Changing Planet: Changing Mosquito Genes

Summary:	Students investigate the topics of evolutionary adaptation and phenotypic plasticity to understand how species respond to the impacts of global climate change	**Materials:** • Student worksheet • 50 lima beans per student group • Metric rulers, 1 per student
Source:	*Created by NESTA/Windows to the Universe team members Missy Holzer, Jennifer Bergman, and Roberta Johnson*	
Grade level:	8-12	
Time:	• Introduction and Part I: 30 minutes • Part II-IV: 90 minutes • Part V: 45 minutes • *Note that parts of this lesson may be assigned for homework*	
Student Learning Outcomes:	• Students understand and correctly apply the terms evolutionary adaptation and phenotypic plasticity • Students collect and interpret data • Students analyze scenarios for types of natural selection • Students predict how different species will adapt to the impacts of global climate change	
Lesson format:	Collect and analyze data, model phenomena	
National Standards Addressed:	• 5-12: Content Standard A: Science as Inquiry • 5-12: Content Standard C: Populations and Ecosystems • 5-12: Content Standard C: Diversity and Adaptations of Organisms • 9-12: Content Standard C: Biological Evolution • 5-12: Content Standard F: Populations, Resources, and Environments • All levels: History and Nature of Science: Science as a Human Endeavor, Nature of Science, History of Science • All levels: Science in Personal and Social Perspective Standard • All levels: Assessment Standard B: The Ability to Communicate Effectively about Science	

DIRECTIONS:

1. For background information on how climate change is affecting mosquito populations watch *Changing Planet: Changing Mosquito Genes.* (http://www.windows2universe.org/earth/changing_planet/mosquito_dna.html) Also explore these topics on the Windows to the Universe website at the links listed below.
2. Gather the materials needed for each part of the lesson, and print out the student worksheet. (http://www.windows2universe.org/teacher_resources/mosquito_genes_students.html) After viewing the Changing Planet episode for this lesson, assess students' understanding of the word

"adapt" by asking them to define the word and provide examples of what it means to adapt. List and save their examples so that it can be reviewed again at the end of the lesson. You will likely find out that students use the word "adapt" quite freely and literally to describe phenomena that is not adaptation, but instead is an organism's ability to acclimate.

3. How organisms respond to the impacts of global climate change is related to their genetic make-up and their ability to adapt or acclimate. These two terms are very different and could mean that in the future we may have genetically different organisms (adaptation) or that the innate flexibility in the organism will allow them to survive in various conditions (acclimation). The foundation for understanding these two phenomena is grounded in the theory of evolution and in natural selection more specifically.
4. If students are unfamiliar with the mechanisms of adaptation, use the Windows to the Universe lesson called Changing Planet: Adaptation of Species (Birds and Butterflies) (http://www.windows2universe.org/teacher_resources/adaptation_species.html) to introduce the concept.
5. In the Changing Mosquito Genes activity, students will learn the difference between microevolution where natural selection and adaptation play key roles, and phenotypic plasticity, which is independent of microevolution but is typically equated with adaptation. Distinguishing between these two concepts sets up the rest of the lesson where students analyze numerous scenarios and put themselves in the role of various organisms (including the mosquito) to assess options on how to deal with the effects of our changing planet.
6. In Part I of the lesson, students are instructed to define a number of terms that will be used throughout the lesson, and they are also asked to provide examples that fit with their definitions. Assign this part of the lesson as homework prior to beginning the lesson to save class time. Be sure to go over the definitions with the students before proceeding with the other components of the lesson.
7. In Part II of the lesson, students are measuring lima beans to assess genetic variability within a species. Feel free to substitute lima beans with another substance that has some variability in its lengths. The students are only looking at a small subset of the lima bean population and they need to understand the role of sampling in statistics and the challenges of generalizing to the entire population.
8. Students can mistakenly use the term adaptation in a species when they should be referring to phenotypic plasticity within the organisms in the species. In the first section of Part III, students make observations of leaves on a tree to note evidence of phenotypic plasticity. This can be found in the north facing versus south facing leaves of a tree where the leaves have been influenced by their environment, and therefore are showing variation in size with the larger leaves on the south facing side of the tree and the smaller leaves on the north facing side of the tree. The "plastic" responses by an organism or species can be intentional or not, whereas an adaptation is not intentional and is caused by genetic variability within the species where the environment favored some gene versions. The plasticity of a species can evolve over time thus increasing the chances of survival of the species. Those organisms that have a high level of plasticity may have an advantage over those with a low level of plasticity since those with a high level can make changes to their behaviors, morphologies and physiologies in order to survive. Finally, students determine whether written scenarios are examples of phenotypic plasticity or evolutionary adaptation. Scenarios 1 and 3 are examples of phenotypic plasticity and scenarios 2 and 4 are examples of evolutionary adaptation. This part of the lesson wraps up with a discussion on the advantages of a high level of phenotypic plasticity and genetic variability when faced with changing environmental factors.
9. In Part IV, students are introduced to the different forms of natural selection -- directional, stabilizing, and disruptive. They are asked to determine which form is evident in the examples provided. The first example is stabilizing, the second example is directional, and the third example is disruptive. Next, students are asked to categorize an array of traits as those

associated with a vulnerable species or a highly adaptive species faced with rapidly changing environmental factors.

10. The lesson culminates in Part V where students are tasked with deciding on which evolutionary strategy would be most productive when faced with the effects of climate change. In the Application, students are evolutionary biologists meeting with the World Ecological Assessment Organization (WEAO) to discuss the fate of their species when faced with the impacts of climate change. Create a list of plants and animals from various latitudes. Ask students to select a species from the list (or another species if you feel it will add to the depth of discussion). Allow students to work in pairs if time is a factor. Close the lesson with a "meeting" of the WEAO and the students discussing the fate of their species, to gain an overall picture of the impacts of a changing planet on species diversity. Assess student ability to incorporate the terms from this lesson in their discourse.

ASSESSMENT:

Assess the students' responses to the questions throughout the lesson. Use class discussion of this complex topic to gently correct any misconceptions. Decide what information students should place in their presentations and develop a rubric for the final presentation as well as their participation in the final discussion.

LAB SAFETY:

Select a safe place to go outdoors for Part III. Always use safe laboratory practices.

CLEAN-UP:

The lima beans and rulers may be stored for future use.

EXTENSIONS:

- If this lesson is used in a biology class, tie it into the study of genetics since it creates a compelling reason to understand molecular biology.
- For advanced students, refer to Rapid Adaptation of Bean Beetles to Novel Hosts (http://tiee.esa.org/vol/v6/experiment/beetle_adaptation/abstract.html) from Teaching Issues and Experiments in Ecology. In this lesson, students use live cultures of beetles that have been raised on mung beans in order to determine if beetles can adapt to a new host.
- This lesson only touched upon the exciting field of evolutionary biology. As an extension, have students explore research journals to find scientific studies of the adaptation of various species. Have students write a review of a research paper, and require students to use the terms from this lesson. Use a search engine such as Google or Google Scholar to assist in locating appropriate journal articles.

BACKGROUND INFORMATION:

DNA stands for deoxyribonucleic acid, which is a substance found in every living cell (http://www.windows2universe.org/earth/Life/life.html) on Earth, including the roughly 10 trillion cells that make up your body. DNA is made up of four subunits: adenosine, cytosine, guanosine, and thymidine, which are often referred to by their initials-A, C, G, and T. These subunits are arranged in strings of specific sequences called genes, and genes contain instructions for building all the parts of the cells, tissues, and organs in which DNA is found.

You can think of the DNA in a cell as the master blueprint for your body, and although all the

members of a species have DNA that is very similar, each individual has DNA sequences that are slightly different from all of the other individuals. These differences are very small, but they're what determine your height, the color of your hair, and all the other unique characteristics that make you who you are. Humans, animals (http://www.windows2universe.org/earth/Life/animalia.html), and plants (http://www.windows2universe.org/earth/Life/plantae.html) have two copies of their DNA, one from each parent. Because the two parents' DNA, each containing differences that are unique to the mother or father, are mixed in a child, a child usually has some of his mother's characteristics and some of his father's.

The small differences in individuals' DNA sequences are really important in nature, because those differences are what leads to diversity. Different people have slightly different versions of the genes that determine how tall a person becomes, and humans around the world can be anywhere from about 4 feet tall to over 7 feet tall! In animals, diversity is found in body size too, as well as in things like fur or feather color, beak size, intelligence, and lifespan. Scientists sum this up by saying that genotypic differences (small differences in DNA) between members of a species lead to phenotypic variation (differences in those members' physical characteristics).

Diversity (http://www.windows2universe.org/headline_universe/olpa/speciation_3july08.html) happens naturally because of the way DNA is copied in the cell (sometimes the cell makes a mistake as it makes a copy of the DNA, and a "difference" is made). It's important to remember that some differences are helpful and some are harmful. For instance, a bird's (http://www.windows2universe.org/teacher_resources/adaptation_species.html) DNA sequence could gain a small change that makes it more brightly colored and helps that individual attract mates, or it could acquire a small change that makes its feathers shorter and hurts the bird's ability to fly. Individuals that have helpful differences in their DNA will have an easier time surviving and reproducing than those that have harmful differences, and over time this will mean that the helpful changes (http://www.windows2universe.org/earth/Life/genetics_microevolution.html) are passed down from generation to generation and become widespread in the population.

What this really means is that in nature, changes are constantly occurring in all species' DNA sequences, and the changes that have a positive effect on an organism tend to be passed on to the next generation. This is called natural selection (http://www.windows2universe.org/cool_stuff/tour_evolution_5.html), and it's the process that shapes life on Earth. It's important to remember that natural selection is still happening, and as a species encounters changes in its environment (like new climate patterns, new predators, or new prey), its DNA changes to adapt to its new situation (for instance, an insect that is being preyed upon by a new predator may adapt by changing its color so it is less easily seen by the new predator). This is easy to see in the example of the mosquitoes in this lesson, where a population of pitcher plant mosquitoes is adapting to climate changes by lengthening their growing season.

RELATED SECTIONS OF THE WINDOWS TO THE UNIVERSE WEBSITE:

- Changing Planet: Infectious Diseases Classroom Activity (http://www.windows2universe.org/teacher_resources/infectious_disease.html)
- Climate and Global Change (http://www.windows2universe.org/earth/climate/climate.html)
- Climate Change and Vector-Borne Disease (http://www.windows2universe.org/teacher_resources/online_courses/health/disease_vectors.html)
- Climate Change Impacts, Adaptation and Vulnerability - Present and Future (http://www.windows2universe.org/earth/climate/ipcc_april2007.html)
- Evidence of Evolution (http://www.windows2universe.org/cool_stuff/tour_evolution_1.html)
- How Many Species Have There Been on Earth?

(http://www.windows2universe.org/headline_universe/olpa/speciation_3july08.html) News story originally written on July 3, 2008
- Life on Earth (http://www.windows2universe.org/earth/Life/life.html)

OTHER RESOURCES:

- Evolutionary Adaptation to Climate Change Lecture by Dr. Bradshaw and Dr. Holzapfel (http://sackler.nasmediaonline.org/2008/biogeography/william_bradshaw/william_bradshaw.html)
- Genetic Shift in Photoperiodic Response Correlated with Global Warming (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC64712/) - Paper by Dr. Bradshaw and Dr. Holzapfel
- Genetic Structure of First Animal to Show Evolutionary Response to Climate Change Determined (http://www.nsf.gov/news/news_summ.jsp?cntn_id=117577&org=NSF) - NSF Press Release
- Mosquito Genes Explain Response To Climate Change (http://www.sciencedaily.com/releases/2007/04/070423130327.htm) - Related Linked Stories
- Species Explosion: What Happens When You Mix Evolution and Climate Change? (http://www.smithsonianmag.com/science-nature/species.html?c=y&page=1)
- Understanding Evolution: Coping with Climate Change (http://evolution.berkeley.edu/evolibrary/news/090501_climatechange)
- Understanding Evolution: Welcome to Evolution 101 (http://evolution.berkeley.edu/evolibrary/article/evo_01)