

**Standards-Based Module  
(Lesson/Unit Plan)**

**Cover Page**

**Content Area:** Life Science

**Grade Level:** 6, 7, and 8

**Title of Lesson/Unit:** Adaptations to the Environment: a Living Fossil - the American Horseshoe Crab

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This project is supported by an award to Clemson University from the Howard Hughes Medical Institute Undergraduate Biological Sciences Education Program.

**Standards-Based Module  
(Lesson/Unit Plan)  
Template**

**Content Area(s):** Life Science

**Grade Level:** 6, 7, and 8

**Time to Complete:** (2) 50 minute class periods

**Title of Lesson/Unit:** Adaptations to the Environment: a Living Fossil - the American Horseshoe Crab

**1. South Carolina State Standards Addressed**

Grade 6

The student will demonstrate an understanding of structures, processes, and responses of animals that allow them to survive and reproduce.

- 6-3.2 Summarize the basic functions of the structures of animals that allow them to defend themselves, to move, and to obtain resources.
- 6-3.5 Illustrate animal behavioral responses (including hibernation, migration, defense, and courtship) to environmental stimuli.

Grade 7

The student will demonstrate an understanding of how organisms interact with and respond to the biotic and abiotic components of their environment. (Earth Science, Life Science)

- 7-4.6 Classify resources as renewable or nonrenewable and explain the implications of their depletion and the importance of conservation.

Grade 8

The student will demonstrate an understanding of Earth's biological diversity over time.

- 8-2.1 Explain how biological adaptations of populations enhance their survival in a particular environment.
- 8-2.3 Explain how Earth's history has been influenced by catastrophes (including the impact of an asteroid or comet, climatic changes, and volcanic activity) that have affected the conditions on Earth and the diversity of its life-forms.
- 8-2.7 Summarize the factors, both natural and man-made, that can contribute to the extinction of a species.

## 2. Lesson/Unit Description:

Students will learn the anatomy and natural history of the horseshoe crab, recognize and explain adaptations used by horseshoe crabs to interact successfully with their environment, and investigate the evolutionary history of the horseshoe crab. They will also examine ecological issues concerning the horseshoe crab and its harvest for medicinal uses.

## 3. Focus Question(s) for Students:

1. What are the basic characteristics and needs of organisms like horseshoe crabs?
2. How did this animal get its name?
3. How do horseshoe crabs use resources, grow and maintain a stable relationship with the environment?
4. What is the evolutionary history of the horseshoe crab? Has it changed much over time?
5. What characteristics have enabled this animal to survive for over 350 million years?
6. What are the medicinal and non-medicinal uses of horseshoe crabs?

## 4. Culminating Assessment:

1. Referring to the images provided in the PowerPoint presentation, introduce the students to horseshoe crabs, their **natural history** (how long they live, how big they get, what they eat, etc.), their **ecology** (their relationship with other organisms and their role in the environment), and their physical structure.
2. Introduce the evolutionary history of the horseshoe crab and discuss any changes it might have gone through over time. Have the students brainstorm any other organisms with the same type of evolutionary history (i.e. virtually no change) and what makes those organisms so successful.
3. Have the students label the main parts of the horseshoe crab on a diagram (see student handout, you can even have them color code the different body parts) based on a live or preserved specimen and then have them put together their own model of the horseshoe crab.
4. Discuss the historical and current uses of the horseshoe crab.
5. Discuss the threats that face this animal and what we can do to protect them.

## 5. Materials/Equipment/Resources:

### Materials Per Class:

- Access to a computer and projector
- Books on horseshoe crabs
- Preserved or live specimen of a Horseshoe Crab

### Materials Per Student:

- Student handout
- Horseshoe crab model
- Tape and scissors

## 6. Teacher Preparation:

1. Read background information and be prepared to explain adaptations to environment and anatomy and physiology of horseshoe crabs.
2. Make sure PowerPoint presentation is ready and make copies of the student handout.
3. Order a horseshoe crab model from the University of Delaware, Marine Communications Office, Newark, DE 19716-3530; phone 302-831-8083; cost \$1 each; also available at: <http://www.ocean.udel.edu/about/giftshop.shtml>; need one for each student.
4. Have access to a live or preserved specimen.

### Background Information

1. What is the American Horseshoe Crab?
  - A. It is aquatic marine invertebrate
  - B. Kingdom: Animalia
  - C. Phylum: Arthropoda (name means jointed appendage)
  - D. Subphylum (or Superclass): Chelicerata (most other members in this group are found on land - spiders, scorpions, mites, ticks, etc.)
  - E. Class: Merostomata ( from the Greek meros meaning thigh and stomata meaning mouth referring to the fact that the mouth lies ventrally in between the legs)
  - F. Order: Xiphosura
  - G. Family: Limulidae (only 4 living species are found in the family Limulidae)
  - H. Genus: *Limulus* (from the Greek limus meaning somewhat oblique or sideways, referring to the position of the compound eyes on the lateral ridges on top of the shell)
  - I. Species: *polyphemus* (from Polyphemus in the Odyssey by Homer who had an eye in the middle of his forehead, referring to the pair of single eyes that are centrally located in the front part of the shell)
2. Physical description
  - A. Adult males average 220mm across the prosoma, while females measure 290mm across the prosoma
  - B. Exoskeleton made of **chitin** (a polysaccharide containing nitrogen that has considerable strength due to its long fibrous molecules, it is also lightweight and resistant to chemicals)
  - B. **Carapace** (covers the head and thorax) shape is specialized for burrowing and shaped like a horseshoe
  - C. Body sections
    - i. Prosoma=**cephalothorax** (fused head and thorax)
    - ii. Opisthosoma=abdomen
    - iii. Telson=tail
      - a. The telson is used to flip the crab over should it get turned on its back.
  - D. **Appendages** (any projection from the body of an animal, i.e. legs, antennae, mouthparts, etc.)

- i. The 1<sup>st</sup> pair is called the **chelicera** (helps maneuver food into the horseshoe crab's mouth)
  - ii. The 2<sup>nd</sup> pair is called the **pedipalps** (this is the 1<sup>st</sup> set of ambulatory walking legs and, in males, this pair is modified to grasp the female during mating)
  - iii. The next 3 pairs are ambulatory legs( the horseshoe crab chews with its legs, it captures and crushes prey with its legs that can then be delivered to the mouth, it does this as it walks)
  - iv. The 6<sup>th</sup> pair is called the pusher legs (they are longer and used for cleaning gills and pushing forward - each pusher leg has a organ on it called the flabellum that detect carbon dioxide and other, as of yet unknown, water chemistry)
  - v. The 7<sup>th</sup> pair is the **operculum** (cover) that protects the book gills and contains genital pores (eggs and sperm are released from these)
  - vi. The last 5 pairs **book gills** (organs of gas exchange over which water flows)
    - a. Have thin, vessel rich surfaces
    - b. Full of **hemolymph** (body fluids in invertebrates with open circulatory systems (no blood vessels)), the horseshoe crab's equivalent of our blood.
    - c. Oxygen carrying molecule in hemolymph is **hemocyanin** which is also found in many crustaceans and mollusks
    - d. Hemocyanin is copper-rich (the copper makes the hemolymph appear blue)
- E. They have 10 eyes!
- i. These eyes are not the same as ours; many function only in light detection
  - ii. The horseshoe crab has a pair of lateral compound eyes on the side of its head
    - a. Function in finding mates during the breeding season
    - b. You can see these eyes easily
  - iii. The horseshoe crab has a pair of simple median eyes on the top and front of its head
    - a. Detect uv light directly from the sun and also as it's reflected from the moon
    - b. Again, these can also be seen fairly easily
  - iv. The horseshoe crab has a pair of rudimentary lateral eyes and a single endoparietal eye which function in **photoreception** (light detection)
    - a. May aid crabs less than a year old to orient to light until the lateral and median eyes are fully developed.
    - b. These lie just under the skin and cannot be seen by the students when looking just at external morphology
  - v. There is a pair of eyes located on the **ventral surface** (underside) of the crab near the mouth
    - a. Their function is not known for sure, they may relay to the brain the light intensity under the animal
    - b. May also function in orientation while the crab is swimming

- c. These also lie just under the skin and cannot be seen by the students when looking just at external morphology
  - vi. A group of photoreceptors is located on the tail which help regulate the **circadian rhythm** (biological cycles and rhythms of the animal over a period of 24 hours)
    - a. These also lie just under the skin and cannot be seen by the students when looking just at external morphology
- 3. Diet
  - A. As prey :
    - i. The horseshoe crab is preyed upon by fish, raccoons, crustaceans, birds, sharks, and marine reptiles (sea turtles)
    - ii. Horseshoe crab eggs, left on the sand after mating, are the principal diet in many migrating shorebird species, especially:
      - a. Red Knot (*Calidris canutus*)
      - b. Sanderling (*Calidris alba*)
      - c. Ruddy Turnstone (*Arenaria interpres*)
      - d. Semipalmated Sandpiper (*Calidris pusilla*)
      - e. After migrating, these birds need a quick fix of food to survive
      - f. With a drop in the horseshoe crab population, there is a corresponding drop in these birds' population
  - B. As predators:
    - i. The horseshoe crab is a omnivorous bottom dweller (generalist feeder), feeding on clams, worms, algae, and **detritus** (decaying matter) and using their legs to disturb the substrate to get to their food source
- 4. Longevity
  - A. Takes 9 to 11 years to mature, going through about 18 moltings
  - B. Live 17 to 19 years
  - C. Females are larger than males (about 20%), females may go through an extra molt to achieve this larger size
  - D. They spend most of their time buried in the mud in coastal waters
- 5. Reproduction and development
  - A. Nesting
    - i. Begins in May or June during full and new moon tides (spring tides)
      - a. **Spring tides** are tides that are higher than normal; they occur twice a month during the full and new moon phases when the sun, moon, and earth are lined up (this causes increased gravitational pull)
    - ii. The female digs a nest just beyond the high tide mark, 15 to 20cm deep
    - iii. The female releases the eggs and the male (who is perched on top of her) releases free swimming sperm (external fertilization)
      - a. All other arthropods either transfer sperm in packets or there is internal fertilization
    - iv. Females can lay 20 egg clusters a year 2,000 to 4,000 at a time, all in separate nests (total of roughly 80,000 eggs in a year)
    - v. Eggs are 1mm in diameter and bright green, they develop for 2 to 4 weeks, then hatch, but remain in the nest until the next high tide, then they swim out to sea

- vi. Hatchlings look like little trilobites, but after first molting, they look like little adult horseshoe crabs
  - vii. Hatchlings live in the near shore sand flats near where they hatched, at least for the first month if not the first year, before moving further out to sea
- B. Mating
- i. Much larger numbers of males than females on nesting beaches
  - ii. Males use vision not scent to seek out the females
  - iii. Usually attach themselves to a female in the ocean (attached males are said to be in "**amplexus**"), then she carries him to the beach, while she digs her nest, and even after she has laid her eggs
  - iv. Satellite males hang around the attached male with his female and will release their sperm when the female lays her eggs hoping to beat the sperm of the attached male in the fertilization race
    - a. This is called **sperm competition**
    - b. Satellite males have a good chance of fertilizing the females eggs
6. Evolutionary history
- A. Horseshoe crabs first appeared in the Paleozoic era
  - B. Fossils have been dated at 360 million years old
  - C. One of their closest ancestors were trilobites, primitive arthropods
  - D. Horseshoe crabs survived many extinctions that killed the majority of marine arthropods
  - E. There were other lines of chelicerates that died out in these extinctions
    - i. Example: Eurypterida was one family, the sea scorpions (marine arthropods that measured up to 3m long)
7. Keys to their long-term success!
- A. Feeding generalist (Omnivore) - during the changes that have occurred over the past 350 million years, horseshoe crabs have been able to take advantage of whatever food was available
  - B. Can breathe atmospheric oxygen as well as dissolved oxygen - this helps not only when they go on land to mate, but during the oceanic changes that have occurred over time, horseshoe crabs could get up and go somewhere else if it was needed
  - C. Light-weight exoskeleton makes it easy to walk on land - again this helps when they are ready to mate (especially for the female since she usually carries the male) and if they needed to move from one place to another during environmentally inhospitable times
  - D. Exoskeleton prevents water loss while on land so they do not become dehydrated and die
  - E. Physiologically, they can adapt to a wide change in salinity
    - i. During the spring, there is lots of rainfall, causing the salinity of shallow and somewhat enclosed saltwater areas to drop
    - ii. Horseshoe crabs can fluctuate their internal ion concentration to match the external environment
    - iii. Overtime, the oceans have changed salinity concentration due to ice ages, etc.
    - iv. They cannot survive in salinity below 2ppt
  - F. They can tolerate very low environmental oxygen concentrations

- i. They can slow their heart rate in the presence of low oxygen availability
  - ii. The book gills muscular movement helps move water over their surface to aid in gas exchange, the movement also aids in moving blood to the heart
  - iii. They can survive inhospitable environments that would and do kill other organisms
- G. Tolerates wide fluctuations in temperature
  - i. The warmer the temperature, the less oxygen the horseshoe crab can absorb
  - ii. They compensate for this by lowering their hemolymph's pH in order to absorb more oxygen
  - iii. Again, this would come in very handy in inhospitable environments
- 8. Non-Medicinal Uses of American Horseshoe Crabs
  - A. Historically, the shells were used to bail out water from fishermen's boats, they called them pan crabs
  - B. Telson used by Native Americans as spearheads
  - C. Although horseshoe crabs are not eaten now, Native Americans also once ate the meat at the base of the tail
    - i. Other Native cultures in the Pacific still eat horseshoe crabs
  - D. Organic fertilizer (early 20<sup>th</sup> century)
  - E. Chicken feed (early 20<sup>th</sup> century)
  - F. The horseshoe crab is currently an important bait animal in commercial fisheries
    - i. It is used to catch: whelk (conch), catfish, and eels
- 9. Medicinal Uses
  - A. The hemolymph of horseshoe crabs contains a compound called *Limulus* amebocyte lysate, or LAL, which binds with bacterial **endotoxins** (a component of bacteria that causes illness; it is released when the bacteria breaks down)
  - B. LAL can indicate if a patient with high fever or toxic shock is infected with gram negative bacteria
  - C. LAL is currently used to test prosthetic devices and injectable intravenous fluids for **pyrogenic materials** (materials that will cause fevers in the patients) for the Food and Drug Administration
    - i. LAL is the only certification the FDA will accept
    - ii. LAL is obtained by bleeding the animal, which does not appear to harm them in any way
  - D. Their eyes have been used in scientific research and have provided valuable insight to the human eye
    - i. The size and number of individual light receptors they have make a good model to conduct tests
  - E. "Blue Blood" is used in research on spinal meningitis, blood clotting, and cancer
  - F. Chitin (from the exoskeleton) is used in surgical sutures and bandages that promote healing in humans
- 10. Threats to the American Horseshoe Crab
  - A. Over-harvesting for medicine
    - i. 250,000 crabs are captured and bled annually for the biotech industry (companies must be licensed by the Food and Drug Administration)
    - ii. Industry worth \$50 million annually

- iii. At least 10% do not survive the bleeding procedure
- iv. Those that do are released back into the environment (but maybe not in the place from which they were collected)
- B. Over-harvesting for fisheries
  - i. 6.1 million pounds were harvested (mainly adult females due to their larger size) in 1997
- C. Habitat destruction
  - i. Horseshoe crabs need protected sandy beaches to spawn
    - a. Development destroys these areas
    - b. Building seawalls and groins or dredging harbors decreases the sandy shoreline
  - ii. Pollution and industrial growth
    - c. Insecticides may have an adverse affect on horseshoe crab development
    - d. Red tide algal blooms which can be caused by organic pollution cause horseshoe crab mortality

## 7. Procedures:

1. Introduction to the Topic:
  - A. Use the PowerPoint presentation to introduce the students to the horseshoe crab, its physical characteristics, its natural history, its evolutionary history, and its historical and current uses.
2. Teacher Directed Discussion:
  - A. The teacher will explain that the horseshoe crab is an interesting and valuable animal that they are going to learn about. Students will participate in class discussion.
  - B. The teacher will explain how a horseshoe crab is classified. The students will participate in class discussion.
  - C. The teacher will lecture about the physical description, growth and reproduction, importance of the horseshoe crab. Students will participate in class discussion.
  - D. The teacher will lecture about the threats to and the protection needed for the horseshoe crab. Students will participate in class discussion.
  - E. The teacher will give groups of students copies of the horseshoe crab anatomy to look at as they discuss each part. The teacher should demonstrate or show parts of a horseshoe crab's anatomy by using live or preserved specimens and photographs (see presentation). Teacher will instruct the groups to study the horseshoe crab's anatomy and label each part on their diagram as the teacher discusses or points out features of the horseshoe crab anatomy (student handout).
3. Equipment and Skills Demonstration:
  - A. If using the purchased horseshoe crab paper model, the teacher will instruct students on how to assemble the horseshoe crab. Students will cut out and glue the horseshoe crab model together.
4. Student Activity:
  - A. Students will complete the student handout on the external morphology of the horseshoe crab.

- B. If using the purchased horseshoe crab paper model, students will make a model of the horseshoe crab.
- C. Students will complete a paragraph emphasizing the adaptations these animals have to their environment.

### **8. Differentiation of Instruction:**

1. Gifted and talented students can access web sources from the recommended list to enrich their learning experience.
2. Students can explore the importance of horseshoe crabs from conservation to biomedical research  
<http://www.ocean.udel.edu/horseshoecrab/Resources/index.html>
3. Students unable to participate in field experiences can access virtual field trips through various websites.

### **9. References**

Tanacredi, John T., editor. 2001. *Limulus* in the Limelight: A Species 350 million years in the Making and in Peril? Kluwer Academic/Plenum Publishers, New York.

Shuster, Carl, Jr., Robert B. Barlow, and H. Jane Brockman, editors. 2003. *The American Horseshoe Crab*. Harvard University Press, Cambridge, Mass.

### **10. Additional Resources**

#### Web Sources:

<http://www.horseshoecrab.org>

<http://www.dnr.state.md.us/education/horseshoecrab/>

<http://www.ocean.udel.edu/horseshoecrab/>