Antibiotics: Man vs. Microbe

For six seasons, millions of students came to understand, appreciate and enjoy the exploration of science through the series, Bill Nye the Science Guy. Bill returns with The Eyes of Nye, a more in-depth look at science subjects making news, changing lives, and impacting policy. From the future of alternate fuel sources and genetic engineering to population growth trends and issues of race, Bill and his expert cohorts bring science to life right in your classroom, helping you Motivate investigation; Assess available information; and Propose lines of argumentation.

This Educator’s Guide includes:

• An Introduction that clearly defines the subject and offers an overview of the issue objectives of the guide; how it relates to science from both a social and personal perspective; as well as pertinent questions and insights regarding the topic.

• A listing of all National Science Education Standards Addressed.

• Detailed procedures highlighted in the MAP Framework (Motivate, Assess, Propose).

• Illustrative Video Clips from The Eyes Of Nye DVDs with pinpoint chapter cues.

• Web Site Resources to help students further investigate and locate research, charts, data as well as experts featured in the program material.

• Easily downloadable Support Materials that include articles, transparencies, charts, and much more.

Introduction:

“Antibiotics” refers to chemical substances that have the capacity to destroy or inhibit the growth of bacteria. They are used chiefly in the treatment of infectious diseases. The Eyes of Nye - Antibiotics: Man vs. Microbe presents a background of infectious disease trends and the effect of antibiotics on those trends, conditions that contribute to those effects, and the decisions we face and solutions we seek as a result.

The issue of antibiotic use is a growing global concern, and one that is not an “all or none” proposition. The questions posed in Antibiotics and the objective of this teacher guide—gaining an understanding of the reasons, possible solutions, and future directions the problem may take—help students prepare for what will surely continue to be a major issue throughout at least a large portion of their lives. The issue also constitutes an excellent example of the never-ending impact of science on technological progress and vice-versa, the
scientific significance of our past historical experiences, and our place as humans in our ecosystem and the larger environment.

National Science Education Standards Addressed

Science As Inquiry
• Abilities necessary to do scientific inquiry
  Identify questions and concepts that guide scientific investigations
  Recognize and analyze alternative explanations and models
• Understanding about scientific inquiry

Life Science
• The cell
• Biological evolution
• The interdependence of organisms

Science and Technology
• Understandings about science and technology

Science in Personal and Social Perspectives
• Personal and community health
• Natural and human-induced hazards
• Science and technology in local, national, and global challenges

History and Nature of Science
• Science as a human endeavor
• Nature of scientific knowledge
• Historical perspectives
On the DVD:

Antibiotics: Man vs. Microbe – Chapters

Chapter 1: Antibiotics Preview
Beginning through 1:52
Ends with title screen.

Chapter 2: Historical Perspectives on Disease and Antibiotics
1:15—7:23
Ends with Bill’s reference to antibiotics being “the same drug that used to kill them.”

Chapter 3: Antibiotics and Resistance
7:24—10:45
Ends with Dr. Tenover saying, “There is no antibiotic in use for which we have no resistance.”

Chapter 4: New Directions in Diagnosis and Treatment
10:45—16:39
Ends with the close of Bill’s interview with Dr. Margaret Riley saying, “That’s the master plan.”

Chapter 5: Curbing Environmental Abuse
16:39 through end of program.
Starts with posted data from the Union of Concerned Scientists.

Antibiotics: Man vs. Microbe – Activity Clips

The Black Plague
1:15—3:27
(referenced in Educator’s Guide step 1)
Ends at close of medieval skit.

The Advent of Antibiotics: A Solution and a Problem
3:27—7:23
(referenced in Educator’s Guide step 2)
Ends with Bill’s reference to antibiotics being “the same drug that used to kill them.”

Antibiotics and Bacteria: The Mutual Acquaintance
7:23—8:49
(referenced in Educator’s Guide step 3)
Demonstrates the effect of the antibiotics on bacteria and ends with the response of the bacteria—CDC data on the rise of antibiotic-resistant strains of streptococcus pneumoniae displayed after Bill says, “That’s the problem.”
Research on Antibiotic-Resistant Bacteria
8:52—10:45
(referenced in Educator’s Guide step 6)
Ends with Dr. Tenover saying, “There is no antibiotic in use for which we have no resistance.”

Bacteria vs. Virus
11:35—12:46
(referenced in Educator’s Guide step 7)
Skit on talk show with antibiotic guest.

Cues from Nature: New Treatments for New Needs
18:13—20:43
(referenced in Educator’s Guide step 7)
Starts with Bill in the grocery store talking about overuse of antibiotics in farming and so forth, and ends with him saying there are antibiotics all throughout our environment, and that we can change the world “even on a smaller, more personal scale.”

Procedure: Motivate Phase

1) Play “The Black Plague” to engage students with the nature of infectious disease and the dangers they pose. Ask students to suggest some characteristics (rapid transmittal, modes of infection, deadliness), possible contributing causes (unsanitary conditions, lack of understanding or respect for scientific or medical solutions), and measures we could take to combat the spread of a similar disease. Students may have noticed the references in the skit to washing hands and use of a bloody knife when the medieval barber performed medical procedures.

2) Ask students what else we could do to combat infectious disease. Based on past experiences students may suggest ideas related to medical advances, or more directly, use of medicines or antibiotics. Play “The Advent of Antibiotics: A Solution and a Problem.” Note the quote of the 1969 U.S. Surgeon General, “We have won the war on infectious disease.” Ask students, “Was infectious disease defeated?” Students are aware that disease was not defeated, but upon asking why, they will have little response. Discuss the data implying that bacteria have recently begun to become resistant to the presence of antibiotics. Ask students if we should have listened to the Surgeon General and believed in the “victory of antibiotics” as we were encouraged to do. In response to “no,” ask what the price is of not listening—point out the social attitudes prevalent in the
time of the Plague. Discuss the importance of recognizing the value we derive from the advancement of science through introduction of new technologies such as those we have witnessed in the medical health field, and though these often result in new problems, problems themselves are often motivating forces that precipitate new solutions. A case in point is the delay in the use of penicillin from its development until World War II, when dire circumstances forced it into service.

3) To those who replied “yes” (we should have listened), ask what price we pay for not seeking additional understanding. Reiterate the notions that social conditions often drive development of new knowledge and that we (societies) are the final arbiter of decisions that have tremendous impact on new advances that in turn have lasting effects on science and society. Ask students if, given the importance of their role, a “no” or “yes” answer is sufficient, and if not, what else we must ask. Play “Antibiotics and Bacteria: The Mutual Acquaintance” to demonstrate the effect of antibiotics on bacteria, hear a summary statement of the problem—bacteria are now mutating faster than antibiotics can kill them—and reinforce the impending danger through the data display depicting the rise of antibiotic-resistant strains of Streptococcus pneumoniae. Lead students through a brief discussion of our “need-to-know” about the scientific causes of infectious disease, the means by which disease-causing organisms develop resistance, and the possible solutions to this dilemma that might exist. Pose the broad question, “Should we restrict the ways in which we use antibiotics, and if so, how?” Generate with students at least two scientific and one social question (possibilities follow) that warrant consideration and investigation.

**Potential scientific questions:**

a) Are antibiotics becoming less successful? Why or why not?

b) What can possibly be done about it scientifically and technologically?

**Potential social/scientific question:**

c) How do we decide on the use or non-use of antibiotics for people and communities, and what factors must we consider in making this decision?

**Procedure: Assess Phase**

4) Recall the demonstration of the effect of the antibiotic on bacteria. Remind students of the brief mention of the antibiotic’s effect on the cell wall of bacteria. Explain that this wall shields the internal structures of a bacterium from the external environment. When the cell wall is destroyed so is the bacterium. Recall, however, that bacteria can also change—increasing the thickness of its cell wall, for instance—and therefore develop strains that are resistant to the antibiotic being used. Explain that this is often accomplished through a biological phenomenon akin to “selection” in which those best suited for survival under certain conditions have the advantage. Illustrate the concept of bacterial selection using the transparency T-BS (see sidebar), describing our body as a type of “ecosystem” where all organisms compete for a finite set of resources. Not only does a strain of bacteria that survives an antibiotic live to do more damage, but
is also aided by the depletion of other bacteria and multiplies to fill the void left by those that have been destroyed.

Illustrate the process of bacterial selection that occurs through the use of typical “broad spectrum” antibiotics. You may choose to contrast this with the effect of newer “narrow spectrum” antibiotics now or wait until the latter are addressed in step 11.

Teacher Note: The study of bacteria and antibiotic resistance involves the use of many terms that are often used interchangeably (for instance, antibacterial and antimicrobial), especially in the normal dialogue of specialists to whom the terms are common. Though you should remain consistent in your choice of terms during early stages of students’ exposure, questions will still arise as well as the need (as at several points in this guide) to compare or contrast certain terms. Use the glossary provided.

See The Eyes of Nye Issue Support Glossary

5) Play “Research on Antibiotic-Resistant Bacteria” in which Dr. Fred Tenover at the Centers for Disease Control and Prevention discusses the increase and extent of resistance of bacteria and the devastating effect of this phenomenon in hospital settings. Ask students why bacteria in these settings have such high resistance to antibiotics. Briefly address the concept of treatment driving more resistance.

Explore experts who have posed claims.

For more on exploring claims and claimants, go to eyesofnye.org

6) Begin to explore the second scientific question posed in step 3 by asking students to consider what we could be doing, purposefully or unknowingly, to encourage the increase of antibiotic-resistant strains of bacteria. Some will suggest by now we are using too many antibiotics, and some may be more specific and say we are prescribing antibiotics for “everything.” Play “Bacteria vs. Virus” for a lighthearted but relevant consideration of the problem. Remind students of the response of bacteria to the demise of competing strains in our bodies as you discuss the potential problems caused by misdiagnosing illness or prescribing antibiotics for every illness we encounter. Broaden discussion to include our larger environment and explain that interdependence and competition of organisms play important roles in any natural ecological system. Suggest the extent of resistance we now find in bacteria might indicate more than overuse of antibiotics in human treatments. Many students will know of other animals that have been given antibiotics. Lead discussion from that point to the impact of those antibiotics on bacteria in nature, then play “Filling the Niches: Misuse and Overuse.”

Optional: Distinguish between bacteria and viruses. Ask students to search for information in order to textually or visually compare and contrast or diagram differences.
7) Students will by now consider most of the problem to be folly on the part of doctors, patients, farmers, and others. However, ask if they are always sure of what they have when they are sick (no), and if their doctor is always sure (surely not). Suggest that our decisions are often difficult, and that while there are things we can do (recall those mentioned above), sometimes the decisions we face about whether or how to use antibiotics (social question in step 3) are personal, dangerous, and very immediate. Begin to focus on these types of decisions we must make by asking if you were a doctor and you were treating a very sick child whose disease was difficult to diagnose, would you consider trying an antibiotic? Suggest to students that sometimes we must consider cases that require treatment. Suggest also that sometimes, as in times past, it takes serious circumstances for us to progress scientifically, technologically, and personally.

Procedure: Propose Phase

8) Distribute or explain the background information on *Bordetella pertussis* (see sidebar), better known as “whooping cough.” Discuss the nature of the disease (e.g., predominant in infants, highly contagious and dangerous, difficult to diagnose, side effects and conflicts associated with vaccination). Recall the general trend showing an increase in disease-related deaths due to resistance in recent years, and provide students with historical trend data showing the number of confirmed cases of pertussis up to 1990 (not beyond).

9) Present the case of The Problem With Pertussis and ask students to consider the details as though they were a parent of the infant, community member, health official, or all. Ask students to decide what they would do, given this scenario, and allow them to brainstorm ideas, list or describe possibilities, and construct a brief plan of action. Be prepared to suggest prompts where needed—they may consider medical treatment solutions to save the life of the infant, causal factors (where the infant possibly got the disease), community or social ramifications (others that may be in danger or be carriers) and the possibility of an epidemic, assistance from other medical facilities, or political aspects (many governments suppress this type of information). You may use a whole class, small group, or individual approach.

10) Provide students with the resolution of The Problem With Pertussis. Discuss the various actions taken in the case, and relate to those proposed by students. Note the case was real, and the resolution as described may or may not have specified certain other actions students suggested in their own plan (we only have what the records indicate). It is also not intended to imply the right actions to be taken in a situation like this. Rather, it illustrates a lack of absolute solutions and the need to consider many options and parallel courses. Ask students to predict what has transpired in the problem with pertussis between the time of the case and now. Use the follow-up note and additional post-case data as needed beyond this point. Share the CDC data that indicates in the intervening
years the incidence of confirmed pertussis cases steadily rose to over 11,000 in 2003, the highest since 1964. Also during that time other erythromycin-resistant strains were identified, cases among adults and adolescents increased dramatically, adults were found to be a reservoir for carrying and transmitting the disease, diagnosis (especially in adults) continued to be difficult, treatment with erythromycin continued as the first line of action for confirmed and potential cases, and that vaccines are now being considered for adults (two patents pending as of January 2005, even given past problems with potential reactions). If not addressed, point out the important—and to students, often unfamiliar—interaction among local health authorities and the CDC, and the increasing efforts being devoted to large-scale surveillance and monitoring (see sidebar). Ask students to consider what they would like to see happen over the next 10 years.

For more on monitoring and surveillance, go to eyesofnye.org

11) Tell students that, just as special circumstances often promote technological and scientific progress, learning from the past likewise provides choices we would not otherwise have. Remind them of risks harbored by the environment, and tell them the reverse is also true—our environment provides many possible solutions, if only we search and learn more about it. Play “Cues From Nature: New Treatments for New Needs” in which Dr. Margaret Riley discusses research in the development of new treatments based on the proteins (bacteriocins) that certain bacteria release to kill closely-related strains of competing bacteria in a highly targeted manner. Distinguish between this “narrow spectrum” treatment and the “broad spectrum” treatments of the past and present, and ask students to suggest the potential future value in this type of approach for combating the increase of antibiotic-resistant bacteria. Suggest this or another similar form of treatment may be part of the issue in the near future. Leave them considering how it may impact future choices they make in these or other similar situations.

Final Teacher Note: The Problem With Pertussis was selected to illustrate numerous factors that compliment The Eyes of Nye - Antibiotics and the learning objectives of this guide. Other cases are available, but avoid “bad endings” or other sensitive details—they do not contribute to the objectives.

Dr. Riley’s work serves as a thoughtful close or as a means of re-entry into an assess phase full of research on new treatment possibilities. It also puts an exclamation point on several recurring themes in the antibiotics issue—the never-ending mutual impact of science and technology, relationships of organisms with the environment and one another, and roles in those interactions, and even learning at the intersection of past theory (e.g., germ theory, evolution, etc.) and findings in newer arenas (e.g., genetics). As such, it is a flagship example for students of “frontier science” sturdily constructed on accepted and consensual principles of “core science.”

For more, go to eyesofnye.org
Further Research

Investigating the Issue: Antibiotics

Historical progress in medical health sciences and technologies, improvements in our quality of life balanced with the potential threats we face from new strains of antibiotic-resistant infectious bacteria, resulting decisions that we (and our students) face in the future as individuals and as members of our society—all form a compelling educational background.

In addition to the information and claims presented in The Eyes of Nye - Antibiotics, students may access a variety of information and data sources related to disease, bacteria, antibiotic-resistance, new treatment efforts and solid core science that supports the quest for new learning. Social considerations and ties are woven so tightly into the issue itself they far exceed the need to explore the claims and claimants. These are provided, but the sources for newly emerging science data (for instance, the Centers for Disease Research and Prevention) also become essential sources for information related to the social fabric; the scientific information itself, whether it describes disease trends, case reports, or new research, is a story of nature and people.

Exploring Disease Trends, Causes, and Future Threats

The Centers for Disease Control and Prevention (CDC) provides a wealth of information, literature, data, and recent reports on both research findings and disease cases and outbreaks. Access at: http://www.cdc.gov

History and Plague

Yersinia pestis is alive and well. Get a reliable overview of the plague from both a historical and modern perspective at:
http://www.cdc.gov/ncidod/dvbid/plague/history.htm

Resistance Monitoring

For information on diseases connected to antibiotic resistance, the public health action plan to fight microbial resistance, susceptibility testing, and the CDC’s surveillance system, see the Antibiotic/Antimicrobial Resistance Web site at:
http://www.cdc.gov/drugresistance/

Or, go to the National Antimicrobial Resistance Monitoring Program at:
http://www.cdc.gov/narms/

Studies of biological diversity in nature and the evolution of microbial defense systems such as antibiotics could play a large future role in the search for solutions to the problem of resistance in infectious bacteria. Exploration of such topics as the evolutionary arms race, microbial population genetics, production of bacteriocins, colicins and microcins, and the ecological role of microbial defense systems can help students to develop ties between new findings and the importance of established theoretical principles developed and honed through years of research and observation of the environment in which we live. Encourage students to explore the perspectives and scientific foundations of the work of Dr. Margaret Riley (featured in The Eyes of Nye - Antibiotics). Also, take a...
closer look at the contributions and work of various colleagues, including Kirkup, Gillor, Wertz, and Kerr, among others.

**Exploring Antibiotics Claims and Claimants**

In *The Eyes of Nye - Antibiotics*, the principal information was provided by Doctors Fred Tenover and Margaret Riley. Teachers may encourage students to conduct open-ended searches for information related to these individuals and the institutions at which they conduct their work.

- **Dr. Fred Tenover**  Centers for Disease Research and Prevention
- **Dr. Margaret Riley**  University of Massachusetts (previously at Yale)