Survival of the Fittest— Battling Beetles

Abstract

Survival of the Fittest—Battling Beetles is a guided inquiry. This series of activities complements the HHMI DVD *Evolution: Constant Change and Common Threads,* and requires simple materials such as M&Ms, food storage bags, colored pencils, and paper cups. An extension of this activity allows students to model Hardy-Weinberg and selection using an Excel spreadsheet. This part of the activity requires computer/printer access. The overall goal of Battling Beetles is to engage students in thinking about the mechanism of natural selection through data collection and pattern recognition.

Appropriate Grade Level

High School Biology – average, honors, and AP

Undergraduate Biology

Goals

This activity is designed to engage students in thinking about the following:

- How does natural selection preserve favorable traits?

- What evidence is there that variation exists within a population?

- What role does variation play in the evolution of a species?

- Why are some variations inherited and others eliminated?

- How do variation, selection, and time fuel the process of evolution?

Time Requirement

This lesson consists of three distinct activities.
- Part One requires one 45-minute block of time.
- Part Two can be done in class or as homework. It will require from 15 to 30 minutes.
- Part Three can also either be done in class or as homework. It will require 15 to 30 minutes.

Required Student Background Information

Students should have a basic understanding of:
- evolution
- natural selection
- mutations
- variation within a species
- algebra
- Hardy-Weinberg

Students should know how to:
- utilize an Excel spreadsheet

Background Information

Variation, selection, and time fuel the process of evolution. Darwin observed that species are capable of producing more offspring than the environment can support. Individuals in a population of the same species exhibit variations in traits. Some members possess variations that increase their chance to survive and reproduce. These variations are due to both the recombination of genes during sexual reproduction and mutations. The selection of a survival type is a function of the environment in which the species lives and is referred to conceptually as natural selection. This is the driving force of evolution. It can also be thought of as a change in the gene frequencies in a species over time.

The differential survival of organisms and consequently their ability to reproduce is due to a number of factors. These include changes in abiotic factors in the habitat such as temperature or pH changes, availability of resources such as nesting sites or food, and interspecies interactions such as predator-prey relationships. It is on these relationships that this series of activities focuses.

Implementing the Activity

There are two different ways to introduce this series of activities. The first probes prior conceptions through an interactive sharing of terms related to the concept of natural selection.
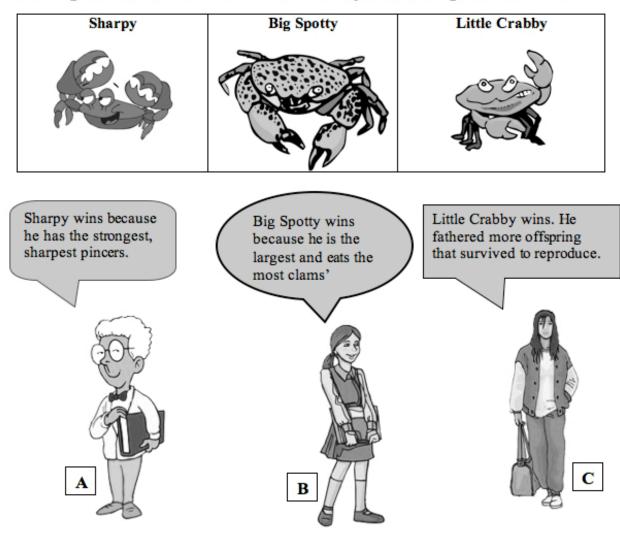
The second is a concept cartoon. Concept cartoons are designed to provoke discussion and stimulate scientific thinking. The cartoon can be used as a handout, on a SMART Board, or in a PowerPoint.

Term Share

1. Have each student make a list of words or phrases that come to mind when they hear the term "natural selection." Allow a few for this but no more than five. The idea is to provide each student with ample time to compile a satisfactory list.

2. Organize students into cooperative groups of 3. Have one student act as the *Recorder*, another as the *Analyzer*, and the third as the *Reporter*. The *Analyzer* should examine the three lists and highlight the words that appear on all three lists. From this, the *Recorder* should compile two lists: one of the terms common to all three students and a second of terms not appearing on all three.

3. After the lists have been compiled, the group should discuss the words they chose and their reasons for including them. Each group should select two words from each of their lists for sharing with other groups. Next, the *Reporter* should report the two selected words from each list and explain to the class why their group included them. Members of other groups should make no comments about the inclusion of the words. This will provide a good idea of where students are in their conceptualization of natural selection in a nonjudgmental atmosphere.

4. The word lists can be held by the teacher or posted on the bulletin board for student reference.

Concept Cartoon

1. Give students a few minutes to look at the cartoon and then ask them to write their own reflection. (There is a clean copy at the end of the Teacher materials.) Ask them to comment on each statement. They should clearly indicate which one they agree with and to give a reason for their choice.

2. Follow the individual reflection period with a pair-share and then a discussion that involves the entire class. Students should be asked to justify or adjudicate between the ideas expressed in the speech bubbles. This will allow you to identify areas of misconception and stimulate thinking. At this time, do not tell students the "right" answer. Let them use the activities as a way to find out which character in the cartoon has the best response. Tell them you will discuss the cartoon with them after completing the investigation.

Arthropod Hall of Fame: Which variety of arthropod is the most fit?

Sharpy	Big Spotty	Little Crabby

Sharpy wins because he has the strongest, sharpest pincers.

A

Big Spotty wins because he is the largest and eats the most clams'

B

Little Crabby wins. He fathered more offspring that survived to reproduce.

C

What do you think?

Answer C is best because Little Crabby won the reproduction contest. Little Crabby was able to survive and reproduce and pass genes on to more offspring that survived than any of the others.

Answers A and B are not the best answers. Being stronger or larger or even having a great defense doesn't guarantee that the individual is the fittest. There are many variations that contribute to which organisms leave the most offspring. Some that students do not typically think of include the ability to use energy more efficiently or to tolerate changes in temperature and other extreme conditions. It might be that the most fit is immune to pathogens or is better able to sense changes in the environment. Hence, Little Crabby possesses a combination of variations that makes him the winner in the Arthropod Hall of Fame.

Materials for Hands-on Activities

Part One—Materials for Hands-on Activities

Per Class of 24

- 12 sealable storage bags* marked "*O. glucosi - red"* each containing 10 red M&M candies
- 12 sealable storage bags* marked "*O. glucosi - blue"* each containing 10 blue M&M candies
- 12 waste containers – paper cups or several paper towels marked "waste"
- 12 small metric rulers
- 12 red and 12 blue colored pencils/markers
- optional: electronic balance(s)
- 24 copies of the student activity

Per student group of 2

- 1 sealable storage bag* marked "*O. glucosi-red*" and another marked *"O. glucosi – blue"* Each bag should contain 10 M&M candies of the color designated.
- 1 waste container - paper cups or several paper towels marked
- 1 small metric ruler
- 1 red and 1 blue colored pencil
- optional: electronic balance
- a copy of the activity for each student

* Use snack-size sealable food storage bags. These keep the candies contained so that during the observational phase of the activity, students do not need to open the bags unless you indicate that they should. The bags are also easy to store, transport, and reuse.

You will also need a copy of the HHMI DVD *Evolution: Constant Change and Common Threads,* a DVD player and television monitor or an LCD projector and a computer with a DVD drive.

Part Three—Using the Hardy-Weinberg Equation to model selection

Students should have access to a computer with the ability to run Excel and a printer.

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Safety Note:

Caution students not to consume any of the candies they are provided with for this activity. Students in other classes may have handled the candies. Also, they should not eat in a science classroom.

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Procedures

Part 1: Phase One

- Each group of two students should be provided with a set of materials and copies of the activity. Introduce the activity and have students complete Phase One.
- Be sure to caution students not to squeeze *O. glucosi* through the bag.
- If using a balance, allow students to remove *O. glucosi* from the bag and determine the mass of both colors.

Part 1: Phase Two

- Demonstrate how to hold and crush the "beetles".

- Once teams have completed the trials for Phase Two, compile class data and make it available to all teams. This can be done using a SMART Board, newsprint, or projector.
- Typically red M&Ms have a stronger covering than the blue. However, there are variations. It may be that in the batch of candy you purchased, blue is stronger than red or that there is no significant difference. What you can do at this point is provide students with data from other classes conducting this experiment. A majority of students found that the red coating is stronger than blue. Discuss why their results may have been different.

Part 1: Phase Three

- Show the animation *Pocket Mouse Evolution* from the HHMI DVD *Evolution: Constant Change and Common Threads*.

Part 2

- This part can be done in class or for homework. Students may want access to calculators.
- Student answers should be discussed.

Background Information

Provide each student with a copy of the blank "Summary Chart" located on the last page of these *Teacher* materials. Have students complete the summary chart as you work through the explanation that follows.

In a hypothetical population consisting of 100 *O. glucosi* beetles, there are 81 blue individuals. Blue is recessive so that any individuals exhibiting a blue phenotype possesses 2 alleles for blue. Their genotype is *rr*. Therefore, these individuals contribute a total of 162 *r* alleles to the gene pool.

☞ The total is now 162 *r* alleles.

In the same population, there are 19 red beetles. 18 of them are heterozygous red. These individuals have a genotype of *Rr* and contribute 18 *r* and 18 *R* alleles to the gene pool.

☞ The total is now 18 *R* alleles and 180 *r* alleles.

The remaining 1 individual is homozygous red and has a genotype of *RR*. This individual contributes 2 *R* alleles to the gene pool.

☞ The total is now 20 *R* alleles and 180 *r* alleles.

Individuals with an *RR* or *Rr* genotype exhibit a red phenotype. The outward expression of the genes an individual possesses is defined as its phenotype.

Summary Chart: Population of 100 individuals with *RR*, *Rr*, and *rr* genotypes

Phenotype	Genotype	Number of *R* alleles in population	Number of *r* alleles in population
81 Blue individuals	81 *rr*	0	162
19 Red individuals	1 *RR* 18 *Rr*	2 18	18
		Total ***R*** alleles = 20	Total ***r*** alleles = 180
		Total alleles = 200	

The number of alleles for exoskeleton color is 200 since each individual in the population of 100 has 2 alleles for the color gene. The frequency of the R allele in this gene pool is 20/200 = 0.1 or 10%. The frequency of the r allele in the gene pool is 180/200 = 0.9 or 90%.

The Hardy-Weinberg Theorem states that in non-evolving populations, the frequencies of alleles (and therefore the genotypes) would remain constant over generations. The shuffling of alleles during sexual reproduction would have no effect. For evolution to occur, agents other than segregation and recombination must act on the gene pool.

When there are two alleles present for a gene and one is dominant over the other, scientists use the letter p to represent the dominant allele and the letter q to represent the recessive allele. In the case of *O. glucosi*, p represents the frequency of the red (R) allele and q represents the frequency of the blue (r) allele. In the above example, $p = 0.1$ and $q = 0.9$ and therefore, $p + q = 1$ (It can also be expressed as $\%p + \%q = 100\%$)

$$\text{If} \qquad p + q = 1 \qquad \text{then} \qquad p = 1 - q \qquad \text{and} \qquad q = 1 - p$$

During sexual reproduction, sperm and egg combine. Their alleles combine to form a zygote. The probability of forming a zygote with an RR genotype is p^2. In the hypothetical beetle population, the frequency of $p = 0.1$. The probability of an R sperm fertilizing an R egg is p^2 (0.1 x 0.1) = 0.01

The probability of an r sperm fertilizing an r egg is q^2 (0.9 x 0.9) = 0.81

There are two ways that an Rr genotype can result. An R sperm could fertilize an r egg. Or, an r sperm could fertilize an R egg. The frequency of heterozygous beetles can be represented by *2pq*. In the hypothetical beetle population, the frequency of the heterozygous genotype is 2 x (0.9 x 0.1) = 0.18. The total of all possible genotypes for exoskeleton color is 0.01 + 0.18 + 0.81 = 1

Part 3

This part can be done with more advanced students. It works well as either an exercise completed by an individual student or as the focus of a guided class discussion. In both situations, students will need a copy of the Part 3 activity sheet.

If completed as an assignment by individuals

- Students should have access to a computer with the Excel *Selection Coefficient* spreadsheet file, a copy of the activity, and a printer. Once students have worked through the exercise and printed their graphs, they should be able to answer the questions on their own or in groups of two.

- Encourage them to investigate what happens when a recessive mutation has a selection advantage. Students may have to increase the number of generations to a much greater number to see an effect with a modest value of s.

If this activity is done as a class project, you will need to project the data generated and graphs. Everyone should be encouraged to provide input.

Answers to Questions

Part One

1. Four traits that accurately describe the appearance of these beetles include:
    - are round with a sort of flat top and bottom
    - have the letter "m" on one surface
    - about 1.2 cm wide and 0.5 cm tall
    - have a hard outer covering
    - are blue in color

2. Four traits that accurately describe the appearance of these beetles include:

- are round with a sort of flat top and bottom
- have the letter "m" on one surface
- about 1.2 cm wide and 0.5 cm tall
- have a hard outer covering
- are red in color

3. There are no obvious differences between the beetles other than color.

4. Class results are more reliable since there are more trials. A larger sample size leads to increased precision and more accurate data.

5. Typically there is little difference in exoskeleton strength. Students should reference data from their charts that confirms that one or the other of the exoskeletons is stronger or that they find no significant difference. Whatever the case, their responses should reflect their data. As an extension of this part of the activity, you might ask students to perform a Chi-square analysis of their results to see if any difference between red and blue beetles is statistically significant.

6. Answers will vary. Class data may show that red beetles survive the crushing competition more frequently than blue beetles. Whatever the case for your students, an acceptable answer is one that is supported by class data.

7. If the landscape is dark, brown pocket mice blend in and are not readily visible to predators. The dark mice have the selective advantage. Light pocket mice would stand out on a dark landscape and be picked off by predators. The mutation resulted in the dark fur color. If the landscape color is light, it is the light colored mice that have the advantage.

8. The hardness of the exoskeleton is what provides a selective advantage.

9. The behavioral adaptation that resulted in some male beetles digging their own tunnels to intersect with those dug by female beetles could result in beetles with stronger exoskeletons no longer having the advantage. Stronger exoskeletons would no longer be selected for and weaker exoskeletons selected against.

Part Two

Problems

10. Ans. $q = 0.5$ Explanation: $q^2 = (4/16)$ or 0.25%   therefore $q =$ the square root of 0.25 or 0.5.

11. Ans. q = 40%   Explanation: If the frequency of p in a population is 60%, the frequency of q is 40%. Since $p + q = 1$ therefore $q = 1 - 0.6 = 0.4$ or 40%

12. Ans. $2pq = 0.04$ or 4%

Explanation: $q2 = 640/1000 = 0.64$.

Next find the square root of 0.64. Thus $q = 0.8$. Next calculate the value of p. $p = 1 - q = 1. - 0.8 = 0.2$

Next, the frequency of p2 = (0.2)(0.2) = 0.04

Questions

13. A change in the allele frequencies does not prove that a mutation occurred. The change could be due to migration, selective breeding, or natural selection.

14. Student values for q^2 will vary depending on class data.

15. When the color mutation occurred, it resulted in a stronger exoskeleton. This provided beetles with the color mutation with a selective advantage over beetles lacking the mutation. If all other factors remain the same, over time the predominant color in the *O. glucosi* population will change.

Part Three—Extended Activity

16. When the value of *s* is increased, the value of *p* increases while the value of *q* decreases each generation. Students should record the values of s and either record or print the values for *p* and *q*. During this exercise, the frequency of the dominant phenotype increases as the frequency of the recessive phenotype decreases.

17. The color of the landscape might change so that some members of the population are more visible to predators than other members. That is what happened in the pocket mouse video. If the landscape becomes dark in color, then light colored mice are at a disadvantage where before they had the selective advantage over mice with dark fur.

    A mutation might make some members of the population more successful when competing for females. This is what happened in the beetle investigation. It might be that red beetles have stronger exoskeletons than blue beetles and therefore gain access to the tunnel and the female. Beetles with the stronger red exoskeleton would have a selective advantage over beetles with a blue exoskeleton. However, the behavioral adaptation that occurred that resulted in a new mating strategy made a big difference in selective advantage. Males that dug tunnels that intersected with those dug by female beetles were reproductively the most successful. No combat would be involved. Exoskeleton strength would no longer provide a selective advantage in regard to mating.

18. The selection coefficient is a numerical representation of how much of an advantage or disadvantage a particular variation or trait provides an organism. It provides a way to mathematically model and predict evolutionary change.

19. The equation can be used to model selection mathematically. The frequency of a particular allele can be determined. This value can then be used to predict its frequency over multiple generations thus modeling selection.

20. a:60 generations, b:32 generations, c:15 generations, d:9 generations. e:39 generations

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Correlation to National Science Education Standards

Unifying Concepts and Processes
- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Evolution and equilibrium

Content Standard A: Science as Inquiry
- Identify questions and concepts that guide scientific investigations
- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence
- Recognize and analyze alternative explanations and models
- Communicate and defend a scientific argument

Content Standard C: Life Science
- Biological evolution
- Interdependence of organisms
- Behavior of organisms

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

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Summary Chart: Population of 100 individuals with *RR*, *Rr*, and *rr* genotypes

Phenotype	Genotype	Number of *R* alleles in population	Number of *r* alleles in population
____ Blue individuals	____ *rr*	____	____
____ Red individuals	____ *RR*	____	____
	____ *Rr*	____	

Total **R** alleles = ____

Total **r** alleles = ____

Total alleles = ____

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Author: **HHMI:**

Mary Colvard   Dennis WC. Liu, Ph.D.
Cobleskill-Richmondville High School (retired)   Satoshi Amagai, Ph.D.
Cobleskill, NY   Jennifer Bricken
mcolvard@tds.net

Field Testers

Donna Abbruzzese
Farnsworth MS-GCSD
Guilderland, NY

Christine Berte
Clayton A. Bouton HS
Voorheesville, NY

Stephanie Branley
Ravena-Coeymans-Selkirk HS
Ravena, NY

Shirley Buel
Neil Hellman School
Albany, NY

Patrick Canniff
Farnsworth MS-GCSD
Guilderland, NY

Diana Hagan
Albany High School
Albany, NY

Todd Hilgendorff
Farnsworth MS-GCSD
Guilderland, NY

Carol Ann Kelly
Farnsworth MS-GCSD
Guilderland, NY

Richard Lasselle
Farnsworth MS-GCSD
Guilderland, NY

Julie Long
Farnsworth MS-GCSD
Guilderland, NY

Ellen Mall-John
Albany High School
Albany, NY

Tom Manera
Greenwich Central School
Greenwich, NY

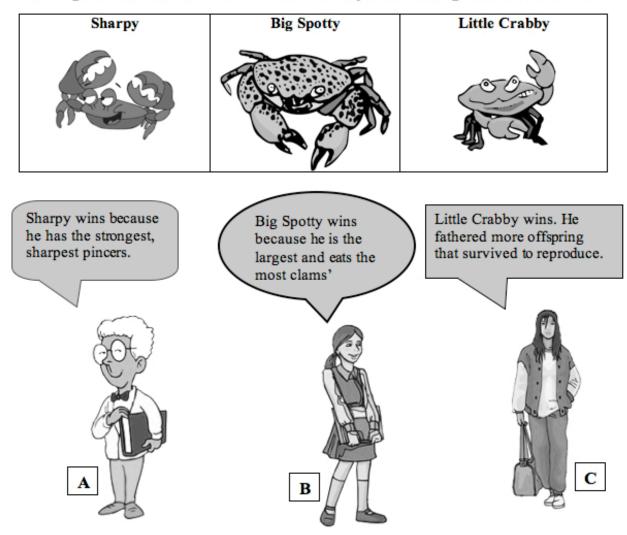Kelly McHale-Sullivan
Voorheesville CSD
Voorheesville, NY

Monica Meissner
Neil Hellman School
Albany, NY

Christopher Reddy
Ravena-Coeymans-Selkirk HS
Ravena, NY

Catherine Vitas
Albany High School
Albany, NY

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Arthropod Hall of Fame: Which variety of arthropod is the most fit?

Sharpy	Big Spotty	Little Crabby

Sharpy wins because he has the strongest, sharpest pincers.

A

Big Spotty wins because he is the largest and eats the most clams'

B

Little Crabby wins. He fathered more offspring that survived to reproduce.

C

What do you think?