Teacher Resources—Animal Arms Races

Learning Outcomes

1. I can **distinguish** between nondefensible and defensible resources.
2. By **analyzing** and **interpreting** evidence about types of competition strategies, the defensibility of resources and the competition for mates, I can predict which animals are likely to develop extreme weapons.
3. I can **explain** how extreme weapons affect the probability of successful reproduction.

Time Estimate

90 minutes (longer for middle school students)

Designed Specifically to Support These NGSS* Standards:

MS-LS4-4

Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

MS-LS1-4

Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

HS-LS4-2

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species.]

Prerequisites

1. Students can locate relevant information from complex diagrams and data tables.
2. Students can compare and contrast multiple drawings of similar objects in order to identify subtle differences.

3. Students can explain that if an organism reproduces, it passes its genetic material to the next generation.
4. Students can explain that the population of organisms may change if only some of the members if the original population reproduce successfully.

To Prepare Before Facilitating:

Make copies of pages 264–269 (double sided/stapled).

It may be helpful to hand out the activity as three separate tasks: pages 264–265, page 266, and pages 267–269.

Make copies of pages 270-271 to hand out as enrichment to teams that finish early.

Additional Resources

Many videos are available to introduce your students to dung beetles. Here is one:

https://www.youtube.com/watch?v=Cz8zVQ0XTR8

Here is a "Bozeman Science" video that summarizes Natural Selection. It would be great for students to watch AFTER completing this activity.

http://www.bozemanscience.com/001-natural-selection

YouTube video: "Animal Structures and What They Mean"

https://www.youtube.com/watch?v=iwGgc73Dv0o&feature=youtu.be

Short video about stalk eyed flies

https://www.youtube.com/watch?v=bGX7zZk0Eo4

For students who are particularly interested in extreme animal weapons, here are interviews with Doug Emlen, the author of the book, Animal Weapons:

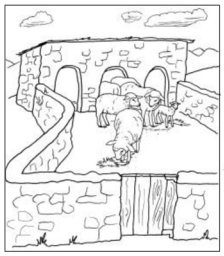
Interview 1: https://www.youtube.com/watch?v=No6mB6V1wL4

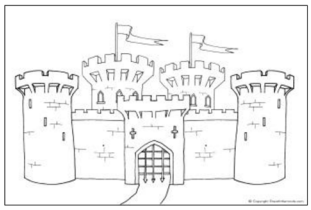
Interview 2: https://www.youtube.com/watch?v=CyidhY2dc5I

Much of the information in this activity is based on unpublished data from 2015 and 2016 interviews of researchers at the Lavine Lab at Washington State University, Pullman WA and the Emlen Lab at University of Montana, Missoula MT. The work was funded through the National Science Foundation Animal Behavior Award NSF IOS 1456731 to the WSU and UM Departments of Entomology.

Assessment Questions

1. Circle the defensible resources.

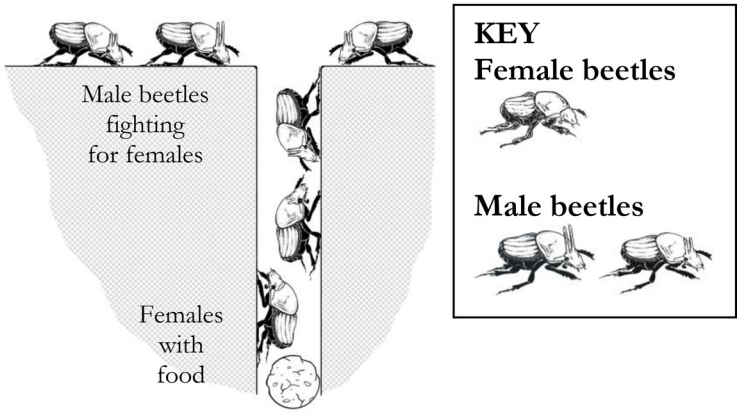




2. Circle the one statement in the final column that is correct.

Type of Animal	Do males compete for females?	Do males have a defensible resource?	Do males engage in one-on-one duels?	Your prediction: Will males have an extreme weapon?
Termites	Yes	Yes	Yes	Yes No
Crows	Yes	No	No	Yes No
Wolf	Yes	Yes	No	Yes No
Rhinoceros Beetles	Yes	Yes	Yes	Yes No

3. Write one or two sentences that explain how extreme weapons affect the probability of reproductive success. Base your answer on the situation shown in the following drawing.



Animal Arms Races

Why? *Answer Key (Suggested Answers)*

You've heard about human arms races where one country builds a fast fighter jet, a destructive nuclear bomb, a very accurate gun. Soon another country responds by building faster jets, more destructive bombs, more accurate guns. This spiral of competition leads to the evolution of faster, more powerful, more accurate weapons. All this effort is invested to defend a country's resources. In nature we find a variety of animals with oversized body parts that act as weapons, such as moose with huge antlers and walruses with gigantic tusks. Yet there are similar animals without these weapons, such as horses and seals. Why do some animals have these large weapons while other similar animals do not? There are even very closely related animals where some species have large weapons and others do not, such as dung beetles. In this activity, we will explore the conditions and behaviors required for species to evolve oversized weapons, and we will investigate a species that seems to defy evolutionary theory.

Use the information from Model 1 to answer Questions 1–5.
Reach an agreement with your team before writing down your consensus answer.

1. List the three column headings in Model 1 (see page 256).

   Defensible Resources, Nondefensible Resources, Difference

2. Circle the items in the following list that are classified as resources in Model 1.

   mates food trees fence homes
   people dung bridge fruit

3. If you had the job of guarding these resources in Model 1, which column would you prefer to defend? Explain your reasoning.

   Defensible resources because there is some type of barrier or restricted access point that is easy to guard. This makes it easier to keep resources away from competitors.

4. Complete the "Difference" column in Model 1.

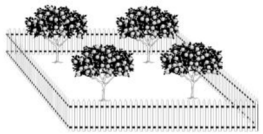
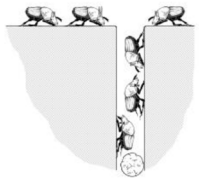
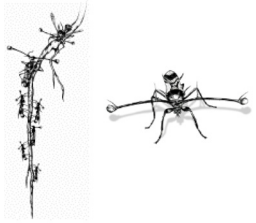
   a. Identify the difference between each pair of examples.
   b. Underline this difference.
   c. Explain how that difference allows the same resource to be protected in one situation but not in the other situation.

Check with your teacher before you continue.

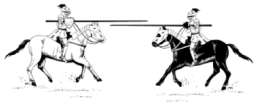
5. In your own words, write one complete sentence that defines the term **defensible resource**.

   It is any resource that the animal (or person) can easily protect from others.

Model 1—What is a Defensible Resource?

Defensible Resources		Nondefensible Resources		Difference
Middle Ages Walled Village Resources: Food, Water, Homes, Animals, People		**Middle Ages Village** Resources: Food, Water, Homes, Animals, People		*A wall: The villagers can close the gate and keep animals and other people away from their food, water, homes and families*
Fenced Fruit Tree Orchard Resource: Ripe Fruit		**Unfenced Fruit Tree Orchard** Resource: Ripe Fruit		Fences: The owner can keep animals and people away from trees when the fruit is ripe, so the owner gets all the fruit. The restricted access makes the resource easier to guard.
Tunneling Dung Beetle Resource: Mate (in tunnel)		**Non-Tunneling Dung Beetle** Resource: Mate with food (dung)		*Tunnel: The male dung-rolling beetle must keep other males away from the female. There is only one way to get into the tunnel where the female is located, and it can be guarded.*
Stalk-Eyed Flies Resource: Small roots to stand on while mating		**House Flies** Resource: Any surface to stand on while mating		*Small root to stand on: The male fly can guard his female mates from other males. There is only one way to get to small root where the females are located, and it can be guarded.*

Model 2—Different Competition Strategies for Defending a Resource

Examples		Competition Strategies: Agility (speed, quick changes in direction)	Competition Strategies: Scramble (competitors approaching from many directions)	Competition Strategies: One-on-One Duel (matched test of strength)
Fighter Pilots		X		X
Jousting Knights				
Elk				X
Football Players Piling on the Ball Carrier			X	
Dragon Flies		X		
Ball-Rolling Dung Beetle			X	

Use the information from Model 2 to answer Questions 6–9.

Reach an agreement with your team before writing down your consensus answer.

6. Discuss how each example of competition should be classified best: agility, a scramble or a one-on-one duel. Draw an X in the one box to show your team consensus answer.

STOP Check with your teacher before you continue.

7. Circle the pictures of examples in Model 2 that have oversized weapons.

8. Circle the type of competition strategy that is always associated with the presence of oversized weapons

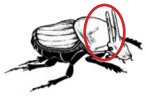
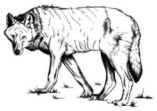
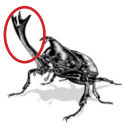
   agility scramble one-on-one duels

9. Predict which of the following species seem most likely to use one-on-one duels as their competition strategy. Circle your answer(s).

   Some students might circle only the crab. That is okay.



Model 3—To Have or Not to Have Extreme Weapons

Type of Animal	Drawing of Male	Do males compete for females?	Do males have a defensible resource?	Do males engage in one-on-one duels?	Do males have an extreme weapon?
Elk		Yes	Yes Herd of females	Yes	***Yes***
Sea Star		No Releases sperm/eggs into the water	Yes Food (sections of shellfish beds)	Yes	***No***
Stalk-eyed Fly		Yes	 Yes Roots to stand on while mating	Yes	Yes
House Fly		Yes	No	No	No
Tunneling Dung Beetles		Yes	Yes Tunnel with dung (food) and female in it	Yes	Yes
Ball-Rolling Dung Beetles		Yes	No Ball of dung in the open	No	***No***
Wolves		Yes	Yes Cave for females	No Not physically, but by dominant personality	No
Rhinoceros Beetle		Yes	Yes Sap (food) oozing from tree	Yes	***Yes***

Use the information from Model 3 to answer Questions 10–16.

Reach an agreement with your team before writing down your consensus answer.

10. Which gender(s) of each species are included in the drawings in Model 3?

Males

11. Compare the **column headings** in Model 1, Model 2 and Model 3. Circle the phrases that are found in more than one of these models.

Defensible resources	Nondefensible resources	Agility
Scramble	One-on-One duel	Extreme weapons

12. Based on the drawings in Model 3, complete the last column of the Model 3 data table.

13. Write Yes or No to answer each of the following questions.

    For all of the eight species shown in Model 3, do **all** of the males…

    a. compete for female mates? ***No***

    b. have a defensible resource? ***No***

    c. engage in one-on-one duels? ***No***

    d. have an extreme weapon? ***No***

STOP Check with your teacher before you continue.

14. List the names of the species with males that develop extreme weapons. Circle the extreme weapon on the drawings of each of your listed species.

    Elk, Stalk-eyed fly, Tunneling dung beetle, Rhinoceros beetle

15. Carefully review Model 3 to determine the situation and the behaviors documented in the species you have circled. In 1–2 complete sentences, clearly summarize the behaviors and situations that are similar in all of the species that develop extreme weapons.

    All of the animals that develop extreme weapons have these behaviors in common: they compete for females and they engage in one-on-one duels. The situation that these animals all have in common is that they have a defensible resource.

16. Consider the following data on three species we have not analyzed. Based on your understanding of the behaviors and situations that lead to the evolution of extreme weapons, fill in the table.

Type of Animal	**Do males compete for females?**	**Do males have a defensible resource?**	**Do males engage in one-on-one duels?**	**Do you predict that males will have an extreme weapon?** Explain your answer clearly and completely.
Fiddle Crab	Yes	Yes Burrow with females in it	Yes	***Yes, the fiddler crab engages in the same behaviors and has the same situations as described in the answer to Question 15.***
Mouse	Yes	Yes Burrow with females in it	No	***No, the mouse shows only two of the three behaviors/situations that seem to be required to develop extreme weapons.***
Termite	Yes	Yes Fortress with limited entrance	Yes	***Yes, the termite engages in the same behaviors and has the same situations as described in the answer to Question 15.***

What I Still Wonder…

17. Write one additional question you have about animal weapons or about changes over time in animal species.
    Answers will vary.

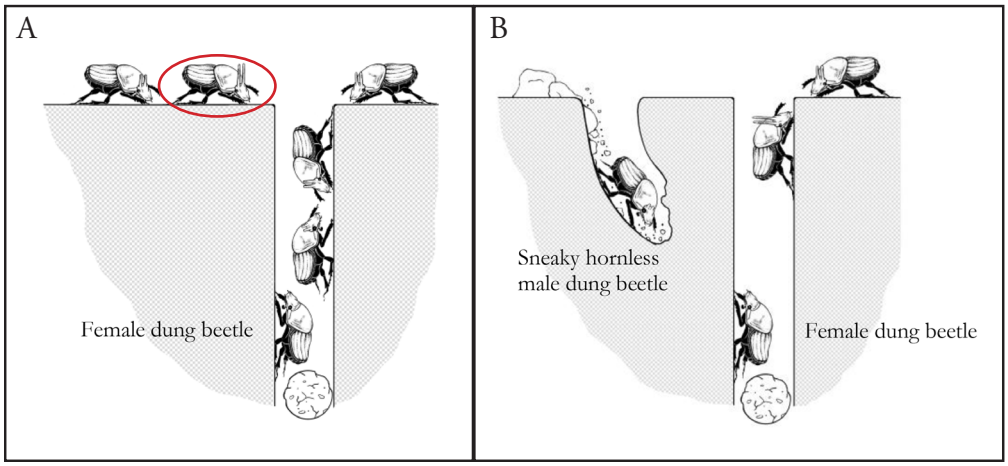
Extension Questions

Read This!

When evolutionary biologists began investigating the evolution of extreme weapons in dung beetles, they encountered a very confusing problem. From observations of horned male dung beetles defending the entrances to their tunnels, it seemed that only the beetles with the longest horns would ever have access to females. Thus their male offspring should develop longer horns, too. **Evolutionary theory would have predicted that over time all of the male beetles would develop longer and longer horns.** Surprisingly, no matter how many generations of beetles the researchers bred, there were always some hornless male beetles in every generation. In Model 4, you will analyze data from underground observations of these beetles to generate an explanation for why hornless male beetles never completely disappeared from the population.

Model 4—The Mystery of the Tunneling Dung Beetle

Type of Animal	Drawing	Do Males Compete for Females	Do Males have a Defensible Resource?	Do males Engage in One-on-one Duels?	Do Males have an Extreme Weapon?
Tunneling dung beetle male (Horned)		Yes	Yes Females in a Burrow?	Yes	Yes
Tunneling dung beetle male (Hornless)		No	No	No	No
Tunneling dung beetle female (Hornless)		---	---	---	



18. In Box A of Model 4, all the male beetles have horns.

    a. How many male beetles are present?

    Four

    b. How many female beetles are present?

    Two

19. Compare the male beetles in Box A. The male beetle with the largest horns usually wins one-on-one duels over access to the tunnel. This beetle is the only one that can mate with the female and produce offspring. Circle the beetle in Box A that is most likely to produce offspring.

20. The horn length of male beetles is most closely related to their father's horn length.

    Predict the type of male beetle offspring that the winner in Box A will produce:

    Hornless Short horns Medium horns Long horns

    Explain your answer:

    The male beetle with the longest horns is most likely to win access to the female. His male offspring will also have long horns, similar to his own.

21. Compare the male beetles in Box B. Based on the drawing, describe what the sneaky hornless male beetle has done to gain access to mate with the female.

    The sneaky hornless male dug a side tunnel to reach the female. This way he didn't need to fight the long-horned male to gain entrance to the female's tunnel!

22. Describe how being hornless might make it easier to sneak into a tunnel unnoticed and mate with a female. Include your ideas about the difficulty of sneaking in to build a side tunnel if you have larger or smaller horns.

    The sneaky hornless males might be able to dig a tunnel more easily than a male with horns. At the least, the tunnel could be smaller than if a horned male beetle tried to dig a tunnel. This way he could get to the female quickly. Also maybe the long-horned male might think the hornless male is a female since they look the same.

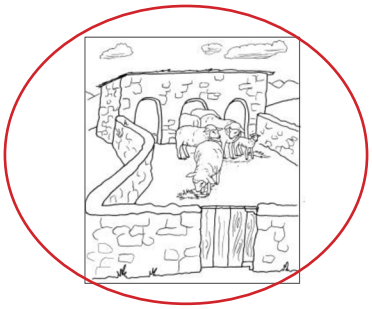
23. Write 3–4 sentences that justify the following claim. Include evidence from Model 4 and your answers to Questions 17–21.

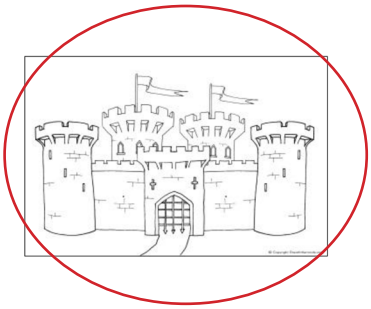
    "As long as tunneling dung beetles continue to behave in the same manner as they did during research observations, there will always be at least some hornless males in the population."

    The processes of evolution should favor more and more long-horned male beetles in the population as time passes since these beetles will be able to mate more frequently and pass on their long-horn genes to their male offspring. Eventually, if all male beetles had to fight to gain access to females, the hornless males would mate so rarely that they would eventually die out and no longer be present in the population. However, if the "sneaky male" behavior continues, at least a few hornless males will be able to mate with females and pass along their hornless gene to their offspring. This means there will probably always be at least a few hornless males in each generation.

Assessment Questions

1. Circle the defensible resources.
Students may or may not include the castle, depending on their assumption of resources held within its walls.

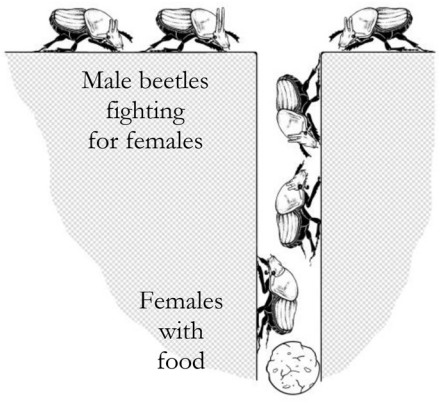


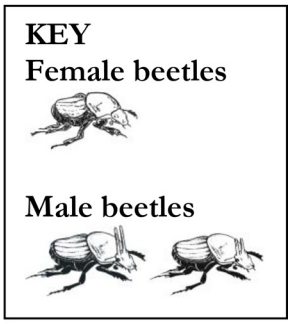


2. Circle the one statement in the final column that is correct.

Type of Animal	Do males compete for females?	Do males have a defensible resource?	Do males engage in one-on-one duels?	Your prediction: Will males have an extreme weapon?
Termites	Yes	Yes	Yes	**Yes** / No
Crows	Yes	No	No	Yes / **No**
Wolf	Yes	Yes	No	Yes / **No**
Rhinoceros Beetles	Yes	Yes	Yes	**Yes** / No

3. Write one or two sentences that explain how extreme weapons affect the probability of reproductive success. Base your answer on the situation shown in the following drawing.





In the situation shown, male beetles are fighting for the females. Because the male with the longest horns win fights with other males, the long-horned male can defend the entry to the tunnel where the females are located. He will be the only male that mates and produces offspring, so he is more likely to have reproductive success than the males without the extreme weapon (horns).

Animal Arms Races

Why?

You've heard about human arms races: one country builds a fast fighter jet, a destructive nuclear bomb, a very accurate gun. Soon another country responds by building faster jets, more destructive bombs, more accurate guns. This spiral of competition leads to the evolution of faster, more powerful, more accurate weapons. All this effort is invested to defend a country's resources.

In nature we find a variety of animals with oversized body parts that act as weapons, such as moose with huge antlers and walruses with gigantic tusks. Yet there are similar animals without these weapons, such as horses and seals. Why do some animals have these large weapons while other similar animals do not? There are even very closely related animals where some species have large weapons and others do not, such as dung beetles.

In this activity, we will explore the conditions and behaviors required for species to evolve oversized weapons, and we will investigate a species that seems to defy evolutionary theory.

Use the information from Model 1 to answer Questions 1–5.
Reach an agreement with your team before writing down your consensus answer.

1. List the three column headings in Model 1 (see page 256).

2. Circle the items in the following list that are classified as resources in Model 1.

   mates food trees fence homes

   people dung bridge fruit

3. If you had the job of guarding these resources in Model 1, which column would you prefer to defend? Explain your reasoning.

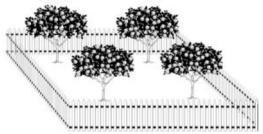
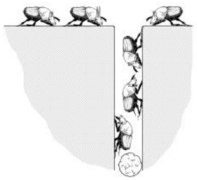
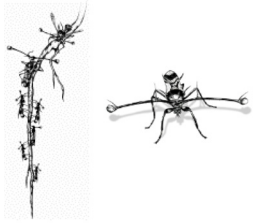
4. Complete the "Difference" column in Model 1.

   a. Identify the difference between each pair of examples.
   b. Underline this difference.
   c. Explain how that difference allows the same resource to be protected in one situation but not in the other situation.

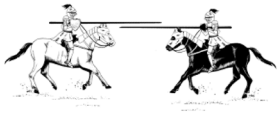
Check with your teacher before you continue.

5. In your own words, write one complete sentence that defines the term **defensible resource**.

Model 1—What is a Defensible Resource?

Defensible Resources		Nondefensible Resources		Difference
Middle Ages Walled Village Resources: Food, Water, Homes, Animals, People		**Middle Ages Village** Resources: Food, Water, Homes, Animals, People		
Fenced Fruit Tree Orchard Resource: Ripe Fruit		**Unfenced Fruit Tree Orchard** Resource: Ripe Fruit		Fences: The owner can keep animals and people away from trees when the fruit is ripe, so the owner gets all the fruit. The restricted access makes the resource easier to guard.
Tunneling Dung Beetle Resource: Mate (in tunnel)		**Non-Tunneling Dung Beetle** Resource: Mate with food (dung)		
Stalk-Eyed Flies Resource: Small roots to stand on while mating		**House Flies** Resource: Any surface to stand on while mating		

Model 2—Different Competition Strategies for Defending a Resource

Examples		Competition Strategies: Agility (speed, quick changes in direction)	Scramble (competitors approaching from many directions)	One-on-One Duel (matched test of strength)
Fighter Pilots				
Jousting Knights				
Elk				
Football Players Piling on the Ball Carrier				
Dragon Flies				
Ball-Rolling Dung Beetle				

Use the information from Model 2 to answer Questions 6–9.

Reach an agreement with your team before writing down your consensus answer.

6. Discuss how each example of competition should be classified best: agility, a scramble or a one-on-one duel. Draw an X in the one box to show your team consensus answer.

Check with your teacher before you continue.

7. Circle the pictures of examples in Model 2 that have oversized weapons.

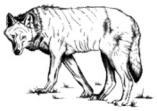
8. Circle the type of competition strategy that is always associated with the presence of oversized weapons

agility scramble one-on-one duels

9. Predict which of the following species seem most likely to use one-on-one duels as their competition strategy. Circle your answer(s).



Model 3—To Have or Not to Have Extreme Weapons

Type of Animal	Drawing of Male	Do males compete for females?	Do males have a defensible resource?	Do males engage in one-on-one duels?	Do males have an extreme weapon?
Elk		Yes	Yes Herd of females	Yes	
Sea Star		No Releases sperm/eggs into the water	Yes Food (sections of shellfish beds)	Yes	
Stalk-eyed Fly		Yes	 Yes Roots to stand on while mating	Yes	Yes
House Fly		Yes	No	No	No
Tunneling Dung Beetles		Yes	Yes Tunnel with dung (food) and female in it	Yes	Yes
Ball-Rolling Dung Beetles		Yes	No Ball of dung in the open	No	
Wolves		Yes	Yes Cave for females	No Not physically, but by dominant personality	No
Rhinoceros Beetle		Yes	Yes Sap (food) oozing from tree	Yes	

Use the information from Model 3 to answer Questions 10–16.

Reach an agreement with your team before writing down your consensus answer.

10. Which gender(s) of each species are included in the drawings in Model 3?

11. Compare the **column headings** in Model 1, Model 2 and Model 3. Circle the phrases that are found in more than one of these models.

Defensible resources	Nondefensible resources	Agility
Scramble	One-on-One duel	Extreme weapons

12. Based on the drawings in Model 3, complete the last column of the Model 3 data table.

13. Write Yes or No to answer each of the following questions.

    For all of the eight species shown in Model 3, do **all** of the males…

    a. compete for female mates?
    b. have a defensible resource?
    c. engage in one-on-one duels?
    d. have an extreme weapon?

Check with your teacher before you continue.

14. List the names of the species with males that develop extreme weapons. Circle the extreme weapon on the drawings of each of your listed species.

15. Carefully review Model 3 to determine the situation and the behaviors documented in the species you have circled. In 1–2 complete sentences, clearly summarize the behaviors and situations that are similar in all of the species that develop extreme weapons.

16. Consider the following data on three species we have not analyzed. Based on your understanding of the behaviors and situations that lead to the evolution of extreme weapons, fill in the table.

Type of Animal	**Do males compete for females?**	**Do males have a defensible resource?**	**Do males engage in one-on-one duels?**	**Do you predict that males will have an extreme weapon?** Explain your answer clearly and completely.
Fiddle Crab	Yes	Yes Burrow with females in it	Yes	
Mouse	Yes	Yes Burrow with females in it	No	
Termite	Yes	Yes Fortress with limited entrance	Yes	

What I Still Wonder…

17. Write one additional question you have about animal weapons or about changes over time in animal species.

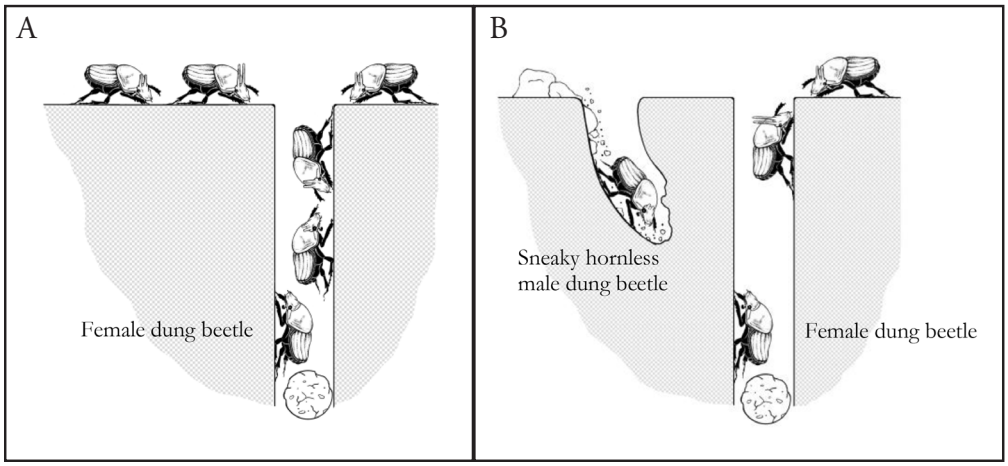
Extension Questions

Read This!

When evolutionary biologists began investigating the evolution of extreme weapons in dung beetles, they encountered a very confusing problem. From observations of horned male dung beetles defending the entrances to their tunnels, it seemed that only the beetles with the longest horns would ever have access to females. Thus their male offspring should develop longer horns, too. **Evolutionary theory would have predicted that over time all of the male beetles would develop longer and longer horns.** Surprisingly, no matter how many generations of beetles the researchers bred, there were always some hornless male beetles in every generation. In Model 4, you will analyze data from underground observations of these beetles to generate an explanation for why hornless male beetles never completely disappeared from the population.

Model 4—The mystery of the Tunneling Dung Beetle

Type of Animal	Drawing	Do Males Compete for Females	Do Males have a Defensible Resource?	Do males Engage in One-on-one Duels?	Do Males have an Extreme Weapon?
Tunneling dung beetle male (Horned)		Yes	Yes Females in a Burrow?	Yes	Yes
Tunneling dung beetle male (Hornless)		No	No	No	No
Tunneling dung beetle female (Hornless)		---	---	---	



18. In Box A of Model 4, all the male beetles have horns.

    a. How many male beetles are present?

    b. How many female beetles are present?

19. Compare the male beetles in Box A. The male beetle with the largest horns usually wins one-on-one duels over access to the tunnel. This beetle is the only one that can mate with the female and produce offspring. Circle the beetle in Box A that is most likely to produce offspring.

20. The horn length of male beetles is most closely related to their father's horn length.

    Predict the type of male beetle offspring that the winner in Box A will produce:

    Hornless Short horns Medium horns Long horns

    Explain your answer:

21. Compare the male beetles in Box B. Based on the drawing, describe what the sneaky hornless male beetle has done to gain access to mate with the female.

22. Describe how being hornless might make it easier to sneak into a tunnel unnoticed and mate with a female. Include your ideas about the difficulty of sneaking in to build a side tunnel if you have larger or smaller horns.

23. Write 3–4 sentences that justify the following claim. Include evidence from Model 4 and your answers to Questions 17–21.

    "As long as tunneling dung beetles continue to behave in the same manner as they did during research observations, there will always be at least some hornless males in the population."