

Unit III Single-celled Organisms

On the cutting edge...

Dr. Wood at the University of Oregon is on the edge of scientific discovery as she explores some of the microscopic inhabitants of the marine environment. She is studying the relationship between a cyanobacteria and a dinoflagellate. She is interested in learning more about how these organisms create a symbiotic relationship that helps them succeed in nutrient-poor tropical waters.

Introduction to Single-celled Organisms

Lesson Objectives: Students will be able to do the following:

- Compare and contrast three types of symbiotic relationships
- Describe the relationship between zooxanthellae and coral
- Explain the effects of nitrogen-fixing bacteria on their symbiotic partners

Key concepts: symbiosis, commensalism, parasitism, mutualism, dinoflagellate, nitrogen-fixing cyanobacteria

Symbiotic Relationships



The word **symbiosis** in its simplest terms means “living together”. This word describes a partnership between two

different kinds of organisms such as a sea anemone and a hermit crab or a squid and a **bacterium**. These relationships are long-term associations that are usually advantageous to at least one member of the partnership. These symbiotic relationships often occur because of the nutritional needs of the members. There are many examples of symbiosis to be found in nature. For example, some hermit crabs have shells covered with sea anemones. The crab is

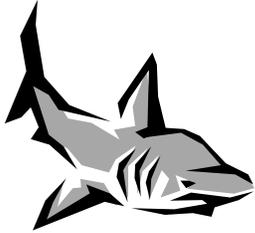
camouflaged from predators and protected with the sea anemones’ tentacles while the anemones are carried to various locations where food gathering is easier. The bobtail squid harbors light emitting bacteria. These bacteria help create light patterns that camouflage the squid during hours of feeding.

Symbiotic relationships can be divided into three broad categories:



commensalism, parasitism, and mutualism. These categories describe how each partner benefits from the relationship. In commensalism, one member benefits while the other is neither helped nor harmed. A good example

of this type of relationship is the remora that can attach itself to a



shark. The remora gets a free ride and eats the scraps left by the shark. It does not harm or help the shark. In

parasitism, one member is helped while the other member is harmed. An example of a parasitic relationship is a tapeworm in a human. The **parasite**, the tapeworm, lives inside the human or **host**. The parasite is helped, because it gets nutrition from the food in the human's intestine. The human can slowly starve, because the tapeworm is using the nutrition from the food the human eats. In mutualism, both organisms benefit as in the case of the fish and the cleaner shrimp.

The fish enters a "cleaning station" where the shrimp removes parasites from the fish's body. The fish gets



cleaned and the shrimp gets a free meal.

Symbiotic relationships occur between organisms of all sizes in all environments. Some partners are vastly different in size as evidenced by the whale and its special barnacle partner that lives in its skin. Some symbiotic partners are similar in size like the hermit crab and the sea anemone. We often think of symbiotic relationships that include organisms that we can see without using a microscope, but symbiosis occurs in the micro-world as well. Some microorganisms such as **diatoms** with their glasslike outer coverings, **dinoflagellates** with their whiplike projections, and even the tiniest bacteria are involved in symbiotic relationships. Some of these relationships involve only microorganisms while others can include much larger animals. We will take a closer look at an example of mutualism between a dinoflagellate and a much larger animal that lives in the marine environment.

Dinoflagellate/Coral Symbiosis

Dinoflagellates are common members of the phytoplankton found in the ocean. There are nearly 2000 species of these single-celled organisms that have been identified. They come in a variety of sizes but are considered the mid-sized members of the micro world. They are generally smaller than the diatoms and larger than the photosynthetic bacteria. Dinoflagellates derive their name from their two distinct **flagella** or

whiplike projections that are used for locomotion. Most of these organisms are covered with armored plates called thecal plates. Scientists use these plates to help classify these organisms. Dinoflagellates also have different lifestyles. Some of them are photosynthetic, producing their own food, while



others must find food. A good example of a symbiotic relationship involving a photosynthetic dinoflagellate is the partnership between a zooxanthellae and a coral. Corals are animals that are



related to sea anemones and form the huge geologically important coral reefs.

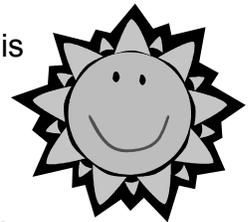
“Zooxanthellae” are a type of dinoflagellate that specializes in living symbiotically within the tissues of animals. In this mutualistic relationship, the zooxanthellae live inside the coral. The zooxanthellae is called an **endosymbiont** and the coral is the host. These two partners recycle the waste products from living processes to continue their relationship. The endosymbiont uses energy from the sun to power the process of **photosynthesis**. The zooxanthellae produces sugar from carbon dioxide in the water and releases oxygen.



The food or sugar produced by this process gives the coral energy. The presence of the zooxanthellae also helps the coral produce calcium carbonate. This material is used to build a cup-shaped skeleton to

support the coral animal. This skeleton becomes a coral reef. The oxygen released during photosynthesis is used by the coral for respiration. Carbon dioxide released during the coral’s respiration is used by the zooxanthellae during photosynthesis. The corals also produce waste products such as ammonium. Some of these products are used as nutrients by the zooxanthellae.

As you can see both organisms benefit from this relationship, but they must also give up something. The dinoflagellate gives up some of its photosynthetic energy to the coral. In return the coral must use a portion of that energy to keep its surface clean and grow branched colonies. This provides the dinoflagellate with adequate sunlight for photosynthesis. The zooxanthellae’s light requirements also restrict the coral to depths at which the coral can grow. Why would organisms enter into a relationship where they had to give up something? In this instance, coral reefs are found in nutrient-poor waters, so this relationship provides both members with sufficient nutrition.



Cyanobacteria

We are going to take a closer look at some very small members of the microscopic world, because they are important in symbiotic relationships. The **cyanobacteria** are sometimes called “blue-green algae” because of

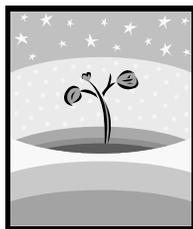
their color and because they also photosynthesize. These organisms are not **algae** but rather a special kind of bacteria. These bacteria are unicellular, but they may combine to form colonies or filaments. Some of

these colonies are large enough to be seen without a microscope.



Typical cyanobacteria get their color from a bluish pigment called phycocyanin. Many marine cyanobacteria contain an additional, pink pigment called phycoerythrin. These pigments are used by the cyanobacteria to capture sunlight during photosynthesis just as most plants use the **chlorophyll** pigment. These very simple, unicellular organisms are found in nutrient-poor waters. They are fascinating to study, and some of them have a unique ability.

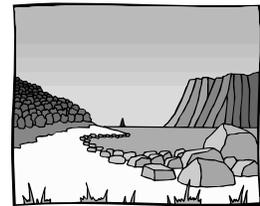
Some cyanobacteria species are among the few organisms that can change atmospheric nitrogen into forms that can be used by plants and animals. Organisms that can do this are called nitrogen-fixing bacteria. Why is it important to have nitrogen-fixers? Nitrogen is the third most abundant element found in organisms. While it is abundant as nitrogen gas in the atmosphere, only nitrogen-fixing organisms can convert nitrogen gas to forms that can be taken up by plants and converted to food that animals can eat. So, nitrogen-fixing organisms ultimately provide the nitrogen required by all other organisms in the food chain. Since nitrogen-fixers provide an essential nutrient plants require, many photosynthetic organisms have



developed symbiotic relationships with a microbe that can fix nitrogen.

These relationships between a nitrogen-fixer and a plant partner can be found in all types of environments from forested areas to open ocean waters. Some plants will even create special homes for these bacteria within their roots or stems in return for the nitrogen they produce. In exchange, the plant provides the bacteria with some of the energy needed to change atmospheric nitrogen into these usable forms.

Cyanobacteria also form symbiotic relationships with other microscopic organisms. One of these organisms is a diatom.



Diatoms are single-celled, photosynthetic organisms found in all types of freshwater and marine environments. They are a primary component of marine **plankton**, but they can also be found in the deep ocean sediments. These organisms are known for their intricate outer skeletons made of **silica**. These silica walls or **frustules** are composed of two overlapping parts that fit together.

It is important to note that diatoms can make their own food, but they must find a source of nutrients. Nutrients provide the building blocks for cells. Without nutrients organisms cannot carry on life processes such as growing. Most



plants get their nutrients from the soil, but diatoms live in the ocean. Where will they get their nutrients? Just as the kelp, diatoms will have to find their nutrients in the water. Unfortunately for some species of diatoms, they live in very clean, pure water that may not contain enough nitrogen. For the diatom, the lack of nitrogen can be limiting. That means that they may not be able to grow even if they have enough food in the form of sugar.

In this case, a symbiotic relationship could solve the problem. If the diatom and the cyanobacteria live together, perhaps they could both get what they need. The diatom and the cyanobacteria are both



photosynthetic, so there will be plenty of food for both organisms. The diatom, being much larger than the cyanobacteria, provides a home for the smaller organism. The cyanobacterium in turn uses its special nitrogen-fixing ability to make usable forms of nitrogen for itself and the diatom. This is exactly what happens in the case of the cyanobacteria and a diatom called *Rhizosolenia*.



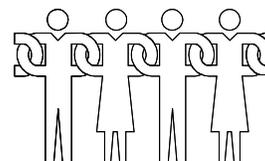
These microscopic symbiotic relationships also occur between cyanobacteria and dinoflagellates. These dinoflagellates are a little bit different than the zooxanthellae that we discussed earlier, and next time we'll see how scientists study one of these interesting relationships.

Activity: Feeding Friends

Some animals develop associations that are advantageous to both of the partners. This type of relationship is a special kind of symbiosis called mutualism. These types of partnerships can be found in all habitats and can include the largest animals to the smallest bacteria. Many times these mutualistic relationships are formed because of the nutritional needs of the members.

Objectives: Students will be able to do the following:

1. Describe a mutualistic relationship.
2. Demonstrate a mutualistic relationship.
3. Analyze the advantages and disadvantages of a mutualistic relationship.



Materials:

- Items to represent food (stuffed animals, folded pieces of paper, items that can be picked up using only elbows, or combinations of these items, etc.) Approximately two items per student is adequate (of course the more items the longer the rounds). These amounts can be adjusted to suit your needs.
- Spot markers (poker chips, paper squares, etc.)

Note to Teacher: This activity requires some students to move with their eyes closed. Always show students how to move safely with their eyes closed prior to the activity. If students are having difficulty, the activity can be done by a few students at a time instead of the whole group.

Procedure:

1. Discuss symbiotic relationships. Have students brainstorm reasons for organisms having such relationships. What are the advantages and disadvantages of these partnerships?
2. Explain that in this activity students will be organisms (either No See Ums or Ferocious Feelers) that must gather food within their habitat. At first they will hunt for food on their own. Later they will take part in symbiotic relationships.
3. Have students choose partners. (Partners should stand next to each other.)
4. Have students form a circle by joining hands and moving apart until their arms are fully extended. Have students drop hands and take two giant steps backwards. The area inside the circle becomes the habitat. (Playing area can be adjusted for groups of various sizes. The area should allow ample room between players on the field.)
5. Place a "spot marker" next to each pair of students.
6. Explain that the inside of the circle represents a habitat. The organisms that are participating will be hunting for food within this habitat. Explain that people that are not organisms during the round are helping to keep their partner safe. They can only speak to warn their partner if someone is coming too close, but they cannot direct anyone to or away from food.

7. Explain the following parameters for the activity. (It is helpful to have a student demonstrate the appropriate behavior as the parameters are read.)
 - Organisms are hunting for food in the habitat. (Show students the items that will be used for food.)
 - Both types of organisms move by crawling.
 - Both types of organisms move very slowly as if they are in slow motion.
 - Organisms that move quickly die from overexertion and must sit outside of the habitat.
 - The No See Ums must close their eyes while they are in the habitat. They collect food using their hands.
 - The Ferocious Feelers can see, but they can only use their elbows to pick up food.
 - Food that cannot be held by the organism may be stockpiled on their “spot marker”.
8. Before the round begins:
 - Have one partner from each pair step into the circle. Have students that are in the circle choose the type of organism they want to be. (Try to have some of both types of organisms for each round.)
 - Have student participants sit randomly in the habitat. No See Ums must have their eyes closed. Ferocious Feelers should have their elbows ready.
 - Distribute food randomly in the habitat.
9. Give a signal for the round to begin.
 - At the signal, students crawl throughout the habitat gathering food according to their restrictions.
 - After all the food is gathered, have students return to their “spot marker”.
10. Repeat using the other half of the students.
11. Discuss the limitations of each type of organism as they tried to gather food. Did one type of organism get more food than the other type?
12. Explain that in the next round organisms will develop symbiotic relationships.
13. Explain that the following parameters apply for this round:
 - The partners in each pair will work together as one organism.
 - In this round food gathered by either partner can be used by both partners.
 - Each pair will consist of a No See Um and a Ferocious Feeler.
 - The partners must stay in contact at all times during this round. (It is up to the partners to decide how to safely accomplish this task.)
 - Once the partners have chosen a point of contact, they cannot change during the round. For example, if one organism places his hand on his partner’s back, then he cannot change to putting his hand on his partner’s arm during the round.
 - Remind students that the No See Um still cannot see and the Ferocious Feeler can still only collect food with their elbows.
14. Give partners time to decide which organism each will be and how they will stay in contact. (One hand is enough.)

15. When students are ready, have symbionts enter the playing area. (The playing area can be enlarged to accommodate more students simply by distributing the food in a larger area. Students still have their “spot markers” to identify home.)
16. Have student partners “connect” and take their starting positions. (No See Ums have their eyes closed. Everyone is still.)
17. Remind students that excess food can be stockpiled on their “spot marker”.
18. At the signal, have students collect food following the parameters given.
19. Discuss ways that various partners solved problems. Was feeding more efficient this time? (Hopefully students will realize that the No See Um is the best food gatherer and the Ferocious Feeler is the best director but other solutions may occur.) Discuss the advantages and disadvantages of being in a symbiotic relationship. What did the partners have to give up to be in this symbiotic relationship?

Possible Extensions:

1. Older students may prefer to walk instead of crawl. For this adaptation, use food items that students may feel as they walk such as stuffed animals rather than flat items such as poker chips. Be sure that these items are soft and will not cause a tripping or falling hazard. The Ferocious Feelers can also be given arm extenders such as sand shovels or tongs to replace their elbow feeding devices. Remember that partners should be watching out for each other’s safety. Teach students how to maneuver safely with their eyes closed using the “bumpers up” position. In this position the arms are partially extended at chest height, fingers pointing upward, palms facing outward. This gives the sightless person a “bumper” to help them feel people or objects in their way.
2. After each round designate a new number of food items necessary to live. Was it easier to get the necessary items with a partner or alone?
3. After one round, designate one item as poisonous. How many organisms were killed? Apply this information to real world situations.

Student Information: Amazing Associations



Everywhere we look in nature, we can see different kinds of organisms living together.

The gopher tortoise shares its home with a snake. The **algae** live within the body of the coral animal. The whale swims through the water with barnacles attached to its skin. In these relationships the partners live together for long periods of time. At least one of the partners will benefit from this association. Scientists use the word “**symbiosis**” to describe these partnerships.

Symbiotic relationships can be found in all types of environments from the largest wooded forest areas to the smallest corner of the deep ocean bottom. Partners in these relationships can be similar in size as in the case of the crab that carries anemones on its back. The partners can be vastly different in size such as the whale and the barnacle or the microscopic algae that lives inside the coral animal. In some of these relationships the smaller partner will live inside

the other partner. In this case the smaller partner is called an **endosymbiont**. The larger partner is called the **host**.

Symbiotic relationships can occur between all types of living organisms. Animals can develop partnerships such as the remora fish and the shark. A photosynthetic organism and an animal can live together as the algae and the coral. Some unicellular organisms with characteristics of both plants and animals can be found in symbiotic partnerships. Even the tiniest microscopic organisms called **bacteria** have important symbiotic relationships. Some of these unicellular organisms are **cyanobacteria**, commonly called “blue-green algae”. Some cyanobacteria are really special; they are among the few organisms that can “fix” nitrogen. That means that they can take nitrogen from the atmosphere and change it into forms that can be used by other living organisms. Even humans can’t do that!

