INQUIRY & INVESTIGATION

Defending the Lowly Prokaryotes: New Challenges for *BIOGaia* Learning Activity

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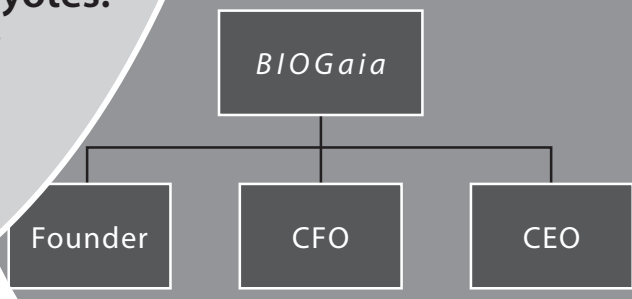

Many educators agree that effective teaching helps students to think critically, communicate more clearly, learn self-discipline, develop an understanding of themselves and others, and cultivate the habit of self-education (Cherif, 1994; Joyce & Weil, 1986). Today's global, multi-cultural environment requires people to work in teams, which in turn requires collaboration and practical approaches to conflict resolution. Therefore, teachers must provide their students with structured group learning experiences that promote the development of these skills (Gayford, 1989). In the following learning activity, we accomplish this by having groups of students work together to solve a problem. Students "act out" conflicts, collect information, learn to take on the roles of others, and improve their social skills and academic performances. Additionally, this activity encourages students to have a desire for the knowledge that will allow them to solve the problem (Cherif & Adams, 1994; Joyce & Weil, 1986). Therefore, they become actively involved in their own learning process.

○ Scenario

You are the founder, the Chief Financial Officer (CFO), and the Chief Engineering Officer (CEO) of *BIOGaia*, a consulting firm that specializes in developing and implementing plans to protect various life forms on Earth. Your employees are highly trained to meet the needs and to serve members of all life forms including Archaea, Bacteria, and Eukarya. *BIOGaia* has access to the latest technology and equipment to provide protection, safety, and security to various life forms. In short, you are very good at what you do. Indeed, your success rate is over 95%, which has brought you, your company, and your employees a good reputation and an increasing number of clients each year.

A New Client

A delegation from the domain Bacteria has just approached you seeking *BIOGaia*'s help in protecting them from other life forms. Your new clients are members of a domain that includes the original and the most basic organisms on the planet that have existed on Earth for four billion years (Koneman, 2002). Indeed, for more than three billion of those years, Bacteria and their cousins Archaea were the only kinds of life on planet Earth. Today, borrowing Bill Bryson's (2003) words, bacteria, which are on and around us in numbers we can't even conceive, inhabit our skin, gut, and nasal passages; cling to our hair and eyelashes; swim over the surface of our eyes; and drill through the enamel of our teeth.

> *... [Our] digestive system alone is host to more than a hundred trillion microbes of at least four hundred types. Some deal with sugars, some with starches, some attack other bacteria. A surprising number, like the ubiquitous intestinal spirochetes, have no detectable function at all. They just seem to like to be with [us]. Every human body consists of about 10 quadrillion cells, but about 100 quadrillion bacterial cells. They are, in short, a big part of us. From the bacteria's point of view, of course, we are a rather small part of them.*
>
> (Bryson, 2003, p. 302-303)

After all, they have not only preceded the more complex eukaryotes by almost two billion years, they have also outnumbered all the other life forms we have known on the planet (Koneman, 2002; Knoll, 2003).

Students "act out" conflicts, collect information, learn to take on the roles of others, and improve their social skills and academic performances.

○ A New Challenge

The natural hosts of bacteria, such as humans, domestic animals, and crops, are no longer dependent on their own natural defense mechanisms when they interact with the members of the domain Bacteria. During the 20th century, humans started using outside help, compounds called "antibacterial" drugs. For example, in the U.S. alone, more than 35 million pounds of antibiotics are produced every year, and about 70% of all these antibiotics are not even used for the treatment of human diseases (Lawson, 2008). Since this time, bacteria have been under constant attack (Koneman, 2002). The members of the domain Bacteria believe that this has violated their right to live, feed, and grow in their natural hosts. The bacterial delegation stated that these host life forms should depend only on their natural defense mechanisms. Bacteria know how to deal with anything that is natural, and they accept the consequences of the interaction between themselves and the natural defense mechanisms of the host life forms. But humans have been using antibiotics and thus, the Bacteria have the right to protect themselves. They would like you (the CFO and CEO of *BIOGaia*) to design and implement a plan to assist them.

You know, as Ridley (1999) convincingly argued, that:

> *Human beings are an ecological success. ... There are nearly six billion of them [on this planet earth, and many more on the way]. ... Moreover, the human species has shown a remarkable capacity*

for colonizing different habitats, cold or hot, dry or wet, high or low, marine or desert. ... No doubt, this ecological success of the human being comes at a high price and we are doomed to catastrophe soon enough: for a successful species we are remarkably pessimistic about the future. But for now we are a success."

(P. 25)

But you also know, as Koneman reminded us in his book, *The Other End of the Microscope: the Bacteria Tell Their Own Story* (2002), that "... through centuries of gene transfers, chromosomal recombinations, and mutations ... prokaryotes have been able to fashion, and pass on to [their] offspring, techniques for survival against the huge variety of defense mechanisms invented by the animals and humans with which [they] cohabit – sometimes even before those mechanisms were invented!" (p. 7).

Client Profile

Even though you have not served any of the members of the domain Bacteria before, you are familiar with its members. For example, you already know that they are prolific creatures; some can double their numbers in ten minutes. You also know that, like all the members of other domains (Archaea and Eukarya), the members of domain Bacteria have cytoplasmic membranes that separate them from the environment. Most of the biological activities needed for life take place in their cytoplasm. They possess genetic material in the form of DNA to control all the biological activities within their cell, including growth, development, and reproduction. You also know that they are unicellular life forms that can only come from pre-existing cells. Furthermore, you are already aware of their nutritional needs, methods of reproduction, and genetic makeup. But your knowledge of their cellular structure and function, their metabolism, as well as their defense mechanisms (which include gene transfers, chromosomal recombinations, and mutations that enable them to fashion defenses and pass them on to their offspring) is not at the level that you can feel confident to make well-informed recommendations on domain Bacteria's problem.

During the meeting with the members of the bacterial delegation, you have discovered that almost all of them have a cell wall around their cytoplasmic membranes (with the exception of the members of Mycoplasma). But this discovery was not a problem for you because you have been dealing with plants, whose cells also have cell walls, for a long time. Indeed, you have already made the inference that one of the reasons *Mycoplasma pneumoniae* is highly elastic and pleomorphic is because it lacks a cell wall (Tortora, Funke & Case, 2007).

Upon further study and investigation, you have discovered that the members of the domain Archaea differ from Bacteria in the following ways:

- They do not have peptidoglycan (the macromolecule composed of protein and carbohydrates) in their cell walls.
- Their membranes have branched lipids and their proteins begin with Met instead of fMet (the specialized amino acid in prokaryotes that initiates a new polypeptide chain in protein synthesis but is not found elsewhere in the protein).
- Notable groups of Archaea include thermophiles and hyperthermophiles (which can tolerate high temperatures), halophiles (which can tolerate high salt concentrations), and methanogens (which produce methane, a greenhouse gas, as part of their metabolism).
- Archaea also inhabit the human body, but none of them are known to be pathogenic (disease causing).

Client Preconditions

Your client made it clear that there are certain things that Bacteria will never give up including:

- their unique growth and metabolism
- the refusal of many of them to grow on nutrient-rich agar which human microbiologists think is the healthy microbial diet needed for most of them (Flannery, 2008)
- their ability to switch their metabolism to a dormant state when enough nutrients are still available in their environment
- their unique reproduction including binary fission
- inhabiting their natural hosts in air, water, and soil and as free-living symbionts, parasites, and pathogens
- their role in the host cells whether it is helpful and or harmful (causing disease, in human terms) to the host life forms. This is simply because the bacterial sole purpose is to survive, replicate, and reproduce.
- their unique small size, which gives them the advantage to grow and multiply rapidly, alter their surrounding environment, and thus successfully live in various environments for many years
- their plasmids that can replicate themselves and carry genes that gives an advantage to the cell's defense mechanism (in many bacteria)
- their ability to share genetic material within members of their own domain
- their ability of gene transfers, chromosomal recombinations, and mutations as defense mechanisms and survival techniques. This includes transposons or "jumping genes" that are already present in the genomes of all organisms including eukaryotes (Klug et al., 2009). Transposons are very important for the domain Bacteria because even though "the genes carried in some [Bacteria] transposons may be of no use to the recipient, in other cases, important new traits may be acquired, turning a placid bacterium into raging pathogen, or even the reverse" (Koneman, 2002, p. 13).
- the ability of some bacteria (such as Staphylococci) to develop an intricate system of signals and a signaling mechanism by which they can sense changes in their environment and make a defensive response. This signaling mechanism is "intricately governed by the activation of gene-controller sensor and response regulator proteins" (Koneman, 2002, p. 92).

○ Your Decision

Even though you have never worked with members of the domain Bacteria before and you know that some of the members of this domain are harmful (by human standards), you feel that this is a new challenge that would be very beneficial to *BIOGaia* and to your employees. You also know that you have the expertise, the techniques, the equipment, and the technology to deal with a problem such as this. In other words, *BIOGaia* is capable and ready for this type of challenge.

Therefore, you make the decision to accept the domain Bacteria as your new clients and to help them protect themselves from the hardship they are facing from humans' use of antibiotics.

Protection Plan & Strategy

1. Individually, you have met with your:
   a. Genetic and Bioengineering team

b. Microbiology team

c. Pharmacology team

d. Pathophysiology team

e. Legal Policy and Ethics team

2. Every team receives an assignment from you regarding this major project.
3. After two weeks, each team reports its findings to you.
4. One week later, you arranges for a joint working meeting with your Planning and Strategy team, the Implementation team, and the leaders of all the other teams.
5. Because of the importance of the project and the meeting, you take charge of running the meeting and overseeing the development of the safety and protection plan and strategy for the members of the domain Bacteria.
6. After five weeks, you invite the delegation of the domain Bacteria to meet with you, your Strategy team, the leader of the Planning and Strategy team, as well as the leaders of the Genetic and Bioengineering, Microbiology, Pharmacology, Pathophysiology, and Legal Policy and Ethics teams.
7. You are the Chief Financial Officer (CFO) and the Chief Engineering Officer (CEO) of your own company, *BIOGaia*, and are the one who will present the safety and protection plan and strategy to the domain Bacteria delegation.

   a. What plan and strategy are you going to present to the domain Bacteria delegation to help and support them in protecting themselves from the constant threat posed by antibacterial agents (antibiotics) invented and used by other life forms?

   b. How should this proposed protection plan and strategy be implemented to maximize their protection?

Hints

1. Know that bacteria are prokaryotes, simple unicellular organisms characterized by:

   a. a cell wall and a plasma membrane

   b. one circular chromosome (not in a membrane, and the bacterial chromosome is free of histones)

   c. possessing no organelles including the nucleus (with the exception of *Gemmata obscuriglobus*, the freshwater budding eubacterium that contains a DNA-containing region separated from the rest of the cell by two nuclear membranes)

   d. cell walls with peptiodoglycan

   e. division primarily by binary fission

2. Know and understand the structure and the function of the cell wall and its role in the survival of bacteria as well as in binary fission.
3. Understand the sensitivity of cell walls to antibiotics.
4. Understand how antibiotics work, including the inhibition of cell wall synthesis, disruption of the cell membrane, inhibition of protein synthesis, inhibition of nucleic acids synthesis, and inhibition of metabolic pathways (Lawson, 2008).
5. Understand the consequence of weaker cells reproducing as well as the factors that might prevent a given bacteria from dividing during binary fission.
6. Understand the composition of the cell membrane and membrane lipids.
7. Understand the relationships among the cell wall, cell membrane, and antibiotics, and their combined influence on cell reproduction.
8. Understand the role of stains and staining technique for allowing doctors to identify many bacteria quickly (Gram positive and Gram negative staining technique).

○ Procedures

1. Divide your class into groups. Each group consists of a leader and five teams (Genetic and Bioengineering, Microbiology, Pharmacology, Pathophysiology, and Legal Policy and Ethics). Depending on class and group size, each student may have to play more than one role.
2. Give each student a copy of this activity and ask him/her to read it individually.
3. Ask the members of each group to meet and divide the roles between themselves by selecting a leader for the group as well as a representative for each team: Genetic and Bioengineering, Microbiology, Pharmacology, Pathophysiology, and Legal Policy and Ethics.
4. The bacterial delegation consists of the instructor of the class plus one or two more volunteer instructors, if available. (If there are no volunteer instructors, then select two high achieving and well-respected students from your class.)
5. Give the groups two to three weeks to prepare for their class presentation.

   a. The few Web sites listed in the References could be a good starting point for your students' reading and preparation for the activity.

   b. Ask students to read Chapter 20, "Small World," from *A Short History of Nearly Everything* by Bill Bryson (2003).

   c. You might also encourage your students to read *The Other End of the Microscope: the Bacteria Tell Their Own Story* by Elmer Koneman (2002). *Life on a Young Planet: The First Three Billion Years of Evolution on Earth* by Andrew H. Knoll (2003) is another inspired book for students to read.

6. You may wish to assign each group a particular antibiotic or particular group of bacteria to focus on. Examples of questions that should be answered by team members in their plan include:

- Genetic and Bioengineering

  How can antibiotic resistance be introduced into bacteria? How can it be transferred among organisms? What is the relationship between the rapid spread of antibiotic resistance among bacteria and the movement of plasmids among the domain Bacteria? (This last question can also be answered by the Microbiology Team).

- Microbiology

  How are bacteria structurally or functionally affected by antibiotics? For example, how does penicillin affect cell wall synthesis? How can bacteria become resistant to antibiotics? Can one type of bacteria be used on a wide scale to influence the growth of other bacteria such as using lactic acid bacteria to influence the growth and in turn the reproduction rate of Salmonella*?* (This last question can also be answered by the Pathophysiology Team).

- Pharmacology

  What are the structures of antibiotics? How do they affect bacteria? What are side effects of antibiotic usage in humans? What has been done to circumvent antibiotic resistant bacteria?

- Pathophysiology

  Why and how do microbes cause disease? How do humans fight off disease naturally? If humans can fight off bacteria, why do we need antibiotics?

- Legal Policy and Ethics

  Is it ethical to introduce antibiotic resistance into bacteria? What might happen to human population? Should a policy of "Living Rights" be extended to microorganisms, including those which cause hardship to humans? Whether "their actions are damaging or fatal, or just bad manners, [bacteria] merely play out what is encoded in their chromosomes. ... But even they simply act as they are created to act, their sole purpose being to survive and to replicate" (Koneman, 2002, p. 9). *Does this automatically condemn them to be considered harmful organisms, and should this be the basis for depriving them of legal and ethical rights extended to other organisms?*

7. For the presentation, each group must:
   a. have a well researched plan and strategy to present to the delegation of domain Bacteria how the group plans to help and support them in protecting themselves from the constant threat from antibacterial agents (antibiotics) used by other life forms, especially humans.
   b. explain how the proposed protection plan will be implemented to maximize the client's protection.
   c. prepare a well researched student handout as well as an illustrated poster.
   d. integrate the use of technology such as PowerPoint, animations, interactive activities, etc. into the presentation. Students should present their plan and strategy, show how they will work, and convince everyone that their plan and strategy are the best for providing the needed protection for domain Bacteria from the constant threat of antibacterial agents (antibiotics) used by other life forms.
8. During the presentation:
   a. The groups will take turns presenting their case to the bacterial delegation and the rest of the class.
   b. The leader of the group will present the proposed plan and the strategy of the group. Then the leader of the group can call on the members of his/her group to talk about how the plan and strategy work to provide the needed protection for domain Bacteria from the constant threat of antibacterial agents (antibiotics) used by other life forms. The members of the delegation can ask up to three questions after a given group finishes its presentation.
   c. When all the groups finish their presentations, the bacterial delegation can ask more questions to all the groups. The students can also ask questions which the members of the bacterial delegation must consider in their final judgment. The members of each group must also take notice of all the questions that were asked.
   d. The members of the delegation will wait until the next class meeting to share their final decision with the groups.
9. After the presentation:
   a. Before the leader of the bacterial delegation reads and defends the delegation's final decision, each group is given three to five minutes to address the delegation one more time. In this short final remark, the groups must have a written statement that can be read to support their case. The written statement doesn't have to be shared with the other groups beforehand. This is a very important stage in the activity and is related to the "Creative Domain" of McCormack and Yager's (1989) taxonomy for science education as we will see in the coming assessment section.
   b. After all the groups present their final remarks, the leader of the bacterial delegation reads and defends the delegation's final decision.
10. You may wish to use Bill Bryson's (2003) audiobook, *A Short History of Nearly Everything,* specifically Chapter 20, "Small World," as part of your class discussion.

○ Assessment

The post-activity discussion is very important for students' cognitive and social development because it encourages understanding of the social and personal dynamics involved in reaching a conclusion. The teacher and students should explore how and why each group reached its decision, and whether this situation could have been approached in other ways (Joyce & Weil, 1986). For assessing students' performance and understanding, as well as the effectiveness of the activity, we suggest the use of McCormack and Yager's (1989) taxonomy for science education as a framework for students' achievement. Some of us have used this framework successfully in the past (e.g., Cherif, Verma & Somervill, 1998; Cherif & Somervill, 1994, 1995). Some examples of assessment criteria follow. Note: Many assessment questions could fall into more than one domain, depending upon how the questions are formed.

Knowledge Domain

Students acquire knowledge of the subject, an understanding of relationships between the bodies of knowledge, and give reasons for their approach to solving the problem. Some questions are:

What concepts did students learn and how well did they understand them? How well did the students integrate knowledge from different subject areas? To what extent did students demonstrate the understanding of multiple relationships of various bodies of knowledge? Were the students able to disprove or verify some of the supporting theories used in the role-playing activity? What kind of explanations did students offer for the relationship they observed and understood?

Process Domain

Students learn how to collect, organize, and analyze data; develop strategies for building rational arguments and thoughts; state problems and generate valid conclusions; participate in teamwork; interpret meaning from the project. Some questions are:

How did members of a given group compile data and information? Was there cooperation in putting the information together? How efficient was each group in presenting and communicating the collected data and information? Was their delivery of statements and arguments smooth and coherent? How well did the students use knowledge meaningfully? Did all members participate in the activity?

Creative Domain

Students apply creative thinking to the project; cultivate the ability to recognize, evaluate, and use data and information provided by the other parts of the role play; learn to modify a given design as needed. Some questions are:

In what new ways did students use objects and ideas generated during the enactment of the role-playing to enlarge their understanding? How imaginative were students in identifying relevant problems, solutions, and conceptualizing new ideas?

Attitudinal Domain

Students learn to listen closely and comprehend the other parts of the role-playing. They also learn cooperation in a group performance and self-evaluation. Some questions are:

How persuasive were group members in articulating their positions in order to change the attitudes of the others? How effectively did each group function? Did students' sensitivity and respect for others develop during the process? Did members of a given party demonstrate skills and abilities to resolve conflicts with others constructively? How might each group have functioned more effectively?

Application & Connection Domain

Students learn to generate alternative approaches, problem-solving strategies, and solutions. Some questions are:

Did they come up with practical and workable solutions? To what extent did the students utilize their personal experiences and collective group understanding in making decisions related to the activity? How well did the students integrate knowledge from different disciplines in problem-solving strategies? How well did the students learn to negotiate constructive solutions to conflicts?

Student involvement in the planning, implementation, and assessment of role-playing helps to counter some of the difficulties of teaching with this method. However, the planning that role-playing teaching requires and the difficulties that may arise entail forethought by instructors.

○ Student Level of Involvement in the Learning Activity

Many instructors rarely emphasize the learning values of a given activity to their students. To make the teaching approach of the given learning activity more productive, teachers should lead students toward greater levels of involvement in the process by including them in planning the five factors that make up a typical role-playing situation:

- the problem to be solved
- the characters to be played
- the roles to be followed
- essential information to be gathered
- procedures for the play to be adapted (Cherif & Somervill, 1994, 1995).

At the first Level of Involvement in the Role-Playing Teaching Model as shown in Table 1, students carry out pre-assigned activities: They are actors for a scripted play. The educational value of the role-playing activities increase as the procedure encompasses greater levels of student involvement. For the highest productivity, instructors should lead students toward Level 6, even if that level cannot be achieved. As the difficulty level increases, so does the amount of time, effort, and best of all, *enthusiasm* among the students. The final Level of Involvement is critical assessment. In this activity, the problem to be solved and the characters to be played

Table 1. Student level of independence in the role-playing process (Cherif & Somervill, 1994, 1995).*

The Level of Involvement	Problem To Be Solved	The Characters in the Play	Role of the Characters	Essential Information	Procedures for the Play
I	Given	Given	Given	Given	Given
II	Given	Given	Given	Given	Not Given
III	Given	Given	Given	Not Given	Not Given
IV	Given	Given	Not Given	Not Given	Not Given
V	Given	Not Given	Not Given	Not Given	Not Given
VI	Not Given	Not Given	Not Given	Not Given	Not Given

* While various students are expected to achieve various levels of involvement in the learning activity based on the grade levels, intellectual maturity, etc., the activity should be considered successful if, for example, AP classes can reach Level I or II, freshmen in college can reach Level III and upperclassmen can reach Levels IV and above.

Table 2. Individual group questions analysis and account.

	Type of Question	Extremely Relevant	Relevant	Not Relevant	Total of Questions
1.	Why				
2.	How				
3.	Which				
4.	What				
5.	When				
6.	Where				
7.	Is/Are				
8.	If…, then… Inquiry wondering statements				
9.	Total of questions and or wondering statements				

Table 3. Tracking the number of questions asked by each group of other groups.

	Bacterial Delegation team	Genetic & Bioengineering team	Microbiology team	Pharmacology team	Patho-physiology team	Policy/ Ethics team	Total Questions
Bacterial Delegation team	X						
Genetic & Bioengineering team		X					
Microbiology Team			X				
Pharmacology team				X			
Pathophysiology team					X		
Policy & Ethics team						X	
Total of Questions							

are given to the students. However, the roles to be followed, the essential information to be gathered, and the procedures for the play to be adapted are part of the learning activity and the students' responsibilities. Thus it is at the fourth Level of Involvement in the learning activity. This is another good reason to try this activity with your students.

Furthermore, instructors can use Tables 2 and 3 as tools to record information and to monitor the level of cognitive involvement of the members of a given group during the activity. In Table 2, instructors can record the type of questions being asked by the members of a given group as well as the relevancy of the questions to the subject matter and to the point being debated. In Table 3, instructors can record the number of questions being asked by the members of a given group to the other groups.

○ Pre- & Post-Test Homework Assignments

To reinforce the learning objectives of the activity and to allow for compiling attitudinal change data, ask the students to answer the following questions, either individually or in groups. (Additional homework assignments can be found in the Appendix.)

Pre-Test Homework Assignment

1. What do you expect the final decision made by the delegates of the domain Bacteria to be? Do you think you would agree with it? Why or why not?
2. What do you think you will learn from the activity at both the academic and personal levels?
3. What will you do to make sure that the final decision reached by the delegates of the domain Bacteria is in your favor?

Post-Test Homework Assignment

1. Reflect on the final decision made by the delegates of the domain Bacteria. Do you agree with it? Why or why not?
2. What have you learned from the activity at both the academic and personal levels?
3. If you had to do this all over again, what would you change or do differently and why?

○ Final Remarks

There are no better final remarks for this activity than to cite Bill Bryson (2003) when he states that:

> *Because we humans are big and clever enough to produce and utilize antibiotics and disinfectants, it is easy to convince ourselves that we have banished bacteria to the fringes of existence. Don't you believe it. Bacteria may not build cities or have interesting social lives, but they will be here when the Sun explodes. This is their planet and we are on it only because they allow us to be. ... Bacteria, never forget, got along for billions of years without us. We couldn't survive a day without them. They process our wastes and make them usable again; without their diligent munching nothing would rot. They purify our water and keep our soils productive. Bacteria synthesize vitamins in our gut, convert the things we eat into useful sugars and polysaccharides, and go to war on alien microbes that slip down our gullet. ... We depend totally on bacteria to pluck nitrogen from the air and convert it into useful nucleotides and amino acids for us. ... Above all, microbes continue to provide us with the air we breathe and to keep the atmosphere stable. Microbes, including the modern versions of cyanobacteria supply the greater part of the planet's breathable oxygen. Algae and other tiny organisms bubbling away in the sea blow out about 150 billion kilos of the stuff every year.*
>
> (p. 303)

Therefore, and from now on, paraphrasing Koneman (2002), we the humans will continue to work harder than ever before to understand what microbes truly do and are, and the secret and various services they perform for the benefit of the entire globe. We will justifiably try to understand them instead of revile, sanitize, misunderstand, misuse, and misname them. Working together, we can help our fellow humans to understand Bacteria and Archaea and why they must take their own rightful place among nature's biota. But most of all, we aim to invoke an interest in learning about the domains Bacteria and Archaea by the students involved, and in turn, excite them to learn about an issue that will likely be theirs to solve as the next generation of physicians, researchers, policy makers, and informed citizens. After all, using Flannery's words, "bacteria–for better or worse–are a fact of human life, and really any life" (2008, p. 300).

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http://commons.wikimedia.org/wiki/Image:Archaea_membrane.svg

Appendix. Additional Homework Assignments

1. Science, health, and society: Conduct Internet research to investigate why Fred Pritzker and Rich Ruohonen, who were named "Super Lawyers" by *Law & Politics Magazine*, were called *E. coli* Lawyers. These two lawyers were also interviewed by *The New York Times, The Wall Street Journal, Lawyers USA,* and other publications. In addition, they both were selected by other lawyers for inclusion in *The Best Lawyers in America*.
2. *Escherichia coli* is "one of the most widely studied of prokaryotes, most versatile in its extent of animal and human colonization, and most innovative in its varied expression of virulence mechanisms" (Koneman, 2002, p. 11). Conduct Internet research to find out:
   a. how *E. coli* infections are caused
   b. the symptoms and complications of *E. coli* foodborne illness, including information on initial symptoms, hemolytic uremic syndrome (HUS), and thrombotic thrombocytopenic purpura (TTP)
   c. how *E .coli* infections are diagnosed and treated
   d. how *E. coli* infections can be prevented
3. Anaphylaxis is a severe, sudden, often fatal whole-body allergic reaction to a foreign substance or antigen that leads to the person's immune system becoming sensitized to that allergen. As a result, histamine and other substances are release by tissues in different parts of the body. This causes the airways to tighten and leads to other symptoms.

   Conduct Internet research to find out:
   a. the causes of anaphylaxis
   b. the symptoms of anaphylaxis and anaphylactoid reactions
   c. whether *E. coli* infection can causes anaphylaxis
4. While a few members of bacteria are harmful, the vast majority are harmless, and many bacteria are helpful for humans. They are present in soil, water, and air and as free-living symbionts, parasites, and pathogens. Define each term and then provide two examples of bacteria for each. Use the table below for your answers.

	Symbionts	Parasites	Pathogens
Definition			
Common host and/ or environment			
First example of bacteria			
Second example of bacteria			

5. Some scientists consider plasmids that are found in bacteria and carry spare genetic information to be:
   a. parasites that survive by providing coding characteristics that promote the survival of their hosts.
   b. the most useful part of the bacterial cell to humans in their endeavors of genetic engineering.

   Conduct Internet research to find out why some scientists (especially microbiologists, geneticists, and biotechnologists) hold these views.

6. Bacteria lack nuclei (with one exception), most other internal organelles, and possess no familiar bones and other hard parts. Yet, the oldest known fossils of any living things are of bacteria. Scientists believe that bacteria appeared when the Earth was approximately one billion years old, and the oldest fossils are probably more than 3.5 billion years old. Conduct Internet research to find out:
   a. the characteristics of an ideal fossil
   b. how a fossil is created
   c. how scientists came to the conclusion that the oldest known fossils are of bacteria
7. Old news to some, new news to others:

   > *Bacteria spores 40 million years old were extracted from a fossilized bee and successfully germinated by US scientists in 1995. It is hoped that prehistoric bacteria can be tapped as a source of new chemicals for use in the drug industry. Any bacteria resembling extant harmful pathogens will be destroyed, and all efforts are being made to ensure no bacteria escape the laboratory.* (QPB, 1998, p. 71).

   Conduct Internet research to find out the outcome of this scientific endeavor.
8. Bacteria usually reproduce asexually by binary fission through which a single cell is divided into two similar daughter cells. The average time that is required for a cell to complete full growth cycle and double in number is called generation time. Conduct Internet research to identify four different bacteria and their generation time. Indicate which of these four examples of bacteria is pathogenic or non-pathogenic. Use the table below to record your answer.

	Less than 30 minutes	30-60 minutes	3 hours	24 hours	More than 24 hours
1.					
2.					
3.					
4.					

9. Conduct Internet research to find out the relationship between the following items and then write a short news story for your local newspaper on the relationship:
   a. Denver pediatrician Dr. James Todd
   b. the use of hyperabsorbent "super" tampons during menstruation
   c. the effect of iron ions on bacterial growth
   d. *Staphylococcus aureus*
   e. cell reproduction and the production of potency of TSST-1 by bacteria
   f. the effect of oxygen in a normal anaerobic vaginal canal
10. The delegation of the domain Bacteria accepted one of the plans presented to them by the consulting firm *BIOGaia*. The consulting firm built the prototype and asked the delegation of the domain Bacteria for permission to pilot the chosen plan and to identify the bacteria which will be used in piloting process. However, the Chief Financial Officer and Chief Engineering Officer (CFO, CEO) of *BIOGaia* made it clear that they don't want *Mycobacterium leprae*, *Mycobacterium tuberculosis*, *Mycoplasma pneumoniae, Gemmata obscuriglobus*, *Thermus aquaticus*, and bacteria with similar characteristics to be part of the first piloting trials. Conduct Internet research and then provide an explanation to why the Chief Financial Officer and Chief Engineering Officer of *BIOGaia* made a request such as this.
11. Conduct Internet research to find out the significance of *Thermus aquaticus* in genetic engineering.
12. Conduct Internet research to find out the relationship between the following items and then write a short news story for your local newspaper on the relationship:
   a. Shane Matthews, former Chicago Bears starting quarterback
   b. 1999
   c. Methicillin-resistant *Staphylococcus aureus* (MRSA)
13. Conduct Internet research to find out the relationship between the following items and then write a short news story for your local newspaper on the relationship:
   a. antibiotic therapy
   b. Cocoanut Grove Night Club
   c. Boston, 1942
   d. penicillin as a drug

BIO

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