Bioluminescence in Algae

Phenomenon/Problem:

Certain microscopic algae, known as *dinoflagellates*, emit a glowing effect when disturbed, creating a unique wave of light under the right conditions. Each of these single-celled algae emits a small amount of light, and together, they make a glowing wave effect.

This bioluminescence is considered an adaptation that likely evolved through natural selection because it increases the algae's chance of survival. When a predator moves through the water, this sudden glow can startle the predator or make it more visible to larger predators.

Similarly, other species use defense mechanisms against predators, such as hoofed mammals like cattle or sheep that herd together. These defensive traits, whether chemical or behavioral, can evolve through natural selection because they improve survival and reproduction in the presence of predators.

Stimuli: How will students experience and/or observe the phenomenon/problem?

Students will observe videos of water glowing as it's disturbed due to glowing algae.



https://www.youtube.com/shorts/8zyT9ykjH5g

Essential Questions:

- Why do certain species of algae bioluminesce when disturbed?
- How do environmental disturbances affect different organisms — from bioluminescent algae in waterways to beef cattle on rangelands?
- How does natural selection impact defense mechanisms in unique organisms, such as algae and cattle?

Related Phenomena/Problems:

- There are multiple bioluminescent organisms that use this feature for different biological purposes. https://education.nationalgeographic.org/resource/bioluminescence/
- Bioluminescence in organisms tends to be blue, red, or yellow. https://www.smithsonianmag.com/science-nature/why-bioluminescence-evolved-be-red-light-and-blue-180969435/
- Organisms may develop defense mechanisms (like herding) that protect them against predators, which are passed down through natural selection.
- When a predator or threat approaches, cattle suddenly pack together tightly instead of running in all directions.

Considerations for Instructional Design:

- Guide students in constructing explanations (SEP: Constructing Explanations) to connect the defense mechanism of bioluminescence to natural selection and adaptation of traits.

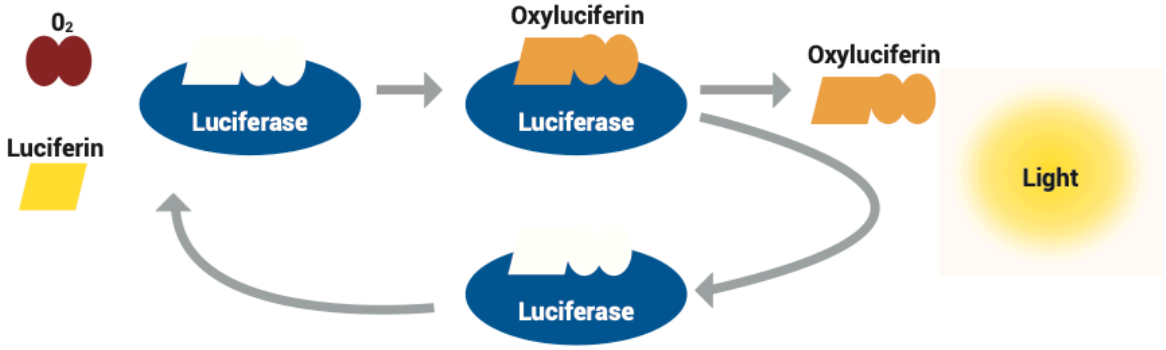
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- Guide students in constructing explanations (SEP: Constructing Explanations) that link cattle's biological defense mechanisms, like herding, to the defense mechanism of bioluminescence through multi-step cause-and-effect relationships (CCC: Cause and Effect).
- Encourage students to develop and use models (SEP: Developing and Using Models) to show how algae with this trait led to the survival and reproduction of more organisms that have this advantageous trait while reducing the number of organisms that did not have this trait.
- Students can compare this defense mechanism in algae with cattle's herding defense mechanism and the impact it has had on survival (CCC: Cause and Effect).
- Prompt students to ask questions (SEP: Asking Questions) about the interactions between bioluminescence and natural selection (CCC: Stability and Change) throughout the investigation. Students will seek answers through research, data analysis, and evidence collection (SEP: Analyzing and Interpreting Data).

Explanation:

Certain species of microscopic algae called *dinoflagellates* can produce light through a chemical reaction inside their cells. When the water around them is disturbed—by waves, boats, or animals swimming nearby—the disturbance triggers ion channels in the cell membrane to open. This causes a rapid chemical reaction between luciferin (a light-producing molecule) and luciferase (an enzyme). The reaction releases energy in the form of blue-green light, which is why the water appears to glow.



https://deepoceaneducation.org/resources/bioluminescence-fact-sheet/

Individually, each *dinoflagellate* produces only a tiny flash of light. But in large numbers, these flashes combine to create the glowing waves or clouds of light observed in the ocean. This light is not just a by-product of chemistry—it is an adaptation that can increase the chances of survival for the dinoflagellates.

Biologists think bioluminescence evolved in these algae through natural selection because it may help protect them from predators. When a predator disturbs the water and causes the algae to glow, the sudden flash of light can startle the predator or make the predator more visible to its own predators. Dinoflagellates that produced brighter or more effective flashes were more likely to survive and reproduce, passing this trait on to future generations. Over many generations, this led to populations of dinoflagellates with the ability to glow when disturbed.

Thus, the glowing effect we see today is the result of cellular mechanisms that produce light and evolutionary processes that favored this trait because it increased survival in the environment where these algae live.

https://nebraskapublicmedia.pbslearningmedia.org/resource/lights-out-for-bioluminescence-video/nature-season-43-san-diego-americas-wildest-city/

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A similar evolutionary process explains why cattle group together as a herd when threatened. When predators such as wolves or coyotes approach, cattle that cluster tightly together are less likely to be singled out or attacked. Grouping also increases the number of individuals detecting danger and makes the herd appear larger and more difficult for predators to confront. Over many generations, cattle with stronger instincts to stay close to others during danger had a higher chance of surviving and protecting their offspring. These individuals passed on genes that influenced herding behavior, and the trait became widespread in the population through natural selection.

Dinoflagellate bioluminescence and cattle herding behavior may appear very different, as one is a cellular chemical response, and the other is a group-based behavioral response. However, they both illustrate the same core scientific idea: traits that increase an organism's chances of survival and reproduction become more common over generations. Both phenomena demonstrate how adaptations evolve through natural selection to help organisms survive in their environments. Each trait improved survival in different environments, but both arose because individuals with the trait left more offspring than individuals without it.

Student and teacher questions about this phenomenon/problem that could be instructionally productive:

- How does bioluminescence protect these algae from predators?
- What other organisms have defense mechanisms like cattle and *dinoflagellates?*
- What other organisms exhibit bioluminescence, and what is the biological purpose?
- What is the chemical process that causes the algae to glow?
- How are bioluminescence and herding similar as survival strategies?
- What other defense mechanisms do algae and/or cattle exhibit?
- Why would predators avoid glowing algae and/or large herds?
- How do these traits become more common over generations?

Explaining the phenomenon/problem or related phenomena could lead students toward developing the following DCIs:

HS-LS4.C-H2: Adaption

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

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Notes about relevance and authenticity (funds of knowledge, interests, identity)
Why might students be engaged?

- Students are likely familiar with fireflies and may not realize that there are other organisms that bioluminesce and why.
- It bridges a fascinating phenomenon of glowing algae to the food chain with cattle.
- It connects an organism's defense mechanism that may be new to students with a defense mechanism they may be familiar with in cattle.
- Students may have seen cattle's herding behavior in real life or videos.
- The comparison between algae and cattle naturally invites conversation, argumentation, and model-building.

Resources/References

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