Lesson Title: Why do young Living Breakwaters (LB) critters look so strange?

Unit: Living Breakwaters Curriculum: Restoration and Resilience in Raritan Bay
Sub-Unit: LB Life Cycles Series: Is Metamorphosis Adaptive?

LESSON OVERVIEW

Grade: 6-8       Class Periods: 1-3       Setting: classroom       Subject Area(s): science

Lesson Summary
Given a set of text-and-image cards depicting separate life stages of a selection of estuarine organisms, students sort the cards into categories, read the cards for evidence that their categories do or do not make sense, and then make inferences and raise questions about the advantages and disadvantages of each life stage for each taxon.

Objective(s)
● Encounter some of the alien-seeming life stages of marine organisms
● Compare and contrast life stages across taxa
● Make inferences and raise questions about the impact on a species of having the particular life stages that it has

MATERIALS & RESOURCES

Supplies
● String (depending on how many students you have you may need a couple hundred yards and it's always good to have extra)
● Clipboards (one for every student)
● Scissors (one for every student)
● Basic classroom supplies like markers and paper

Handouts
● LB Life Cycle Cards -- the class needs one printed copy of these two-sided cards, and each student needs digital access to the whole set - see Preparation
● Thumbnail pix only - LB Life Cycle Cards - each student needs a set printed on only one side of the paper - see Preparation
● You think your card does not belong in a category with any other cards in the class: what's your evidence? -- prepare about 10 copies
● You think your cards belong together in one category: what's your evidence? -- prepare about 10 copies
● Marine Animal Life Stage Pros and Cons -- one for each student
● Predict the life stage before and after - exit slip -- one for each student

Teacher Resources
● 2002 section “Eggs” from college bio textbook
● 2003 article "Who came first - larvae or adults? Origins of bilaterian metazoan larvae" in professional science journal
● 2017 article "Larval evolution - I’ll tail you later" in journal for professional biologists who are not specialists in evolution or development
● 2019 summary “Fish biology: How the cytoplasm separates from the yolk” of contemporary research article

BEFORE YOU GET STARTED

Tips for Teachers
● One way to differentiate within this lesson is to assign the juvenile cards to students you think need more scaffolding. The juveniles look most familiar, and the main differences between juveniles and adults are size and sexual maturity -- familiar concepts for a human adolescent! Sometimes juveniles are found in different habitats than adults, which might also have an interesting human analog.

● An ideal sequence is to first monitor an Oyster Research Station or other BOP oyster installation. There, students can encounter some of these organisms in real life! To tie that field work more closely to this lesson, you might ask students to measure or estimate the sizes of the organisms they find while they are in the field.

● The Living Breakwaters Curriculum is designed to open up multiple opportunities for student-directed research. We hope that during these lessons, your students will grow authentically curious, and that you can capture their curiosity by writing down their questions and exclamations. Side-by-side with these lessons, or as a final activity, we hope your students can revisit their curiosity, and let it guide their original research. That’s why it’s so important to record your students’ unanswered questions throughout the lessons.
  ○ When students describe the information they need -- e.g. suppose a student says “I would need to know if XYZ is true in all fish” -- rephrase that as a question and record it among the unanswered questions -- e.g. “Is XYZ true in all fish?”

● Be creative about rephrasing students’ words as questions - any time you think they are curious about something, record the specific topic of their curiosity where everyone can see! For instance, if a student is looking at a picture of a yolk-sac larva and says, with some passion, “look at that”!, you can record it as a question along the lines of, “what is a yolk-sac larva?”
  ○ Later, you may have an opportunity to ask that student to explain more specifically what made them exclaim when they saw the picture. Then the question might become something more specific, like “what is wrong with that yolk-sac larva’s head?”
  ○ It doesn’t have to be a great research question right now. It just has to capture that unique thing that makes that unique student curious.
● We encourage all participants to present their work at the Annual BOP Research Symposium in June!

Preparation

● **LB Life Cycle Cards** should be printed with the images on one side of the card and the main text on the other side of the card.
  ○ You need one printed set of these cards for the class.
  ○ These cards should be laminated, hole punched and strung, so they hang around a student’s neck. This allows the students to be hands-free during the activity.

● **Thumbnail pix only - LB Life Cycle Cards** should be printed on only one side of the paper, so that students can cut out the small images and manipulate them at their desks.
  ○ Each student needs a printed copy of these cards.

● Set up a place to record students’ questions, where everyone can see.

● Arrange the desks in groupings, with the idea that students are likely to move the desks around during the *Explore* section of the lesson.

**INSTRUCTION PLAN**

**Engage**

1. Each student has a complete set of **Thumbnail pix only - LB Life Cycle Cards**. Each student cuts out the 27 different pictures.

2. Students categorize the pictures. The goal is to group together the pictures that are *most similar* to each other.

3. Students write a few words to describe each of their categories.

4. Pairs of students compare their categories, and work together to create a set of categories so that:
   ○ Each category has a name or description (e.g. long and skinny)
   ○ Each card fits one category
   ○ No category is ‘other’ or ‘miscellaneous’

For the next activity, students leave their cutouts and writing at their chairs, with their bags.

**Explore**

1. Each student wears ONE full-page, two-sided, laminated *LB Life Cycle Card*, around their neck so others can see it. Students stand, and chairs are at the perimeter of the room. Desks remain in groups.

2. Explain: for now, don’t read the text on the back of your card. Find the other students in the room with cards that are most similar to yours. Once you are satisfied with your grouping, pull
up your chairs with your belongings, and sit together at a group of desks.

3. Ask: Which cards don’t seem to fit with any other cards?
   ○ When students share their answers, ask: Any ideas? Could there be a good fit for this card in one of our groups?”
   ○ Note: There is no singular correct answer: there are logical ways to classify all the cards in groups, and there are logical ways to classify some in groups while leaving some cards solo.

4. Ask: How does each group seem to be organized?
   ○ You could follow up with questions like:
     ■ Did you go by the picture? In that case, what about your pictures suggests that you belong together?
     ■ What about the titles? Do the titles suggest the same groupings as the pictures?
       ● For example, which titles have the word ‘embryo’ in them?
       ● What about ‘feeding’?
       ● ‘Settler’?

5. Ask: Do you think some cards belong in different groups?
   ○ Students make their cases, and each student decides for herself whether to switch groups.

6. Each group names itself, based on its organizing principle, e.g.
   ○ Swimmers with tails
   ○ Circles
   ○ Settlers
   ○ Feeders
   ○ Note: It’s not important to reach consensus about the best way to organize the groupings. This discussion is intended to get people thinking, and focusing their attention on the images on their cards.

**Explain**

1. Assuming some students remain on their own, tell them:
   ○ Your job will be to explain to the class why you don’t belong in any of the groups. You can do this on your own, or join forces with another solo card-holder and help each other along.
   ○ In any case, these solo-card students can sit together.

2. Addressing the grouped students, say:
Your job is to identify the important things you have in common, and the important differences among you. Also you will develop a graphic to share that information with the class more clearly.

3. Students get the handout that applies to them. Each group needs only one copy of its handout:
   - You think your card does not belong in a category with any other cards in the class: what’s your evidence?
   - You think your cards belong together in one category: what’s your evidence?

4. As the handouts are going around the room, ask the students:
   - Is your group’s life stage visible to the naked eye? Can you see something that size without a microscope?”
     - As students respond, you might ask: What might it be like to be so small?

5. Groups complete their respective handouts, referring to the vocabulary as needed.

Elaborate
1. Some or all of the groups present their work products to the class, with time for questions and inferences
   - Meanwhile, start recording your students’ unanswered questions where they can see them, and where you can retrieve them for later. One way is on a board, and at the end of class you can preserve an image of the board.

2. At some point during each presentation, ask the entire class to think about, write down, and then share with their group / tablemates:
   - What is most striking to you about this stage of the life cycle of some organisms?
   - What if they all skipped that stage of life stage? What do you think would be different for them in the next life stage?

Evaluate
1. All students have digital access to the whole set of LB Life Cycle Cards -- with images and text.

2. Each student selects one of the following generalized life stages to think more about. It’s ok if their card from before does not match the stage they choose now. These stages are organized by function:
   - Embryo inside Egg
   - Yolk-Sac Larva
   - Free-Swimmer
   - Feeder
   - Settler
3. Each student refers to their chosen stage while completing the handout *Marine Animal Life Stage Pros and Cons*. The activity in the handout asks students to consider:
   - Evolutionary advantages and disadvantages of the life stage
   - Relationships between structure and function at this life stage

4. Debrief as a class. You can ask questions like:
   - Why do you think there are life cycles? Do you think it’s necessary for living things to go through life cycles?
   - Instead, could organisms reproduce by making tiny versions of their adult forms?
   - Would the offspring have to be tiny?

   ■ Throughout this discussion, ask the students: “what’s your evidence?” and “what kind of information would you need, as evidence, to be more certain?”
   ■ Meanwhile, continue to record students’ unanswered questions.

Extend

Extension 1
As an exit slip, you can ask:

- Go back to your individual card from the start of this lesson and make some predictions. What stage of life do you think comes just before your card? You don’t need to tell me what it’s called. Just describe: what do you think this organism is like just before this moment in its life? What stage of life do you think comes just after your card? In other words, describe: what do you think this organism is like just after this moment in its life?

Provide at least two pieces of evidence to support your predictions. The evidence can be a quotation from your card, specific reference to something someone said in class, or an original idea you have right now.

Extension 2
1. All students focus on eelgrass, and read its cards.
2. The class discusses:
   a. How is the eelgrass life cycle similar to and different from a generalized animal life cycle?
      - Note: you can ask the class to construct the generalized animal life cycle, or you can provide one that is something like:
        ■ sperm cell and egg cell merge to form fertilized egg
        ■ embryo develops inside protective egg
        ■ organism
          - meets the world -- hatching or birth
          - grows larger than its egg/parent’s womb, and moves through space - yolk-sac larva
          - feeds - feeding larva
          - settles (this stage is most applicable to marine and estuarine species), and may or may not metamorphose - settler larva or settler juvenile
• increases in size - juvenile and sometimes adult
• becomes able to produce sperm cells and egg cells - adult

b. This will not work perfectly, but let’s see how well we can map the stages of the eelgrass life cycle -- which, by the way, are the same as the stages of most flowering plants, which are most of the plants you are familiar with -- onto the stages of this generalized animal life cycle

c. What part of the eelgrass life cycle is most similar to…
   ■ “Sperm cell and egg cell merge to form fertilized egg?”
      ● How is that part of the eelgrass life cycle similar to and different from its animal analogues?
         ○ Continue this comparison through the complete eelgrass life cycle

d. Which parts of the general animal life cycle are most similar to parts of the flowering plant life cycle?
   ■ What do you think is so important about those parts of animal and flowering plant life cycles?

   ■ Do you think all animals and all plants share it? Why or why not?"

   ■ Do you think all organisms share it? What about single-celled organisms? Do you think single-celled organisms could do something like that?

      ● Remember, the ocean and estuary are full of single-celled organisms!

FEATURED IMAGE
Featured image:

Standards -- NYC Scope and Sequence Science Grades 6-8

Science and Engineering Practices
- argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

Crosscutting Concepts
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS1-4), (MS-LS1-5)
- Structures… can be visualized… and used to describe how their function depends on the shapes, composition, and relationships among their parts (MS-LS3-1)

Grade 6, Unit 3: Ecosystems -- Why does the Earth never run out of matter or energy?
Disciplinary Core Ideas organized by Performance Expectations
- MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
  - Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.
  - Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)
  - In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1)
  - Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)

Grade 8, Unit 3: Growth, Development, and Reproduction of Organisms
Disciplinary Core Ideas organized by Performance Expectations
- MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.
  - Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.
  - Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4)
  - Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)

- MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include the genes responsible for size differences in different breeds of dogs. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.

Assessment does not include genetic mechanisms, gene regulation, biochemical processes, or natural selection.

Grade 8, Unit 4: Evolution, Natural Selection, and Adaptations
Disciplinary Core Ideas organized by Performance Expectations

- MS-LS4-3. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.
  - Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.
  - Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.
  - Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (MS-LS4-3)

NGSS High School standards
Disciplinary Core Ideas

- LS1.A Structure and function
  Systems of specialized cells within organisms help perform essential functions of life. Any one system in an organism is made up of numerous parts. Feedback mechanisms maintain an organism's internal conditions within certain limits and mediate behaviors

- LS2.A Interdependent relationships within ecosystems
  ....The fundamental tension between resource availability and organism populations affects the abundance of species in any given ecosystem

- LS2.D Social interactions and group behavior
  Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

- LS4.B Natural selection
  Natural selection occurs only if there is variation in the genes and traits between organisms in a population. Traits that positively affect survival can become more common in a population.

- LS4.C Adaptation
  Evolution results primarily from genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce....
Crosscutting Concepts

● Patterns
  ...students… cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale....

● Cause and effect
  ...students…. suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system....

● Scale, proportion, and quantity
  ... students… recognize… some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly....

● Structure and function
  In grades 9-12, students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system’s function.... They infer the functions and properties of natural… objects and systems from their overall structure [and] the way their components are shaped and used...

● Stability and change
  In grades 9-12, students understand much of science deals with constructing explanations of how things change and how they remain stable. They... model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it....

Science and Engineering Practices

● Asking questions and defining problems
  ○ Ask questions
    ■ that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
    ■ to clarify and refine a model [or] an explanation....
  ○ Ask and/or evaluate questions that challenge the premise(s) of an argument, or the interpretation of a data set.....

● Developing and using models
  ○ Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

● Analyzing and interpreting data
  ○ Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.

● Constructing explanations (for science) and designing solutions (for engineering)
  ○ Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena...
○ Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

● Engaging in argument from evidence
  ○ Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.
  ○ Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
  ○ Make and defend a claim based on evidence about the natural world… that reflects scientific knowledge and student-generated evidence.

● Obtaining, evaluating, and communicating information
  ...in 9-12 progresses to evaluating the validity and reliability of the claims, methods, and designs.
  ○ Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
  ○ Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).