



HOW TO USE THIS RESOURCE

The images for this resource, [Living Together](#), can serve as anchoring phenomena to explore the key concepts described below through the example of symbiosis between bobtail squid and their microbes, which provide the squid with camouflage during hunting and increase their success in catching prey.

The pedagogical practice of using phenomena to provide a context for understanding science concepts and topics is an [implementation practice](#) supported by the Next Generation Science Standards (NGSS). Phenomena are observable occurrences that students can use to generate science questions for further investigation or to design solutions to problems that drive learning. In this way, phenomena connect learning with what is happening in the world while providing students with the opportunity to apply knowledge while they are building it.

The “Implementation Suggestions” and “Teacher Tips” sections provide options for incorporating the images into a curriculum or unit of study, and can be modified to use as a standalone activity or to supplement an existing lesson. The student handout includes reproductions of the images and the “background” section.

KEY CONCEPTS

- A. Symbiosis is a close, long-term interaction between organisms of at least two different species, often a large host and one or two species of microbe.
- B. Species interactions can affect resource availability and, over the course of each organism’s life cycle, determine the resources available to each.

NGSS PERFORMANCE EXPECTATIONS

[MS-LS2-2](#). Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

[HS-LS2-2](#). Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

BACKGROUND INFORMATION

The Hawaiian bobtail squid, a walnut-sized relative of the octopus, can be found in the shallow coastline waters of the Hawaiian island of Oahu. Juvenile bobtail squid filter luminescent bacteria from seawater into an internal pouch called the light organ. Amazingly, only one type of bacteria, typically bioluminescent *Vibrio fischeri*, is able to stay in a developing light organ; all other species are washed back out into the ocean. Once established in the fully developed light organ, bacteria emit a blue light that matches the moonlight entering the ocean, rendering the squid virtually invisible to predators from below—a phenomenon called counterillumination. Thus, the light provides camouflage to squid hunting at night at the ocean surface. The relationship between squid and bacteria is a classic example of symbiosis: the squid provide the bacteria with food and shelter, and the bacteria provide a luminous glow that conceals the squid from predators and prey. Understanding the biology of squid-bacteria symbiosis can provide insights into other symbiotic relationships.

IMPLEMENTATION SUGGESTIONS

The following suggestions outline several options for incorporating the images into a unit of study as the anchoring phenomenon:

Engagement, establishing prior knowledge, and providing context:

- Show students the first image of the squid in the Student Handout and ask them to make observations about the image. Students may note the squid's size, shown by its contrast to fingers and using the scale bar; its coloration; and the appearance of being tinged blue or iridescent, particularly in its mantle.
 - From their observations, ask students to generate a list of possible reasons the squid has the characteristics they've noticed (e.g., "The squid is small to avoid predators."). Students may note that the squid is speckled for camouflage but wonder why it appears blue or shiny.
 - Show students the video clip of the bobtail squid burying itself (<http://www.hhmi.org/biointeractive/bobtail-squid-swimming-and-burrowing>) and ask them to note when squid are active (at night) and why they bury themselves during the day (camouflage from visual predators).
- Show students the second picture on the student handout, which is a picture of the bobtail squid's light organ.
 - Tell students that the image was created by overlaying multiple frames of a video-microscopy recording, so the "streaks" represent movements of parts of the light organ over time, just like streaks of car lights in a long-exposure image reveal the flow of traffic. Because of difficulty in seeing how the light organ moves water currents, researchers tracked how cilia on the light organ moved beads back and forth. The image was generated in black-and-white and later colorized to increase contrast.
 - This image shows the ciliated appendage of the light organ, which only exists in juvenile squid and degenerates after the light organ is colonized with the bacteria that the ciliated appendage helps to capture. The longer "hook" of the appendage is approximately 300 μm .
 - In order to contextualize the picture, it may be helpful to show Figure 1 from the Educator Materials film guide for the *I Contain Multitudes* video (<http://www.hhmi.org/biointeractive/film-guide-for-natures-cutest-symbiosis-the-bobtail-squid>), which students can watch later in the implementation sequence.
 - Additionally, this YouTube video of the motion of this organ's cilia can further clarify the image: <https://www.youtube.com/watch?v=W2-dC-Hu9hg>.
 - Ask students to annotate the images using the prompt, "I notice ... I wonder..."
 - Tell students that this image is of a part of an animal that emits light. Ask students to consider the following: "Why would a nocturnal animal hunted by visual predators have an organ that emits light?" Have students consider that question in pairs or small groups and generate a list of possible reasons. Have a brief class discussion in which students share possible reasons, noting whether different groups of students propose the same reasons.
- Have students read the background information in the student handout, noting the terms "counterillumination" and "symbiosis." It may be helpful to have students summarize the paragraph to one another.
- Ask students to work in pairs to write two or three questions based on the caption and images based on the relationship between the squid and bacteria. Example questions could include "How does the squid know which bacteria are the 'correct' bacteria?," "How does the squid control how much light is emitted?," or "How do the bacteria know when to glow?". Students may also pose questions about what happens to squid in the absence of bacteria or bacteria without a squid host.
- Have students share their questions via a class discussion, or collect them (via Post-its or index cards) to categorize for future class discussions.

Exploration, assessment, and extension:

- Exploration: Have students revisit the image of the bobtail squid's light organ, noting that the streaks around the organ represent flow patterns. These flow patterns show how squid recruit beneficial bacteria to colonize their light organ. Ask them to consider and discuss the following questions: How can we explain why the squid is trying to attract bacteria? Why do the bacteria communicate to gain entry into the squid? How does that demonstrate symbiosis?
 - Use the video, *Nature's Cutest Symbiosis: The Bobtail Squid* [<http://www.hhmi.org/biointeractive/natures-cutest-symbiosis-the-bobtail-squid>] with the accompanying film guide [<http://www.hhmi.org/biointeractive/film-guide-for-natures-cutest-symbiosis-the-bobtail-squid>] to explore answers to student questions and a handout for students to complete as they watch the video. This guide includes further information about the light organ's structure, its maturation over the course of the squid's life, and the interaction between the microbes and the squid. Students can also explore this symbiosis using the Symbiotic Bioluminescence Click & Learn [<http://www.hhmi.org/biointeractive/symbiotic-bioluminescence>], which includes video explanations to many questions students are likely to have.
- Assessment: Sample assessment questions are available using the student handout that accompanies the video and film guide. The handout includes questions in which students need to support, with evidence and reasoning, that the bacteria and squid have a mutualistic relationship, and that each ensures the other's access to resources including food.
- Extension: The video and guide include information on the number of bacteria the squid houses in its light organ. Each day, the squid ejects 95% of its bacteria; the remaining population then grows over the course of the day to a high enough density to produce light at night. Students can explore different models of population growth using the Population Dynamics Click & Learn [<http://www.hhmi.org/biointeractive/population-dynamics>] and the accompanying worksheet.

TEACHING TIPS

- Present students with the image(s) first, before they read the background information.
- Background information may be edited to support student proficiency, course sequence, etc.
- The image(s) may be projected in lieu of handouts.
- Pair or group students to work through one or more of the implementation suggestions.

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