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Antibiotic Resistant Bacteria, Play It to Learn It

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Antibiotic resistance in bacteria is a topic that is particularly hard to teach effectively to students taking their first biology class. Students have several erroneous preconceptions about how resistance works such as: "if you take antibiotics your body becomes immune to the antibiotic and it will not work anymore" or "bacteria get stronger". They lack the foundation to understand what happened to allow some bacteria to survive after most were killed. Also, when asked the question "When prescribed antibiotics, do you finish taking the whole dosage, or do you stop after a couple of days if you feel better?" About half say they think it is OK to not finish the antibiotics and save them for future use. This exercise can be a complement to an antibiotics lab, or as role –play in lecture. Students play the bacteria and are virtually sprayed with antibiotics multiple times; some survive the early rounds of antibiotic treatment, but only one bacterium survives all rounds. The "choice" of who lives is based on an obvious trait that some but not all of the students exhibit, symbolizing a trait that the resistant bacteria possess. After playing this game several times, and reviewing the idea of mutation, and how fast bacteria can reproduce, students will watch the mega plate Petri dish video on bacteria evolution; write their explanation of what happens; and pair-share before the whole class discussion. Since using this approach to teach antibiotic resistance, the number of students that demonstrate understanding the concept of antibiotic resistance in exams has almost doubled.

Keywords: role-play, antibiotic resistance, pair-share, bacterial evolution

Introduction

Antibiotic resistance in bacteria is a topic that is particularly hard to teach effectively to students (Cloud-Hansen *et al.* 2008), particularly those taking their first biology class.

Starting out with asking students if they have ever taken antibiotics; what antibiotics treat; and if they ever heard of antibiotic resistant bacteria or "super bugs" takes the first step in getting the facts right.

Students come in with several erroneous preconceptions of how antibiotic resistance happens. Such ideas range from "if you take antibiotics your body becomes immune to the antibiotic, so it will not work on you anymore", or "bacteria get stronger" without the knowledge of what happened to allow some bacteria to survive after most were killed.

When asked the question "When prescribed antibiotics, do you finish taking the whole dosage, or stop after a couple of days if you feel better?" about half of the students state they think it is OK to not finish the prescribed antibiotics course and save the remainder for future use.

After trying several versions of a traditional lecture to teach antibiotic resistance and bacterial evolution and having a low success rate, as measured on an essay question and a few multiple choice questions in the exam, a role-play version was attempted and has been repeated with success.

The level of comprehension of the topic almost doubled when the role-play approach was used to teach the subject.

To begin, students are asked to stand and told they are all live bacteria about to be sprayed with an antibiotic. Then the instructor pretends to spray the students with "antibiotics." Next the instructor chooses a trait most students have, for example, in NYC black or dark clothes work. Students with the selected trait are told that they are dead and to sit down. The few students with lighter clothes are told they are alive, and now have all the space and food available to divide. A second trait is selected and another spray dosage is applied and a few more are told they are "dead". After another round or two there will be only one alive, and no matter how many times the antibiotic is given, that student stays up and "takes over." The other students are asked to imagine the room full of copies of this one student, the antibiotic resistant bacterium.

This exercise is followed by questions for pair-share, such as "Would the survivor have had a chance to take over without the antibiotic?"; "What was the selective pressure that led to the evolution of this population?" or "Did the survivor already have what it took to survive the antibiotic?"

After class discussion, a short explanation of the mechanisms of antibiotic resistance in bacteria is given followed by a request for suggestions on what can be done to avoid antibiotic resistance in the population. Students will usually think about their personal use of antibiotics, and not about the extensive use in food production. A few articles on this topic may help to understand the dimensions of the problem.

This exercise may be followed by the short video, *The Evolution of Bacteria on a "Mega-Plate" Petri Dish* (Kishony Lab), to visualize the result of exposure to increasing concentrations of the same antibiotic.

The role-play approach works well in lab or lecture, and has the added advantage of getting the students to move and stay alert and engaged. This role-play approach to teach science although not completely new, has been used mostly with children (Dolenc *et al.* 2016, Cherif and Somervill, 1995) but works well with college students as well.

Student Outline

Objectives

- Relate antibiotic resistance to evolution
- Understand that some mutations are only valuable in the presence of a selective pressure
- Comprehend that antibiotic use may lead to resistance

Introduction

The accidental discovery of antibiotics in 1928 by Alexander Fleming (Fleming, 1929) changed the course of human history (Haven 1994). Many of us would not be here today because we, our parents or grandparents might not have survived infections that were successfully treated by antibiotics. Antibiotics are substances that kill bacteria or prevent them from reproducing. Antibiotic resistance can be the result of bacteria evolving enzymes that degrade antibacterial drugs; alteration of bacterial proteins that are antimicrobial targets; or changes in membrane permeability to the antibiotic (Kohanski *et al.* 2010).

Unfortunately, the antibiotics are no longer as reliable in treating many deadly and debilitating diseases as they were only decades back (Spellberg *et at.* 2008). Bacteria exposed to antibiotics may carry random mutations that cause them to no longer be susceptible. Exposed to the antibiotic often, the survivors of multiple rounds of treatments will keep increasing in number, possibly accumulate more mutations, and pass on genetic resistance to previously vulnerable bacteria. In this exercise, you will be able to experience this process as "bacteria", and see antibiotic resistance for what it is: bacterial evolution with the antibiotic as the selective pressure.

Methods and Data Collection

The instructor asks students to stand up; tells them they are living bacteria in a Petri dish; and will pretend spray these students with antibiotic. The instructor will choose some accessory or piece of clothing that most students have and asks those with the selected trait to sit down - they are "dead bacteria" killed by the antibiotic. The few survivors are told they are resistant to the antibiotic and are reproducing and now have plenty of space and food available. A second trait is picked (e.g, carrying a pencil) and with a second application of antibiotic, survivors possessing this second trait "die" and sit down. After a couple of rounds of selecting vulnerable traits and killing off susceptible bacteria with antibiotic sprays, there should be just one student / "live bacterium" standing. Students are then asked to imagine copies of this student/resistant bacterium taking all their seats as he/she keeps dividing unaffected by the antibiotic.

Ask students to try to answer these questions with the person next to them, pair-share:

- What was the selective pressure?
- Why did some bacteria survive a few dosages of antibiotics but eventually died?
- What does that have to do with taking all the prescribed dosage?

Play or assign the video *The Evolution of Bacteria on a "Mega-Plate" Petri Dish* (Kishony Lab) https://www.youtube.com/watch?v=plVk4NVIUh8 Have the students share what they saw in the video. Reinforce the concepts after the class discussion.

Materials

A spray bottle for pretend antibiotic.
Video *The Evolution of Bacteria on a Mega-Plate Petri Dish* (Kishony Lab)
https://www.youtube.com/watch?v=plVk4NVIUh8

Notes for the Instructor

In this role-play exercise, choosing the trait that most students have in common for example, "wearing a dark color on at least half of your clothes (works well in NYC) will determine what bacteria die on the first round of antibiotic application. A trait that only a few students have, such as a hat for example, will allow them to survive a few rounds. A particular print or color will determine what student is fully resistant and survives all rounds, representative of a mutation that was there already.

The number of rounds, and how to keep track of how many bacteria survived each round may vary with an instructor's preferences. Four rounds are enough to get students to understand the importance of eliminating partially resistant bacteria and why it is important for a patient to finish a prescribed dosage even after the patient is already feeling well. To make the case more relevant, you may choose the species of bacteria your students represent and identify a specific antibiotic that is to be applied.

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About the Authors

Catarina Mata teaches majors Biology, non-majors Biology and Plant Biology at the Borough of Manhattan Community College since 2007. She did her PhD at Utrecht University, The Netherlands, in Plant Ecophysiology. She is interested in plant ecology and physiology, and on pedagogy that will engage her students to learn. She does research with students on plant biology and environmental topics related to sustainability.

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