This lesson was created in partnership and with the support of Maryland Sea Grant

Crab Physiology

Objective

Students will understand the components and functions of a crab's circulatory and respiratory systems, and how crabs may serve as indicators of environmental degradation.

National Science Education Standards

Content Standard A: Science as Inquiry (9-12)
- Ability to Do Scientific Inquiry
- Understandings About Scientific Inquiry

Content Standard C: Life Science (9-12)
- Interdependence of Organisms
- Behavior of Organisms

Warm-Up

Discuss with students whether they think animals can feel stress, and ask them to describe factors that might cause stressful situations for particular animals. Ask them if they think it is possible to measure an animal's stress level, and if so, how? How might this information be beneficial to humans?

Background

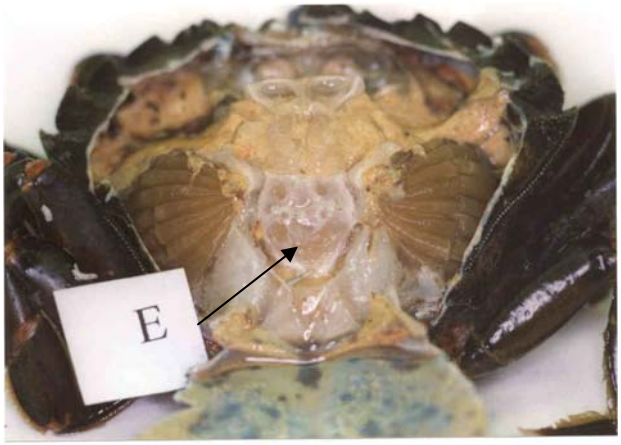
Is That "Crab Breath"?

Crabs, along with other types of crustaceans, breathe using **gills**. The gills are enclosed in a chamber underneath the carapace (hard outer shell), and are used to extract oxygen from the water, while excreting waste products such as carbon dioxide. Blue crabs have eight gills on each side of their bodies but other crab species have different numbers of gills. Within the gills are **setae** (see' tee), which are brushes or hair-like appendages that filter out dirt and other debris. A crab keeps water flowing through its gills by using its **gill bailers**, which act as small paddles to push the water along. Crabs can also reverse the flow of water through the gills, and accomplished by reversing the direction in which the gill bailers are beating. This reverse flow behavior is thought to be helpful when there

is insufficient oxygen in the water, or when debris needs to be removed from the gills.

During respiration, oxygen molecules, whether in the form of gas (air) or dissolved in seawater, dissolve into a layer of moisture surrounding the gill membranes. The molecules are so tiny that they pass right through the membrane and over numerous blood vessels, where they are absorbed into the blood. For this absorption to occur, the membrane must be wet, which is why it is important for crabs that live in the intertidal zone or on land to keep their gills wet. They do this by having the gill chamber sealed tightly so that little moisture is lost. They also use fluids from inside their bodies to keep their gills wet. Crabs that spend most of their time out of the water will seek out cool, moist, dark hiding places where they can avoid predators and still keep breathing. These land crabs also have special adaptations to prevent drying out, such as specialized pockets in their bodies that store water.

A Crab With Heart



The "E" tag in this photo labels the heart, and the gills are also visible as the brown feathery structures on either side of it. *Photo courtesy of Dr. Shaw Bamber.*

A crab's circulatory system is fairly simple and is classified as an **open circulatory system**. The circulatory system is the primary way of transporting oxygen, carbon dioxide, waste products, and food to and from its cells. The circulatory system consists of a single-chambered heart, sinuses (openings or space around organs), arteries, and blood (called **hemolymph**). The hemolymph has a bluish tinge due to the presence of hemocyanin, a blood pigment that contains copper. Comparatively, human blood has the element iron bound to hemoglobin that serves to carry oxygen in the circulatory system. A crab's heart is located dorsally in the center of the carapace and is suspended under the surface of the carapace by strands of connective tissue.

Humans and other vertebrates have a **closed circulatory system**, where blood is confined to vessels, and does not mix freely with other fluids in the body. Crabs

have an **open circulatory system**, which means that the hemolymph circulates throughout the body and bathes the internal organs directly. The organs are surrounded by sinuses and when the animal moves, the sinuses contract and aid in circulating the hemolymph throughout the heart and body. When the heart relaxes, hemolymph is drawn in through valved openings called **ostia** (ah'stee-uh), which close as the heart contracts and pumps out the hemolymph.

Can Crabs Get Stressed Out?

What kinds of stressors exist for marine organisms? There are natural stressors, such as climate change or food availability, and human-induced stressors, such as pollution or dredging activity. Like humans, crabs and other marine organisms respond to stress in their environment. Global Heartbeat uses crabs' physiological responses to indicate exposure to stress such as pollution.

Scientists Michael Depledge and Shaw Bamber of the University of Plymouth (UK) conducted experiments on shore crabs (*Carcinus maenas*) from four estuaries with varying degrees of pollution. Site A had little or no industrial waste input. Site B was influenced by sewage and industrial discharges. Site C was affected by sewage and an outfall pipe from a landfill, and its sediments were contaminated with heavy metals. Site D was influenced by mining operations and its sediments were contaminated with heavy metals. After the crabs had grown accustomed to their tanks, their resting heart rates were measured using Computer-Aided Physiological Monitoring (CAPMON). Using the CAPMON system requires placing a sensor on the crab's shell directly over the heart. An infrared beam from the CAPMON unit is then emitted through the shell and onto the heart muscle tissue. When the heart fills (with hemolymph) and empties, its shape changes, which also changes the amount of light reflected back to the sensor. A detector measures these changes, and the heartbeat pattern is presented on a computer monitor. Scientists found that the crabs from Site A had resting heart rates that were higher than those from the other sites.

After putting the crabs on a shaking table for "crab aerobics" for one hour in their tanks, their heart rates were measured again. Interestingly, the crabs that lived in the least polluted waters had maintained a fairly even and elevated heart rate throughout their workout. Readings from the crabs that lived in the more polluted estuaries showed a steady decline in heart rate throughout the hour of

exercise, thus revealing a relationship between contaminant exposure and the ability of these crabs to maintain their heart rates during periods of stress.

Studies like this one show the potential for using marine organisms as bioindicators (or biomarkers) of aquatic contamination, and may serve as an early warning of pollution in our waters. The earlier we become aware of aquatic pollution, the better chance we have to control or remediate it before it becomes severely damaging.

Student Activities

1. **Crab Lab.** After measuring the crabs' heart rates when they are first put in their tanks, design two experiments that you think will help them to relax. It will be important that you use controls for your experiments so that you have a standard of comparison. (Remember that crabs are very visual creatures, and are stimulated by what they see. Also think about what their natural environment is like.) As time allows, record their heart rates every ten minutes to see if they become less stressed during your experiments. Summarize and explain your results.

2. **Bioindicator Blitz.** Working in small groups, pretend that you are scientists competing for a $50,000 grant from the federal Environmental Protection Agency (EPA) to develop the best marine bioindicator. By using the internet, find out what other organisms are used as indicators of pollution in the marine environment. Choose one and design a presentation that would convince the EPA that your organism, based on your research, shows the most promise as the best potential bioindicator. Make sure you can defend your arguments based on the research you uncovered on the Internet. (You may want to search for "bioindicators" "indicator species" "biomarkers" or "environmental indicators.")

Assessment

1. Explain why crabs need to stay moist in order to breathe.
2. Give a description of the differences between the circulatory systems in a crab and human.
3. What are the differences between crab and human blood?
4. Explain how and why crabs may be used as indicators of pollution in estuarine environments.

Additional Resources

To read the following two articles in their entirety, please visit www.globalheartbeat.org and after entering the site, click on "Publications."

Evaluation of Changes in the Adaptive Physiology Of Shore Crabs (Carcinus Maenas) as an Indicator of Pollution in Estuarine Environments
by S. D. Bamber and M. H. Depledge, *Marine Biology* (1997) 129: 667-672.

The Conceptual Basis of the Biomarker Approach
by M.H. Depledge (facilitator) J.J. Amaral-Mendes, B. Daniel, R.S. Halbrook, P. Kloepper-sams, M.N. Moore and D.B. Peakall.

Tales of the Blue Crab (contains color photos of internal anatomy and different sexes)
http://www.serc.si.edu/education/resources/bluecrab/

Blue Crab Archives
http://www.blue-crab.org/faq.htm

British Marine Life Study Society (contains color photos of different crab species)
http://ourworld.compuserve.com/homepages/BMLSS/CRABSX.htm

Environmental Indicators

Environmental Protection Agency
http://www.epa.gov/bioindicators/html/marinetidal.html

Chesapeake Bay Program
http://www.chesapeakebay.net/indicators.htm

Maryland's Environmental Indicators
http://www.mde.state.md.us/AboutMDE/Reports/indicators.asp