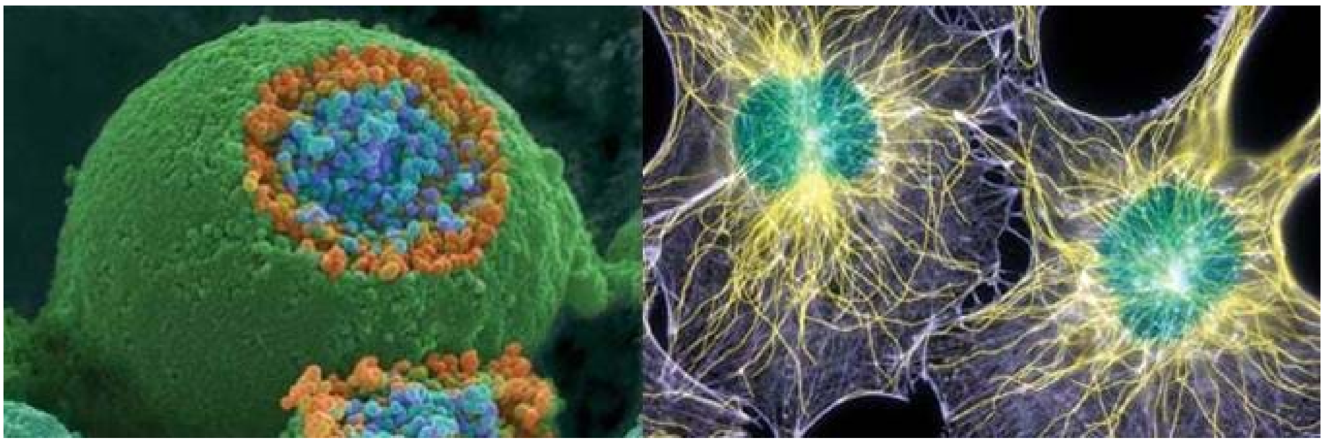
Curricular Unit: **Cells**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level: 7 (6-8)
Time Required: 300 minutes
(60 minutes for the lessons + 240 for all the activities)



Detailed microscopic images of living cells.

Summary

In this unit, students look at the components of cells and their functions and discover the controversy behind stem cell research. The first lesson focuses on the difference between prokaryotic and eukaryotic cells. In the second lesson, students learn about the basics of cellular respiration. They also learn about the application of cellular respiration to engineering and bioremediation. The third lesson continues students' education on cells in the human body and how (and why) engineers are involved in the research of stem cell behavior.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Engineers design systems to remove harmful bacteria found in drinking water. So, clearly, they know a lot about cell behavior in order to design beneficial systems. And, engineers use their knowledge of cells to make products that offer strong protection against harmful bacteria *and* also enhance the growth of beneficial bacteria (such as soap vs. compounds to break down harmful pollution). Through the process of bioremediation, engineers use their knowledge of cells to promote the growth of cells that break down toxic compounds into harmless byproducts that aid in the protection of our environment.

From engineering tools for observation on the molecular level to chemical and bioengineering of natural fluorescent dyes to examine cell replication in an organism, engineering developments and design have helped advance research of all types of cells. Engineering influences science and medical research by facilitating the understanding of how cells are influenced in all directions by their environment and how they behave in our bodies.

Unit Schedule

- Day 1: Cell Celebration! lesson
- Day 2 and Day 5: Sudsy Cells activity (Note: 50 minutes for the initial activity, two days (48 hours) for incubation of Petri dishes and 50 minutes to record and analyze results)
- Day 3: Cellular Respiration and Bioremediation lesson

- Day 4: Breathing Cells activity
- Day 6: The Cloning of Cells lesson
- Day 6-7: Glowing Flowers activity

Contributors

See individual lessons and activities.

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Supporting Program

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Lesson: **Cell Celebration!**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level: 7 (6-8)
Time Required: 20 minutes
Lesson Dependency : None

Figure 1. A chemical and biological engineer develops new antibiotics.

Summary

Students look at the components of cells and their functions. The lesson focuses on the difference between prokaryotic and eukaryotic cells. Each part of the cell performs a specific function that is vital for the cell's survival. Bacteria are single-celled organisms that are very important to engineering. Engineers use bacteria to break down toxic materials in a process called bioremediation, and they also disable or kill harmful bacteria through disinfection.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Engineers rely on their knowledge of cellular function to control the growth of microorganisms. For example, engineers design systems to remove harmful bacteria commonly found in drinking water. Engineers use their knowledge of cells to make products that offer strong protection against harmful bacteria and also enhance the growth of beneficial bacteria. Soap is an example of a product that offers protection from harmful bacteria. The cell membrane, the protective layer surrounding a cell, is made of fat layers. If the cell membrane is broken, then the cell dies. This is why soaps, which break up fats and the fatty layers, can kill bacteria. Thus, soap is an engineered product that was made for a specific purpose (solving the problem of dirty, contaminated "things"), but is widely used for a multitude of applications.

Learning Objectives

After this lesson, students should be able to:

- Compare and contrast prokaryotic and eukaryotic cells.
- List examples of how engineers use cells to keep people and the environment safe and healthy.

Introduction/Motivation

Today, we are going to talk about cells and how important they are. Even though most cells are much too small for us to see, they are still very important. Engineers use their knowledge of cells to benefit our health and safety, by creating disenfectants, medicines, materials and many other "things" that rely on cells. Did you know that there are millions of cells living in and on your body right now? (Note: If students seem to already know this, take a few comments about what kinds of cells live in and on our bodies.) We have bacteria in our digestive tracts that help us turn our food into energy so that we can run, jump and grow. There are also microorganisms in our body that can make us sick. For example, strep throat is another a type of bacteria, but it makes us sick instead of helps us digest food and nutrients.

Engineering advancements help people stay healthy — clean drinking water, for example. Engineers work to protect people from harmful cells while making sure they do not destroy beneficial cells. Can anyone think of a way that we might protect ourselves from cells that might make us sick? (Possible examples include: washing your hands and covering your mouth when you cough; the sterilization of surgical tools; the treatment of drinking water before it comes out of the tap.) Now, can anyone name one way to make sure that helpful bacteria stay alive? (Discuss how doctors recommend that we eat unpasturized yogurt to keep good bacteria in our digestive tract.)

Not only is it important to have good bacteria living in our bodies, but it is also beneficial to have organisms in the environment that "eat" pollution. Have any of you seen pictures of oil spills? (Note: If available, show students pictures from the Deepwater Horizon oil spill in the Gulf of Mexico in 2010 or the Exxon Valdez oil spill off the coast of Alaska in 1989.) They are very damaging to the environment. Although we can clean up a lot of the oil, it is usually impossible to clean up *all* of the oil right away since the spills often cover a large area and spread quickly. Engineers have learned to use bacteria that "eat" oil as a way to speed up oil spill clean-up. This process is called *bioremediation*.

For engineers to control cell growth, whether it is to promote it or prevent it, they must know how the cells live. Today we are going to learn about the two major types of cells: *eukaryotes* and *prokaryotes*. Eukaryotes are the cells that make up our body, and they have many parts called *organelles*. Prokaryotes are cells that are found in bacteria, and they do not have organelles. Even though the two types of cells are very different, they are both able to eat, breathe, grow and reproduce.

Lesson Background and Concepts for Teachers

Cells are living organisms. In order to be alive, a cell must have a metabolism, respond to stimuli and reproduce. While the science behind cells is important to know, the engineering behind cells is fascinating. Let's briefly review the science behind cells.

Prokaryotes

Prokaryotes are simple cells that do not contain a nucleus or other membrane bound organelles. The major parts of a prokaryotic cell include: cell wall, cell membrane, ribosomes, and a nucleoid (see Vocabulary section). Even with a minimal number of parts, these cells are able to eat, breathe and reproduce.

Two kingdoms of organisms comprise prokaryotes: bacteria and archaea. Bacteria make up most of the prokaryotes. In additon, archaea are found in extreme environments such as hot springs or near volcanoes. The difference between bacteria and archaea is their type of cell wall: archaea have a thicker cell wall that is very strong and protects it from the heat and chemicals found in harsh environments, and bacteria have a more permeable cell wall that provides less protection from high temperatures or extreme pH, but takes less energy to build. Both bacteria and archaea are unicellular organisms. Although they sometimes live in colonies, each cell could survive on its own and reproduce without the others.

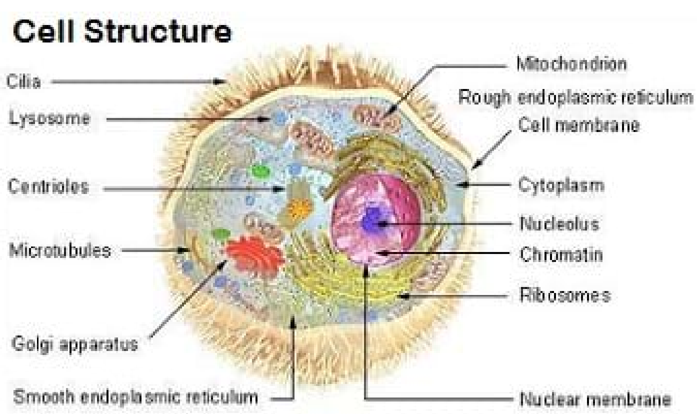

Figure 2. The diagram of a cell.

Eukaryotes

Eukaryotes are complex cells with many organelles. The major organelles found in a eukaryotic cell are: cell membrane, cell wall, ribosomes, nucleus, mitochondria, endoplasmic reticulum and lysosomes (see Vocabulary section). There are both unicellular and multicellular eukaryotes. The four kingdoms of eukaryotic organisms are plants, animals, fungi and protists. Plants are photosynthetic organisms containing cell walls and specialized reproductive tissue. Animals are organisms that lack cell walls, but are capable of locomotion and have a digestive tract. Fungi digest their food externally and then absorb it through their cell walls. Plants, animals and fungi are all multicellular organisms. Protists are single celled motile organisms that can be either photosynthetic or heterotrophic.

Eukaryotes and Prokaryotes Similarities

Some similarities between prokaryotes and eukaryotes exist. First, they both have cell membranes that separate the cell interior from the outside environment. They both have ribosomes that help make proteins and enzymes for metabolism. Finally, both prokaryotes and eukaryotes have their genetic material in the form of DNA. Deoxyribonucleic acid, or DNA, contains the information the cell needs to make proteins to breakdown food into energy as well as the instructions for reproduction.

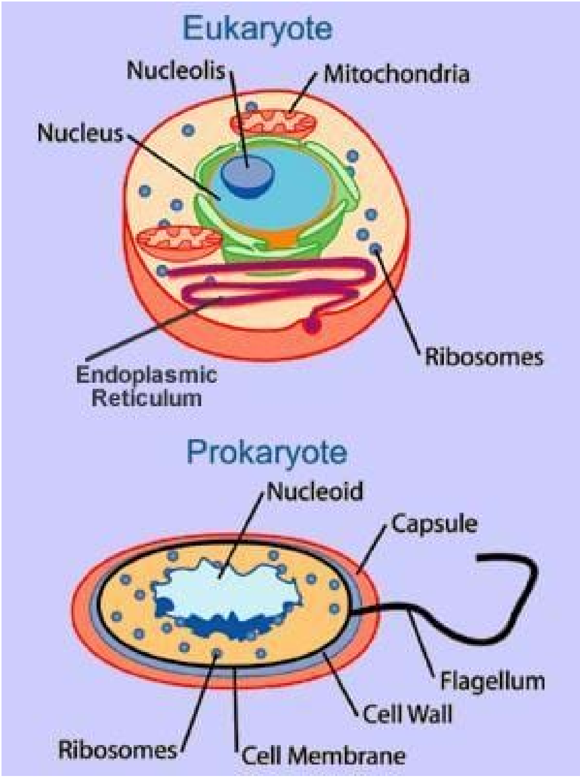

Figure 3. Eukaryotic and prokaryotic cells.

Vocabulary/Definitions

cell membrane : (P) (E) A thin layer that separates the inside of the cell from the outside environment; a boundary that governs what goes in and out of the cell.

cell wall : (P) A layer that supports the cell and acts as a further barrier between the cell interior and the environment.

chloroplast : (E) Captures energy from sunlight in a photosynthetic cell.

cytoplasm : (P) (E) A fluid inside the cell that is similar to gel.

deoxyribonucleic acid : (P) (E) Known as DNA; contains the information the cell needs to make proteins to breakdown food into energy as well as the instructions for reproduction.

endoplasmic reticulum: (E) A system of membranes that transports nutrients and proteins within the cell; some parts of it are covered with ribosomes to facilitate making proteins.

enzyme: (P) (E) Protein the cell produces to speed up chemical reactions.

golgi apparatus: (E) The part of a cell that modifies and transports proteins.

lysosome: (E) A sack that contains various enzymes.

mitochondria : (E) The part of a cell that produces energy for the cell by respiration.

nucleoid : (P) The circular genetic material found in a coil in a prokaryotic cell.

nucleus : (E) The control center of the cell that contains the DNA; found in strands in the nucleus.

organelle : (E) "Little organs" inside the cell; examples are the mitochondria, ribosomes, endoplasmic reticulum, golgi apparatus and lysosomes.

ribosome : (P) (E) The structure that reads DNA in order to make proteins.

Lesson Closure

Today we learned about the two types of cells: eukaryotes and prokaryotes. Can anyone tell me one difference between the two kinds of cells? (Answer: Prokaryotes do not have a nucleus or other membrane bound organelles while eukaryotes do.) Can anyone name one example of a prokaryote? (Answer: Bacteria that can make us sick or the beneficial bacteria used in bioremediation and in our digestive tract.) Can anyone give an example of a eukaryote? (Possible answers: Plants, animals, mushrooms, algae, not all eukaryotic organisms are multicellular.) The differences and similarities between the two types of cells are important to engineers because they use this information when trying to control cell growth in the environment, which is important to plans, animals and especially humans. Engineers must understand cell structure in order to design strategies to destroy harmful cells so that we can lead healthy lives. For example, engineers must understand cell structure before designing soaps that can break up the fatty layers of a cell membrane in order to destroy the cells that can make us sick. It's fascinating!

Attachments

Prokaryotic Cell Overhead (jpg)
Prokaryotic Cell Overhead (doc)
Eukaryotic Cell Overhead (jpg)
Eukaryotic Cell Overhead (doc)
Eukaryote and Prokaryote Cell Bingo Sheet (doc)
Eukaryote and Prokaryote Cell Bingo Sheet (pdf)
Eukaryote and Prokaryote Cell Bingo Sheet Answers (doc)
Eukaryote and Prokaryote Cell Bingo Sheet Answers (pdf)

Assessment

Pre-Lesson Assessment

Discussion Question: Ask a discussion question to get students to think about the upcoming lesson. Ask the students about organisms that are good for them and those that can make them sick. See if any students already know about prokaryotes and eukaryotes or that a classification system exists for organisms.

Post-Introduction Assessment

Voting: Ask a true/false question and have students vote by holding thumbs up for true and thumbs down for false. Count the votes and write the totals on the board. Give the right answer.

- True or False: Eukaryotes are complex cells with a nucleus and other membrane bound organelles. (Answer: True)
- True or False: Bacteria are an example of eukaryotes. (Answer: False, bacteria are an example of prokaryotes.)
- True or False: Engineers try to kill all bacteria because they are all harmful. (Answer: False, engineers often use good bacteria to help keep humans and the environment healthy.)
- True or False: Through a process called bioremediation, engineers try to promote the growth of bacteria to can eat substances that are toxic to humans. (Answer: True)

Lesson Summary Assessment

Cell Bingo: Give students a sheet of paper with either a eukaryotic or prokaryotic cell drawn on it (see Attachments section). Cut small strips of paper and write one of the following words on each piece of paper: cell membrane, cell wall, nucleoid, ribosome, cytoplasm, nucleus, mitochondria and endoplasmic reticulum. Place all strips of paper with cell structures written on them in a hat. Remove only one cell structure from the hat at a time. Students who have that structure in their cell must fill in the blank on their bingo sheet. The first student to fill in all the blanks on his/her cell raises his/her hand. To be the winner, the student must have labeled each structure properly and be able to tell the class the function of each cell structure and what type of cell it is.

Lesson Extension Activities

Make Your Own Yogurt: As engineers, students can make their own yogurt (by growing prokaryotes in milk) and sweeten it with preserves from fruit (eukaryotes). It takes 6-8 hours to culture, so if the activity is done in the morning, it should be ready by the end of the day. The recipe for making your own yogurt is: 1.75 cups powdered milk, 4 cups very warm water (110-125˚F), 1/3 cup plain yogurt with no preservatives. Whisk the first two ingredients until smooth and then whisk in yogurt. Incubate in an insulated cooler to keep it warm for 6-8 hours. Add fruit preserves to sweeten the yogurt and enjoy. It might also be interesting to note that the pH of the yogurt is very low, making it difficult for other, potentially harmful, bacteria to grow in the yogurt.

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Supporting Program

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Last modified: July 20, 2017

Hands-on Activity: **Sudsy Cells**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level:	7 (6-8)
Time Required:	100 minutes Note: 50 minutes for the initial activity, two days (48 hours) for incubation of Petri dishes and 50 minutes to record and analyze results
Expendable Cost/Grp :	US $4.00
Group Size:	2
Activity Dependency :	None

Which type of soap is most effective at killing bacteria?

Summary

Students culture cells in order to find out which type of surfactant (in this case, soap) is best at removing bacteria. Groups culture cells from unwashed hands and add regular bar soap, regular liquid soap, anti-bacterial soap, dishwasher soap, and hand sanitizer to the cultures. The cultures are allowed to grow for two days and then the students assess which type of soap design did the best job of removing bacteria cells from unwashed hands. Students extend their knowledge of engineering and surfactants for different environmental applications.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Engineers spend a lot of time trying to prevent the spread of bacteria cells that make humans sick. One example of products designed by engineers is surfactants or soaps that remove bacteria cells from our hands. Surfactants are compounds that act as wetting agents to decrease the interface tension of two liquid, such as oil and water. Engineers design surfactants for a variety of applications including detergents, emulsifiers, paints, adhesives, agrochemicals, biocides, and soil and water remediation.

Pre-Req Knowledge

The students should know the parts of a prokaryotic cell. They should also be able to calculate averages and percentages.

Learning Objectives

After this activity, students should be able to:

- Describe how surfactants work to remove surface tension between two compounds.
- Understand how engineers use processes to evaluate the effectiveness of different designs.
- Describe the effect of adding surfactant to a prokaryotic cell.
- List several engineering applications of surfactants in everyday life.

Materials List

Each group needs:

- log sheet
- 2 sterile cotton swabs
- 2 Petri dishes with nutrient media (Note: the Petri dishes are sold in packs of 10 through Carolina Biological, http://www.carolina.com/(catalog #821862) for $18 (+S&H). If you have access to an autoclave (a machine that sterilizes solutions and tools using high temperature and pressure), it is less expensive to make your own media. However, it is much easier and less time consuming to buy the already-prepared nutrient media.)
- Sudsy Cells Worksheet

To share with the entire class:

- bar soap (any type; least expensive is okay)
- liquid hand soap (any type; least expensive is okay)
- liquid dish soap (any type; least expensive is okay)
- anti-bacterial soap (any type; least expensive is okay)
- hand sanitizer (any type; least expensive is okay)
- magnifying glass (optional)
- bowl of water (for teacher demonstration)
- pepper shaker (for teacher demonstration)

Introduction/Motivation

Cell growth in a Petri dish.

Today we're going to learn more about one way that engineers help protect humans and the environment from harmful bacteria. Why do we wash our hands? We wash our hands to get rid of bacteria that we may have picked up that could make us sick. What do we use to wash our hands? Soap! What type of soap do you use? Many different types of soap are available: bar, liquid, anti-bacterial, and even special soaps for medical people to use before they perform surgery. Engineers are involved in designing the soap products that we use every day. Chemical engineers look at different mixtures of chemical compounds, called *surfactants*, and design products that are suited for different situations, from hand washing to medical cleansers to washing the oil out of the ocean after an oil spill.

Surfactants, or surface acting agents, are compounds that reduce the interface tension between water and an organic compound, such as oil. Basically, adding a surfactant to a solution of oil and water, breaks down the barriers between the oil and the water, allowing them to mix. Surfactants have very special chemical properties that help them combine with both oil and water. Think about when you wash dishes that have grimy grease or heavy oil on them. Dishwasher soap (a surfactant) breaks down the grease or oil on the dishes into the water, so you can to clean the dish. Surfactants are used in many ways, including dishwashing detergents, shampoos and conditioners, paints, adhesives, ski and snowboard wax, fire extinguishers, sanitizers, medical cleansers, and hand soaps, among many other uses. Surfactants are also used in environmental engineering to clean up oil spills and pollution in water and soil. Engineers design different surfactants depending on what purpose they want the design to serve. As with all designs, they need to keep in mind design criteria and constraints.

To understand why surfactants such as soap are effective at killing bacteria, we need to know all the parts of a target cell. Let's build a bacteria cell on the chalk board together.

Bacteria are what kind of cells? Right, prokaryotes. Who can tell me a part of a prokaryotic cell? (Answer: The parts are cell wall, cell membrane, cytoplasm, nucleolis and ribosomes.) When we wash our hands, the soap attacks one part of the cell and kills it. Can anyone guess what part of the cell the soap destroys? Soap attacks the cell wall of a prokaryotic cell. So, when we wash our hands, the soap destroys the cell wall of the bacteria, spilling out all of the cell contents. The cell is no longer able to function properly — to eat, breathe and reproduce without a cell wall holding its parts together. Basically, the cell is inactivated. The reason why soap destroys the cell wall is because the cell wall is made of fat molecules (an organic compound), and soap (a surfactant) has the chemical properties that break down fats.

(Teacher demonstration using a bowl of water, pepper and liquid dish soap.) Here is a short demonstration to show how a surfactant changes the surface of water. This is a bowl of water (show water to students). Now I'm going to shake some pepper onto the surface of the water. See how it is evenly spread across the surface (walk around the students' desks showing the bowl of peppered water). Now watch as I release one drop of liquid soap on the top of the water. See how the pepper moved to the side. This is because the soap broke the surface tension of the water just like it breaks the cell wall when we wash our hands.

Today, we are going to work as engineers and test some surfactants by culturing bacteria that comes from our hands. Bacteria culturing is a technique that scientists and engineers use to study cells. The number of cell colonies on a culture plate tells us the effects that different surfactants have on the number of bacteria on our hands, and allows us to evaluate different soap designs. To culture bacteria cells, we must make sure that the culture media contains all of the food, vitamins and physical characteristics that the cells need to survive. For this experiment we are using a prepared nutrient-rich media, but some types of cells (especially those found in the natural environment) do not grow well on these types of media; they need a media that only has a small amount of nutrients. For today's activity, we will look at the effects of different surfactants on bacteria and develop a design for an improved surfactant to use in a variety of environmental situations.

Vocabulary/Definitions

cell colony: When bacteria reproduce they form colonies — groups of identical cells from the same parent cell.

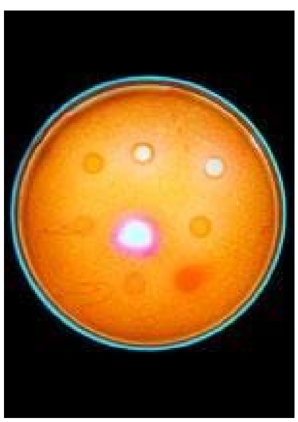
culture media: Contains all of the nutrients and food necessary for bacteria to grow and reproduce.

inactivate: To lose disease causing capabilities, to render non-functional; that is, the cells are no longer dangerous and cannot make us sick.

soap: Soap is a chemical that breaks up cell membranes and also acts as a surfactant.

surfactant: Surfactants can attach to both polar and non-polar molecules making them good at dissolving non-polar molecules (such as oil), in polar liquids (such as water); soap is a type of surfactant.

Procedure

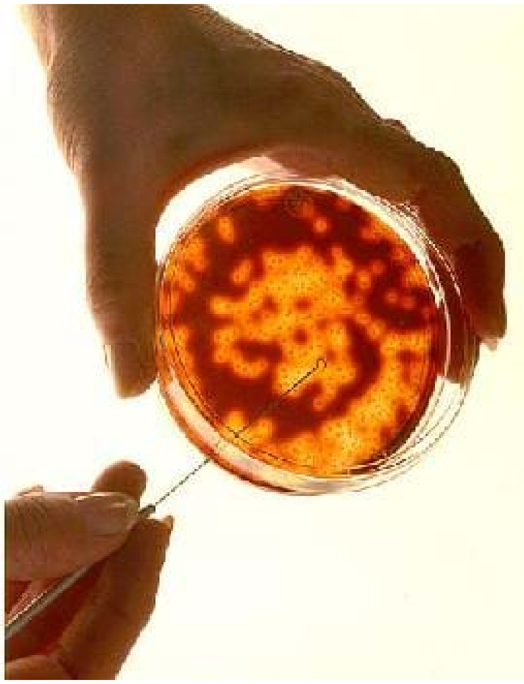


Bacteria growing on a Petri dish. The orange color is a coral disease. The white spots are bacteria that can inhibit the growth of the disease, keeping the coral healthy.

keeping the coral healthy.

Background

It is important to keep the cultures sterile so that the bacteria that grow on the Petri dish only represent the bacteria from the students' hands, not those on the desks, for example. Discuss why it is important to have controls and the how the experimental process works. There are some assumptions that we make when using culturing as a technique, including: each colony represents one cell from the swab. and all of the cells on the swab were able to live off of the chosen media. The media for this experiment was chosen to grow bacteria, but there are many other types of media available for growing different types of microorganisms.



The transference of cells to a Petri dish.

Before the Activity

- Gather materials and make copies of the Sudsy Cells Worksheet.
- If you are preparing the Petri dishes with media rather than buying them, do this a day in advance so the media has time to cool completely.
- Assign each student group one type of soap to use. Student groups should be counted off with the first five groups each using a different type of soap (bar soap vs. liquid hand soap, etc) and then assigning the next five groups the five different types of soaps, etc.

With the Students

1. Go over the procedures for the activity with the class. Remind students about the basics of what a cell needs to survive and reproduce (food, room to grow, air to breathe). Talk about how the nutrient media meets the needs of the cells and that each cell should reproduce enough to form a visible colony by the end of the incubation period (2 days).
2. Divide the class into groups of two students each. One is the washer, the other the recorder.
3. Have students discuss a hypothesis and record it on their worksheet. The hypothesis should be an assertion of what the experiment will tell us about the specific surfactant (soap) and the number of cells on the hands washed with it. An example is: The hand washed with liquid soap will have half as much bacteria on it as the unwashed hand. Have each group tell the class their hypothesis.
4. Have students answer the second pre-lab questions on their worksheets. Give the groups time to answer the question and then discuss the right answers as a class. Make sure that the students understand the idea of a control and how important it is for quality scientific experimentation, and a fair evaluation of designs. In this experiment, the unwashed hands are the controls. The effectiveness of the soaps will be determined by comparing the number of colonies grown on the unwashed hand (the control) to the number of colonies on the washed hands.

5. Next, have groups gather the materials they need for the experiment. Each group needs two Petri dishes, two sterile swabs, and one type of surfactant (soap).
6. Have groups decide who will wash his/her hands with the soap for the group. This student must swab her hand and wipe the swab on the first Petri dish *before* washing her hand with the assigned soap and swabbing a sample for the second Petri dish. *Note: If students need to leave the classroom to wash their hands, make sure the other group member goes with him/her to open doors and make sure the first student does not touch anything on the way back.*
7. Put all the Petri dishes in a warm dark place to be incubated for 48 hours.
8. When it is time to analyze the results of the experiment, have groups retrieve their Petri dishes and bring them back to their desks. The first thing the groups should do is draw on their log sheets what the Petri dishes look like.
9. Have the second student (recorder) count the number of colonies on each Petri dish. Each colony represents a cell cultured from the student's hand. Students should fill in the appropriate spots in the table on the log sheet.
10. Have students compare the number of colonies on the control (unwashed hand) and the number of colonies on an experimental dish. Have them write their group's answers on the board.
11. Have students complete the chart on their worksheet.
12. As a class, have students determine which soap design best decreases the amount of bacteria on dirty hands.
13. Have the students discuss what the design criteria would be for the different soaps. For instance, the number of cells that must be removed as a percentage. Ask the students if the design criteria might change depending on the application (hospital soaps vs. soaps in your house).
14. Have students think about designing a new surfactant for various applications. Remind students that this is similar to what engineers might do when designing a solution to an organic compound (like bacteria or oil) problem in people or the environment. Engineers study the ingredients in different surfactants (soaps) and design a surfactant product that would remove the offensive bacteria or organic compound. (Note: A next step in the design process [that they will not do in this activity] might be to test their new surfactant design on cultures of the organic compound for that situation.

Attachments

Sudsy Cells Worksheet (doc)
Sudsy Cells Worksheet (pdf)

Troubleshooting Tips

If the cells are clumped together, the students could calculate the area covered by placing the Petri dishes over graph paper and the number of squares covered by bacteria can be used instead of counting individual colonies.

Also, if the colonies seem very small, they can be incubated longer than 48 hours or the students can use a magnifying glass to count them.

Assessment

Pre-Activity Assessment

Prediction: Have students predict the outcome of the activity before the activity is performed.

- Which soap will destroy the most bacteria during this activity?

Practice Math Calculations: Have students answer the following word problems to prepare for the activity.

- Samantha, Bridget and Tony counted three cells on their plate after culturing a hand washed with bar soap, while Pete, Eric and Shelley counted five cells on their plate after culturing a hand washed with the same soap. What is the class average of the two trials? (Answer: Find the mean by adding the total cells counted for all trials [5+3] and then dividing by the number of trials [2]: [5 + 3] / 2 = 4.)
- The class average was 12 cell colonies on the Petri dish after culturing an unwashed hand and three cell colonies on the Petri dish after culturing a hand washed with anti-bacterial soap. What percentage of bacteria was removed by the antibacterial soap? (Answer: Find the difference between the control and the soap that is tested [12-3], and

divide that by the number of colonies in the control [12] and then multiply by 100% to turn it into a percentage: [12-3] / 12 x 100% = 75%)

Activity Embedded Assessment

Worksheet: Have students complete the Sudsy Cells Worksheet, which asks them to draw pictures of the experiment as well as analyze the results using averages and percentages. Have them check with their groups to see if they got the right answers. Review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Engineering Surfactant Impacts: Have students think about the impacts of engineering surfactants on individuals, society and the environment. Some surfactants are known to be toxic to the environment, other animals and humans. For example, industrial cleansers may remove harmful pollutants from entering the air stream but can be harmful to the environment if waste products are dumped into local waterways. Have students pick one of the following scenarios and discuss what impacts need to be considered in the design of a surfactant for that application.

- A large laundromat that cleans sheets and towels for a local hospital.
- An airport that removes airplane oil spills from the tarmac.
- A farm that removes weeds from their crop using an herbicide (surfactant).
- For recycling purposes, a factory that removes ink from old newspapers using a deinker (surfactant).
- A cleaning company that cleans the playground equipment at a school.

Activity Extensions

If microscopes are available, have students make slides with the cultured bacteria. See if different kinds of bacteria are present in the cultures and determine which soaps worked best with different bacteria. If possible, find out the types of bacteria by using an identification key. To extend the activity to oil spills, have students try out their soap design on some vegetable oil poured into a small bowl of water. Which soap design worked the best at breaking up the oil in the bowl?

Activity Scaling

- For upper grades, engage students in a more rigorous discussion of the factors affecting cell growth. Also, bring up the idea of antibiotic resistance and how microorganisms can adapt to our anti-bacterial products, rendering them ineffective.
- For lower grades, have students analyze results in a more qualitative way instead of calculating averages and percentages.

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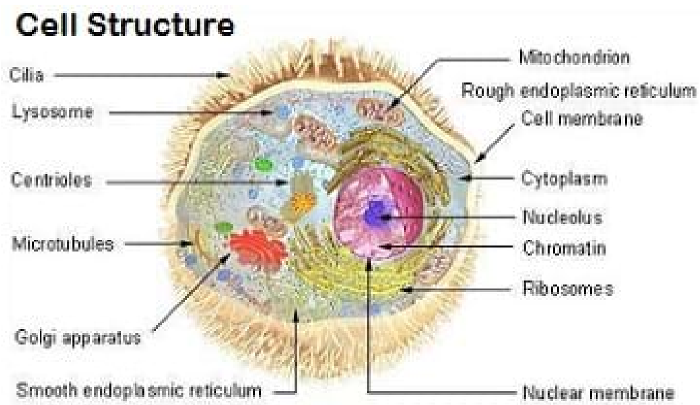
Last modified: November 7, 2017

Lesson: **Cellular Respiration and Bioremediation**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level: 7 (6-8)
Time Required: 20 minutes
Lesson Dependency : None



The diagram of a cell.

Summary

Students learn about the basics of cellular respiration. They also learn about the application of cellular respiration to engineering and bioremediation. And, they are introduced to the process of bioremediation and examples of how bioremediation is used during the cleanup of environmental contaminants.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

In bioremediation, bacteria digest toxic compounds and break them down into harmless byproducts in a process that is analogous to the way humans eat, breathe and produce waste. Engineers can monitor whether bioremediation is occurring by measuring a decrease in what the bacteria are "inhaling" and an increase in what they are "exhaling." Measuring these results of cell functions is a generally easier process than trying to keep track of the actual amount of toxic material that exists. In bioremediation, engineers promote the growth of cells that break down toxic compounds into harmless byproducts. By understanding how the cells "breathe," engineers can monitor cell growth by measuring the changes in concentration of chemicals that bacteria "inhale" and "exhale."

Learning Objectives

After this lesson, students should be able to:

- Explain the purpose of cellular respiration.
- Describe bioremediation.
- Give examples of when engineers use bioremediation to clean up the environment.

Introduction/Motivation

Did you know that all cells, even plant cells, grow and reproduce through cellular respiration? Cells get energy from their food by breaking it into water and carbon dioxide. Cells require oxygen to breathe and carbon-based food sources from the environment to get energy. Here is a simplified chemical reaction that is used to describe cellular respiration (write it on the board):

$$C_6H_{12}O_6 \text{ (food)} + 6O_2 > 6H_2O + 6CO_2 + \text{energy to use for other things}$$

This equation tells us that cells need food and oxygen in order to get energy from their environment. The energy that the food and oxygen help produce is used for the cell to grow, live and reproduce. Cells can actually use many different types of food in this equation; the food just needs to be carbon based.

The three main steps in cellular respiration are: glycolysis, the Krebs cycle, and the electron transport chain. The main purpose of all these complex steps is to get energy for the organism to grow, survive and reproduce. The steps of cellular respiration take place in the cytoplasm of prokaryotic cells and the cytoplasm and mitochondria of eukaryotic cells.

Engineers have developed a way to use cells that like to eat pollution (as their food source) to clean up the environment. These cells can help clean up polluted soil and water by eating the contaminants. Has anyone heard the word *bioremediation* before? Bioremediation is when something living, like a microorganism, fungus or green plant, is used to return a polluted environment back to an unpolluted, original state. Bioremediation is a process used by environmental engineers to clean up polluted areas. Some examples of pollutants that bioremediation can be used to clean up are oil, fuel, toxic metals and cleaning agents.

Bioremediation can be classified two ways: *in situ*, when something is introduced to the contaminated area, or *ex situ*, when the contaminated materials are removed and bioremediation is done elsewhere. Microorganisms are often used for bioremediation of oils and detergents. Microorganisms cannot be used for some things, including heavy metals. In the case of contamination by metals such as lead and mercury, plants are used for bioremediation because they can store the heavy metals in the parts of the plant that are above ground and can then be harvested for removal.

Lesson Background and Concepts for Teachers

Steps in Cellular Respiration

The three steps to cellular respiration are: glycolysis, the Krebs cycle (also called the citric acid cycle), and the electron transport chain.

In *glycolysis*, the cell turns the carbon-based food source into ATP (adenosine 5 triphosphate) for energy and other byproducts. This part of the cycle does not require oxygen and is also part of anaerobic cellular metabolism.

The byproducts of glycolysis are converted to more ATP in the Krebs cycle. The *Krebs cycle* takes place in the mitochondria of the cell. Enzymes are used to break down the food further and produce ATP.

In the final part of cellular respiration, the *electron transport chain*, the cell uses oxygen to replenish the molecules needed to keep the Krebs cycle going. The cell gets rid of extra electrons produced in the Krebs cycle. O_2 is converted to CO_2.

All parts of cellular respiration use enzymes. Enzymes are proteins made by the cell that help the cell break bonds in food molecules to make energy for cellular growth and reproduction.

Vocabulary/Definitions

cellular respiration: The process where cells convert food into energy for metabolic processes.

electron transport: The third step in cellular respiration; the process whereby cells convert energy into ATP that can then be used by the cells to run metabolic processes.

glycolysis: The first step in cellular respiration whereby carbon molecules (food) is converted into energy by the cell.

Krebs cycle: The second step in cellular respiration whereby carbon molecules are converted into ATP, water and CO2.

photosynthesis: Plants form carbohydrate molecules that the cell can later use as an energy source from CO2, sunlight and water.

Lesson Closure

Who can tell me what cells require for life, or to complete cellular respiration? (Answer: they need water, oxygen and a carbon-based food source.) So, we learned today that cells break down "food" during cellular respiration to get energy for growth, survival and reproduction. Engineers use their understanding of cells and cellular respiration to clean up contamination in the environment through a process called bioremediation. Bioremediation involves microorganisms, fungi and plants whose cells can "eat" pollution for food in order to remove that pollution from soil and water. These cells convert contaminants into energy through cellular respiration which they then use to sustain their life. In the case of some types of contaminants, such as toxic metals, the metals are not converted into food energy but are simply stored in the organism (for example some metals may removed from the soil by plants, and then get stored in the plants' leaves, these leaves can then be harvested and disposed of safely).

Assessment

Pre-Lesson Assessment

Discussion Question: Ask a discussion question to get students to think about the upcoming lesson. After soliciting answers, explain that these questions will be answered during the lesson.

- What does a cell need to grow, survive and reproduce?

Post-Introduction Assessment

Question/Answer: Ask the students questions and have them raise their hands to respond. Write their answers on the board.

- What is cellular respiration? (Answer: The process in which cells convert food into energy for growth and reproduction.)
- What type of food source does a cell need for cellular respiration? (Answer: A carbon-based food source.)
- How do engineers use cellular respiration to clean up the environment? (Answer: Engineers use cellular respiration through bioremediation to clean up the environment. Bioremediation is a process in which cells are used to remove toxins from soil and water.)
- What do the cells do with the pollutants during bioremediation? (Answer: The cells digest the pollutants and convert the carbon-based source into energy for growth and reproduction. The cells help remove the pollutants from the environment.)

Lesson Summary Assessment

Engineering Bioremediation Impacts: Have the students think about the impacts of engineering bioremediation on individuals, society and the environment. As a class, list the pros and cons of bioremediation in cleaning up a contaminated environment.

Lesson Extension Activities

Have students research different types of bioremediation that are in use today. Some examples include bioventing, phytoremediation, bioreactors, composting, biostimulation and rhizofiltration.

Have students learn more about using plants for bioremediation. Which plants are most successful in bioremediation? Some examples include sunflowers, ragweed, poplar trees, and sugar beets. What types of environmental contaminants have been removed successfully using plants?

This lesson can be combined with the lesson about photosynthesis since they are opposites. Cellular respiration consumes the products of photosynthesis and vice versa. It is important to mention that plants perform both cellular respiration and photosynthesis while animals only perform cellular respiration.

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Last modified: June 6, 2017

Hands-on Activity: **Breathing Cells**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level:	7 (6-8)
Time Required:	50 minutes
Expendable Cost/Grp :	US $1.00
Group Size:	2
Activity Dependency :	None

Students investigate cellular respiration

Summary

Students use a simple pH indicator to measure how much CO2 is produced during respiration, at rest and after exercising. They begin by comparing some common household solutions in order to determine the color change of the indicator. They review the concepts of pH and respiration and extend their knowledge to measuring the effectiveness of bioremediation in the environment.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

When toxic materials are spilled into the environment, engineers can use microorganisms, fungi or plants to clean up the spill through a process called bioremediation. The engineers choose an organism that can "eat" the target contamination. One way that engineers can tell if the bioremediation is working is by measuring how much the bacteria are "breathing." Engineers measure how much organisms are breathing by changes in pH of the soil or water in which they are growing. Measuring the results of cell activity is usually easier than trying to keep track of the actual amount of toxic material in the environment.

Pre-Req Knowledge

Students should have a basic understanding of pH. It is also helpful to have a basic understanding of cellular respirations, as discussed in the associated lesson, Cellular Respiration and Bioremediation.

Learning Objectives

After this activity, students should be able to:

- Describe the effects of cellular respiration on pH.
- Explain how engineers use pH to measure cellular respiration in bioremediation of contaminated soils.

Materials List

Each group needs:

- 4 small clear plastic cups
- 2 straws
- 1 spoon
- Breathing Bubbles Worksheet

To share with the entire class:

- water

- red cabbage indicator solution (Instructions: Chop a cabbage into small pieces and steep in boiling water for at least 10 minutes. Then, filter out the cabbage pieces using a coffee filter or tea strainer. You should be left with a bluish/purple solution at neutral pH.)
- 4 clear different solutions to measure pH (examples: diluted lemon juice and/or vinegar, baking soda mixed with water, water, soda pop, etc.)
- pH meter (if available) or pH paper strips (optional)
- plastic gloves (optional)

Introduction/Motivation

What do you know about *pH*? The pH of a solution is a measure of how much *acid* or *base* is in a solution. A low pH corresponds to an acidic solution, and a high pH corresponds to a basic solution. As a point of reference, a neutral pH would be 7. What is an example of a solution with a low pH? This would be anything acidic, such as citrus fruit or vinegar (remember: low pH equals high acidity). What solution has a neutral pH? Distilled water is a solution that has a perfectly neutral pH. What is an example of a solution that has a high pH, or is basic? Basic solutions would include baking soda, ammonia and bleach (remember: high pH equals low acidity, or is basic). pH measures the amount of hydrogen ions in a solution. Lots of hydrogen ions form an acidic solution, and fewer hydrogen ions form a basic solution.

Did you know that cellular respiration has a pH value? When a cell goes through cellular respiration, it consumes oxygen and produces CO_2 which lowers the pH of water (forming an acidic solution). On the other hand, when cells go through photosynthesis, they produce oxygen, which raises the pH of water (forming a basic solution).

Bioremediation is a process whereby engineers use something living, like a microorganism, fungus or green plant, to return a polluted environment back to its original state. During bioremediation, some cells can use certain types of pollution as food for cellular respiration, to create energy for growth, life and reproduction. How do you think engineers can use pH to measure bioremediation? Well, pH tells us about the chemistry of water and soil. Engineers can test the pH of an area to determine if bacteria or other cells are growing and performing cellular respiration in the area. If the pH is very acidic, then cellular respiration may be occurring (or the water may be acidic due to the presence of inorganic acids). The organisms that engineers use for bioremediation are microscopic. So, it is hard to detect them directly. It is much less expensive and faster for engineers to measure the pH that bacteria cells produce when they grow and reproduce in the environment than to develop complex equipment to detect their presence. If you measure the pH of a polluted system and then add microorganisms in order to eat up the pollution, the pH of the system should decrease over time as the microbes do their job. This decrease in pH provides evidence that the bioremediation is proceeding as it should.

Today we are going to measure the pH of a variety of solutions and then measure how much CO_2 we breathe out when we are resting and when we are exercising. First, we are going to test our pH indicator on four different solutions by adding a few drops of the indicator to each solution. Once we have determined which solutions are acidic, basic or neutral, we will try to identify the solutions as a class. Next, we will measure how much CO_2 we produce when we are resting and exercising, using the same indicator we used to determine the identity of the four solutions. Lastly, we will think about how we can use pH to help engineers optimize bioremediation.

Vocabulary/Definitions

carbon dioxide: (CO2) A gas at room temperature that is produced during cellular respiration; when bubbled into water, CO2 lowers the pH of the water creating an acid called carbonic acid.

oxygen: A gas that is consumed during cellular respiration.

pH: A measure of how much acid or base is in a solution; a low pH corresponds to an acidic solution, and a high pH corresponds to a basic solution. A neutral pH is equal to 7.

pH indicator: A solution that changes color depending on the surrounding pH.

Procedure

Background

In this activity, students measure how many breaths it takes to change the color of the indicator to acidic from neutral when they are resting and then after they have been exercising. Their bodies naturally produce more CO_2 when they have been exercising than when they are resting. The indicator should turn to acidic faster after they have been exercising.

Cabbage indicator colors (see Figure 1):

- Acidic pH turns the cabbage juice red.
- Neutral pH keeps the cabbage juice purple.
- Basic pH turns the cabbage juice blue.

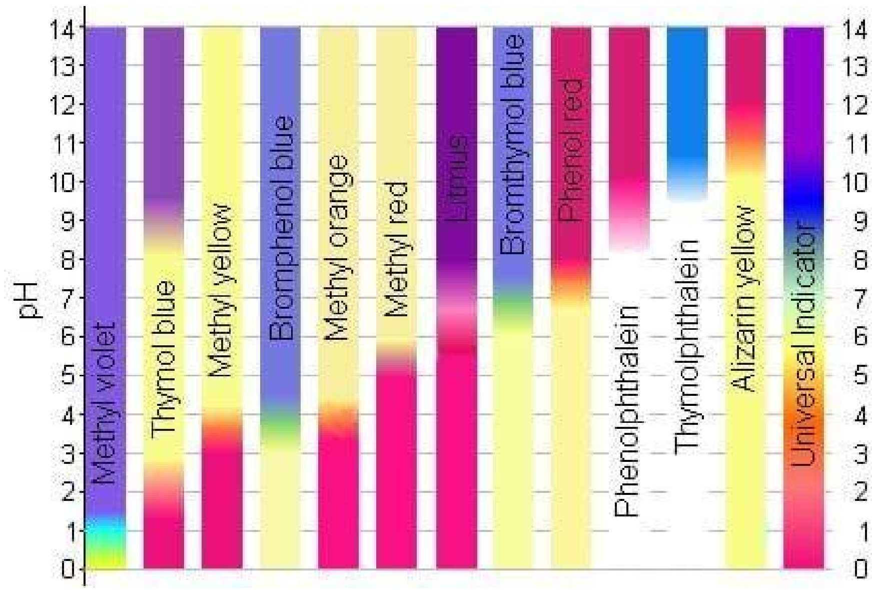

Figure 1. A pH indicator.

Before the Activity

- Gather materials and make copies of the Breathing Bubbles Worksheet.
- Make the red cabbage indicator solution the day before. (See instructions in Materials List section)

With the Students

1. Pass out materials to students. Have them line up their four cups to receive the "unknown" solutions.
2. Pour samples of four unlabeled solutions, one in each cup, to each team of students. Have students use the indicator to assign identities to four clear solutions by adding a spoonful of indicator into the solution until it turns color. For acidic solutions, the indicator should turn red, and for basic solutions the indicator should turn blue. Have students record their observations on their worksheets.
3. Next, have students thoroughly rinse their cups. Pour cabbage juice indicator into all four of the cups, about halfway full.
4. Remind students that CO_2 is produced during cellular respiration and O_2 is consumed. This results in an acidic solution being created. Have students record on their worksheets the color of the cabbage juice indicator before the experiment begins.
5. Next have each student breathe into one cup of the indicator solution through the straw, remembering not to drink the indicator but blow into it. Record the number of breaths that it takes to turn the indicator to an acidic pH.
6. Next, have students sprint, briskly walk up and down stairs, or do some jumping jacks.
7. Have the students repeat the process of breathing into the indicator solution through the straw, and record how many breaths it takes to turn the solution to an acidic color after exercising.
8. Have students report their results to the class and record the results on the board.
9. Next, have students answer the results and engineering questions on their worksheets.
10. As a class, discuss how engineers can use a similar technique to measure the amount of microbial activity in the water or in the soil where a toxic spill has occurred. Engineers can save time and money by measuring changes in pH after they have added bacterial cells or plants to a bioremediation site instead of trying to culture organisms in

the lab.

Attachments

Breathing Bubbles Worksheet (doc)
Breathing Bubbles Worksheet (pdf)

Safety Issues

Do not use any toxic liquids for your pH testing; students may inadvertently get some solution on their hands or in their mouths.

Although it is not harmful, remind students not to drink the indicator solution.

Troubleshooting Tips

The students need to thoroughly wash out their four cups after testing the unknown solutions. Any residue left in the cups may affect their breathing experiment.

If the indicator solution does not change color, the students can use pH paper to measure the pH of a solution of water after they breathe into it while resting and then after they have been exercising.

Assessment

Pre-Activity Assessment

Class Discussion: Gauge the students' prior knowledge of the material by asking the following questions:

- What is pH? (Answer: The pH of a solution is a measure of how much acid or base is in the solution.)
- What is cellular respiration? (Answer: The process in which cells convert food into energy for growth, survival and reproduction.)

Activity Embedded Assessment

Worksheet/Pair Check: Have students record measurements and follow along with the activity on their worksheets. After students have finished their worksheets, have them compare answers with their peers.

Post-Activity Assessment

Engineering and Bioremediation Costs: Bioremediation has many cost and efficiency benefits. Have students think about how the expense and resources put into bioremediation might be different than developing tools and equipment to remove contaminants from soils and water. Have them write a paragraph or hold a class discussion comparing bioremediation vs. land removal in contamination cleanup. Use the following questions to frame the advantages and disadvantages of the two remediation options systematically:

- What materials are needed for land removal? (Excavation equipment, usually a backhoe to dig out the soil, a giant bin to store the excavated soil, and a large truck to transport the excavated soil to the appropriate disposal facility.)
- Which remediation option (bioremediation or land removal) do you expect to be less expensive? (There are fewer costs associated with bioremediation because biodegradation is a naturally occurring process. Engineers harness the ability of microbes or larger organisms such as plants to degrade contaminants during bioremediation.)
- Can we use bioremediation at any contaminated site? What conditions must be present for bioremediation to be effective? (Microbes must be present at the contaminated site in order for bioremediation to be possible. Alternatively, microbes can be introduced to the site, but the success rates with non-native microbes are much lower.)
- Which remediation option has a higher likelihood of failure? (There are more variables influencing the success of bioremediation; for example, if the soil conditions and the contaminant are not conducive to microbial growth, then bioremediation will not work. Land removal is more straightforward and predictable because to eliminate the contaminant, all you have to do is excavate the soil.)

To systematically evaluate the two remediation options, have students complete the chart below. The chart should help students to organize their thoughts from the previous discussion.

Remediation Option	Advantages	Disadvantages
Bioremediation		
Land removal		

Engineering Recommendations: Have students pretend to be consultants for an engineering firm for one of the following scenarios. Ask the students to make recommendations about how to monitor the bioremediation of the area based on what they learned during this activity.

- A piece of land contaminated with heavy metals and oils from an old industrial factory.
- A former shipyard that has leaking barrels of oil in one area.
- A piece of farmland that has been previously treated with several harmful pesticides.
- A piece of land that has been contaminated with soaps and solvents used by a dry cleaning company.
- A nuclear waste site that has very high amounts of radioactive materials leeching into the soil and groundwater.

Activity Extensions

Have students learn more about monitoring the effects of bioremediation. Several measurements are usually performed, including oxidation reduction potential (redox), pH, temperature, and oxygen content.

Use the same pH indicator to measure the "breathing" of yeast cells. Have the class grow yeast cells in a solution of warm water and sugar and add indicator to the yeast solution in order to watch the pH change as the yeast cells produce acid when they digest the sugar.

Activity Scaling

- For upper grades, have students describe pH and indicators quantitatively. Have them create scales for measuring the pH of different solutions using the cabbage juice indicator.

References

Helmenstine, Anne Marie. How to make red cabbage pH indicator: Acid base chemistry. Accessed August 23, 2008. http://chemistry.about.com/library/weekly/aa012803a.htm

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Last modified: May 25, 2017

Lesson: **The Cloning of Cells**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level: 7 (6-8)
Time Required: 20 minutes
Lesson Dependency : None

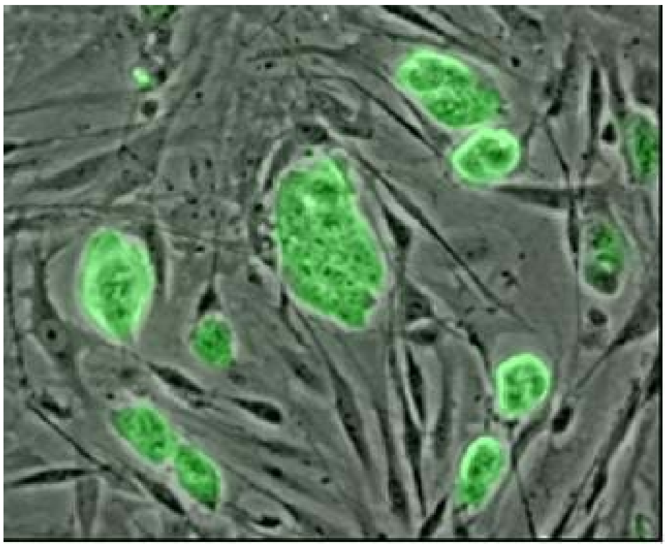

Figure 1. Mouse embryonic stem cells stained with a fluorescent marker.

Summary

Students continue their education on cells in the human body. They discuss stem cells and how engineers are involved in the research of stem cell behavior. They learn about possible applications of stem cell research and associated technologies, such as fluorescent dyes for tracking the replication of specific cells.

Engineering Connection

From engineering tools for observation on the molecular level to chemical and bioengineering of natural fluorescent dyes to the examination of cell replication in an organism, engineering developments and design have helped advance research of all types of cells. Engineering influences science and medical research by facilitating the understanding of how cells are influenced in all directions by their environment and how they behave in our bodies.

Pre-Req Knowledge

Students should have knowledge of the parts of a cell and cell function.

Learning Objectives

After this lesson, students should be able to:

- Define stem cells.
- List several applications of stem cells research.
- Describe engineering designs that are advancing stem cell research.

Introduction/Motivation

We have cells throughout our entire body.... thousands upon thousands of cells. Who can tell me what cells do? They keep us alive! They are the foundation of life and without them; there would be no life on Earth. We have so many cells throughout our bodies that it is hard to count them all. Does anyone have any guesses on how many cells are in an average human body? About 100 trillion! They are typically very small, around 10 μm – that's smaller than the diameter of a human hair. *(Fun Fact: The largest known single cell is actually quite large – an ostrich egg!)*

We have about 210 different types of cells in our bodies, with each having a different function, or job, to keep us alive and healthy. Blood and immune system cells, including red and white blood cells, keep blood running through our body to our organs and help fight off illness. Brain cells, including *neurons*, carry electrical signals through our brains, transmitting information and instructions. When we are in class, our brain cells are working to store new information that is being learned, while at the same time, also carrying information to different parts of the brain to tell our bodies to keep our hearts beating and our lungs breathing so we stay alive.

Since cells are so important, what can we do if our cells get "sick"? Well, among trying to return the cells to a healthy state, some people believe *stem cells* are the answer to treating life-threatening diseases or medical conditions. While controversial (that is, meaning people disagree about it), stem cell research is a popular research subject now.

Lesson Background and Concepts for Teachers

Cancer, one of the main causes of death in America, is a disease in which one type of cell divides and replicates rapidly within tissue that has a specific type of cell needed for proper body function. What do you imagine might happen if "sick" blood cells began dividing rapidly in our brains and invading the space that neurons usually occupy? How would our bodies know to keep our hearts beating and lungs breathing if neurons began to be replaced by blood cells? Among many treatment options for cancer are surgery and *chemotherapy*. The goal of surgery is to entirely remove the cancer cells. Unfortunately, this is not always possible, and much depends on where the cancer is actually located. Chemotherapy, on the other hand, is not the removal of the "sick" cells, but the interference with cell division to destroy cell life and additional cell growth. However, the chemotherapy process targets all rapidly dividing cells, not just cancer cells, which can then affect other "healthy" cells in the body, such as hair and intestinal cells, causing a person to get sick from the treatment procedure itself.

Another treatment option being researched involves the use of a certain type of cell called *stem cells*. Does anyone know what a stem cell is? Two types of stem cells are: embryonic stem cells, found in a developing human embryo, and adult stem cells, found in umbilical cord blood and bone marrow (see Figure 2). Stem cells have the ability to replicate themselves by *mitosis* and be grown and differentiated into the many cells in our bodies, including different types of muscle and brain cells. In adult humans, stem cells work to replace damaged tissue but are also involved in normal regeneration of cells, such as skin and blood. Embryonic stem cells can actually regenerate into more than 200 types of adult cells, given the right environment and stimulation for that cell type. The applications of stem cells for medical therapies include treatments of cancer and spinal cord injuries, among others.

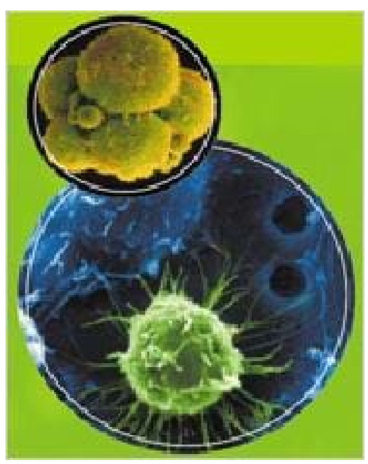

Figure 2. Stem cells collected from human bone marrow.

Researching how stem cells behave in our bodies is crucial before stem cell treatments can be used. Engineers play a big part in this research. One engineering design currently being researched is the development of a three-dimensional microscopic housing structure that would allow scientists to look at stem cell behavior from every direction. This is very important since stem cells are indeed affected from all directions. For example, if we were looking for an apartment in a multi-story building and we were told that the noise level of the next-door neighbors was very low, we would be very disappointed if we moved in and found out that the residents below and above us were extremely loud. It is clear to us, then, that we did not have all of the information needed before we chose that apartment. Without an engineered technology to analyze stem cells from every direction, scientists would not have all the information they need to develop safe and effective medical treatments.

Another key role of engineers in stem cell research is developing ways to track stem cell behavior once injected into an organism. Chemical engineers helped to develop different fluorescent proteins that act as markers based on naturally occurring fluorescent proteins in jellyfish. These green fluorescent proteins (GFPs) can be linked to naturally-occurring proteins and injected into an organism, such as a mouse. The mouse then produces fluorescent green, protein-linked cells, including stem cells, which can be extracted and injected into another mouse to see where the new fluorescing stem cells travel (see Figure 3). Shining a blue light onto the mouse causes the GFPs to glow brightly and easily be seen. The injected stem cells with GFPs (see Figure 1) can then be easily traced to see if they move toward a certain part of the body and what type of cells they differentiate into within the animal.

The Controversy

Stem cells are currently a controversial topic because the use of embryonic stem cells involves either the destruction of a human embryo or therapeutic cloning of cells, which is the basis of cloning animals and possibly even humans. Research is being done to find a way to generate embryonic stem cell lines without the destruction of embryos. Little controversy exists with the use of adult stem cells found in adult tissues. In fact, adult stem cells have been used for years to treat leukemia and bone cancers through bone marrow transplants.

Figure 3. Mice born with green fluorescent protein (GFP) stain, inherited from a father who received a donation of spermatogonial stem cells.

Arguments against embryonic stem cell research include concerns around reproductive cloning and challenges to personal or religious beliefs. Arguments for embryonic stem cell research include insistence that stem cells are necessary for the advancement of medical science and may save lives. Proponents of stem cell research position that the only embryos used for research are those that would be discarded anyway. The social and ethical challenges behind stem cell research have had a large impact on government funding and regulations.

Vocabulary/Definitions

fluorescence: Bright light shining from an object as a result of high energy photons (light), such as ultraviolet light or x-rays.

green fluorescent protein: (GFP) A dye created by engineers to simulate naturally occurring fluorescence in jellyfish.

stem cell: A cell that is able to replace itself and differentiate into another cell type in the body.

Lesson Closure

Stem cells are able to replace themselves and be grown and differentiated into the various cell types in our bodies. Stem cell research has looked at using stem cells to replace damaged tissue and regenerate cells like skin and blood. The applications of stem cells for medical therapies include treatments of cancer and spinal cord injuries. Engineers are highly involved in stem cell research. They design the technologies that lead to the understanding of stem cells, their structure, and how they differentiate into other cells. Engineers also develop ways to find and track stem cells when placed into different environments. One example is the development of green fluorescent proteins (GFPs) that have been injected into mice to follow the replication and differentiation of stem cells. Can you think of other ways that engineers are involved in the medical field? (Ask students to get into groups of three and write or draw pictures of engineering applications that involve cells and medical research. Discuss these as a group.)

Attachments

Cancer and HeLa Cells Lesson Extension handout (.pdf)
Cancer and HeLa Cells Lesson Extension handout (.doc)

Assessment

Pre-Lesson Assessment

Discussion Question: Ask a discussion question to get students thinking about the upcoming lesson. Write student responses on the board. After soliciting answers, explain that these questions will be answered during the lesson. Leave the responses on the board and refer to them for discussion throughout the lesson. Ask the students:

- What are cells? Give me your definition.
- What are stem cells?

Post-Introduction Assessment

Question/Answer: Ask the students questions and have them raise their hands to respond. Write their answers on the board.

- What are stem cells? (Answer: A cell that is able to replace itself and transform into another cell type in the body.)
- Why are scientists interested in learning more about stem cells? (Answer: They may have medical applications that could help treat specific diseases and injuries.)
- How do engineers make it possible for scientists to study stem cells? (Answer: They create instruments to look at the stem cells from every direction and develop specialized proteins to study stem cells in animals.)

Lesson Summary Assessment

Engineering Impacts: Engineers have to think about the broader impacts of a design when developing new systems and technologies. Have the students, in pairs or as small groups, think about the different considerations an engineer would likely think about when designing technologies for stem cell research. Some of these might include the impacts on individuals, society and the environment, as well as ethical, economic, social and political considerations.

Lesson Extension Activities

Court is in Session: Ask the class to split into two groups: one in support of stem cell research and one against it. Have each team research the controversy behind stem cell research. Ask each team to prepare an argument to bring to "court." This should include drawings on butcher paper, diagrams, facts referenced from a reliable source, pros and cons, etc. A simple debate can be performed, or each team can choose a couple of witnesses (such as an engineer and a politician, etc.) and a couple of lawyers to question the witnesses from the other team. The judge can be the teacher. Opening and closing arguments should be similar to having a debate.

Cancer and HeLa Cells: Introduce students to HeLa Cells by having them read individually the Cancer and HeLa Cells Lesson Extension handout. Have students follow the links below to learn more about HeLa cells. If desired, have students conduct further research and write a report about their findings and the many uses of HeLa cells. Another option is to have a class debate in which students argue whether it was right or wrong to use Henrietta's cells without her consent.

- A video explaining the origin and application of HeLa cells can be found at: http://www.cbsnews.com/stories/2010/03/15/sunday/main6300824.shtml

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Supporting Program

Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

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Hands-on Activity: **Glowing Flowers**

Contributed by: Integrated Teaching and Learning Program, College of Engineering, University of Colorado Boulder

Quick Look

Grade Level:	7 (6-8)
Time Required:	90 minutes (over two days)
Expendable Cost/Grp :	US $2.00
Group Size:	2
Activity Dependency :	None

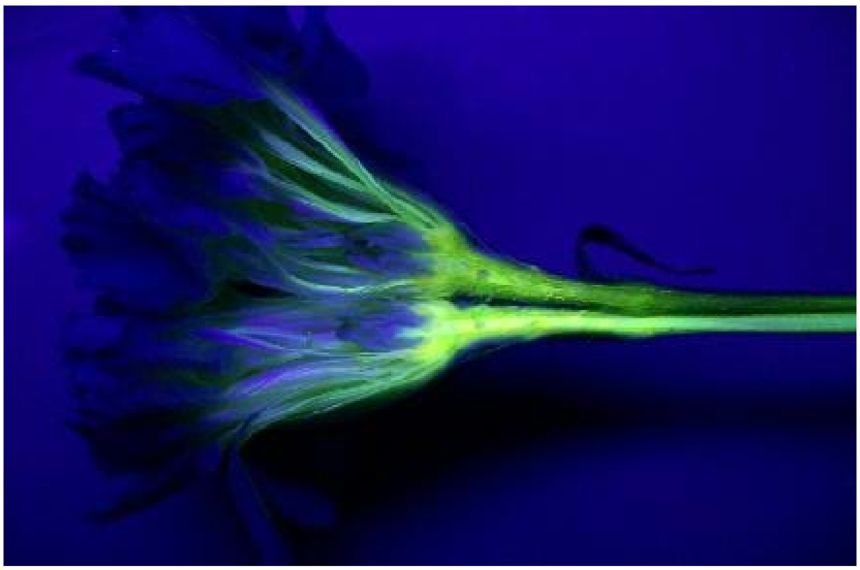

Figure 1. A flower injected with fluorescent dye under ultraviolet light.

Summary

Student teams learn about engineering design of green fluorescent proteins (GFPs) and their use in medical research, including stem cell research. They simulate the use of GFPs by adding fluorescent dye to water and letting a flower or plant to transport the dye throughout its structure. Students apply their knowledge of GFPs to engineering applications in the medical, environmental and space exploration fields. Due to the fluorescing nature of the dye, plant life of any color, light or dark, can be used — unlike dyes that can only be seen in visible light.
This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Engineers develop technologies to advance the possibilities of scientific research. From microscopes designed to see extremely small things, to spacecraft that can peer into far-away galaxies, to a special dye that make stem cells glow, we learn about how things work in our world with the help of engineers.

Engineers play a large supporting role in recent advances in medicine, including research on the treatment of cancer. Research on using stem cells for management of diseases and injuries are among these treatments. Engineering developments in this area allow researchers to study the behavior of stem cells and how they replicate, travel and react in our bodies.

Pre-Req Knowledge

Students should have know the parts of a cell and cell function. It is helpful to complete the associated lesson, The Cloning of Cells, to introduce students to the engineering applications in stem cells research.

Learning Objectives

After this activity, students should be able to:

- Describe why fluorescence is useful to observe cells in living organisms.
- Describe engineering designs that are advancing stem cell research.

Materials List

Each group needs:

- 3 flowers or leaves of their choice (Note: Choose flowers/leaves from a pile collected by the teacher or have the class go outside and find samples from school grounds. Be sure to advise students how to take clippings without damaging the tree, plant or surroundings. Note: Carnations work well.)
- 1 plastic cup
- 4 latex gloves (2 per person)
- 1 pair tweezers or tongs
- 1 razor blade or other cutting tool to "dissect" the plants. (Note: Advise students on proper cutting techniques or have a "cutting station" where they can bring their specimen to be cut by an adult.)
- 1 square brown or black (darker colored) cardboard, ~ 1 ft x 1 ft
- Dyeing Plants Worksheet

To share with the entire class:

- fluorescent blacklight (~15W) (Note: A fluorescent blacklight may be purchased for ~$20. Incandescent lights are less expensive, but do not provide enough energy for this activity.)
- radiator leak detection dye (available at NAPA or other auto parts store for ~$3)
- (optional) microscope (to take a closer look at the dye in the veins of the plant)

Introduction/Motivation

Student Scientist Roger: I just put stem cells into this mouse, but I have no idea where they went! To its feet? Its heart? How do I see them?

Master Scientist Ebert: You should talk to the engineer down the hall. I heard he created a dye that you can add to the stem cells and see them as they move through the mouse!

Student Scientist Roger: Wow! That's amazing! Engineers are so helpful.

Cancer is a type of disease in which a cell or group of cells shows uncontrollable growth, invasion or displacement of surrounding cells or tissues, and sometimes spread to other areas of the body through blood or lymph fluids. Many cancers form a tumor; however, some cancers, such as leukemia, do not. Cancers can be found in other animals besides humans, as well as plants. Cancer treatment currently involves surgery, radiation therapy, and/or chemotherapy. Another treatment option for cancer that is being researched involves the use of stem cells. Does anyone know what a stem cell is? Stem cells are specific cells that have the ability to replicate by mitosis and can be grown and differentiated into the many cells in our bodies, including different types of muscle and brain cells. The two classes of stem cells are: embryonic stems cells found in a developing human embryo, and adult stem cells, found in umbilical cord blood and bone marrow. Stem cell research includes the study of using these specialized cells to replace cancerous cells in the body and treat other injuries like spinal cord injuries.

Engineers are involved in the advancement of stem cell research. One example of an engineering innovation that is helping with stem cell research is the development of green fluorescent proteins (GFPs) (see Figure 2). Chemical and bioengineers develop these proteins in a lab based upon a naturally-occurring protein in jellyfish that makes them glow. This particular engineered protein glows bright green under a blue light which helps the observer determine where the protein is located in a Petri dish or in an organism. Engineers have developed modified forms of this protein that can be genetically linked to specific naturally-occurring proteins within the cells of an organism. Basically, the GFP protein is joined to a specific naturally-occurring protein in a laboratory. The GFP protein is small and does not damage the natural protein's function. The modified protein is placed back into the organism. When the GFP-linked natural proteins and cells replicate, the attached GFPs replicate along with it. This way, the observer can really see how and where a specific protein replicates within the body of an organism.

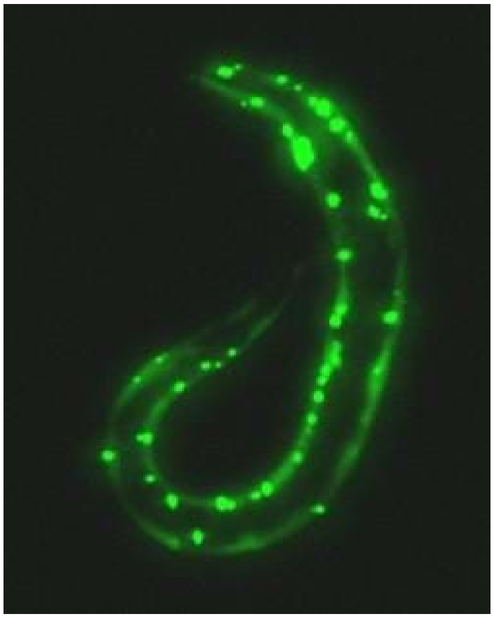

Figure 2. A worm injected with green fluorescent dye.

For example, donor mice can be injected with a GFP-linked protein which functions just like a regular protein in the mouse. The GFP-linked proteins replicate within the different cells in that mouse, creating a donor mouse in which the cells glow bright green under a blue light. Target cells from the donor mouse (such as stem cells) can then be removed and injected into another mouse to see (under a fluorescent blue light) where the injected GFP-linked cells go in the new body, as shown in Figure 3. This is especially important for stem cell research since stem cells can differentiate into a number of different cells when injected into a body. This engineered fluorescing protein helps researchers answer critical questions, such as, "What kind of cells are generated from stem cells?" and "Can these cells replace damaged cells and help cure diseases?"

Figure 3. Mice born with green fluorescent protein (GFP) stain, inherited from a father who received a donation of spermatogonial stem cells.

Vocabulary/Definitions

donor: A person or animal providing blood, an organ, cells, or other biological tissue for another person or animal

fluorescent: A glowing effect caused by the energy difference between an absorbed and emitted photon (light)

GFP: (green fluorescent protein) A protein naturally found in jellyfish that fluoresces green when exposed to a blacklight.

Procedure

Before the Activity

- Gather materials and make copies of the Dyeing Plants Worksheet.
- Mix the fluorescent solution by adding 1 part of the radiator detection dye to 50 parts water. The water should look medium to dark orange. (Note: This should be done carefully by the teacher, with gloves, and the students should be careful handling it as it may easily dye/discolor anything with which it comes in contact.)
- Fill plastic cups to about 1-½ inches with dye solution
- Cut flowers, leaves and any other plant specimens that you want to study to about 6 -7 inches long so that stems fit in the cup without the flower/leaf resting directly in the dye solution.

With the Students

Day 1: Setting up the activity (30 minutes)

1. Review stem cell and cell biology background with the students.
2. Ask students what they think will happen when the plants are placed in the dye. Will we be able to see the dye even in dark-colored leaves? (Ask them to write their hypotheses on their worksheets.)
3. Divide the class into groups of two students ieach. Have each pair choose their three plant/flower specimens (from either the teacher's collection or from outside).
4. Have students place all three specimens in one cup with dye solution, making sure that the end of the stem is in the liquid by at least one inch and the leaf or flower is not touching the solution.
5. Leave the specimens in the dye overnight in an undisturbed location.

Day 2: (60 minutes)

1. Set up a blacklight station/area in the classroom where all students can see.
2. Ask all students to gather their materials, collect their specimens, put on their gloves and ready their tweezers or tongs.
3. Have students pull each specimen from the cup with the tweezers/tongs and lay them on cardboard. (Tip: Hold the cup over the cardboard to prevent dripping during the moving process. The dye is very strong.)
4. Once every group has specimens arranged on the cardboard, turn off the lights and have each group bring their specimens to the blacklight station one at a time.
5. Shine the blacklight on the plants/flowers so the class can observe the samples from each group (see Figure 1).
6. Have the students draw pictures on their worksheets of what their specimens look like when under the blacklight. Have them include written descriptions of their pictures to clarify.
7. If time permits, have students cut into the veins or stem of the plant and take a closer look.
8. Again, have students bring their cut samples to the blacklight station one at a time.
9. Ask each group to share their discoveries with the class and discuss any changes from their hypotheses to their observed results.
10. Ask the students to finish their worksheets.
11. Engage the class in a group discussion based on the worksheet questions, including which plants/flowers were brighter from the dye and where the dye was carried throughout the flower.
12. Engineers design fluorescing proteins that can be replicated within animals and plants for many different purposes. Have students imagine the variety of ways that fluorescing proteins could advance our knowledge of the world around us, including, but not limited to, medical, environmental and space exploration applications.

Attachments

Dyeing Plants Worksheet (doc)
Dyeing Plants Worksheet (pdf)

Safety Issues

The dye is toxic if ingested and easily dyes anything in which it comes in contact. Always use gloves when handling the dye and dyed plants; only the teacher should handle the concentrated dye.

Troubleshooting Tips

To be able to best see the fluorescent dye, use a fluorescent bulb of ~15W. (Note: Do not use an incandescent light; it will not work in this experiment.)

Assessment

Pre-Activity Assessment

Prediction: Have students predict the outcome of the activity before it is performed. What will happen to the dye solution when the plant is placed in the dye overnight?

Activity Embedded Assessment

Dyeing Plants Worksheet: Have students record their observations using the activity worksheet; review their answers to gauge their mastery of the subject. Which plant fluoresces the most? Where did the dye move to within the plant?

Post-Activity Assessment

Engineering Applications: Engineers have developed different GFPs that can be linked to various proteins in a plant or animal. Not only have they developed GFPs that glow green, but engineers have developed fluorescing proteins that glow in other colors including reds, blues and yellows. One application of this is attaching different colored proteins to different cells within one organism. For example, neurons in the brain of mice have been linked with the different colored fluorescing proteins to follow the wiring of the brain. This may help researchers understand how to treat life-altering diseases such as Alzheimer's. With a partner, think about one or more ways that multicolored fluorescent proteins could be used to find out something about an organism.

Activity Extensions

If possible, use a microscope to get a closer look inside the plant's veins.

Have students research other uses for GFPs. Some of these include identifying organisms based on individual differences (for example, two types of compound eyes are found in fruit flies and house flies), detection of carbon dioxide by mice, and cloning of organisms.

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