KCS @ home

Summer Edition

Biology

Activity 2

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Biology Activity 2 – Unity and Diversity of Life: How Populations Change

Name: _____

LEARNING TARGETS

- Explain how selective pressures in the environment could cause shifts in the physical traits of a population
- Use data to describe how changes in the environment affect the physical traits of a population

This worksheet is designed to complement the KCS@Home Biology Summer Content Activity 2. Complete the tasks below while following along with the video.

Start the Instructional Lesson 2 Video. Pause when instructed to completed the tasks below

1. First, go to the quizlet link (or type in the following URL: bit.ly/lesson2pretest)and let's see what you know about natural selection. Complete the quizlet with flashcards, matching, quiz, as you review.
   Return to Lesson 2 Video

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2. Complete this table using just your prior knowledge.

Term	Description	Example
Allele		
Dominant		
Recessive		
Phenotype		
Genotype		
Homozygous		
Heterozygous		

Return to Lesson 2 Video

3. After watching the short TEDEd video on heredity add to or change your answers above.

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4. How would you define the term evolution?
    a. Record your thoughts below based on what you know-do not google ☺

    Return to Lesson 2 Video
    b. What do you notice or wonder about the official definition of evolution provided?

    Return to Lesson 2 Video

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5. Watch the video at this link (or type in the following URL: bit.ly/lesson2naturalselection)
    a. The video will stop and ask you questions along the way!
    Return to Lesson 2 Video

Let's revisit and build on the Rock Pocket Mice Model of Genetics from Lesson 1

Introduction:
The tiny rock pocket mouse weighs just 15 grams, about as much as a handful of paper clips. A typical rock pocket mouse is 172 millimeters long from its nose to the end of its tail, which is shorter than an average pencil. Its impact on science, however, has been enormous.

Populations of rock pocket mice are found all over the Sonoran Desert in the southwestern United States. Two varieties occur widely in the area—a light-colored variety and a dark-colored variety. Similarly, there are two major colors of substrate, or surface material, that make up the rocky desert floor. Most of the desert landscape consists of light-colored sand and granite. Here and there, however, separated by several kilometers of light-colored substrate, are patches of dark volcanic rocks that formed from cooling lava.

Dr. Michael Nachman of the University of Arizona and his colleagues have spent many years researching the genetics of fur color in rock pocket mice. In particular, they were interested in understanding the forces that shape genetic variation in natural populations. Investigating the adaptive value of different coat colors in rock pocket mice is an example of how scientists are attempting to connect genotype with phenotype for fitness-related traits.

This activity will focus on connecting selective pressures in the environment to shifting allele and phenotype frequencies in a population. In other words, this activity will illustrate natural selection.

6. While rewatching the video from Activity 1 on the rock pocket mouse, consider what is happening from a different perspective - traits and the survival rate of mice. Rewatch the short film at this link: The Making of the Fittest: Natural Selection and Adaptation (or type in this URL: bit.ly/rockpocketvideo). As you watch, record the following information.

    a. What specific trait did researchers study in this investigation?

    b. How does this trait affect the survival of the mice in different environments?

c. What is the genetic basis of the trait?

The genetic definition of “evolution” is “a change to a population’s gene pool.” “Gene pool” is defined as “the total number of alleles present in a population at any given point in time.”

To determine whether a population’s gene pool is changing, we need to be able to calculate allelic frequencies. Suppose, for example, a gene has two alleles, A and a. Each individual has one of three genotypes: AA, Aa, or aa.

In rock pocket mice, several genes code for fur color. Each gene has several possible alleles. That’s why there is a range of fur color from very dark to light. For simplicity, we will work with two alleles at one gene. The allele for dark-colored fur (D) is dominant to the allele for light-colored fur (d). In this scenario, individual rock pocket mice can have one of three genotypes and one of two phenotypes, as summarized in the table below.

Rock Pocket Mice Genotypes and Phenotypes

Population	Genotype	Phenotype
Homozygous dominant	*DD*	Dark
Heterozygous	*Dd*	Dark
Homozygous recessive	*dd*	Light

Dr. Nachman and his colleagues collected rock pocket mice across 35 kilometers of the Arizona Sonoran Desert, which included both dark, rocky lava outcrops and light, rocky, granite areas. They recorded substrate color and coat-color frequencies for each location. Each site was separated from any of the others by at least eight kilometers. The researchers trapped a total of 225 mice. Their data are summarized below.

Field Data Summary

Collecting Site	Substrate Color	Number of Mice	Phenotype	
			Light	Dark
1	Light	6	6	0
2	Light	85	80	5
3	Dark	7	0	7
4	Dark	5	0	5
5	Dark	45	3	42
6	Light	77	34	43

Source of data: Hoekstra, Hopi E., Kristen E. Drumm, and Michael W. Nachman. “Ecological Genetics of Adaptive Color Polymorphism in Pocket Mice: Geographic Variation in Selected and Neutral Genes.” *Evolution* 58, no. 6 (2004): 1329–1344.

7. Calculate the overall frequencies of light-colored mice and dark-colored mice caught on light colored substrates. (frequency = number of mice of one color/total number of mice)

Frequency of light-colored mice _____ Frequency of dark-colored mice _____

8. Calculate the overall frequencies of light-colored mice and dark-colored mice caught on dark colored substrates. (frequency = number of mice of one color/total number of mice)

Frequency of light-colored mice _____ Frequency of dark-colored mice _____

9. Would the gene pool of populations of rock pocket mice on light-colored substrates have higher or lower frequency of the recessive allele? Explain your answer using evidence from tables above.

10. *Challenge Question – do some math to provide evidence for your claim!*
Which fur color seems to have the greatest overall selective advantage? Use data collected from both dark-colored and light-colored substrates to support your answer.

11. According to the film, what environmental change gave a selective advantage for one coat color over another?

12. Recall that evolution can be defined as the change in frequencies of alleles in populations over time. To determine if the rock pocket mouse population is evolving, explain why it is necessary to collect fur color frequency data over a period of many years.

Keep Going to Next Task-Do Not Return to Lesson 2 Video Yet!

Let's Focus in on the Process of Natural Selection that led to this change in the population

Review the Conditions necessary for Natural Selection to occur and provide the evidence:

Condition for Natural Selection to Occur	Description of Condition	Evidence from Rock Pocket example
Variation	Individuals in a population or group differ in some trait of interest.	13.
Inheritance	The variation in the trait of interest is at least partially inherited (passed from parents to offspring). The variation stems from random mutations and the recombination that accompanies sexual reproduction. The genetic variation may have arisen many generations in the past.	14.
Selective pressures	More offspring are born than can survive, resulting in competition among individuals within a population. Some individuals with a particular trait are more likely to survive and/or have relatively more offspring compared to individuals that do not have that trait. Selection depends on the specific context of a species. Traits that are beneficial in one environment may cause problems in another environment. The frequency of the trait that helps individuals survive or leave more offspring will increase in the population over time, as will the alleles	15.

	that affect the trait. This process can take many generations and extend over very long periods of time.	

16. How would biologists explain how the mice on the lava flow evolved black fur? Include all the elements you think are needed for a full explanation.

17. Would biologists say that the mice changed because they wanted or needed to change? Why or why not?

Keep Going to Next Task-Do Not Return to Lesson 2 Video Yet!

Putting It All together

18. Define “mutation.”

19. Is the following statement true or false? Justify your answer in one or two sentences: “Mutations are caused by selective pressure in the environment.”

20. Is the following statement true or false? Justify your answer in one or two sentences: “The same mutation could be advantageous in some environments but deleterious in others.”

21. Is the following statement true or false? Justify your answer in one or two sentences: “The appearance of dark colored volcanic rock caused the mutation for black fur to appear in the rock pocket mouse population.”

22. Explain how the environment plays a role in changing the frequency of a mutant allele in a population.

24. Near the end of the film, Dr. Sean B. Carroll states that “while mutation is random, natural selection is not.” In your own words, explain how this is possible.

25. Suppose you are studying a recently discovered population of rock pocket mice with dark colored fur that lives on volcanic rock. You take a DNA sample from a member of this new population and determine the DNA sequence of a gene known to play a role in fur color. The sequence you get is identical to that of the same gene in another rock pocket mouse population with dark-colored fur that lives on a different patch of volcanic rock. Which of the following could explain this observation?
    a. The mice in the two populations evolved from the same ancestral population.
    b. The volcanic rock caused the same mutation in each rock pocket mouse population, resulting in dark coloration.
    c. The same mutation spontaneously arose in the two different populations.
    d. Both (a) and (c) are possible.
    e. All of the above are possible.

26. For rock pocket mice, which of the following contributes to selective pressure favoring dark colored fur? Write "yes" or "no" next to each of the four possible responses. There may be more than one yes response.
    Predators _____ Genetic mutations _____
    Rock color _____ Availability of food for the rock pocket mice _____

Return to Lesson 2 Video

Reflections

27. Summarize your learning in one paragraph. Review the Learning Targets at the beginning of this handout. How would you explain how populations change?

28. What is something you would still like to learn about evolution?

Extension Activities

29. Explore answers to your questions from #29 above.

30. Visit Nova's evolution resources at this link (or this URL: https://bit.ly/novaevolutionsite).
    - explore the site -the videos are great
    - play the evolution game! (Students get hooked on this game!)

**This lesson was modified from the online resources listed below:*

- *https://www.biointeractive.org/classroom-resources/allele-and-phenotype-frequencies-rock-pocket-mouse-populations*
- *https://www.biointeractive.org/classroom-resources/activity-natural-selection-and-adaptation*
- *https://www.biointeractive.org/classroom-resources/making-fittest-natural-selection-and-adaptation*
- *https://www.biointeractive.org/classroom-resources/developing-explanation-mouse-fur-color*

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Name: ____Answer Key_____

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2. Complete this table using just your prior knowledge.

Term	Description	Example
Allele	different forms of a gene	Y and y
Dominant	an allele that is always expressed if it is present in the genotype	Y (uppercase)
Recessive	an allele that is masked when it occurs with another version of the gene	y (lowercase)
Phenotype	physical characteristics of the organism	yellow green
Genotype	genetic make-up or organism set of alleles for each gene	YY or Yy or yy
Homozygous	Both alleles are identical	YY
Heterozygous	The two alleles are different	Yy

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various answers

Return to Lesson 2 Video

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6. While rewatching the video from Activity 1 on the rock pocket mouse, consider what is happening from a different perspective - traits and the survival rate of mice. Rewatch the short film at this link: The Making of the Fittest: Natural Selection and Adaptation (or type in this URL: bit.ly/rockpocketvideo). As you watch, record the following information.

a. What specific trait did researchers study in this investigation?

Fur color, specifically melanism, is the trait they studied.

b. How does this trait affect the survival of the mice in different environments?

Depending on the color of the substrate, fur color may or may not help rock pocket mice blend in with their environment. On a light-colored substrate, mice with fur that is light in color are camouflaged and are not very obvious to predators. On a dark substrate, mice with dark-colored fur blend in and are better able to avoid predation. Predators readily spot mice with light-colored fur. Mice that survive predation are more likely to live, reproduce, and pass on their favorable trait for fur color.

c. What is the genetic basis of the trait?
Mutations in the Mc1r gene are responsible for the appearance of dark fur color in this particular population of rock pocket mice.

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To determine whether a population's gene pool is changing, we need to be able to calculate allelic frequencies. Suppose, for example, a gene has two alleles, A and a. Each individual has one of three genotypes: AA, Aa, or aa.

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7. Calculate the overall frequencies of light-colored mice and dark-colored mice caught on light colored substrates. (frequency = number of mice of one color/total number of mice)

   Frequency of light-colored mice 120/168 = 71% Frequency of dark-colored mice 48/168 = 29%

8. Calculate the overall frequencies of light-colored mice and dark-colored mice caught on dark colored substrates. (frequency = number of mice of one color/total number of mice)

   Frequency of light-colored mice 3/57 = 5% Frequency of dark-colored mice 54/57 = 95%

9. Would the gene pool of populations of rock pocket mice on light-colored substrates have higher or lower frequency of the recessive allele? Explain your answer using evidence from tables above.
   Student answers should indicate a higher frequency of the recessive allele due to the increased number of light mice in those areas. Students should indicate that light mice are homozygous for recessive allele; therefore, these populations would have a higher frequency of the recessive allele. Various data from sites may be used to support this claim.

10. *Challenge Question – do some math to provide evidence for your claim!*
    Which fur color seems to have the greatest overall selective advantage? Use data collected from both dark-colored and light-colored substrates to support your answer.
    Dark fur color seems to have the greatest selective advantage. On the light-colored substrate, 29% of the mice have dark fur, while only 5% of the mice on the dark-colored substrate have light fur. Also, at collecting site no. 6, where there is a light-colored, rocky substrate, 43 out of 77 mice

collected had dark-colored fur—over half of the sampled population. Dark-colored fur seems to have a selective advantage over light fur color

11. According to the film, what environmental change gave a selective advantage for one coat color over another?
The color of the landscape changed so that some members of the population were more visible to predators than other members were. That is what happened in the film. When sections of the landscape became dark, the light colored mice were at a selective disadvantage.

12. Recall that evolution can be defined as the change in frequencies of alleles in populations over time. To determine if the rock pocket mouse population is evolving, explain why it is necessary to collect fur color frequency data over a period of many years.
The data collected represent only one moment in time. If the population is evolving, the frequency of the two alleles for fur color will change over time/generations. If the population is not under selective pressure, or is not evolving, the frequencies will remain approximately the same.

Keep Going to Next Task-Do Not Return to Lesson 2 Video Yet!

Let's Focus in on the Process of Natural Selection that led to this change in the population

Review the Conditions necessary for Natural Selection to occur and provide the evidence:
If needed rewatch the video: The Making of the Fittest: Natural Selection and Adaptation

Condition for Natural Selection to Occur	Description of Condition	Evidence from Rock Pocket example
Variation	Individuals in a population or group differ in some trait of interest.	13. There are black rock pocket mice and tan rock pocket mice, and they belong to the same species. • Black mice may be found in a population of tan mice with a frequency of about 1 for every 100,000 births
Inheritance	The variation in the trait of interest is at least partially inherited (passed from parents to offspring). The variation stems from random mutations and the recombination that accompanies sexual reproduction. The genetic variation may have arisen many generations in the past.	14.New mutations cause black color (time mark 3:24). • Fur color is controlled by many genes (4:29). • Most genes are identical, but dark and light rock pocket mice differ in one gene (Mc1r; 4:55).
Selective pressures	More offspring are born than can survive, resulting in	15. Mice of different fur colors do not show a

	competition among individuals within a population. Some individuals with a particular trait are more likely to survive and/or have relatively more offspring compared to individuals that do not have that trait. Selection depends on the specific context of a species. Traits that are beneficial in one environment may cause problems in another environment. The frequency of the trait that helps individuals survive or leave more offspring will increase in the population over time, as will the alleles that affect the trait. This process can take many generations and extend over very long periods of time.	preference for background color, but predators weed out mice that do not match their background (2:58). • Tan mice blend into the environment when on desert sands but stand out when on dark lava (1:32). The video suggests that on the dark lava flows, darkcolored rock pocket mice are more numerous than light-colored mice. • A survival advantage of 1% for dark rock pocket mice on a dark background, starting at 1% of the population, would result in 95% of the mice having dark fur in 1000 years (6:18). • A survival advantage of 10% would cause the same change in a population in only 100 years (6:34)

16. How would biologists explain how the mice on the lava flow evolved black fur? Include all the elements you think are needed for a full explanation.
    - Variation: Within a population of mice on the lava flow, some individuals had the dark fur trait, whereas others did not.
    - Inheritance: The differences in mouse fur color are inherited (passed from parents to offspring). The origin of the variation stems from mutations.
    - Selective pressures leading to differences in survival/reproduction: In certain environments, individual mice that have dark fur will survive and have more offspring than mice with tan fur. The frequency of the mice with dark fur and the alleles that cause dark fur will increase in the population over generations. In this case, the population will change from one in which most of the individuals had tan fur to one in which most of the individuals have dark fur.

17. Would biologists say that the mice changed because they wanted or needed to change? Why or why not?

Keep Going to Next Task-Do Not Return to Lesson 2 Video Yet!

Putting It All together

18. Define “mutation.”

A mutation is a change in an organism’s DNA sequence. Students may also mention that the change is random, but this is not necessary for a complete answer.

19. Is the following statement true or false? Justify your answer in one or two sentences:
“Mutations are caused by selective pressure in the environment.”

False; the mutations discussed in this film occurred at random. (Mutations can be nonrandom, but they are not caused by selective pressure.) Students may also mention that environmental selective pressure acts on the phenotype that results from the mutations but does not cause the mutations or the phenotype to appear

20. Is the following statement true or false? Justify your answer in one or two sentences: “The same mutation could be advantageous in some environments but deleterious in others.”

True; the environment or selective pressure determines whether a mutation is beneficial.

21. Is the following statement true or false? Justify your answer in one or two sentences: “The appearance of dark colored volcanic rock caused the mutation for black fur to appear in the rock pocket mouse population.”

False; selective pressure does not cause mutations but rather determines whether a mutation is advantageous or deleterious in a particular environment. Students may also mention that the dark-colored volcanic rock played a role in making dark-colored fur (and the corresponding alleles or mutations) favored, but this is not necessary for a complete answer.

22. Explain how the environment plays a role in changing the frequency of a mutant allele in a population.

Some traits are more advantageous (or deleterious) in certain environments than others. As a result, organisms with traits (and therefore the mutations that result in those traits) that make them better suited to a particular environment are more likely to have offspring and pass on their genes. Over time, this results in an increase in the frequency of mutations that encode beneficial traits for that environment (or, conversely, a decrease in the mutations that influence deleterious traits in that particular environment). Students may provide an example to support their answers (such as the rock pocket mice from the film), but this is not necessary for a complete answer

24. Near the end of the film, Dr. Sean B. Carroll states that “while mutation is random, natural selection is not.” In your own words, explain how this is possible.

A complete answer for this question should include the idea that natural selection acts on traits, which results in the mutations for those traits being more likely to be passed on to the next generation. However, it does not actually cause the mutations to appear in the population; many mutations appear randomly. Paraphrasing the above quote is not sufficient for a complete answer

25. Suppose you are studying a recently discovered population of rock pocket mice with dark colored fur that lives on volcanic rock. You take a DNA sample from a member of this

new population and determine the DNA sequence of a gene known to play a role in fur color. The sequence you get is identical to that of the same gene in another rock pocket mouse population with dark-colored fur that lives on a different patch of volcanic rock. Which of the following could explain this observation?

a. The mice in the two populations evolved from the same ancestral population.

b. The volcanic rock caused the same mutation in each rock pocket mouse population, resulting in dark coloration.

c. The same mutation spontaneously arose in the two different populations.

d. Both (a) and (c) are possible.

e. All of the above are possible.

26. For rock pocket mice, which of the following contributes to selective pressure favoring dark colored fur? Write "yes" or "no" next to each of the four possible responses. There may be more than one yes response.

Predators yes Genetic mutations no

Rock color yes Availability of food for the rock pocket mice no

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Reflections

27. Summarize your learning in one paragraph. Review the Learning Targets at the beginning of this handout. How would you explain how populations change?

various answers

28. What is something you would still like to learn about evolution?

various answers

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