Teaching and Learning Module on Antibiotic Resistance in Bacteria

Learning Objectives:

1. Apply the general definition of Natural Selection to explain the evolution of antibiotic resistance in bacteria populations.
2. Use data (evidence) to make claims about variation, fitness, selection and evolution in populations.

Before class, students work on a Just in Time Teaching (JiTT) assignment that involves reading an article on the evolution of antibiotic resistance in bacteria populations and answering two questions (below).

JiTT: Answer the following questions after reading the paper by Genereux and Bergstrom (2005).

[Q1 - 2 Points]: "Some mutations change the bacterial proteins that are often the targets of antibiotic treatment. (...) Consider a random mutation that changes a bacterial protein..."

1a. How does a random mutation cause a change in a protein?
1b. How can such a change affect fitness in bacteria populations?

[Q2 - 3 Points]: Bacteria carrying a mutation that confers resistance to a given antibiotic have increased fitness, whether the antibiotic is present or not.

Is this statement correct or incorrect? Explain (i.e., provide adequate warrants for your claim).

In Q1, we ask students to explain a quote from the article. We want students to think about the concepts and connections that are implicit in this statement (e.g. what is a mutation? What is the mechanism leading from a mutation to a change in a protein?). We also want students to think about the impact of a mutation at higher levels of biological organization (individuals and populations).
In Q2, we ask students to make a claim (whether a given statement about fitness is correct or not) and to support it with appropriate reasoning. Students have already learned the definition of "fitness" and discussed it in other cases. We want, now, to solidify the understanding that fitness is dependent on the environment an organism is in.

Slide 1:

Antibiotic resistance

- Do you use antibacterial soap? Why or why not? Discuss in your groups.

Engagement slide: students are invited to explain why they use antibacterial soap or why not. Students begin the discussion in small groups, then some groups report out.

Slide 2:

Clicker Question:

Mutation acts <u>directly</u> on ....

A. DNA
B. RNA
C. Amino acids
D. Protein
E. Phenotype

JiTT processing:

This clicker question relates directly to Q1 on the JiTT assignment.
We want to make sure that students understand what biological molecule is the DIRECT target of mutations.
We only proceed once we make sure that "A" is the majority choice.

Clicker Question:

Mutation acts <u>directly</u> on ....

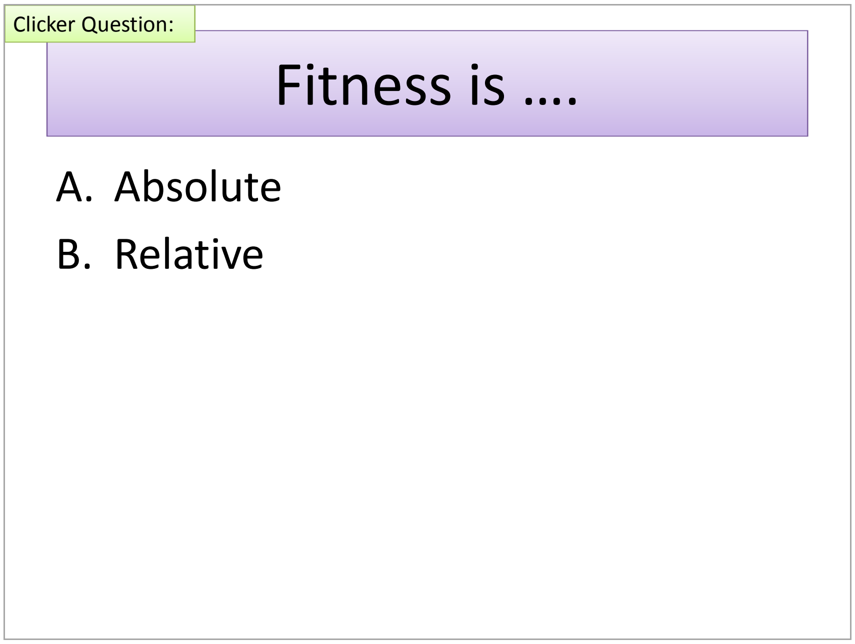
A. DNA
B. RNA
C. Amino acids
D. Protein
E. Phenotype

MUTATION changes a protein –

JiTT processing:

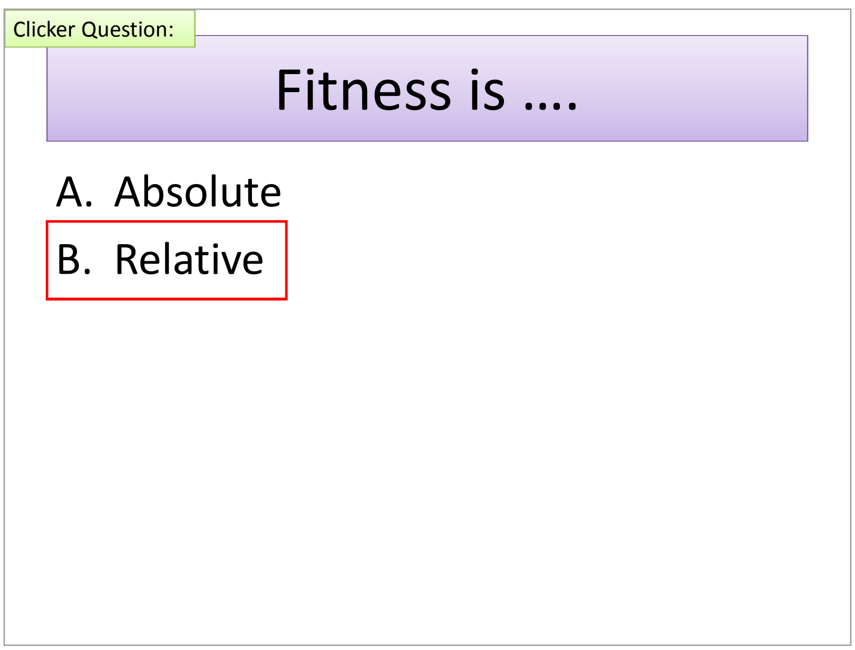
Now we go back to the statement in the article that "mutation changes a protein".
Is this a true statement?
Yes, but something important (the biological mechanism) is only IMPLIED.
We take 2 minutes to allow students to make the link between gene and protein (genotype and phenotype) explicit.

Slide 3:



JiTT processing:

This clicker question directly addresses the concept of fitness, which students reasoned about in Q2 on the assignment.
We review what absolute and relative mean (these concepts were in the article students read).



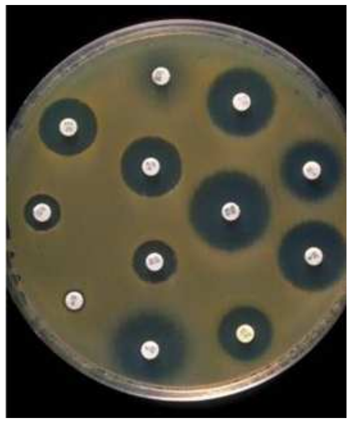
JiTT processing:

Why is fitness relative? Because it depends on the environment.
We discuss briefly the students' answers to Q2. Before proceeding, we clarify the concept that traits that are beneficial and lead to increased fitness in certain environmental conditions may be neutral in others.

Slide 4:

Antibiotic Resistance in Bacteria: an experimental approach

1. Redraw this model and label:
   a) Bacterial lawn
   b) Inhibition zone
   c) Discs of antibiotics
2. Label a point on the model where bacteria are likely most resistant to an antibiotic.



A population of bacteria growing as a uniform "lawn" on an agar plate can be exposed to multiple different antibiotics. We can do that by soaking small paper discs in different antibiotics, and placing them on the plate. Each antibiotic will diffuse in all direction from the paper disc, and create a round "zone of inhibition", where it will inhibit growth of sensitive bacteria. Students observe this figure, redraw it on their notebooks, identify important elements, and interpret the meaning of zones of inhibition around paper discs (what does the absence of a zone of inhibition mean?)

Antibiotic Resistance in Bacteria: an experimental approach

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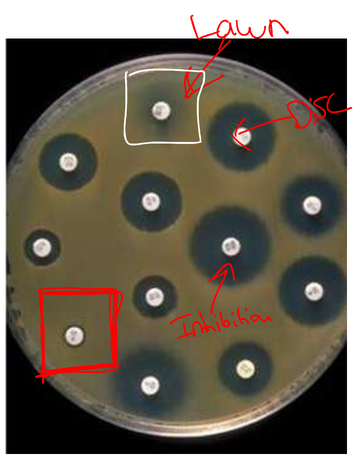
ANTIBIOTICS ⇒ environment



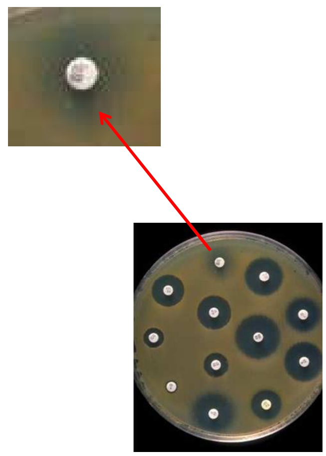
Students report out, and we label the slide to reflect their answers.

We point out that the different antibiotics, in this case, determine local variations in the environment bacteria are exposed to.

Slide 5:

Variation and Antibiotic Resistance.1

1. Do you think there is variation among these bacteria? Explain.



We zoom in and look more closely at one of the discs; we elicit a classroom discussion regarding the appearance of the bacterial lawn around this specific paper disc.

Students work on building a scientific explanation as an argument (a <u>claim</u> based on <u>evidence</u> and supported by <u>reasoning</u>).

Variation and Antibiotic Resistance.1

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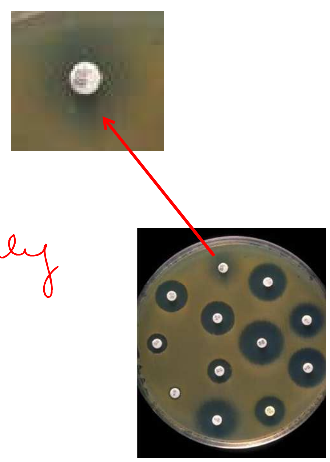


There is a halo : only SOME bacteria survive

Students observe that around this disc there is not a zone of inhibition with sharp edges, rather a gradual halo (<u>evidence</u>).

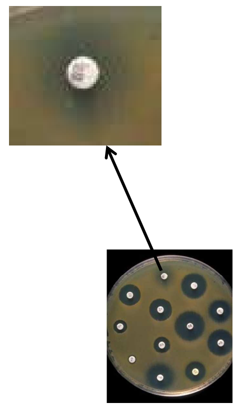
The interpretation of this evidence is that some bacteria are surviving that antibiotic while others are not (<u>reasoning</u>).

Students conclude that there is <u>variation</u> among the bacteria (claim).

Slide 6:

Variation and Antibiotic Resistance.2

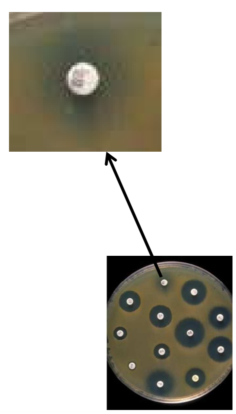
1. Do you think there is variation among these bacteria? Explain.
2. What is the origin of this variation?
3. Is the variation heritable?



Once we agree that there is variation between individual bacteria, we ask that students discuss briefly in their groups (2 minutes) what the origin of such variation is, and if the variation is heritable.

Variation and Antibiotic Resistance.2

1. Do you think there is variation among these bacteria? Explain.
2. What is the origin of this variation? a mutation present in a few individuals
3. Is the variation heritable? yes



Groups report out: we write down their answers.

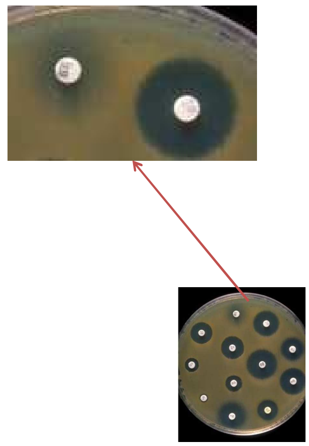
The origin of variation is in mutations that occurred by chance in some bacteria; because mutations are in the bacteria genetic material, they are heritable.

Slide 7:

Fitness and Antibiotic Resistance

Does the environment vary across the Petri plate?

Are these bacteria equally *fit* in all environments?

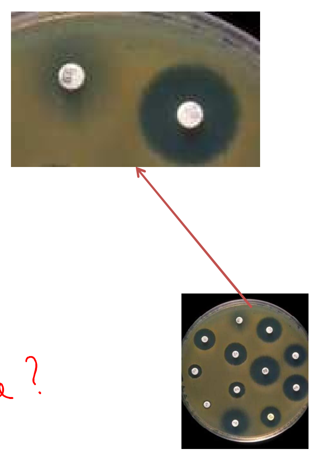


Students work on building another argument based on evidence, to answer the questions on the slide.

Fitness and Antibiotic Resistance

Does the environment vary across the Petri plate? yes

Are these bacteria equally *fit* in all environments? no evidence?

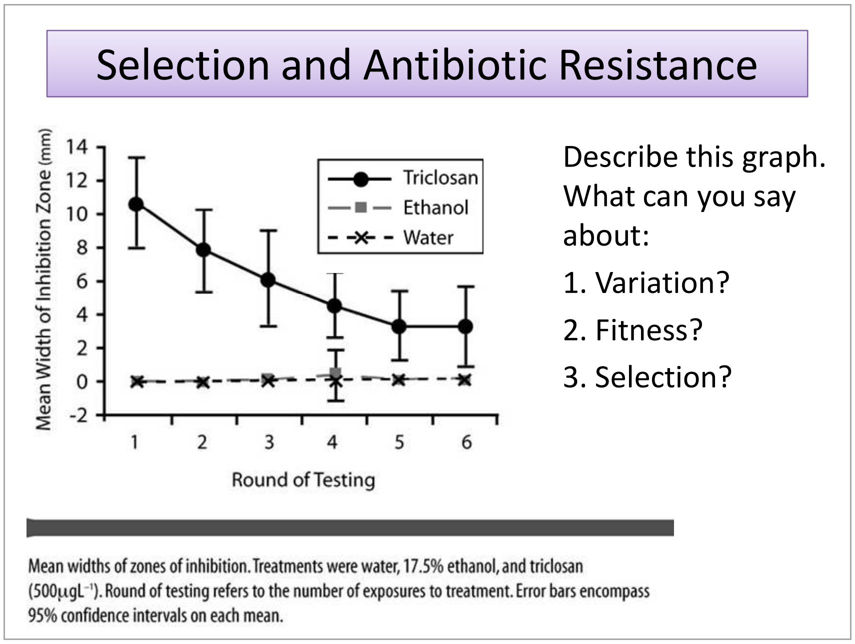


Evidence: the environment varies across the plate, due to the presence of multiple different antibiotics;

Reasoning: areas that are sufficiently far from the paper discs are likely to be antibiotic-free, because the bacterial lawn there is undisturbed. Areas that are close to the discs are zones in which bacteria either die or do not reproduce enough to create a lawn.

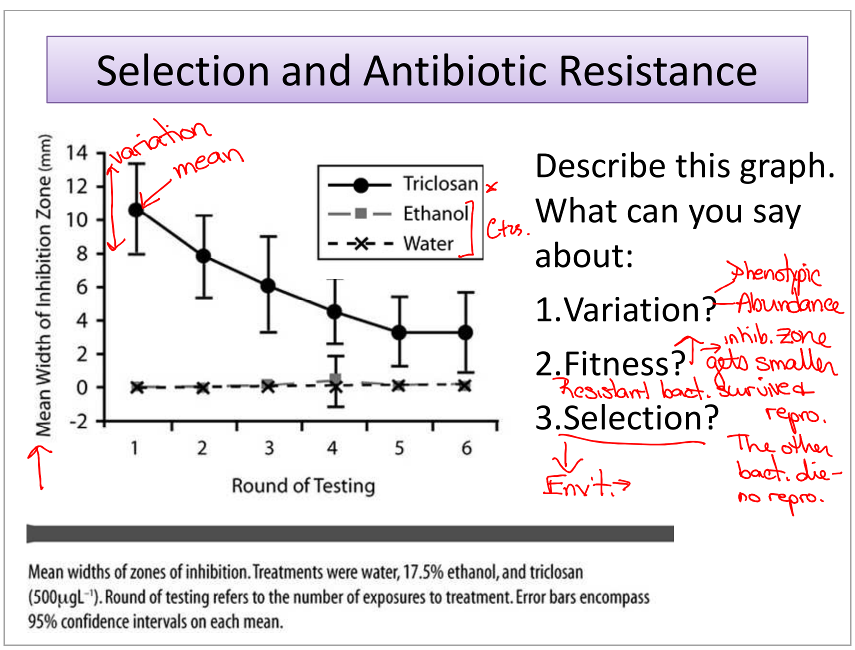
Claim: the fitness of these bacteria varies with the location on the plate (e.g. whether or not they are exposed to an antibiotic, and which antibiotic it is)

Slide 8:



Triclosan is the active ingredient of some antibacterial soaps. Bacteria can become resistant to Triclosan and "in vitro" experiments can illustrate the selection of resistant bacteria in the presence of this substance.

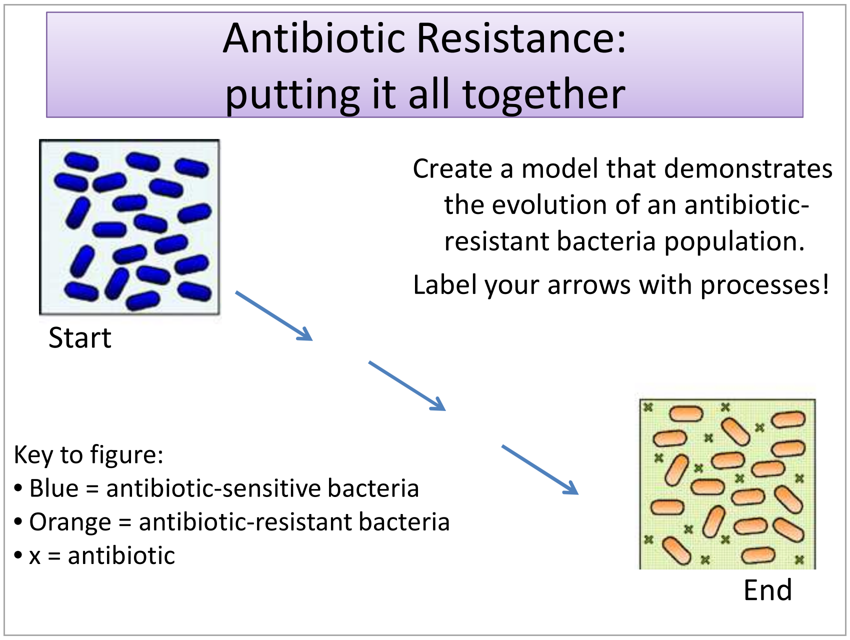
Students, now, can interpret this graph (from an article by Welden and Hossler, 2003). They work for a few minutes in groups to answer the questions on the slide, then one or two groups are called to report out.



Questions for classroom discussion:

- *What do you think the experimenter did between rounds of testing?*
- *Which population of bacteria did she sample?*
- *What occurred in the bacteria populations between rounds of testing?*
- *Why did the experimenter also use ethanol and water?*
- *Why are there error bars? What do they mean?*

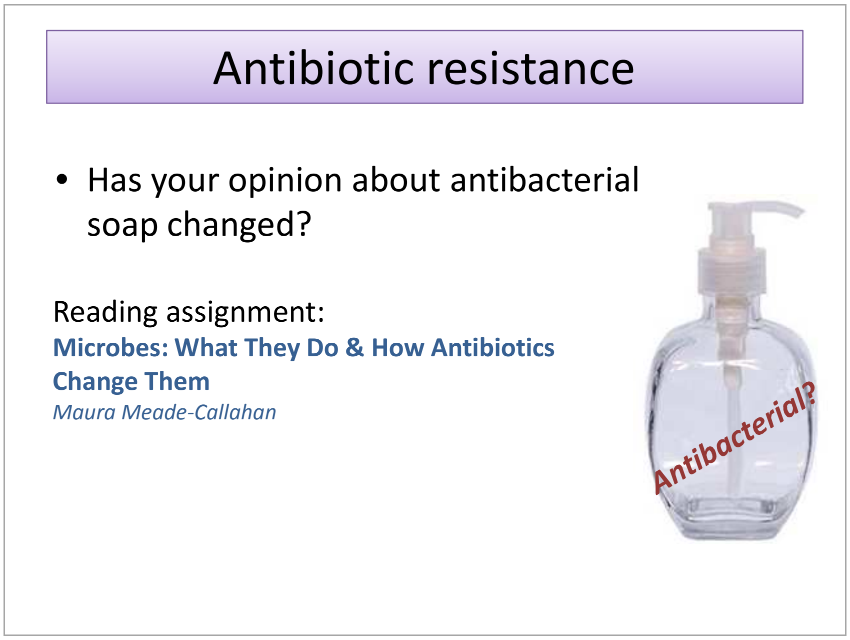
Slide 9:



Students demonstrate their understanding by modeling the evolution of an antibiotic-resistant bacteria population, starting from a population of bacteria that are sensitive (non-resistant).

At this point in the semester, students know that by "model" we mean a box-and-arrow diagram in which boxes represent elements or parts of the system (Structures) connected by arrows indicating relationships or processes (Behaviors) . Students' models need to convey the overarching output (Function) of the system, which in this case is the evolution of antibiotic-resistant bacteria populations.

Slide 10:



Book-end: wrap up the class meeting by returning to the discussion-starter (the issue of whether or not we should use antibacterial soap and why).

References:

Genereux, D. and Bergstrom, C. T. (2005). Evolution in Action: Understanding Antibiotic Resistance. In: Evolutionary Science and Society: Educating a New Generation. J. Cracraft and R. W. Bybee, Eds., AIBS/BCSC.

Welden, C. W. and Hossler, R. A. (2003). EVOLUTION IN THE LAB: Biocide Resistance in *E. coli*. The American Biology Teacher *65*: 56-61.