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SHINING A LIGHT ON INFECTIONS: COMBINING PHYSICS AND BIOLOGY TO SOLVE A BIG PROBLEM

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YOUNG REVIEWERS:

ALESSANDRO
AGE: 11

DREW
AGE: 14

Bacteria are everywhere. Most of the time this is perfectly fine, and often it is a good thing. The bacteria in our guts help make the most of the nutrition in our food, for example. However, bacteria can also cause infections. Antibiotics are drugs that are often used to fight off infection-causing bacteria, but something worrying is happening—bacteria are becoming harder to kill. This is bad news because it means that we face a future in which infections are difficult to cure. Scientists all over the world—including biologists, chemists, engineers, and physicists—are working together to find a solution to this problem. In this article, we take a look at why infections are becoming harder to treat, and how a type of light called ultraviolet light might help.

WHY WE NEED NEW WAYS TO TREAT INFECTIONS

Our bodies are made up of trillions of tiny cells. Alongside our human cells, **microorganisms** like bacteria, which are much smaller than our own cells, inhabit pretty much every part of our bodies. It is estimated that we have just as many bacteria in and on our bodies as we have human cells [1]. Most of the time, these bacteria do not cause us any harm. However, sometimes bacteria can multiply in an uncontrolled way, causing what we call an infection. Infections can be serious enough to need medical attention. Doctors try to kill infection-causing bacteria using drugs called **antibiotics**.

MICROORGANISM

A life form that can only be seen using a microscope. Microorganisms Include bacteria, fungi, and algae.

ANTIBIOTIC

A type of medicine that kills or stops the growth of microorganisms.

The first antibiotic was developed by a Scottish biologist named Alexander Fleming [2]. He was growing colonies of bacteria to study them. One day he saw that some mold had got into his colonies, and it was preventing the bacteria from growing normally. He realized that the mold must be defending itself against the bacteria. Fleming found that the mold was secreting a liquid that killed the bacteria. This liquid was later developed into the first ever antibiotic—penicillin. Since the discovery of penicillin, many other antibiotics have also been discovered.

Although antibiotics were designed to defend *us* against bacteria, bacteria have started developing clever ways of defending *themselves* against antibiotics! Bacteria can pass these defenses on when they reproduce, through the genetic instructions in their DNA (Figure 1). Experts believe that bacterial **antibiotic resistance** is one of the biggest health problems facing the world right now. In fact, the World Health Organization predicts that, by 2050, 10 million people will die each year from antibiotic-resistant infections. This is greater than the number of people killed by cancer. As generations of bacteria become resistant to the antibiotics that we have relied on, we must think of new, creative ways to treat infections. Some scientists think the sun holds clues to fighting antibiotic resistance!

ANTIBIOTIC RESISTANCE

means some germs cannot be killed by the medicine (antibiotics) that used to work against them, making it harder for doctors to cure infections.

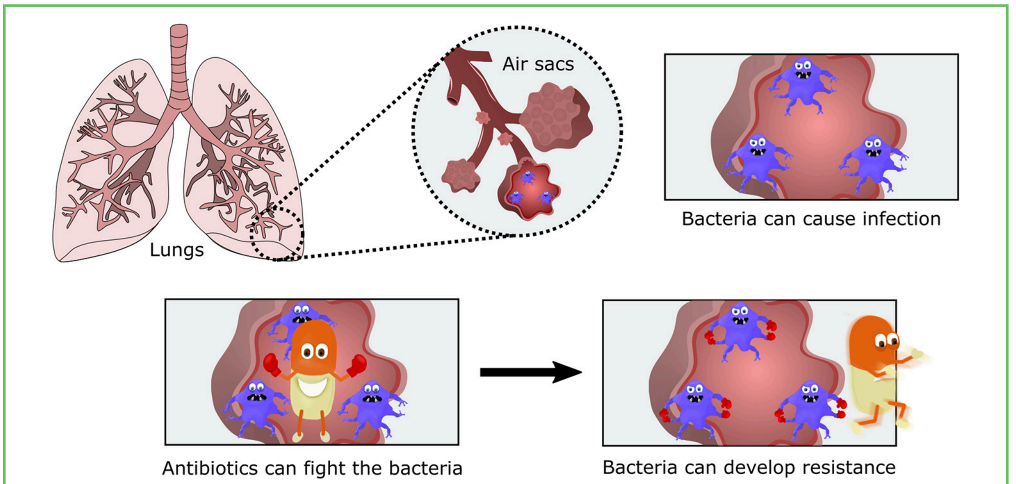

Figure 1

Figure 1

Bacteria can cause infections all over the body, but in this figure bacteria are multiplying inside the lungs. This happens in diseases like pneumonia and tuberculosis. A doctor will give antibiotics to fight off the bacteria, and normally this treatment works. However, over time, bacteria learn ways to defend themselves against antibiotics, making the antibiotics ineffective.

LEARNING FROM SUNLIGHT

The sun sends out a **spectrum** of light, which contains the entire color range of light that we can see—from blue to green to red and everything in between. Sometimes, when the weather conditions are just right, you can see these colors separate into a rainbow. This happens because water droplets in the atmosphere split up the sunlight spectrum. However, not all the light that reaches Earth can be seen by human eyes (Figure 2). Just outside the spectrum of visible light is **ultraviolet** (UV) light which, incredibly, can be seen by some animals including bees, hedgehogs, and reindeer. These animals use UV light to find food or to see better at night or in the snow. You can think of UV light as an extra "color" that is invisible to humans.

SPECTRUM

The range of colors contained in light. We can see part of the spectrum of sunlight when looking at a rainbow.

ULTRAVIOLET

A high-energy part of the spectrum of light that humans cannot see.

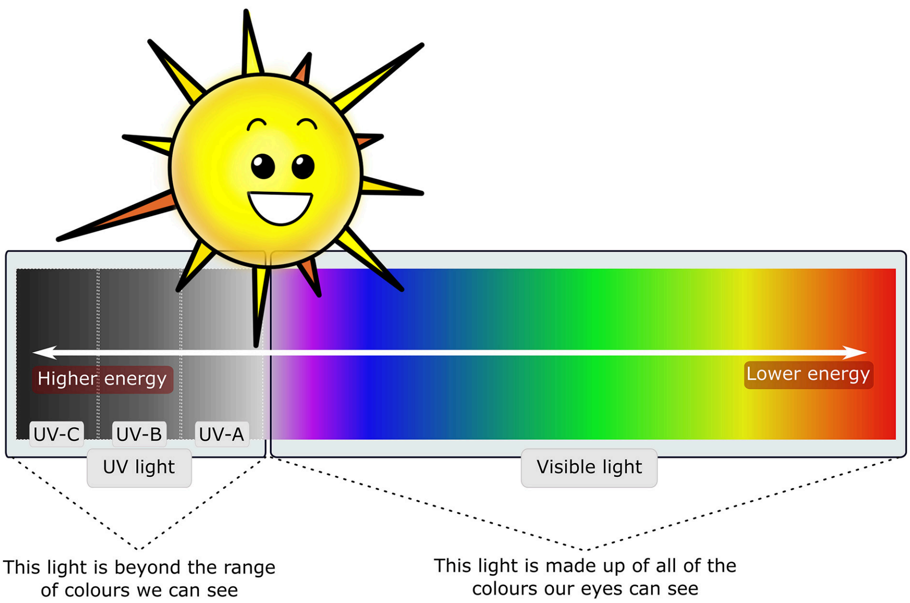

Figure 2

Figure 2

Most of the light on Earth comes from the sun. The light we can see (visible light) is made up of various colors, each with their own energy. There is also a region of light we cannot see, called ultraviolet (UV) light. It is shown here as gray but, in reality, we do not know what "color" it is because we cannot see it! UV light carries a lot of energy—so much so that it can burn your skin if you are outdoors on a sunny day.

Particles of UV light carry a lot of energy, and scientists have established that it is possible to kill bacteria with it. This suggests that UV light may be a way to treat infections or even to prevent infections—by sterilizing the air in a room, for example [3]. This would be an amazing way to combat bacterial antibiotic resistance! The problem is that UV light is also dangerous to humans, as you will learn in the next section. Scientists are wondering if there is a way to use UV light against bacteria without harming people in the process.

UV LIGHT DAMAGES CELLS

If you have ever spent too much time outdoors without sun protection, you know that it is possible for human skin to burn. The cause of this burning is the UV part of the sun's spectrum. Specifically, a type (or color) of UV light called UV-B light damages skin cells.

Sunburns do not happen immediately because skin contains a defense mechanism: a pigment called melanin that absorbs some of the sunlight's damaging energy.

The sun also emits UV-C light, with an *even higher* amount of energy than UV-B light. UV-C light carries enough energy to damage the DNA inside living cells [4], making cells unable to replicate and thus killing them. Fortunately, Earth's atmosphere stops most UV-C light from reaching us. But this means we have never evolved a defense mechanism against UV-C, like the melanin we have to protect us from UV-B light. Many other living things on Earth, including bacteria, lack a defense mechanism against UV-C.

FIGHTING BACTERIA WITH UV-C

Although UV-C light can be harmful, most UV-C light loses its strength rapidly when it hits the material in our cells. You can think of this like slamming on the brakes when driving really fast. This means that the light struggles to travel far enough into cells to reach their nuclei, where it can damage the DNA. Since bacteria are much smaller than human cells, it is possible for UV-C light to reach bacterial DNA before it loses strength, meaning that UV-C light should kill bacteria without harming human cells (Figure 3). We are in the early days of testing UV-C light to treat infections, and much more research is needed to make sure it is safe and effective.

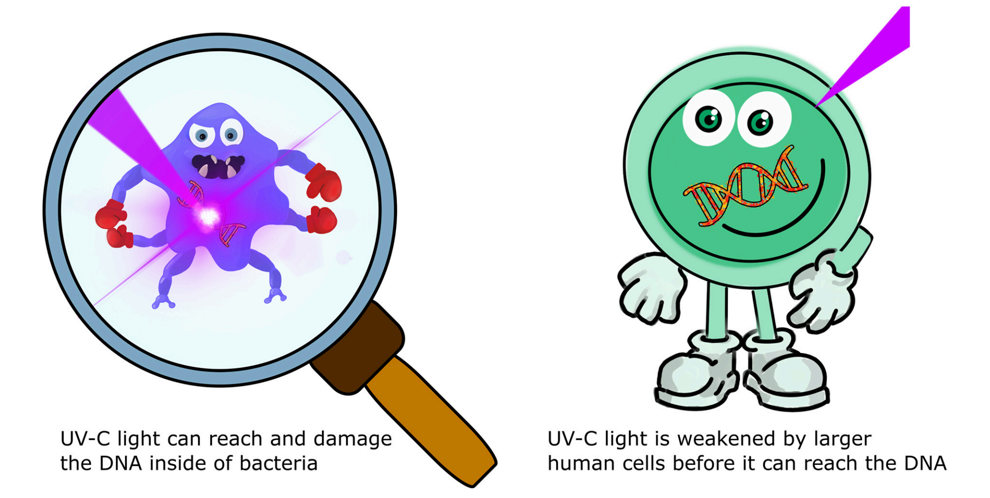

Figure 3

High-energy UV-C light can only travel a short distance before losing its strength. Since bacteria are much smaller than human cells, this means that UV-C light can reach and damage the DNA inside of bacteria without damaging human cells. Damaged DNA means bacteria cannot reproduce, and they will die. It might therefore be possible to use UV-C light instead of antibiotics to treat some types of infection.

Motivated by this knowledge, scientists are creating technologies that give out UV-C light. One example is a special type of lamp called an excimer lamp, which contains a specially chosen gas mixture that can be excited to produce UV-C light. These lamps could be used to disinfect bathrooms, for example, but they are not suitable for killing bacteria in the body.

LASER

A device that emits an intense beam of one particular "color" of light.

To kill bacteria in the body with UV-C light, special **lasers** could be developed. A laser is a device that produces a very specific color of light. Unlike the spectrum of light that comes from the sun or even from the lightbulbs in your house, a laser emits only one color. A laser is made by pumping a material with energy and then allowing the concentrated energy to come out, in the form of light. The first laser, built in 1960 by a physicist named Theodore Maiman, emitted pure red light [5]. A newspaper article at the time described it as "*a light from hell…a hundred thousand times brighter than the sun…*.". Since then, many types of lasers have been invented for lots of uses, including surgery, DVD players, and the barcode scanners in shops.

The color of a laser is determined by the material that it is made of. Maiman's laser emitted red light because he used a ruby. Physicists are working on developing laser materials that can emit the exact color of light that will kill bacteria but not harm humans. If they succeed, we may be able to treat people suffering from bacterial infections with light instead of with antibiotics.

CONCLUSION

Infections are becoming deadlier because bacteria are developing resistance to antibiotics. We must discover new ways to treat such dangerous diseases. If we combine ideas from multiple areas of science, for example ideas from biology and ideas from the physics of light, we can find creative new solutions to global problems like antibiotic resistance. We call this type of collaboration **interdisciplinary science**. We hope that a whole new generation of students, like you, will emerge with their own ideas about how to connect separate areas of knowledge in ways that can help people all over the world.

INTERDISCIPLINARY SCIENCE

When people from different areas of science work together to solve a big problem, like doctors, engineers, and biologists working together to make a new technology to treat a disease.

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YOUNG REVIEWERS

ALESSANDRO, AGE: 11
I am Alessandro and I am 11 years old. My favorite sport is Rugby, which is the sport I play. I love Rock music, I play Electric guitar and I like to play on the PlayStation with my friends. I would like to be a doctor when I grow up, because it is very important for me to help people. I really enjoyed being a Young Reviewer.

DREW, AGE: 14
Drew is a 9th grade student who lives in Washington DC. He likes science, math, playing basketball and football. He has 2 cats, 1 dog, 2 brothers and 1 sister.

AUTHORS

HELEN E. PARKER
Despite being interested in medicine from a young age, Helen ended up studying physics at university. While there, she learnt that physicists actually work on a variety of topics, including medicine. So, she decided to do her Ph.D. work at the University of Edinburgh, developing medical devices that use light to help doctors diagnose

lung diseases. After that, she moved to Sweden and developed optical fiber devices for medical diagnostics. Helen is now a researcher at Heriot-Watt University, working with lasers, lungs, and photonic lanterns. *helen.parker@nih.gov

ROBERT R. THOMSON
Robert is a professor of photonics at Heriot-Watt University, in Edinburgh, Scotland. Robert works with lots of types of lasers that do many things. Sometimes he uses them to manufacture clever technology to help astronomers measure the light coming from distant stars. Other times he uses lasers to help diagnose and treat diseases. Robert is currently leading a large team of multidisciplinary scientists who are developing antimicrobial medical technology.