gas dissolved in a liquid (gas – solute, liquid – solvent). Raising the temperature increases the kinetic energy of the CO_2 gas molecules. This higher energy allows them to have a higher chance of escaping the solvent. Therefore, a higher temperature decreases the solubility of a gas dissolved in a liquid.

The colder the bottom layer of a lake is the more CO_2 it can contain in dissolved form.

Lab #4: Building a Density Column

Length of Lesson: One class period

Scientific Processes Addressed: Observing, Measuring, Predicting

Science Concepts Addressed: Density, Polarity

National Standards Addressed: A, B

Objectives: Students will:

1. Define density.
2. Develop a working knowledge of density.
3. Calculate the densities of various substances.
4. Explain why some substances do not mix.

Materials:

3 cups of any kind
Transparent cup or glass jar
Food coloring
Water
Corn Syrup
Vegetable Oil
Crayons, Raisins, Leggo blocks, Pennies, etc.
Pipetes
Weigh boats or beakers
Balance

Procedure: Students can work independently or in groups for this activity.

Main Activity:

1. Pour equal amounts of water, corn syrup and cooking oil into the three cups.
2. Drop a different drop of food coloring into each cup and note which dye was dropped into which cup.
3. One at a time, slowly pour the contents of each cup into the transparent cup.

4. Observe what happens to the three different liquids when they are mixed together in the transparent cup. Predict which liquid has the highest density, which has the lowest from visual observation.
5. Drop various objects and record where they stop in the density column. Calculate the relative densities of the solid objects tested in relation to each other.
6. Go back to the source material for each liquid.
7. Tare the balance to an empty weigh boat or clean beaker.
8. Measure 1-5 mls of liquid in a pipet and determine it's mass using the balance.
9. Calculate the density for each liquid (Density = mass/volume).
10. Determine if your observations of the density column agree with your calculations from the balance.

Data Table: Relative Density of Objects

Objects	Relative Density

Data Table: Calculated Densities of Fluids

Liquid	Mass	Volume	Calculated Density

Expected Conclusions:

Students should understand how to calculate density of a liquid from this experiment. They should be able to explain that if substance A is denser than substance B, substance A will tend to sink to the bottom.

Assessment:

Students should be assessed on how the carried out the activity, their completion of the data tables and the accuracy of their conclusions. Calculated Densities of the three liquids should be posted on the board for a class comparison of results.

Extension Activities:

Computer Skills – Have students research the term 'polarity' on the web and come up with a working definition. This should help students understand that differences in density alone do not explain why some solutions do not mix.
Math – Students can estimate the density of solid objects, such as coins, by first determining the area of the object and then using the mass/volume calculation. [Volume of a cylinder – $V = (\pi r^2)h$]

References:

CyBerScience – The Helix 43 – Density column. Available on-line at: http://www.publish.csiro.au/cyberscience/helix/TH43/TH43B2.htm

Experiments you can do at home: Density. Available on-line at: http://library.thinkquest.org/2690/exper/exp25.htm

Lab #5: Density of Gases

Length of Lesson: 15-30 minutes

Scientific Processes Addressed: Observing, Predicting

Science Concepts Addressed: Density, Combustion

National Standards Addressed: A, B, D, F

Objectives: Students will:

1. Conclude that different gases have different densities.
2. Explain that an absence of oxygen will cause flames to be extinguished.
3. Describe how gases can be released from chemical reactions.

Materials:

Clear plastic box
Vinegar
Baking soda
Funnel
Empty one gallon jug
3 birthday candles (1 inch, 1.5 inch and 2 inches tall)

Procedure: This can be preformed as a demonstration by the teacher with students asked to predict which candle will go out first.

Main Activity:

1. Position the candles in the bottom of the box.
2. Pour 1.5 cups of vinegar into the empty jug.
3. Using a funnel, add 0.25 cups of baking soda to the jug containing the vinegar. Let it set for about 30 seconds or so until the reaction has finished. In the meantime, light the candles.
4. Ask the students to predict what will happen as you pour the carbon dioxide gas into the plastic box near the end where the tall candle is.

Expected Conclusions:

Students should understand that, since carbon dioxide is denser than air, it fills the plastic box from the bottom up, just as water would. As a result the shortest candle is snuffed out first even though it is farthest from the source of the gas in the jug. This is very similar to what happened near Lake Nyos in Africa.

Lab 6: Cellular Respiration

Length of Lesson: Two class periods or one lab period

Scientific Processes Addressed: Observing, Predicting

Science Concepts Addressed: Respiration, Pressure

National Standards Addressed: B, C

Objectives: Students will:

1. Discover the process of cellular respiration through an experiment.
2. Identify glucose and oxygen as the inputs of the respiration reaction.
3. Identify carbon dioxide and water as the outputs of the respiration reaction.
4. Explain that respiration is a biochemical process in that it requires a living organism to perform the chemical reaction.

Lab Experiment: Cellular respiration produces carbon dioxide in the alcoholic fermentation pathway using yeast as the biological organism and sucrose as the carbon source.

$$C_{11}H_{12}O_{11} + H_2O + \text{yeast} \longrightarrow 4C_2H_5OH + 4CO_2$$

Materials

Yeast
Table sugar (sucrose)
Warm water (~60F)
20% Sucrose Solution
Graduated Cylinder
6 Test tubes
Test tube rack
Stoppers
Ruler
Stop watch

Increased Carbon Output with Increased Carbon Input

Procedure: Reaction A –

NOTE: Students should wear safety glasses when performing this experiment.

1. Set up 6 tubes for your first reaction. Mark the tubes as 1-6.
2. Measure out 20 mls of warm water into each tube and add the prescribed amounts of sucrose into the corresponding tube.

Tube #	Water	Sucrose	% Sucrose
1	20 mls	0.0 grams	0%
2	20 mls	0.2 grams	1%
3	20 mls	0.4 grams	2%
4	20 mls	1.0 grams	5%
5	20 mls	2.0 grams	10%
6	20 mls	3.0 grams	15%

3. Put a rubber stopper in the test tube and shake the tube gently until the sugar is dissolved.
4. Weigh out 0.25 grams of yeast for each tube.
5. Add the yeast to each tube, put the stopper in the test tube and gently mix the solution by turning the test tube up and down a few times. Leave the stopper loosely on top of the test tube.
6. Place the tubes back in the rack and start timing your reaction with a stop watch.
7. Record the time you see gas starting to form in each tube.
8. At the 15 minute mark, measure the amount of bubbles, or froth, at the top of the solution and record that information in the data table.
9. Graph the results of %Sucrose vs. amount of CO_2 produced.
10. Draw in a 'goodness of fit' line to fit your data. Calculate the slope of this line to determine the rate of CO_2 produced over/% of sucrose.

Expected Conclusions:

This experiment is a good introduction to balancing a chemical equation. The more carbon (sucrose) that went into a reaction, the more carbon (CO2) will come out of a reaction. Students should see a linear relationship between the percentage of sucrose and the amount of carbon dioxide gas produced.

Effect of biological organisms on rate of a reaction.

Procedure: Reaction B

NOTE: Students should wear safety glasses when performing this experiment.

1. Add 20 mls of warm 20% Sucrose solution to each tube.
2. Weigh out the amount of yeast needed for each test tube.

Tube #	Yeast	% Yeast
7	0.00 grams	0.0%
8	0.10 grams	0.5%
9	0.15 grams	0.8%
10	0.30 grams	1.5%
11	0.40 grams	2.0%
12	0.50 grams	2.5%

3. Add the yeast to the corresponding test tube and gently mix by turning the tube up and down a few times. Leave the stopper loosely on top of the test tube.
4. Place the tubes back in the rack and start timing your reaction with a stop watch.
5. Record the time you see gas starting to be produced in each tube.
6. At the 15 minutes mark, measure the amount of bubbles or froth, at the tope of the solution and record that information on the data table.
7. Graph the results of % Yeast vs. amount of CO_2 produced.
8. Draw in a 'goodness of fit' line to fit your data. Calculate the slope of this line to determine the rate of CO_2 produced over/% of yeast.

Expected Conclusions:

Students should understand that respiration is a biochemical process; it will not work unless a living, biological organism is present.

Assessment:

Students should be assessed by their ability to perform the experiments, record their data in the data table and by graphing their results. This lab can be written up in the form of a lab report which should include a conclusion. Questions students should answer in the conclusion include:

- Was the time it took to form CO_2 gas affected by varying the amount of sucrose added? Was it affected by varying the amount of yeast added?
- How did increasing the amount of sucrose affect the height of the froth layer on top of the tube?
- How did increasing the amount of yeast affect the height of the froth on top of the tube?
- Why did tube #1 in Reaction A have to be included? What did you learn by including that tube in the experiment?
- Why did tube #7 in Reaction B have to be included? What did you learn by including that tube in the experiment?

Data Table for Cellular Respiration Experiment

Data Table for Reaction A:

Tube #	% Sucrose	Time when CO_2 started to form	CO_2 layer on top of solution (cm)
1	0%		
2	1%		
3	2%		
4	5%		
5	10%		
6	15%		

Graph your results as Amount of CO_2 formed (cm) vs. % Sucrose.

Data Table for Reaction B:

Tube #	% Yeast	Time when CO_2 started to form	CO_2 layer on top of solution (cm)
7	0.0%		
8	0.5%		
9	0.8%		
10	1.5%		
11	2.0%		
12	2.5%		

Graph your results as Amount of CO_2 produced (cm) vs. % Yeast.

Lab 7: Waste Products of Cellular Respiration

Student Activity: Cellular respiration by yeast

Objective: Students will:

1. Determine that Carbon dioxide, the gaseous waste they exhale, is the same gas produced in cellular respiration by yeast. (Lab 6)

Materials:

Soda bottle or erlyenmeyer flask
1 teaspoon of sugar
½ package of powdered yeast
18 inches of tubing (aquarium tubing will work)
Modeling clay
Limewater (see page ___)

Procedure:

1. Pour ½ package of dry yeast into the soda bottle
2. Fill the bottle, or flask, one-half full with warm water.
3. Add 1 teaspoon of sugar to the bottle.
4. Cover the top and shake vigorously.
5. Place one end of the tubing in the top part of the bottle.
6. Use the clay to seal off the bottle and to hold the tubing in place in the bottle.
7. Insert the free end of the tube into a glass that is one-half full with limewater.
8. Observe periodically for several days.
9. Pour another cup of limewater and have a student breath into it with a straw and record the observation.

Expected Conclusions:

Limewater turns cloudy when carbon dioxide bubbles through it. Students should come to this conclusion when they test the limewater with their own breath. Yeast is producing carbon dioxide as a by-product of cellular respiration as it uses sugar and oxygen to produce energy for itself.

Assessment:

Students should be assessed by their conduction of the experiment, the accuracy of their conclusions and their identification of the chemical reaction of respiration.

$$6O_2 + C_6H_{12}O_6 \longrightarrow 6\,CO_2 + 6H_2O$$

Extension Activities:

Math – Have students estimate how many molecules of carbon dioxide will be produced if 12, 120, or 1200 molecules of glucose are present and if glucose is the limiting element.

Higher Order Thinking Skills – Have students construct a list of organisms that use respiration vs. those that get their energy from photosynthesis.

Reference:

VanCleave, J. (1989). Chemistry for every kid. Canada: John Wiley & Sons, Inc.

Expected Conclusions:

Higher Order Thinking Skills – Have students construct a list of organisms that use respiration vs. those that get their energy from photosynthesis.

Making Limewater

Limewater is an indicator solution for carbon dioxide.

Materials:

Lime (the kind used in making pickles)
Tablespoon
2 glass quart jars with lids

Procedure:

1. Fill one jar with water.
2. Add 1 tablespoon of lime and stir.
3. Secure lid and allow the solution to stand over night.
4. Decant the clear liquid into the second jar. (The clear liquid is a saturated solution of limewater.) Be careful not to pour any of the lime that has settled onto the bottom of the first jar.
5. Keep the jar closed until you're ready to use the limewater.

Lab # 8: Photosynthesis Experiments

Length of Lesson: 1-2 class periods

Scientific Processes Addressed: Observing, Communicating

Science Concepts Addressed: Photosynthesis, Transpiration

National Standards Addressed: A, B, C, F

Objectives: Students will:

1. Observe the effect of light on plant growth.
2. Determine that light energy is utilized by plants in the process of photosynthesis.
3. Identify the products of photosynthesis as oxygen and glucose.

Materials

Potting Soil
Pea or bean seeds
Paper cups
Ruler
Colored filters (red, blue, green)
Mature plants with healthy leaves
Glass jar
Paper

Main Activities

Part I – 1-2 weeks

1. Have students pot up their seeds in the paper cups with holes punched in the bottom for drainage.
2. Water the seeds and place them in different parts of the classroom under different kinds of light. (i.e. a dark corner, a bright window sill, under grow lights.) Some seeds can be placed under red, blue and green filters. Try to have 3 or more seedlings in each test area.
3. Students should keep careful records of the seeds positions and light availability.

4. All plants should be under the exact same conditions (water, temperature, etc.) The only difference between them should be the quality of light.
5. View the plants for 10 – 14 days.
6. At the end of the observation period, compare the different sets of seedlings with each other.
7. Pull the seedlings out of their pots and measure them, keeping track of what type of light each seedling was exposed to.
8. Generate a table of measurements and determine the 'average' seedling length for each type of light exposure.
9. Produce a graph, either on paper or by computer, to visually represent the results.
10. Students should report their findings to the class and discuss their results.

Expected Conclusions:

Students should conclude that energy from light is essential to growing plants and that plant growth and health can be directly affected by different kinds of light exposure.

$$6\ CO_2 + 6H_2O \longrightarrow 6O_2 + C_6H_{12}O_6$$

Assessment:

Students should be graded on their ability to conduct the experiment, the tabulation and graphing of results and their understanding of the process of photosynthesis.

Extension Activities:

Science Journal – All students should keep track of experimental conditions in a lab notebook. Record should include observations of when seeds were planted and sprouted as well as a daily log of room temperature, weather conditions (if using natural light) and a list of when and how seedlings were watered.
Math – Students should generate a mean and standard deviation for each set of results (conditions A, B and C). Advanced students can conduct an ANOVA test to conclude if the plant lengths are significantly different from one another.
Computer Skills - Means, standard deviations and ANOVA tests can be preformed using the Microsoft Excel program.

Data Table for Photosynthesis Experiment

Plant type ___________________
Condition A ____________________________________
Condition B _____________________________________
Condition C _____________________________________

Seedling	Root Length	Stem Length	Total Length	Stem:Root Ratio
A-1				
A-2				
A-3				
A-4				
A-5				
B-1				
B-2				
B-3				
B-4				
B-5				
C-1				
C-2				
C-3				
C-4				
C-5				

Results:

	Root length - A	Root Length - B	Root Length - C	Stem Length - A	Stem Length - B	Stem Length - C
Mean						
Median						
Std dev						

Photosynthesis Experiment Part II, III & IV

Part II – 1 week

1. Place a plant with healthy leaves in a sunny window.
2. Cover one leaf with a piece of paper, secured with a paper clip.
3. Have students observe what happens to the leaf over a number of days.
4. Students should be encouraged to explain what caused the changes in the leaf when it was deprived of sunlight.

Expected Conclusions:

Students should observe that light is essential to the process of photosynthesis. Without light energy to drive the reactions the plant cannot produce the sugar (glucose) needed to maintain the leaf.

Part III (Starch Storage in Algae) – 1 class period

Much of the glucose produced during photosynthesis is stored as starch. The presence of starch can be determined using a simple test; iodine solution reacts with starch to change it to a bluish-black color. Plants and algae that are undergoing photosynthesis should test positive for starch, plants that have been kept in the dark should test negative.

Materials

Glass slides
Cover slips
Zygnema algae cultures (Available from Wards)

- Keep one culture under a lamp
- Keep one culture in the dark for a day prior to the experiment

Lugol's iodine solution
5% Starch solution

Procedure – Demonstration of Starch Test

1. Place a clean glass slide on a piece of white paper.
2. Using a clean dropper, place a drop of water on the left side of the slide.
3. Place a drop of starch solution on the right side of the slide.
4. Add a drop of iodine solution to each drop of liquid on the slide.
5. Write down your observations.

Procedure – Test Algae for presence of Starch

1. Place two glass slides on a piece of paper.
2. Place two drops of the algae exposed to light on one of the slides.
3. Place two drops of 'light deprived' algae on the other slide.
4. Add a drop of iodine solution to the algae on the right slide of each of the slides.
5. Place a clean cover slip over each drop on the slides and observe the cells under a microscope at 100x and 400x magnification.
6. Record your observations in the table below.

Light	Iodine	Description of cells	Starch test (positive/negative)	Sketch of cells
Yes	No			
Yes	Yes			
No	No			
No	Yes			

Part IV – Testing Geranium Leaves for the Presence of Starch

Materials:
Geranium Plants

- Keep one plant exposed to light
- Keep one plant in a cupboard for a day prior to the experiment

Lugol's iodine solution
95% Ethanol
Beaker
Petri Dish
Forceps
Hot Plate

Procedure:
1. The instructor should set up a beaker of boiling alcohol on a hot plate. (WARNING! Alcohol is highly flammable! USE CAUTION! Students should wear safety glasses!)
2. Remove one leaf from each of the two geranium plants.
3. Cut a distinct notch in each leaf to distinguish your leaves from those of other students.
4. Drop the leaves into the boiling alcohol using forceps. Allow them to boil for 5 minutes, until they are nearly white in color.
5. Remove the leaves with forceps onto a paper towel to drain.
6. Place both leaves into a Petri dish containing enough water to cover them.
7. Add several droppers full of iodine solution to the water and swirl the plate to mix.
8. Observe and record any color changes.
9. Determine which geranium was kept in a closet and which was exposed to the light.

Expected Conclusions:
Students should determine that starch is present in the algae and plant leaves exposed to light.

Extension Activities:
Computer Skills – Students can locate sources of information about photosynthesis on the Internet.

Related Materials:

Web sites on Photosynthesis
ScienceNet: http://www.sciencenet.org.uk/database/Biology/Lists/pl
Photosynthesis is Fun: http://khanda.unl.edu/~nikku/photosyn.html#a.5
Encarta: http://encarta.msn.com/alexandria/templates/lessonFull.asp

References:

Encarta Encyclopedia. Encarta Schoolhouse - Close encounters of the green kind: Photosynthesis. Available on-line as of May 2001. http://encarta.msn.com/alexandria/templates/lessonFull.asp?page=2313

Boreale, N. Encarta School House - Photosynthesis and Transpiration. Available on-line as of May 2001. http://encarta.msn.com/alexandria/templates/lessonFull.asp?page=407

Glossary

ATP – Adenosine Tri-Phosphate. Chemical storage molecule for energy. Energy is released when a phosphate bond of ATP is broken to produce ADP.

Autotrophs – Organisms that can make their own food. Autotrophs use energy to build organic molecules from inorganic materials.

Carbon Dioxide – One of the by-products of cellular respiration, released as a gas.

Chlorophyll – Light absorbing compounds found inside chloroplasts. Any organism that contains chlorophyll is capable of photosynthesis

Chloroplast – The organelle in plant cells which carries out photosynthesis.

Dark Reaction – The reaction in photosynthesis that leads to 'fixing' of the carbon molecule in carbon dioxide to glucose.

Density – Mass/Volume.

Dissolved Oxygen – Oxygen present in water. The colder the temperature, the more dissolved oxygen the water can hold.

Electron Transport Chain – The passage of electrons from a high energy level to a lower energy level by electron carriers.

Epilimnion – The warm upper layers of a lake in summer. Photosynthesis takes place in the epilimnion.

Eutrophic Lake – A lake rich in dissolved nutrients but often shallow and seasonally deficient in oxygen.

Eutrophication – A condition which happens when a lake becomes enriched with organic nutrients, causing an increased proliferation of plants and algae. This increase in the algal population leads to a decrease in dissolved oxygen which kills other organisms in the lake, such as fish.

Fermentation – The process of breaking down pyruvic acid without the use of oxygen.

Fixing Carbon – Turning an inorganic source of carbon (carbon dioxide) into an organic source of carbon (glucose).

Glycolysis – Bacterial fermentation – the oldest form of respiration. Breaks down glucose to pyruvic acid. (anaerobic)

Heterotrophs – Organisms that cannot make their own food. They must eat other organisms to survive

Hypolimnion – The deep cold waters of a lake in summer.

Light Dependent Reaction (LIGHT) – The reactions in photosynthesis that lead to the production of ATP. Transforms solar energy into chemical energy.

Light Independent Reaction (DARK) – Reactions that form organic compounds (glucose) by using energy stored during the light-dependent reactions. (Calvin Benson cycle)

Limiting Nutrient – The nutrient in short supply in an ecosystem. This nutrient will be exhausted first and will limit cellular growth.

NADP – During a biochemical pathway, NADP 'captures' a Hydrogen molecule (NADPH) to keep the Hydrogen from reforming with Oxygen to form water.

Oligotrophic Lake – A lake deficient in plant nutrients by having abundant dissolved oxygen.

Oxygen – An element which forms 21% of our atmosphere and is necessary for cellular respiration.

Photosynthesis – A process which converts radiant solar energy to chemical energy stored in the bonds of an organic compound.

Photosystem – A unit of several hundred chlorophyll molecules and carrier molecules.

Respiration – The release of chemical energy for cellular use.

Solvent – A liquid capable of dissolving another substance.

Solute – A substance that is dissolved in a liquid.

Stratification – To divide into distinct layers. Lakes divide, or stratify, into 3 layers during the summer months.

Stroma – Part of the Thylakoid membrane when the light-independent reaction takes place.

Thermocline – A region of rapid temperature shift in a stratified lake.

Thylakoid – Sites of light absorption in a chloroplast. Flattened, membranous sacs.

Transpiration - When a plant gives off water vapor from the surface of its leaves.

Web Sites

Eutrophication

- University of Manitoba. Experimental Lakes Area - Eutrophication (Nutrient Pollution): http://www.umanitoba.ca/institutes/fisheries/eutro.html
- Nixon, S.W. (1998). Enriching the Sea to Death. Scientific American. [1998, August]: http://www.sciam.com/specialissues/0898oceans/IMG/0898nixon.html.

Hypoxia

- First Gulf of Mexico Hypoxia Management Conference (Dec 5-6, 1995). : http://pelican.gmpo.gov/nutrient/front.html

Lake Information

- Ocean Planet-Smithsonian: http://seawifs.gsfc.nasa.gov/ocean_planet.html
- Great Lakes Science Center: http://www.glsc.nbs.gov/newinfo/exploring_science.htm
- Fialkowski, C. Water Density: Its impact on lakes and ponds. The Field Museum: http://www.mos.org/learn_more/cheapbook/waterdensity/index.html
- North American Benthological Society: http://www.benthos.org/index.asp
- The Great Lakes Commission: http://www.glc.org/
- Wisconsin Department of Natural Resources – Oxygen: Understanding Lake Data: http://www.dnr.state.wi.us/org/water/fhp/lakes/under/oxygen.htm
- Wisconsin Department of Natural Resources – Mixing and Stratification: http://www.dnr.state.wi.us/org/water/fhp/lakes/under/mixing.htm

Lake Nyos

- Kling, G. Lake Nyos and Lake Monoun: The Killer Lakes of West Africa: http://biology.lsa.umich.edu/~gwk/research/nyos.html
- Halbwachs, M. Degassing Nyos: http://perso.wanadoo.fr/mhalb/nyos/nyos.htm
- Pictures of the Lake Nyos disaster in 1986: http://shanklin.intrasun.tcnj.edu/cameroon