This Module for Interactive Teaching (MINT) may be found online at
https://ivv.rit.edu/nh-mint.php

Natural Selection

- Mutations exist prior to selection

Contents:

MINT Learning Objectives

- Explain that mutations are random events that happen independent of selective events.
- Explain that mutations are changes in the DNA of an organism.
- Describe how natural selection acts on genotype through phenotype.
- Recognize that individuals in a population may have variation within their genome.
- Recognize there may be more than one genotype that leads to a given phenotype.
- Individuals in a population may have variation within their genome
- Describe how natural selection acts on genotype through phenotype.
- Articulate how and why antibiotic selection is analogous to natural selection.
- Explain that fitness is a function of phenotype.
- Recognize that experimental controls allow the experimenter to consider variables in isolation from other variables
- Recognize that experimental controls may serve different purposes.
- Design appropriate controls, and explain why, as part of an experimental design process.
- Identify sources of error and/or explain unexpected laboratory results by analyzing data from control experiments.
- Troubleshoot when experiments don't go to plan and confirm conclusions when things do go to plan, using control data.

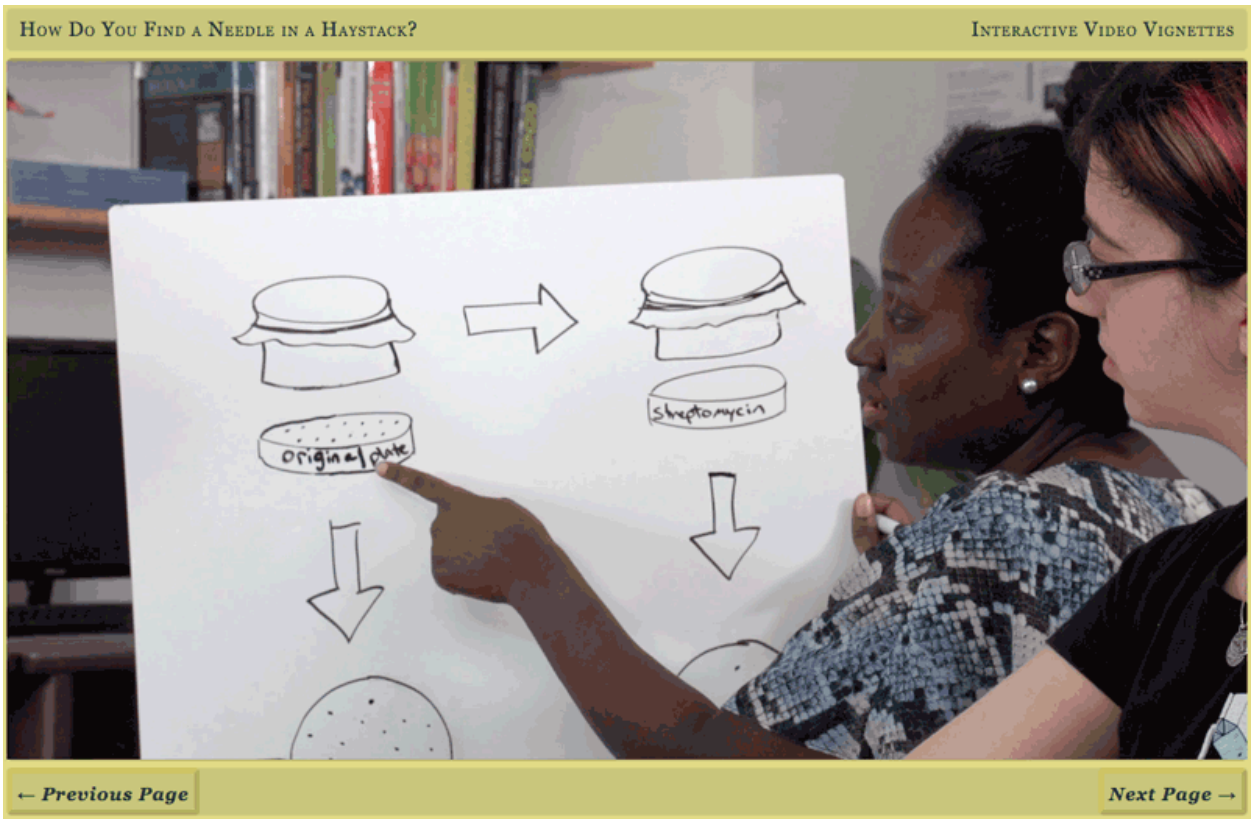
National Standards Alignments:

- Vision and Change Core Concepts and Competencies (http://visionandchange.org)
  - Core Concept:
    - Evolution: The diversity of life evolved over time by processes of mutation, selection, and genetic change.

        - Information Flow, Exchange, and Storage: The growth and behavior of organisms are activated through the expression of genetic information in context
    - Core Competencies:
        - Ability to apply process of science: Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.
        - Ability to use quantitative reasoning: Biology relies on applications of quantitative analysis and mathematical reasoning.
        - Ability to understand the relationship between science and society: Biology is conducted in a societal context
- Biocore Guide (Brownell et al., https://doi.org/10.1187/cbe.13-12-0233)
    - Evolution: Multiple molecular mechanisms, including DNA damage and errors in replication, lead to the generation of random mutations. These mutations create new alleles that can be inherited via mitosis, meiosis, or cell division.
    - Evolution: Mutations and epigenetic modifications can impact the regulation of gene expression and/or the structure and function of the gene product. If mutations affect phenotype and lead to increased reproductive success, the frequency of those alleles will tend to increase in the population.
    - Information Flow: Information stored in DNA is expressed as RNA and proteins. These gene products impact anatomical structures and physiological function.
    - Information Flow: In most cases, genetic information flows from DNA to mRNA to protein,but there are important exceptions.
    - Information Flow: Individuals transmit genetic information to their offspring; some alleles confer higher fitness than others in a particular environment.
- American Society for Microbiology Curriculum Guidelines (https://www.asm.org/)
    - Evolution: Mutations and horizontal gene transfer, with the immense variety of microenvironments, have selected for a huge diversity of microorganisms.
    - Information flow: Genetic variations can impact microbial functions (e.g., in biofilm formation, pathogenicity and drug resistance)
- Next Gen Science Standards (http://www.nextgenscience.org/)
    - All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS3- 1.)
    - All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS -LS1-1.)
    - Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the

similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)
    - Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2),(HS-LS4-3)
    - The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)
    - Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)
- Process of Science Skills, Pelaez, N, *et al*. "The Basic Competencies of Biological Experimentation: Concept-Skill Statements" (2017). PIBERG Instructional Innovation Materials. Paper 4. http://docs.lib.purdue.edu/pibergiim/4
    - Posing Problems
        - Library research important
    - Generating hypotheses
        - Unexpected results used to modify hypothesis
        - New knowledge incorporated with old to form new hypotheses
    - Designing experiments
        - Identification of proper controls and comparisons
    - Testing hypotheses
        - Multiple samples required due to variation within a population
    - Interpreting/evaluating data
    - Determining follow-up

Interactive Video Vignette Information



IVV Title: *How do You Find a Needle in a Haystack?*

IVV URL for students: https://ivv.rit.edu/NH/2/
Copy the URL to the Clipboard. Either paste it into an email to your students, or use it to create a link in your course management system.

IVV description:
A student is working on an undergraduate research project in biology involving cloning a gene in bacteria. She is not getting the results she expects and must investigate more deeply. In the end, she learns how an antibiotic selects for resistant bacteria that are already present at low numbers in a population, which clarifies how natural selection works and why antibiotic resistant bacteria are a major health issue.

Novice Ideas and IVV Learning Goals

Novice Ideas

- Selective agents cause mutation (e.g. antibiotics cause antibiotic resistance)
- Mutation always results in a bad or negative result.
- The term “mutation” can be used to indicate any type of change.
- A phenotype is the result of a particular genetic change, not by multiple possible genetic changes
- Evolution cannot be demonstrated or proven in a lab.

- Macroevolution is the only kind – evolution happens on big time scales, it is slow.
- Controls must have negative results.
- Controls are separate from experimental samples and do not contribute to data analysis (students do not think controls provide useable information).

Ideas addressed in the IVV

- Genomic variation exists in a population prior to selection.
- Inclusion of antibiotics in growth medium is a selective agent.
- Changes in the genomic sequence may result in a phenotype such as antibiotic resistance.
- Antibiotic resistance may be due to plasmid or due to genomic changes.
- Antibiotic selection is analogous to natural selection.
- Identify proper negative control for cloning experiment.
- Controls that don't have expected results assist in interpretation of experimental data.
- Controls allow you to distinguish between alternative hypotheses.

Recommended In-class Curricular Material

Please see the MINT FAQ (https://ivv.rit.edu/FAQ.php) for general information on the use of MINTs and IVVs with your class. The following curricular materials are provided as examples of resources that may be used in class to further student learning towards IVV and MINT learning objectives.

- Hoefnagels M, Taylor MS. Boost your evolution IQ: An evolution misconceptions game. *CourseSource*. 2016. https://doi.org/10.24918/cs.2016.12
- Govindan, B. Bacterial Survivor: An Interactive Game that Combats Misconceptions about Antibiotic Resistance. J Microbiol Biol Educ. 2018. doi:10.1128/jmbe.v19i3.1675

Assessment Question Information:

The research team has developed multiple select questions for assessing IVV effectiveness. Please contact the research team (https://ivv.rit.edu/about.php) if you are interested in assessing IVV use in your course.

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