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To accompany the peer-reviewed article by Jim J. Bull, Ph.D.:
"Evolutionary Biology: Technology for the 21st Century" (August 2000)
http://www.actionbioscience.org/newfrontiers/bull.html

Applied Evolution: How Will We Get There from Here? (January 2003)

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Grades & Levels:

- **Handout 1:** high school (general-advanced)
- **Handout 2:** high school (advanced/AP) – undergraduate (year 1)

Time Recommendations:

- 1-2 class periods for article review and discussion questions
- 1 class period for basic natural selection simulation (handout 1, part A)
- up to 1 week for group projects (either handout) or lab experiment (handout 2, part B)

NSES (USA) Content Standards, 9-12:

- NSES 1.2. Unifying Concepts & Processes: evidence, models, and explanation
- NSES 1.3. Unifying Concepts & Processes: change, constancy, and measurement
- NSES 1.4. Unifying Concepts & Processes: evolution and equilibrium
- NSES 2.1. Science as Inquiry: abilities necessary to do scientific inquiry
- NSES 4.2. Life Science: molecular basis of heredity
- NSES 4.3. Life Science: biological evolution
- NSES 4.6. Life Science: behavior of organisms
- NSES 8.1. History & Nature of Science: science as a human endeavor

Note: View the NSES content standards on this site to choose other curricular applications for additional activities at: http://www.actionbioscience.org/educators/correlationcharts.html

Learning Objectives: Students will…

- explain the basic process of natural selection
- explore how people can manipulate the process of natural selection
- describe various consequences of natural selection on daily life
- examine modern applications of evolutionary biology in basic and applied science

Key Words Include:
antibiotic, attenuation, biotechnology, drug resistance, enzyme, evolution, HIV, mitochondria, molecular epidemiology, mutation, natural selection, pathogen, phylogenetic tree, vaccine

Preparation

Article Discussion: After students read the article by Jim Bull at http://www.actionbioscience.org/newfrontiers/bull.html on their own, complete the Article Discussion on page 2 using one of the following methods:

- have students answer questions in class or discuss answers in small groups, or
- have students complete the content questions on their own, perhaps as a short-answer writing assignment, and discuss extension questions in groups.

Student Handout 1: Part A involves food (candies) in the lab; appropriate precautions should be taken to ensure that table surfaces are clean and that alternative methods be available for students with dietary restrictions to candies. For the activity to work, the teacher will "reproduce" the remaining candies at the end of each round by doubling the surviving number of each color (e.g., if a student has 5 blue candies left, the teacher will add 5 more for a new total of 10). Additional or alternate projects are provided in Part B.

Student Handout 2: The experiment in Part B involves growing the bacterium *S. marcescens* on nutrient agar plates; observe and teach students standard sterile protocol. An inexpensive UV light box can be constructed by cutting an opening in the lid of a Styrofoam cooler for the UV lamp; cut just to fit. Both the bacterium and other materials are readily available from any commercial science supplier. The activity is intended for groups of 3-4 students sharing a common set of supplies. Other activities, which can also serve as alternate projects when lab supplies are limited, are provided in Part A.

Student Handouts 1 and 2:

- Review Part A of Handout 1 & Part B of Handout 2 for required supplies and to prepare instructions for safety precautions. If unfamiliar with the latter, refer to Micklos & Freyer's *DNA Science* (1990).
- Refer students to "Useful Links" in the *Educator Resources* section at the end of the Bull article. These links help students with their activities and provide a source for research information.

For Educators: Article Discussion

About the article by Jim J. Bull, Ph.D.:
"Evolutionary Biology: Technology for the 21st Century"
http://www.actionbioscience.org/newfrontiers/bull.html

Content Questions:

1. How was the development of the polio vaccine an example of evolution?
2. What causes the evolution of drug resistant bacteria?
3. What are four modern applications of evolutionary biology?
4. How can scientists prolong the usefulness and effectiveness of drugs and vaccines?
5. What is a phylogenetic tree?
6. How have scientists used the evolution of the HIV virus to track its spread?
7. What are some biochemicals being produced in industry through the process of natural selection?
8. What are the various fields that evolutionary biology will impact in the future?

Extension Questions:

1. What is the original theory of evolution and how have biologists modified it through today's research?
2. Why is the use of pesticides and herbicides in agriculture an example of evolutionary biology?
3. Besides AIDS and bacteria, what other microbes and parasites have evolved resistance to our ability to treat them?
4. What are some ways that medical and public health professionals might prevent the development and spread of resistant pathogens?
5. What are some examples of how the process of evolution affects our daily lives, other than those listed in Bull's article?
6. What are some of the dangers of scientists deliberately engaging in "test tube evolution?"
7. Should "test tube" and other forms of "artificial" evolution be regulated? Why or why not? If so, who should regulate this work?

Applied Evolution: How Will We Get There from Here?

Student Handout 1

PART A: "AN INTRODUCTION TO NATURAL SELECTION" EXPERIMENT

SIMULATION -- To understand the process of evolution better, experiment with a simulation. At your table, you will find a cup of M&Ms® (or any variety of candy).

1. Sort them by color and count each color; record this in your data chart below.
2. Then, when you are told to do so, you will be asked to pick up the candy ONE AT A TIME and eat it. You must chew and swallow each candy before you are allowed to pick up the next one. Also, when your teacher tells you to stop eating, you must do so.
3. At the end of each round, sort and count the number of candies by color. RECORD YOUR NUMBERS ON THE DATA CHART. Then, your teacher will help what's left to "reproduce."
4. Repeat the above steps twice, and after the final third round, you may eat any remaining M&Ms at your table. While you are doing so, be sure to answer the questions following your data chart.

DATA CHART

Color	**Round 1**		**Round 2**		**Round 3**	
	# start	# finish	# start	# finish	# start	# finish
Orange						
Brown						
Yellow						
Red						
Blue						
Green						
	Total ____				Total ____	

ANALYSIS & CONCLUSIONS

a) Total the numbers of the first column in round one. Then determine the percentage of each color at the beginning of round one, (e.g., [# Brown ÷ # Total] x 100). Put these numbers in the percentage chart below.
b) Total the numbers of the last column in round three. Then determine the percentage of each color at the end of the final round and put these numbers in the percentage chart below.

PERCENTAGE CHART

	% Beginning	**% Ending**
Orange		
Brown		
Yellow		
Red		
Blue		
Green		

c) Answer the following questions:

- What happened to the percentages of each color? Which ones increased and which ones decreased?
- What caused some numbers to go up and some to go down?
- What is the term biologists use for what happened in this lab?

PART B: OTHER PROJECTS

1. HIV: A Case Study in Evolution

You are a representative of an organization that educates the public about HIV and AIDS. Create a print or media presentation to inform the public about:

- why drug treatments for HIV pose difficulties
- where, geographically, HIV is spreading the most rapidly and why
- what a united world can do to alleviate the problems

2. Antibiotic Resistance Public Campaign

You are part of a television production team. Design a ten-minute segment for a story about the dangers of antibiotic resistance and how it can be prevented. Present it as a written script or Power Point presentation.

3. Debate: Genetically-Modified Organisms (GMOs)

Set up teams to debate the following issue: *GMOs pose a threat to the natural progress of evolution.* Be prepared to answer questions from the audience (the rest of the class).

4. Court Case

Review the story about the case of intentional HIV injection in Louisiana (in Bull's article, #3 in section "Modern applications of evolutionary biology"). Simulate the court case. You will need to research pathogen tracking and HIV in order to present your arguments. Team members can choose to take the roles of lawyers, judge, defendant, accused, and witnesses. Present the courtroom drama in class and see if the jury (the rest of the class) arrives at the same verdict as the actual one.

Applied Evolution: How Will We Get There from Here?
Student Handout 2

PART A: GROUP PROJECTS

1. An Evolution Puzzle: Where Did We Come From?
All organisms, when they reproduce, make offspring that are slightly different from themselves (e.g., you don't look 100% like either mom or dad) and sometimes these differences give the offspring a better chance of surviving and reproducing (e.g., a deer with longer legs can run faster; so it is likely not to get eaten and, therefore, have fawns). If enough generations acquire enough differences that are passed on to their children, eventually the offspring won't be like their ancestors and a new species arises. Thus, the process of evolution is basically inherited changes that occur over time until an organism is no longer like its original.

To understand this better, solve a problem. Your assignment is:

- compare each of the pairs of organisms below (a pair per team) and describe what kinds of changes had to take place in order for ancestors of the first kind of organism to evolve into the second
- then, for each pair, explain why each change might have happened (what selective environmental forces might make such a change an advantage)

Pair 1: a small, bacteria cell → a sponge
Pair 2: a sponge → a mollusk
Pair 3: a mollusk → an arthropod
Pair 4: an arthropod → an amphibian
Pair 5: an amphibian → a mammal

Then create a presentation (e.g., brochure, display, CD-ROM) for the visiting public to a natural history museum that explains what general process occurred to cause the evolutionary events in the evolution of these organisms.

2. Hantavirus Tracking
You've been assigned to a team to track the source of a recent outbreak of hantavirus. Create a field journal that describes how you intend to go about the task and why. You will need to set the appropriate geographical stage for the outbreak.

3. New Frontiers
Your team is planning a film documentary about where evolution might take Earth and its inhabitants in the future. Create a script outline that proposes several possible scenarios. Base each scenario on projections based on modern breakthroughs in biology, such as genetic engineering.

PART B: "MAKING EVOLUTION HAPPEN" EXPERIMENT, OR "MARTY THE MUTATING *MARCESCENS*"

Bull's article discusses "test tube evolution" or modern biology's ability to make evolution happen. In this lab, you will "evolve" a common bacterium, *S. marcescens*. This bacterium exhibits different colors as it grows in different temperatures (red below 32^{o}C; white above that temperature), and so it has a simple genetic mechanism for pigment production that you can "play" with to evolve changes in the bacterium.

The selective force you will use is ultra violet or UV radiation. UV is a powerful *mutagen* (something that causes mutations in pieces of DNA). When you expose *S. marcescens* to it, you can create alterations in the organism. Follow the instructions below to evolve your bacterium. Then answer the questions at the end.

INSTRUCTIONS

1) You will be working with bacteria; so it is extremely important that you **read all directions first and follow the safety rules your teacher has demonstrated!**
2) Collect 5 fresh agar plates. Label them with your group ID. Then label them 1, 2, 3, 4, & 5 in order.
3) Get the tube with 500 microliters of *S. marcescens* bacteria growing in broth. Swirl the tube of bacteria to remix them evenly.
4) Next, use the micropipette to collect 100 microliters of bacteria broth from the tube. Turn agar plate #1 right side up and, when ready, lift the lid and transfer the 100 microliters to the middle of the gel on the plate.
5) Use a fresh sterile swab to gently smear the bacteria over the entire surface of the plate. DO NOT RUB THE GEL HARD WITH THE SWAB OR YOU WILL DAMAGE THE GEL.
6) Repeat steps 4 & 5 for agar plates #2-5. IT IS OK TO REUSE THE SAME PIPETTE TIP IN THIS LAB BUT BE ABSOLUTELY SURE TO USE A NEW SWAB EACH TIME!
7) Take four bacteria plates to the source of UV light your teacher has set up. One at a time, remove the lid of each plate and place it under the UV light for the amount of time indicated below. **WARNING: UV light can damage your eyes! Do not look into the light under any circumstances ever!** When exposure time is done, place the lid back on the plate.
    a) PLATE #1 -- 0 seconds (DO NOT EXPOSE THIS PLATE)
    b) PLATE #2 -- 30 seconds
    c) PLATE #3 -- 60 seconds
    d) PLATE #4 -- 90 seconds
    e) PLATE #5 -- 120 seconds
8) Now place plates #1-5 in the 30^{o}C incubator indicated by your teacher for two days. Record what color you think the different bacteria colonies will be after they have grown in your journal.
9) In two days, remove the plates and observe the different bacteria colonies.

ANALYSIS

1) What did the bacteria look like:
   a) on plate #1? b) on plate #2? c) on plate #3? d) on plate #4? e) on plate #5?
2) How are these results different or the same from what you predicted?
3) What would happen with unexposed bacteria grown at 25^{o}C? At 37^{o}C?

CONCLUSIONS

1) What happened to the DNA of the bacteria when exposed to UV light? Did the amount of exposure time make any difference?
2) What was the effect on the bacteria, following exposure to UV light, when grown at 30^{o}C (how had it evolved)?

EXTENSION QUESTIONS

1) a. How could you use this process to attenuate a virus (as described in Bull's article)?
   b. What other "test tube" evolutionary purposes might you use this technique for?
   c. What other mutagens besides UV light might you use for an experiment like this one?
2) Discussion On Evolutionary Technology:
   Bull states in his article that "enzymes are being evolved to work in detergents." Now that you have experimented with "test tube evolution" (and using your knowledge about DNA, mutagens, and enzymes relationships), discuss with your group how you might "evolve" a detergent enzyme.