

LT: I can describe how bacteria evolve resistance. 4.3.1

1. Explore the various media and text resources found on pages 2-10
  - a. Multimedia Links: page 2
  - b. Article 1 "**Superbugs: A silent health emergency**": pages 3-6
  - c. Article 2 "**The War on Superbugs**": pages 7-10
  
2. Describe how the following terms relate to "antibiotic resistance:"
  - Mutation
  - Variation
  - Antibiotic
  - Resistance
  
3. Draw a sequence diagram to show how antibiotic resistance happens.
  
4. What might be a possible solution to antibiotic resistance?  
\*\*\*You may answer this question in 1 **thorough and detailed** paragraph that answers the following:
  - What is antibiotic resistance?
  - What is one cause of antibiotic resistance? Explain.
  - What are the solutions to the cause you mentioned?

Multimedia Links:

- a. <https://www.youtube.com/watch?v=W-WumllRPLI>
- b. <https://www.youtube.com/watch?v=znp-Ivj2ek>
- c. <http://www.eduplace.com/kids/hmsc/activities/simulations/gr6/unita.html>
- d. <https://www.npr.org/sections/health-shots/2016/09/08/492965889/watch-bacteria-invade-antibiotics-and-transform-into-superbugs>

# Superbugs: A silent health emergency

## **Bacteria are outsmarting antibiotics to an alarming degree**

BY ESTHER LANDHUIS 8:57AM, JULY 10, 2014

- 1) Bacteria and other microbes can make us sick. But there's a lurking danger with some germs that's far more frightening than a bout of food poisoning or an infected wound. Today, drugs exist to fight most of these germs. They're called antibiotics. Before these medicines came along, common infections frequently killed people. And that's where the danger lies: What will happen if antibiotics no longer kill germs?
- 2) Already some antibiotics have lost their superpowers. Many others are beginning to lose theirs. Biologists describe this problem as *resistance*. Across the globe, germs are becoming resistant to antibiotic medicines. In a sense, these "superbugs" have begun to laugh at those former wonder drugs.
- 3) But resistance is no laughing matter. As germs toughen up against drugs that are supposed to slay them, treatable conditions such as TB — tuberculosis — can spread. And surgeries that rely on antibiotics could turn from life-saving to life-threatening.

## **The threat is huge**

- 4) "Alarming levels" of drug-resistant bacteria already exist in many parts of the world. That's the conclusion of a 257-page report published in April. It was issued by the World Health Organization (WHO).
- 5) This United Nations agency, based in Geneva, Switzerland, recently reviewed how well these germ slayers perform in 114 countries. In some places, it found, antibiotics no longer work for half of all people being treated against common diseases. Those diseases include pneumonia and gonorrhea.
- 6) The Centers for Disease Control and Prevention (CDC), based in Atlanta, Ga., also has been investigating the problem. It estimates that in the United States alone, antibiotic-resistant infections now sicken some two million people each year. At least 23,000 of them die.
- 7) But even antibiotic-resistant germs that don't kill can be a problem. Their infections become harder to treat — and more expensive. Consider one estimate — \$233 million — published May 20 in the journal *Antimicrobial Resistance and Infection Control*. That's how much researchers calculated that it costs the United States each year to deal with just one resistant superbug. That germ causes a lung disease known as pneumonia.
- 8) Drug-immune bugs that flourish in the human gut can enter the environment with every flush of the toilet. Researchers discovered how big this problem is when they analyzed wastewater from 11 sites in one French city. Antibiotic-resistant bacteria tainted 96 percent of their samples. A May 1 paper in *Clinical Infectious Diseases* describes the disturbing details.

9) Some scientists have scouted for such germs in the environment. They collected superbugs at hospitals. Then they probed the germs, identifying parts of their genes that appear to make them resistant to antibiotics. Next, the researchers looked in the outdoor environment for that same genetic fingerprint of superbugs. And they turned up that superbug DNA in 71 places — from the soil and seawater to human wastes. The researchers reported their findings May 8 in *Current Biology*.

## Why it's happening

10) Drug designers have created antibiotics to kill bacteria, as well as some fungi and other germs. But sometimes, a few treated germs survive. They survive because they're stronger. Or they may have certain genetic mutations that allow them to break down the drug. They might even have evolved a way to keep the drugs from harming their operational machinery. Over time, all germs susceptible to a drug will die off. That will leave behind *only* superbugs — those microbes that medicines can't kill.

11) This is not surprising. In fact, it's quite natural. Part of evolution, it's known as *survival of the fittest*. Scientists stumbled onto the first antibiotic, penicillin, around 1930. Since then, research has produced a medicine cabinet full of additional ones. It appeared that these would make many of the worst bacterial infections ever more manageable. So, during the 1970s, drug developers began focusing on noninfectious health problems, such as cancer and heart disease. As a result, in the past 30 years, no new types of antibiotics have been developed.

12) Right now, bacteria are outsmarting antibiotics faster than developers can make new ones. And there are no signs things will change, says Stewart Cole. He directs the Global Health Institute at the Ecole Polytechnique Fédérale de Lausanne in Switzerland. Writing in the May 12 *Philosophical Transactions of the Royal Society B*, he argues that the “golden age” of antibiotic development “is a distant memory, and the likelihood of there being another seems slim.” This lack of new types of germ killers, he says, has been allowing superbugs to morph and thrive.

13) One of the most famous of them is known as MRSA (pronounced MER-sah). The letters stand for methicillin-resistant *Staphylococcus aureus*. Methicillin is a widely used antibiotic. And *Staph aureus* is a germ that can cause boils, food poisoning, toxic-shock syndrome and more. These bacteria sicken (and sometimes kill) by releasing potent natural poisons — called toxins — into the body.

14) Despite its name, MRSA is resistant to far more antibiotics than just methicillin. That makes this superbug particularly nasty in hospitals and prisons. These are places where people often have open wounds or weak immune systems. Both increase a person's chance of picking up an infection.

## Too much of a good thing

- 15) Drug resistance can develop at any time. But its likelihood climbs as the use of antibiotics increase. And this is especially true when an antibiotic is overused. That's when a doctor prescribes it for infections it has no hope of curing.
- 16) For instance, doctors sometimes prescribe antibiotics to treat an infection before they learn if the disease is caused by bacteria. If viruses are responsible, then antibiotics will be useless. The reason: Antibiotic medicines *do not kill viruses*. Yet by giving an antibiotic to someone with a viral infection, that drug will reach good bacteria living in our bodies. And over time, some of these bacteria will become resistant to the drug.
- 17) Last year, the CDC reported that up to half of the antibiotics that U.S. doctors prescribed went to people who didn't actually need them. Take, for example, someone who visits a doctor for a lingering cough. Viral infections cause most coughs. So a viral cough won't be helped by drugs and will tend to go away on its own. Yet 71 percent of the time, doctors will still prescribe antibiotics for patients coming in with a common cough, a May 21 study finds.
- 18) "I think there's this perception among both doctors and patients that coughs don't go away without antibiotic treatment," Jeffrey Linder told *Science News for Students*. Linder, who coauthored the new report, is a doctor at Brigham & Women's Hospital in Boston, Mass. He and Michael Barnett, also from the hospital, tracked the drugs that doctors prescribed during more than 3,000 U.S. clinic visits between 1996 and 2010. They reported their findings in the *Journal of the American Medical Association*.
- 19) A small number of people who visit a doctor with a cough turn out to have bacterial pneumonia. These cases do require antibiotic treatment. But Linder says doctors should easily be able to recognize these few from the hordes of people coming in with a routine, viral cough.

## Perilous profit

- 20) Antibiotic overuse also has become a problem on farms. In the United States, animals — not people — receive about 80 percent of all antibiotics. Sometimes the drugs are used to save an infected animal or prevent disease from spreading through a herd. More often, though, feed suppliers put small amounts of these drugs into the food that will be given to healthy animals. These antibiotics help speed the animals' growth. And this has boosted farmers' profits.
- 21) But using antibiotics just to beef up livestock is "a direct threat to human health," argues Kellogg Schwab. He's an environmental microbiologist at Johns Hopkins University in Baltimore, Md. Earlier, he and his coworkers detected bacteria that are resistant to antibiotics in the exhaust air blowing out of farm buildings. That suggests these superbugs can spread through the air from animals to people.
- 22) Germs that are immune to antibiotics also can hitch a ride into your body through ground beef or the chicken breast on your cutting board. Biologists have found that much of the fresh beef, pork and poultry sold in grocery stores contain bacteria resistant to antibiotics.

- 23) Even if those germs don't sicken us or cause other immediate harm, they can offload their resistance genes into other bacteria that normally live inside our bodies. Sometimes, like with the MRSA superbug, resistance is carried on circular pieces of DNA called *plasmids*. These plasmids can slip easily from one bacterial cell into another. In this way, our gut microbes can become "a reservoir of resistance," says Sharon Peacock. She's a microbiologist at the University of Cambridge in England. Later, "when we actually get sick and need an antibiotic, we may already carry a resistance gene" that may keep that drug from working, she says.
- 24) In the United States, farmers have fought against banning antibiotics as growth promoters. They say it will reduce their profits because more animals will get sick, slowing their growth. But that's not been the experience in other countries.
- 25) The U.S. Food and Drug Administration, or FDA, has proposed banning antibiotic use in healthy animals. But for more than 30 years, the livestock industry and Congress have fought such action. Recently, the FDA stepped up its efforts to end this practice.
- 26) In December 2013, FDA laid out a plan to phase out within three years the use of antibiotics on farms to boost livestock growth. Its stated reason: concern that farm use of these drugs has made more germs immune to the antibiotics needed to fight life-threatening infections in people. And that's a worry because the same germs that sicken animals often sicken people.
- 27) Antibiotic resistance is a complex and growing problem. Many microbiologists worry that the time when antibacterial medicines no longer work could be coming. Thankfully, doctors and many patients are becoming more aware of the problem. Researchers also are hard at work creating new tools to keep superbugs from taking over.

## Questions:

1. What is antibiotic resistance? Why are people worried about it?
2. What evidence supports the claim "antibiotic resistant germs are more expensive"?
3. How can antibiotic-resistant germs travel from people out into the environment?
4. Why is MRSA "particularly nasty" in hospitals and prisons?
5. Why shouldn't a person infected with a virus be treated with an antibiotic? How does mis-prescribed antibiotics add to the issue of resistant strains of bacteria?
6. Why do farmers give antibiotics to healthy animals?
7. How can the genes of superbugs spread from animals to humans?
8. How do plasmids affect the development of resistant strains of bacteria?
9. Who do you feel is most responsible for the growing concern of superbugs?

# The war on superbugs

## New innovations are exploring how to battle extra-menacing bacteria

BY ESTHER LANDHUIS 9:01AM, JULY 16, 2014

1. Antibiotics are wonder drugs. They treat a range of bacterial infections, from battle wounds and pneumonia to tuberculosis and pinkeye. But these medicines are losing their edge. Germs are becoming immune to the drugs that had been created to slay them. This dangerous trend has been emerging across the globe.
2. Consider tuberculosis, or TB. This bacterial disease infects the lungs. It has been killing people — legions of them — for most of recorded history. Today it takes the lives of some 2 million people each year. And across the globe, it remains the leading cause of death among young adults.
3. Someone with active TB need only talk, cough or sing to spew bacteria into the air. All it takes are a few TB cells to become infected. Today, another person acquires TB every second of every day, according to the U.S. National Institutes of Health.
4. Since the 1940s, antibiotics have been available to kill TB germs. Those drugs were so successful that some disease experts thought this scourge might be wiped out across the planet by 2025.
5. But that isn't going to happen. A super-TB germ began to surface. It is proving immune to one or more antibiotics. Today, cases of TB that are resistant to two or more antibiotics have shown up in 92 countries. They cause almost a half-million of these multi-drug-resistant infections each year. And because they are hard to treat, it is highly likely an infected person will spread these germs. Some disease experts worry that in the near future, TB may no longer respond to any drug.
6. Fortunately, as we show here, physicians and scientists are actively working to beat this problem with new policies and treatments.

## Getting doctors to prescribe fewer antibiotics

7. Doctors know that prescribing antibiotics drives up resistance. Yet here's one reason many of them feel they have to write so many prescriptions. They think: "If I don't give antibiotics and the patient winds up having an infection, it could be catastrophic" for that patient, says Scott Flanders. He's a doctor at the University of Michigan in Ann Arbor. "Physicians view the patient sitting in front of them as their first and foremost responsibility," he notes. Doctors often prescribe an antibiotic if they believe a person may have a treatable infection.
8. Lately, researchers have been working on a few thoughtful ways to help doctors stop prescribing antibiotics for infections they won't help.

9. Daniella Meeker of the RAND Corp. in Santa Monica, Calif., developed one of them. She works with doctors and researchers in southern California. Her team identified 15 doctors around Los Angeles who regularly treat adults. It asked half of these doctors to sign a written pledge. In it, the doctors vowed not to prescribe drugs for any illness that was likely due to a virus.
10. The signed pledge hung as a poster for 12 weeks in each doctor's exam room. That way, all patients could see it. The other doctors signed no pledge and hung up no poster. All of the doctors continued seeing patients as usual.
11. Signing that pledge was a relatively simple thing to do. Yet it had a strikingly big effect. Flu is a viral disease. And antibiotic prescriptions dropped by 20 percent during flu season. Most of the drop seemed to come from no longer prescribing antibiotics for flu. But this drop showed up only among doctors who had signed the pledge. Meeker's team reported its findings January 27 in *JAMA Internal Medicine*.
12. Another strategy makes use of hospitalists. These are doctors who work for a hospital, focusing on the care of admitted patients. Research has shown "it's safe to stop antibiotics that do not appear to be effective," Flanders notes. Hospitalists can record when antibiotics are prescribed, when the patient took them and how symptoms are progressing. They also can begin looking for signs — starting a few days after treatment has begun — that a patient may have a virus and therefore *not* need to continue use of antibiotics.
13. The CDC has proposed that hospitals routinely follow this kind of practice. A June 2013 report in the journal *Clinical Therapeutics* found that many hospitals now do this. And it's been cutting inappropriate prescriptions for antibiotics.

## **Technology and innovation**

14. But there are times when this approach won't work. For instance, some diseases such as tuberculosis "take ages to grow" in the lab, Sharon Peacock told *Science News for Students*. She's a microbiologist at the University of Cambridge in England. For such germs, it might take two months to figure out which drugs would work best. And doctors can't wait that long to start treating an infection.
15. Fortunately, help may be on the way.
16. Researchers can get a full read-out of all genes in a TB germ in just a day or two. Then they can scout for altered genes that have been linked with resistance to a particular germ-killing drug, Peacock notes in the May 29 *Nature*.
17. At a July 11 meeting in Washington, D.C., the President's Council of Advisors on Science and Technology, or PCAST, also pushed for doctors to use this approach across the United States. Explains PCAST co-chair Eric Landers, three patients may show up the same clinic with the same disease. Right now, it's impossible to know if their diseases come from the same germs or from slightly different versions — ones that may respond differently to drugs.



18. However, each bacterium's DNA "contains a record," says Landers. He's a systems biologist at Harvard Medical School in Boston, Mass. If the germs in each patient are identical, which would happen if they spread from one patient to another within a facility, their DNA "will be almost identical." But if they came from different places, small "telltale genetic differences" will show up in the germ's genes.
19. Other researchers are working to enhance how well existing drugs work. James Collins of Boston University is one of them. This bioengineer made use of phages (PHAH-zhez) — viruses that infect bacteria. His is to create phages that can help antibiotics work against even resistant bacteria.
20. Previously, his lab showed that antibiotics trigger chemical reactions that damage DNA. So his team engineered the creation of new phages. These viruses make proteins that derail the bacteria's DNA-repair system. (Proteins are the molecules that carry out a cell's activities.)
21. The novel phages can boost by 100 to 10,000 times how well an antibiotic works, the researchers reported in 2009. In essence, Collins explains, the phages re-sensitize superbugs. It's "making them vulnerable to the drug to which they've grown resistant," he says.

## **Enlisting good bacteria to fight bad ones**

22. Another problem: Doctors often prescribe broad-spectrum antibiotics. These are drugs that kill many different types of germs. But because such medicines aren't very precise, they also may kill many beneficial bacteria, including those living inside us.
23. Scientists estimate that bacterial cells in our bodies outnumber human cells by 10-to-one. And each of those bacteria — many of which keep us healthy — also may become resistant to the antibiotics. Later, those microbes may then spread that resistance to their neighbors in the body or in the environment.
24. With that in mind, Collins' team started a new line of experiments. They work with *Lactobacillus* (LAK-toh-bah-SILL-us). It is the type of good bacteria found in yogurt. Inside the human gut, these helpful bacteria can fight infections. Collins' group wants to re-engineer the genes in *Lactobacillus*. This new breed of bacteria would be able to sense when disease-causing bacteria are nearby. Then it would produce a toxic substance, one tailored to kill only one particular invader. For instance, this tweaked microbe might scout for — and attack — the bacterium responsible for cholera. Its infection causes life-threatening diarrhea.
25. Juan Borrero's team at the University of Minnesota in Minneapolis recently tried something similar. They engineered harmless lactic acid bacteria to sense and destroy a disease-causing gut bacterium called *Enterococcus faecalis* (EN-tur-oh-KOK-us FEE-kah-lis). To test if the newly modified bacteria could do their job, the researchers grew two batches of *E. faecalis*. They added their modified lactic acid bugs to one batch. And the bad bacteria in this batch only grew 25 to 50 percent as much as did those in the untreated batch. Borrero's group shared its success June 4 in the journal *ACS Synthetic Biology*.

26. Help in the fight against drug-resistant germs also might come straight from the natural environment. Scientists in Canada have just announced their discovery of a potential substance that can turn off antibiotic resistance.
27. Gerard Wright of McMaster University in Hamilton, Ontario, and his co-workers isolated the substance from a soil fungus in eastern Canada. The fungus makes a chemical that disarms a gene in certain drug-resistant bacteria. That gene had allowed the bacteria to survive certain antibiotics. The researchers described their achievement June 25 in the journal *Nature*.
28. Such findings suggest that in some cases, resistance can be switched off. And that might restore former wonder drugs into miracle cures.

## What have we learned?

29. Around 1930, Alexander Fleming was working at St. Mary's Hospital in London, England. There he discovered a mold — *Penicillium* — that killed certain disease-causing bacteria. From that mold, Fleming created the antibiotic penicillin. A few years later, a second major class of antibiotics came along, known as sulfa drugs. Together, these early antibiotics launched a new era in medicine.
30. For the first time, doctors could knock out common diseases that once killed many, from tooth decay to TB. Back then, the action of these new drugs seemed nothing short of miraculous.
31. But the miracle is fading. Antibiotic resistance is a serious problem. The high-tech approaches now being used to fight this resistance are costly. Some scientists believe they would not have been needed, at least not for a long while, if people had used antibiotics more sparingly.
32. And doctors fear — truly fear — that, despite researchers' efforts, a time may be quickly approaching when common diseases will again turn deadly, with no hope of a cure. That's why they now argue that it's the job of everyone — from scientist and doctor to patient, farmer and grocery shopper — to see that antibiotics are used when necessary, but *only* when necessary.

## Questions:

1. How have experts' thoughts on TB changed since the 1940s?
2. Why might a doctor prescribe an antibiotic for a patient that won't be helped by it?
3. How did Daniella Meeker have doctors reduce the number of antibiotics they prescribed?
4. How can researchers find out what kind of antibiotics a TB germ might be resistant to?
5. How can phages be used to combat resistant strains of bacteria?
6. What are broad-spectrum antibiotics and why are they a problem for antibiotic resistance?
7. How can *Lactobacillus* bacteria be used to combat resistant strains of bacteria?
8. Why do some scientists believe that high-tech approaches now being used to fight this resistance would not have been needed?
9. What might happen if more bacteria become resistant to antibiotics?

