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the science of MICROBES

Activity: Milestones in Microbiology

from *The Science of Microbes Teacher's Guide*

by Nancy P. Moreno, Ph.D., Barbara Z. Tharp, M.S., Deanne B. Erdmann, M.S., Sonia Rahmati Clayton, Ph.D., and James P. Denk, M.A.

RESOURCES

Free, online presentations of each activity, downloadable activities in PDF format, and annotated slide sets for classroom use are available at www.bioedonline.org/ or www.k8science.org/.

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ISBN-13: 978-1-888997-54-5
ISBN-10: 1-888997-54-0

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Development of The Science of Microbes educational materials is supported, in part, by a Science Education Partnership Award from the National Center for Research Resources (NCRR) of the National Institutes of Health (NIH), grant number 5R25 RR018605. The activities described in this book are intended for school-age children under direct supervision of adults. The authors, Baylor College of Medicine (BCM), the NCRR and NIH cannot be responsible for any accidents or injuries that may result from conduct of the activities, from not specifically following directions, or from ignoring cautions contained in the text. The opinions, findings and conclusions expressed in this publication are solely those of the authors and do not necessarily reflect the views of BCM, image contributors or the sponsoring agencies.

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ACKNOWLEDGMENTS

This guide was developed in partnership with the Baylor-UT Houston Center for AIDS Research, an NIH-funded program (AI036211). The authors gratefully acknowledge the support and guidance of Janet Butel, Ph.D., and Betty Slagle, Ph.D., Baylor-UT Houston Center for AIDS Research; and William A. Thomson, Ph.D., BCM Center for Educational Outreach. The authors also sincerely thank Marsha Matyas, Ph.D., and the American Physiological Society for their collaboration in the development and review of this guide; and L. Tony Beck, Ph.D., of NCRR, NIH, for his assistance and support. In addition, we express our appreciation to Amanda Hodgson, B.S., Victor Keasler, Ph.D., and Tadzia GrandPré, Ph.D., who provided content or editorial reviews; and J. Kyle Roberts, Ph.D., and Alana D. Newell, B.A., who guided field test activities and conducted data analyses. We also are grateful to the Houston-area teachers and students who piloted the activities in this guide.

We are endebted to many scientists and microscopists who contributed SEM and TEM images to the CDC’s Public Health Image Library, including Janice H. Carr, James D. Gathany, Cynthia S. Goldsmith, M.S., and Elizabeth H. White, M.S. We especially thank Louisa Howard and Charles P. Daghlian, Ph.D., Electron Microscope Facility, Dartmouth College, for providing several of the SEM and TEM images used in this publication. We thank Martha N. Simon, Ph.D., Joseph S. Wall, Ph.D., and James F. Hainfeld, Ph.D., Department of Biology-STEM Facility, Brookhaven National Laboratory; Libero Ajello, Ph.D., Frank Collins, Ph.D., Richard Facklam, Ph.D., Paul M. Feorino, Ph.D., Barry S. Fields, Ph.D., Patricia I. Fields, Ph.D., Collette C. Fitzgerald, Ph.D., Peggy S. Hayes. B.S., William R. McManus, M.S., Mae Melvin, Ph.D., Frederick A. Murphy, D.V.M., Ph.D., E.L. Palmer, Ph.D., Laura J. Rose, M.S., Robert L. Simmons, Joseph Strycharz, Ph.D., Sylvia Whitfield, M.P.H., and Kyong Sup Yoon, Ph.D., CDC; Dee Breger, B.S., Materials Science and Engineering, Drexel University; John Walsh, Micrographia, Australia; Ron Neumeyer, MicroImaging Services, Canada; Clifton E. Barry, III, Ph.D., and Elizabeth R. Fischer, National Institute of Allergy and Infectious Diseases, NIH; Mario E. Cerritelli, Ph.D., and Alasdair C. Steven, Ph.D., National Institute of Arthritis and Musculoskeletal and Skin Diseases, NIH; Larry Stauffer, Oregon State Public Health Laboratory-CDC; David R. Caprette, Ph.D., Department of Biochemistry and Cell Biology, Rice University; Alan E. Wheals, Ph.D., Department of Biology and Biochemistry, University of Bath, United Kingdom; Robert H. Mohlenbrock, Ph.D., USDA Natural Resources Conservation Service; and Chuanlun Zhang, Ph.D., Savannah River Ecology Laboratory, University of Georgia, for the use of their images and/or technical assistance.

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HIV virus particle. L. Howard, C. Daghlian, Dartmouth College.

INTRODUCTION

Microbial Challenges

Infectious diseases have plagued humans throughout history. Sometimes, they even have shaped history. Ancient plagues, the Black Death of the Middle Ages, and the "Spanish flu" pandemic of 1918 are but a few examples.

Epidemics and pandemics always have had major social and economic impacts on affected populations, but in our current interconnected world, the outcomes can be truly global. Consider the SARS outbreak of early 2003. This epidemic demonstrated that new infectious diseases are just a plane trip away, as the disease was spread rapidly to Canada, the U.S. and Europe by air travelers. Even though the SARS outbreak was relatively short-lived and geographically contained, fear inspired by the epidemic led to travel restrictions and the closing of schools, stores, factories and airports. The economic loss to Asian countries was estimated at $18 billion.

The HIV/AIDS viral epidemic, particularly in Africa, illustrates the economic and social effects of a prolonged and widespread infection. The disproportionate loss of the most economically productive individuals within the population has reduced workforces and economic growth in many countries, especially those with high infection rates. This affects the health care, education, and political stability of these nations. In the southern regions of Africa, where the infection rate is highest, life expectancy has plummeted in a single decade, from 62 years in 1990–95 to 48 years in 2000–05. By 2003, 12 million children under the age of 18 were orphaned by HIV/AIDS in this region.

> For an emerging disease to become established, at least two events must occur: 1) the infectious agent has to be introduced into a vulnerable population, and 2) the agent has to have the ability to spread readily from person to person and cause disease. The infection also must be able to sustain itself within the population and continue to infect more people.

Despite significant advances in infectious disease research and treatment, control and eradication of diseases are slowed by the following challenges.

- The emergence of new infectious diseases
- An increase in the incidence or geographical distribution of old infectious diseases
- The re-emergence of old infectious diseases
- The potential for intentional introduction of infectious agents by bioterrorists
- The increasing resistance of pathogens to current antimicrobial drugs
- Breakdowns in public health systems

Baylor College of Medicine, Department of Molecular Virology and Microbiology, www.bcm.edu/molvir/.

Using Cooperative Groups In The Classroom

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. Suggested job titles and duties follow.

Principal Investigator
- Reads the directions
- Asks the questions
- Checks the work

Maintenance Director
- Follows the safety rules
- Directs the cleanup
- Asks others to help

Reporter
- Records observations and results
- Explains the results
- Tells the teacher when the group is finished

Materials Manager
- Picks up the materials
- Uses the equipment
- Returns the materials

* Jones, R.M. 1990. *Teaming Up!* LaPorte, Texas: ITGROUP.

Overview

Students will read about six important events in the history of microbiology and decide on these events' most probable chronology, based on evidence provided. Students will learn that most scientific discoveries are related to other work, and that scientific advances often depend on the development of appropriate tools and techniques (see Answer Key, sidebar, p.2).

Ebola virus. CDC\1836 C. Goldsmith.

TIME

Setup: 10 minutes

Activity: 45 minutes for one or two class periods

MILESTONES IN

Microbiology

Very little attention was paid to the world of microbes until the 1600s, when Robert Hooke developed a primitive compound microscope (one which uses two lenses in sequence) and described tiny organisms that he observed with it. Even more detailed observations of microscopic organisms were made by Anton van Leeuwenhoek, who developed precise techniques for grinding magnifying lenses. Van Leeuwenhoek observed numerous small, swimming organisms in pond water and named them "animalcules."

It was not until the mid-1800s that scientists had enough tools to begin serious studies of microbes. In the 1850s, Louis Pasteur studied the fermentation of wine, which he found to be caused by yeast cells. He proposed that microorganisms also could cause disease, and later developed the process of pasteurization to remove harmful bacteria from food.

Pasteur's work stimulated that of Robert Koch, a physician who studied anthrax (a disease of cattle and sheep). Koch is credited with developing many culture techniques, including the use of nutrient agar for growing bacteria. He also established a set of rules to guide decisions about whether a given microbe actually caused a disease. These rules are known as "Koch's Postulates" (see sidebar, right).

Much later, in the 1930s, Walter Fleming accidentally discovered that substances produced by a common fungus, *Penicillium,* could kill *Staphylococcus* bacteria in cultures. His work led to the development of penicillin, the first antibiotic.

Since viruses are so much smaller than bacteria, most research on viruses and viral diseases began later than work on other microbes. In the 1890s, two investigators working separately, Martinus Beijerinck and Dmitrii Ivanowski, studied juices extracted from the leaves of plants infected with what is now known to be tobacco mosaic virus. They filtered the juices to remove bacteria and found that even when highly diluted, the liquid still could cause infection in plants. Ivanowski concluded that an infectious agent other than a bacterium—a filterable "virus"—led to the disease. Beijerinck called the substance "contagious living fluid."

Neither investigator was able to observe or grow the hypothesized disease-causing agents. Later, in the 1930s, Wendell Stanley isolated crystals of tobacco mosaic virus. The invention of the transmission electron microscope by Ernst Ruska in 1933 made it possible to observe viruses for the first time at magnifications of 10,000 times or more. For this, Ruska received the Nobel prize in physics.

The process by which microbiology knowledge has accumulated is typical of how science proceeds. Often a critical tool, such as the microscope, is needed before questions even can be

Continued

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

History and Nature of Science

- Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields, such as the health professions.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry.
- Many individuals have contributed to the traditions of science.
- Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.

KOCH'S POSTULATES

One can conclude a microbe causes a disease if:

- the same microbe is present in every case;
- it is possible to take a sample from a sick animal and grow the microbe in the laboratory;
- a healthy animal exposed to a sample from the microbes grown in the lab develops the same disease; and
- it is possible to isolate and grow the same microbes from the newly infected animal.

asked. Progress occurs unevenly, with one critical discovery suddenly opening entire new areas of investigation.

MATERIALS

Teacher (see Setup)

- 24 sheets of cardstock

Per Group of Students

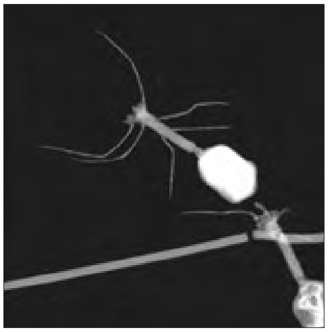
- Set of prepared *Discovery Readings* cards
- 4 highlighters (4 different colors)
- Pair of scissors
- Paper clips
- Transparent tape
- Copy of the *Timeline* student sheet (see Answer Key, left sidebar)
- Group concept map (ongoing)

SETUP

Make six copies of the student sheets on cardstock. Cut out the *Discovery Readings* to make sets of cards (one set of all readings per group). Place materials in a central location. Have students work in groups of four.

PROCEDURE

1. Ask students a question about how one discovery or invention can lead to another, such as, *Which came first, the wheel or the cart?* Or *Would a light bulb be of any value if ways to utilize electricity had not been invented?* Discuss students' responses.
2. Distribute the *Discovery Readings* sets to each group. Tell students that they will use clues from each reading to figure out the historical order in which events described in the articles occurred. Have each student select a highlighter and one article from the group's set. Instruct students to highlight words that provide clues related to the order of events.
3. When a student finishes an article, he or she should pass it to another group member until all members have read and marked all of the articles. If a word or phrase already has been highlighted and the next reader agrees with the marking, that reader should draw a line with his or her highlighter above the mark.
4. Next, have each group discuss and determine the most likely order of events and discoveries.
5. At the bottom of each reading, have each group list major clues that might help others recreate the order of events.
6. Distribute the *Timeline* sheets. Have groups cut out the sections and tape the timeline together.
7. Tell students to paper clip (not tape) the articles in order along the top of the timeline. Have each group share its results with the class. Discuss any differences among the groups' timelines. If there is a disagreement, let students present their cases. Lead the class toward consensus. Ask, *Why do all of the groups have the same article first on the timeline?* (microscope) *What is the most logical second event?* (agar plates) Ask, *Why is the development of this technique important?* (It provided a reliable way to grow bacteria for study.)
8. Based on the readings, it will be difficult for students to decide whether "The Discovery of Penicillin" or "Contagious Living Fluid" came first. Ask, *What additional information might help us to make a decision?* You may want to ask students to research these topics on their own.
9. Finally, have groups calculate the number of years between events and discuss the possible reasons for the varying time intervals between discoveries. You may wish to discuss why related discoveries sometimes occur close together in history.
10. Allow students time to add this information to their concept maps.



Rod-shaped tobacco mosaic virus and alien-like T4 bacteriophages (viruses that infects bacteria). NIAMS, NIH\A.Steven, M. Cerritelli, and Brookhaven National Laboratory\M. Simon, J. Wall, J. Hainfeld.*

ANSWER KEY

1600s - A New World: Early microscopes make tiny life forms visible.

1881 - A Culture Medium: Culture techniques make it possible to "grow" bacteria.

1884 - Mechanisms of Disease: Scientists learn how to connect a specific bacterium to a disease.

1890s - Contagious Living Fluid: Scientists learn that something smaller than a bacterium can cause disease.

1929 - The Discovery of Penicillin: Scientists find that penicillin acts to kill bacteria in culture.

1930s - Seeing Viruses: Science advances sufficiently to allow viruses to be observed.

* Fibers enhanced by M. Young, Baylor College of Medicine. Image courtesy of the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS), NIH. Image taken with the Brookhaven National Laboratory Scanning Transmission Electron Microscope.

Ebola virus. CDC\1836 C. Goldsmith.

Discovery Readings

Seeing Viruses

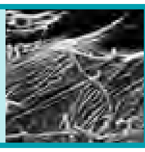
Wendell Stanley and his collaborators found particles of what they believed was tobacco mosaic virus. They learned that the particles could cause the disease in other plants and concluded they had tracked down a virus first described by Ivanowski and Beijerinck. Each particle was made of several thousand viruses. At the same time, other scientists found that they could grow viruses in the living cells of fertilized eggs. This allowed them to produce larger quantities of viruses for study. Finally, thanks to a new microscope designed by German physicist **Ernst Ruska**, it became possible to see viruses for the first time. Ruska created the first electron microscope, which allowed magnifications up to 10,000 times.

Clues about when this happened:

The Discovery of Penicillin

An Englishman named **Alexander Fleming** was studying *Staphylococcus,* a bacterium that causes skin and other diseases. Scientists already had studied many different bacteria, and Fleming was about to make an important new contribution. Before going on vacation, he started some cultures of *Staphylococcus* on agar plates. He had opened the plates several times to study them, which exposed the plates to the air. When Fleming returned, he discovered that one plate was full of *Penicillium,* a common green mold, and that no bacteria were growing near the mold. He grew more *Penicillium* in a liquid culture and added a few drops to a different plate of *Staphylococci*. He was amazed to see that the *Staphylococci* were destroyed. His work laid the foundation for the development of modern antibiotics, such as penicillin.

Clues about when this happened:



Ebola virus. CDC\1836 C. Goldsmith.

Discovery Readings

Mechanisms of Disease

Scientists were beginning to realize that infections by bacteria might lead to diseases, such as tuberculosis or anthrax. However, they couldn't figure out how to decide whether a particular microbe actually caused an illness. **Robert Koch** developed a series of rules, now known as "Koch's Postulates," to help make the decision. He proposed that in order to conclude that a microbe causes a disease: 1) the same microbe must be present in every case; 2) it must be possible to take a sample from a sick animal and grow the microbe in the laboratory; 3) a healthy animal must develop the same disease when exposed to a sample from the microbes grown in the lab; and 4) it must be possible to isolate and grow the same microbes from the newly infected animal.

Clues about when this happened:

Contagious Living Fluid

Martinus Beijerinck, a Dutch biologist, worked mostly with bacteria, but he became curious about another scientist's work on diseases of tomato and tobacco plants. The other scientist, named **Dmitrii Ivanowski**, had squeezed juice from the leaves of a diseased plant and filtered the juice to remove any bacteria. He discovered that the juice still caused other plants to get the disease. Beijerinck repeated the work and observed that even when diluted, the filtered liquid could cause the disease. He concluded that the disease was caused by something smaller than a bacterium. The two scientists are credited with finding the first known virus, tobacco mosaic virus, which Beijerinck called "contagious living fluid." However, they did not yet understand what it was or how it caused disease.

Clues about when this happened:

Ebola virus. CDC\1836 C. Goldsmith.

Discovery Readings

A New World

Anton van Leeuwenhoek and **Robert Hooke** created the first microscopes. They were simple by today's standards, but these early microscopes allowed scientists to see tiny insects, plant cells, bacteria and protozoans for the first time. Hooke is credited with inventing the compound microscope, which has two lenses. He also was the first person to use the word "cell" in biology. Van Leeuwenhook perfected the process for making glass lenses. He made detailed observations of tiny organisms never seen before, and was the first person actually to see bacterial cells. Over the course of his lifetime, he made more than 400 microscopes by hand.

Clues about when this happened:

A Culture Medium

Robert Koch used a microscope to study anthrax and other bacteria. One of the technical challenges he faced was finding a substance on which bacteria would grow. He tried liquids, such as broth (clear soup), potato slices, and even gelatin. None of these methods worked well. Then, **Angelina Hesse**, (the wife of **Walter Hesse**, one of Koch's collaborators) suggested trying agar-agar, a seaweed agent that was used to thicken jellies and puddings. Together, this team developed a gelatinous product that could be poured into the bottoms of thin flat plates. Once cooled, the gelatin remained solid at room temperature. Scientists now had a way to grow and observe bacteria. Today, the gelatin used for the culture of bacteria often is called "nutrient agar."

Clues about when this happened:

Ebola virus. CDC\1836 C. Goldsmith.

Timeline

Cut out the sections and tape together to form a long strip, starting with the 1600s on the left and ending with the 1930s on the right.

1600s	1884	1929
1881	1890s	1930s