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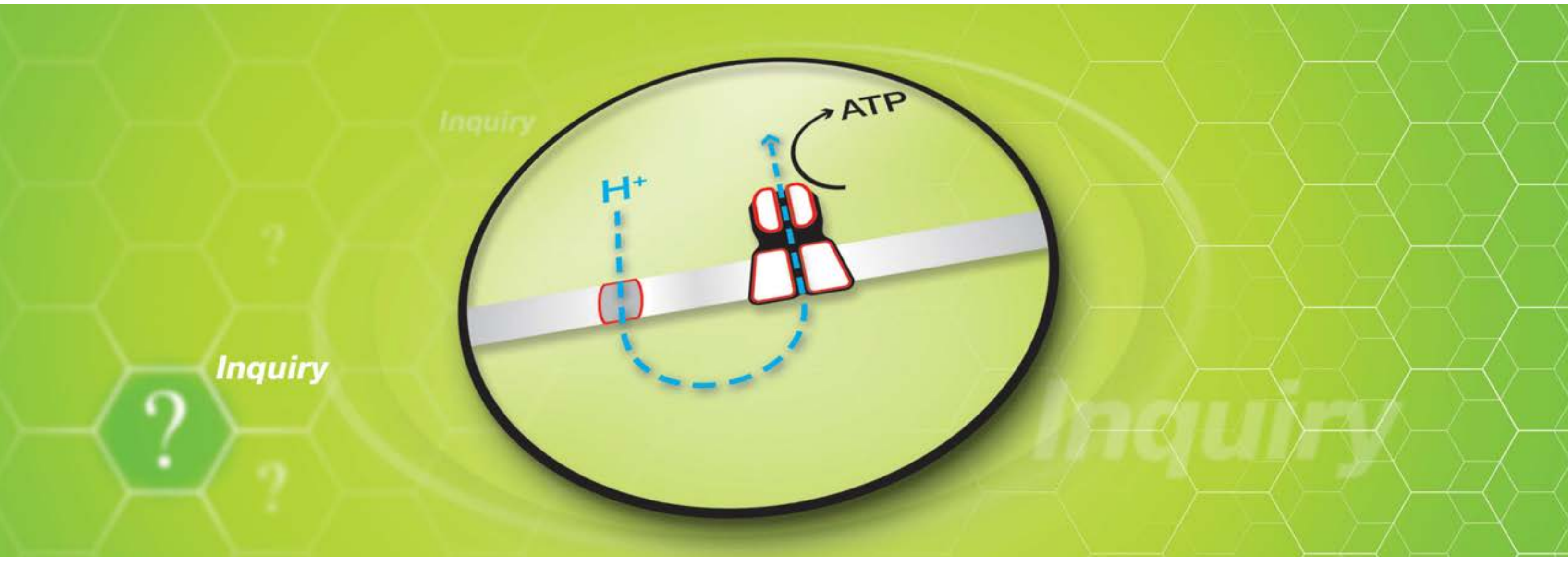

Photosynthesis and Cellular Respiration Kit

A ThINQ!™ Investigation

Catalog #17001238EDU

AP Biology | Science Case Study

BIO-RAD

Part 1

Where Have All the Brown Shrimp Gone?

Hank Despaux leaned over to inspect his net. It was his eighth try of the day, and he was beginning to lose hope. As with the seven tries before, this one pulled up a water haul — a virtually empty net, containing only eight lethargic crabs, a number of tiny silver fish flapping about, and a solitary brown shrimp, the real goal of his trip. Hank is a shrimper whose family has made a living in the waters off the Louisiana coast for three generations. The last ten years, however, have been increasingly difficult, and this season, he fears, may be his last.

A number of economic factors affect the shrimp industry in the Gulf of Mexico. For one, the price of shrimp has dropped dramatically over the last few decades. As demand has increased, cheaper imports have come in to fill the void. Because they are less expensive, these imports have forced Gulf shrimpers to lower their price per pound by as much as 50%. Add to that increasing costs of fueling, running, and maintaining a boat, and it becomes clear the profession has become very difficult to sustain.

In the last few decades, an ecological phenomenon has also contributed to the hardships of shrimpers like Hank: the annual Dead Zone. The Dead Zone is a phenomenon in which the waters at the bottom of the Gulf become hypoxic (have low concentrations of dissolved oxygen). This forces the shrimp, fish, and other creatures that live there to flee to fresher waters or die. In the case of the brown shrimp Hank is after, the Dead Zone blocks juvenile brown shrimp from reaching their offshore spawning grounds, where they reproduce.

During these summer months, shrimpers and fishermen like Hank can spend weeks, if not months, not catching much of anything, and this puts an even tighter squeeze on their bottom line. They must fish in waters much farther off the coast, which costs more and which is not even possible for some of the smaller boats. Some years, the fishing industries curtail the official shrimping seasons in order to ensure the long-term health of the fishing and shrimping industries. "If you're already struggling to provide for your family, if your profit margin is so small that you rely on every month's catch to make a living, it's going to affect you," Hank says. "You can be in real trouble."

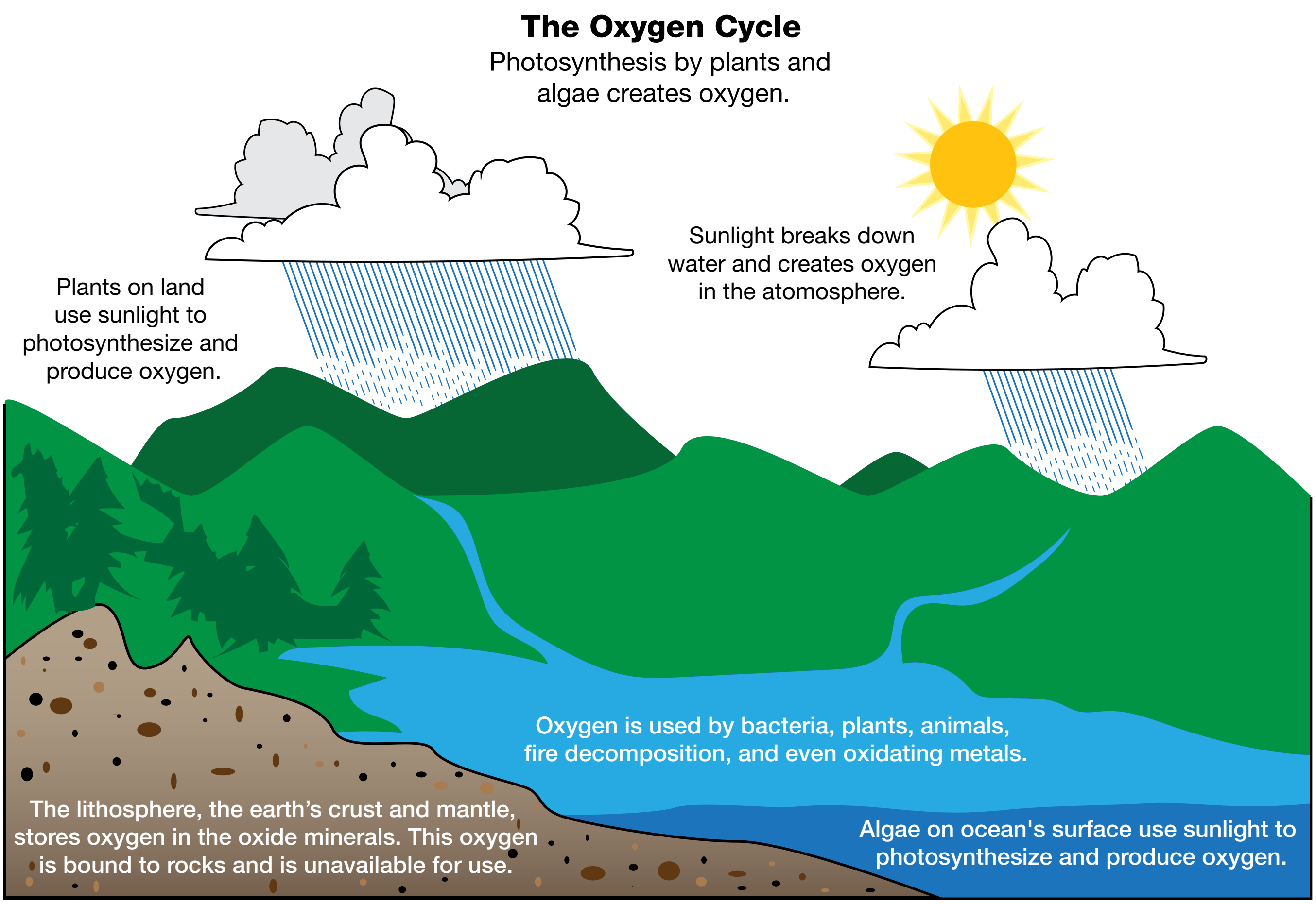

Fig. 1. The oxygen cycle.

1. Water is considered hypoxic (lacking oxygen) if it contains 2 mg/L or less dissolved oxygen. Think of the food chain that exists in the Gulf of Mexico: What are the types of organisms that likely live at the bottom of the Gulf, where the water is most hypoxic? How can a lack of oxygen affect them? Which cellular processes are affected by a lack of oxygen?

2. Oxygen is much less abundant in water than in air. Air contains 21% oxygen, but the oxygen content in water is only 0.001%. What factors (physical and biological) can affect the levels of dissolved oxygen in the Gulf waters? Think of the oxygen cycle (Figure 1).

Part 2

Too much photosynthesis?

The Dead Zone is a huge ecological and economic problem that is caused by some of the Gulf's smallest residents: microalgae and aerobic bacteria.

Microalgae (microscopic algae) live and grow in the sundrenched top layers of the Gulf waters where, under normal conditions, they perform their photosynthetic duties and, as its primary producers of oxygen, make life in the Gulf possible. In fact, microalgae around the world make all our lives possible, as they produce about half of the oxygen we breathe. Ironically, these tiny microscopic sustainers of life are also the ultimate cause of the Dead Zone. When favorable conditions prevail (abundant sunlight, nutrients, and the right water conditions), their growth can spiral out of control, and a vast algal bloom (overgrowth) appears. These blooms can stretch for hundreds of miles and suffocate life in the waters below them. This is because as the microalgae grow and ultimately die, they sink into the waters below, where they are digested by aerobic bacteria in a process that consumes oxygen (cellular respiration).

Under normal conditions, wind-driven ocean churning (due to storm activity and natural upwelling) helps stir the waters enough to bring oxygenated surface water down to the lower depths to alleviate any temporary hypoxia. In the Gulf of Mexico, however, the warm surface waters and cooler bottom waters — and diminished storm activity in spring and summer — create a stable water column that discourages this churning. In addition, fresh water pouring into the Gulf from the Mississippi River also traps oxygen-depleted saltwater below (Figure 2). As a result, organisms living at greater depths, including most marine animals, cannot acquire necessary oxygen. This timing is especially bad, as the summer months are a time of active reproduction by fish and benthic (bottom-dwelling) invertebrates.

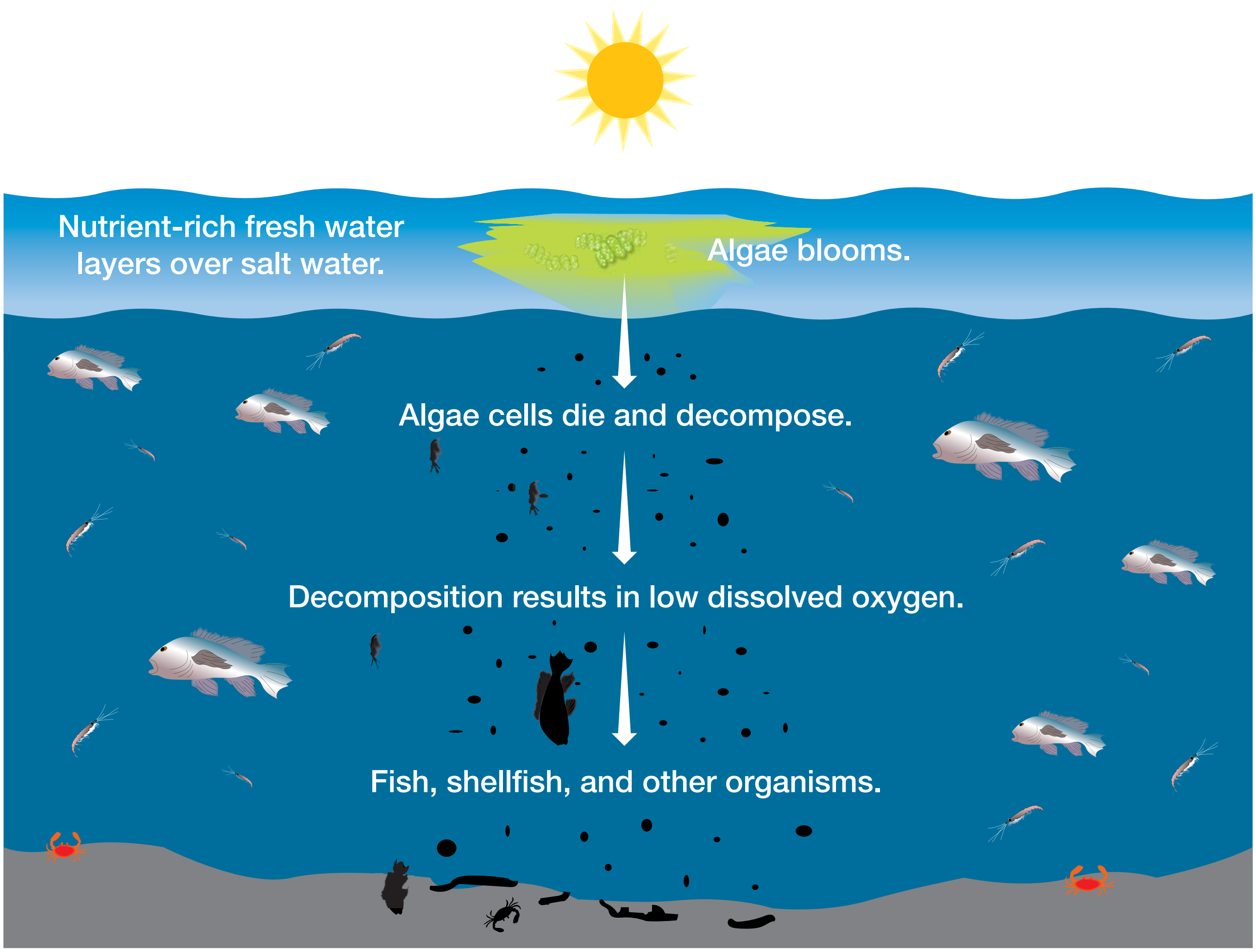

Fig. 2. Factors present that lead to Dead Zone formation in the Gulf of Mexico.

Although they are often noted for their harmful effects, algal blooms (red tides, for example) occur as a part of natural upwelling cycles and sustain the beginning of the marine food chain. In healthy marine ecosystems, algae grow and reproduce as conditions permit, producing food, energy, and oxygen that support the rest of the food chain. As they and the organisms that feed on them die, they become part of the sediment at the bottom. Decomposers such as bacteria then effectively recycle these organisms back into the food chain. Then, as offshore winds blow across the ocean surface, surface water is displaced, allowing cooler water to rise up from below to replace it. This water that rises to the surface as a result of upwelling is also rich in nutrients that "fertilize" surface waters, triggering new algal blooms and supporting the growth and reproduction of the organisms that depend on them. It is not surprising that good fishing grounds typically are found where upwelling is common.

Fig. 3. Size and locations of the Dead Zone and Mississippi River basin.

3. Microalgae are primary producers (see introduction for the definition of producer) in the Gulf of Mexico. What environmental factors are necessary to sustain their growth? What do they produce in return?

4. Draw a diagram that connects substrates and products of photosynthesis and cellular respiration (CO_2, O_2, H_2O, etc.). Which of these processes is (are) performed by microalgae? By aerobic bacteria?

5. Compare the algae in the Gulf of Mexico with terrestrial plants (for example, crop plants): where and how do they each obtain the nutrients they need to grow and reproduce?

6. Scientists mapping the size of the algal blooms and Dead Zone have noticed a correlation between the amount of annual rainfall and the size of the bloom. In 1988, a year of drought, the Dead Zone was relatively small, but in 1993, a year of flooding on the Mississippi River, the Dead Zone was quite large. In 2014, the Dead Zone was larger than average: at 5,840 square miles, it was about the size of Connecticut. As described above, the freshwater boundary caused by Mississippi freshwater runoff is one factor that contributes to Dead Zone formation. Refer to Figure 3. Can you provide another hypothesis as to how and why the size of algal bloom might be affected by annual rainfall totals? Consider your answers to the previous two questions in the context of the major economic activity in the Mississippi River basin: agriculture.

7. What types of measurements or experiments could you perform to explore your hypothesis?

8. The Atlantic hurricane season runs from June through November. What environmental occurrences/factors might contribute to reoxygenation of the hypoxic layer and removal of the Dead Zone at the end of the summer?

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