

Symbiosis

A wide array of interactions among plants, animals, and microorganisms occurs in nature. Some of these relationships are characterized by a close physical association among species that persists for a significant period of the life cycle. In 1879 German botanist Heinrich Anton de Bary coined the term "symbiosis" to describe these relationships, meaning the living together of different species of organisms.

An interaction is considered a symbiosis based on the closeness of the physical association among the organisms rather than on the effect or outcome of the interaction. Symbiotic relationships span a spectrum from beneficial to detrimental effects. Many people associate symbiosis with **mutualism**, interactions that are beneficial to the growth, survival, and/or reproduction of *both* interacting species. But symbiotic interactions also include commensalism (one species receives benefit from the association and



Cleaner shrimp cleaning a zebra moray eel. Mutualistic relationships such as these promote the well-being of the host fishes and provide food for those that do the cleaning.

the other is unaffected), amensalism (one species is harmed, with no effect on the other), and parasitism. An example of commensalism is found in the anemone fish, which gains protection from living among the poisonous tentacles of the sea anemone, but offers no known benefit to its host.

In parasitic interactions, one species lives on or within a host organism and receives nourishment from the host, whereas the host is harmed by the interaction. In **obligate** interactions, the relationship is essential to at least one of the interacting species. Facultative interactions are those that are beneficial to at least one of the interacting species, but not essential.

Mutualisms in Plants

A common and widespread symbiosis occurs between terrestrial plants and fungi that colonize their roots. These associations are called "mycorrhizae," a word meaning "fungus-root." Unlike **pathogenic** fungi that cause disease, mycorrhizal fungi benefit the plant in several ways. These fungi germinate from spores in the soil to form thin threadlike structures called hyphae, which grow into the roots of plants. Once the roots are colonized, the fungal hyphae grow out from the root in an extensive network to explore the soil beyond the reach of the roots, gathering essential mineral nutrients and transporting them into the plant, increasing its growth. In return, the plant provides **carbohydrates** as a food source for the fungus.

Mycorrhizal symbiosis occurs in about 80 percent of all plant species. It is essential to many plants in low-nutrient environments because their roots alone are incapable of absorbing adequate amounts of some essential **minerals** such as phosphorus. The symbiosis is essential to the fungus because, unlike plants, fungi cannot make their own food via photosynthesis.

Mycorrhizal fungi provide other benefits to plants including improved resistance to drought and disease. The additional mineral nutrients acquired by these fungi have been

shown to aid plants in coping with competitors and herbivores. This symbiosis plays a large role in the growth and functioning of plants in both natural and agricultural **ecosystems** .

Legumes and certain other plants are colonized by *Rhizobium* bacteria that form small swellings or nodules on their roots. These symbiotic bacteria carry out the process of nitrogen fixation, the conversion of nitrogen gas into ammonia. Nitrogen is an essential element required by all organisms. Although nitrogen gas is abundant in the air, plants are unable to use nitrogen in this form, but they can readily use the ammonia formed by these bacteria and thus benefit from this symbiosis. As with mycorrhizal associations, the host plant benefits its symbiont by providing a carbohydrate energy source.

Mutualisms in Animals

In animals, a common mutualistic symbiosis occurs between many herbivores and microorganisms of their digestive tracts. **Ungulates** (hoofed animals) and some other animals eat plant material that is high in **cellulose** , even though they lack enzymes capable of breaking down cellulose molecules. They obtain energy from cellulose with the help of symbiotic bacteria and protozoa living within their digestive tracts. These microbes produce enzymes called cellulase that break down cellulose into smaller molecules that the host animal can then utilize. Similarly, wood-consuming termites depend upon symbiotic protozoans living within their intestines to digest cellulose. These are obligate symbioses. The termites cannot survive without their intestinal inhabitants, and the microorganisms cannot live without the host. In each of these symbioses, the host animal benefits from the food provided by the microorganism and the microorganism benefits from the suitable environment and nourishment provided by the host.

A variety of animals engage in a mutualistic relationship referred to as cleaning symbioses. Birds such as oxpeckers benefit their large ungulate hosts by removing their external **parasites** , benefiting in return from the food source the host provides. In the marine environment, certain species of fish and shrimp similarly specialize in cleaning parasites from the outside of fishes. This mutualistic relationship promotes the well-

being of the host fishes and provides food for those that do the cleaning. Unlike herbivores and their gut microorganisms, these interactions do not involve a close association of one organism living exclusively within another. These and other mutualistic but not clearly symbiotic relationships, such as those between plants and their pollinators, are sometimes referred to as proto-cooperation.

Parasitism

Perhaps the most common type of symbiotic interaction in nature is parasitism. Many kinds of worms, protozoa, bacteria, and viruses are important animal parasites. Some, such as fleas or ticks, are ectoparasites, living on the outside of their host. Others, such as tapeworms or hookworms, are endoparasites that live inside their host.

A variety of parasitic **symbionts** also occur in plants. In some plants, insects deposit their eggs within the growing shoot tips or other plant part, at the same time producing chemicals that cause the development of a large swelling or tumorlike growth called a gall. The insect larvae then develop within the gall, feeding on the plant tissue as they grow. When its development is completed, the adult insect emerges from the gall to mate and then initiate the gall-forming cycle again. This is an obligate symbiosis because the insect larvae lives inside the plant and cannot complete its life cycle without its host plant. It is also a parasitic association because the insect living within the plant consumes plant tissue and causes harm to its host plant, while benefiting from the food resources and shelter provided by the plant. In addition to insects, other gall-forming symbionts include viruses, bacteria, and fungi.

Symbioses are widespread and important in the life of many organisms and ecologically important in the functioning of natural ecosystems. The patterns of adaptations of mutualists, parasites, and hosts suggest that these interactions are the product of coevolution, leading to increasingly specialized, and often increasingly beneficial, associations. In many mutualistic symbioses such as lichens (symbioses of algae and fungi) and corals (cnidarians and endosymbiotic algae), the adaptive value of the association is that one organism acquires from its partner some new metabolic capability (for example, photosynthesis) that it does not itself possess.

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