2.12 Explore an Issue: Bacterial Resistance to Antibiotics

BACKGROUND INFORMATION

At the end of the nineteenth century, the French microbiologist Jean-Paul Vuillemin noted that fungi and yeasts could destroy bacteria by a process called antibiosis—the association between organisms in which one is harmful to the other. The discovery and classification of antibiotics and their effects quickly followed. Several main types of antibiotics are used today, almost all of which were developed in the nineteenth and twentieth centuries. This list includes penicillins, cell-wall antibiotics other than penicillins, aminoglycosides, tetracyclines, macrolides, and quinolones. In the twenty-first century, there is one new antibiotic, linezolid. It is the first new antibiotic in 35 years, and is in a new class (oxazolidinones).

Today, a primary concern for health care researchers is the development of bacterial resistance to an antibiotic. Bacteria can interrupt the action of antibiotics in several ways: by developing mechanisms that prevent the drug from reaching its target in the bacterial cell (making the cell membrane impermeable to the antibiotic or rapidly eliminating the antibiotic from the cell); by inactivating the antibiotic with enzymes, which destroy penicillins and cephalosporins before they reach their targets; and by altering the target so that the antibiotic can no longer satisfactorily bind to the bacteria. Resistance can result from mutation in a bacterial cell that is passed to daughter cells. More commonly, resistance is spread by the transfer of genetic material (conjugation) from one bacterium to another, which may even be a different species. Resistant bacteria survive exposure to an antibiotic and can easily multiply and spread, first locally (e.g., within a hospital) and then widely (often throughout the world). Resistance develops through both misuse and inappropriate use of antibiotics. If a patient requires a 10-day course of antibiotics to eliminate an infection but doesn't finish taking all the medication because he or she feels better, only the most sensitive organisms will have been killed; the more resistant ones will survive and flourish. A dose of antibiotics that is too low will produce the same effect. The prophylactic use of antibiotics (using them to prevent, rather than treat, diseases), especially long term, is a big contributor to antibiotic resistance, as sensitive organisms are eliminated and resistant bacteria survive.

Misconceptions

Students may believe that a civilization able to put people in space is one that has developed cures for all diseases. However, infectious diseases remain a challenge. Attempts have been made since World War II to prevent epidemics using antibiotics, vaccines, sanitation, and pesticides. Exposure to microbial pathogens has also been reduced by practices such as refrigeration, sterilization, and disinfection. However, old diseases have reappeared and new diseases have emerged.

Vancomycin, once touted as a "super-antibiotic," was discovered in 1956—the product of *Streptomyces orientalis*, a soil fungus. Vancomycin inhibits growth of many sensitive Gram-positive bacterial species that have become resistant to penicillin. However, this medicine may cause serious side effects, including hearing and kidney damage, most often in elderly patients. In the past 10 years, vancomycin-resistant strains of bacteria have emerged and the search continues for new super-antibiotics. One with promise was linezolid, aimed at drug-resistant germs that cause potentially deadly cases of pneumonia and dangerous skin and blood infections. But in 2001, only

a year after linezolid had been approved for use in the United States, and two months after it had been approved for use in Canada, the first case of resistance to linezolid was reported.

Related Background Resources

- Canadian Committee on Antibiotic Resistance: http://www.ccar-ccra.org
- Antibiotics: Antibacterial Agents: http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/Antibiotics.html
- Fact Sheet: Antimicrobial Resistance: http://www.niaid.nih.gov/factsheets/antimicro.htm
- Brief History of Infectious Disease: http://www.bayerpharma-na.com/healthcare/hc0108.asp
- Fighting Antibiotic Resistance: http://www.fda.gov/fdac/features/2002/402_bugs.html
- Antibiotics: http://www.tipsofallsorts.com/antibiotics.html
- Antibiotics Information: http://www.prairiepublic.org/features/healthworks/antibiotics/
- The Multiplicity of Microbes: http://www.clf.org/pubs/microbes.htm
- Antibiotics: http://www.sigmaaldrich.com/cellcult/pdfs/antibi.pdf
- *The Use of Drugs in Food Animals: Benefits and Risks*, Committee on Drug Use in Food Animals, Panel on Animal Health, Food Safety, and Public Health, National Research Council, 276 pages, 1999

ASSESSMENT PLANNING

Overall Skills Expectations

SIS.05
SIS.06
SIS.07
SIS.10

Overall Expectations

M.03

Specific Expectations

M3.01 evaluate the impact of viral, bacterial, and fungal infection on the health of host organisms, and on humans in particular

Achievement Chart Categories	Assessment/Evaluation Opportunities (Evidence)	Assessment Tools
Knowledge/Understanding	Understanding the Issue, q. 1–4 M3.01	Rubric 1: Knowledge/Understanding
Communication	Take a Stand, q. (a)–(d) M3.01	Rubric 3: Communication Rubric 6: Research Skills Self-Assessment Checklist 2: Research Skills
Making Connections	Understanding the Issue, q. 5–7 M3.01	Rubric 4: Making Connections

Assessment Opportunities

Knowledge/Understanding Collect student answers to Understanding the Issue questions 1 to 4 and compare to answers provided in the Solutions Manual. To determine their level of achievement, use *Assessment Rubric 1: Knowledge/Understanding* assessment criteria:
- Understanding of concepts, principles, laws, and theories (identifying assumptions, communicating misconceptions, providing explanations)
- Knowledge of facts and terms
- Transfer of concepts to new contexts
- Understanding of relationships among concepts

Communication Collect student work for the Take a Stand. To determine their level of achievement, use *Assessment Rubric 3: Communication* assessment criteria:
- Communication of information and ideas
- Use of scientific terminology, symbols, conventions, and standard (SI) units
- Communication for different audiences and purposes
- Use of various forms of communication (e.g., reports, essays)
- Use of information technology for scientific purposes (e.g., specialized databases)

Assessment Rubric 6: Research Skills (all criteria) and *Self-Assessment Checklist 2: Research Skills* may also be used with this question.

Making Connections Collect student work for Understanding the Issue questions 4 to 7. To determine their level of achievement, use *Assessment Rubric 4: Making Connections* assessment criteria:
- Understanding connections among science, technology, society, and the environment
- Analysis of social and economic issues involving science and technology
- Proposing courses of practical action in relation to science- and technology-based problems

INSTRUCTIONAL PLANNING

Suggested Time

Narrative/Understanding the Issue questions—40 min
Take a Stand—Research 1–2 weeks; Debate 20–30 min, plus 10–15 min summary

TEACHING SUGGESTIONS

- The example of cyanide in the first sentence of this section was used as an attention grabber. In fact, although cyanide is toxic to humans, this chemical can be used as a nutritional source of carbon and nitrogen by some bacteria; other bacteria excrete cyanide as waste.
- Assign the narrative reading and accompanying questions to give students a solid appreciation of the facts. Some may consider bacterial resistance to antibiotics a non-debatable issue. The logic may be that if misuse of antibiotics is causing bacterial resistance, then antibiotics must be used properly. But how can antibiotic use be controlled and where should legislation start? To make this a fair issue—one in which information can be presented on both sides of the argument—the emphasis is on livestock production. Students will recognize the connection between antibiotic use in animals and antibiotic resistance in humans. Most students will see the value of being able to control animal and human diseases using antibiotics. Other students will be aware of issues surrounding overuse of antibiotics and the use of antibiotics in

livestock as possible health and environmental problems. Some students will have ethical concerns about testing drugs on animals. The open-ended nature of this activity allows students to research their area of interest.

- To set this issue in context, some background information on types of antibiotics and the diseases they control is helpful. Assign the task of collecting it to students, or distribute the information in **LSM 2.12-1: Types of Antibiotics**.
- Divide students into groups and allow research time outside class for students to list points and counterpoints. **Workbook 2.12 Explore an Issue: Bacterial Resistance to Antibiotics** provides structure for this task. An alternative suggestion is to divide the class into "for" and "against" teams, with the obligation of researching their position. Each member of both teams can then be assigned some point to present to the class.
- A formal debate can be staged. Again, divide the class into "for" and "against" teams and allow each team research time. The teams will then select a limited number of speakers (perhaps six). All members will help prepare an introductory statement to be made by the first speaker for their team. Set a time limit (2–4 min) for each opening statement. All members will help to select the points that their team will present. Hold a class discussion to determine the number of points. All members will help to prepare a set of possible counterpoints that their team may use as rebuttals to their opponent's points. Set time limits (perhaps 2 min for each point and 2 min for each rebuttal). Each side will help to prepare a closing statement to be made by the last speaker for each team. Set a time limit (3–6 min) for each closing statement.
- Self-assessment is effective in this task. Ask students to evaluate their own contribution to research, planning, and presentation. Ask them their opinion about which side was more convincing, if the debate method was used. For peer assessment, ask students to evaluate and rank the contributions each member made. For formal assessment, ask students to prepare a short summary of their original views and the degree to which these views were modified as a result of the debate. Collect these summaries.
- As this section completes the content on fighting infection, the use of antibacterial agents, and antibiotics, assign **Workbook 2.9–2.12 Self Quiz**. By comparing their answers to those in the back of the Workbook, students can identify areas that they need to review.