Night of the Twisted Helix - Mutation & Natural Selection

Secrets of the Sequence Video Series on the Life Sciences • Grades 9 — 12
Teaching materials developed by **VCU** Life Sciences

Virginia Commonwealth University

Classroom Tested Lesson

Video Description

"Secrets of the Sequence," Show 135, Episode 2

"Night of the Twisted Helix – Mutation and Natural Selection" – approximately 9 minutes viewing time

We are all mutants under the skin. Some mutations are good, some are bad. Some give us special abilities. Some kill us with diseases such as cancer. These mutations, also called polymorphisms, drive the process of life. It is less how the genome is spelled than how it is misspelled that makes all the difference. And the human genome, far from being a fixed target, is a fluid, dynamic, evolving, variable mutating code and is constantly updating what we are.

Ward Television
Producer: Paul Gasek
Associate Producer: Julie James
Featuring: Dr. David Altshuler, Whitehead Institute, Harvard Medical School; Mark Daly, Computational Biologist, Whitehead Institute; Dr. Todd Golub, Whitehead Institute, Harvard Medical School; and Dr. Andy Futreal, Cancer Genome Project, Wellcome Trust Sanger Institute
Lesson Author; Reviewers: Peggy Deichstetter; Dick Rezba, Catherine Dahl
Trial Testing Teachers: Ed Terzian, Lynn Visone, Pam Sparks

National and State Science Standards of Learning

National Science Education Standards Connection

Content Standard A: Life Science

As a result of their activities in grades 9 - 12, all students should develop

- understandings about scientific inquiry.
- abilities necessary to do scientific inquiry.

Content Standard C: Life Science

As a result of their activities in grades 9 - 12, all students should develop an understanding of

- molecular basis of heredity.
- biological evolution.
- interdependence of organisms.
- behavior of organisms.

Content Standard F: Science in Personal and Social Perspectives

As a result of their activities in grades 9 - 12, all students should develop an understanding of

- population growth.

- personal and community hazards.
- natural and human-induced hazards.

Content Standard G: History and Nature of Science

As a result of activities in grades 9-12, all students should develop an

- understanding of:
- science as a human endeavor.
- nature of scientific knowledge.
- historical perspective.

Selected State Science Standards Connection

Use http://www.eduhound.com (click on "Standards by State") or a search engine to access additional state science standards.

Illinois

Standard 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.
Standard 12: Understand the fundamental concepts, principles, and interconnections of the life, physical and earth/space sciences.
Standard 13: Understand the relationship among science, technology and society in historical and contemporary contexts.

Virginia

BIO.2 The student will investigate and understand the history of biological concepts. Key concepts include

- scientific explanations of the development of organisms through time.

BIO.5 The student will investigate and understand life functions. Key concepts include

- how their structures are alike and different.
- analyses of their responses to the environment.
- human health issues, human anatomy, body systems, and life functions.

BIO.6 The student will investigate and understand common mechanisms of inheritance and protein synthesis, including

- effects of genetic recombination and mutation.
- events involved in the construction of proteins.
- exploration of the impact of DNA technologies.

BIO.7 The student will investigate and understand bases for modern classification systems. Key concepts include

- comparison of DNA sequences in organisms.
- examination of protein similarities and differences among organisms.

BIO.8 The student will investigate and understand how populations change through time. Key concepts include

- investigating how variation of traits, reproductive strategies, and environmental pressures impact on the survival of populations.
- c) recognizing how adaptations lead to natural selection.
- h) use, limitations and misuses of genetic information.
- I) exploration of the impact of DNA technologies.

Overview

Mutants!!!! Are they scary? A mistake? A freak of nature? Mutations!!! When do they occur? Some occur in a day, some in a lifetime, and some over centuries. It's evolution. It's going on right now. If there is a mutation that protects against a deadly infectious disease, and a wave of that disease hits, then that mutated gene will be more common in offspring because parents who had the gene survived and passed it on to their offspring.

Some mutations are good. Others are a mixed bag - the gene that causes sickle cell disease also protects against malaria. Some mutations have little or no impact but other mutations are monsters, killers from the inside. They cause cancer. By understanding these 'misspellings' in the DNA code, therapies for cancers could be developed. Why do mutations for cancer occur? Chemical carcinogens, UV radiation and just natural mistakes are some reasons. What drives cancer cells? It breaks all the rules. Understanding these mutations gives us a knowledge base and more power to control cancers.

Not all mutations are reduced by natural selection. Before the invention of glasses if you couldn't see, you couldn't hunt and you probably couldn't win a mate so genes for poor eyesight weren't passed on. However, that is not the case today, and the unwelcome gene continues on. In this lesson students will develop an understanding of how 1) mutation occurs, 2) nature can choose the best mutation to be passed on to the next generation, and 3) cancer is caused by mutations.

Testing: A sample related multiple choice item from State Standardized Exams

Which statement is <u>NOT</u> supported by the Theory of Natural Selection?

a. Living things change through time
b. When organisms compete for resources, those best suited to the environment survive
c. Changes in body cells are passed to offspring *
d. Organisms with common characteristics descend from a common ancestor

Source: North Carolina Biology Sample Items

Video Preparation

Preview the video and make note of the locations at which you will later pause the video for discussion.

Before Viewing

1. Conduct Student Activity 1: The Survival of the Most Fit *Varicolorus candiius* Beetle - The Evolution of M&M's. See Teacher Notes for the activity.

2. Before showing the video, write the following questions on the board or prepare a handout *for students to complete while viewing the video*:
   a. How long does it take to make a mutation? (*A day, a lifetime, or centuries)*
   b. List three things that cause cancer mutations. (*Chemical Carcinogens, U-V radiation, errors made in DNA replication)*
   c. Explain why natural selection doesn't work for poor eye sight. Nature is no longer selecting for good eyesight. (*With the invention of glasses, people with poor vision no longer worry about "the fight for survival." Their poor vision is no longer a threat to their survival.)*

During Viewing

1. START the video.

2. PAUSE the video at 2:40 when Dr. David Altshuler says, "… copies of the gene that protect against that infection will be more common in the offspring because the offspring that survive had to be resistant to that disease."

   Ask: Why would there be more of the gene that protects against the disease in the population after the plague of that disease? (*Look for evidence that students can apply to what they learned from the M&M activity, such as: people without the gene died; people with the gene survived and passed on this gene to their offspring.)*

   Note: Trial test teachers suggested re-playing or repeating to students what Dr. Altshuler said so it could 'sink in'. You might also wish to give the students an example, such as: "Let's say 70% of Europeans died after the Black Plague. If the plague hit again in 200 years, would the percentage be any different? How would the percentage change if it hid a third time 200 years after that, and so on? Why does resistance exist after hundreds of years?" *Percentage of deaths would go down every time because the plague-resistant gene would be increasing in frequency within the population and passed from generation to generation.*

3. RESUME the video and play to the end.

After Viewing

Discuss students' responses to the questions given to them before viewing the video.
Conduct Student Activity 2: The Meaning of Genetic Variation

Teacher Notes for Student Activity 1: Survival of the Most Fit *Varicolor candiius* Beetle

Goal: For students to observe and understand the process of Natural Selection

In this activity you will need 2 large bags of plain M&Ms and small cups to distribute the candy
Time: approximately 20 minutes

Materials

- Copies of the competition grid that pairs various colors of the beetle
- Bathroom size cups of M&M's to each pair of students. (Gain experience with the amount you need by first conducting the lesson with only one class. Trial test teachers began with two large bags for the initial class)

Procedure

- Explain to the students that today they are going to see *Natural Selection* in action. They will use colored beetles to determine which one is the fittest and thus able to survive and reproduce. You may wish to tell them (before they know that the colored beetles are really M&M's) that they can eat the losing beetles. Distribute copies of the Student Handout Activity 1, which is a competition grid that pairs various colors of beetles in fitness combat.
- Demonstrate how to determine fitness:
    - Use the first pair of colored "beetles" (M&M's) on the competition grid (yellow and red); put them between your thumb and forefinger. (see Student Handout: Activity 1- competition grid for color pairings)
    - Apply pressure, squeeze them together until one of them cracks and splinters (Hint: to keep the M&M's from flying off, lightly surround the M&M's with the forefinger and thumb of the other hand.)
- Students may eat the poorly adapted, inferior beetle because they (the students) are predators.
- The winning beetle moves on to the next round and the fitness procedure is repeated. But DON'T use the winning beetle - he's been weakened and needs rest. *Use a new beetle of the same winning color for the next round.*

- Discuss how they will use the competition grid.
- All students should try the first round, but to save time and M&M's, have students work in pairs.
- Have one student record the results, while the other does the squeeze competition.
- Distribute the M&Ms (By now students are relieved that you really don't expect them to eat real beetles.)
- Once students have finished their competitions, collect the data and display the results.

Discussion

Ask: Looking at the class data, which color of beetles (M&M's) is most likely to survive so it can reproduce?

- *In some classrooms it was the red and brown M&M's that won the competition. [Results varied in trial classrooms; your results may be different as well]*

Ask: Looking at the data, which color of beetles (M&M) is least likely to survive so it can reproduce?

In some classrooms it was usually the blue M&M's that never won. Yellow, green, and orange averaged about the same number of wins. [Again, results varied in trial classrooms; one teacher's class found equal number of winners/losers for all the colors, which led to a discussion of how all the colors would continue and none would be eliminated from the population. Regardless of the results, the activity leads to good discussion and understanding.]

Ask: What would happen to the colors of this population of beetles over several generations? Why?

From the results in some classrooms: over several generations the population would become mostly red and brown with some yellow, green and orange. However, there would be no blue beetles, unless a favorable mutation occurred. Blue beetles are poorly adapted and don't survive to pass their genes on to the next generation. Note: occasionally you will get an M&M mutation - an M&M that is misshapen, pointier, or flatter than the rest. Almost invariably this proves to be a weakness, but on very rare occasions it gives the candy extra strength. In this way, the 'species' continues to adapt to its environment.

If all M&Ms are not created equal, develop a hypothesis on why red and brown M&Ms (or other colors) usually win and why blue (or another color) M&Ms don't.

- Students should develop their own hypothesis. There is no right or wrong answer. It just needs to make sense based on the results in your class.

Ask: Perhaps it isn't color at all that makes the difference in the fitness results. What other variables might be involved that are affecting who wins and who loses?

- *Perhaps the determining variable is location - the M&M on top usually wins?*
- *Or perhaps the one on the bottom usually wins?*
- *Or perhaps the winner is most always the one on the broader surface of the thumb?*
- *Or is the winner the one against the narrower forefinger?*

Teacher Notes for Student Activity 2: The Meaning of Genetic Variation

Goal: Building on the understanding of Natural Selection from Activity 1, students view a short video on sickle cell anemia, complete related questions on a handout, and discuss their understanding of mutations and evolution. Time: approximately one class period.

Note: This activity will help students to review their application of basic Mendelian genetics including the Punnett square. Because sickle cell anemia is a textbook example, this activity will allow students to see it in real world context. The discussion of rates of the sickle cell gene in the US and in Africa is a good link to population studies and elicits critical thinking.

Materials

- Copies of the student handout for Student Activity 2: The Meaning of Genetic Variation

Procedure

- Go to http://science-education.nih.gov/supplements/nih1/genetic/activities/activity2.htm
- Have the students watch the video on sickle cell disease. Distribute copies of the student handout to be completed before discussing the questions below.

Discussion

Note: These questions may be confusing if a student does not understand Natural Selection.

Are all mutations good or bad?

- *Most mutations are neither good nor bad. It is usually the environment (nature) that gives the mutation a value. Example: In times of famine the fat conservation gene would be very good. However, in times of plenty, conserving fat leads to life threatening diseases such as to diabetes and heart disease.*

If a mutation is good, what happens to it?

- *It depends on whether or not the good mutation gives the organism a competitive edge. If the gene gives a competitive edge, then more organisms with that gene will survive and be able to reproduce and pass on the good gene*.

If a mutation is bad, what happens to it?

- *Bad genes are only lost if the organism doesn't live to reproduce. For example, Huntington's disease is a genetic disease that generally does not express itself until around the age of 40, after the individual has had children*.

Explain how the sickle cell gene remains in the population.

- *75% of the offspring born to parents with the gene (Nn) are not affected (NN, Nn). The 25% of the offspring who inherit two copies of the gene may die before reproducing (nn). In areas were Malaria is present, those person who are heterozygous (Nn) are protected against it. Therefore, in areas with Malaria, the gene gives a competitive edge. Because having a single gene doesn't kill before reproduction, the gene remains in the population.*

Extending your Investigation: Go to Web site
http://science-education.nih.gov/supplements/nih1/genetic/guide/guide_toc.htm
and click on "Manual" for directions for student activities, and then click on "Masters" to download Masters 2.1-2.3. This activity gives students a hands-on opportunity to discover that a mistake of just one letter (nucleotide) means the difference between healthy red blood cells and sickle cell ones.

Student Handout: Activity 1
Survival of the Most Fit - *Varicolor candiius* Beetle

Goal: To observe and understand the process of Natural Selection

Time: approximately 20 minutes

Materials:

- Copies of the competition grid that pairs various colors of the beetle
- Cup of M&M's

Procedure:

Step 1: Using the competition grid, begin by using the first pairing of colored beetles (M&M's) and place them between your thumb and forefinger.

Step 2: Apply pressure to squeeze them together until one of them cracks and splinters (Hint: to keep the M&M's from flying off, lightly surround the M&M's with the forefinger and thumb of the other hand.)

Step 3: Record the winner in the competitive Grid below.

Step 4: You may now eat the poorly adapted, inferior beetle because you (the student) are a predator.

Step 5: The winning beetle moves on to the next round and the fitness procedure is repeated. But DO NOT use the winning beetle - he's been weakened and needs rest. *Use a new beetle of the same winning color for the next round.*

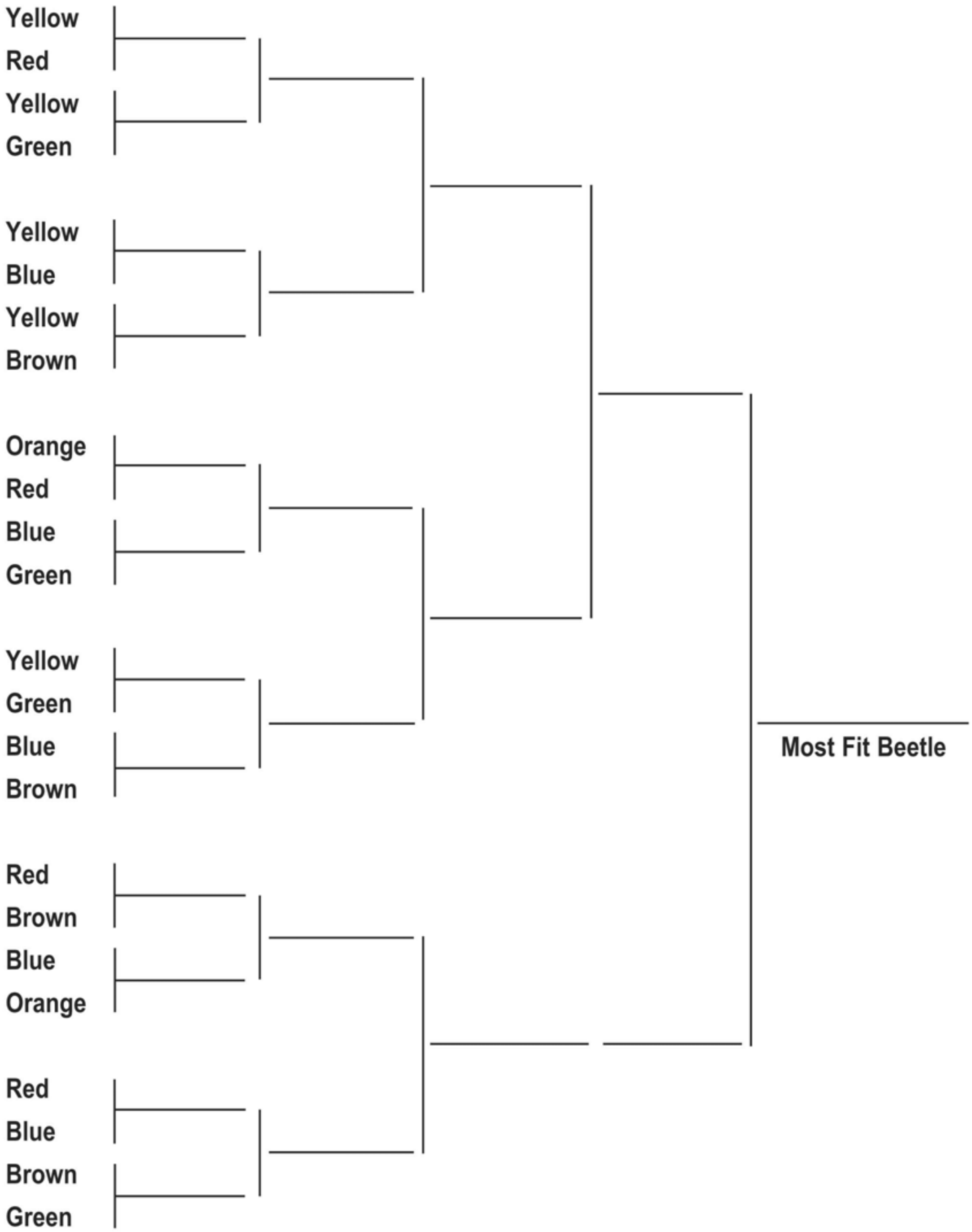
Step 6: Continue the competitive rounds using the colors as given and recorded on the grid. If you are lacking a specific color, see your teacher for additional 'beetles'.

Step 7: Once you have completed your grid, submit your data to your teacher and be prepared to discuss the following points.

- Which color of beetles is most likely to survive so it can reproduce?
- Which color of beetles is least likely to survive?
- What would happen to the colors of this population of beetles over several generations and why?
- Develop a hypothesis on why some colors usually win and why others do not.
- What other variables might be involved that are affecting who wins and who loses?

Competitive Grid for Activity 1:
Survival of the Most Fit — *Varicolor candiius* Beetle

Name ____



Student Handout for Activity 2: Genetic Variation

Name ____

1. Make a Punnett Square of two parents who are carriers for sickle cell disease (Nn).

1.	2.
3.	4.

2. What chance does an offspring have of being homozygous (NN) for normal red blood cells?

3. What chance does an offspring have of being a carrier (Nn) of the trait and therefore protected against malaria?

4. What chance does an offspring have of having sickle cell disease (nn)?

5. If nature selects the fittest to survive, how can a disease that causes pain, damage to organs, and even death be selected for? (In other words, if the disease causes death, why doesn't the disease disappear after several generations, like a particular color of M&Ms might have in Activity 1.)

6. Using your answers from questions 2-5 explain how the sickle gene remains in the population.

7. The rate of the sickle gene is 4% in Africa. The United States has a much lower rate: only 0.25%. Based on what you have learned, develop a hypothesis to explain why there are more people in Africa that have the Sickle Cell gene.

Answer Key for Student Handout for Activity 2: Genetic Variation

Name <u>Answer Key</u>

1. Make a Punnett Square of two parents who are carriers for Sickle Cell Disease (Nn).

	N	n
N	NN NN	Nn
n	Nn Nn	nn

2. What chance does an offspring have of being homozygous (NN) for normal red blood cells?
   25% or 1 in 4

3. What chance does an offspring have of being a carrier (Nn) of the trait and protected against malaria?
   50% or 1 in 2

4. What chance does an offspring have of having Sickle Cell Disease (nn)?
   25% or 1 in 4

5. If nature selects the fittest to survive, how can a disease that causes pain, damage to organs, and even death be selected for? (In other words, if the disease causes death, why doesn't the disease disappear after several generations, like a particular color of M&M's might have in Activity 1?) *There must be some survival value to having the sickle cell trait. The value appears to be protection from Malaria.*

6. Using your answers from questions 2-5, explain how the sickle gene remains in the population. *In the Punnett Square, the 25% who are normal (NN) have no protection from Malaria and could die. The chances are 50% that offspring (Nn) will <u>not</u> have the Sickle Cell Disease but will be protected from Malaria. This gives 50% of the offspring the best chance for survival.*

7. The rate of the sickle gene is 4% in Africa. The United States has a much lower rate: only 0.25%. Based on what you have learned, develop a hypothesis to explain why there are more people in Africa that have the Sickle Cell gene. *The rate of the sickle cell gene is higher in Africa because the people who are normal (NN) have no protection from Malaria, the number one killer disease in the world. When a normal (NN) person dies of Malaria his normal genes are lost. In the United States people don't die of Malaria so the sickle cell gene has no survival value.*

Additional Resources

Because Web sites frequently change, some of these resources may no longer be available. Use a search engine and related key words to generate new Web sites.

Are mutations harmful? This Web site explores causes of mutations on it way to supporting the theory of evolution. It examines some very interesting mutations, like a bacteria that can eat nylon, as well as, several diseases, including sickle cell. http://www.talkorigins.org/faqs/mutations.html

History of Darwin's Theory of Natural Selection. This Web site includes the history of the Theory of Natural Selection, several examples of natural selection, as well as a quiz on the material. http://anthro.palomar.edu/evolve/evolve_2.htm

The National Institutes of Health Office of Science Education. Receive a free supplement on Human Genetics Variation. http://science.education.nih.gov

National Library of Medicine. Find out about this Sickle Cell disease that affects the blood. Determine the risks with a Flash activity for passing sickle cell anemia to the next generation. Learn about a doctor who made the study of this disease one of her life focuses. http://www.nlm.nih.gov/changingthefaceofmedicine/activities/

Museum of Science and Industry. Take a virtual tour of the genetics exhibit at the Museum of Science and Industry in Chicago. Get an interactive demonstration of different types of mutation. Watch videos of genetic engineering, development and the Human Genome project. http://www.msichicago.org/exhibit/genetics/mutations.html

PBS series on evolution. Outstanding Web site that accompanies the video series on evolution. The site has several examples of natural selection, an explanation of evolution, and a course to help teachers teach evolution. http://www.pbs.org/wgbh/evolution/index.html

The National Human Genome Research Institute led the Human Genome Project for the National Institutes of Health, which culminated in the completion of the full human genome sequence in April 2003. Now, NHGRI moves forward into the genomic era with research aimed at improving human health and fighting disease such as sickle cell. http://www.nhgri.nih.gov and http://www.genome.gov/10001219

Genomic Revolution
http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtml
The Web site to the government-funded Human Genome Project with links about genomics, the history of the project, and more.

Secrets of the Sequence Videos and Lessons
This video and 49 others with their accompanying lessons are available *at no charge* from www.vcu.edu/lifesci/sosq