NAME ______________________________

DATE ______________________________

Carolina™ Natural Selection for AP Biology

Background

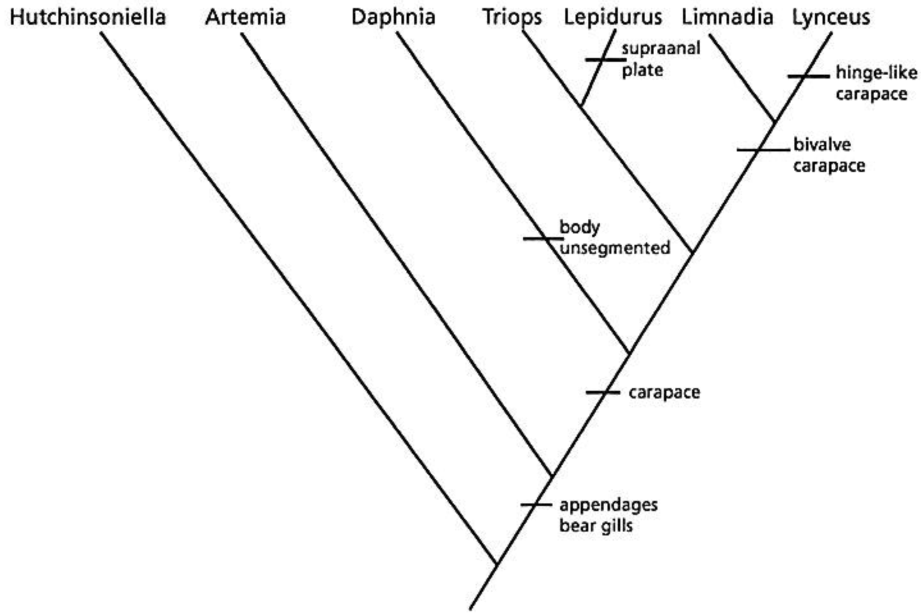
Have you ever gone on a hike and come across an animal that blends in so well with its surroundings that you almost did not notice it? Camouflage is a type of adaptation that helps many animals evade predators or capture prey. An adaptation is a beneficial trait that populations develop over generations. The environment effectively selects against ill-suited individuals (by eliminating them) and for well-suited individuals (by "allowing" them to live longer lives, during which they produce more offspring that tend to pass along the adaptive traits, increasing the prevalence of those traits in the population). The environments' favoring (or disfavoring) a particular trait in a population is known as natural selection. In this experiment, you will examine natural selection, using brine shrimp and saltwater solutions as model organisms and environments.

Environmental conditions on Earth change—features such as temperature, moisture, amount of UV radiation, and salinity fluctuate. These changes may be small-scale and short-term or large-scale and long-term, and any of them may influence the survival of organisms. Scientific evidence points to our time as the period of the sixth mass extinction that has occurred on Earth. A relatively large number of species has become extinct since the last Ice Age and that extinction rate continues. The five other mass extinctions that occurred were likely due to large-scale changes that took place more rapidly than many populations' ability to adapt to them (e.g., periods of global warming or global cooling). After each mass extinction, a period of speciation occurred. Numerous species evolved from the populations of organisms that survived the extinction. The species derived from populations that had inherited adaptations favored by the changed environmental conditions. The availability of unoccupied new niches helped spur the radiation of new species during each of these biological recoveries.

A population's ability to adapt to changing conditions begins with genetic variation among individuals. Genetic variations arise from mutations of the genome. Mutations are often harmful (such as those that lead to cancer or birth defects), and they are often benign; however, they may also be beneficial. Some individuals in a population possess traits that allow them to survive environmental conditions that others cannot tolerate. The genes that the survivors pass on to their offspring include the genes for the beneficial trait (e.g., thicker fur). Over time, these genes (and traits) become more prevalent.

There are many structural and physiological similarities among organisms. Shared characteristics often indicate common descent. Phylogenetic trees and cladograms illustrate relationships among groups of organisms and thus reflect evolutionary history.

A cladogram shows grouping on the basis of shared adaptations, referred to as "shared derived characters," which indicate probable relationships. For example, all organisms that belong to the class of crustaceans known as branchiopods (meaning "gill foot") have gills on their appendages. Examine the cladogram of branchiopods (on the following page). The point at the base represents the common ancestor of all the organisms included on the cladogram. The organisms at the tips of the cladogram represent extant (living) species. The paths from the common ancestor to the living organisms represent the possible evolutionary history. Each horizontal line across the cladogram represents an adaptation shared by the group(s) above it on the diagram. For example, the bivalve carapace is shared by two genera, *Limnadia* and *Lynceus*. But only one genus, *Lynceus*, has a hinged carapace. The more shared derived characters two groups have in common, the more closely related they are considered to be. *Hutchinsoniella* is not a branchiopod and does not share derived characters with other organisms on the cladogram; it is presented as an "outgroup" on the cladogram, to help viewers orient the branchiopods in the larger tree of life.

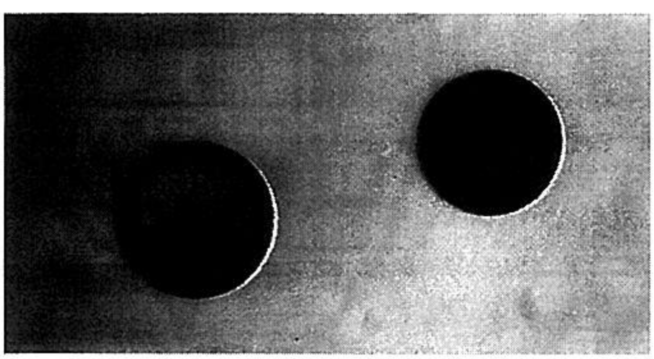


Cladogram showing physical adaptations and possible evolutionary relationships of the branchiopods, the class of arthropods that includes brine shrimp

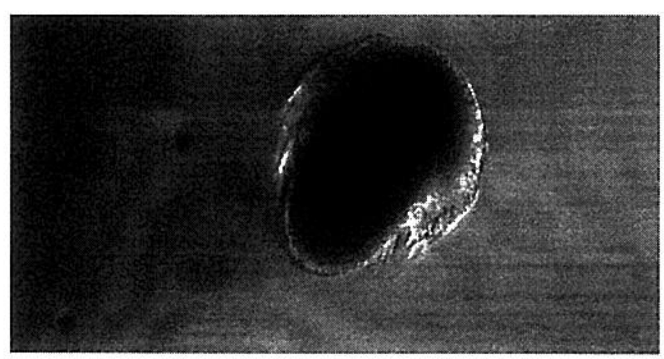
Brine Shrimp

Brine shrimp (*Artemia* sp.) are small crustaceans found in various saltwater lakes around the world. Their development is easy to observe with a microscope. A unique adaptation makes them an interesting model for studies of natural selection. Under ideal environmental conditions, female brine shrimp produce eggs that hatch quickly into live young; however, when conditions become less conducive, the shrimp instead produce cysts—encased embryos that cease development (enter diapause) until conditions are again favorable. When the temperature or the dissolved oxygen level becomes too low or the salinity too high, each egg laid is covered in a hardened, brown chorion, which may keep the embryo viable for many years (in a dry, oxygen-free environment). The brine shrimp used in this activity have been stored in this dormant stage. Once the cysts are incubated in saltwater, the embryos quickly resume their development and hatch.

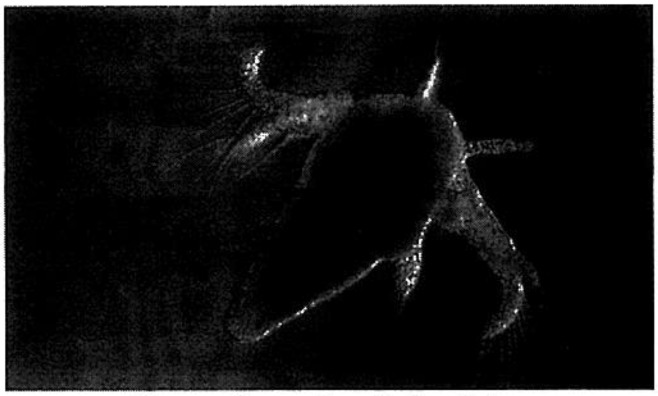
After the cyst breaks open, the brine shrimp remains attached to the shell, surrounded by a hatching membrane. This stage is known as the umbrella stage. The hatching membrane remains attached to the cyst for a number of hours until the young brine shrimp, known as a nauplius, emerges. During the first larval stage, the nauplius subsists on yolk reserves until it molts. During the second stage, the nauplius begins to feed on algae. The nauplius progresses through approximately 15 molts before reaching adulthood in 2 to 3 weeks.



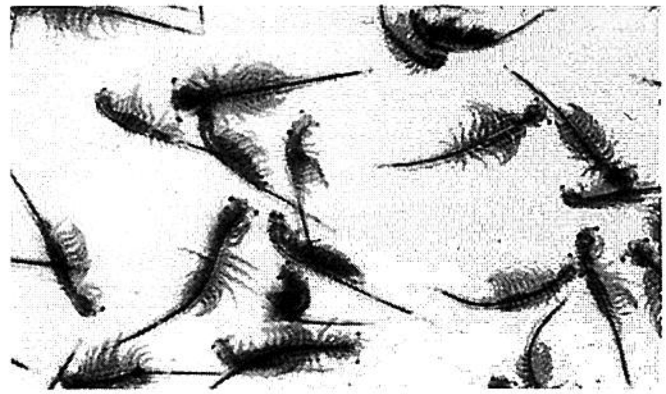
Cysts, dormant brine shrimp eggs



The umbrella stage



The nauplius, or larval brine shrimp



Adult brine shrimp

Brine shrimp populations are greatly influenced by environmental factors such as salinity. Given the relatively short development time from cyst to nauplius (24–48 hours), the use of brine shrimp in this study is a fast and easy way to observe how some individuals of a population may be better adapted to develop and survive in different environmental conditions.

Pre-laboratory Questions

1. Define "adaptation" in your own terms and give an example.
2. Five petri dishes containing solutions of various salinities are prepared. The percentage of the salt in solution is as follows: 0%, 0.5%, 1%, 1.5%, and 2%. Predict what will occur if you place several brine shrimp eggs in each petri dish.

Guided Activity

Materials

- brine shrimp eggs
- scissors
- 5 pipets
- paintbrush
- 5 microscope slides
- 1 stereomicroscope
- double-sided tape
- dechlorinated water
- 5 petri dishes
- permanent marker
- stirring rod
- graduated cylinder
- scale
- weigh boats
- lab spoons
- 5 beakers
- sodium chloride

Procedure

Day 1

1. Prepare and label five beakers of 30-mL salt solutions, using sodium chloride and dechlorinated water. The solutions should be 0%, 0.5%, 1%, 1.5%, and 2% NaCl. Use the space in the Analysis section that follows to determine what mass of sodium chloride to add to each solution.
2. Label five petri dishes, 0%, 0.5%, 1%, 1.5%, 2%.
3. Use a graduated cylinder to measure 30 mL of 0% salt solution and pour it into the petri dish labeled 0%.

4. Likewise measure and pour 30 mL of each of the remaining concentrations into their corresponding petri dishes.
5. Measure and cut 1.5 cm of double-sided tape.
6. Stick the double-sided tape to a microscope slide.
7. Lightly touch the paintbrush to the side of the bag containing the brine shrimp eggs. Your goal is to collect only approximately 20 eggs on the brush. You do not want to cover the tip of the brush in eggs.
8. Dab the paintbrush onto the tape on the microscope slide.
9. Examine the slide under a stereomicroscope.
10. Count the number of eggs on the slide and record this number in Table 1 under "0 hours."
11. Place the microscope slide in the 0% petri dish, tape-side up, and place the lid on the dish.
12. Follow steps 5–11 for the remaining slides and dishes, until you have prepared five microscope slides of eggs, recorded the numbers in Table 1, and placed each slide in its appropriate salt solution.
13. Allow the dishes to sit at room temperature undisturbed for 24 hours.

Day 2

1. Examine one petri dish with a stereomicroscope.
2. Count the number of swimming brine shrimp. With a pipet, gently catch them and move them into another container—your instructor may have prepared a beaker of saltwater for this purpose. Try not to remove excess water with the pipet. Record the number of swimming shrimp in Table 1 under "24 Hours."
3. Count the number of dead or partially hatched shrimp and record this number in Table 1 under "24 Hours."
4. Count the number of unhatched eggs and record this number in Table 1 under "24 Hours."
5. Repeat steps 1–4 for each of the petri dishes. Use a separate pipet for each petri dish.

Day 3

1. Examine each petri dish with a stereomicroscope.
2. Count the number of swimming brine shrimp. With a pipet, gently catch them and move them into a beaker. Record the number of swimming shrimp in Table 1 under "48 hours."
3. Count the number of dead or partially hatched and record this number in Table 1 under "48 hours."
4. Count the number of unhatched eggs and record this number in Table 1 under "48 hours."
5. Repeat steps 1–4 for each of the petri dishes. Use a separate pipet and beaker for each petri dish.

Table 1. Brine Shrimp Hatching Viability

		0 hours	24 hours			48 hours			
Dish #	% NaCL	# Eggs	# Eggs	# Dead or Partially Hatched	# Swimming	# Eggs	# Dead or Partially Hatched	# Swimming	Hatching Viability
1									
2									
3									
4									
5									

Analysis

1. Calculate the amount of salt to dissolve into a 30-mL solution for each petri dish.

   0%:

   0.5%

   1%

   1.5%

   2%

2. In the Hatching Viability column, calculate and record the viability percentages after 48 hours. Show your calculations below.

   $$\text{hatching viability} = \frac{\text{\# swimming at 24 hours + \# swimming at 48 hours}}{\text{total number of eggs initially placed in petri dish}}$$

   Multiply your result by 100% to get a percentage.

3. Plot the data from Table 1. Title the graph and label the axes after identifying the independent and dependent variables.

   a. The independent variable is ________________.

   b. The dependent variable is ________________.

   Plot the independent variable on the x-axis, and the dependent variable on the y-axis.

Laboratory Questions

1. In which petri dish did you observe the highest hatching viability? Did the results support your prediction in Pre-laboratory Question 2?

2. Explain, in terms of natural selection, why one saline solution yielded the highest hatching viability of brine shrimp.

3. Describe two variables that are not controlled in this experimental procedure?

4. If brine shrimp eggs were transported on shorebirds' feet from one hypersaline lake into a less salty one, what might happen to them?

5. How could a laboratory researcher determine if there are differences among the brine shrimp that hatched in the solutions of 0% sodium chloride, 2% sodium chloride, and 1% sodium chloride?

Inquiry Activity

Based on what you learned in the Guided Activity, develop a question to test about natural selection and brine shrimp. In developing an experimental question, consider the materials and equipment available to you. Consult your instructor for the availability of additional supplies.

Materials

sulfuric acid	sand
thermometers	oil
cooling packs	screens
heating pads	lamp
calcium carbonate	aluminum foil

Procedure

1. In your group, collaborate to come up with a testable question about natural selection and brine shrimp. If you have trouble, ask your teacher for guidance.
2. Design an experiment to test your question. Consider the following as you frame your experiment:
    - Question - What are you testing in your experiment? What are you trying to find out?
    - Hypothesis - What do you think will happen? Why do you think so? What do you already know that helps support your hypothesis?
    - Materials - What materials, tools, or instruments are you going to use to find the answer to the question?
    - Procedure - What are you going to do? How are you going to do it? What are you measuring? How can you make sure the data you collect are accurate? What are the independent and dependent variables in this experiment? What is/are your control(s)? What safety practices do you need to use?
    - Data Collection - What data will you record, and how will you collect and present it? Show and explain any data tables and graphs that you plan to use.
3. Have your teacher approve the experimental procedure before you begin the exercise.
4. After you perform the experiment, analyze your data:
    - Data Analysis - What happened? Did you observe anything that surprised you? Show and explain any tables and graphs that support your data.
    - Conclusion - What conclusions can you draw from the results of your experiment? How does this compare with your initial hypothesis? Identify some possible sources of error in your experiment. If given the opportunity, how might you conduct the experiment differently?
5. Be prepared to present the findings of your experiment to the class according to your instructor's specification.

Experimental Design Template

Part A: To be completed and approved before beginning the investigation

What question will you explore? ______________________________

____

On the basis of your previous laboratory exercise, background knowledge, and research, what is the hypothesis that you will test? ______________________________

____

____

What will be the independent and dependent variables? ______________________________

____

What will be the control group(s)? ______________________________

____

What equipment and materials will you need (list items and quantity)? ______________________________

____

____

What procedure (step-by-step) will you follow? ______________________________

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What safety steps will you follow (equipment and procedures)? ______________________________

____

____

How will you collect data? ______________________________

____

How will you analyze data? ______________________________

____

Teacher approval to begin your investigation: ______________________________

Part B: To be completed during or after your investigation

What changes or modifications have you made to the investigation? ______________________

Attach any data collection or analysis as instructed by your teacher.

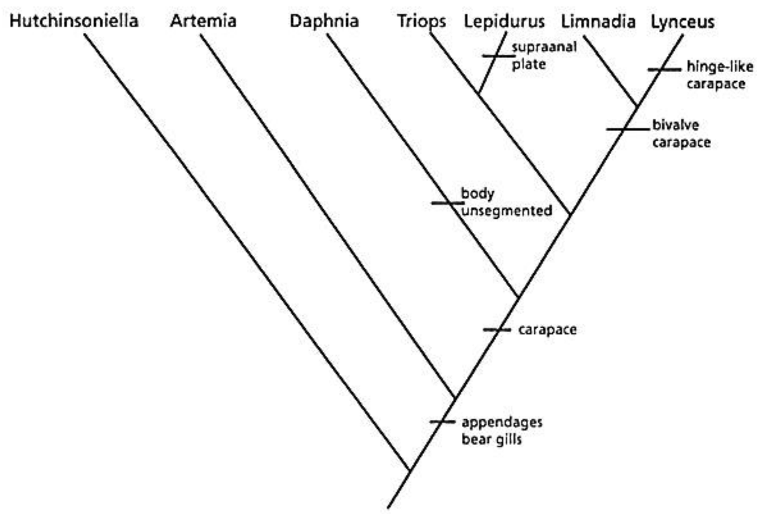
What results did you see in the experiment?

Was the hypothesis accepted or rejected? What conclusions can you draw on the basis of the data and analysis? ______________________

What sources of error may have existed, and how might the experiment have been conducted differently? What additional questions arose from the experiment?

Big Idea Assessments

Scientists recognize that organisms share certain processes and features. In an attempt to establish the relationships between organisms, a model known as a phylogenetic tree or cladogram is used. A cladogram is shown below.



Cladogram showing the morphological similarities of the Branchiopods, the class of arthropods that includes brine shrimp

1. A naturalist discovers a new species and names it *Branchiopodidae madurai*. These organisms are similar to *Artemia*, the brine shrimp, in that they lack a carapace and have appendages bearing gills. However, unlike *Artemia*, *B. madurai* has fused abdominal body segments. Construct a new cladogram of the branchiopods that includes *B. madurai* and its derived character.
2. Suppose that *B. madurai* is commonly collected in freshwater areas near boat harbors and marinas but is rarely found in pristine waters. First, design an experiment that tests an adaptation of *B. madurai* to some aspect of its environment. In your design, be sure to include a question to test, a hypothesis, and a plan for how you will collect and analyze data. Then, describe experimental results that would support your hypothesis.