This is to certify that the

thesis entitled

BACTERIA: FRIEND OR FOE?
A BIOLOGY UNIT

presented by

Michelle Marie Corlew

has been accepted towards fulfillment
of the requirements for

Masters degree in Biological Science

Howard Hagerman
Major professor

Date April 5, 1996

BACTERIA: FRIEND OR FOE?
A BIOLOGY UNIT

By

Michelle Marie Corlew

A Thesis

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Division of Science Education

1996

ABSTRACT

BACTERIA: FRIEND OR FOE?
A BIOLOGY UNIT

By

Michelle Marie Corlew

Do high school students enrolled in a first year biology course view bacteria as friend or foe, and will student attitudes change as a result of a unit examining the many roles of bacteria and the interactions between humans and bacteria? An attitudinal survey was administered to two biology classes prior to and at the conclusion of a unit devoted to bacteria. In this thesis, the attitudinal survey is analyzed and the details of the unit outlined. Analysis of the attitudinal survey indicate perceptions of bacteria as both friend and foe prior to the unit, but following the five weeks of study attitudes revealed student perceptions of bacteria as powerful, exciting, and important.

This thesis is dedicated to the memory of
Morgan Bennett Corlew, beloved grandfather
who passed away during the course of my studies.

Acknowledgements

As with any project, this thesis would not be complete without the help of many friends and colleagues. I would like to gratefully acknowledge the following people for their special contributions to this thesis.

First of all, my thanks to my biology colleagues at Waubonsie Valley High School for their willingness to try something new, especially Elaine Modine and Julie Callan for their support and infinite capacity for listening. I would like to thank my other colleagues in the science department, especially Carolyn Gloeckle, whose continuing encouragement and help have made it possible for me to focus my energies on this area. A huge thanks to science coordinator Dr. Sheryll Renken for her help in analyzing the data and invaluable support as we strive to become better teachers.

I want to thank Drs. Howard Hagerman, Marty Hetherington, Clarence Suelter, and Merle Heidemann for their guidance and encouragement, and for structuring an outstanding graduate experience at Michigan State University that allows teachers to explore the field of biology and apply what they have learned in the classroom.

Finally, I would like to thank my parents, Phil and Louise Corlew, and my grandparents Mary and Morgan Corlew, who taught me to value education, encouraged and supported me in my educational wanderings, and never discouraged me from taking the long way home.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Chapter 1
Introduction

Bacteria are among the oldest forms of life on earth; they are enormously successful. They have been found everywhere that man has thought to look, including places where conditions were considered too harsh to support life. From floating bacterial mats deep in the ocean to sulfur-laden hot springs, from deep in the earth's crust to the gut tracts of termites and mammals, from *Thermophilus sp.* to *Escherichia coli* to *Rhizobium sp.*, researchers have found ever-increasing numbers of bacterial species as sampling techniques have become more sophisticated. Bacteria play an integral part in earth's ecosystem, forging amazingly complex interactions with their environment and with other organisms.

How then are relationships between humans and bacteria characterized? "Wash your hands!" "Don't touch - icky bad!" Children are taught from an early age that bacteria are bad because they cause disease, yet only one percent of all microorganisms are pathogenic. What about all the good things that they do? Bacteria also function as nature's decomposers, aid in digestion, produce and enhance food products, produce numerous compounds for industry, and provide tools crucial to genetic study. With this staggering array of functions, how could bacteria be man's foe?

High school students tend to see issues as black or white, good or bad, right or wrong. When problems are presented to them, they have a difficult time accepting gray areas, searching for facts to push the idea to one extreme or another. Allowing students to explore and define the gray area of the complex relationships between man and bacteria is the focus of this thesis.

Are bacteria mankind's friend or foe? Most students have no idea of the vast scope of organisms that live in worlds they have never seen, and have little understanding of the important roles bacteria play in their own bodies and in today's society. Prior to the development of the bacteria unit, this instructor felt that the prevailing attitude of students would be that bacteria are man's foe. For this thesis, a survey was developed to assess student attitudes regarding bacteria and to determine if a unit devoted to the study of bacteria would change student perceptions. Two identical surveys were administered prior to and at the conclusion of an instructional unit, developed for students in a first year biology class in order to dispel misconceptions about bacteria, and to develop an understanding of the complex of roles bacteria play in our world. The student replies were compiled, the differences between the surveys calculated, and the results analyzed in the following pages. It was this instructors hope that the instructional unit outlined in this thesis would change student attitudes regarding bacteria.

LITERATURE REVIEW

"This is a heady time to be a microbe" writes Thomas Canby in his article "Bacteria: Teaching Old Bugs New Tricks" for National Geographic (1993). Students are inundated with information about bacteria and other microbes, and not only through magazine articles and news programs. Fictionalized accounts of killer microbes from the movie Outbreak to the television mini-series of Stephen King's The Stand as well as the Michael Crichton classic The Andromeda Strain are well known; add to that the best-selling non-fiction book The Hot Zone by Robert Preston and students hear of pathogens capable of wiping out the entire human race, both real and imagined, from a variety of sources. Attempting to capitalize on this interest and hopefully counteract these Hollywood scare tactics are a variety of articles such as Canby's extolling the virtues of microbes, particularly beneficial bacteria.

> With clever coaching from microbiologists, bacteria and other "bugs" are being put to work in wondrous ways...Some microbes serve as factories - making pharmaceuticals, pesticides, solvents, and plastics. Some help make the snow at your ski resort. Some separate gold and copper from ores, reducing the need for chemicals like cyanide. Some rejuvenate tired oil wells. Some make enzymes for snipping DNA, the first step in genetic engineering. Some are our fermenters, converting sugars into bread, beer, sauerkraut, cheese, yogurt, vinegar, wine. And some microbes, of course, are age-old enemies, the invisible messengers of tuberculosis and cholera and other scourges. But those are relatively few. (Canby, 1993)

Literature extolling the benefits of bacteria is not a recent trend; in 1981 the journal Scientific American devoted not just an article but an entire issue to industrial microbiology. "Industrial microbiology ... is a well-established factor in the world economy, responsible for a current annual production valued at tens of billions of dollars in the U.S. alone ... with a rich history that goes back thousands of years." (Demain and Solomon, 1981). Phaff (1981) asserts that "There is no ready way to classify microorganisms into the useful and the nonuseful. All are useful in the sense that they help to recycle the molecules of the organic world. In this role they are not merely useful but indispensable." (1981)

Other articles in the 1981 Scientific American special issue describe the evolving roles of microorganisms in the production of food and drink, pharmaceuticals, and industrial chemicals (See Bibliography). Another article discusses applications to agriculture, which are particularly important as the world population continues to grow exponentially. "The growing demand for food and other agricultural products is ample practical justification for undertaking the enormous research effort that will be needed to apply the methods of microbiology to agriculture." (Brill, 1981)

Much literature has also been devoted to the story of antibiotics, from the accidental discovery by Alexander Fleming of *Penicillium's* effect on staphylococci to the production of the first penicillin by Howard Florey. The legend of Ethel Florey's "pee patrol," collecting the urine of patients treated with penicillin to extract the excess penicillin from the urine to be used again, and the discovery of the highly productive *Penicillium chrysogenum* strain on a moldy cantaloupe brought in by "Moldy" Mary Hunt of Peoria, Illinois made for interesting classroom discussions (See Appendix F for Interesting Facts About Antibiotics).

Educators have seen the need to provide a balance of information to students in regards to pathogenic and beneficial microbes. The imbalance of information to which students are exposed, heavily favoring pathogens, was noted by Williams and Gillen.

> The news media publish many articles about microbes that cause disease but few articles about microbes that are useful. Students have the impression that microbes are harmful and they fear studying them. We call this attitude microbe phobia, or a fear of microbes. The teacher must convince impressionable students that many microorganisms make products that we use every day and the microbes have an important role in our life. (Williams and Gillen, 1991)

The discussion by Williams and Gillen on microbial action in common food production led to an important component of this instructor's thesis unit, the student reports on Products of the Microbial World (Appendix E).

The accidental discovery of antibiotics also provides a crucial vehicle for classroom discussions regarding the importance of basic research. The following quote is illustrative:

> We need to be reminding our students that basic research is important. For example, 50 years before antibiotics were discovered, scientists had been studying bacteria that cause disease. They were not looking for a biochemical treatment to cure disease. Antibiotics were discovered by accident. If basic bacterial research had not been done and specific microorganisms causing specific diseases had not been found, the search for antibiotics would not have made sense. There is a need to show students that basic research is important in itself. Only with basic research can there be technology...We need to communicate to students the beauty of and the need for pure science. This massing of interesting knowledge for its own sake then will be ready for technological developments of the future. (Lundgren, 1991)

Helping students discover some of the unexpected benefits of basic research will lead to more public support and funding for scientific research in the future.

PRINCIPLES DEMONSTRATED IN UNIT

In the bacteria unit designed as part of this thesis project, students engaged in a laboratory-based exploration of bacteria, focusing on the interactions between man and microbes. In addition to laboratory activities, lectures, videos, and library research were also included as part of the unit. The unit was divided into two parts; basic structure and function, classic laboratory techniques used to study bacteria, action of pathogens on humans, interactions between antibiotics and bacteria, and the development of resistant bacterial strains were studied first. The second portion of the unit focused on the beneficial aspects of bacteria, including their role as decomposers, importance in food production and manufacturing, and the importance and potential of bioremediation.

Five laboratory activities were completed by the students during the course of this unit (See Appendix D for laboratory exercises). In the first lab, "Bacteria of the W.VH.S. Environment", students developed the technique of inoculating plates of nutrient agar with sterile swabs. Students traced the source of a simulated communicable disease spread through the class much as an epidemiologist would at the Center for Disease Control in Atlanta in work done to complete the second laboratory, a group activity entitled "Who's Got the Bug." For the third laboratory, "Controlling the Growth of Bacteria," students inoculated nutrient agar with a live culture, and checked for zones of inhibition around filter paper discs soaked with samples of antiseptics, disinfectants, and antibiotics.

While the first three laboratory exercises dealt with bacteria as foe, the last two dealt with bacteria as friend. "Testing for Bacteria in Foods," the fourth laboratory, introduced students to an indirect method of detecting bacteria by testing for a product of respiration, carbon dioxide. The importance of indirect testing cannot be overemphasized since isolation of unicellular organisms is so difficult in a classroom setting. The final laboratory experience conducted by the students, constructing a "Pop Bottle Landfill," focused on the role of bacteria as decomposers.

THE BACTERIA UNIT AND THE COURSE CURRICULUM

The bacteria unit was new to the biology curriculum at Waubonsie Valley High School when this study was conducted, as well as for the K-12 Science curriculum of Indian Prairie School District. None of the instructors had previously included a unit on bacteria or microbiology at any level in the district. The biology curriculum at the high school previously consisted of ten units of varying length. Most units were of short duration, approximately two to three weeks; longer units were broken down into two to three week sections for testing purposes. These units, composed of core activities and exams, as well as the sequence of instruction, have traditionally been determined by a group of experienced teachers at the high school. This instructor was expected to follow the established sequence as a teacher new to the curriculum, although newly developed activities could be added.

During the 1993-94 school year, when this study was conducted, the units for the first semester included Characteristics of Life, Ecology of Wetlands, Cell Structure, Function, and Transport, Microscopes, and DNA, RNA, and Protein Synthesis which was concluded during the second semester. Immediately preceding this study unit were units on Genetics, Evolution, and Classification. Following the bacteria unit, an extensive unit on Anatomy and Physiology wound up the school year. The bacterial unit developed during graduate work at Michigan State University was added to the biology curriculum by shortening and deleting portions of other units in the curriculum.

Waubonsie Valley High School was and continues to experience a strong initiative to align the curriculum, both to improve instruction and in order to implement assessment requirements, with Illinois' recently mandated School Improvement Plan. A push for consistency between sections of the same course and the edict to give a common final exam for all sections was implemented at the high school during the 1992-93 school year. Inserting a bacteria unit into this instructor's classroom meant other instructors had to add it to their curriculum as well. Fortunately the other instructors were amenable to the idea; some were more enthusiastic than others depending on their comfort level with the topic. All agreed that this was an area that was relevant to students, was something they would need to know about later in life, and fit in with the newly developed school philosophy of students as active participants in learning.

COMPARISON OF NEW AND OLD APPROACHES

Because microbiology was not previously taught, no comparison between old and new approaches is possible. However, compared to other units in the biology curriculum, the bacteria unit included more laboratory experiences and activities, more audio-visual resources, and more student library research than any other unit. Other units in the biology curriculum include one or at most two laboratory exercises; some instructors assign library research on genetic diseases in the advanced genetics unit but no other student research had been conducted in the biology classes. The inclusion of questions requiring the interpretation of laboratory results on the unit exam was also a new experience for students compared to other units in the curriculum.

REVIEW OF WRITTEN MATERIALS USED IN UNIT

This unit was prepared primarily during the summer of 1993 at Michigan State's Kellogg Biological Station funded by a grant from the National Science Foundation. It was modified during the 1993-94 school year and implemented in March 1994 at Waubonsie Valley High School in Aurora, Illinois.

Much of this instructional unit was inspired by and drew heavily from a biotechnology unit on antibiotics prepared to meet the requirements of the Cellular and Molecular Biology Workshop held at Michigan State University in East Lansing during the summer of 1992 by this instructor and her colleagues Greg Deurloo, Tim Hoshal, and Colleen Pringle. On campus research yielded a wealth of information on the origin, production, use, and impacts of antibiotics on society (Appendix F).

Material from the Center for Microbial Ecology presented in 1991 and 1993 at Kellogg Biological Station for the Environmental and Behavioral Biology Workshop was also reviewed. This includes material from Microcosmos (Zook, 1989), the laboratory manual "Environmental Spectrum: Hands on the Environment" (1993), and laboratory experiences provided by a variety of instructors. A share session between colleagues at Kellogg Biological Station during the 1993 workshop yielded the activity "Who's Got the Bug".

The "Pop Bottle Landfill" laboratory was written by Kathy Conley and Jane Moss, then revised by Jill Quinley, Steve Lawhead, Eric Buhr, and this instructor during the summer of 1993 at Kellogg Biological Station. A lecture by Jim Pestka on Food Safety / Technology given through the Frontiers in Science series during the spring of 1994 at Michigan State University also contributed material for this unit.

CONCEPTS PRESENTED AND THEIR RELATION TO EXISTING CURRICULUM

The bacteria unit sought to continue building on three concepts that run through the biology curriculum at Waubonsie Valley High School. **Diversity of life** was introduced during the first unit of the year on characteristics of life, and continued through the next unit examining the ecology of wetlands. Diversity continued to be emphasized in units on cell reproduction, genetics, evolution, and classification. The concept of **continuous change through adaptation** also introduced at the beginning of the year and was also emphasized in the evolution unit taught immediately prior to the bacteria unit. Finally, an emphasis on **personal wellness** was expressed through the unit on genetics, and continued through anatomy and physiology.

The bacteria unit also addresses these three issues. The diversity of life was demonstrated as the variety of roles bacteria play in nature and industry were observed. Change through adaptation was exhibited by the appearance of antibiotic-resistant bacterial strains. Finally, personal wellness was addressed through the study of bacterial diseases and prevention of food borne illness.

Chapter 2
Instruction

OUTLINE OF UNIT

The bacteria unit was scheduled in this instructor's two biology classes for a five week period, plus one additional day to complete the Post-Unit Survey, for a total of 26 class periods. The unit was also taught concurrently to other biology sections by other instructors at Waubonsie Valley High School. The other instructors chose to do a condensed version of the unit lasting approximately 18 class periods, to allow them to move on the extensive anatomy and physiology unit taught at the conclusion of the school year. While all biology students learned about bacteria, an attitudinal survey was administered only to students in this instructor's classes.

The original plan was to have students spend one week becoming acquainted with bacterial structure and habitat, as well as with laboratory techniques traditionally used to study bacteria (See Appendix C for Unit Outline). Following this, two weeks were set aside for exploration of bacteria as foe. The first topics to be addressed were the scope of bacterial diseases and modes of transmission. A great deal of emphasis was to be given to the role of antibiotics in treating bacterial disease in this portion of the unit. The origin of antibiotics, the mechanisms by which they halt the growth of bacteria, and their impact on our society were also to be examined. In addition, the causes and concerns arising from antibiotic resistance were scheduled for discussion. A special lecture discussing the role of bacteria in food borne illness was prepared, emphasizing the prevention of such outbreaks.

Working in pairs, students were to research specific bacterial diseases and to report their findings to the class.

The final two weeks were to be spent examining the role of bacteria as man's friend. Students were to explore the importance of bacteria in food production and the efficiency of bacteria as decomposers. The role of bacteria in digestion in the gut tracts of animals, and the vast potential for bioremediation via bacterial action was to be explored by students in the laboratory as well as in lecture. Finally, pairs of students were assigned a microbial product, such as yogurt, researched production methods, and reported their findings to the class.

Ideally, equal time was to be devoted to the friend and foe portions of the unit, but as always happens in public schools, events intervened and some class periods were lost. State testing took away approximately two class periods, and an all-school assembly chipped off more time. In addition to the shortened time slot, activities took more class time than originally scheduled, particularly the researching and presentation of bacterial disease reports. This resulted in progressing only through Day 22 of the Unit Outline (Appendix C). The bacteria as friend portion of the unit was shortened and condensed as this instructor was forced to wrap things up and move on to the next unit.

Although this unit did not follow the original plan exactly, students had the opportunity for many new experiences. Students stepped into the central role in the classroom by performing five laboratory exercises, completing two short research projects and presenting their results, and interviewing elderly relatives about medical practices before the age of antibiotics. Each of these activities will be described in turn.

AUDIO-VISUAL AIDS

Three audio-visual aids were used in this unit. First, laser disc images were used to allow students to observe the differences between gram positive and gram negative of bacteria. Two other audio visual aids used were videos recorded from newsmagazine shows aired during the spring of 1994.

The first video clip was a short segment (approximately twelve minutes) from Primetime Live entitled "Superbugs." This report, which aired just prior to the start of the unit in 1994, illustrated the alarming increase in antibiotic resistance, tracing its causes and illustrating the dangers to the populace.

The second video, entitled "Is Your Food Safe," was an installment of the news magazine 48 Hours, hosted by Dan Rather, that also aired during the 1993-94 school year. This 50 minute video focused on the problem of bacterial contamination in meat, and had a variety of meats bought in a supermarket tested at a commercial laboratory for a variety of pathogens. Both videos were extremely effective in conveying the concerns and current problems to the students.

LABORATORY EXERCISES

Five laboratory exercises, including one group activity, were utilized to aid students in developing a clearer picture of the microbial world. The first laboratory experience, "Bacteria of the W.V.H.S. Environment" (Appendix D) was first generated by the instructor and others as part of a biotechnology unit on antibiotics during the Molecular and Cellular Biology Workshop at Michigan State University. It was used as an introductory activity to pique student interest. Students also practiced basic aseptic techniques and had their first experience inoculating petri dishes with bacterial samples.

Students brainstormed various places in the school to find bacteria to be cultured prior to conducting the laboratory. Locales to be sampled ranged from the bathroom, locker room, school pool, doorknobs, and the principal's phone. Other student ideas included more personal areas such as hair, lips, hands, and coins from their pockets. After listing these ideas on the board and discussing appropriate technique, students were given pre-poured plates and were encouraged to sample whatever they wanted. Students used sterile swabs donated by a local hospital rather than using inoculating loops. Working two to a plate, the students were most excited about being allowed to leave the classroom. For two days, students recorded both qualitative and quantitative observations of their bacterial colonies, then exchanged plates and made more observations. As a wrap-up, the class grouped cultures by their color and growth patterns, then completed post-lab questions.

The second laboratory titled "Who's Got the Bug?" was a group activity rather than an experiment (See Appendix D). Students used test tubes containing a clear liquid (either distilled water or a very dilute sodium hydroxide solution) and, with a straw, exchanged liquids with three different partners; the names and order of exchanges were recorded. The tubes were tested by adding a drop of phenolphthalein indicator to each test tube; a pink result meant the student was "infected" with the simulated disease. Students analyzed the compiled data to determine the original "carriers" (students with sodium hydroxide solution), using the order of contacts to rule out affected individuals. A discussion concerning transmission of diseases, as well as social stigmatization of affected individuals followed the activity. Finally, students answered post-activity questions regarding methodology, transmission and prevention of communicable diseases, and the effect of the incubation period on tracing the source of the disease.

The third laboratory, "How To Stop the Growth of Bacteria" (see Appendix D), was the most complex laboratory exercise included in the unit. Students first inoculated plates with a live culture, either *E. coli* (gram negative) or *Micrococcus luteus* (gram positive), using appropriate techniques and under direct supervision of the teacher. Sterile swabs were used because inoculating loops were not available. Students tested various household antimicrobial agents, with the constraint that they test one antiseptic, one disinfectant, and one antibiotic (antibiotic discs were donated from the local hospital). Each set of lab partners was encouraged to test different combinations of products and organisms. Using distilled water as a control, small discs of filter paper were soaked in the agent to be tested and carefully placed with forceps on the petri dish divided into quadrants. Students observed their plates after 24 and 48 hours of incubation.

A large class data table was compiled to compare the effectiveness of the various agents on the growth of the two different organisms. Students were surprised to learn that antibiotics were specific to the organism tested. Discovering that the school soap was not an effective antibacterial agent was a source of concern for students. The importance of a control was also nicely highlighted when one pair of students failed to correctly inoculate their plate with the live culture. Working with a live culture, practicing aseptic technique, distinguishing between disinfectants, antiseptics, and antibiotics, and noting the specificity of antibiotic - organism interactions were all valuable learning experiences for the students in this exercise.

The fourth laboratory exercise introduced students to the bacteria as friend concept. In "How Can You Test for Bacteria in Foods," students tested various food products for carbon dioxide, the product of respiration in bacteria (as well as many, many other organisms) using the indicator bromthymol blue (See Appendix D). While there was not an opportunity for student exploration in this exercise (all students tested all food products), students greatly enjoyed the opportunity to work with food in a laboratory setting (most likely because of the color changes in the bromthymol blue, or perhaps because class was held before lunch). While reviewing their results, students were challenged to find common factors in all foods that tested positive. One student immediately said "They all taste good!" accurately summing up the concept that bacterial action may improve the taste and texture of some foods.

The final laboratory exercise performed by the students was the construction of a "Pop Bottle Landfill." More an exercise in composting than a landfill, students brought in food scraps (vegetables only) from home as well as packaging scraps, then constructed a model "landfill" using garden soil and reconstructed pop bottles (See Appendix D). Students took apart their landfills and examined their refuse two days later in order to compare decomposition rates of vegetable scraps and packaging scraps. Attempts were made to quantify this lab but decomposition occurred so rapidly that after two days virtually none of the food scraps were measurable. The benefits and ease of composting food scraps at home were then discussed in class. Some of the problems that arose during this exercise led to interesting class discussions. Some students had added too much water to the soil and their landfills became anaerobic (much to the class' disgust), providing a valuable and aromatic illustration of the differences between aerobic and anaerobic decomposition. Another instructor used potting soil, which is sterile, instead of garden soil; this mistake stimulated discussion on the benefits of composting and enriching the microbes in the soil, as well as the importance of reading labels.

Evaluation of the laboratory experiences is based on the quality of student answers to questions on lab reports, teacher observation of student enthusiasm, student comments, and feedback from colleagues regarding observations of their own students. Students were enthusiastic and excited while performing their laboratories, were cautious enough to carefully follow correct procedures, and were eager to show off their results to the instructor and their peers. Most students took ownership of their petri plates and came into class the next day demanding to check on their cultures immediately. Post-lab discussions were lively with all students participating, drawing conclusions and generating questions. After these discussions, students completed and turned in lab reports and were able to answer post-lab questions quickly and completely. They were very quick to make the appropriate connections between the laboratory experiences, lectures, and relevance to their world.

Other instructors teaching the unit reported that they had noted similar occurrences in their classes when teaching this unit, with laboratory exercises generating a high level of enthusiasm and curiosity. Some of these teacher comments are included in Chapter 3. In addition, several teachers expressed a desire to modify the curriculum of other units to include more laboratory experiences, suggesting we use this unit as a model curriculum unit.

ADDITIONAL EXERCISES

In addition to the above laboratory exercises, students spent time researching both bacterial diseases and bacterial products in the school library, and presenting reports of their findings to the class. They also were encouraged to interview elderly relatives or friends to find what life was like before the development of antibiotics for extra credit reports.

The first research project was to emphasize the role of bacteria as foe to the students. Pairs of students chose a disease or group of related diseases from a list prepared by the instructor. Students used the school library, researching causative agents, symptoms and treatments, methods of prevention, at-risk groups, and interesting historical facts. They gave oral reports and prepared a visual aid detailing their findings while the other students took notes on a prepared template (See Appendix E). Students were required to turn in "fact sheets" rather than written reports, as well as their sources for these reports.

The second research project, entitled Products of the Microbial World (See Appendix E), was completed during the "Bacteria as Friend" portion of the unit. Groups of three to four students were given a grouping of microbial products to research in the school library. Oral reports were given on the production methods of each product, and how bacteria are involved in the manufacturing process. Again, students turned in fact sheets and sources rather than written reports.

The newest technique to be implemented in this unit was the interview (See Appendix G). Given as an extra credit assignment, students were encouraged to interview someone over the age of sixty-five to obtain first-hand accounts of what life was like before antibiotics. After completing a specified list of questions, students generated a question of their own, then were required to write two paragraphs summing up what they learned from the interview.

INNOVATIVE METHODS

Although none of these ideas are innovative, to this school and in particular this biology curriculum these methods and ideas were new. First of all, the inclusion of five laboratory exercises in one unit was a change for the students. Most units only had one or two laboratory exercises, three at most; some included no laboratory exercises at all, just paper and pencil activities.

Also before this unit, students were rarely encouraged to choose materials to be tested in laboratory exercises. They were accustomed to following a strict protocol, and the chance to choose what to culture or what antimicrobial agent to test was exciting for them. Also, all student data became important to the class during the analysis. This gave students ownership of the results; they were not just duplicating what everyone else in class had done. While it would be wonderful to allow the students to take the next step and design their own experiments as a follow-up, the ever-expanding amount of material and the ever-shrinking amount of class time generally prohibits in-depth exploration of topics in this first year biology survey course.

Surprisingly, this was the first time most biology classes used the media center for a research project (a few had researched genetic diseases prior to this unit). For the research on bacterial diseases, most students chose diseases that had some relevance to their lives, such as the student who picked tuberculosis because his uncle had contracted the disease. Some students were able to make connections between science and history, such as those researching the bubonic plague. Most enjoyed the chance to present their information to the class, and attempted to make their presentations memorable in some way, like bringing in samples of their microbial products for everyone to taste.

Student-conducted interviews of senior citizens are a technique used in social studies classes that are just beginning to be brought into science curricula. Not only do interviews increase student knowledge, but they build bridges between generations. Most students interviewed relatives, and were amazed at the stories they heard. One third of each class chose to participate in this activity; nearly every student that completed the assignment reported learning something new about their family history. The personal interview was a wonderful way to establish a dialogue between the generations, based on science.

CHAPTER 3

Chapter 3

Did the Students Attitudes Concerning Bacteria Change?

CLASS DEMOGRAPHICS

The biology curriculum at Waubonsie Valley High School is taught at the sophomore (10th grade) level to average students. It is a survey course and is the second year of a required two year science sequence for graduation. As freshman, these students enrolled in Introduction to Physical Science; most go on to take Chemistry their junior year. In addition to those following the traditional sequence, several students had recently moved into the school district, bringing varied backgrounds. As an alternative to biology, sophomores can be enrolled in General Science II, a fundamental life science course, or Accelerated Chemistry for honors students who have already completed a year of Honors Biology.

Students live in portions of Naperville and Aurora, far west suburbs of Chicago, Illinois. The community is affluent, a white collar suburb along an area known as the Hi-Tech Corridor because of the many research divisions of corporations located along the main traffic artery, Interstate 88. It is not unusual to have a student in class whose parent is a Ph.D. researcher at Amoco Research Center or Fermilab National Accelerator Laboratory. Families move to the area because of the proximity to corporate jobs and the solid reputation of the schools. So many families move to the area that, at a growth rate of 1500 children per year, Indian Prairie School District is the fastest growing district in Illinois.

Currently the only high school in the Indian Prairie School District, Waubonsie Valley's student population increases approximately 300 students per year. In addition to the high number of families moving in, many also move out throughout the school year as parents are transferred to different job sites.

The community places a high emphasis on success, whether it is in athletics, music, drama, or academics. In general, students recognize the value of high achievement, particularly grades, primarily in order to be admitted to the college of their choice. Typically it can be difficult to convince the students that hard work is necessary to earn these grades. Most students also hold a part-time job by the time they are sixteen, not to help support their family but to allow them to drive a nice car. They work hard to juggle their responsibilities between family, academics, extra-curricular activities, and employers. Students and parents alike have high expectations of the teachers and the school.

Students at Waubonsie Valley are sophisticated in their exposure to both cultural events and the sciences. Most students have participated in a variety of extra-curricular academic experiences, particularly at the elementary level. Family Math Night, Science Fairs, and the Fine Arts Festival are commonplace events for students in Indian Prairie School District. In addition, many have toured or attended programs at Fermilab National Accelerator Laboratory, Argonne National Laboratory, or Amoco Research Center, all located near the borders of the school district. Because of this high level of exposure, students can sometimes seem jaded, and finding a fresh approach can be difficult.

In the K-12 science curriculum, no units on bacteria are included and students do not have the opportunity to develop the laboratory techniques found in the bacteria unit described in this paper. While they may have discussed some bacterial diseases in the health curriculum, this unit was a new frontier for the students in the spring of 1994. In addition, students (and parents) in the district are routinely surveyed on a variety of issues. The biology students also completed a survey on the wetlands unit in addition to the pre- and post-surveys surrounding the bacteria unit during the 1993-94 school year.

In addition to pre- and post-unit surveys, students completed pre- and post-tests as well as a quiz during the course of the unit. Because this thesis addresses attitudinal changes, the results of these tests are not included. It is an obvious conclusion that student knowledge of bacteria increased as a result of this unit; this is evidenced by some of the items on the pre- and post-unit surveys.

This instructor's two biology classes at Waubonsie Valley High School were surveyed and participated in the bacteria unit during the spring of 1994 (1993-94 school year), the results of which are reported here. The first class started with 27 students at the beginning of the unit, and ended with 26 (one student moved away during the period of instruction). The second class had 24 students.

CONSTRUCTION OF PRE- AND POST-SURVEY

The attitudinal survey (See Appendix B) was constructed during the fall and winter of 1993-94 school year. This instructor included a great deal of material on attitudes toward science along with attitudes toward bacteria to provide a semblance of disguise due to the sophistication of the students. A brief analysis of these attitudes towards science is included to check on reliability of the survey. These issues were not directly addressed in the bacteria unit although it was hoped that perhaps this unit would improve attitudes toward science.

The Pre-Unit Survey was administered at the beginning of class prior to beginning the unit. Students were unaware of the subject of the next unit when taking the Pre-Unit Survey. In an effort to avoid bias, students were told it was a survey developed by a colleague in Virginia for her master's thesis, rather than this instructor's thesis. They were instructed to take their time, consider each answer and circle the choice that best reflected their opinion, not what they thought someone would want to hear. The mood in the classroom was very positive that day.

The first portion of the survey was not directly addressed in the bacteria unit. Items 1 through 18 consisted of bipolar adjectives using a seven point scale to define a range of meaning with respect to the phrase "Science is ..." (Doran, 1980). In order to keep students from consistently circling the same number, pairs of adjectives considered positive and negative were alternated so that 7 was sometimes positive and sometimes negative. The adjectives chosen were drawn in part from Doran's Basic Measurement and Evaluation of Science Instruction (1980), and a survey written by Sandi Kransi (1991) in a Master's Thesis for Michigan State University. The results for the first part of the survey are listed in Table 1 found in Appendix A.

The second portion of the survey, items 19 through 30, also consisted of bipolar adjectives on a seven point scale used to define a range of meaning but this time with respect to the phrase "Bacteria are .." Again, positive and negative terms were alternated. Items 19 and 30, bacteria are important / unimportant, were made identical to check the reliability of the survey. Three items that were more factual than attitudinal (items 21, 26, and 29) were also included. This portion of the survey was the most important to this instructor. The results for this second part of the survey are listed in Table 2 found in Appendix A.

Scoring for the first two sections of the survey was done by multiplying the point value of the response by the frequency of the response to obtain a weighted sum, which when divided by the number of responses gave a weighted mean (see formula below). Point values were assigned so that 1 was negative and 7 was positive; this required the reversal in scoring of every other item to provide consistent results.

$$\text{Weighted Mean} = \frac{\text{Point Value* x Frequency}}{\text{Total Number of Responses}}$$

* adjusted on some items so that a score of 1 reflected the most negative adjective, and 7 the most positive

The third section of the survey, items 31 through 50, consisted of statements to be read by the students, who would then respond via a 6-point scale ranging from strongly agree to strongly disagree. Statements regarding science in general (items 31, 32, 40, and 50) were interspersed with statements regarding bacteria. Results for this part of the survey are listed in Table 3 found in Appendix A.

Scoring for this section was also completed through calculation of a weighted mean. Scores of 1 to 6 were assigned, with 6 representing the answer desired (as defined by this instructor), whether it was strongly agree or strongly disagree.

The fourth and final portion of the survey, items 51 through 60, consisted of a list of activities. Students were to choose between attempting a given activity given time and knowledge (3), not attempting the activity (1), or remain indifferent (2). Results for this part of the survey are listed in Table 4 found in Appendix A.

In addition to the loss of one student in 2nd period, another student chose not to answer the last portion of the survey. This made the comparison of Pre- and Post-Surveys particularly difficult, so totaled responses were converted to percentages of the sample so that trends could be discerned.

The Post-Unit Survey was administered the day after the unit exam. Students were unhappy with the length of the post-test, and the amount of writing required. In contrast to the upbeat mood in the classroom the day the Pre-Unit Survey was administered, students were tired of school, and anxiously awaiting the fetal pig dissection to be done in the next unit. This instructor believes this had some influence on the results of the survey. When tabulating the results, on the Post-Unit Survey two students (who sat next to each other) simply circled the most negative answer possible, and one of these students did not complete the last page; these surveys were omitted from the results. In addition, the length of the survey worked against it.

On reflection, a shorter and direct survey of twenty-five questions administered prior to testing may have been more effective in assessing student attitudes. This instructor would eliminate the first portion of the survey completely, but keep the entire second section (items 19 - 30). In addition, some of the statements from the third section would be retained (items 31, 32, 34, 35, 36, 38, 39, 42, 46, 47, 49, and 50). The final section would either be eliminated completely or reworked to make it clearer and to force students to choose rather than giving them the option to be indifferent.

Figure 1 Survey Results Items 1 - 18

Science Is ...

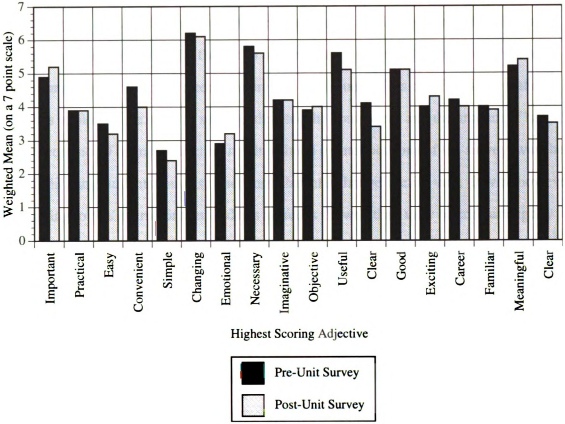


Figure 1 A comparison of Pre- and Post-Survey results (weighted means) for the first portion of the attitudinal survey, Science Is... Students circled a number on a scale of 1 to 7 between pairs of bipolar adjectives to indicate their response to the phrase "Science Is..." Only the highest scoring term is included in this figure (See Table 1 in Appendix A for both adjectives).

STATISTICAL ANALYSIS OF PRE- AND POST-SURVEY

A comparison of the first part of the Pre- and Post-Unit surveys, Science is ..., shown in Figure 1 above shows little change in student attitudes. Only seven of the eighteen items showed a movement greater that 0.2 (on a 7-point scale), with four of these in a negative direction and three in a positive direction as defined by the instructor. Following the unit, student attitudes reflected science was slightly more difficult, less convenient, and more harmful than prior to the instructional unit. As stated previously, these survey items were not directly addressed by the unit. This could indicate that as students explore more areas of science, they see the complexity and the amount of hard work required. The most puzzling result, echoed in later portions of the survey, was the data indicating students found science more harmful that before the unit. It was, however, heartening to this instructor that students attitudes showed they view science as slightly more important, exciting, and emotional upon the conclusion of this unit.

Analysis of the majority of the items in this first section showed that students attitudes began and remained in the middle of the scale (3.5 to 4.5) for six items, finding science a balance between theoretical and practical, imaginative and unimaginative, subjective and objective, hobby and career, confusing and clear, and strange and familiar. In addition, students scored several items at the high end of the scale (greater than 5). This illustrates attitudes in which science is important, changing, necessary, useful, good, and meaningful. Although the negative movements on items 4, 11, and 12 were somewhat discouraging, when looking at the overall scores on the scale this instructor feels that perhaps students have a clear view of what science is about.

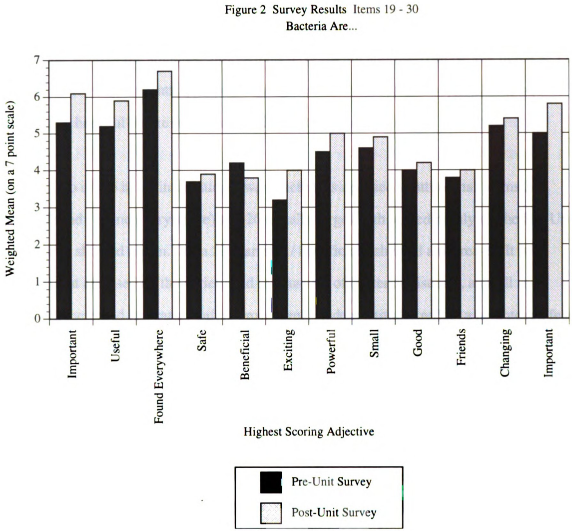


Figure 2 A comparison of Pre- and Post-Survey results (weighted means) for the second portion of the attitudinal survey, Bacteria Is... Students circled a number on a scale of 1 to 7 between pairs of bipolar adjectives to indicate their response to the phrase "Bacteria are..." Only the highest scoring term is included in this figure (See Table 1 in Appendix A for both adjectives).

The second portion of the survey, Bacteria are ..., was the most important to this instructor. Many changes between the Pre- and Post-Survey occurred in this section. Nine of the twelve items showed a change greater than 0.2 (on a seven point scale), with eight of these nine showing a gain. One thing this instructor did not predict was the existing knowledge level of the students; although bacteria are not addressed anywhere in the K-12 district curriculum, students appeared to grasp the essential idea that bacteria were both helpful and harmful before beginning the instructional unit.

Two of the items in the survey were factual as opposed to attitudinal; items 21 (rarely found / found everywhere) and 26 (small / large) both scored highly on the Pre-Unit Survey and showed a gain. Item 23 (harmful / beneficial) showed a decrease. It is possible that after seeing the variety and seriousness of bacterial diseases, as well as following increased laboratory safety procedures, student attitudes reflect a heightened fear of bacteria rather than the healthy respect this instructor intended to engender. This result is consistent with the decrease seen in items 36 in the next section of the survey and 11 in the previous section.

Scoring in the middle of the scale (3.5 to 4.5) were items 22, 27, and 28 with the adjectives dangerous / safe, bad / good, and enemies / friends showing little change (+0.2) from the Pre-Survey to the Post-Survey. Scoring on the high end of the scale (greater than 5.0), were items 25 and 29. Item 29, unchanging / changing, showed little change (+0.2), while item 25, weak / powerful, showed more change, (+0.5) towards powerful.

The largest increases (0.7 to 0.8 on the seven point scale) occurred in identical items 19 and 30 (unimportant / important) and items 20 (useless / useful) and 24 (dull / exciting), as student attitudes indicate a perception of bacteria as more useful, exciting, and important than before the unit. Items 19/30 and 20 (useful and important) scored at the high end of the scale, while item 24 (exciting) was in the middle. It is interesting to note that although the weighted means for identical items 19 and 30 are different (5.8 versus 5.6 during the Post-Unit Survey), the amount of change from the Pre- to Post-Survey is the same (+0.6), illustrating the reliability of the data.

The third portion of the survey had students agree or disagree on a six-point scale with a variety of statements (See Table 3 in Appendix A). Four of these statements (31, 32, 40, and 50) concerned science in general. There was no change in items 31 and 32 as students mildly disagreed with statements that they "would like a career working as a scientist," and that "science could be left to the experts." A slight decrease (-0.2) was calculated for items 40 and 50, but students still disagreed with the statement "The knowledge of science is final and does not change," and agreed with the statement "Careers in science are interesting and rewarding". One thing worth noting is dichotomy in the students attitudes, in which they believe careers in science are interesting and rewarding, but show little interest in a career in science for themselves.

Little or no change (0 to 0.2) was seen in items 33, 36, 41, 42, 44, 45, 46, 47, 48, and 49. Both before and after the unit, students mildly agreed that it is important to classify and identify the functions of bacteria, bacteria are useful tools for studying genetics, and that the government should fund the study of harmful and beneficial types of bacteria. Students agreed that bacteria occupy an important niche in the environment, and that without bacteria we would not be alive. In addition, students mildly disagreed with reducing and eliminating bacteria from earth, that they do not need to know about bacteria and that it is difficult to find bacteria in a clean house. They disagreed with the statement "Bacteria are so small it is not important to study them."

More change (0.3 to 0.4) was seen in items 36, 37, and 39, with all movement in the desired direction as defined by the instructor. Following the unit, more students agreed that precautions such as washing hands were important than before. This can again be tied to the strong emphasis on safety in the laboratory, where students washed down counters with a bleach solution before and after each activity. More students disagreed with the statement "It is unsafe to study bacteria." This indicates to the instructor that students have internalized the idea that bacteria are found everywhere. While overall students mildly disagreed with "People who study bacteria should be paid a great deal of money," there was an increase (+0.4) in the number of students that agreed with this statement. This instructor found these results intriguing, working in an area where so much emphasis is placed on financial success. It is unclear whether those students whose attitudes changed upon the conclusion of this unit placed more value on this activity because they view it as more important, or whether they place more value on it because they believe it requires a mastery of certain skills and some risk-taking.

A recurring result was the decrease (-0.4) in the number of students disagreeing with the statement "It is unsafe to study bacteria." This could be the result of raising student awareness of pathogens in the laboratory and throughout the school, and perhaps over-emphasizing laboratory safety concerns, and echoes the results of items 11 and 23 in previous sections of the survey.

Finally, the largest amount of change (0.6 to 0.7 on the six-point scale) seen in the third section of the survey occurred in items 38 and 43. Students mildly agreed with "Bacteria are useful in manufacturing;" this statement is more factual than attitudinal. By far the largest change between the two surveys had students disagreeing with the statement "Without bacteria we would lead happy and healthy lives " (item 38). This hopefully reflects student thoughts that bacteria are an integral part of life, and indicates that the unit was successful in raising student awareness.

The final portion of the survey addressed a list of laboratory-based activities which related to bacteria. Students could choose to theoretically perform these activities, not to perform these activities, or remain indifferent. Some of the students (about 10) were unfamiliar with the meaning of indifferent, and were confused by this section and asked for clarification. In addition, in this section it was very difficult to establish a comparison between Pre- and Post-Survey attitudes; to account for the changing sample size (52 vs. 48) results were converted to percentages as previously stated. However, the percent changes from Pre- to Post-Survey are not balanced. For example, item 52 recorded changes of -2%, -5%, and +10% in the three categories; somewhere in the changing sample size 3% is lost. Rather than a strict comparison of percentages, this instructor looked for overall trends in the computed differences for items 51 through 60. See Table 4 in Appendix A for results.

The results of this section were disappointing; more students chose not to do many of the listed activities or were indifferent to the activities after the unit compared to before the unit. This was a surprising result after the positive reactions from students. It could be the result of two things; students had done many of these activities and were ready to move on to something new, or once they saw the complexity involved in some of the tasks they lost interest. If this instructor were to administer this survey again, this section would either be eliminated or changed so that it could be scored in a manner similar to the first two sections of the survey.

Following the unit, decreases were seen in five of the ten items (51, 54, 55, 58, and 60) of the final portion of the survey. Fewer students wanted to perform scientific research, design and produce new food products, determine the cause of food borne illness, inspect restaurants for bacterial contamination, or work in a science-related field upon completion of the unit. One interesting result is that fewer students were indifferent about running a pharmaceutical company (item 57); strong movement was shown in both directions as student were intrigued by or rejected this activity. A large number of students remained interested in designing new food products (item 54) even though interest levels dropped.

More students however, were interested in culturing bacteria in a laboratory and searching for oil-eating bacteria (items 52 and 59) at the conclusion of the unit. This may be due to the increase in comfort level culturing bacteria, and high levels of interest in the environment.

SUBJECTIVE EVIDENCE REGARDING EFFECTIVENESS OF UNIT

Much that goes on in the classroom cannot be easily quantified. A great deal of informal discussion took place during the bacteria unit. Students were eager to share personal anecdotes, and generated many questions as connections were made between subject matter and their own lives. In fact, one of the reasons some planned activities were eliminated by this instructor was the number of student questions; it was difficult to move quickly through lectures and post-lab discussions.

The interest level in the class and the enthusiasm displayed by the students in this instructors classroom, particularly before spring break, was very high; as high as the genetics unit (the most popular unit of the year) earlier the same quarter. Students were very excited to be working with so many laboratory exercises, although wary of working with live organisms. In addition, colleagues teaching other sections of biology reported high interest levels and satisfactory experiences with the laboratory exercises, both from themselves and their students. The only problem reported was that the unit was too long; since this instructor spent five to seven days more on the unit than other instructors she echoes that criticism.

Other instructors at Waubonsie Valley High School that taught the bacteria unit were surveyed in regards to their experiences teaching the bacteria unit. They were asked to comment on laboratory exercises, videos, and for any general comments. The following comments were made regarding the "Bacteria of W.V.H.S Environment" laboratory exercise:

> "Cool!"
> "They especially liked this lab...they were amazed at how much bacteria was all around them."
> "Fun to do and to see the results - can surprise the students!"
> "Students really enjoy!"

Indicating student enthusiasm was high in other classrooms, one instructor noted that after the students performed "Who's Got the Bug" that "students liked this so much, they wanted to do it twice."

Instructors were most excited about the opportunities for student exploration and class discussion following the laboratory "Controlling the Growth of Bacteria." They made these comments:

> "Good lab."
> "Neat - understood throat cultures much better after this lab."
> "Very effective in addressing how specific some anti-microbial agents are."

One instructor noted about testing for bacteria in food products "The use of foods in the laboratory was new to the students and made them see a positive side to bacteria, although it was a messy lab for clean-up."

Reactions to the lab "Pop Bottle Landfill" were mixed:

> "Worked out very well - shows bacterial roles as decomposers nicely."
> "Move it to the ecology unit - integrate bacteria."
> "A good idea and somewhat worthwhile but takes too much time...also messy and smells bad - but kids seem to like it."
> "Get rid of it."

Instructors felt that the videos shown in class were excellent and provoked a great deal of student thought and discussion. Some of the comments were:

> "Is Your Food Safe was one of the best videos this year."
> "They liked it a lot but it grossed them out."
> " [Superbugs] illustrates there are no 'quick fixes' anymore"
> "Good thought-provoking videos, but more direction and activities related to the videos would be helpful."
> "Students changed their habits - like washing their hands more and being more cautious of kitchen pathogens at home... won't eat a raw hamburger at a restaurant...some also turned vegetarian (they claim)."

Finally, instructors made the following comments regarding the unit in general:

> "I enjoyed teaching this unit. One major benefit was bacteria were no longer abstract invisible creatures students knew nothing about. The labs made concepts more concrete for the kids and more enjoyable for me to teach."
> "One of the more relevant units we teach. Students have changed their habits."
> "Nice unit, but I feet it takes way too long to fit into a year-long biology curriculum - especially when one would want to address viruses too."
> "An enjoyable unit - the students seem to really like it."

CHAPTER 4

Chapter 4
Discussion and Conclusions

EFFECTIVE ASPECTS OF THE UNIT

Did students change their attitudes towards bacteria? Survey results from 1994 inidcate there was not a great deal of change in attitudes as students already viewed bacteria as both friend and foe. However, results of the post-unit survey presented in the previous chapter indicate that after completing this unit, students view bacteria as powerful, exciting, and important. These results lead this instructor to the conclusion that overall, this instructional unit effectively raised student interest. Some areas of the unit, however, were more effective than others based on student and teacher reactions.

All biology instructors agreed that the most effective portions of the bacteria unit were the laboratory exercises and the videos shown. The" Bacteria of W.V.H.S." was an exciting beginning to the unit. Students had a chance to explore their ideas, grow something they found truly disgusting, and move around not just the classroom but the school to gather samples. It was a wonderful initiation and effectively introduced students to the microbial world.

"Who's Got the Bug?" accurately portrayed the social stigma that accompanies communicable diseases; students immediately connected the analogy of the mixing of fluids in the "Who's Got the Bug" activity as representative of the spread of HIV (Human Immunodeficiency Virus) in our society. Students loudly and repeatedly claimed they were "clean" and did not have the disease. When they tested positive, immediate accusations were made that someone else had infected them. No one would believe that they were the source of the epidemic.

"Controlling the Growth of Bacteria" was, in this instructor's opinion, the best laboratory experience for the students in the unit. Students had a chance to explore the actions of common household items and pharmaceuticals even though it was occasionally difficult for the instructor to supervise appropriate techniques. All student data became important; students could not just check to see if they "did it right." The parallel of having a culture for strep throat done at the doctor's office (a common experience for most in the class) reinforced the feeling that they were doing "real science."

The laboratory the students seemed to enjoy the most, "Testing for Bacteria in Foods", was the one with which they had the most difficult time answering post-lab questions (See Appendix D for questions). They loved doing the lab itself, and could accurately discern the presence of bacteria by the color change, but had a difficult time explaining the concept behind this indirect method of testing. The quality of answers to these laboratory questions were poor, as well as on a corresponding essay question on the Bacteria Quiz (See Appendix I for quiz).

The "Pop Bottle Landfill" was very successful for some students, but not for all. Those students whose landfills remained aerobic were excited about the results, but those whose landfills became anaerobic due to too much water were not pleased. In addition to this lab, student and teacher comments were mixed concerning the reports on bacterial diseases. Some students really enjoyed that portion of the unit and did a terrific job, others complained of having a difficult time finding materials or getting their partner to do their fair share of the work. One teacher commented "It was worthwhile" while another said

"My students were <u>not</u> attentive to the other presentations. I feel this time should have been spent on other worthwhile hands-on activities."

Those students that did the personal interview concerning the impact of antibiotics on society were very positive in their assignment summary, feeling that they had established new links with elderly relatives. One instructor commented "Students witnessed some neat conversations with grandparents and learned more than just about antibiotics. One student said 'I never knew my grandma was such a neat person. We'll talk again sometime soon.'"

The most effective thing about the unit could not have been planned. The increased attention given by the media to bacteria, antibiotic resistance, and food borne illness in the weeks immediately prior to and during the unit keenly raised student interest. Sometimes with students, the only things that are "real" are the things that are reported on television. Coverage on the evening news and newsmagazines of the illness caused by contaminated hamburgers at Jack-In-The-Box, contamination of the Milwaukee water supply by *Cryptosporidium* species, and news of the resistant "flesh-eating bacteria" served to raise student awareness more than anything this instructor could do in the classroom. These news stories could then be used to begin classroom discussions, to illustrate a point, or to make connections between laboratory exercises and real-world events.

INEFFECTIVE ASPECTS OF THE UNIT

Four things about the bacterial unit were not effective. First, the reports on "Products of the Microbial World" were difficult for the students and of poor quality as the class raced to complete the assignment and wrap up the unit. The inability of the students to quickly and adequately access information in the school library led to a high frustration level. In the following school year, this assignment was reworked and combined with the reports on bacterial diseases; students research and report on both at the same time. Having experience with the project, the school librarians organize material in advance and are better prepared to help students access information quickly.

Some students now take advantage of the Internet to obtain information; the new modems in the computer lab facilitate use of this additional resource. Instructions for both reports were clarified and grading criteria included (see Appendix H) to make this a more successful project for the students. Student comments have been more positive and reports of higher quality since implementing this change. In addition, students see a better balance of bacteria as friend and foe, and use less class time to complete the project

Secondly, students were also very hostile about the unit test; the common complaint was too much essay. Previous tests throughout the year contained essay as well as fill in the blank, but also contained matching and multiple choice sections. Although this instructor informed them of the test format, students felt they were not told what to expect and this raised their frustration level. It was in this atmosphere that they completed the Post-Unit Survey. Next time, this instructor would administer any survey items <u>before</u> testing to eliminate this problem.

The strong emphasis on additional safety procedures instituted in the laboratory while working with live cultures led students to develop high levels of anxiety rather that the attitude of healthy respect the instructors intended to cultivate. This anxiety was evidenced by the hesitant actions of the students and the questions asked during the laboratory experiments, and is most likely responsible for the results noted in survey items 11, 23, and 36. While still insisting on the same safety procedures (primarily use of a 10% bleach solution to wipe down counters before and after laboratory exercises), instructors use a low-key approach and try to help the students establish a comfort zone while working with live organisms.

The biggest problem with the unit, however, was not one particular activity but the length of the unit. Most units in the curriculum were two to three weeks in length, with longer units broken into two to three week segments for testing purposes. While the students enjoyed almost every activity in this unit, they tired of studying bacteria and wanted to move to the anatomy and physiology unit. The situation was exacerbated as other classes moved on but they did not. Students were extremely anxious that they would not have enough time to complete the fetal pig dissection they had been looking forward to all year despite the assurances of this instructor.

Several changes to the unit have been made since its implementation in the Spring of 1994. The unit has been shortened to 15 class periods (See Appendix J for 1995-96 schedule). The amount of lecture material was reduced slightly when a slide presentation on clinical microbiology was omitted. Instructors are better organized, and some items completed in class, such as worksheets on the classification of bacteria, are now given as homework. Small quizzes break up the unit into manageable portions for the students.

Laboratory materials and their distribution are better organized by the department's laboratory technician and activities can be conducted much more rapidly now that instructors are familiar with the exercises. The "Pop Bottle Landfill" was moved to the ecology unit on wetlands by most instructors, where it continues to reinforce the important role of bacteria as decomposers. Some instructors demonstrate the laboratory "Testing for Bacteria in Foods" rather than having the entire class perform the exercise. An alternative activity, observation of bacterial cultures in yogurt, is also performed by some instructors.

In the future, the sequencing of the unit will be altered to present the "Bacteria as friend" portion of the unit first to emphasize this aspect of the unit to the students. This should help to alleviate some of the negative changes in the student attitudes indicated by the Post-Unit Surveys (particularly item 23). This instructor also intends to incorporate an exercise on bacterial transformation to the genetics unit because students now have experience working with live bacterial cultures.

In addition to bacteria, a short segment (2-3 days) on emerging viruses was added to the unit in the 1995-96 school year. Bombardment by the media regarding HIV, Ebola, and other viruses has shown students that this is something they will be dealing with for years to come. Another outstanding episode of the television show 48 Hours entitled "In the Danger Zone" addresses the emergence of lethal viruses from the rainforest and shows laboratories where they are studied .

Because of its success in the sophomore biology curriculum, in the 1995-96 school year the bacteria unit was incorporated into the honors biology curriculum. In addition to completing the same activities as the sophomore biology students, instructors use the activities as springboards to bring in fermentation, teach respiration and the production of ATP, and to study population curves. With these changes, the bacterial unit has become an integral part of the biology curriculum at Waubonsie Valley High School and, this instructor is pleased to say, a favorite of instructors and students.

SUMMARY

This instructor is very pleased with the bacteria unit incorporated into the biology curriculum as a result of graduate work completed at Michigan State University. In addition to providing new experiences for students , the material is immediately relevant to the students' lives. With so much material and so little time in a general biology course, this instructor and her colleagues feel that teaching topics most likely to be relevant to the student's future will drive future decisions of which units to keep and which to discard.

The increased amount of hands-on laboratory experiences is an extremely positive change for the biology curriculum at Waubonsie Valley, and has encouraged this instructor and others to reach out and try new ideas. Other instructors in the department have mentioned using this unit as a template for reevaluating other units in the curriculum. This instructor would have never predicted, back in the Summer of 1992 at the Cellular and Molecular Biology Workshop held at Michigan State University, that developing a biotechnology unit on antibiotics would lead to the myriad of changes in the biology curriculum at Waubonsie Valley High School.

APPENDIX A

Appendix A

SURVEY RESULTS

Table 1. Survey Results for Items 1 - 18 Science is ...

	Lowest Scoring Term (1)	Pre-Unit Survey (52)	Post-Unit Survey (49)	Amount of Change	Highest Scoring Term (7)
1.	Unimportant 1	4.9	5.2	+0.3	Important 7
2.	Theoretical 1	3.9	3.9	0	Practical 7
3.	Difficult 1	3.5	3.2	-0.3	Easy 7
4.	Inconvenient 1	4.6	4.0	-0.6	Convenient 7
5.	Complex 1	2.7	2.4	-0.3	Simple 7
6.	Unchanging 1	6.2	6.1	-0.1	Changing 7
7.	Unemotional 1	2.9	3.2	+0.3	Emotional 7
8.	Unnecessary 1	5.8	5.6	-0.2	Necessary 7
9.	Unimaginative 1	4.2	4.2	0	Imaginative 7
10.	Subjective 1	3.9	4.0	+0.1	Objective 7
11.	Harmful 1	5.6	5.1	-0.5	Useful 7
12.	Fuzzy 1	4.1	3.4	-0.6	Clear 7
13.	Bad 1	5.1	5.1	0	Good 7
14.	Dull 1	4.0	4.3	+0.3	Exciting 7
15.	Hobby 1	4.2	4.0	-0.2	Career 7
16.	Strange 1	4.0	3.9	-0.1	Familiar 7
17.	Meaningless 1	5.2	5.4	+0.2	Meaningful 7
18.	Confusing 1	3.7	3.5	-0.2	Clear 7

Table 1. The weighted means for items 1 through 18 of the Pre- and Post Attitudinal Surveys for each pair of adjectives are compared, showing the amount of change on a 7-point scale. Both adjectives and their adjusted values are included in the table. 52 students responded to the Pre-Unit Survey, and 49 responded to the Post-Unit Survey.

Table 2. Survey Results for Items 19 - 30 Bacteria Are ...

	Lowest Scoring Term (1)	Pre-Unit Survey (52)	Post-Unit Survey (49)	Amount of Change	Highest Scoring Term (7)
19.	Unimportant 1	5.3	6.1	+0.8	Important 7
20.	Useless 1	5.2	5.9	+0.7	Useful 7
21.	Rarely Found 1	6.2	6.7	+0.5	Found Every-where 7
22.	Dangerous 1	3.7	3.9	+0.2	Safe 7
23.	Harmful 1	4.2	3.8	-0.4	Beneficial 7
24.	Dull 1	3.2	4.0	+0.8	Exciting 7
25.	Weak 1	4.5	5.0	+0.5	Powerful 7
26.	Large 1	4.6	4.9	+0.3	Small 7
27.	Bad 1	4.0	4.2	+0.2	Good 7
28.	Enemies 1	3.8	4.0	+0.2	Friends 7
29.	Unchanging 1	5.2	5.4	+0.2	Changing 7
30.	Unimportant 1	5.0	5.8	+0.8	Important 7

Table 2. The weighted means for items 19 through 30 of the Pre- and Post- Attitudinal Surveys for each pair of adjectives are compared, showing the amount of change on a 7-point scale. Both adjectives and their adjusted values are included in the table. 52 students responded to the Pre-Unit Survey, and 49 responded to the Post-Unit Survey.

Table 3. Survey Results for Items 31 - 50 Science is ...

	Statement SA = Strongly Agree SD = Strongly Disagree	Pre-Unit Survey (52)	Post-Unit Survey (49)	Amount of Change	Result
31.	I would like to have a career working as a scientist SA = 6	2.8	2.8	0	Mildly Disagree
32.	Most people can leave science to the experts and do not need to understand how science works SD = 6	4.2	4.2	0	Mildly Disagree
33.	It is important to try to classify and identify the function of as many types of bacteria as possible SA = 6	4.4	4.6	+0.2	Mildly Agree
34.	Bacteria are so small it is not important to study them SD = 6	5.2	5.1	-0.1	Disagree
35.	Without bacteria, we would not be alive SA = 6	4.7	4.9	+0.2	Agree
36.	It is unsafe for anyone to study bacteria SD = 6	5.0	4.6	-0.4	Disagree
37.	It is important to observe simple precautions such as washing your hands before preparing food SA = 6	5.4	5.7	+0.3	Agree
38.	Without bacteria, we would lead happy and healthy lives SD = 6	4.0	4.7	+0.7	Disagree
39.	People who study bacteria should be paid a great deal of money SA = 6	3.1	3.5	+0.4	Mildly Disagree
40.	The knowledge of science is final; it does not change SD = 6	5.2	5.0	-0.2	Disagree

Table 3 (continued)

	Statement SA = Strongly Agree SD = Strongly Disagree	Pre-Unit Survey (52)	Post-Unit Survey (49)	Amount of Change	Result
41.	Bacteria are important tools in the study of genetics SA = 6	4.2	4.4	+0.2	Mildly Agree
42.	Scientists should work to reduce or possibly eliminate bacteria from the earth SD = 6	4.1	4.2	+0.1	Mildly Disagree
43.	Bacteria are useful in manufacturing SA = 6	3.8	4.4	+0.6	Mildly Agree
44.	The government should fund the study of harmful bacteria SA = 6	4.2	4.3	+0.1	Mildly Agree
45.	The government should fund the study of beneficial bacteria SA = 6	4.4	4.3	-0.1	Mildly Agree
46.	The government should fund the study of bac-teria whether they are harmful or beneficial SA = 6	4.4	4.3	-0.1	Mildly Agree
47.	It is difficult to find bacteria in a clean house SD = 6	4.7	4.9	+0.2	Disagree
48.	I do not need to know anything about bacteria SD = 6	4.5	4.5	0	Disagree
49.	Bacteria occupy an important niche in the environment SA = 6	4.8	4.9	+0.1	Agree
50.	Careers involving science are interesting and rewarding SA = 6	4.0	3.8	-0.2	Agree

Table 3. The weighted means for items 31 through 50 of the Pre- and Post- Attitudinal Surveys are compared, showing the amount of change on a 6-point scale. Results of student choices between Strongly Agree (SA) and Strongly Disagree (SD) are shown in the last column. 52 students responded to the Pre-Unit Survey, and 49 responded to the Post-Unit Survey.

Table 4. Survey Results for Items 51 to 60

Circle: 3 If you would like to attempt such an activity
2 If you are indifferent about attempting such an activity
1 If you would **not** like to attempt such an activity

	Statement		**1** Pre-Unit (52)	**1** Post-Unit (48)	**2** Pre-Unit (52)	**2** Post-Unit (48)	**3** Pre-Unit (52)	**3** Post-Unit (48)
51.	Perform scientific research	Total	15	15	24	23	13	10
		%	29	31	46	48	25	21
		Diff.		+2		+2		-4
52.	Culture bacteria in a laboratory	Total	21	18	20	16	10	14
		%	40	38	38	33	19	29
		Diff.		-2		-5		+10
53.	Test food products for bacterial contamination	Total	17	17	17	17	16	14
		%	33	35	33	35	31	29
		Diff.		+2		+2		-2
54.	Design and produce new food products	Total	11	15	19	17	21	16
		%	21	31	37	35	40	33
		Diff.		+10		-2		-7
55.	Determine the cause of an outbreak of a food-borne illness	Total	15	20	23	19	14	9
		%	29	42	44	36	27	18
		Diff.		+13		-8		-8
56.	Use bacterial cultures to study genes	Total	18	18	25	23	8	7
		%	35	38	48	48	15	16
		Diff.		+3		-0		+1

Table 4 (continued)

Circle: 3 If you would like to attempt such an activity
2 If you are indifferent about attempting such an activity
1 If you would **not** like to attempt such an activity

	Statement		**1** Pre-Unit (52)	**1** Post-Unit (48)	**2** Pre-Unit (52)	**2** Post-Unit (48)	**3** Pre-Unit (52)	**3** Post-Unit (48)
57.	Run a pharmaceutical company	Total % Diff.	26 50	27 56 +6	20 39	14 29 -10	5 10	7 16 +6
58.	Inspect restaraunts for bacterial contamination	Total % Diff.	26 50	24 50 0	14 27	16 33 +6	11 21	8 17 -4
59.	Search for oil-eating bacteria	Total % Diff.	27 52	25 52 0	16 31	11 23 -8	8 15	10 21 +6
60.	Work in a science-related field	Total % Diff.	22 42	21 44 +2	14 27	15 31 +4	15 29	12 25 -4

Table 4. The total responses, percent of responses, and calculated percentage differences for items 31 through 50 of the Pre- and Post- Attitudinal Surveys are compared. 52 students responded to the Pre-Unit Survey, and 48 responded to the Post-Unit Survey.

APPENDIX B

Appendix B

Science Opinion Post-Unit Survey

Please circle the number the best represents your opinion. You may only circle one number.

Science is...

1.	important	1	2	3	4	5	6	7	unimportant
2.	theoretical	1	2	3	4	5	6	7	practical
3.	easy	1	2	3	4	5	6	7	difficult
4.	inconvenient	1	2	3	4	5	6	7	convenient
5.	simple	1	2	3	4	5	6	7	complex
6.	unchanging	1	2	3	4	5	6	7	changing
7.	emotional	1	2	3	4	5	6	7	unemotional
8.	unnecessary	1	2	3	4	5	6	7	necessary
9.	imaginative	1	2	3	4	5	6	7	unimaginative
10.	subjective	1	2	3	4	5	6	7	objective
11.	useful	1	2	3	4	5	6	7	harmful
12.	fuzzy	1	2	3	4	5	6	7	clear
13.	good	1	2	3	4	5	6	7	bad
14.	dull	1	2	3	4	5	6	7	exciting
15.	career	1	2	3	4	5	6	7	hobby
16.	strange	1	2	3	4	5	6	7	familiar
17.	meaningful	1	2	3	4	5	6	7	meaningless
18.	confusing	1	2	3	4	5	6	7	clear

Science Opinion Survey
Page 2

Please circle the number the best represents your opinion. You may only circle one number.

Bacteria are...

19.	important	1	2	3	4	5	6	7	unimportant
20.	useless	1	2	3	4	5	6	7	useful
21.	found everywhere	1	2	3	4	5	6	7	rarely found
22.	dangerous	1	2	3	4	5	6	7	safe
23.	beneficial	1	2	3	4	5	6	7	harmful
24.	dull	1	2	3	4	5	6	7	exciting
25.	powerful	1	2	3	4	5	6	7	weak
26.	small	1	2	3	4	5	6	7	large
27.	good	1	2	3	4	5	6	7	bad
28.	enemies	1	2	3	4	5	6	7	friends
29.	changing	1	2	3	4	5	6	7	unchanging
30.	unimportant	1	2	3	4	5	6	7	important

Science Opinion Survey
Page 3

For the next portion of the survey, please read each statement and decide if you strongly agree (SA), agree (A), mildly agree (MA), mildly disagree (MD), disagree (D), or strongly disagree (SD) and circle your choice below each statement. You may circle only one choice.

31. I would like to have a career working as a scientist.

    SA A MA MD D SD

32. Most people can leave science to the experts and do not need to understand how science works.

    SA A MA MD D SD

33. It is important to try to classify and identify the function of as many types of bacteria as possible.

    SA A MA MD D SD

34. Bacteria are so small it is not important to study them.

    SA A MA MD D SD

35. Without bacteria, we would not be alive.

    SA A MA MD D SD

36. It is unsafe for anyone to study bacteria.

    SA A MA MD D SD

37. It is important to observe simple precautions such as washing your hands before preparing food.

    SA A MA MD D SD

38. Without bacteria, we would leave happy and healthy lives.

    SA A MA MD D SD

39. People who study bacteria should be paid a great deal of money.

    SA A MA MD D SD

40. The knowledge of science is final; it does not change.

    SA A MA MD D SD

Science Opinion Survey
Page 4

41. Bacteria are important tools in the study of genetics.

SA A MA MD D SD

42. Scientists should work to reduce or possibly eliminate bacteria from the earth.

SA A MA MD D SD

43. Bacteria are useful in manufacturing.

SA A MA MD D SD

44. The government should fund the study of harmful bacteria.

SA A MA MD D SD

45. The government should fund the study of beneficial bacteria.

SA A MA MD D SD

46. The government should fund the study of bacteria whether they are harmful or beneficial.

SA A MA MD D SD

47. It is difficult to find bacteria in a clean house.

SA A MA MD D SD

48. I do not need to know anything about bacteria.

SA A MA MD D SD

49. Bacteria occupy an important niche in the environment.

SA A MA MD D SD

50. Careers involving science are interesting and rewarding.

SA A MA MD D SD

Science Opinion Survey
Page 5

Below is a list of science-related activities. You are to rate these on a scale from 3 to 1 as follows:

3 If you would like to attempt such an activity

2 If you are indifferent about attempting such an activity

1 If you would **not** like to attempt such an activity.

You are to assume that you have ample time and knowledge to attempt any activity which may interest you.

51.	3	2	1	Perform scientific research.
52.	3	2	1	Culture bacteria in a laboratory.
53.	3	2	1	Test food products for bacterial contamination.
54.	3	2	1	Design and produce new food products.
55.	3	2	1	Determine the cause of an outbreak of a food borne illness.
56.	3	2	1	Use bacterial cultures to study genes.
57.	3	2	1	Run a pharmaceutical company.
58.	3	2	1	Inspect restaurants for bacterial contamination.
59.	3	2	1	Search for oil-eating bacteria.
60.	3	2	1	Work in a science-related field.

Thank you for your time!!

APPENDIX C

Appendix C

Unit Outline and Objectives 1993-94
Bacteria: Friend or Foe?

Week 1	**An Introduction to Bacteria**
Day 1	Pre-Unit Survey and Pretest Introduction to Bacteria Group Question Sheet
Day 2	Demonstrate aseptic technique, discuss its importance Demonstrate innoculation of agar plate Brainstorm areas for sampling bacteria Lab: Bacteria Cultures From the W.V.H.S. Environment
Day 3	Observe cultures from Day 2 Go over Intro to Bacteria Group Sheet Lecture - Introduction to Bacteria
Day 4	Observe cultures from Day 2; disposal of plates Complete Wrap-up Questions from lab with partner Notes - Bacteria (and Antibiotics), Part I
Day 5	Observation of gram stained slides with Scopecam or images from laserdisc Assign bacterial disease reports Classification of Bacteria Worksheets
Week 2	**Foe: Bacteria, Disease and Antibiotics**
Day 6	Who's Got the Bug? Activity Notes - Chain of Infection
Day 7	Finish notes - (Bacteria and) Antibiotics, Part II Introduction of Antibiotic Resistance Antibiotic Resistance Activity Review bacterial disease assignment
Day 8	Library Time - Research bacterial diseases
Day 9	Continue discussion- Interesting Facts About Antibiotics Give Extra Credit Assignment - Interview Antibiotics and Society Show short Video - "Superbugs"
Day 10	Video: Is Your Food Safe?

Unit Outline (continued)
Bacteria: Friend or Foe?

Week 3 Foe: Bacteria, Disease, and Antibiotics

Day 11	Notes - Foodborne Illness Prelab - How Can the Growth of Bacteria Be Controlled?
Day 12	Lab - How Can the Growth of Bacteria Be Controlled? Article Questions - The End of Antibiotics?
Day 13	Check cultures from Day 11 Give Disease Reports
Day 14	Check cultures from Day 11 Continue Disease Reports
Day 15	Wrap up Lab - Controlling the Growth of Bacteria Slide Presentation on Clinical Microbiology

Week 4 Friend: Bacteria in Our Food and Our Bodies

Day 16	Notes - Beneficial Aspects of Bacteria Products from the Microbial World Assignent - format for report and poster Review for Quiz
Day 17	Quiz - Bacteria Prelab - Testing for Bacteria in Foods
Day 18	Lab - Testing for Bacteria in Foods Lab Wrap-up
Day 19	Library Research - Products from the Microbial World
Day 20	Lab - Popbottle Landfill

Unit Outline (continued)
Bacteria: Friend or Foe?

Week 5 Friend: Composting, Bioremediation and Technology

Day 21	Check Popbottle Landfill Microbial Products Reports
Day 22	Check Popbottle Landfill Complete Microbial Products Reports
Day 23	Lecture - Microbial Technology Prelab - Bioremediation with Oil-Degrading Bacteria
Day 24	Lab - Bioremediation with Oil-Degrading Bacteria Lab - Examination of Termite Gut Tract
Day 25	Post-Test

Week 6 Wrap-up

Day 26	Post-Unit Survey Check cultures from Day 24 Discussion of Unit

Objectives
Bacteria: Friend or Foe?

At the end of this unit, students will:

1. Identify bacteria as the earth's oldest living organisms.
2. Prepare and observe bacterial cultures using aseptic techniques.
3. Diagram and identify the structures of a bacterium.
4. Diagram and identify the 3 basic shapes of bacteria.
5. Be able to distinguish between gram positive and gram negative bacteria and discuss the important differences between the two.
6. Identify where bacteria can be found and describe conditions which are optimal for bacterial growth.
7. Discuss the historical and cultural changes resulting from the use of antibiotics.
8. Describe the mechanisms by which antibiotics control bacterial growth and reproduction.
9. Describe techniques for commercial production of antibiotics.
10. Describe techniques and/or agents which slow or stop the growth of bacteria (in addition to antibiotics).
11. Interpret the effects of antibiotics, disinfectants, and antiseptics on bacterial cultures.
12. Give examples of antibiotic resistance, factors which lead to its development, and the resultant effect on bacterial populations.
13. List and describe several diseases caused by bacteria.
14. Describe the spread of bacterial diseases and what can be done to prevent transmission of these diseases.
15. Model how communicable diseases are spread through a population.
16. Discuss the role of bacteria in foodborne illnesses and techniques to prevent the spread of these diseases.
17. Discuss importance of bacteria in the gut tracts of animals.
18. Describe the role of bacteria in the decomposition of organic wastes in a landfill and in nature.
19. Define and give examples of bioremediation.
20. List common food items that are bacterial products and how they are produced.
21. Define and use the following terms:

bacteria	gram positive	obligate aerobes
colony	gram negative	obligate anaerobes
pathogen	disease	facultative
coccus	resistance	anaerobes
bacillus	communicable	bioremediation
spirillum	virulence	vaccination
antibiotic	sterilization	aseptic technique
toxin	disinfectant	bactericidal
		bacteristatic

APPENDIX D

Appendix D

Laboratory Exercises

Bacterial Cultures from the W.V.H. S. Environment

Objective:	Students will collect samples from the local environment, grow bacterial cultures on a nutrient agar and make observations of these cultures.	
Materials:	Pre-poured nutrient agar in petri dish	Grease pencil
	Wire loop or sterile swab	Bunsen burner
Safety:	Be sure to follow all microbiology lab safety precautions while observing your cultures!!	

Procedure:

1. With your teacher, brainstorm collection sites for bacteria. These can be in the classroom, or if your teacher permits, outside the classroom as well. Assign a student to collect each sample.

2. Obtain a petri dish with agar. DO NOT OPEN YOUR PLATE UNTIL YOU ARE READY TO SMEAR YOUR SAMPLE ONTO THE AGAR!! Use the marker to draw a line on the bottom of the plate (agar side) splitting the plate into twos or threes as directed by your teacher. Label the plate with your initials, the period, the date, and the sampling site.

3. To sterilize the wire loop, hold it in the hottest part of the Bunsen burner flame until it glows red, then allow it to cool (about 30 seconds). If you are using a sterile swab, remove it from the package. Do not let the loop or swab touch anything except your sample and do not breathe on them!

4. Obtain your sample by directly wiping the loop or swab onto the collecting site. Once you have done this, be sure not to breathe on or touch the loop / swab to any other surface.

5. Once you have collected your sample, streak your portion of the plate with the wire loop / swab, opening the plate from the side as your teacher demonstrates and immediately closing it. Place the plate upside down to prevent condensation in the incubator. Double check that it is correctly labeled.

6. You will make observations of your cultures after 24 and/or 48 hours. You will need to measure the size of your colony and note this in your data table along with other observations as color and shape. YOU MUST OBSERVE ALL SAFETY PRECAUTIONS WHILE MAKING OBSERVATIONS!!

7. If directed by your teacher, make observations of your classmate's cultures. Again, you must observe the proper safety precautions.

8. When done with the experiment, dispose of your plate as the teacher directs.

Bacterial Culture Observation Record

Date Cultures Started: ___________

Collecting Site	Incubation Time	Number of Colonies	Color of Colonies	Size (mm) of Colonies	Other Remarks

Bacteria of the WV Laboratory
Lab Wrap-up Questions

1. What areas did the class decide had a great deal of bacteria?

   Why do you suppose this is?

2. Another class tested the drinking fountain. They found the fountain was high in bacterial growth, but the water proved negative for bacterial growth (no bacteria grew when the water was tested). Why do you suppose the bacterial growth was high in the drinking fountain?

3. Would carpeting show more or less bacterial growth than a bare floor? Why?

4. What can be done to keep a house or apartment free of high bacterial growth. Explain fully at least 5 ways.

5. Why is an incubator used to grow bacteria?

6. How could this experiment be improved to give more accurate results?

Disease Detectives: Who's Got the Bug?

Materials: Small test tube with liquid
Small straw

Directions:

1. Place the straw into your test tube and place your finger over the end of the straw, then transfer the contents of that straw (keep your finger over the end so the liquid will stay in!) to your partner's test tube. Have your partner transfer a strawful of their liquid into your test tube. Stir to mix thoroughly. In the first line of the table under "primary contact", write the name of your partner.

2. Find a different partner. Be sure to write their name under "secondary contact." Exchange strawfuls of the liquid in your test tubes using the same technique as in step 1; mix thoroughly with your straw.

3. Find a third and different partner. Be sure to write their name under "tertiary contact." Exchange strawfuls of the liquid in your test tubes using the same technique and mix thoroughly.

4. You will now be tested to see if you have been infected with the disease. Obtain a drop of phenol red or phenophthalein from your teacher. Indicate in the last column whether your test result was positive (+) or negative (-).

5. Copy your line down on the overhead transparency of class results, and copy the rest of the results onto your paper. Dispose of your materials as directed by your teacher.

Questions:

1. Which member(s) of the class originally had the disease?

____

____

2. How did you determine this? Describe the method an epidemiologist might use to trace an infectious disease.

____

____

____

____

3. How was this disease spread?

____

4. Name some other ways that diseases are spread.

____

____

5. How could you have avoided the spread of this class disease?

____

____

____

6. List some other ways you can avoid the spread of other diseases.

____

____

____

7. Suppose this disease had a very short incubation period. How would this affect the spread of the disease?

____

____

____

8. Suppose this disease had an extremely long incubation period, such as AIDS. How would this affect the spread of the disease?

____

____

____

Disease Detectives: Who's Got the Bug?
Class Results

Name	Primary Contact	Secondary Contact	Tertiary Contact	Test

Teacher's Notes
Disease Detectives: Who's Got the Bug?

Fill the number of test tubes you will need with tap water, about 2/3 full. To two or three of the test tubes, add a few drops of dilute NaOH. These will be the "diseased" test tube. Do not use too strong a solution or the students may smell the "disease"!

Phenol red or phenophthalein are both good indicators to use. One drop should do the trick. If phenolphthalein is used, a pink color is a positive result and clear is a negative result. If phenol red is used, a purple color is a positive reaction, and a yellow color is a negative reaction.

Make a transparency of the table for students to write their results on. You might wish them to design a flow chart to determine their answer.

Do not reuse the straws! Just throw them out. You will need a set of uncontaminated test tubes for your next class - Don't reuse!

Try to subtly mark the test tubes with the NaOH - it can be difficult to determine the exact number of carriers during some trials.

How Can the Growth of Bacteria Be Controlled?

Background: Chemical substances that either kill bacteria or inhibit bacterial growth are called antimicrobial agents. These chemicals are of three basic types: **antiseptics**, chemicals used to inhibit the growth of or kill bacteria on living tissue; **disinfectants**, chemicals used to inhibit the growth of or kill bacteria on non-living tissues; and **antibiotics**, chemical substances produced by living organisms that inhibit the growth of bacteria. In this lab, you will test the effectiveness of an antiseptic, a disinfectant, and an antibiotic in inhibiting the growth of either *E. coli* or *Micrococcus luteus*.

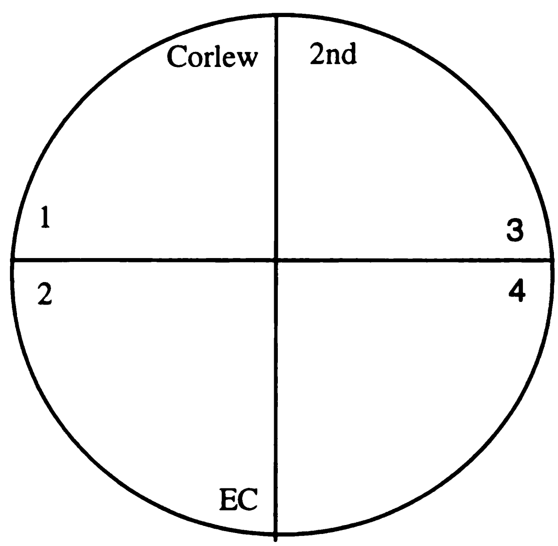
Before working in the microbiology lab, wipe down your lab area with 10% bleach solution. Allow it to air dry.

Procedure: Part A

1. Obtain a culture of either *E. coli* or *Micrococcus luteus* and a sterile nutrient agar plate.

2. Turn the agar plate over and lay it on the work bench. Using a marking pen, draw lines dividing the plate into quadrants as shown on Figure 1. Number the quadrants 1 through 4, placing the numbers near the edges of the dish. Also write your initials, and the letters EC or ML depending on whether you use *E. coli* or *Micrococcus luteus*.

Figure 1



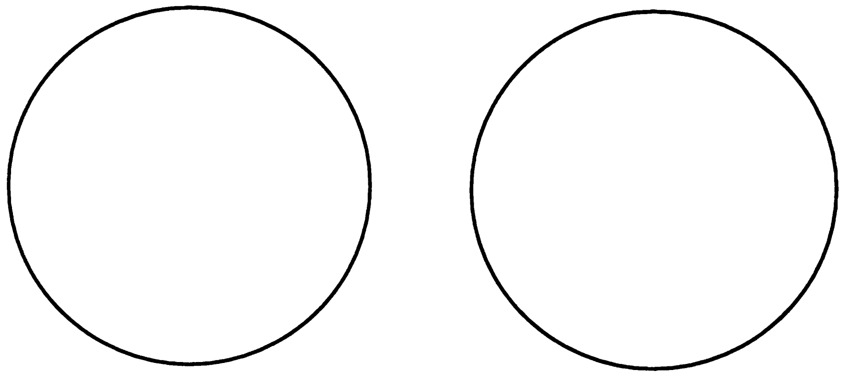
3. Obtain a sterile cotton swab by peeling the wrapper down just far enough to pull out one swab. Do not lay it down on the table or touch it to any object.

4. Light your Bunsen burner. Open the culture tube and flame the mouth of the tube as demonstrated by your teacher.

5. Put the cotton swab into the culture tube and take a small sample of the bacteria. Flame the mouth of the tube again and replace the cap on the tube.

6. Using one hand, open the lid of the petri dish and inoculate the plate by gently spreading the swab over the surface of the agar. Streak from the top to the bottom of the plate, then turn the plate 90° and streak from top to bottom again to provide maximum coverage (See Figure 2). **Be careful not to push the cotton swab down into the agar!**

Figure 2



7. Place the used cotton swab in the beakers of disinfectant at your lab station.

Part B:

1. Select an antiseptic and a disinfectant to test. You will also need two filter paper disks and some forceps. Your teacher will also assign you an antibiotic to test. Record your type of bacteria, antiseptic, disinfectant, and antibiotic on the data table before going on to the next step.

2. Pass your forceps through the flame of your Bunsen burner. Pick up a filter paper disk with the forceps and soak it in the antiseptic. Tape off any excess liquid.

3. Again using one hand, open the inoculated agar plate and position the paper disk in the center of quadrant 1. With the tip of the forceps, gently press the disk against the agar until it sticks.

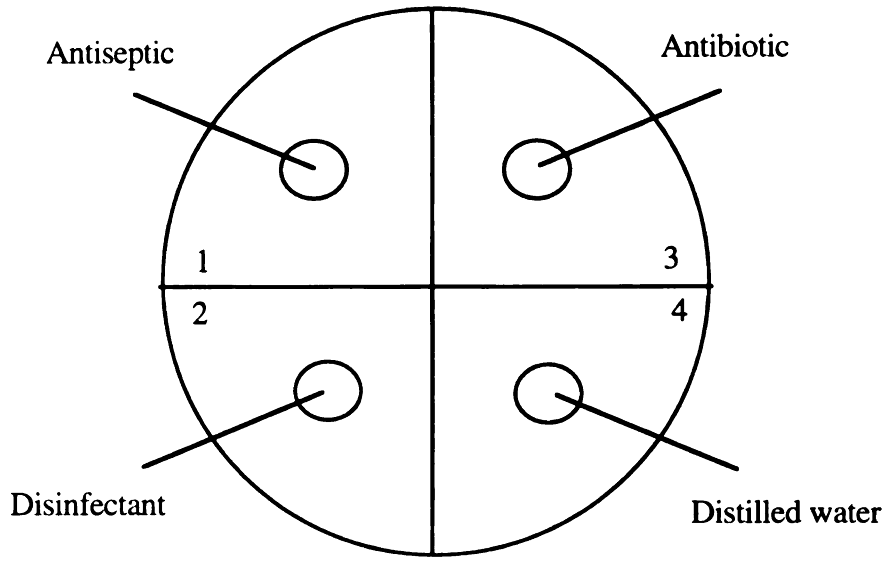
4. Re-flame the forceps. Repeat steps 2 and 3 with the disinfectant, placing the disk in quadrant 2 this time.

5. Re-flame the forceps again. Obtain the tube of antibiotic disks, and dispense a disk onto the surface of the agar in quadrant 3. Use the sterile forceps to gently press the disk onto the surface of the agar.

6. Re-flame the forceps again and repeat steps 2 and 3 with distilled water, placing the disk in quadrant 4.

7. Your plate should look like the plate in Figure 3. Tape the edges of your plate closed. Incubate the plate upside down in a 37° C incubator for 48 hours.

Figure 3



Part C:

1. Observe the plates after 48 hours of incubation. White or cloudy areas on the agar indicate bacterial growth. Notice any clear areas called **zones of inhibition** surround some of the filter paper disks. A clear area indicates that bacterial growth was inhibited. You may need to hold the plate to the light to see the zones more clearly.

2. With a millimeter ruler, measure the size of the clear zone surrounding each disk. Record your measurements in the data table. If no clear zone of inhibition is present, record the measurement as 0.

3. Report your results on the class data table, then trade plates with a group that used a different bacterial culture than you did. Observe their results. Are they the same as yours?

	Name of Substance	**Measurement of Zone of Inhibition**
Bacteria tested		
Antiseptic tested		
Disinfectant tested		
Antibiotic tested		
Distilled water		

Controlling the Growth of Bacteria
Class Data Table

Substance Tested	*Micrococcus luteus*	*E. coli*
Water		
Antiseptic #1		
Antiseptic #2		
Antiseptic #3		
Disinfectant #1		
Disinfectant #2		
Disinfectant #3		
Antibiotic #1		
Antibiotic #2		
Antibiotic #3		
Antibiotic #4		

1. Which antiseptic was most effective in inhibiting the growth of bacteria?

2. Which disinfectant was most effective in inhibiting the growth of bacteria?

3. Which antibiotic was most effective in inhibiting the growth of the bacteria?

4. Were all the antibiotics effective for both types of bacteria? Suggest a reason for your results.

5. Write a conclusion for this experiment.

How Can You Test For Bacteria in Foods?

Bacteria are living things too small to be seen without a microscope. Bacteria are said to be microscopic. Often a test can be done to show the presence of microscopic living things. The test can be done with a chemical indicator.

As its name says, a chemical indicator is a chemical that "indicates" something. One type of chemical indicator will tell you if carbon dioxide is present. The chemical turns from blue to yellow or green if carbon dioxide is present.

Respiration in bacteria and other living things produces carbon dioxide. Thus, this chemical can tell if bacteria or other living things are present in a sample being treated. Bacteria are used to make many dairy products. The samples you will be testing in this exercise are different dairy products.

Materials

6 test tubes
6 cork stoppers
test tube rack
wax pencil
2 droppers
3 wooden splints
bromthymol blue solution
dairy products - milk, buttermilk, yogurt, cottage cheese, sour cream

Procedure

1. Label 6 test tubes 1 through 6
2. Fill each test tube with the bromthymol blue solution
3. Use a clean dropper to add one drop of the following to each tube. Do not let the dairy products go down the slides of the test tubes. Figure 1 shows you how.

Tube 1	nothing
Tube 2	cottage cheese
Tube 3	buttermilk

4. Using a wooden splint, add an amount about the size of a green pea of the following to each tube.

Tube 4	plain yogurt
Tube 5	cottage cheese
Tube 6	sour cream

5. Stopper each tube with a cork. Record in Table 1 the color of the tube contents. Leave the tubes undisturbed. Do not shake.

6. Observe and record the color of tube contents at the bottom of each tube, both at the end of the class period and the next day.

Data

Tube	Contents	Color at Start	Color at end of class	Color 1 day later	Carbon dioxide present?	Bacteria present?
1						
2						
3						
4						
5						
6						

Questions

1. Was there a color change in the contents of Tube 1 one day later? ________

   What was the purpose of Tube 1? ______________________________

   What name is given to this part of the experiment? ____________________

2. In which tubes was a color change detected one day later? ______________

   Which foods were added to these tubes? __________________________

   Do these foods contain bacteria? ________________

   What is your proof? ______________________________________

   ____

3. What is the variable in this experiment?

   ____

4. Why are bacteria important to the dairy industry?

   ____

   ____

5. Are bacteria in dairy products helpful or harmful?

   ____

   ____

Popbottle Landfill

Introduction

Solid waste disposal is reaching crisis proportions in many communities. Our throw away mentality, as well as our increased use of nonbiodegradeable plastics and other synthetics, has substantially increased our solid waste output. It has been estimated that **the average American produces four to six pounds of garbage per day**. This volume, coupled with the increasing toxicity of the garbage, makes landfilling more technically challenging than ever before.

Siting of landfills has become a volatile issue and the acronym NIMBY (Not In My Backyard) reflects the feelings of most U.S. citizens. Public concern is focused on aesthetics, odors, groundwater contamination and the spread of diseases. New methods of disposal are needed to address our current and future waste streams which are composed of biodegradable and nonbiodegradable materials. Biodegradable materials can be broken down into simpler substances by bacteria and other decomposers. A simple compost pile which harnesses the power of bacteria to "recycle" in the backyard would eliminate much of the waste that often ends up in landfills. In modern landfills the decomposition process can take decades because of the lack of oxygen, sunlight, and other factors which often speed up the process of decomposition. Nonbiodegradable materials are not broken down by biological organisms and include plastics, aluminum, and many chemicals used in industry and agriculture.

Scientists and citizens must address the effects on the environment, as well as the economic impact of handling our wastes. In the investigation, students will study the results of bacterial decomposition, as well as some of the characteristics of their waste stream and the problems associated with its disposal. A simulated landfill will be constructed using garden soil and containing discarded food samples and discarded packaging samples at room temperature.

Materials

2-liter pop bottle
garden soil
scissors
tweezers or forceps
water
permanent marker
distilled water
metric ruler
newspaper
discarded food samples - vegetables or fruits, etc., but ABSOLUTELY NO MEAT!!!
discarded packaging samples - paper, plastic, aluminum foil, etc.

CAUTIONS

1. Hands should be washed before and after this lab with soap and water.

2. ABSOLUTELY NO FOOD OR DRINK IN THE LAB AT ANY TIME DURING THE COURSE OF THIS LAB!

3. Lab area should be wiped with a 10% bleach solution before and after setting up the lab and before and after examining the contents of the landfill.

4. Use a wafting technique for detecting odors.

5. Lab area should be uncluttered with NO books, pens, etc.

6. Special care should be used when cutting the pop bottles. Plastic, as well as scissors, can cause cuts.

7. At the completion of the lab, dispose of all materials as directed by your teacher.

Procedure

1. Obtain a 2-L plastic pop bottle and remove the label, leaving only a clear bottle. Use the marker to label the bottle with your name, class period, and date.

2. Using scissors, cut the discarded food samples into small pieces, approximately 3 square centimeters in size, keeping all samples uniform in size. Repeat this procedure for the pieces of discarded packaging.

3. With the scissors, cut each pop bottle in half. Using a trowel, fill the base of the bottle with approximately 6 cm of garden soil.

4. Record the size, color, texture, odor, and any other important characteristic features of each sample in your data table. Include a prediction as to how each sample will look after three days.

5. Using a pair of tweezers of forceps, place an assortment of food and packaging samples on the soil in the bottle. Cover the samples completely with approximately 3 cm of garden soil.

6. Add enough water to the soil to moisten it. Contents should not be soggy but should feel like a damp sponge.

8. Place the top half of the bottle over the bottom half. Patience and repeated attempts are needed at this point, making sure that the top half is pushed down far enough for a tight fit.

9. After 2-3 days, examine the bottle by carefully removing the top layer of soil into a shallow pan or some newspaper, then remove food and packaging material with forceps or tweezers. Measurements can be taken but be very careful not to touch the specimens!

10. Replace the samples and the soil in the bottle and reseal. Observe the bottles after a week but DO NOT REOPEN THE BOTTLE. Observations can be made by rotating the bottle on its side and viewing through the plastic. Record your observations in the data table.

11. Follow your teacher's instructions for proper disposal of all materials.

Popbottle Landfill Data Table

Sample	Initial characteristics (size, color, texture, odor, etc.)	After 3 days (size, color, texture, odor, etc.)	After 1 week (size, color, texture, odor, etc.)

Questions

1. Rank the samples in order of fastest to slowest rates of degradation. Give an explanation for the different rates of decomposition.

   Fastest ____________________

   ____

   ____

   ____

   ____

   ____

   Slowest ____________________

2. Based on your data, classify each sample in this lab as biodegradable or nonbiodegradable.

   Biodegradable ____________________

   Nonbiodegradable ____________________

3. What causes the decomposition (degradation) the samples? Why?

   ____

   ____

4. Why does condensation collect on the inside of the bottle?

   ____

   ____

5. Can any of your samples that did not degrade be recycled in the community? How?

   ____

   ____

6. How can your reduce the amount of garbage going into the landfill in your community?

   ____

   ____

APPENDIX E

Appendix E

Research Projects

Bacterial Disease Research Project

You and your partner will be assigned a disease caused by a bacterium. You are to research that disease and produce a report which you will give to the class. In this report, you must describe the symptoms of the disease and who is at risk for contracting the disease, the bacterium responsible for the disease and where it is likely to be found, and how to prevent the spread of this disease. You may also want to tell a little of the history of the disease, who is responsible for finding a cure, or anything else interesting you find in your research. You will be required to present to the class the information you have found; since your classmates will be taking notes it is probably best to make an overhead transparency outlining your presentation. Transparencies and markers are available in the library. In addition, you may wish to make a small poster to hang in the classroom for a few points extra credit. We will have one class period in the library, 4/15, to work on this project; you will need to spend additional time on your report. Your reports will be given on Wednesday, April 20 in class. If your partner is absent, you will still be required to give your report (whether or not your materials are present); if both partners are absent you will be expected to give your report first thing on Thursday April 21. In addition to the 40 points this assignment is worth, you will grade your own partner. Good luck!!

My bacterial disease is: ______________________________

Bacterial Diseases

Pneumonia
Scarlet Fever
Meningitis (bacterial form)
Legionnaire's Disease
Rocky Mountain Spotted Fever
and Lyme's Disease
Syphilis and Gonorrhea
Salmonella and Botulism
Impetigo, Boils, and Pimples
Tonsillitis and Strep Throat
Ear Infections and Rheumatic Fever
Toxic Shock Syndrome
Diphtheria and Pertussis
Leprosy
Tuberculosis
Bubonic, Pneumonic, and
Septicemic Plagues

Bacterial Disease Reports - Organizer

Disease	Who's Affected?	Symptoms	Bacterium Responsible	Where found and how spread	How can it be prevented?	Misc.

Bacteria - Man's Friend
Microbial Technology Assignment

Your group will be assigned several foods whose manufacture involves the use of bacteria, or other processes which benefit from the use of bacteria. The use of bacteria or other microbes to produce a marketable product is called **microbial technology**. You are to research those processes assigned to your group, fill in the accompanying table, and report to the class what you found about your products. Your classmates will fill in their tables from your information.

I want this to be a brief assignment; you should give your report in no more than 5 minutes. You can see this project doesn't require a lot of in-depth research; simple reports will be the best. Your group is responsible for finding the answers for your products - the class is counting on you! You will have Tuesday in the LMC to find your information and determine who will talk. You'll have Wednesday to make your reports; there will not be any other time and you need this information for your test on Friday. Of course, your group is responsible for reporting on Wednesday no matter who is there.

You will need to turn in a fact sheet as before, listing the information you found and the sources you use. You should have **at least two sources which are not general reference encyclopedias.** Don't forget to check the computers and the magazines for current information. If anyone wishes to make a poster illustrating a particular product of microbial technology to hang in the room for some extra credit, see me before or after school.

__Group 1__

Blue cheese
Swiss cheese
Coffee beans
Insecticide - B.t.
(*Bacillus thuringensis*)

__Group 2__

Sourdough bread
Sausages
Yogurt
Insulin

__Group 3__

Olives
Pickles
Peas
Sauerkraut
Detergent

__Group 4__

Sour cream
Soy sauce
Vinegar
Man-made snow

__Group 5__

Cheddar cheese
Cottage cheese
Nitrogen fixation
(*Rhizobium sp.* - essential part of the nitrogen cycle)

HINT: The August 1993 __National Geographic__ has a HUGE article on beneficial bacteria!!

Microbial Technology Reports

Product	What it's made from	How bacteria are involved in its production	Miscellaneous Information

APPENDIX F

Appendix F

Classroom Notes

Introduction to Bacteria

Working together in groups of two or three, answer the following questions based on what you know about bacteria.

1. Where in the environment are you likely to find bacteria. List at least 5 spots.

   a. ____________________ c. ____________________

   b. ____________________ d. ____________________

   e. ____________________

2. How many bacteria are found on a square centimeter of skin? ___________

3. What type of conditions do most bacteria prefer?

   ____

4. How many bacteria are in your digestive tract?

   ____

5. How many bacteria are passed in a typical bowel movement?

   ____

6. What are some ways we can prevent the growth of bacteria?

   ____

   ____

7. Are we born with bacteria?

   ____

8. List 5 diseases you think are caused by bacteria.

   a. ____________________ c. ____________________

   b. ____________________ d. ____________________

   e. ____________________

9. Can people die from a bacterial infection?

   ____

10. Have you ever taken an antibiotic? What are they used for? ____________

____

11. How many antibiotics are sold in a year?

____

____

12. What benefits do we get from bacteria?

____

____

13. Are there any places where it is important to have bacteria?

____

____

14. Are there any products in our society today that are made with bacteria?

____

____

15. Are bacteria bad or good?

____

____

____

Bacteria and Antibiotics Notes

A typical bacterium (plural = bacteria) has the following cell parts:

_______________________ (not always present)

____

____

____

____

Remember: Bacteria are _______________________ (have no ________________)

Often grow in ___________________________, groups of similar cells attached to one another

Bacteria are classified two ways:

1. Basic shape

a. ___________________ (singular = ___________________)
spherical shape, sometimes singular, sometimes pairs or clusters

ex: streptococcus (causes strep throat)

b. ___________________ (singular = ___________________)
rod-like, sometimes singular but often grow in chains

ex: E. coli (found in your intestinal tract; most studied bacterium)

c. ___________________ (singular = ___________________) and
spirochetes
spiral or corkscrew shaped, grow as single cells, usually very small

ex: bacteria that causes syphilis

2. **Gram stain** - laboratory technique for staining bacteria to make them easier to see and for identification purposes

a. ____________ ________________________

stain absorbed by _______ __________, appear __________
cell wall is thicker; usually more sensitive to antibiotics

b. ____________ ________________________

stain not absorbed, appear ______________
thinner cell wall; often if cell wall lyses (cell membrane ruptures), bacteria will release toxins (poisons) into host

Antibiotics

anti = ________________________ biota = ________________________

- over __________ known antibiotics, but < ___% have medicinal values
- _______ antibiotics used commercially
- most important groups are the penicillins, cephalosporins, and cephamycins (antibiotics with the same endings are related, ex: -cillin, -cycline)
- most widely manufactured microbial products; over 100,000 tons produced yearly, gross sales > $5 billion dollars

How do antibiotics stop bacterial infections?

Either kill the bacteria (______________________________) or inhibit their growth (____________________________)

Antibiotics use 4 different mechanisms to stop bacterial infections:

1. **Inhibit synthesis of cell wall** (________________________)
cell wall weakens, eventually lyses; not good for _______ ______________ bacteria

ex: bacitracin, penicillin G, ampicillin, cephalosporin

2. **Inhibit cell membrane function** (____________________________)
changes permeability of cell membrane; cell becomes "leaky"

3. **Inhibit synthesis of protein** (______________________________)
attaches to bacteria's ________________________

ex: erythromycin,tetracycline, streptomycin

4. **Inhibit nucleic acid synthesis**
(________________________ or ________________________)
some inhibit RNA synthesis, others incorporate into ________ causing it to become defective so that the bacterium is unable to reproduce

example: rifampin

There are some antibiotics whose mode of action is not known

Interesting Facts About Antibiotics

Effect of Antibiotics on Society

Before antibiotics, it was possible to die from a scratch from a rosebush, or a prick of your finger that became infected.

In the 1930's, microbial disease was the primary disease in over half the patients in a hospital.

In 1937 the mortality rate of women in childbirth was 48.9 deaths per 10,000 live births. In 1957, after antibiotics, the mortality rate was down to 4.1 deaths per 10,000 live births.

During World War I, 15 percent of the battle casualties died from infected wounds. Once penicillin was abundant during World War II (from D-Day forward) virtually no casualties died of infection.

Ten years after antibiotics were widely available, the death rate from 8 diseases influenced by antibiotics was reduced by 50%, saving 80,000 lives.

Within a span of 20 years, life expectancy in the U.S. was extended 10 years as a direct result of the introduciton of antibiotics. If all deaths due to cancer were eliminated, only result a 2 year extension of life expectancy would result.

After the introduction of antibiotics, the following medical procedures became possible:

new and more complex surgical techniques
cardiac surgery
organ transplants
management of severe burns

The use of antibiotics has greatly increased the total number of elderly in our society, and reduced the child mortality rate.

Pharmaceutical companies became huge conglomerations with research and development programs that can lead to new, significant, and highly profitable items of biomedical technology.

Most new pharmaceuticals, including antibiotics, take at least 7 years to make it to the marketplace where they can be used by the population.

Effects on Physicians

"One day we could not save lives, or hardly any lives; on the very next day we could do so across a wide spectrum of diseases. This was an awesome aquisition of power..." John McDermott (see Bibliography)

Before antibiotics, doctors would stay up all night with a sick patient, and often saw little success.

After antibiotics, they had a drug that could perform "miracles." Could this have led them to detach themselves from other and think of themselves as miracle workers?

With a vast plethora of antibiotics that could be used by anybody suddenly available, patients began demanding and questioning the prescription of different antibiotics.

Early Work with Antibiotics and Miscellaneous Facts

Those working with bacteria were at risk of contracting a disease from pathogens. One case of this was Ronald Hare, who in 1936 pricked his finger with a sliver of glass infected with streptococci bacteria. His life was saved by an experimental sulfur drug, Prontosil, he was given by his colleague Leonard Colebrook. Prontosil is a dye, and Hare turned bright pink when first given the drug. Colebrook also saved the life of one of his technicians, W. R. Maxted, who was suffering from severe tonsillitis contracted from his work with strepticocci.

The first man to be treated with purified penicillin was Albert Alexander, a 43-year old policeman, on Feb. 12, 1941.

-he had an infection that was the result of being scratched by a rosebush in December
-the infection spread to his face, eyes, scalp, and eventually his lungs
-his eye was removed on Feb. 3rd
-given penicillin on Feb. 12, next day his temperature was normal and he sat up in bed and ate his meals
-extracted penicillin from his urine and re-injected it
-ran out of penicillin and he died on March 15

Penicillin resistant strains were first observed in 1942 - before widespread use.

The first known death attributed to penicillin was in 1947 - the woman died in minutes.

Antibiotics are used to fight some forms of cancer; actinomycins are used to inhibit a variety of tumors and fight Hodgkin's disease, some are used to treat leukemia.

Antibiotics are vital in the treatment of diseases contracted by AIDS patients .

Purification and Production

In 1941 there wasn't enough penicillin in the U.S. to treat a single case.
In 1942, there was barely enough penicillin to treat 100 cases.
In 1943, the penicillin needs of our Armed Forces, and those of our allies were all met.
By 1944, penicillin supplies were "unlimited" - a second miracle in the antibiotic story.
50 years after Fleming's paper on penicillin appeared, there were 5 grams of penicillin for every person on the planet .

Ethel Florey, wife of the Nobel Prize winner Dr. Howard Florey, used to go around on her bike to collect the urine of patients treated with penicillin, then would take this urine back to Oxford where the penicillin was extracted from the urine.

All the penicillin manufactured went to the Armed Forces until about 1945. During World War II, the Army paid from a high of $20 per 100,000 units to less than 2 cents / 100,000 units - the cost of the packaging was greater than the cost of the drug.

Purification of penicillin was ongoing at Oxford in England during 1940 - 41, while Germany was bombing London. Because of this, large scale production was sought in the United States.

The first mass production of penicillin was pioneered in Peoria, Illinois at the Northern Regional Research Lab of the USDA.

Mass production of penicillin was given top priority by the United States government (commandeering supplies, equipment) - 2nd only to the Manhattan Project (atomic bomb).

A Peoria woman - "Moldy Mary" Hunt - brought in a moldy canteloupe which turned out to have a more productive strain of Penicillium chrysogenum.

In order to speed up mass production of penicillin, a higher yielding strain was needed. Mutation was accelerated by use of X-rays and UV (ultaviolet) light.

Penicillin and World War II

The development of penicillin played a major role in the Allied victory in World War II:
- -Axis powers had access only to sulfur drugs throughout the war
- -On the Black Market Germans would obtain large amounts of urine from patients treated with penicillin, and then try to extract any penicillin

Mass production of penicillin was given top priority by the United States government (commandeering supplies, equipment) - 2nd only to the Manhattan Project (atomic bomb).

Purification of penicillin was ongoing at Oxford in England during 1940 - 41, while Germany was bombing London. Because of this, large scale production was sought in the United States.

Although civilians heard about the wonders of penicillin, they were unable to obtain it until 1945 - all the penicillin manufactured was sent to the Armed Forces.

There was a great fear that the Germans would invade England. If this happened, Drs. Florey and Chain and their colleagues, working on the purification and clinical trials of penicillin, would have to destroy their notes on production, cultures, and any product in the lab. Just in case this happened, Florey and his colleagues smeared the linings of their coats with spores of the Penicillium fungus.

Effect of Antibiotics on Tuberculosis

Tuberculosis (TB) was the leading cause of death in the United States in 1937. It was also the greatest cause of death and disability in people aged 15 to 45, and common in ambitious young people working two jobs or going to school and working.

A common name for TB was "consumption"

Diagnosis with TB meant:
- giving up your job, your schooling, your home, and your family
- going to live in a TB Sanitarium, possibly hundreds of miles away
- being confined to bed
- living as an invalid, never regaining your former strength

TB is still a major problem in Third World countries; 50 - 100 million people are infected, 3 million die every year. 80% of these people liver where antibiotics are too expensive to use.

Waksman was awarded the Nobel Prize for the discovery of streptomycin, the first antibiotic effective against TB, in 1952.

APPENDIX G

Appendix G

Antibiotics and Society Interview
Extra Credit

Interview a person who remembers what life was like before the use of antibiotics became commonplace. This means they should be at least 65 years old. This interview should be completed by April 30.

Interviewer: ______________________________

Person Interviewed: ______________________________

Date of Birth: ____________

How do you know this person? ______________________________

Date of interview: ____________

1. What do you know about antibiotics?

2. What was medical treatment like before antibiotics were used (before WWII)?

3. What were hospitals like before WWII?

4. ____
(Write your own question about antibiotics)

5. Is there anything else you'd like to tell me? A personal anecdote about the family or friends?

Signature of Interviewee: ______________________________

Signature of Interviewer: ______________________________

To complete the assignment:

On a separate piece of paper, write two paragraphs telling what you learned while doing this assignment. It doesn't have to be about antibiotics!

APPENDIX H

Appendix H

Bacterial Disease and Microbial Technology Research Project 1994-95

You and your partner will be assigned both a disease caused by a bacterium and a product that is made by or with the help of bacteria (**microbial technology**). You are to research both the disease and the product, and produce a report which you will give to the class. Your classmates will fill in their tables from your information - you'll be the teacher! Your report should be about 5 minutes in length - no more. You will need to turn in a fact sheet which lists the information you found and the sources you used. You should have **at least two sources which are not general reference encyclopedias.** Don't forget to check the computers and the magazines for current information!

Your report must meet the following criteria. For the disease, you must describe the symptoms of the disease, who is at risk for contracting the disease, the bacterium responsible for the disease and where it is likely to be found, and how to prevent the spread of this disease. You may also want to tell a little of the history of the disease, who is responsible for finding a cure, or anything else interesting you find in your research. For the product, you must discuss how it is made, how bacteria are involved in its production, and any miscellaneous information you can find.

You will be required to present to the class the information you have found; since your classmates will be taking notes it is probably best to make an overhead transparency outlining your presentation. Transparencies and markers are available in the library ($0.10 per sheet). In addition, you may wish to make a small poster to hang in the classroom for a few extra credit points. We will have two class period in the library, _____ and ____, to work on this project; you will need to spend additional time on your report.

Your reports will be given on __________________________ in class. If your partner is absent, you will still be required to give your report (whether or not your materials are present); if both partners are absent you will be expected to give your report at the beginning of the next class period. This assignment is worth 50 points; you will have a chance to grade your own partner. Good luck!!

My bacterial disease is: ____

My bacterial product is: ____

My partner is: _______________________________________

Phone # ____________

Microbial Products

Blue cheese
Swiss cheese
Coffee beans
Insecticide - B.t.
(Bacillus thuringiageinsis)
Sour cream
Pickles
Peas
Sauerkraut
Detergent
Cheddar cheese
Nitrogen fixation
(Rhizobium - essential part of the nitrogen cycle)

Sourdough bread
Sausages
Yogurt
Insulin

Olives
Soy sauce
Vinegar
Man-made snow
Cottage cheese

HINT: The August 1993 National Geographic has a HUGE article on beneficial bacteria!!

Bacterial Diseases

Pneumonia
Scarlet Fever
Meningitis (bacterial form)
Legionnaire's Disease
Rocky Mountain Spotted Fever
and Lyme's Disease
Syphilis and Gonorrhea
Salmonella and Botulism
Impetigo, Boils, and Pimples

Tonsillitis and Strep Throat
Ear Infections and Rheumatic Fever
Toxic Shock Syndrome
Diphtheria and Pertussis
Leprosy
Tuberculosis
Bubonic, Pneumonic, and
Septicemic Plagues

APPENDIX I

Appendix I

Bacteria Quiz

1. Sketch a typical bacterial cell and label its parts. Be sure to include the cell wall, the flagella, the cell membrane, the DNA, the cytoplasm, and the capsule.

2. What is a microorganism?

____

____

3. What three roles do bacteria play in the environment?

   a. ______________________________

   b. ______________________________

   c. ______________________________

4. Name and sketch the three basic bacterial shapes:

   a. ____________________ sketch:

   b. ____________________ sketch:

   c. ____________________ sketch:

5. For the following statements, decide whether it describes a bacterium that is

   a. gram positive b. gram negative

   ______ organism stains a purple color

   ______ organism stains a pink color

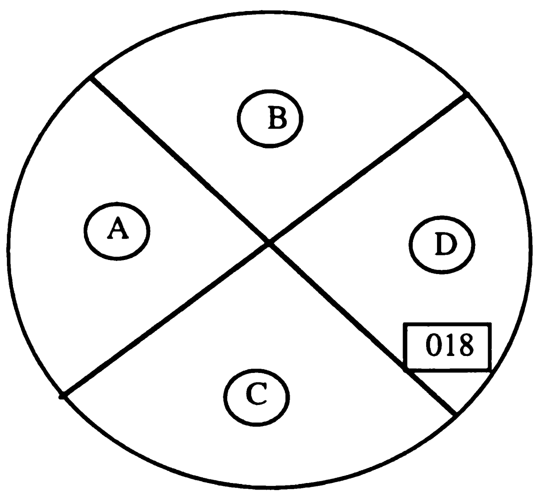
   ______ thin cell wall

   ______ thick cell wall

MATCHING: Some choices will not be used

_______	6.	an antimicrobial agent applied to living tissue	a.	Monera
_______	7.	organism capable of causing disease	b.	eukaryote
______	8.	organism with no membrane-bound organelles or nucleus	c.	Animalia
_______	9.	kingdom in which bacteria are placed	d.	disinfectant
______	10.	an antimicrobial agent that is applied to non-living surfaces	e.	pathogen
			f.	antiseptic
			g.	prokaryote

Use the following diagram and information to answer the questions below.



Culture Record #018
Patient: G. Elmen
Physician: M. Corlew
Date: 3/25/94
Throat Culture

A patient comes to Dr. Corlew with a throat infection, which Dr. Corlew samples with a sterile swab. She spreads the bacteria on the agar in a petri dish and places four antibiotic discs, A through D, on the plate. After 24 hours, the plate appeared as above.

11. Which antibiotic do you recommend Dr. Corlew should prescribe for the patient? Why?

____

____

____

12. What is the area free of bacterial growth around the antibiotic called?

____

13. What two conditions did Dr. Corlew need to provide to grow the bacteria? In what device did she place the plate?

____

____

____

14. Suppose Dr. Corlew ran some other tests on the bacteria, such as gram staining, and was able to identify the bacteria causing the infection. She looks in the PDR to recommend an antibiotic, and she sees that Antibiotic C **should** have killed the bacteria. What can she conclude about the bacteria causing this infection?

____

____

15. Dr. Corlew has to be cautious when working with potentially pathogenic bacteria. What is the name of the group of safety precautions she follows?

________________ ________________________

16. List at least 3 safety precautions Dr. Corlew should take while culturing her patient. List more for extra credit!!

a. ____

b. ____

c. ____

Extra Credit:

APPENDIX J

Appendix J

Bacteria and Virus Unit Outline 1995

Day 1	Demonstrate aseptic technique, discuss importance Demonstrate inoculation of agar plate Brainstorm areas for sampling bacteria Lab: Bacteria Cultures from the W.V.H.S. Environment
Day 2	Check cultures from Day 1 Introduction to Bacteria Group Question Sheet Notes - Bacteria and Antibiotics, Part I Homework: Classification of Bacteria Worksheets
Day 3	Check cultures from Day 1 Assign bacterial disease and bacterial products reports Finish notes
Day 4	Yogurt Lab - Observation of live cultures; comparison with prepared slides
Day 5	Library Research
Day 6	Video: "Is Your Food Safe?" (48 Hours)
Day 7	Notes - Bacteria and Antibiotics, Part II (focus on difference between bacteria and virus) Prelab - Controlling the Growth of Bacteria
Day 8	Lab: How Can the Growth of Bacteria Be Controlled? Discussion: Foodborne Illness
Day 9	Check plates Quiz - Classification, Structure / Function Complete Discussion: Foodborne Illness
Day 10	Activity: Who's Got the Bug? Notes - Chain of Infection
Day 11	Lab: Testing for Bacteria in Foods Lecture - Beneficial Aspects of Bacteria
Day 12	Video: "In the Danger Zone" (48 Hours)
Day 13	Lecture packet on viruses
Day 14	Student Reports
Day 15	Test over Bacteria and Virus Unit

BIBLIOGRAPHY

BIBLIOGRAPHY

Aharonowitc, Yair and Cohen, Gerald, "The Microbiological Production of Pharmaceuticals," Scientific American, Vol. 245 No.3 September 1981, pgs. 141-154.

Canby, Thomas Y., "Bacteria: Teaching Old Bugs New Tricks", National Geographic, August 1993 pgs. 36-60.

Center for Microbial Ecology, "Environmental Spectrum: Hands on the Environment" Laboratory Manual, Michigan State University, East Lansing, Michigan 1993.

Demain, Arnold L and Solomon, Nadine A, "Industrial Microbiology," Scientific American, Vol. 245 No.3 September 1981, pgs. 67-76.

Doran, Rodney L., Basic Measurement and Evaluation of Science Instruction, National Science Teachers Association, Washington , D.C., 1980.

Eveleigh, Douglas E., "The Microbiological Production of Industrial Chemicals", Scientific American, Vol. 245 No.3 September 1981, pgs. 155-178.

Kransi, Sandy, "Evaluation of a Stream Study Unit Used As An Introduction to High School Biology", Michigan State University, East Lansing, Michigan 1991.

Phaff, Herman J., "Industrial Microorganisms," Scientific American," Vol. 245 No.3 September 1981, pgs. 77-89.

Rose, Anthony H., "The Microbiological Production of Pharmaceuticals", Scientific American, Vol. 245 No.3 September 1981, pgs. 127-140.

Williams, Robert P. and Gillen, Alan L., "Microbe Phobia and Kitchen Microbiology," American Biology Teacher, Vol. 35 No. 1 January 1991, pgs. 10-11.

Zook, D., Microcosmos: A Curriculum Guide to Exploring Microbial Space, Kendall Hunt Publishing, Iowa, 1989.

GENERAL REFERENCES

Bottcher, Helmuth M. Wonder Drugs - A History of Antibiotics, J. B. Lipincott Company, Philadelphia and New York, 1964.

Brock, Thomas and Madigan, Michael, Biology of Microorganisms, Prentice Hall Publishing, Englewood Cliffs, New Jersey, 1991

Boyd, Robert F., General Microbiology, Times Mirror Mosby College Publishing, St. Louis, 1984.

Galdston, Iago M.D., ed., The Impact of Antibiotics on Medicine and Society, International Universities Press, 1958

Lancini, Giancarlo and Parenti, Francesco, Antibiotics - An Integrated View, Springer Verlag Publishers, New York, 1982.

Lappe, Marc Ph.D., Germs That Won't Die - Medical Consequences of the Misuse of Antibiotics, Anchor Press,Garden City, New York, 1982.

Maugino, Richard A., A Laboratory Manual for Microbiology, J. Weston Walch, Portland Maine, 1975.

McDermott, Walsh with Rogers, David E., "Social Ramifications of Control of Microbial Disease," Johns Hopkins Medical Journal, Vol. 151 No. 6, December 1982, pgs. 302-312.

Parascondola, John, A History of Antibiotics: A Symposium, American Institute of Pharmacy, Madison, Wisconsin, 1980.

Wainwright, Milton, Miracle Cure - The Story of Penicillin and the Golden Age of Antibiotics, Basil Blackwell, Ltd., 1990.

Welch, Henry Ph.D. and Marti-Ibanez, Felix, The Antibiotic Saga, Medical Encyclopedia Inc., New York, 1960.