

## CHAPTER 26

### COEVOLUTION

One of the most peculiar and interesting aspects of evolution is the adaptation of one species to another. These adaptations are so common and so obvious that they are often presented as proof of God's wisdom and purpose. We have already mentioned in passing two of these pairings that caught Darwin's attention: the ability of the coconut crab to open coconuts (page 89) and the co-adaptation of a trumpet flower and a hawkmoth (page 91). There are many other adaptations, some of which can be identified by casual observation. Darwin in later years invested considerable effort in a study of the extreme variation in the varieties of orchids, noting that many orchids strongly resembled female insects. Some were so effective in this mimicry that males tried to copulate with the flowers, in the process pollinating them (Fig. 26.1). In a more local setting, if you go to any large outdoor display of flowers and you look closely, you will find insects that you perceive to be wasps or hornets, but which on closer inspection prove to be harmless flies that merely look like wasps (Fig. 26.2). If you have a sassafras tree in your vicinity, you may notice some leaves that are rolled up. If you unroll the leaf, suddenly a large green head with threatening eyes and an orange, evil-smelling tongue will jump out at you. If you are not too startled (birds have been seen to rear back in fright) you will see that it is only a relatively large green caterpillar pretending to be a snake (Fig. 26.3). If you live in the Southeast of the United States, you may have heard the rhyme by which you can distinguish between the deadly coral snake and the harmless but very similar-appearing milk snake: "Red, black, and yellow, dangerous fellow; red, yellow, and black, he's all right, Jack". The larva of the monarch butterfly feeds on milkweed and incorporates enough of its toxin to make a bird sick. A bird that eats one of these beautiful and showy butterflies will not touch another for years, and there is a completely harmless butterfly that resembles it so closely that animals and humans usually cannot tell the difference. Many species of wasps or other threatening creatures tend to look a lot alike. Even some hawkmoths have body coloring that make them look like wasps as they hover near a flower. These are all examples of aposematic mimicry, in which a harmless creature imitates a more dangerous one and thus garners the protection of mistaken identity. Other organisms cooperate, to their mutual benefit. Lichens, common in adverse climates, are known as individual species but they are a combination of an alga, which can conduct photosynthesis and thus produce biological energy, and a fungus, which provides a stable, water-retaining structure in which the alga can



*Figure 26.1.* Some orchids, such as these *Phalanopsis*, resemble and smell like female insects so that males of the species actually try to copulate with the flower. In doing so, they get the pollen on themselves and, when they visit the next flower (they don't learn from their mistakes), deposit the pollen onto that flower, Credits: © Photographer: Mario Koehler | Agency: Dreamstime.com

survive. The yucca plant, a large and spectacular succulent of the western desert, produces more long-lasting flowers than most desert plants. The female of one species of moth deliberately collects pollen from one plant, flies to another, and packs the pollen onto the pistil (the female reproductive organ) of the flower of the other plant. She then lays her eggs in the flower. The caterpillars hatch and eat some but not all of the seeds, and the bargain is complete: some seeds have been fertilized and mature, and the moth has likewise assured the survival of the next generation. Some marine animals are toxic because they allow deadly stinging anemones to attach to their shells. Other organisms use mimicry and other forms of adaptations for many purposes. Walking sticks and leaf insects closely resemble the plants on which they live, as do many other animals (Fig.11.1). An anglerfish



*Figure 26.2.* This fearsome-looking insect is not a wasp but a harmless fly. Even its front legs are shaped and held so that they appear to be the antennae (feelers) of the wasp, since flies have very unobtrusive antennae. Credits: [http://www.cirrusimage.com/fly\\_syrphid\\_Temnostoma.htm](http://www.cirrusimage.com/fly_syrphid_Temnostoma.htm) Date06/15/2005 Author Bruce Marlin (wikipedia)

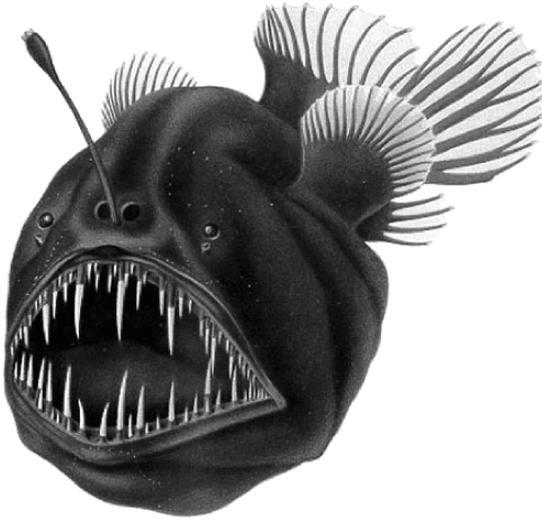
sports a feeler-like appendage that looks very much like a small, innocent but tasty fish, dangling directly over its large but otherwise inconspicuous mouth (Fig. 26.4). For many fruiting plants, the fruit is bitter and unpalatable or even poisonous (like nightshade or tomato) until it is ripe, whereupon it turns color and becomes sweet. Even then, the seed is either indigestible or unpalatable so that it is spit out or, better yet, passed intact through the digestive tract to be deposited in a little pile of fertilizer. Poison ivy, clinging to the trunks of trees, turns a spectacular red just as its berries ripen, attracting the attention of migrating birds, which eagerly consume the energy-rich berries, while spitting out or excreting the unpalatable seeds.

All of these examples describe a form of cooperation among two or more completely unrelated species, but they fall into different categories. In some instances, two species cooperate to provide an efficient assurance of survival or reproduction for both species. Many types of organisms hide by imitating plants, animals, or objects in their environment. In other instances, one species finds protection in its resemblance to an unrelated noxious species. Poisonous or dangerous species are frequently quite showy—they REALLY want their “don’t mess with me” message to get out—and often look alike, so that a potential predator need learn only once that a particular showy pattern spells danger. We can classify the forms of cooperation into different groups.

*Mutualism* describes the general situation in which two unrelated species reside together in a cooperative arrangement. Mutualism can cover situations from the most casual to the most intimate. For instance, suckerfish or remoras cling to the bodies of sharks, eating scraps that these rather messy eaters drop, and otherwise



*Figure 26.3.* Tiger swallowtail larvae normally spin a silk pad so that a leaf tends to curl around them. If a curious bird pokes its head into the leaf, the caterpillar puffs up its anterior end and usually everts a forked orange gland that looks like a snake's tongue and smells awful. The "eyes" are entirely decoration; the small true head can be seen at the anterior end. Birds have been seen to give a shriek of horror and quickly fly away, Credits: © Photographer: Jill Lang | Agency: Dreamstime.com, Swallowtail larva 2 - <http://www.ctbutterfly.org/tiger-swallowtail-larvae.jpg>



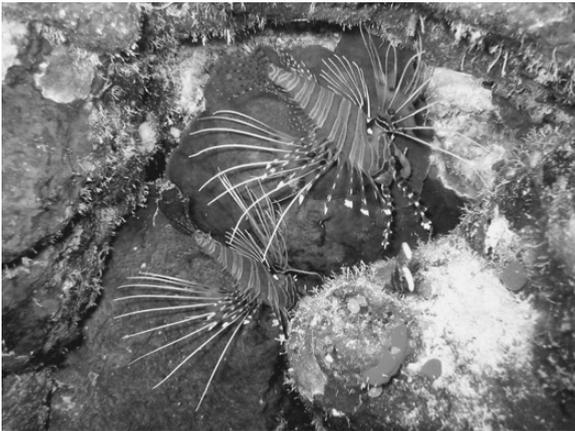
*Figure 26.4.* This anglerfish has projecting from its head a remarkably fish-like attachment on a wand. It slowly waves this attachment back and forth. When another fish, looking for a nice snack, comes too close, the anglerfish lunges and grabs it in its very big mouth. The fish is also very well camouflaged. Credits: Humpback anglerfish (*Melanocetus johnsonii*), a species of black seadevil (*Melanocetidae*). From Brauer, A, 1906. *Die Tiefsee-Fische. I. Systematischer Teil.* In C. Chun. *Wissenschaftl. Ergebnisse der deutschen Tiefsee-Expedition 'Valdivia' 1898–99.* Jena 15: 1–432

removing parasites from the gills of the sharks. In this instance, both are free-living but benefit from the cooperative arrangement. The same is true for the cowbirds that hang around and sit on cattle, eating the parasitic flies that continually attack the cattle. But mutualism can go further, involving two species that cannot survive without each other, like lichens or the wood-digesting protozoa that live in the stomachs of termites. It is easily demonstrated that many rodents get many of their vitamins from the bacteria that reside in their intestines and will die if the bacteria are destroyed by antibiotics. Humans too derive many nutrients from the bacteria in their intestines, and cattle (ruminants, or animals that “chew their cud”) can live on grass because bacteria break down all the cellulose and turn it to sugar. The cud is a mass of grass and bacteria, held in a sort of pre-stomach, that the cattle can bring back up and re-chew, physically breaking it up so that the bacteria can get to it. Some protozoa benefit from commensal respiring or photosynthesizing bacteria, and today we feel that mitochondria and chloroplasts are the evolutionary descendents of an originally commensal arrangement. However, mitochondria and chloroplasts can no longer live independently.

Modifications of body shape and color are usually forms of *mimicry*, but the mimicry can be direct, protective or camouflage, or aposematic. Direct mimicry is used by one species to fool another, as does the orchid in mimicking an insect. Protective or camouflage mimicry serves the obvious purpose of making potential

prey animals less visible to predators, and it can work extremely well. Not only does the skin bear the color and bumps of the environment, it is very important that the outline of the eyes, which have a similar form among all vertebrates, and the outline of the body be made less easy to discern. Thus markings and protuberances have the effect of confusing the overall discrimination of shape (Fig. 26.5). Even bright colors can work to this effect. The brilliant reflective blue colors of the morpho butterfly, for instance, are very confusing in its native environment. The light in a tropical rainforest is dim and dappled, interrupted by shafts of brilliant light. The undersides of the wings of the butterfly are brown and dappled, like the trunks and soil of the forest. When it flies, it briefly opens its wings, and one sees a bright flash of blue light, then it closes its wings and coasts, now becoming almost invisible. Suddenly a new flash of light appears elsewhere. It is almost impossible to track the flight of the butterfly. In a less spectacular fashion, the very common underwing moths perform the same trick. Their upper wings are quite cryptic, and their underwings are bright red or yellow and black. A predator pursues this brightly colored edible moth, but as soon as the moth lands it covers its hindwings, and the moth that the predator pursued has vanished. Finally, dangerous creatures take real advantage in flaunting their threat in having aposematic or warning coloration, well understood by most predators, and many animals profit by pretending that they, too, are dangerous. At a time when New York subways were considered to be dangerous, one defense considered to be reasonably effective was to maintain a posture and facial expression that communicated, "I just might be an undercover policeman, and armed." This is aposematic mimicry.

These types of interrelationships serve many purposes but they all address essentially the same issue. One means of assuring a niche is to develop a special



*Figure 26.5.* A pair of lionfish. Disguising one's outline is very important to success, in these cases to hunt but in other cases to hide. Normally the fish adjust their colors to blend in with the environment, but you would not be able to see the fish in a black-and-white figure. That, of course, is the point, Credits: Wikipedia.org

relationship with another organism, such that both species benefit and neither is destroyed by the other. This relationship can result in a considerable reduction in the cost of living, such as in the situation of the lichen. The alga would need to build elaborate cell walls or other means of retaining or trapping water in a harsh drying environment, but the fungus already has that capacity and can protect the alga, while the alga can trap sunlight to yield digestible products that the fungus can use. As astonishingly elaborate as these relationships are, they are assumed to have evolved by the continual selection of an initially incidental interaction or resemblance. One example would be the resemblance of the viceroy butterfly to the monarch (Fig. 26.6). Strictly speaking, this is not mutualism, since the monarch does not benefit from the relationship. Rather, it is commensal, meaning that only one partner benefits.

The closest relatives of the viceroy do not resemble monarchs, other than the overall structure of butterfly wings and the basic layout of butterfly wing patterns. The relatives are purplish-black butterflies. One can imagine a past situation in which among the ancestors of the viceroy there were individuals with variations on the color. Some had a mutation so that the purplish-black color was not so intense, and was a bit more red. Insects, as far as we can tell, see red as black but can distinguish colors a bit into the ultraviolet, so that the colors that we see may have been more or less obvious to predatory insects or birds. All that we need is for the variant to raise sufficient doubt in the mind of a bird or predatory insect that it hesitates and abandons the pursuit a few percent of the time. Selection will favor the variant and, in future generations, the selection will continue, always favoring the variant that is harder to distinguish from the toxic monarch. Today a skilled entomologist can easily distinguish the two. The viceroy is smaller, has an extra thin stripe on its hind wings, and glides with its wings flat rather than in a wide V as does the monarch. On the other hand, if you were going to quickly grab a fruit or a sandwich from a cafeteria line, and one of the fruits or sandwiches looked off-color, potentially spoiled capable of making you sick, what would you



*Figure 26.6.* The monarch (left) is poisonous but the viceroy (right), which in life is slightly smaller than the monarch, is a very good mimic. To a naturalist, the extra stripe on the hind wing gives it away.  
Credits: Viceroy - Date 2005-08-22 Author PiccoloNamek Permission English Wikipedia

do? Ultimately in many situations the advantage to both sides is such that selection of both partners moves to the same goal. For instance, although the yucca loses many seeds to the caterpillars of the yucca moth, the guaranteed pollination of some ensures more successful reproduction than randomly attracting pollinating insects in a desert situation in which water lost by flowers is very expensive for the plant.

This form of selection works so well that it is generally considered that the most virulent disease-causing organisms are those that have only recently begun to attack their hosts. Many organisms that cause severe disease in one host produce extremely mild or no symptoms in other hosts. In these cases it can often be demonstrated by DNA sequencing that the host with the mildest form of the disease is the original host. A bacterium or virus that promptly kills its host has not only lost its resource but may not have a means of finding a new host. A far better, if less dramatic, means of survival would be simply to go along for the ride, not weakening the host in any way and, if possible, supporting the survival of the host. Thus both parasite and host evolve toward a less noxious form of interaction. We will examine this consideration in Chapter 27.

## REFERENCES

- Darwin, Charles, 2004 (1859) *The origin of the species*, Introduction and notes by George Levine, Barnes and Noble Classics, New York.
- Gould, Stephen Jay, 2002, *The structure of evolutionary theory*. Harvard University Press, Cambridge MA.

## STUDY QUESTIONS

1. Research the following question: If you were to eliminate all the bacteria from your digestive tract, would your health improve or deteriorate? Explain.
2. Research the same question, but for cattle rather than humans.
3. Research the same question, but for termites rather than for humans.
4. What is your first reaction to seeing a very brightly-colored, as opposed to camouflaged, bug?
5. Do you recall ever having gotten sick shortly after having eaten something unusual, and having felt a revulsion to that food afterward? How long did that memory and behavior last? Do you think that the incident relates to the question of aposematic mimicry?