Antibiotic Resistance and Bacterial Evolution

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Introduction

We are surrounded by bacteria. Bacteria live all around us, on us, and even inside of us! In fact, some scientists estimate that there are as many bacterial cells in a person's body as there are human cells. The population of bacteria that lives inside of our bodies makes up our **microbiome**. We still have a lot to learn about the microbiome and its impact on human health, but we do know that some bacteria influence our health in a positive way and others are capable of causing infection and making us sick. In this lesson, you will explore how the use of antibiotics is leading to the formation of populations of resistant bacteria. Can new research help us avoid an antibiotic crisis?

What To Do

STOP & read Science Bite:

Antibiotic Resistance and Bacterial Evolution: Using a Big Tool to Visualize a Big Problem

After reading the Science Bite, answer the analysis questions below, stopping to watch the video when instructed.

Analysis Questions

1. Think back to the video from the beginning of class about the *Contagion* billboard. Write down three observations about this billboard.

2. In your own words, describe why the evolution of resistance to antibiotics is a major problem facing society today.

3. The MEGA-plate contains bands of antibiotic at different concentrations. Why didn't the researchers use a set of normal Petri dishes, each containing a different concentration of antibiotic, for their experiments?

4. **Connect to the Big Question**.What is the major advantage of studying evolution in bacteria instead of an organism like a human? (Hint: think about what it is possible to observe in each case).

5. The experiment described uses only one type of bacteria, *E. coli*. When grown on the MEGA-plate they all look the same. Are they? Explain your reasoning.

6. Many people think that mutations are always bad for the organism. Explain why that is not correct, using the bacteria used in MEGA-plate experiment as an example.

& watch the video:

The Evolution of Bacteria on a "Mega-Plate" Petri Dish

Observe **Figure 1** below and read the caption.

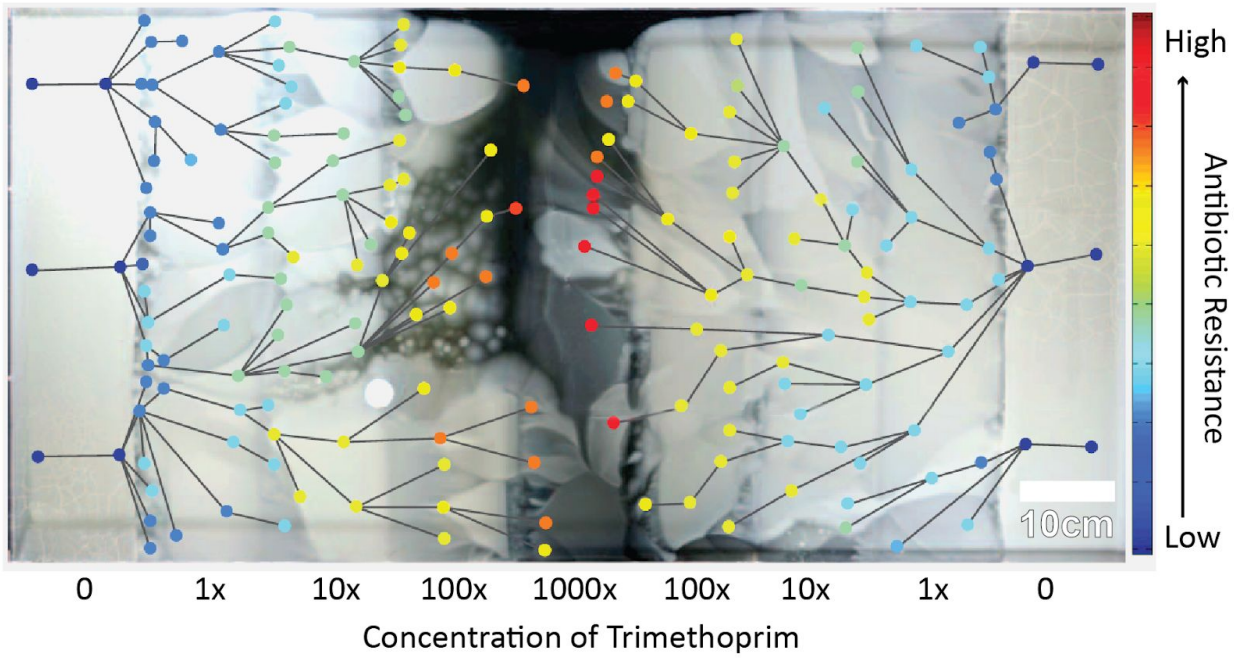

Figure 1. Evolution in the MEGA. Here we are looking down on the MEGA-plate from above 11 days (280 hours) after the start of the experiment. The concentration of the antibiotic trimethoprim increases toward the center of the MEGA plate. The left and right edges of the plate contain no antibiotic, and the center of the plate contains a high dose, 1000-times what would ordinarily prevent the growth of an *E. coli* bacterium. Bacteria were introduced on the left and right edges of the plate, essentially letting the researchers run the experiment twice at the same time. After the study was completed, the lines and colored dots were added to the image, modeling how evolution of resistance to trimethoprim occurred. The colored dots represent colonies of *E. coli*. Each dot is colored based on that colony's level of resistance to trimethoprim. A dot that is dark blue means the colony in that location is not resistant at all, while dark red means the colony is very resistant. Lines connecting the dots indicate the movement of the bacteria across the plate. *Source:* Figure modified from Baym, *et al.* 2016.

The MEGA plate was stained black so that the cloudy white color of the bacterial colonies would show up easily.

7. Did all the bacterial colonies grow at the same rate? Use evidence from the figure to support your conclusion.

To confirm their observations, the scientists created a MEGA-plate with a different antibiotic. Observe **Figure 2** below and read the caption.

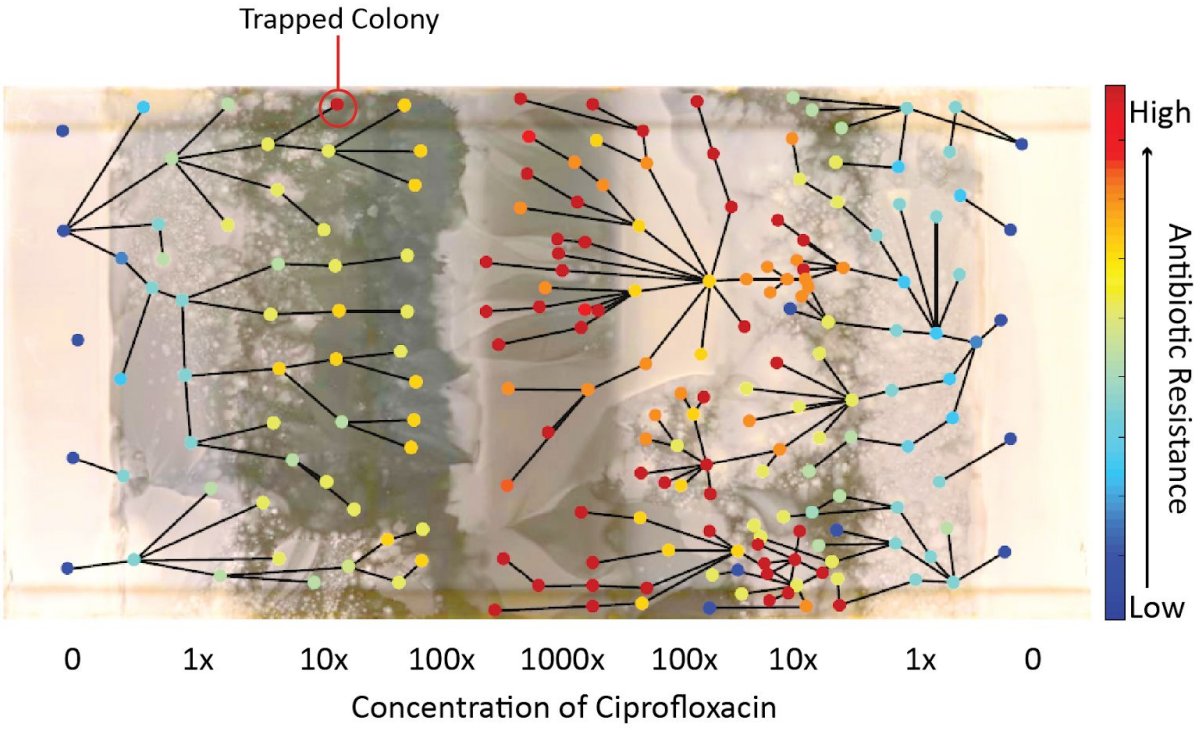

Figure 2. Evolution in the MEGA. Here we are looking down on the MEGA-plate from above after 14 days (340 hours) into the experiment. The set-up of the experiment is similar to the one in Figure 1, only instead of the antibiotic trimethoprim, the antibiotic ciprofloxacin is used. *Source:* Figure modified from Baym, *et al.* 2016.

8. The results of this experiment are very different from those presented in Figure 1 with Trimethoprim. Notice that some of the colonies with the highest resistance (dark red) are "trapped" at the 10x antibiotic concentration and never make it to the middle of the plate.

a. What do you suppose is preventing them from moving?

b. Occasionally, bacteria evolve to having a lower antibiotic resistance level than previous generations. How could that occur?

You are on the team of scientists studying the MEGA-plate. You take samples of antibiotic resistant bacteria from the MEGA-plate, and put them onto clean Petri dishes with no antibiotic. You observe that some of the growth rate of some bacteria that evolved antibiotic resistance has slowed down compared to the starting population. Confused by your results, another scientist says “You probably made a mistake and sampled the bacteria without resistance, because natural selection ensures that only the fittest and fastest bacteria survive. Therefore the bacteria that evolved resistance must grow more quickly than the bacteria that didn’t.”

9. Think about what you have just read.

a. What is wrong with this claim made by the other scientist?

b. If the bacteria that evolved resistance grew at a slower rate, then why did they survive?

c. Based on the evidence from the study, and your understanding of evolution, which of the following claims do you support? Explain your reasoning.

Claim 1: Bacteria with a higher resistance to antibiotics are better than bacteria with a lower resistance to antibiotics in any environment.

Claim 2: Bacteria with a higher resistance to antibiotics have an advantage in certain environments over bacterial with a lower resistance to antibiotics.

10. In the video, the scientist says the following: “When the mutants reach the next boundary, they too have to pause and develop new mutations.” What is wrong with this statement? How would you have said it differently?