Bottleneck Genes

Objectives

Students will (1) describe biodiversity as it relates to natural systems, species, or individuals; (2) articulate that genetic diversity is essential to the health of a species because it facilitates adaptation to change and provides sources for new genetic material; (3) explain how natural selection favors individuals with traits adapted to their environment; and (4) explain that for a wildlife population to sustain itself, there must be enough habitat to support a healthy-sized population that will carry a healthy-sized gene pool.

Method

Students will simulate the gene-pool analysis of a population of black-footed ferrets using colored beads.

Grade Level: 9–12

Subject Areas: Science, Environmental Education

Duration: one 40-minute session

Group Size: eight groups of two to four students each

Setting: indoors

Conceptual Framework Topic Reference: BDI, BDIA3, BDIB2, BDIC1, BDIC2, BDIIIE

Key Terms: gene pool, adapted, genetic diversity

Appendices: none

Materials

One large, long-necked glass bottle; eight sets of the Key to Environmental Situations cards (copy and cut) on page 175; eight copies of the Key to Genetic Characteristics on page 174; eight copies of the Black-Footed Ferret Bottleneck Scenario worksheet on page 176; beads of each of the following colors: yellow, black, orange, pink, blue, green, purple, red, and white (Pony beads, a type of craft bead, approximately 3/8" in diameter and 1/4" in length, or something similar, seem to work well.)

Background

Diversity is essential to the survival of a species. There are three kinds of biological diversity: diversity found in an individual, diversity within a species or given population, and diversity within an ecosystem. The ability of an individual to survive changes in the environment comes from the extent of genetic diversity the individual has, thus giving it the ability to adapt to those variations. Diversity within a population means that there are enough organisms to continue producing a variety of genetic combinations within the group. The third type of diversity, biodiversity, deals with the ecosystem. A diverse ecosystem provides a variety of food sources for those living there, which allows for a higher survival rate.

In the world of "survival of the fittest," an organism must have the genetic resources that allow it to survive immediate changes in its environment and that allow the species to adapt to long-term changes around it. The only way to ensure this will happen is to make sure that the genetic choices in the population are large enough to have the greatest variety of attributes passed along to individuals in the next genera-

tion. The best way to ensure a large and healthy population with enough gene choices is to have sufficient habitat to support it. When the number of individuals decreases, the genetic pool also decreases, causing what is called a "bottleneck" in the population, or a limited variety in gene diversity.

The purpose of this activity is to demonstrate what the importance of genetic variability is to health within a species and how this diversity facilitates adjustment to ecosystem changes. Students will simulate what happens when a population of black-footed ferrets begins to decrease in size, and they will examine how this decrease affects the gene diversity within the group. Following the simulation, the students will look at the effects of a limited gene diversity, or pool, on the population in a changing ecosystem over the period of a year.

NOTE: For information on the black-footed ferret, see the Project WILD activity "Back from the Brink" or visit **www.blackfootedferret.org** on the Internet.

Procedure

1. Divide the class into groups of two to four students. Give each group a copy of the Key to Genetic Characteristics, a Key to Environmental Situations and a Black-Footed Ferret Bottleneck Scenario.
2. Review the terms "genetic diversity," "biodiversity," and "population bottlenecks" as found in the Background section.
3. Review the gene color key. Discuss the benefits of the different attributes.
4. Place all of the genes (colored beads) into the glass bottle. Shake it gently to mix the colors. Explain to students that the genes will be distributed randomly, as would be found in a real population.
5. Distribute a small handful of beads to each group. These beads represent the genes available in the population of black-footed ferrets for each group. Have the students match their genes to the gene key and circle the colors or genes on the Key to Genetic Characteristics for their ferret population. (Please note that the students must be given a small amount of beads to ensure that they do not receive all nine colors.)
6. Have the students choose five Environmental Situation Cards randomly from the deck.
7. Students work with the Black-Footed Ferret Bottleneck Scenario worksheet to complete the following:
   a. Calculate the genetic diversity in their population.
   b. Describe their population according to its current genetic makeup.
   c. Develop and write a prediction for their population in the environmental situation they have chosen for approximately a 1-year period. Then address the following:
   - Is the population genetically equipped to survive in this environment? How well or how poorly?
   - How does a high or low percentage of genetic diversity affect the population's survival?
   - How do random changes in the environment affect the population? (Remind students that for this question they are concerned with how many beads of each color they have.)
8. Each of the groups should present their results to the class.
9. Discuss the following questions:
   - Why does gene diversity help protect a population?
   - Why would a smaller population have a higher risk of being eliminated than a large population?
   - Why do you think smaller populations have a harder time surviving disease? (Inbreeding depletes the gene pool that provides a variety of traits. If there are fewer genes that help an animal fight off disease, the population becomes more susceptible to pathogens.)

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Extensions

1. Discuss the impact of dominant versus recessive traits. Recessive traits have a much lower probability of becoming evident in the population unless the population becomes small enough to interbreed and bring forth those recessive traits, or unless that trait makes the animal better able to survive in its environment. Repeat the activity using two colors for each genetic characteristic (to represent dominant and recessive traits). For instance, dark blue beads could represent healthy jaw formation and light blue beads could represent a jaw malformation or deformity. Also use separate containers for each characteristic, and have students pick two beads from each of those containers. If the group receives only recessive color beads for a characteristic, then the recessive trait will be expressed. If the group receives only dominant color beads or if it receives a mix of dominant and recessive color beads for that characteristic, then the dominant trait will be expressed. (If the color selection of beads is limited, another token, such as colored paper squares, may be used.)
2. After the initial round, randomly pair the groups to see how combining genes from different populations affects diversity. Discuss how this relates to habitat fragmentation.
3. Visit a local zoo, and talk to staff members about their attempts to ensure genetic diversity with their breeding animals. Discuss any attempts they may be involved in to re-establish endangered species in the wild.
4. Have students choose an endangered or threatened species from a local zoo and design a plan for breeding that would ensure, or greatly improve, the chances for genetic diversity and, therefore, survival.

Evaluation

1. Steps 6 through 9 in the Procedure section can be used as an evaluation tool.
2. Have the students research a threatened species found in their area. Students can determine whether genetic diversity within the species had an effect on its depletion. They should also examine whether the species was placed on the threatened list because of degradation or loss of habitat. Have students check their conclusions with the state's natural resources agency or a local office of the U.S. Fish and Wildlife Service.
3. Ask students what challenges concerning genetic diversity many zoos face in trying to re-establish endangered animals.

Adapted with permission from Smithsonian Institution, Conservation & Research Center School Outreach Program, "Black-Footed Ferret Ambassador Program, Secondary School Program Teacher Guide," Jennifer Buff, Shannon Dodge, and Susan Peachey, 1999.

Key to Genetic Characteristics

Yellow	camouflage
Black	precise vision
Orange	accurate sense of smell
Pink	strong claws and forearms
Dark blue	healthy jaw formation
Green	agility
Purple	acute hearing
Red	healthy rate of reproduction
White	immunity to canine distemper

Key to Environmental Situations

1. A farmer has been trying to protect his wheat fields by exterminating prairie dogs. Very little prey is available. Given the genetic makeup, how would your population survive?

2. A golden eagle hunts from high above and will prey on available animals such as the black-footed ferret. Does your population have the gene for precise vision to avoid being captured? Given the genetic makeup, how would your population survive?

3. Black-footed ferret kits disperse from their home territory and are able to establish new populations in nearby prairie dog towns. Given the genetic makeup, how would your population survive?

4. An interstate highway has been built near your prairie dog town. How does this road affect your black-footed ferret population? Given the genetic makeup, how would your population survive?

5. Ranchers are allowing their dogs to run loose. Will your population's genes protect it against canine distemper, assuming the dogs carry it? Given the genetic makeup, how would your population survive?

6. A new generation of captive-born black-footed ferret kits has been preconditioned to live in the wild and are ready to be released at a nearby reintroduction site. Given the genetic makeup, how would your population survive?

7. A plague has hit your prairie dog town, and most of the prairie dogs die from the disease. How does your black-footed ferret population adapt to a reduction in food supply? Given the genetic makeup, how would your population survive?

8. As a coyote silently prowls nearby, only its odor might warn of its presence. Does your population have the gene for an acute sense of smell to warn about the coyote?

9. Black-footed ferrets eat prairie dogs and use prairie dog burrows for shelter. Does your ferret population have the agility gene to catch an aggressive prairie dog in its dark, narrow, winding tunnel system? Given the genetic makeup, how would your population survive?

10. Black-footed ferrets are nocturnal creatures that leave their burrows at night to feed. Does your ferret population have the camouflage gene to keep well hidden from the great horned owl hunting for its dinner? Given the genetic makeup, how would your population survive?

11. A badger is moving quietly around the prairie dog town. Does your population have the gene for acute hearing to avoid this predator? Given the genetic makeup, how would your population survive?

12. A prairie dog colony has just been established in a state park only a few miles away. How does the colony affect your populations of ferrets? Given the genetic makeup, how would your population survive?

13. It will be difficult for your population to take over and adapt to prairie dog burrows without the gene for strong claws and forelegs. Given the genetic makeup, how would your population survive?

14. Humans who are building homes have wiped out a prairie dog town 10 miles away. The surviving black-footed ferrets from that area are moving into your territory. Given the genetic makeup, how would your population survive?

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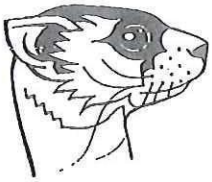


Black-Footed Ferret Bottleneck Scenario

Names of Team Members_____

On your Key to Genetic Characteristics, circle the **COLORS and GENES** that your population received through the bottleneck.

1. **Calculate the percentage of genetic diversity (heterozygosity) of your population.**

   Nine genes (colors) represent 100 percent genetic diversity in the original population.

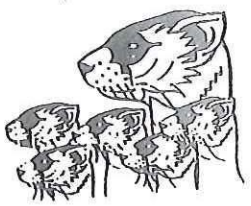
   _____ genes received ÷ 9 original genes = _____(decimal) x 100 = _____%

2. **List the genetic characteristics (colors) that your population received through the bottleneck.**

3. **List the genetic characteristics that your population lost when it came through the bottleneck.** (colors not received)

4. **Using the five environmental situations, write a prediction about what will happen to your population during the coming year.**

   Is the population genetically equipped to survive in its environment? How well or how poorly? How does a high or low percentage of genetic diversity affect the population's survival? How do random changes in the environment affect the population?



Bottleneck Genes Adaptations for Deer and Piping Plover applications

Key to Genetic Characteristics- Deer

Yellow	Strong Immune System
Black	Precise Vision
Orange	Acute Sense of Smell
Pink	High Density Bones
Blue	Inclination to disperse
Green	Developed agility
Purple	Acute Hearing
Red	Tendency to Twin
White	Large size

Key to Genetic Characteristics- Piping Plover

Yellow	Camouflage
Black	Migration timing
Orange	Bill development
Pink	Reduced Calcium Production
Blue	Assertive behavior
Green	Agility
Purple	Acute Sight
Red	Immunity
White	Parental Bonding

Environmental Situations- Deer

1. Unleashed dogs have been introduced into the area through recreational activities and development of the area. How would your population survive based on your genetic makeup?	2. Recent tidal storms have struck the area and removed large paths of shrubs and trees. Given the genetic makeup of your population, how would you survive?
3. Chronic Wasting disease has occurred in Connecticut, infection deer around the area leading to neurological defects and abnormal behavior. How will you population fair based on your genetics?	4. Loss of understory trees and shrubs due to extreme heat trends has limited food availability especially in the fall and spring months. Will your population survive? How?
5. Development of parking areas and trails for travel to a recreational site has increased in your area. Will this affect your population's survival?	6. The size of the preserve has doubled due to recent land donations. How will your population adjust to these changes?
7. Sudden Oak Death- An infection that causes rapid death in oak trees, is detected in your area. How will this affect your population?	8. Deer yearlings disperse from their parent and spread out to cover new territories. Based on your genetics how will your population react to introduction of new homes surrounding your preserve?
9. Deer are herbivores and require good vision and hearing to evade predators. Given your genetic makeup will your' herd survive the hunting season?	10. Rehabilitated deer, raised in captivity due to loss of parent, from the western part of Connecticut have been released into the park territory. A total of 5, 3 female and 2 male. How will this affect the population?
11. Sea level rise has altered the beach zone and caused flooding inland. The area has been affected by loss of low transition zones and wetlands. How will you population adapt?	12. Increased bird activity has increased tick populations in the area. Based on your genetics will you adapt to increased ticks?
13. Due to budget cuts the cost of hunting permits has risen and the number issued has gone down. Based on your genetics how will your population react if controlled harvest is not enforced?	14. The access to the habitat is increased between the town and preserve by construction of rail to trails now connecting the park to areas and preserves across town. How will your genetics be effected?

White Tailed Deer Bottleneck Scenario

Names of Team Members _____

Identify the genetic distribution of your herd below.

Color Bead	Genetic Characteristic	Number present	% of genetic makeup
Yellow	**Strong Immune System**		
Black	**Precise Vision**		
Orange	**Acute Sense of Smell**		
Pink	**High Density Bones**		
Blue	**Inclination to Disperse**		
Green	**Developed Agility**		
Purple	**Acute Hearing**		
Red	**Tendency to Twin**		
White	**Large Size**		
		Total #	

Calculate the percentage of genetic diversity of your population.

Nine genes (colors) represent 100 percent genetic diversity in the original population.

_____ genes received divided by 9 original genes = _____(decimal) x 100 _____ %

List the genetic characteristics that your population received through the bottleneck.

List the genetic characteristics your population lost when it came through the bottleneck.

Using the environmental situations, write a prediction about what will happen to your population during the coming year.

Is your population genetically equipped to survive in its environment? How well or how poorly? How does a high or low percentage of genetic diversity affect the population's survival? How do random changes in the environment affect the population?