Growing Up in the Ocean

Complex Life Cycles of Common Marine Invertebrates

Katie Bennett and Laurel Hiebert

Abstract. Most people are familiar with the concept that animals come in all shapes and sizes and that the body plan of some animals can completely transform during their lifetime. Well-known examples of such complex life cycles of terrestrial animals include butterflies and frogs. Many people are unaware, however, that complex life cycles are exceedingly prevalent in marine environments. Marine invertebrates, such as sea urchins, sea stars, and crabs, all have a microscopic pelagic larval stage that looks nothing at all like the familiar adult form. The authors have developed a lesson to teach students about complex life cycles using crab larvae and adult crabs. This lesson allows 3rd- to 6th-grade students to compare and contrast body plans while learning about adaptations the larvae and adults have made to their respective habitats. Throughout the lesson, students practice skills important for scientific inquiry: making observations, drawing what they see, asking and answering questions, and learning to use scientific tools such as microscopes.

Keywords: adaptation, invertebrate, larva, life cycle, meroplankton, metamorphosis, planktonic

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Before reading any further, take a moment and make a mental list of common tide pool animals. Chances are that sea stars, sea urchins, or crabs—perhaps all three—made your list. It is likely that one or all of these organisms would also make the list of an elementary school student issued the same challenge. Now close your eyes and picture what these animals look like when they are newborn, or during their youngest life stage. It is much harder. These common tide pool animals, relatively well known in their adult form, have a comparatively unfamiliar early life stage called a *larva* (Figures 1–3). A microscopic larval sea star, for example, is well adapted to its life adrift in the water column but bears almost no resemblance to its adult form found clinging to rocks on the wave-swept rocky shore.

Before teaching this lesson, we asked more than 200 students in grades 3–6 to envision and then draw baby sea stars, urchins, and crabs. Without exception, they all drew miniscule replicas of the adults (see Figure 4). This suggests that preschoolers' misconception that biological growth and development is signified only by getting "bigger and bigger" (Inagaki and Hatano 2004) persists into older grades. The *National Science Education Standards* (National Research Council [NRC] 1996) state, "As students investigate the life cycles of organisms, teachers might observe that young children do not understand the continuity of life from, for example, seed to seedling or larvae to pupae to adult" (128).

The concept of complex life cycles is a familiar one in existing K–6 curricula. The second benchmark of the Oregon State Science Standards (2001) requires students to "describe the life cycle of common organisms." One of the three life science content standards described by the *National Science Education Standards* (NRC 1996) is for students to have an understanding of life cycles of organisms. The fifth principle of the Ocean Literacy Campaign also emphasizes the unique life cycles and wide range of sizes of marine organisms (National Geographic Society et al. 2007).

A chrysalis hanging in a terrarium in an elementary school classroom is a familiar sight. Although butterflies and perhaps frogs might be the best-known examples of animals with complex life cycles, larval development is the mode of development most commonly found in the animal kingdom, with a wide range of representatives living in the world's oceans (Young 2002). Life cycle curricula that include marine organisms have many advantages:

- Students are easily engaged when looking at marine larvae; the larvae are beautiful and strange and have provided the inspiration for more than one cinematic science-fiction alien.

***FIGURE 1. Brachiolaria larva of the sea star* Pisaster ochraceus.**

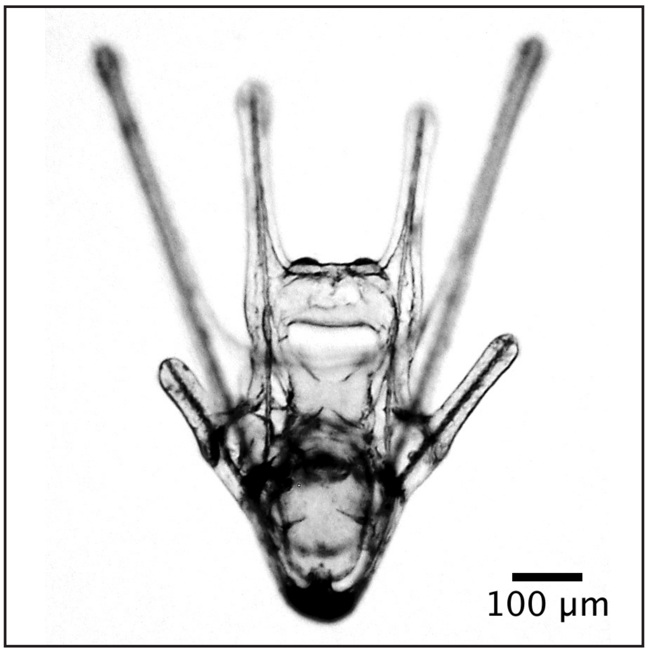


***FIGURE 2. Pluteus larva of the sand dollar* Dendraster excentricus.**

- A single organism that lives in dramatically different habitats during its life allows students to look closely at the adaptations that are specific to a certain habitat. This allows students to make conceptual leaps in relating form to function (e.g., Why do adult sea urchins have tube feet whereas their larvae do not?).

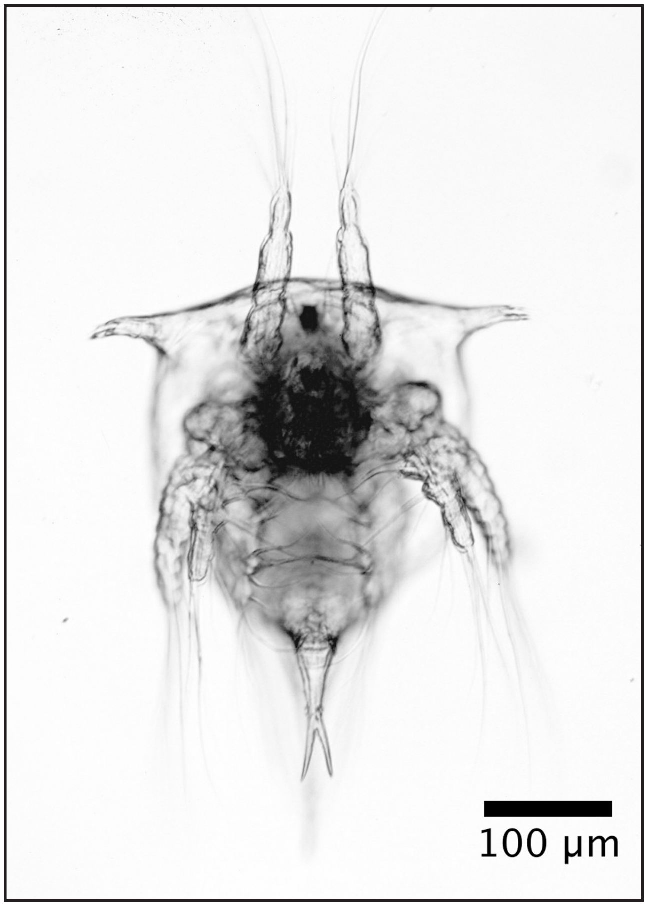


***FIGURE 3. Nauplius larva of the barnacle* Balanus nubilus.**

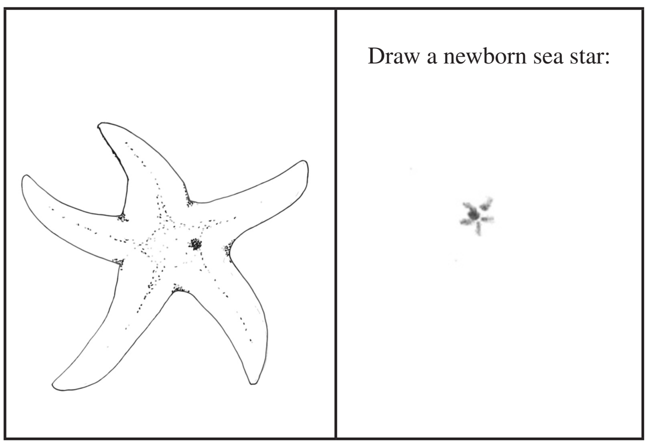


FIGURE 4. An example of a typical student drawing of a baby sea star.

Name___________________________

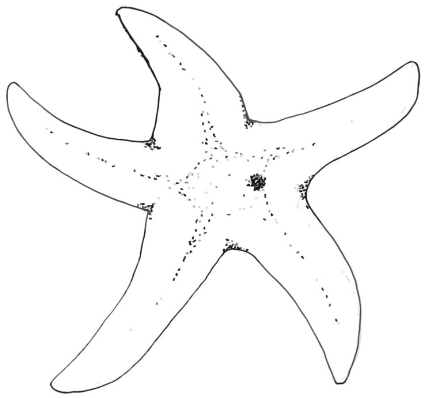
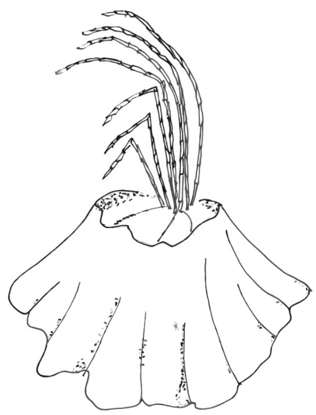
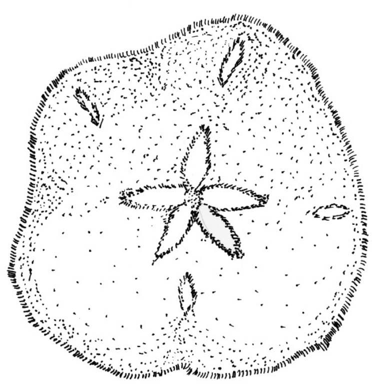
	Draw a newborn sea star:
	Draw a newborn barnacle:
	Draw a newborn sand dollar:

FIGURE 5. Worksheet 1 for drawing newborn marine invertebrates.

- Knowledge of the marine invertebrate life cycle is fundamental for studying important ocean concepts such as colonization and dispersal.
- Drawing what they see, as scientists do, requires students to look carefully at an organism's structures.

In this article, we present a lesson designed to teach children about the wonders of marine invertebrate life cycles. We developed this lesson for fifth and sixth grades, but we have also taught a simplified version to earlier grades. We have taught this lesson using sea urchins and their larval form (the pluteus) and crabs and their larval forms (the zoea and the megalopa). In the lesson provided here, we opted to use crabs because they are more readily available to teachers in noncoastal communities. For teachers who have access to local tide pools and a permit for collection, urchins are a wonderful study organism, and prepared slides of their larvae can be obtained online (see Resources). This lesson takes 1.5 hr or can be broken down into two 45-min sessions.

Materials

- 1–2 microscopes per group, for observing larvae; we use the inexpensive and durable Brockscopes (see Resources)
- 1–2 hand lenses per group, for observing adult organisms
- One crab per group (easily obtained at seafood market)
- Prepared slides of crab zoea and megalopa, one slide of each per group (see Resources)
- Worksheet 1 for drawing newborn marine invertebrates (see Figure 5)
- Pictures of marine invertebrate larvae (see Figures 1–3)
- Teacher copy of basic anatomy of crab and larvae (see Figures 6–8)
- Trays and ice, to keep crabs from getting too smelly

Procedure

Engage

Hand out worksheet 1 (Figure 5). Have the students close their eyes. Ask them to imagine a newborn sea star and to think about what it looks like and where it might live. Have the students open their eyes and draw the baby sea star they imagined. Have them write one or two sentences describing where they think it lives. Follow the same procedure for the other two organisms on the sheet. Make sure the students have time to really form a picture in their mind before they draw it. Walk around the class and ask students about what they are drawing and writing.

Surprise the students by showing a photo of a sea star larva. In our classes, this was met with cries of amazement and disbelief. Have them compare the image to their own drawings. Now show them images of the sand dollar larva and the barnacle larva. Each time, give students a moment to compare the actual larva to their own renderings. Write the word *larva* on the board. Define a *larva* as an animal in an early stage of development that differs greatly in appearance from its adult stage.

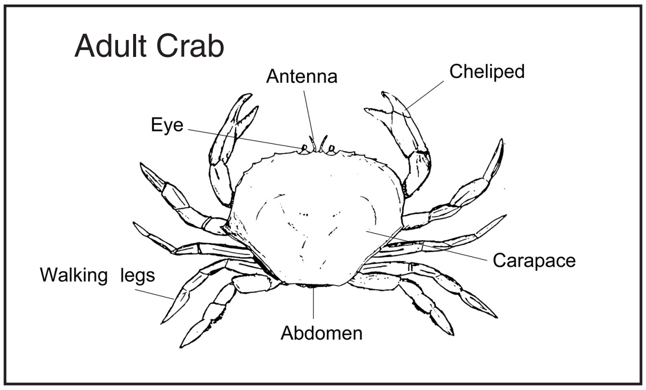


FIGURE 6. Basic anatomy of an adult crab.

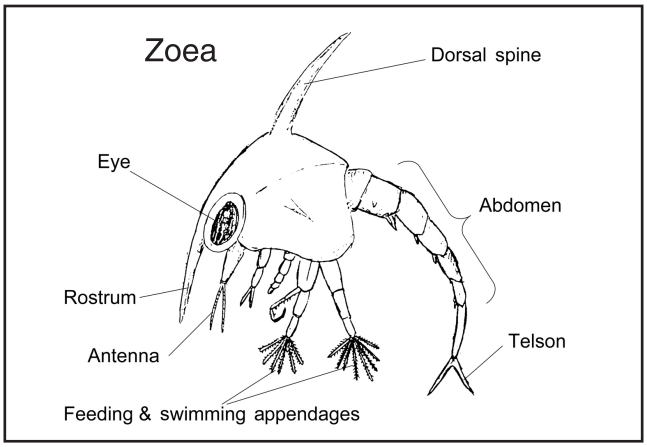


FIGURE 7. Basic anatomy of a crab larva in the zoea stage.

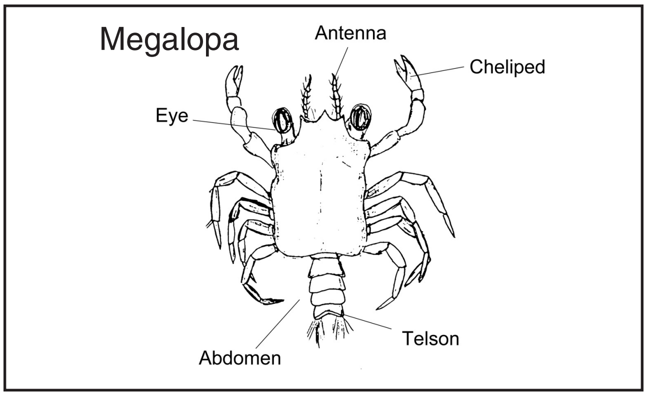


FIGURE 8. Basic anatomy of a crab larva in the megalopa stage.

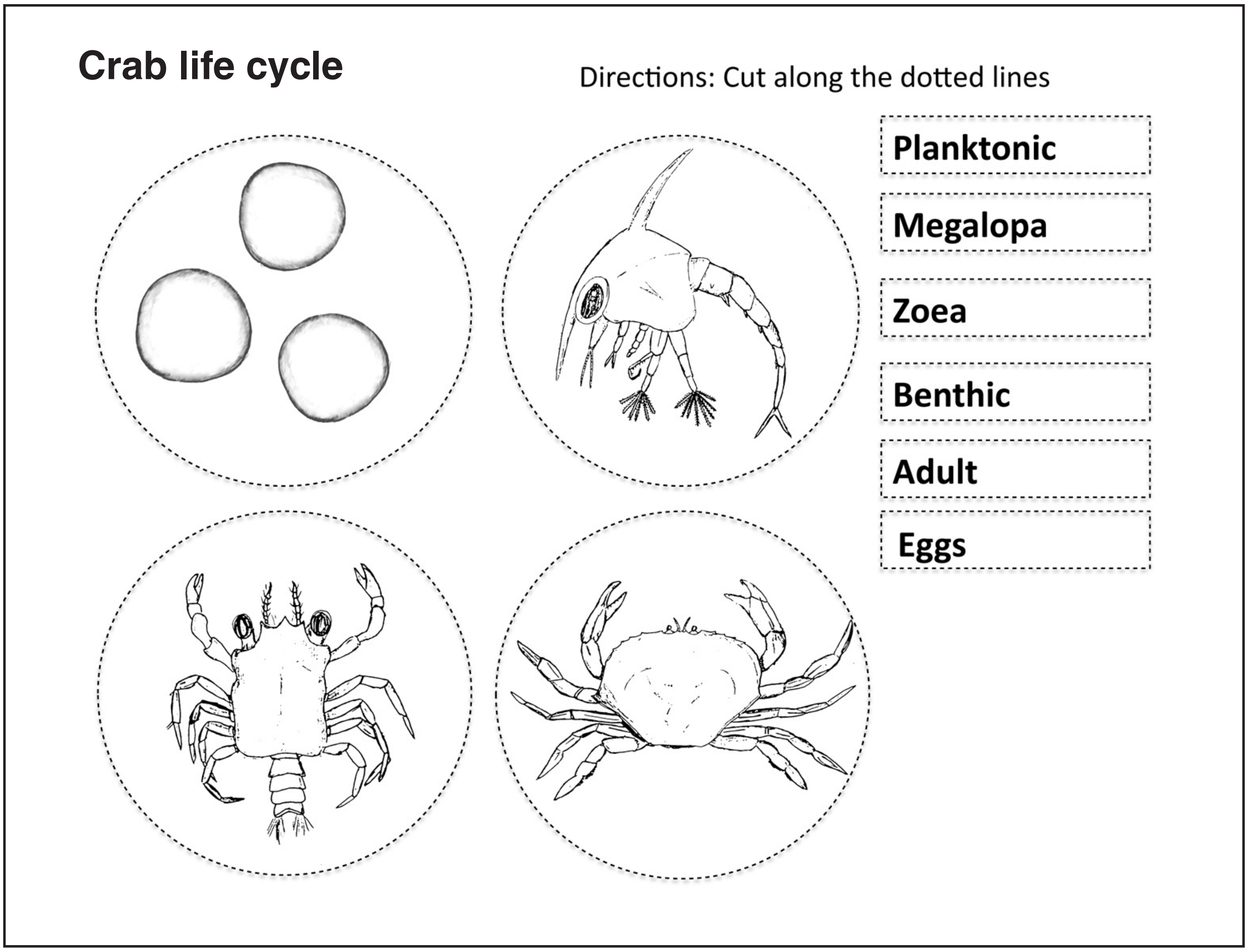


FIGURE 9. Crab life cycle puzzle pieces.

Ask the students if they can think of another example of an animal with a larva. Guide them by saying that it is a larva until it undergoes metamorphosis and changes completely (*metamorphosis* is often a trigger word that students associate with what they might already know about the life cycle of a butterfly). In our classes, *butterfly* was by far the most common answer, but students also came up with *frogs*, *flies,* and, in one case, *mosquitoes*. Ask the students to describe a butterfly larva. What is it called? What does it look like? How does it move? What does it eat? Then ask them to answer the same questions about the adult butterfly, which looks, lives, and feeds differently from the larva. We have found that using the familiar example of a butterfly makes the concept of complex life cycles in the ocean less foreign and abstract.

The focus of the lesson now shifts entirely to crabs and their larvae. Ask students to describe a crab and its habitat. What does an adult crab look like? Where does it live? How does it move? Ask the students to consider why the larva of a crab looks so different from the adult. Give them some time to think, then discuss their ideas as a class. Tell the students that one reason the larva looks so different is because it does not live in the same habitat as an adult crab. The early crab larva, called a *zoea*, swims and drifts in the open water; it is planktonic. The zoea stage of Dungeness crabs have been found as far as 100 miles offshore. The zoea then metamorphoses into the intermediate larval stage, called a *megalopa*, which rides the currents and swims back toward shore and, ultimately, its adult habitat. Zoea only swim, megalopae primarily swim but also can crawl on the bottom, and adult crabs are incapable of swimming and are entirely benthic, dwelling at the bottom of the ocean. (At this point, it may be helpful to show a video clip of crabs in their habitat; see Resources.)

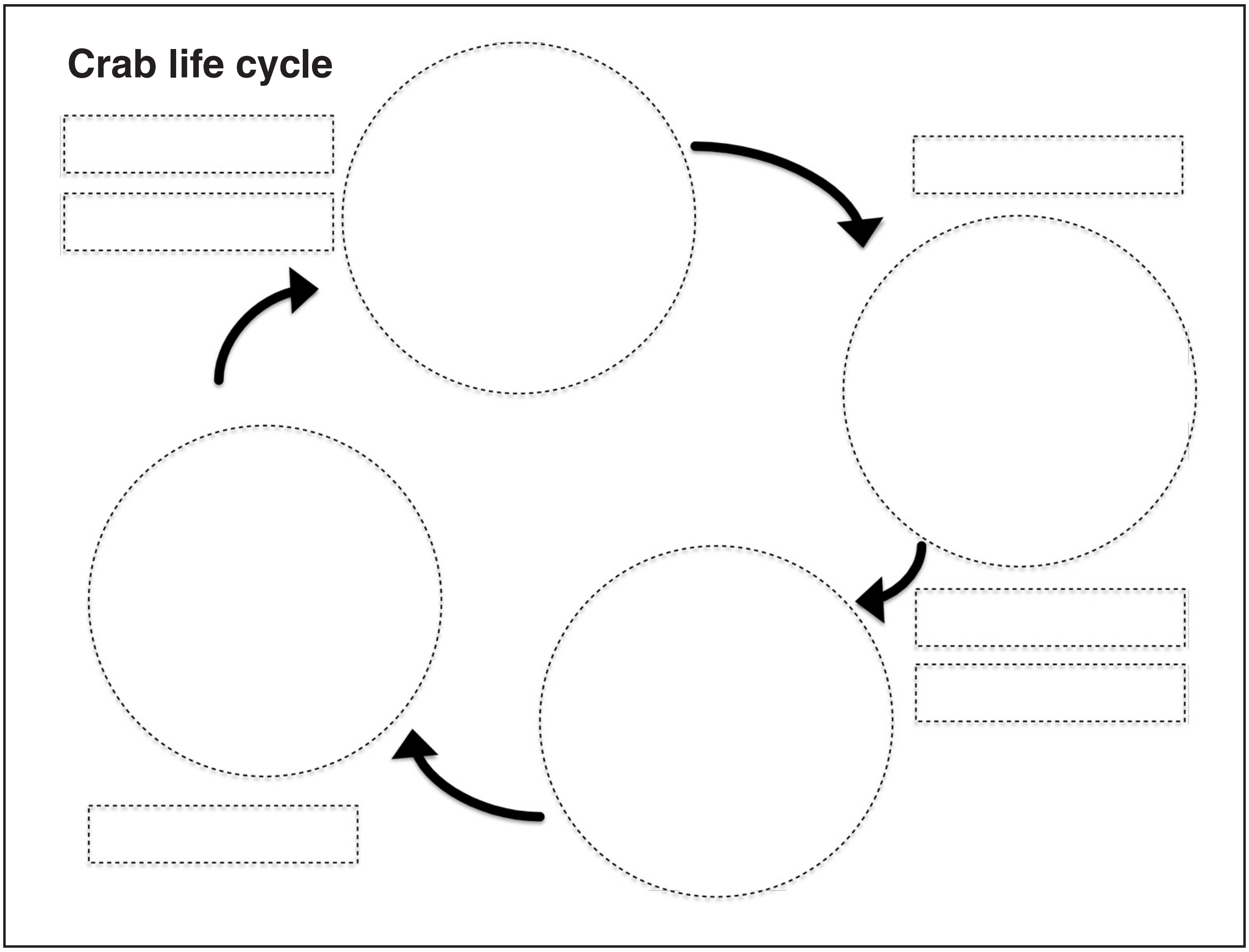


FIGURE 10. Crab life cycle puzzle worksheet.

Explore

Divide the students into groups of five or six and give each group the following materials:

- unlined paper for drawing organisms (two sheets per student),
- an adult crab on ice,
- one or two hand lenses,
- a microscope with a zoea slide and a megalopa slide, and
- a labeled diagram of each life stage (Figures 6–8).

The goal of this part of the lesson is for students to make careful observations of the organisms and to draw what they see. If necessary, set an amount of time for each student to use the microscope to ensure that all members of the group get a chance to see the larvae. After the students have had time to draw, project the basic anatomy sheet (Figures 6–8) on a screen so all students can use the diagrams to help them label their drawings. At the bottom of their paper, have students choose a body part and describe what they think the function might be (i.e., how it might be a useful adaptation for that specific life stage).

Explain

Next, the students reconvene and discuss their observations. Divide the blackboard into three columns and write *zoea*, *megalopa*, and *adult crab* at the tops of the columns. Ask the students to share their observations with the group. How did the zoea and the adult look the same? How were they different? In what ways did the megalopa look like the zoea? In what ways did it resemble the adult? After students have shared some of their observations, write the words *planktonic* and *benthic* on the board. Can students think of any ways in

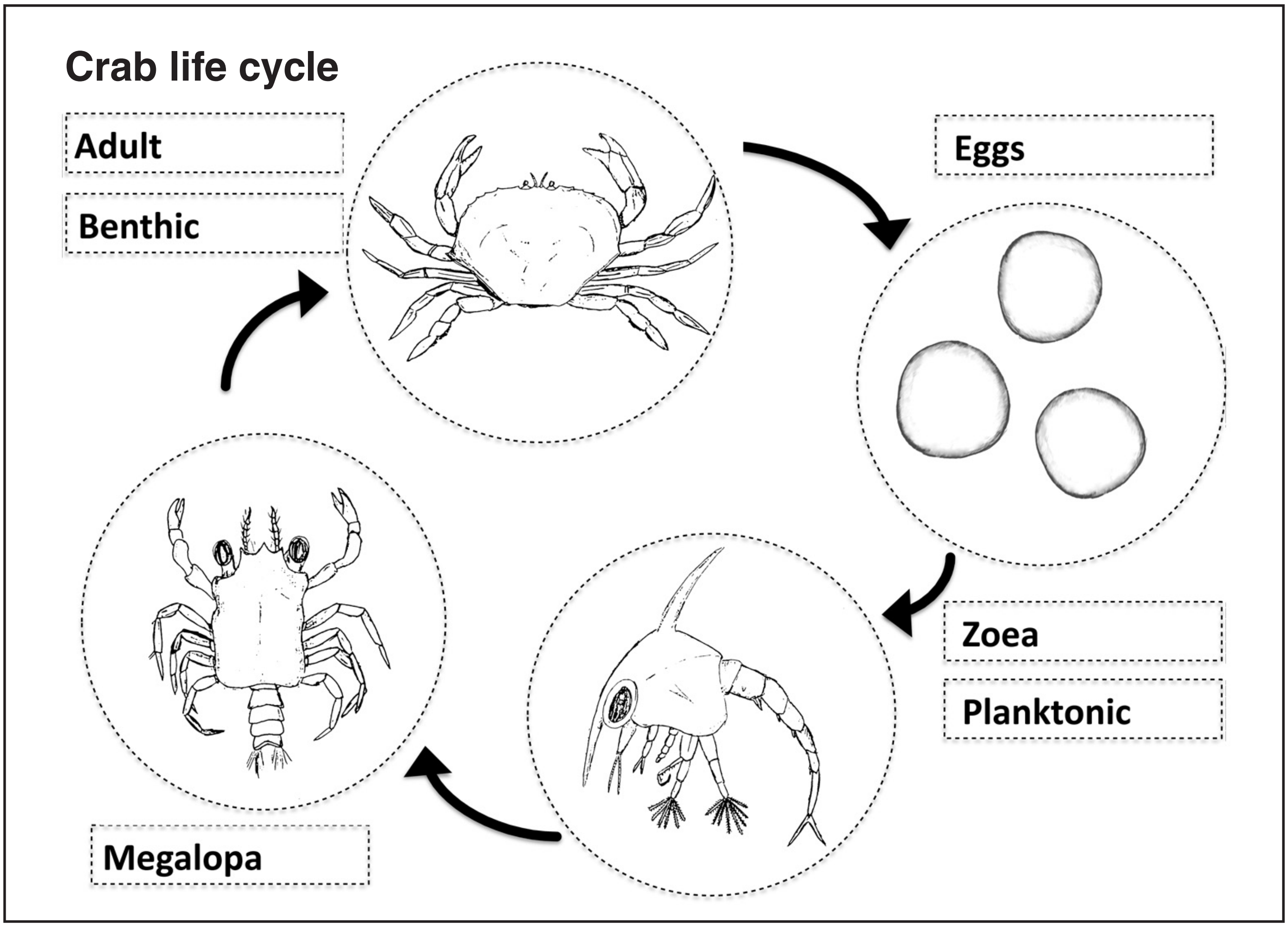


FIGURE 11. Completed crab life cycle puzzle.

which each life stage is well adapted to its habitat? If the students are struggling, you might guide them by asking about the body shape of the two life stages, (e.g., whether having a large, hard shell would help or hinder an organism drifting in the water). You could also ask the students to use the body shapes to predict which life stage(s) eat plankton. Would it make sense for an animal that eats plankton to have pincers? Would pincers, which are useful for tearing off chunks of flesh, be useful for catching tiny food that is floating in water? We found that our students did a terrific job of relating form to function in this portion of the lesson.

Discussion and Findings

We have found that teaching marine invertebrate life cycles is a great way to engage students in science. This lesson provides basic skills required for inquiry, such as making careful observations, asking and answering scientific questions, and using scientific tools such as microscopes.

Extensions and Cross-Curricular Applications

Assessment of this lesson is based primarily on the students' observational drawings and their participation in the class discussion. We have also included a life cycle puzzle in which students put the life stages of the crab in order and specify each stage's habitat (Figures 9–11). To further the activity, students could look at images of other invertebrates and their larval forms (e.g., barnacles, sand dollars, urchins), describe where the adult lives and the adaptations that make it successful in that habitat, and then note where the larva lives and how its adaptations differ from the adult's. In this way, you will be able to determine if the students are able to relate the morphology of each life stage to its specific habitat.

The study of marine invertebrate life cycles presents many interdisciplinary opportunities. For language arts, students might write a story of an intertidal invertebrate and its journey from a free-swimming larva to a benthic adult. The children's book *Pagoo* by Holling Clancy Holling (1985) is a beautifully illustrated tale of a hermit crab that begins as a zoea wondering just what kind of animal it might be. For a cross-curricular math application, have the students calculate the size difference between a zoea and an adult crab.

Conclusion

The study of complex life cycles is undisputed in its importance as part of the K–12 curriculum. Most existing lessons, however, focus exclusively on the life cycles of frogs and butterflies. Think back to the mental list of common tide pool animals that you made as you first began reading this lesson. We would argue that one or more of the animals that made your list, such as a crab or a sea star, is as recognizable an animal to most K–12 students as a butterfly or a frog. Incorporating the study of the larval stage and dramatic metamorphosis of one of these marine organisms not only addresses the tenets of the National Science Education Standards, but also enhances ocean literacy.

Understanding the marine invertebrate life cycle is an essential precursor to further study of the broader topics of marine ecology, population dynamics, dispersal, and colonization of habitats. One additional benefit that we have noted in our classes is that students are much more easily engaged in the study of physical oceanography when they know that those ocean processes may be responsible for the direct transport of their favorite tide pool inhabitant.

Acknowledgments

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Resources

Invertebrate larvae: Carolina Biological Supply, www.carolina.com, Keywords: *zoea*, *megalops*, *plutei*

Brockscopes: www.magiscope.com

Video clips of crabs in their habitat: www.arkive.org, Keyword: *cancer pagurus*

Video clip of a crab releasing zoeae: www.arkive.org, Keyword: *carcinus maenas*

References

Holling, H. C. 1985. *Pagoo*. Boston: Houghton Mifflin.

Inagaki, K., and G. Hatano. 2004. Vitalistic causality in young children's naïve biology. *Trends in Cognitive Sciences* 8:356–62.

National Geographic Society, National Oceanic and Atmospheric Administration (NOAA), Centers for Oceanic Sciences Education Excellence (COSEE), National Marine Sanctuary Foundation, National Marine Educators Association, College of Exploration. 2007. Ocean literacy: The essential principles of ocean sciences grades K–12, a jointly published brochure. http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf (accessed April 16, 2009).

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Oregon Department of Education. 2001. *Oregon state science standards*. http://www.ode.state.or.us/teachlearn/real/standards/sbd.aspx (accessed April 16, 2009).

Young, Craig M., ed. 2002. *Atlas of marine invertebrate larvae*. San Diego: Academic Press.

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