Two-Faced Bacteria: What Would Happen if Beneficial Bacteria Go "Bad"?

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Overview

Achoo! Cough, cough! Sniffle. You turn to see person across from you wipe her nose on her sleeve. Eww. "Do you want a tissue?" you ask. She shakes her head no and reaches for your pencil. "Can I borrow this?" she asks. Before you can respond, she whisks the pencil away, uses it, and gives it back. You refuse to touch the pencil, but by the end of the period, you absent-mindedly pick up the pencil and put it away. Two days later your throat feels irritated and you have a fever. What happened?

Strep throat, *Streptococcal pharyngitis,* is a bacterial infection of the throat. It is passed from an infected person as she breathes, coughs, or sneezes into the air in the form of tiny droplets. An uninfected person breathes these droplets in, and within two to five days symptoms begin to manifest.[i] But how do the bacteria actually make you sick? Bacterica that make you sick, such as *Streptococcal pharyngitis,* are called pathogenic bacteria. These bacteria can cause illness in one host or several hosts. There are three outcomes affecting the host: one is to adapt to the bacteria and there is no damage to the host; the host is able to fend off the bacterial invasion, and the bacteria dies; or the bacteria multiply so quickly and take over the host and the host dies. How bacteria makes there host sick is in this way: Bacteria can have either pili or flagella that allow it to get to the site of where they will cause infection. Pili, or little hairs around its body, grow into the host and the bacteria are able to remain inside the host, and take in nutrients. Bacteria with flagellum, or whiplike tail that allows for movement, are able to swim to areas where the bacteria will be able to thrive. Once there, bacteria will begin to grow and thrive and the body's immune system gets to work fighting off the invasion. Depending on how good the immune system is will depend on how effective it is against the bacterial infection. Some bacteria are even harder to fight off, as they secrete toxins that make us sick –inducing vomiting and diarrhea. Lastly, there are even some bacteria that have developed a way to invade our cells and take over, consuming the cellular content of the area that they are in. TB, or *Mycobacterium tuberculosis,* is an excellent example of this, as it will invade the cells of the lung, and reside there forever, unless those parts of the lung are removed. [ii]

So why learn more about beneficial and harmful bacteria? More and more, bacteria are becoming resistant to antibiotics. The use and overuse of antibiotics is creating a new form of bacteria known as super bugs. A super bug is not really a bug at all. Super bugs are antibiotic- resistant bacteria, which do not react to normal antibiotic treatments. For instance, *Staphylococcal aureus* (commonly referred to as a Staph infection) is resistant

to the antibiotic meticillin, a form of penicillin. This bug is now known as MRSA (meticillin-resistant *Staphylococcus aureus*). However, MRSA refers to at least seventeen strands of Staphylococcal infections.[iii]

The concept of the super bug is not new. Over the past sixty years antibiotics have been used to treat bacterial infections in humans and farm animals. Today, 70% of the bacteria treated with antibiotics are resistant to these treatments.[iv] And it's not just the use of antibiotics that are turning these bacteria into super bugs. Antibacterial soaps, hand sanitizers, and sprays encourage bacteria to evolve and become more virulent than they were before.[v] In an August 24 *Nature* Article, a doctor from New York University has warned against the use of antimicrobials and antibiotics, claiming that they not only create superbugs, but also "may be having unintended consequences causing permanent changes in the body's protective, friendly flora and causing harm to the body's natural defense system. This may be even more dangerous to health than the creation of resistant super bugs, which have garnered much attention over the last few years."[vi]

Students in my biology classes barely think twice about the antibiotics or antimicrobials that they use. They use these items in order to protect themselves from illnesses and germs in the classroom, in public, and at home. The fear of getting sick and the possibility of acquiring MRSA run deep. However, because they do not understand the biology of the bacteria, they do not see how overusing such items will lead to more superbugs than they realize.

Why a unit about bacteria and superbugs? In our district and statewide curriculum, there is a mini-unit about antibiotic-resistant TB. The students watch a series of short movie clips about Debbie, a white middle-class student who contracts antibiotic-resistant TB. The students complete worksheets about Debbie, antibiotic-resistant TB, how the bacteria evolve and the possible modes of contracting this form of TB. That is all. They do not learn about the structure of the bacteria, how antibiotics are supposed to work, why in the end they fail to work on some bacteria, and which bacteria out there are beneficial to us. This mini-unit follows a very extensive unit on evolution.

This unit is designed to incorporate aspects of the existing curriculum but encourage the students to look more closely at the beneficial bacteria and how they can potentially change into antibiotic-resistant bacteria. The focus of the unit would be on the beneficial human bacteria—*Helicobacter pylori, Bacteroides fragilis, Clostridium difficile, Lactobacillus bulgaricus, Streptococcus thermophilus ,Escherichia coli, Staphylococcus epidermidis, Pseudomonas aeruginosa.* Students will learn about each of these bacteria through readings, computer research, videos, crafting the bacteria structure themselves, and applying the knowledge of how antibiotics could potentially affect each of them. They will compare the bacterial cell structure to the structure of a eukaryotic (animal/plant) cell. At the end of the unit, students will write a persuasive letter to

humans, telling us why we need to take care of these beneficial bacteria and what might happen if we don't.

Rationale

The reason for teaching this unit is to make students aware of how they might be contributing to an up-and-coming epidemic. Parents do not think twice about taking their children to the doctors to get an antibiotic for the common cold. Health professionals encourage the use of antibiotics and antimicrobials to stop widespread bacterial infections. Why are we so hasty in our decisions to go to doctors to get antibiotics for something so small as the common cold? Why are we so dependent upon the antimicrobials that could be killing the beneficial bacteria we need to keep us healthy?

Students must understand that making good decisions about their health and welfare has greater implications for the world they live in. They must understand that while they might be killing off harmful bacteria, they are also killing off beneficial bacteria as well.

Another reason for developing this unit is to reinforce the ideas of mutation and natural selection within organisms that are not eukaryotic, or plants and animals. Many forget about bacteria even though they are a major part of our ecosystem and biology. They fail to see that these prokaryotes, even in their simplest form, are complicated organisms that have developed an effective design for surviving in this world.

My goal is that students come away with a deeper understanding of the microbial world and how they survive. In the past when I have taught about bacteria, students have not taken it seriously, nor do they really think about the design of the bacteria and how they are able to survive and evolve in our ever-changing world.

Objectives

Appoquinimink High School is located in Middletown, Delaware. Its population of students mainly comes from the rural areas of Middletown. Middletown is quickly changing from a rural town into a bustling suburb. Suburban sprawl is taking over Middletown. We are acquiring students not just from the old suburbs but also from cities like Philadelphia, New York, and Baltimore.

Appoquinimink is a newer high school that opened in the 2008-2009 school year. The first graduating class from Appoquinimink was in 2011. AHS boasts 21st century facilites. Many of the classrooms now support SMARTboard Technology or have overhead projectors and screens.

This unit will be designed for the 10th grade coordinated science course, which is primarily biology and biochemistry. This is the year that students in this grade level take

the science test within the Delaware Comprehensive Assessment System (DCAS). They will eventually be taking the end of course assessment for biology as well. This topic is covered in the DCAS and end of course assessment (see Appendix A). This unit will take approximately two to three weeks to complete.

There are already many lessons and case studies of the common MRSA and antibiotic resistant bacteria, but nothing about the beneficial bacteria that can and sometimes do go bad and may even become antibiotic-resistant. I would like to explore the other side of bacteria, the beneficial side. This side benefits humans, but when it is mistreated, it can cause us severe illness. From this mistreatment we rush to use and overuse antibiotics and antimicrobials.

Nobody wants to talk about bacteria unless there is an antibiotic involved. No one wants to know that bacteria can be and are very beneficial to us and to our biotic potential. When introducing the topic of bacteria, students and friends alike, crinkle their noses and make faces exclaiming “ewwww” and asking, “Why do we need to know this?”

My intention in this unit is to portray the beneficial side of bacteria while still cautioning my students to handle them with care. I want them to know that we can live harmoniously with bacteria and to choose wisely when we should and shouldn’t use antibiotics and hand sanitizers.

At the end of this unit students will:

1. Understand the structure and function of beneficial bacteria and the ways they sometimes evolve to become harmful.
2. Design a bacterium based on certain criteria and analyze how the design of their bacterium will be an advantage or disadvantage in its struggle to survive and flourish.
3. Compare and contrast different designs of several bacteria and investigate how they react to certain antibiotics and hand sanitizers.
4. Defend their stance on the use or misuse of antibiotics and antimicrobials within our society is a benefit or detriment to our health and well-being.
5. Relate the survival and reproduction of organisms that have adapted to changes in a population’s environment to changes in the genetic information of a population.

Students will utilize various strategies within the unit. I will use a Jigsaw to teach students the science literacy portion of the unit. A group of students will read a different article and then present their findings to the rest of the class. Each article focuses on how bacteria evolve.

Additionally, students struggle greatly with the diverse and extensive vocabulary they need to discuss bacteria. To facilitate vocabulary acquisition, I will use graphic organizers and build more exposure to the vocabulary through student’s background

knowledge. Students will watch a series of videos that explain the problems of bacterial resistance, which will build upon their vocabulary and critical viewing. Students will adopt a bacterium that is listed and conduct computer research to compare and contrast the pros and cons of their species of bacteria. Video analysis and building their own bacterial structure will expand their visual literacy, critical viewing, and vocabulary analysis. Within the vocabulary strategies, students will use examples and non-examples to explain certain vocabulary, such as using the Frayer Model. In the end, students will use error analysis to identify problems with the overuse of antibiotics in a comic strip or Prezi about bacteria and antibiotics. A Prezi is a multimedia format that allows pictures, words, sound files and video clips to be presented in a specific sequence (free to use at Prezi.com).

Unit Background

What are bacteria? By definition they constitute one of two prokaryotic domains of life, the other being Archaea. But what does that really mean? Scientists have classified bacteria into their own kingdom, Monerans. They are prokaryotic cells that lack membrane bound organelles and nucleus. This structure allows bacteria to be very adaptive to their environment, clone themselves easily, and evolve quickly. Bacteria have four common shapes: cocci, bacilli, spirilla, and spirochetes. Cocci are spherically shaped; bacilli are rod shaped; spirilla are spiral shaped; and spirochetes use rotating, internal filaments to spiral through their environment.

Bacterial infections are determined through staining techniques that identify the cell wall composition of the bacteria. The results are either gram-positive or gram-negative. Gram-positive bacteria have a cell wall structurally less complex than gram-negative bacteria, usually less toxic more easily treatable than gram-negative bacteria. Gram-negative bacteria, which characteristically have a cell wall composed of a thin layer of a particular substance (called peptidoglycan) that makes them usually more toxic than gram-positive bacteria, are usually found in the gastrointestinal tract.

Bacteria that cause infections are called pathogens. Pathogens can hibernate and survive harsh environments before infecting their host. Bacteria have an endospore, which is a thick-coated protective cell produced within a bacterial cell. This allows the bacteria to become dormant and survive harsh environmental conditions. Some bacteria secrete exotoxins, which are poisonous to their host.

Bacteria change their DNA through three different processes: transduction, transformation, and conjugation. Bacteria reproduce asexually, a process that does not allow for genetic variance. However, through the three processes listed above, bacteria can introduce new genetic information and evolve to gain advantage in their environment. Transduction is the transfer of bacterial genes from one bacterial to another by a phage (virus). Transformation is the incorporation of new genes into a cell from

DNA that the cell takes up from the surrounding environment. Conjugation is the union (mating) of two bacterial cells and the transfer of DNA between those two cells. This process helps in the natural selection of bacteria. Natural selection is the process by which individuals with certain inherited traits are more likely to survive and reproduce than individuals that do not have those traits.

Antibiotics are powerful medicines that fight bacterial infections. Used properly, antibiotics can save lives. They either kill bacteria or keep them from reproducing. Antimicrobials, on the other hand, are substances that kill or inhibit the growth of microorganisms such as bacteria, fungi, or protozoans. Antibiotics can be classified in terms of their chemical structure, microbial origin, or mode of action on the bacteria. Their effective range designates most antibiotics.

How Do Bacteria Make Us Sick? And Do All Bacteria Make Us Sick?

Bacteria are foreign bodies that invade areas of our body and cause us to become ill. Most times, bacteria that live in our body are commensalistic, or live in our body and do not cause us any harm. However, if that bacterium finds its way into another area of our body, that is when they will begin to cause harm. They can be passed from organism to organism through several different paths – contact with other organisms, through the food we eat, through water we drink and bathe in, from the air and from the soil. Once the bacteria find their way into a new, warm, and moist environment, they will begin to grow and take in nutrients from their host.

Some bacteria are able to move to a new location through movement of pili or flagellum. Pili are cilia like hairs on the outside of the organism and move in a wave like motion to the intended location. Once there, the bacteria's pili will grow and anchor the bacteria into the cellular lining of the organism. Now anchored to their host, the bacteria will now be able to multiply without being washed away from their location. Other bacteria have flagella, a whiplike tail that thrashes back and forth, that will allow them to swim to the intended location.

Some bacteria will secrete an endotoxin that will cause their host to become severely ill – inducing vomiting or diarrhea. This weakens the host's defenses and makes it harder for the bacteria to be killed off by the immune system. Other bacteria have evolved a way to enter into the cell and consume the cellular material in that area. *Salmonella typhimurium* and *Mycobacterium tuberculosis* are two examples of bacteria that will invade cells. [vii]

As previously mentioned, not all bacteria make us sick. However, if mistreated, these bacteria could make us sick. There are ten times more bacteria than human cells in the human body. [viii] These bacteria protect us by competing with pathogenic species of bacteria, and creating a healthy environment. Other benefits of these beneficial bacteria

are that they help us to convert or absorb certain vitamins, eliminate toxins, or help to breakdown digested food.

How Antibiotics Work

Although there are a number of different types of antibiotics, they all work in one of two ways: bactericidal or bacteriostatic. A bactericidal usually either interferes with the formation of the bacterium's cell wall or its cell contents. A bacteriostatic stops bacteria from multiplying.[ix]

Penicillin is a bactericidal. It will prevent the final step in the process of making a peptidoglycan (amino sugars and peptides) that most bacteria produce as a cell wall. With this interruption, the cell wall bursts, killing the bacterium. Sulfonamides, Tetracyclines, and Ciprofloxacins are bacteriostatics that target the metabolic pathways of the bacterium. Specifically, sulfonamides imitate a critical compound for the synthesis of folic acid in the bacterium. Folic acid is needed for the diffusion of the bacterium into the human cell. Once interrupted, the reproduction of the bacterium is halted. Tetracycline inhibits the process of protein synthesis in bacteria, halting growth. Tetracycline diffuses across the bacterial cell membrane, accumulates and blocks a key RNA interaction. Ciprofloxacin, aka Cipro, targets the enzyme in bacteria that unwinds the chromosomal DNA. Without the unwinding of the DNA, bacteria cannot copy the DNA, and thus the bacterium growth is inhibited.[x]

Super bugs

A Super bug is an antibiotic-resistant bacterium that does not react to normal antibiotic treatments. Super bugs can gain resistance through two primary ways: by mutation and by using a built-in design feature to swap DNA. If bacteria have a mutation in their DNA that codes for the proteins that ultimately determine the design of the bacteria, the antibiotic cannot inhibit the growth of the bacteria, and the mutant bacteria survive. Due to the survival stress placed on the bacteria, the process of natural selection will occur, favoring the survival and reproduction of the mutant bacteria. Thus, the mutated bacteria will multiply and cause illness to the patient.[xi] In most cases, the bacterial infection is nosocomial, in other words the infection originated or took place in the hospital. Hospitals are a primary area for antibiotic-resistant bacteria because the sterilization of hospital equipment favors the natural selection of antibiotic-resistant bacteria.[xii]

The Cast: *Beneficial Bacteria*

Helicobacter pylori– Elimination of H. pylori actually increases the risk of gastric reflux, which is associated with asthma and esophageal diseases; is an indicator organism for microbiota.[xiii] A spiral shaped organism with flagella, it has a potent enzyme that enables it to survive in acidic pH conditions and colonize the gastric environment.[xiv]

Bacteroides fragilis- *Bacteroides fragilis* is a gram-negative, rod shape, and non-motile. Many *Bacteroides* species live in the colon and intestines of humans and animals. Once *Bacteroides fragilis* leaves the lumen and travels to adjacent areas and organs, it can be detrimental, for it contributes to a variety of infections in the upper body, abdomen, skin and many others. *Bacteroides fragilis* now acts as a pathogen and invades its host by producing the enterotoxins. Due to its role as a pathogen, *Bacteroides fragilis* can be very complex. It can survive and adapt in most environments like its neighbor, *E.coli*.[xv]

Clostridium difficile – gram-positive, bacillus shaped, endospore former. It resided in the human genital tract and human feces. This microbe is responsible for nearly all gastrointestinal infections, ranging from mild diarrhea to severe or even fatal colitis, that follow antibiotic therapy. Pseudomembranous colitis the infection that is caused by overgrowth of *C. difficile* in the colon after normal flora is disturbed by antimicrobial therapy. The organism produces toxins that are lethal to the intestinal epithelium that cause small patches (pseudomembranes) of cell debris, inflammatory cells and clotted serum to form on the colon's lining. Transmission of *C. defficile* is fecal-oral route Treatment includes penicillin, ampicillin, vancomycin, metronidazole. Lactobacillus may also be prescribed to restore normal intestinal flora. The name "difficile" came from the fact that this organism is *difficult* to isolate and study.[xvi]

Lactobacillus bulgaricus - Helpful bacteria used in the production of cheese and yogurt, symbiotic micro-organisms that can shrink or multiply within the environment of the mucous lining in the gastro-intestinal tract, an interface between the absorption of needed nutrients and the diversion of harmful microbes and toxins.[xvii]

Streptococcus thermophilus – The most commercially important of the lactic acid bacteria is known to promote gastrointestinal health. A starter strain is used to make yogurt. It lacks the genes that contain the surface proteins harmful bacteria use to attach to mucosal tissues and hide from the body's defensive actions.[xviii] Streptococci are nonmotile, Gram-positive, non-spore-forming bacteria that live in pairs or chains of varying length. They are characteristically round or ovoid in shape.[xix]

Escherichia coli - Most varieties are harmless or cause relatively brief diarrhea. E. coli contributes to the manufacture of vitamin K and vitamin B12 and fosters the synthesis of vitamin K and B complex vitamins like B6 and B12 in our bodies.[xx] It is a Gram-negative, rod-shaped bacterium.[xxi]

Staphylococcus epidermidis - Typically lives on the human skin and mucosa. The increased use of biomaterials in the clinical environment has made it one of five most common organisms that cause noscomial infections. Coccus shaped.[xxii]

Pseudomonas aeruginosa - An opportunistic human pathogen that seldom infects healthy individuals but often colonizes immunocompromised patients.[xxiii]

Classroom Activities

Overview

This unit is to help students understand what bacteria are, what antibiotic resistant bacteria are, and then primarily focus on beneficial bacteria and their role in the human body. Students will first be introduced to antibiotic resistance through watching video clips and reading different articles on bacterial evolution. This will focus on what they currently know or what they have heard about bacteria. Then students will be introduced to the beneficial bacteria and how antibiotics affect them. They will design their own bacteria, explain what happens when antibiotics are introduced into the human body, and predict what could happen evolutionarily to these bacteria. Students will then take on the role of the bacteria and tell their side of the story.

Lesson Plan One

The first lesson should take about one class period to complete. The goal of this lesson is to introduce students to antibiotic resistant bacteria and the issues they can cause in the human body. The essential question for this lesson will be "What are bacteria? What is antibiotic resistance?" I will give students time to answer in their journals. I will not look for a correct answer at this point. This is just to see what students know about bacteria and what antibiotic resistance is. I will ask students to report out their answers. However, I will not let them know what is or isn't correct about their answers.

I will then begin with NIH's "Debi's Story". This is a five segment video series that tells the story of Debi and how antibiotic resistant TB affected her. Students will not only watch the videos, but will also take notes as they watch the clips. Each clip sets up the next, in a mystery setting – what does Debi have? Why is she sick? How long did it take her to get better? Will she ever get better? Students will watch the first segment and answer the discussion questions. I will then go over their answers with them, not telling them the answers in the end. I will then show the second segment, and the students will answer the discussion questions that go along with this segment. This will be the format until the final segment is shown.

Students will then develop a timeline (graphic organizer) to show when Debi got sick, how long she was sick, what needed to happen for her to get better and when she got better. The lesson will conclude with the timeline of Debi's story and a summary of how Debi got sick and how she got better from each student.

At the end of the lesson students will be able to identify why Debi is sick, describe what Debi had to do in order to get better, and identify what caused Debi's illness. The video segments can be on NIH's Website (see Appendix B), along with Discussion Questions.

Lesson Plan Two

The second lesson should take about one to two class periods to complete. The goal of this lesson is to provide students with background information about how bacteria develop resistance to antibiotics. This is a continuation of the discussion from the first lesson about Debi and antibiotic resistant TB. Using the Jigsaw activity students will investigate what antibiotic resistance is. The Jigsaw will center around three readings about how bacteria evolved resistance to antibiotics.

The essential question for this particular lesson will be "What is antibiotic resistance and how do bacteria develop antibiotic resistance?" Students will be given time to answer. They should know what antibiotic resistant bacteria are from the first lesson. They may not know how bacteria become or develop resistance. I will let them know if they are correct about antibiotic resistance. However, I will not let them know if they are correct about how bacteria develop antibiotic resistance. The lesson will then move on to the Jigsaw activity.

For the Jigsaw activity, each table or group will receive one article. Students will read and gather information in the group about the article that they received. The article titles are "Drug Resistance, Explained", "Germ Zapper..", and "When the antibiotics quit working...." (links to these articles can be found under the Teacher Resources section). Students will receive a data table that relates to each of the articles. They will only fill in the part of the data table that relates to their article. They will also create a list of vocabulary terms they do not understand when reading their article. When all the groups are finished reading and each student has become an expert on the article he or she has read, students will be split into groups of three. Students will then share out the information that they gained from the readings, filling the rest of the data table that relates to each of the articles. Students will then return to their original groups, compare their notes, and compile a final list of all the vocabulary that they got from reading the articles. This list will be used in another lesson. The teacher will then lead a discussion about what the class learned from the article. At the end of the jigsaw students will be able to describe how bacteria evolve resistance to antibiotics.

If the lesson moves into the next day, the next essential question will be "How do bacteria develop antibiotic resistance? What characteristics do bacteria have that allow them to develop resistance to antibiotics?" I may need to fill in some more detail about how each bacterium is affected by antibiotics. This would also be the time that I would go over the basic structure of bacteria and what gives each kind of bacteria an advantage.

I would also introduce how different antibiotics affect different bacteria. This would be the preview of information for the next lesson. Students would be encouraged to draw a sketch of a bacterium, labeled correctly. They would also develop a data table that organizes which bacteria are affected by the different types of antibiotics and how they are affected. For example, penicillin interrupts the formation of the cell wall of the bacteria and the bacteria bursts open as it takes in too much fluid. The information is found in the unit background section of this unit.

At the end of the second lesson, students will pick three vocabulary words from the list they compiled that they know and three words that they don't know. They will define the words they know and predict the definitions what the other three words they do not know on the index card. I will collect the index cards. I will compare the lists and compile the list of words students do not know and develop a worksheet from these words. I will also use the words that the students do know and use this worksheet as a warm up for the next lesson.

Lesson Plan Three

This lesson will most likely take about a week to complete: a day to construct the bacteria, a day or two to create scenarios that show what happens to these bacteria in the body in the presence of an antibiotic, and a day for replication of the bacteria and the potential harmful effects that these bacteria could have on the human body. The goal of the lessons from day one to day four is to introduce students to bacterial structure and function and simulate what happens when bacteria are exposed to antibiotics. Students would build their own bacterium, learn how it reacts to antibiotics, and identify possible mutations that would make the bacterium a superbug. On day five students will be assessed on their understanding of bacteria, bacterial resistance to antibiotics, and ways to prevent antibiotic resistant strains of bacteria.

The essential questions for each of the lessons are Day one: Do you think that there are "good" (beneficial) bacteria? Why or why not? What is the structure of a bacterium? Day two: How do bacteria react to antibiotics? How do bacteria evolve antibiotic resistance? Day three: What is a super bug? What mutations would have to happen to a bacterium in order for it to become a super bug? Day four: What happens when you take antibiotics? Which bacteria do these antibiotics affect? Day five: Do you think that beneficial bacteria could develop into a super bug? Why or why not?

Procedure

Day one

Ask students: "Do you think that there are "good" (beneficial) bacteria? Why or why not? What is the structure of a bacterium?" Allow students to answer the question. This time I

will let students know the answer to the question. Each student group will then be given a data sheet on one of the bacteria listed in the cast (outlined in the background information – more information may need to be gathered). Information should include the general structure of each bacterium, the role it plays in the human body, and how it reacts to antibiotics. Students will be instructed that they will need to build the bacteria on their data sheet from the information outlined on the sheet.

Students should construct each bacterium with materials that highlight the structure of the bacteria. For example, a gram-positive bacterium should have a weaker cell wall than a gram-negative bacterium. The structure will also be dictated by whether or not penicillin kills the bacterium by breaking the cell wall, or sulfonamides, tetracyclines, and ciprofloxacins that target the metabolic pathways of the bacterium. The organelles that are targeted by sulfonomides, tetracyclines, and ciproflaxins should be weaker than those organelles that are not affected by them. Depending on the size of the group will depend on how many students within that group will make their bacterium "stronger". This way at least one bacterium in each group will survive to the next day and have a chance to replicate. The materials that will be used to create the bacterium should model the characteristic of the organelle within the bacterium. For example, if the bacterium has a thick cell wall, the cell wall should be made from Popsicle sticks or some other material that would be difficult to break. Materials I most likely will use would be play dough, Popsicle sticks, straws, yarn, toothpicks, cellophane, beads, and other craft materials. Students would be encouraged to decide which materials to use for each organelle. They would be guided on which materials they should possibly use, however ultimately it would be their decision, and they would be assessed on their choices. Students would name their bacteria, and design a Facebook page about their bacteria's information. At the end of the lesson, students would turn in a quick summary about what makes their bacterium special and which antibiotic would be harmful to it.

Day Two, Three and Four

Ask students, "How do bacteria react to antibiotics? How do bacteria evolve antibiotic resistance?" Allow students to answer the question. This time I will let students know the answer to the question. Give students this scenario: Even though this takes care of some of the harmful bacteria, your bacteria are also harmed. At this point, students who have bacteria that is affected by penicillin would then have then have to put their bacteria in the "dead cell" box. Those bacteria that are "stronger" would survive til the next day. Group members should describe what happens to each type of bacterium, how the antibiotic kills them, and why certain bacteria survive. Students will fill in a worksheet for what happened inside the human and to their bacterium and the other student's bacteria. I would repeat this issue for two more days changing the type of antibiotic prescribed to the human and changing to the respective essential questions listed above. Also for the next couple of days, the bacteria that survived replicate and grow in population size. I would talk about how the bacteria replicate by binary fission. While

more research must be conducted to determine how beneficial bacteria react in the presence of antibiotics, students should be able to predict what might happen to the bacteria when someone takes too many antibiotics.

Day five

Ask students: Do you think that beneficial bacteria could develop into a super bug? Why or why not? They would write this down in their journal and then report out answers. I will also do a journal check to see how they answered. Other questions I will address in this lesson will be: How does the structure of the bacteria help it to survive and evolve in the presence of an antibiotic? How might beneficial bacteria be affected by antibiotics? What should we do to prevent superbugs? Students will answer these questions as a debriefing about what happened to their bacterium and their classmates. Students will be given the assignment to take on the role of their bacterium and create a comic strip, children's book or Prezi (Prezi.com) to show what they've learned about how bacteria react to antibiotics.

Students will be given a choice of writing prompts in RAFT format (R=role, A=audience, F=format, and T =topic). Students will take the role of their bacterium they designed and learned about. They will be addressing the human that they live in. The topic will be antibiotics, antibiotic resistance, and what happens or could happen to beneficial bacteria in the body when exposed to antibiotics. Students will write down their predictions about what could happen to beneficial bacteria when someone takes too many antibiotics. Project will be graded based upon a rubric.

Endnote

By the end of this unit, students will hopefully understand that bacteria, either beneficial or harmful have the ability to adapt to their surroundings and evolve to meet their survival needs. From this point, I will go on to address the ideas of evolution in organisms, especially microbes. After this mini-unit on bacteria, I will move on to viruses and fungus. Students will have to compare and contrast structures of each and what they use adapt to their environments. I will include the use of antibiotics and antimicrobials to kill off viruses and fungi. For viruses, unless you are inoculated with the virus, the use of antibiotics is useless. If you contract a fungal infection, you would use an antimicrobial, however it could have the same effect as the use of antibiotics on bacteria. By the end I would like students to come aware with an understanding that just because you use an antibiotic or antimicrobial, the organism that you are trying to kill will not go down without a fight. And that when you use antibiotics and antimicrobials, that you just aren't killing off the harmful organisms. You are also affecting the beneficial organisms as well, which can affect your health in a negative way.

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Appendix A

DCAS PLD Performance Level 4

Students are able to consistently, effectively, and skillfully demonstrate knowledge of grade-level science content. Students are able to apply their content knowledge in a variety of new contexts.

Relating the survival and reproduction of organisms that have adapted to changes in a population’s environment to changes in the genetic information of a population.

Delaware State Science Standards

Standard 6

B. Cells take highly varied forms in different plants, animals, and microorganisms. Structural variations among cells determine the function each cell performs. Level: Essential

A. Certain chemicals, pathogens, and high-energy radiation seriously impair normal cell functions and the health of the organism. Level: Compact

B. The scientific investigation of cellular chemistry enables the biotechnology industry to produce medicines, foods, and other products for the benefit of society. Level: Essential

Standard 7

C. Mutations in DNA of organisms normally occur spontaneously at low rates, but can occur at higher rates (i.e., exposure to pathogens, radiation and some chemicals). Most mutations have no effect on the organism, but some may be beneficial or harmful depending on the environment. Level: Essential

I. Embryological development in plants and animals involves a series of orderly changes in which cells divide and differentiate. Development is controlled by genes whose expression is influenced by internal factors (i.e., hormones) and may also be influenced by environmental factors (i.e., nutrition, alcohol, radiation, drugs, and pathogens). Alteration in this balance may interfere with normal growth and development. Level: Compact

A. Evolution is a change in allelic frequencies of a population over time. The theory of evolution is supported by extensive biochemical, structural, embryological, and fossil evidence. Level: Essential

C. The process of natural selection occurs when some heritable variations that arise from random mutation and recombination give individuals within a species some survival advantages over others. These offspring with advantageous adaptations are more likely to survive and reproduce, thus increasing the proportion of individuals within a population with advantageous characteristics. When populations become isolated, these changes may accumulate and eventually result in new species. Level: Essential

D. Evolution does not proceed at the same rate in all populations; nor does it progress in a linear or set direction. Environmental changes have a strong influence on the evolutionary process. Other factors that influence evolution include: sexual selection, mutation, genetic drift, and genetic modification. Level: Important

Notes

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Curriculum Unit Title	Two-Faced Bacteria: What would happen if beneficial bacteria go "bad"?	**Author**	Samantha Neubert

KEY LEARNING, ENDURING UNDERSTANDING, ETC.

Understand that there are both harmful and beneficial bacteria. Identify structures that allow bacteria to evolve to survive in their environment. Construct models of bacteria and model how they would survive in the human body. Explain how antibiotics work and how they affect bacteria, both harmful and beneficial.

ESSENTIAL QUESTION(S) for the UNIT

How do bacteria develop antibiotic resistance? What characteristics do bacteria have that allow them to develop resistance to antibiotics? What is the structure of a bacterium? How do bacteria react to antibiotics? How do bacteria evolve antibiotic resistance? What is a super bug? What mutations would have to happen to a bacterium in order for it to become a super bug? What happens when you take antibiotics? Do you think that beneficial bacteria could develop into a super bug? Why or why not?

CONCEPT A	**CONCEPT B**	**CONCEPT C**
Bacteria Basics and Antibiotic Resistance	Beneficial bacteria	Super bugs
ESSENTIAL QUESTIONS A	**ESSENTIAL QUESTIONS B**	**ESSENTIAL QUESTIONS C**
What are bacteria? What is antibiotic resistance? How do bacteria develop antibiotic resistance? What characteristics do bacteria have that allow them to develop resistance to antibiotics?	Do you think that there are "good" (beneficial) bacteria? Why or why not? What is the structure of a bacterium? How do bacteria react to antibiotics? How do bacteria evolve antibiotic resistance?	What is a super bug? What mutations would have to happen to a bacterium in order for it to become a super bug? What happens when you take antibiotics? Which bacteria do these antibiotics affect? Do you think that beneficial bacteria could develop into a super bug?
VOCABULARY A	**VOCABULARY A**	**VOCABULARY A**
bacteria, antibiotics, antibiotic resistance, organelles, bacterial structure, evolution, penicillin, tetracycline, sulfonamides, cipro, cocci, bacilli, spirilla, and spirochetes, pathogens, antimicrobials	*Helicobacter pylori*, *Bacteroides fragilis*, *Clostridium difficile*, *Lactobacillus bulgaricus*, *Streptococcus thermophilus* ,*Escherichia coli*, *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, beneficial, gram-negative, gram-positive, peptidoglycan, commensalistic	nosocomial, bactericidal, bacteriostatic, sterilization

ADDITIONAL INFORMATION/MATERIAL/TEXT/FILM/RESOURCES

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