Emerging and Re-emerging Infectious Diseases

developed under a contract from the
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BSCS

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Red blood cells being ruptured by proliferating malaria parasites (yellow spheres inside the disk-shaped cells).

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Please contact NIH with questions about this supplement at *supplements@science.education.nih.gov*.

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Foreword

This curriculum supplement, from the *NIH Curriculum Supplement Series*, brings cutting-edge medical science and basic research discoveries from the laboratories of the National Institutes of Health (NIH) into classrooms. As the largest medical research institution in the United States, NIH plays a vital role in the health of all Americans and seeks to foster interest in research, science, and medicine-related careers for future generations. NIH's Office of Science Education (OSE) is dedicated to promoting science education and scientific literacy.

We designed this curriculum supplement to complement existing life science curricula at both the state and local levels and to be consistent with the *National Science Education Standards*.[1] It was developed and tested by a team of teachers, scientists, medical experts, and other professionals with relevant subject-area expertise from institutes and medical schools across the country, representatives from the National Institute of Allergy and Infectious Diseases, and curriculum design experts from Biological Sciences Curriculum Study (BSCS) and Videodiscovery. The authors incorporated real scientific data and actual case studies into classroom activities. A three-year development process included geographically dispersed field tests by teachers and students. For the 2010 (third) printing, key sections of the supplement were updated, but the Student Lessons remain basically the same.

The structure of this module enables teachers to facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements include a conceptual flow of lessons based on the BSCS 5E Instructional Model (see page 5), cutting-edge science content, and built-in assessment tools. Activities promote active and collaborative learning and are inquiry-based to help students develop problem-solving strategies and critical-thinking skills.

Each of our curriculum supplements comes with a complete set of materials for teachers, including extensive background and resource information, detailed lesson plans, masters for student worksheets, and a Web site with videos, interactive activities, updates, and corrections (as needed). The supplements are distributed at no cost to educators across the United States upon request. They may be copied for classroom use but may not be sold.

We welcome your feedback. For a complete list of curriculum supplements and ordering information, or to submit feedback, please visit *http://science.education.nih.gov*.

We appreciate the valuable contributions of the talented staff at Biological Sciences Curriculum Study (BSCS) and Videodiscovery, Inc. We are also grateful to the NIH scientists, advisors, and all other participating professionals for their work and dedication. Finally, we thank the teachers and students who participated in focus groups and field tests to ensure that these materials are both engaging and effective.

I hope you find our series a valuable addition to your classroom and wish you a productive school year. We welcome your feedback.

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[1] The National Academy of Sciences released the *National Science Education Standards* in 1996, outlining what all citizens should understand about science by the time they graduate from high school. The *Standards* encourages teachers to select major science concepts or themes that empower students to use information to solve problems rather than stressing memorization of unrelated information.

About the National Institutes of Health

Founded in 1887, NIH is the federal focal point for health research in the United States. Today, NIH is one of the agencies within the Department of Health and Human Services. Its mission is science in pursuit of fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to extend healthy life and reduce the burdens of illness and disability. NIH works toward meeting the mission by providing leadership, direction, and grant support to programs designed to improve the health of the nation through research.

NIH's education programs contribute to ensuring the continued supply of well-trained basic research and clinical investigators, as well as the myriad professionals in the many allied disciplines who support the research enterprise. These efforts also help educate people about scientific results so that they can make informed decisions about their own—and the public's—health.

This curriculum supplement is one such education effort. It is a collaboration among the National Institute on Allergy and Infectious Diseases, the NIH Office of Science Education, Biological Sciences Curriculum Study, and Videodiscovery, Inc.

For more about NIH, visit *http://www.nih.gov*.

About Biological Sciences Curriculum Study

Headquartered in Colorado Springs, Colorado, BSCS was founded in 1958 as a curriculum study committed to an evidence- and inquiry-based approach to science education. BSCS instructional materials and professional development services are based on current research about teaching and learning for all science classrooms, kindergarten through college.

BSCS's materials are extensively field-tested in diverse settings across the country and evaluated for proven effectiveness. The BSCS 5E Instructional Model and inquiry are hallmarks of its materials, placing students at the center of their learning.

The BSCS mission is to transform science teaching and learning through research and development that strengthens learning environments and inspires a global community of scientifically literate citizens. BSCS is a 501(c)3 nonprofit organization. For more information, please visit *http://www.bscs.org*.

About the National Institute of Allergy and Infectious Diseases

The National Institute of Allergy and Infectious Diseases (NIAID) traces its origins to a small laboratory established in 1887 at the Marine Hospital in Staten Island, New York. In the 1880s, boatloads of immigrants were heading toward America, some of them unknowingly bringing with them cholera and other infectious diseases. No one knew what caused these diseases, and physicians relied on clinical signs alone to determine whether someone might be carrying an infectious agent. Scientists used the laboratory for research on these diseases, and it soon became an early part of the Public Health Service.

By 1948, the Rocky Mountain Laboratory and the Biologics Control Laboratory, both dating to 1902, joined the Division of Infectious Diseases and the Division of Tropical Diseases of the National Institutes of Health to form the National Microbiological Institute. Six years later, Congress gave the Institute its current name to reflect the inclusion of allergy and immunology research. Today, NIAID conducts and supports basic and applied research to better understand, treat, and ultimately prevent infectious, immunologic, and allergic diseases. For more than 50 years, NIAID research has led to new therapies, vaccines, diagnostic tests, and other technologies that have improved the health of millions of people in the United States and around the world.

NIAID is composed of four extramural divisions: the Division of AIDS; the Division of Allergy, Immunology, and Transplantation; the Division of Microbiology and Infectious Diseases; and the Division of Extramural Activities. In addition, NIAID scientists conduct intramural research in laboratories located in Bethesda, Rockville, and Frederick, Maryland, and in Hamilton, Montana.

Following is a brief description of the major areas of investigation.

Acquired immunodeficiency syndrome (AIDS). NIAID is responsible for conducting and supporting basic research on the pathogenesis of the human immunodeficiency virus (HIV), which causes AIDS; developing new drug therapies; conducting clinical trials of promising experimental drugs for HIV infection and related opportunistic infections and cancers; carrying out epidemiologic studies to assess the impact of HIV on the populations most severely affected by the epidemic; and developing and testing HIV vaccines.

Asthma and allergic diseases. Research on asthma and allergies has revealed much about their underlying mechanisms and contributed to the development of new ways to help affected individuals. NIAID has established a network of asthma, allergic, and immunologic diseases research centers to transfer results rapidly from fundamental studies in immunology and clinical studies of allergy to clinical practice. The Institute also supports the National Cooperative Inner-city Asthma Study to define factors that influence the disease's severity and to design and evaluate programs to reduce asthma episodes and deaths among African American and Hispanic children.

Emerging diseases. New diseases are arising worldwide and old diseases are re-emerging as infectious agents evolve or spread, and as changes occur in ecology, socioeconomic conditions, and population patterns. NIAID conducts and supports research on Lyme disease, hantavirus, multidrug-resistant tuberculosis, and other emerging diseases to develop new or improved diagnostics, treatments, and vaccines.

Enteric diseases. Worldwide, diarrheal diseases such as cholera and rotavirus infection are major causes of illness and death in infants and children. In contrast, viral hepatitis in its various forms can cause severe disease in older children and adults, although it produces few symptoms among younger age groups. NIAID supports basic research on how enteric agents cause illness as well as studies aimed at developing and testing vaccines to prevent enteric infections.

Genetics and transplantation. NIAID supports studies aimed at improving immunosuppressive therapies, further developing reagents needed for precise tissue matching, defining the genetic regulation of the immune response, and understanding the molecular mechanisms that control immune system genes. NIAID is participating in the first NIH cooperative clinical trial in kidney transplantation, designed to translate developments in basic research into new therapies to prevent graft rejection.

Immunologic diseases. The immune system is a complex network of specialized organs and cells that defends the body against attacks by foreign invaders. When functioning properly, the system fights off infections by such agents as viruses and bacteria. A malfunction, however, can unleash an enormous variety of diseases, from allergy to arthritis to cancer. NIAID research focuses on the basic biology of the immune system and mechanisms of immunologic diseases including autoimmune disorders.

Malaria and other tropical diseases. Diseases such as malaria, filariasis, trypanosomiasis, and leprosy disable and kill millions of people worldwide. NIAID's research efforts in tropical medicine are conducted by U.S. and foreign investigators receiving Institute support and by NIAID scientists in Bethesda, Maryland. NIAID supports a number of centers for tropical medicine research in countries where such diseases are endemic.

Sexually transmitted diseases (STDs). About 19 million Americans each year acquire infectious diseases other than AIDS through sexual contact, and almost half of those are among young people 15 to 24 years old. STDs such as gonorrhea, syphilis, chlamydia, genital herpes, and human papillomavirus can have devastating consequences, particularly for young adults, pregnant women, and newborn babies. NIAID-supported scientists in STD Cooperative Research Centers, NIAID laboratories, and other research institutions are developing better diagnostic tests, improved treatments, and effective vaccines.

Vaccine development. Effective vaccines have contributed enormously to improvements in public health in the United States during the past hundred years. Research conducted and supported by NIAID has led to new or improved vaccines for a variety of serious diseases, including rabies, meningitis, whooping cough, hepatitis A and B, chicken pox, and pneumococcal pneumonia. NIAID supports vaccine evaluation units for the testing of new vaccines in people at several U.S. medical centers.

Other areas of research include fungal diseases, hospital-associated infections, chronic fatigue syndrome, respiratory diseases, and antiviral and antimicrobial drug development.

You can find more information on NIAID's research efforts at *http://www3.niaid.nih.gov*.

Introduction to *Emerging and Re-emerging Infectious Diseases*

Objectives of the Module

Emerging and Re-emerging Infectious Diseases has two objectives: to introduce students to major concepts related to emerging and re-emerging infectious diseases and to convey to students the relationship between basic biomedical research and the improvement of personal and public health. The improvement of personal and public health is the central mission of the National Institutes of Health, the world's largest organization devoted to biomedical research and the funding agency for this module.

In medieval times, most people believed that supernatural forces created diseases to punish humankind for its sins. Nevertheless, as early as 1530, Gerolomo Frascatoro, an insightful Italian, suggested in a poem that syphilis and other diseases could be contagious—that is, they could be transmitted by direct contact with an infected person, contaminated materials, or infected air. The discovery of microorganisms by Anton van Leeuwenhoek in the late 1600s led some to speculate that these microscopic organisms might be the cause of disease. Although this "germ theory of disease" was first proposed in 1762, it was fully developed by Robert Koch in the 1870s as he studied anthrax, a disease of cattle and sometimes of humans.

Table 1. Discovery of bacterial causes of several diseases.

Disease	Year discovered	Scientist
anthrax	1876	Koch
gonorrhea	1879	Neisser
tuberculosis	1882	Koch
plague	1894	Kitasato, Yersin
whooping cough	1906	Bordet, Gengou

Koch devised a set of steps, now called Koch's postulates, to prove that a particular bacterium causes a specific disease:

1. The organism should always be found in animals suffering from the disease;
2. the organism must be isolated from the animal's body and cultivated in pure culture;
3. the culture should induce the same disease when inoculated into a healthy animal; and
4. the organism should be reisolated and cultured from the healthy animal and found to be the same as the original organism.

Following Koch's initial work on anthrax, scientists identified the bacterial cause of many common diseases.

Despite great advances in determining the infectious agent involved in many bacterial diseases, the causes of many other diseases remained elusive. In 1898, Friedrich Loeffler and P. Frosch studied foot-and-mouth disease, a skin infection of animals. They discovered that the infectious agent for this disease was small enough to pass through filters that would screen out all known bacteria. Other experiments indicated that the causative agent was not a chemical toxin but a "minute living being." In 1899, Martinus Beijerinck, a Dutch microbiologist who investigated the cause of tobacco mosaic disease in tobacco and tomato plants, proposed that the infectious agent was a "filterable virus" that must be incorporated into cells in order to reproduce. In 1900, Walter Reed discovered that yellow fever in humans is caused by a virus.

The work of these and other researchers led to an understanding of the viral basis of many diseases. The development of more sophisticated biochemical techniques in the early 1900s revealed the chemical simplicity of viruses

(consisting of just protein and nucleic acid), and the invention of the electron microscope in 1932 allowed viruses to be seen.

In addition to bacteria and viruses, physicians recognized that some infectious diseases are caused by fungi, protozoa, and helminths from the roundworm and flatworm phyla. Protozoa and helminths are sometimes collectively called parasites, meaning organisms that live at the expense of another organism (termed "the host"). Technically, infectious bacteria and viruses could also be considered parasites. In addition, some neurological disorders are due to infection by unusual proteins called prions.

Even as scientists began to understand the microbial cause of infectious diseases, medical workers were searching for ways to prevent or treat these diseases. For example, physicians had long known that survivors of many infectious diseases were immune from further infection by the disease-causing agent. For centuries, the Chinese had used variolization (introducing dried material from smallpox lesions into scratches on a healthy individual's skin) to induce a mild smallpox infection that would prevent the individual from contracting a severe or lethal case later in life. This procedure spread through Asia and was eventually introduced to the European community. Unfortunately, variolization occasionally caused severe and even lethal cases of smallpox.

In 1798, the rural English physician Edward Jenner made a curious observation. His patients who had contracted and recovered from cowpox, a disease similar to but much milder than smallpox, seemed to be immune not only to further cases of cowpox, but also to smallpox. By scratching the fluid from cowpox lesions into the skin of healthy individuals, he was able to immunize those people against smallpox. Louis Pasteur later developed vaccines for anthrax (caused by a type of bacterium) and rabies (caused by a virus) by treating the infectious agents for those diseases so that they lost their disease-producing abilities. Vaccination is now used to immunize people against many diseases.

Biologists also identified conditions and chemical agents that killed bacteria, leading to the prevention of many diseases. Pasteur used heat to sterilize culture media, eliminating unwanted microorganisms. The process of pasteurization, named in his honor, is now used to kill bacteria in a variety of beverages. Joseph Lister sprayed surgical rooms with aqueous phenol to reduce wound infections. People also began to recognize the importance of clean water and of treating sewage for preventing disease.

A key step forward in the fight against infectious disease was the discovery and development of drugs that could kill the microbe involved without killing the patient. Antibacterial drugs were discovered first. In the 1930s, Gerhard Domagk discovered that prontosil, a sulfonamide, could cure streptococcal infections in mice. In 1929, Alexander Fleming discovered that a substance produced by a *Penicillium* mold killed cultures of staphylococcal bacteria. He characterized the product and named it penicillin. Later, in the early 1940s, a group of British scientists directed by Howard Florey showed that penicillin was effective in controlling some infectious diseases and developed procedures for its mass production. The pharmaceutical industry flourished after World War II, and many additional antibacterial and antifungal drugs were discovered or synthesized.

Developing antiviral drugs has been more challenging. Because viruses reproduce inside host cells, it is difficult to find drugs that interfere with viral reproduction but are not toxic to host cells. Most of the drugs used today interfere with the enzymes involved in viral replication and do not affect (or affect only slightly) enzymes that are essential for the host cell. Acyclovir, used to treat genital herpes, and amantadine, used to prevent influenza A, are two examples of drugs that interfere with viral replication. AZT, the first drug to be widely used in the treatment of AIDS, also interferes with viral reproduction. In contrast, the newer protease inhibitors used to treat AIDS interfere with the process of virus packaging. Antifungal, antiprotozoan, and antihelminthic drugs have also been discovered; these drugs

frequently have serious side effects and must be administered carefully. (For a list of all current HIV/AIDS treatments, see *http://www.fda.gov/oashi/aids/virals.html*.)

Science and medicine have made dramatic advances over the past two centuries in understanding, preventing, and treating infectious diseases. Despite these advances, the past two decades have witnessed the emergence of a number of previously unrecognized diseases and the re-emergence of several previously well-controlled ones. This phenomenon is intriguing from a biological standpoint but alarming from a public health standpoint.

Concepts Covered in the Module

In this module, students explore the biological factors associated with disease emergence and re-emergence and consider the human activities that can increase or decrease the likelihood of outbreaks of infectious diseases. There are many concepts we could have addressed, but we chose, with the help of a variety of experts in this field, a relatively small number for your students to explore. Those concepts follow.

- Infectious diseases continue to be a major cause of human suffering and death, both in the United States and around the world. Emerging infectious diseases are diseases that have not occurred in humans before or that occurred only in small numbers in isolated places. Re-emerging infectious diseases are diseases that once were major health problems globally or in a particular country and then declined dramatically, but are again becoming health problems for a significant proportion of the population.
- A major cause of the emergence of new diseases is environmental change (for example, human encroachment into wilderness areas and increased human traffic through previously isolated areas).
- The re-emergence of some diseases can be explained by evolution of the infectious agent (for example, mutations in bacterial genes that confer resistance to antibiotics used to treat the diseases).
- The re-emergence of some diseases can be explained by the failure to immunize enough individuals, which results in a greater proportion of susceptible individuals in a population and an increased reservoir of the infectious agent. Increases in the number of individuals with compromised immune systems (due to the stress of famine, war, crowding, or disease) also explain increases in the incidence of emerging and re-emerging infectious diseases.
- Infectious diseases have a devastating impact nationally and globally, but a variety of strategies can alleviate suffering due to these diseases. Because resources are limited, allocating funds among projects that address different diseases raises complex ethical questions. Understanding the relevant biological principles can help in making these difficult decisions.

We hope the module's five lessons will carry these concepts to your students effectively. Although the lessons contain much interesting information about specific infectious diseases, we suggest that you focus your students' attention on the major concepts the module was designed to convey. The concluding steps in each lesson are intended to focus the students' attention on these concepts.

Implementing the Module

The five lessons in this module are designed to be taught either in sequence, as a supplement to your standard curriculum, or as individual activities that support or enhance your treatment of specific concepts in biology. The following pages offer general suggestions about using these materials in the classroom; you will find specific suggestions in the procedures provided with each lesson.

What Are the Goals of the Module?

Emerging and Re-emerging Infectious Diseases is designed to help students reach the following major goals associated with biological literacy:

- to understand a set of basic scientific principles related to emerging and re-emerging infectious diseases,
- to experience the process of inquiry and develop an enhanced understanding of the nature and methods of science, and
- to recognize the role of science in society and the relationship between basic science and personal and public health.

Table 2. Conceptual flow of the lessons.

Lesson	Learning Stage	Major Concepts
Lesson 1 *Deadly Disease Among Us*	Engage	Infectious diseases continue to be a major cause of human suffering and death, both in the United States and around the world. Emerging infectious diseases are diseases that have not occurred in humans before or that occurred only in small numbers in isolated places. Re-emerging infectious diseases are diseases that once were major health problems globally or in a particular country and then declined dramatically, but are again becoming health problems for a significant proportion of the population.
Lesson 2 *Disease Detectives*	Explore/Explain	A major cause of the emergence of new diseases is environmental change (for example, changing methods of agriculture and animal husbandry; human encroachment into wilderness areas and increased human traffic through previously isolated areas).
Lesson 3 *Superbugs: An Evolving Concern*	Explore/Explain	The re-emergence of some diseases can be explained by evolution of the infectious agent (for example, changes in the influenza virus that allow it to evade immunity and cause serious illness).
Lesson 4 *Protecting the Herd*	Explore/Explain	The re-emergence of some diseases can be explained by the failure to immunize enough individuals, which results in a greater proportion of susceptible individuals in a population and an increased reservoir of the infectious agent. Increases in the number of individuals with compromised immune systems (due to the stress of famine, war, crowding, or disease) also explain increases in the incidence of emerging and re-emerging infectious diseases.
Lesson 5 *Making Hard Decisions*	Elaborate/Evaluate	Infectious diseases have a devastating impact nationally and globally, but a variety of strategies can alleviate suffering due to these diseases. Because resources are limited, allocating funds among projects that address different diseases raises complex ethical questions. Understanding the relevant biological principles can help in making these difficult decisions.

What Are the Science Concepts and How Are They Connected?

We have organized the lessons to form a conceptual whole that moves students from an introduction to emerging and re-emerging infectious diseases (*Deadly Disease Among Us*), to an investigation of some of the causes for the emergence and re-emergence of infectious diseases (*Disease Detectives, Superbugs: An Evolving Concern*, and *Protecting the Herd*), to a discussion of how people make decisions about allocating funds to combat infectious diseases (*Making Hard Decisions*). Table 2 illustrates the sequence of major concepts addressed by the five lessons.

Although we encourage you to use the lessons in the sequence outlined in Table 2, many of them can be taught individually to replace or enhance a more traditional approach to the same or related content. Table 3 provides recommendations for inserting the lessons into a standard high school curriculum in biology.

How Does the Module Correlate with the *National Science Education Standards*?

Emerging and Re-emerging Infectious Diseases supports teachers in their efforts to reform science education in the spirit of the National Research Council's 1996 *National Science Education Standards (NSES)*. Table 4 lists the specific content and teaching standards that this module primarily addresses.

How Does the BSCS 5E Instructional Model Promote Active, Collaborative, and Inquiry-Based Learning?

The lessons in this supplement use a research-based pedagogical approach called the BSCS 5E instructional model, or the BSCS 5Es. The BSCS 5Es are based on a **constructivist** theory of learning. A key premise of this theory is that students are active thinkers who build (or construct) their own understanding of concepts out of interactions with phenomena, the environment, and other individuals. A constructivist view of science learning recognizes that students need time to

- express their current thinking;
- interact with objects, organisms, substances, and equipment to develop a range of experiences on which to base their thinking;
- reflect on their thinking by writing and expressing themselves and comparing what they think with what others think; and
- make connections between their learning experiences and the real world.

The three key findings related to student learning identified in *How People Learn* (Bransford et al., 2000), a comprehensive review of research on learning, support the pedagogical strategies promoted by implementing the BSCS 5Es:

- Students enter class with a variety of preconceptions that may later significantly interfere with learning if those preconceptions are not engaged and addressed,
- To develop competence in a given subject, students must build a strong foundation of factual knowledge within the context of a coherent conceptual framework.
- Students benefit from a metacognitive approach to learning that emphasizes goal setting and self-monitoring.

The BSCS 5Es sequence the learning experiences so that students can construct their own understanding of a science concept over time. The model leads students through five phases of active learning that are easily described using words that begin with the letter *E:* Engage, Explore, Explain, Elaborate, and Evaluate. Rather than just listening and reading, students are also analyzing and

Table 3. Correlation between lessons and topics in standard high school curricula.

Topics	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
Infectious diseases (causes)	Yes	Yes	Yes	Yes	Yes
Society and infectious diseases	No	Yes	Yes	Yes	Yes
Antibiotics and antibiotic resistance	No	No	Yes	No	Yes
Natural selection	No	No	Yes	No	Yes
Vaccination	No	No	No	Yes	Yes

Table 4. Correlation to the National Science Education Standards.
A. The Content Standards

Standard A: As a result of activities in grades 9–12, all students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• Identify questions and concepts that guide scientific investigations.	Lessons 2 and 3
• Design and conduct scientific investigations.	Lesson 3
• Use technology and mathematics to improve investigations and communications.	Lesson 4
• Formulate and revise scientific explanations and models using logic and evidence.	Lessons 2, 3, and 4
• Recognize and analyze alternative explanations and models.	Lessons 2, 3, and 4
• Communicate and defend a scientific argument.	Lessons 4 and 5
• Understanding scientific inquiry.	Lessons 2, 3, and 4
Standard C: As a result of their activities in grades 9–12, all students	**Correlation to *Emerging and Re-emerging Infectious Diseases***
should develop understanding of the molecular basis of heredity.	
• In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA.	Lesson 3
• Changes in DNA (mutations) occur spontaneously at low rates.	Lesson 3
should develop understanding of biological evolution.	
• Species evolve over time.	Lesson 3
should develop understanding of the interdependence of organisms.	
• Human beings live within the world's ecosystems.	Lesson 2
Standard E: As a result of activities in grades 9–12, all students	**Correlation to *Emerging and Re-emerging Infectious Diseases***
should develop abilities of technological design and understandings about science and technology.	
• Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations.	Lesson 2
• Science often advances with the introduction of new technologies.	Lesson 5
• Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.	Lessons 1–5
• Science and technology are pursued for different purposes.	Lessons 1–5
Standard F: As a result of activities in grades 9–12, all students should develop understanding of	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• personal and community health	Lessons 1–5
• natural and human-induced hazards	Lessons 1–5
• science and technology in local, national, and global challenges	Lesson 5
Standard G: As a result of activities in grades 9–12, all students should develop understanding of	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• science as a human endeavor	Lessons 2 and 5
• nature of scientific knowledge	Lessons 3, 4, and 5
• historical perspectives	Lesson 1

Table 4. Correlation to the National Science Education Standards. (continued)
B. The Teaching Standards

Standard A: Teachers of science plan an inquiry-based science program for their students. In doing this, teachers	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• develop a framework of yearlong and short-term goals for students	Each lesson provides short-term objectives for students. Tables 2 (Conceptual Flow of the Lessons) and 8 (Suggested Timeline for Teaching the Module) also help teachers plan.
• select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students	Using the modules helps teachers update their curriculum in response to their students' interest in this topic.
• select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners	The focus on active, collaborative, and inquiry-based learning helps teachers meet this standard.
Standard B: Teachers of science guide and facilitate learning. In doing this, teachers	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• focus and support inquiries while interacting with students	All of the lessons in the module encourage and support student inquiry.
• orchestrate discourse among students about scientific ideas	All of the lessons in the module promote discourse among students.
• challenge students to accept and share responsibility for their own learning	All of the lessons in the module challenge students to accept and share responsibility for their learning.
• recognize and respond to student diversity and encourage all students to participate fully in science learning	Combining the BSCS 5E Instructional Model with active, collaborative learning is an effective way of responding to the diversity of student backgrounds and learning styles.
• encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science	Annotations for the teacher that occur throughout the lessons provide many suggestions for how teachers can model these attributes.
Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• use multiple methods and systematically gather data about student understanding and ability	Each lesson has a variety of assessment components embedded within its structure. Annotations draw teachers' attention to these opportunities for assessment.
• analyze assessment data to guide teaching	Annotations provide answers to questions that can help teachers analyze student feedback. The annotations also suggest ways for teachers to change their approach to students, based on that feedback.
Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers	**Correlation to *Emerging and Re-emerging Infectious Diseases***
• display and demand respect for the diverse ideas, skills, and experiences of all students	The answers provided in the annotations for teachers model these qualities.
• nurture collaboration among students	All the lessons are designed to be completed by students working in collaborative groups.
• structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse	All the discussions in the activities model the rules of scientific discourse.
• model and emphasize the skills, attitudes, and values of scientific inquiry	The annotations for teachers provide many suggestions about how to model these skills, attitudes, and values.

evaluating evidence, experiencing, and talking with their peers in ways that promote the development and understanding of key science concepts. These inquiry-based experiences include both direct experimentation and development of explanations through critical and logical thinking. Students often use technology to gather evidence, and mathematics to develop models or explanations.

The BSCS 5Es emphasize student-centered teaching practices. Students participate in their learning in ways that are different from those seen in a traditional classroom. Tables 5 and 6 exemplify what teachers do and what students do in the BSCS 5E Instructional Model.

The following paragraphs illustrate how we implemented the BSCS 5Es in *Emerging and Re-Emerging Infectious Diseases*.

Engage

The primary purpose of the Engage phase is to capture students' attention and interest. It also gives teachers a chance to find out what students already know or think they know about the topic and concepts to be developed. Students come to learning situations with prior knowledge, which may or may not be congruent with the concepts presented in this module.

The Engage lesson in this module, Lesson 1—*Deadly Disease Among Us*, is designed to make connections between past and present learning experiences and to anticipate upcoming activities. By completing it, students should become mentally engaged in the topic of infectious diseases and should begin to think about how the topic relates to their previous experiences. Successful engagement results in students who are intrigued by the concepts they are about to study in depth.

Explore/Explain

Lessons 2, 3, and 4 serve as the Explore and Explain phases of the model. Lesson 2 helps students discover that human activity in the environment is a major factor in the emergence of new diseases worldwide. Likewise, Lessons 3 and 4 help students understand the evolution of antibiotic resistance and the failure of immunization procedures as explanations for the re-emergence of diseases once thought conquered, or largely so.

Explore and Explain activities give students opportunities to develop their own understandings of important concepts and then to articulate their developing understanding to one another and to the teacher. These activities are also where you introduce formal labels for concepts and phenomena. Keep in mind, however, that these activities are still *student*-centered. That is, the students are developing their own explanations for the emergence and re-emergence of infectious disease. Here, your role is to guide students so that they have ample opportunity to develop their understanding. Students ultimately should be able to explain their understanding by bringing together their experiences, prior knowledge, and vocabulary.

Elaborate/Evaluate

During the Elaborate and Evaluate phases of the model, exemplified in this module by Lesson 5—*Making Hard Decisions*, students are challenged to extend and assess their understanding of infectious diseases. Through a new set of questions and experiences, students develop a deeper, broader understanding of the topic, obtain more information about areas of interest, and refine their scientific and critical-thinking skills.

A teacher's primary goal in the opening Elaborate phase is to help students articulate generalizations and extensions of concepts and understandings that are relevant to their lives. The final portion of the activity, where students present arguments for the proposals they have decided to recommend for funding, acts as the Evaluate portion. At this point, students see they can extend and apply their understanding of infectious disease to the real world. It is also important here that they receive feedback on the adequacy of their explanations and understandings.

Elaborate and Evaluate activities are complex and challenging, and Lesson 5 will stretch your students' abilities to listen, think, and speak.

To review the relationship of the BSCS 5E Instructional Model to the concepts presented in the module, see Table 2.