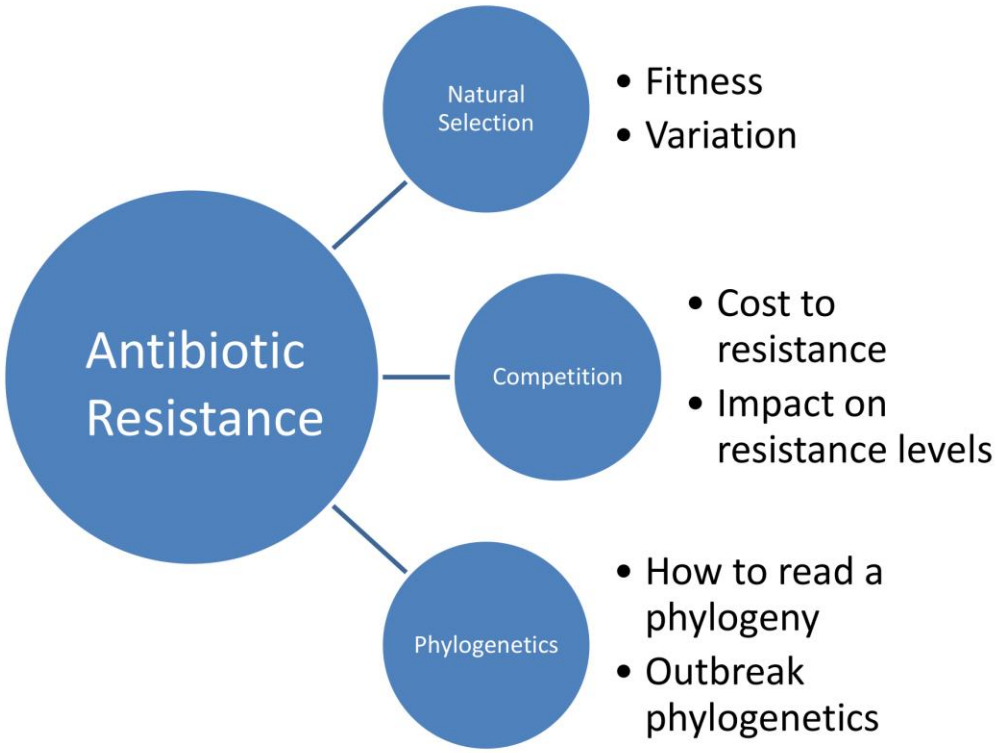
Fundamentals of evolution are important in a student's understanding of biology and the world around them. By placing key concepts in the context of antibiotic resistance, students are able to relate to these topics and see their importance in daily life.

Key concepts:



Natural Selection in the context of antibiotic resistance

Students will learn the four main principles of natural selection:

- Heritability
- Variation
- Selection
- Fitness and Survival of the fittest

It is then important to place these principles in the context of antibiotic resistance. Below are resources for accomplishing this.

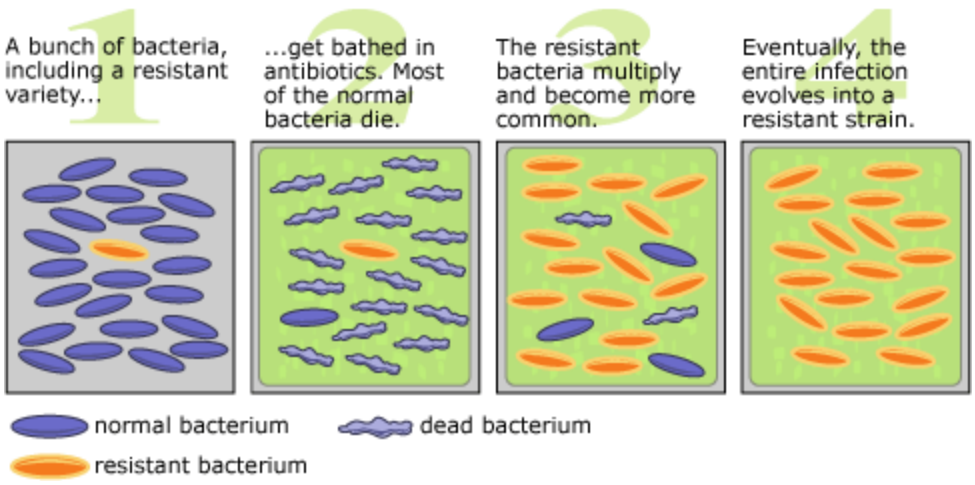


Image credit: University of California Museum of Paleontology's Understanding Evolution (http://evolution.berkeley.edu)

Evolution in Action -> Antibiotic resistance
https://www.youtube.com/watch?v=plVk4NVIUh8

Ted-Ed talk by Kevin Wu on causes on antibiotic resistance:
https://www.youtube.com/watch?v=znnp-Ivj2ek

Depending on the level/focus of your course, you may also want to cover the four main mechanisms of antibiotic resistance:

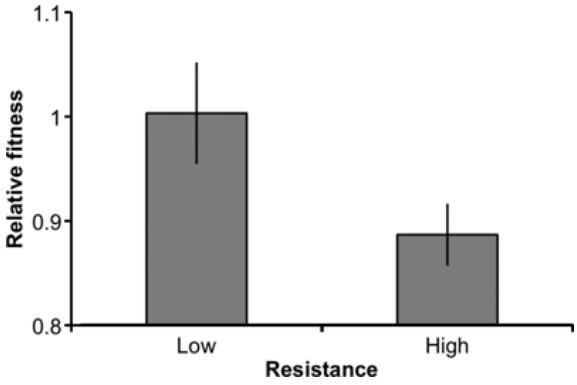
- Enzymatic degradation of antibacterial drugs
- Alteration of bacterial proteins that are antimicrobial targets (reduce binding capacity)
- Changes in membrane permeability to antibiotics (porin)
- Modify metabolic pathways to circumvent antibiotic effect (efflux pump)

Understanding these mechanisms allows students to research the effects of the antibiotic resistance genes they identify during the bioinformatics project. Additionally, if they are told the mechanism of a specific antibiotic, they can predict which mechanism of resistance is likely to evolve in response.

Competition

Along with natural selection, understanding the role of competition is important in a student's understanding of antibiotic resistance and evolutionary biology.

In many instances we see that traits that confer resistance could lower other fitness components. Resistant microbes might be less fecund, poorer competitors, show slower growth, and be slower to reproduce.



Hall et al. 2011 Ecology Letters

Low levels of drug-resistant microbes (resistant through natural variation as learned in the natural selection unit) are kept in check through competition with drug-sensitive microbes. Antibiotics kill the drug-sensitive microbes and with the competition removed, drug-resistant microbes survive and increase. If antibiotic use ceases, the microbial population may over time lose its resistance due to the costs of resistance previously discussed. Understanding the impact of competition can teach students why resistance levels are typically low, how populations may evolve resistance once competition is removed, and why the disuse of antibiotics can eventually lead to susceptible microbial populations.

Phylogenetics

Most courses will likely need to start with the basics and teach phylogenetics terminology:

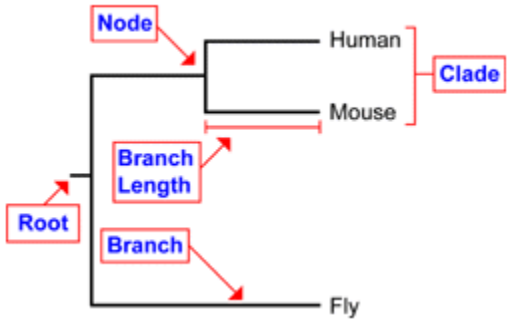
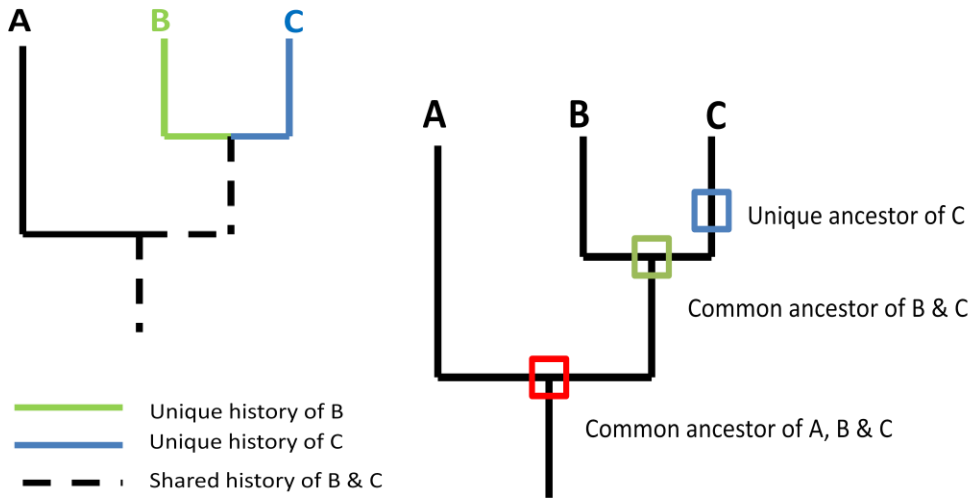


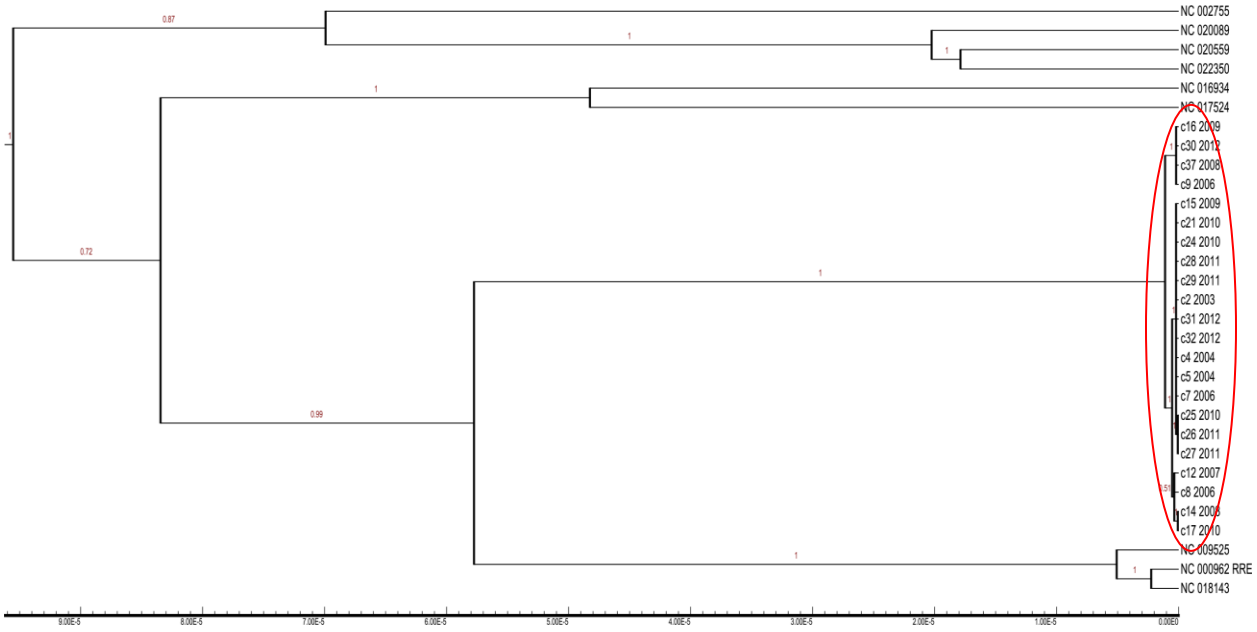
Image credit: NCBI

The below images may also be useful in helping students understand how to read a phylogeny:



Another resource for teaching phylogenies is:
http://epidemic.bio.ed.ac.uk/how_to_read_a_phylogeny
This resource contains trees relevant to disease and provides an introduction to understanding the spread of disease using phylogenetics.

After the students learn the basics of reading phylogenetic trees, they can be introduced to outbreak phylogenies. Below is an example:



In an outbreak, the pathogen spreads rapidly resulting in relatively low genetic differentiation among patients/samples. This results in very short branch lengths, sometimes represented by a vertical bar containing multiple samples. In the above example, the outbreak is shown in the red circle.

Information specific to hospital outbreaks and project introduction can be found in the "Hospital_outbreak_resources.pdf"