

Supplemental Material

CBE—Life Sciences Education

Kalinowski *et al.*

Please read the following passages and answer the questions that follow. The questions relate to evolution. Please answer the questions as you think an evolutionary biologist would.



Anteaters are mammals that live in South America and eat only ants. Anteaters have several traits that help them catch and eat ants efficiently. Firstly, anteaters have remarkably large claws that allow them to easily rip open ant hills. Anteaters feed by sticking their tongue into tunnels in the ant hills. Their entire head and mouth is adapted for catching

ants. Their tongues are 24 inches long and covered with sticky saliva. Anteaters cannot open their mouth, and do not have teeth. Even the stomachs of anteaters are unique: unlike most mammals, anteaters do not secrete acid in their stomachs. None is needed. Ants naturally contain formic acid; ants eaten by anteaters digest in their own acid. Biologists have concluded that anteaters evolved all of these unique traits from ancestors that looked similar to rats.

1. Which of the following is the best description of how anteaters evolved long tongues?
 - a. Anteaters grew long tongues because they needed to reach inside ant hills.
 - b. Anteaters grew long tongues because they constantly stretched their tongues.
 - c. Random mutations occurred because anteaters needed to change.
 - d. Each year, anteaters with the longest tongues were most likely to live.
 - e. Changes like this depend on many factors, so it is impossible to answer.
2. A disease infects many ant colonies in a forest. The disease does not affect anteaters, but kills most of the ants. What is most likely to happen to the anteaters?
 - a. Anteaters will grow slightly longer tongues.
 - b. Anteaters will find other food.
 - c. Anteaters will share the food available.
 - d. Many of the young anteaters will die.
 - e. Anteaters will survive on less food.
3. A female anteater gives birth to a baby. What traits of the mother will the baby inherit?
 - a. The mother's traits that helped her survive and reproduce.
 - b. The mother's traits that changed because she used or did not use them.
 - c. The mother's traits that were changed by the environment during her lifetime.
 - d. The mother's traits that were determined by genes.
 - e. The mother's traits determined by genes plus one or more other traits listed above.
4. A biologist captures ten healthy, adult male anteaters and compares them to each other. Which of the following traits are likely to be different among the anteaters?
 - a. The length of the femur ("thigh") bone.
 - b. The rate at which their livers break down toxins naturally found in ants.
 - c. The stickiness of the saliva on the tongues of anteaters.
 - d. Two of the above.
 - e. a, b, and c

5. Anteaters evolved long claws from ancestors that had shorter claws. Think about the first anteater to have claws as long as modern anteaters. Why did this individual have such long claws?

- a. The anteater dug up many anthills, and these efforts affected its claws.
- b. The anteater was lucky a genetic accident gave it long claws.
- c. The anteater needed long claws to dig up ants, so they developed.
- d. The anteater needed long claws to eat, so a mutation changed its DNA.

6. A biologist studies a population of anteaters living in a large nature reserve. The reserve is surrounded by farms where anteaters are not safe, but the reserve is a perfect place for anteaters: there are few predators and lots of ants. The biologist counts the number of anteaters in the reserve every year for twenty years and finds the size of the population does not change much. Which of the following is the best description of what life in this reserve is probably like for these anteaters?

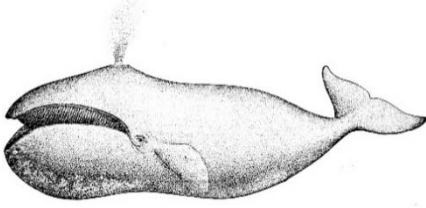
- a. The anteaters have little or no difficulties obtaining food and raising offspring.
- b. Adult anteaters compete for food and many young anteaters die.
- c. It is impossible to know without actually observing anteaters in the reserve.

7. Modern anteaters do not have teeth, but their ancestors did. Which of the following is the best description of what caused anteaters to lose their teeth?

- a. Anteaters did not use their teeth while feeding on ants.
- b. Anteaters did not need their teeth to survive and raise their young.
- c. Anteaters without teeth had more young than anteaters with teeth.
- d. This happened entirely by chance.
- e. Changes like this depend on many factors, so it is impossible to answer.

8. An ancestor of modern anteaters has a tongue that is only half as long as modern anteaters. Because her tongue is relatively short, she has to work hard to extend her tongue far enough inside ant hills to catch ants. How will these efforts affect the tongues of her offspring?

- a. Her efforts will probably give her offspring slightly longer tongues.
- b. Her efforts will not affect the tongues of her offspring.
- c. Growth is affected by many factors; the effects of her actions cannot be predicted.



Bowhead whales are the only species of large whales that live their entire life in the icy water of the Arctic Ocean. They have a couple adaptations that help them do this. First, bowhead whales have a thick layer of fat under their skin called blubber that helps keep them warm. The blubber of bowhead whales is 18 inches thick, which is thicker than any other whale. Second, bowhead whales have a remarkably thick skull. This allows

them to break thick ice in order to get air to breathe. No other whales have such thick skulls. Available evidence shows that bowhead whales evolved from ancestors that lived in the warm waters of the Pacific Ocean and did not have either thick blubber or thick skulls.

9. Which of the following is the best description of the role cold water played in the evolution of thick blubber?

- a. It caused mutations that gave whales thicker and thicker blubber.
- b. It helped determine which whales each generation survived and which did not.
- c. It directly influenced the growth and development of the whales.
- d. It made the whales work to stay warm and these efforts caused whales to change.
- e. It forced all the whales to change so they could survive and reproduce.

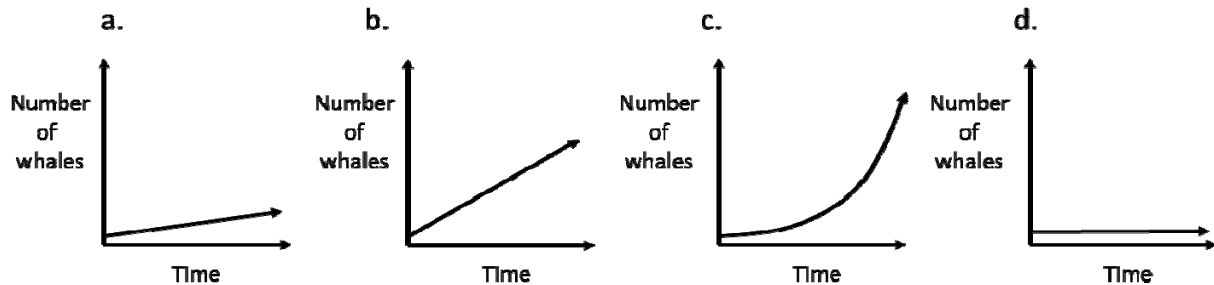
10. What is the best way to describe the evolutionary changes that occurred among the whales while the species evolved thick skulls?

- a. The skull of each whale got a little thicker during its lifetime.
- b. Whales with thick skulls reproduced and became more common.
- c. The population changed randomly each year.
- d. Mutations increased the skull thickness of more and more whales each year.

11. What was most likely true regarding genetic mutations that occurred during the time bowhead whales were evolving thick blubber?

- a. Most of the mutations helped the whales survive in their new environment.
- b. The number of mutations occurring in the whale population increased when the whales moved into the icy water of the Arctic Ocean and then decreased when the whales finished adapting to their environment.
- c. The mutations occurred because whales needed to adapt in order to survive and reproduce in the icy water of the Arctic Ocean.
- d. The mutations were not affected by water temperature or the needs of the whales.

12. Bowhead whales were highly sought after by whalers, and 99% percent of the bowhead whales in the Arctic Ocean were killed during the 20th century. Whaling has stopped and the Arctic ecosystem has everything the whales need to recover. Bowhead whales, however, grow slowly. Females are pregnant for 16 months and nurse their young for years. They may reproduce only once in ten years. Because of this, the bowhead whale population in the Arctic will only grow a few percent each year. Which graph best shows how the population of bowhead whales in the Arctic will grow in the next 100 years?



Answer: C

13. Orcas (also known as “killer whales”) hunt bowhead whales. A biologist wants to know how fast bowhead whales can swim when chased by orcas. She observes female whales being chased by orcas and measures the maximum speed these whales can swim. What will she most likely observe? Why?

- All of the whales swim the same speed because they are the same species.
- There will be notable differences among the whales because each whale has had different amounts of nutrition and exercise during its life.
- There will be notable differences among the whales because each whale has different genes.
- Both “b” and “c”.
- It is impossible to predict given the information provided.

14. Consider a baby whale born during the time the ancestors of modern bowhead whales were evolving thicker skulls. When this whale grows up, how will its skull compare to the skulls of its parents?

- When the baby whale grows up, its skull will probably be slightly thicker than the skulls of its parents.
- When the baby whale grows up, its skull will probably be similar to its parents.
- When the baby whale grows up, its skull will probably be slightly thinner than the skulls of its parents.
- Skull development is affected by many factors, so we cannot predict how this whale’s skull will grow.



Saguaro cacti live in the scorching hot deserts of Arizona and Mexico where it is common for less than eight inches of rain to fall in a year. Not surprisingly, saguaro cacti have special traits that help them live in this harsh landscape. Like many cacti, saguaro have no leaves. The leaves of the ancestors of saguaro evolved into spines. This prevents water from evaporating from leaves and deters animals from feeding on the saguaro. Photosynthesis occurs within the stem and branches of saguaros. Water loss is further minimized by a waxy covering on the “skin” of saguaro. Beneath the ground, saguaros have an extensive root system—much longer than plants living in wetter climates. These roots are also remarkably shallow. Most of them are only a few inches below the surface of the ground. This enables saguaros to absorb water from rainfall before it evaporates back into the air.

- 15.** Which of the following is the best description of how saguaro cacti evolved to have long roots?
- Saguaro cacti needed to develop longer roots to survive in the desert.
 - Mutations occurred because the climate of Arizona and Mexico was hot.
 - Saguaros with short roots produced fewer seeds each year than saguaros with longer roots.
 - Each generation of saguaro cacti worked hard to grow roots as long as possible.
 - Changes like this depend on many factors, so it is impossible to answer.
- 16.** During the time period saguaro cacti were evolving to their current form, there were years with very little rain. What likely happened to the saguaro cacti during the driest years?
- The saguaro cacti managed to obtain the water they needed.
 - Saguaro cacti with the shortest roots died.
 - The saguaro cacti survived with less water than normal.
 - The saguaro cacti grew longer roots.
- 17.** Every individual plant and animal is affected by the environment during its lifetime. For example, a person will become tan if exposed to the sun, and a tree will grow slanted if it lives on a windy ridge. What role did the responses of individuals to their environment (like these) play in the evolution of waxy skin among saguaro cacti?
- Responses like these were the sole reason saguaro cacti evolved waxy skin.
 - Responses like these contributed to saguaro cacti evolving waxy skin.
 - Responses like these played no role in the evolution of waxy skin in saguaro cacti.
 - Responses like these might have played a role in the evolution of cacti—if saguaro respond to intense sunlight or drought by growing waxier skin.
- 18.** A large population of saguaro cacti thrives in a wide valley in Southern Arizona. The valley floor is flat and there are no gullies, rock outcrops, or variation in the soil. Which of the following statements best describes similarities and differences among full-grown saguaro cacti living in the valley?
- The saguaro cacti share all the same traits and are essentially identical to each other.
 - The saguaro cacti share all of the most important traits, and the small differences between them do not affect how long they live or how well they reproduce.
 - The saguaro cacti are all identical on the inside, but have many differences in appearance.

d. The saguaro cacti share many important traits, but also have differences that may affect how long they live or how well they reproduce.

19. The ancestors of modern saguaro cacti did not have long and sharp spines. Consider the first ancestor of saguaro cacti to grow spines that were as long and sharp as the spines on saguaro cacti living in Arizona today. Why did this cactus grow such sharp spines?

- a. It was fortunate a genetic mistake gave it extra sharp spines.
- b. The cactus needed sharper spines to stop animals from eating it.
- c. Animals chewing on the cactus caused it to grow sharper spines.
- d. Mutations changed the DNA of this cacti because it was injured by an animal.
- e. The hot climate caused this change.

20. Saguaro cacti produce fruits that contain thousands of seeds. These seeds are often eaten by birds. When a seed is eaten, it passes through the bird's digestive system unharmed and falls to the ground. If a seed lands in suitable soil, escapes being eaten by mice, and receives enough rainfall during the first years of its life, it may eventually grow into a seedling. Which of the following is the best description of what influences whether saguaro cacti produce seedlings?

- a. The production of seedlings is purely a matter of chance.
- b. Chance plays a big role, but the characteristics of individual cacti are also important.
- c. The production of seedlings is not influenced by chance.

Malaria is a tropical disease caused by a single-celled parasite. People become infected with malaria when they are bitten by a mosquito that carries the single-celled parasite. Infection with the malaria parasite causes fever, vomiting, and aches in people. Each year, over 200 million people suffer from malaria, and one million people die.

A common approach for preventing malaria is killing the mosquitoes that spread the parasite. In the 1940s the insecticide DDT was discovered to be highly effective at killing mosquitoes. DDT was sprayed in many tropical countries and initially killed 99% percent of the mosquitoes in the areas where it was used. This dramatically reduced the number of people contracting malaria in those areas.

Soon after DDT was first used, health workers in Africa discovered that mosquito populations evolved to be resistance to DDT: each year DDT was applied, fewer and fewer of the mosquitoes exposed to DDT died. By the end of the 1940s DDT was no longer effective in some regions and had to be replaced with other insecticides. This happened everywhere DDT was used. Switching insecticides proved to be only a temporary fix; mosquitoes evolved resistance to each insecticide that has been used to combat malaria. This is likely to be a serious health problem for years to come.

21. Which of the following is the best explanation of the process that caused mosquito populations in Africa to become resistant to DDT?

- a. The immune systems of mosquitoes exposed to DDT developed resistance. These mosquitoes passed some of this resistance to their offspring so that each generation of mosquitoes became more likely to survive exposure to DDT.
- b. Some mosquitoes were fortunate to be naturally able to survive exposure to DDT (even though DDT had never been used in their area before), and passed this ability to their offspring.

- c. The mosquitoes became resistant, because if they did not, they would die.
- d. DDT caused widespread mutations in the DNA of mosquitoes.

22. Consider a female mosquito that was exposed to DDT during the years a population was evolving resistance to DDT. She survives and later lays a cluster of eggs. How will her exposure to DDT likely affect her offspring?

- a. Her exposure to DDT will give her offspring increased resistance to DDT.
- b. Her exposure to DDT will have no effect on her offspring.
- c. The effect on her offspring of her DDT exposure cannot be predicted.

23. What was most likely true regarding the genetic mutations that occurred during the years mosquitoes were evolving resistance to DDT?

- a. The number and effect of mutations that occurred was not influenced by DDT.
- b. Most of the mutations that occurred helped the mosquitoes survive.
- c. The number of mutations occurring in the population increased when DDT was first applied, and then decreased when the mosquitoes finished adapting.
- d. The mutations occurred because mosquitoes needed to survive.

24. The chemical deltamethrin (DM) is another insecticide that is used to kill mosquitoes. Not surprisingly, mosquito populations sprayed with DM for several years evolve to become resistant. However, if DM spraying is stopped for a few years, the population will lose its resistance. What is the most likely description of how this occurs?

- a. Mosquitoes do not need to be resistant to DM when it is not present.
- b. The immune systems of mosquitoes not exposed to DM gradually lose their ability to cope with DM.
- c. When DM is not present, mosquitoes that are resistant to DM do not survive as well as mosquitoes that are not resistant to DM.
- d. This was purely a random event.