Letter from the Desk of David Challinor
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My wife and I took our three young daughters (1963) on a Sierra Club trek to the high Sierras. In preparation, we spent two days in Yosemite's Tuolumne Meadows to adapt to the altitude. I remember clearly the rust red patches of dead fir foliage in the forested foothills above and surrounding the meadows. These distinctive scattered patches were the result of attacks by bark beetles. At the time, park managers were subject to considerable pressure from different interest groups to: 1) begin a massive spray campaign to halt the spread of the invading beetles, 2) fell the blighted trees to remove these eyesores from the landscape, 3) not intervene at all. The Park Service, I recall, exercised the last option and I believe rightly so. Since then, I have often thought of the inexorable connection between humans and insects involving their endless competition over shared resources. This letter considers some of those conflicts, the degree to which they truly exist and, finally, that plants, insects and humans are still evolving to exploit all available niches.

From the short-term human perspective, bark beetles are bad guys. They kill trees we want to convert to lumber, and they damage the aesthetic symmetry of evergreen forests by causing red splotches on the forested green landscape. Despite their unpopularity with loggers and others, many forest entomologists consider them a keystone species. There are some 6,000 different species of bark beetles in the world and usually each is limited to one host species. Bark beetles drill holes through tree bark and lay eggs within. After hatching, the larvae feed on the tree's layer of phloem cells. These are the narrow band of cells just inside the bark that carry nutrients from the crown to the rest of the tree—generally downwards. Infected trees are riddled with dendritic (multibranching) passageways used by the feeding larvae. When the phloem layer has been severed around the trunk, the tree is girdled and dies. After four instars (shedding skin four times as they grow), the larvae pupate, subsequently become adults and emerge to start the cycle again.

Conifers, in particular, are not helpless; healthy, vigorous ones often flood the beetles' penetrating holes with resin to force out the invader. Beetles searching the bark for a penetration point are vulnerable to woodpeckers and other bark-gleaning, insect-eating birds. The beetles are also predated by other arthropods such as the red-bellied clerid beetle. In fact, over 70 insect species have been found to prey on the Western pine beetle alone. Bark beetles, to ensure their own survival, can never kill all their host trees because there has to be a reserve for future generations. Bark beetles have an important role in regeneration of many western pines, particularly lodgepole and ponderosa. When these species succumb to an attack, their dried-out remnants become fuel for lightning-triggered fires. Lodgepole regeneration is dependent on heat from fires to open its serotinous (tightly closed and sealed with hard resin) cones. The seedlings are light-demanding and old growth canopy fires result in the full sunlight the seedlings need for their germination and early growth, i.e. Yellowstone fires and regeneration.

After a beetle infestation has bared the forest canopy, the total biomass of stricken areas will, after five years, often be more than double that of unattacked equivalent areas, because the increased sunlight reaching the forest floor fosters the growth of leafy vegetation in the understory. This in turn provides fodder for deer and elk, as well as habitats for birds and small mammals.

Most pine bark beetles concentrate on dead or dying trees and are thus an integral part of the continuous recycling system that sustains conifer forests. Only a few species are capable of attacking healthy trees. The relationship between bark beetles and their hosts is a relatively balanced one that has evolved over millennia. What throws the system off balance is an alien invader against which the locals have no resistance. Thus, just as many Native American communities were decimated or even extinguished by measles or small pox to which they had no resistance, so too have American elms been ravaged by the accidentally introduced European elm bark beetle, which arrived here in the 1930's. Unlike many pine bark beetles, the elm bark beetle is host to a fungus. When the beetle penetrates to the cambium (a layer of cells between the phloem and the xylem that multiply to expand radial growth), the fungal mycelia (hair-like white strands) eventually encircle the stem and, by blocking the up and down flow of nutrients, kill the tree. Fortunately, American elms produce voluminous quantities of seeds and grow rapidly, so there is little likelihood of their extirpation.

For me one of the most fascinating of plant/insect interactions is that of carnivorous plants and their insect pollinators. Such plants live all over the world and have adapted to sites where there is adequate sunlight, but where important soil nutrients such as nitrogen, phosphorous and potassium are in short supply. The plants receive their nutrients by eating insects. Using various techniques, most often by having visible nectaries (glands that secrete nectar), they lure their meals to entrapment. These plants are the ultimate sit-and-wait predator for they can never move from their growing site. Some use flypaper-like foliage to capture insects. More sophisticated are the Venus fly traps, a not uncommon bog-growing denizen. In this plant the nectaries are located on the edges of the leaf traps. When a hungry insect touches one of the trigger hairs at the base of the trap, the two leaves rimmed with curved spikes snap shut in what may be the fastest controlled motion of any plant. Once entrapped, the plant digests its prey with secreted enzymes. Some carnivorous pitcher plants drown their prey in the water-filled cavity formed by their leaves, the inner surfaces of which are so smooth and slippery that trapped insects cannot climb out. Those pitcher plants that lack enzyme-secreting cells rely on bacteria, protozoa, etc. in their stored water to break down their prey to receive the necessary nutrients. Even though carnivorous plants are but a small fraction of the plant world, they have evolved within four major plant orders to exploit an otherwise nutrient-poor niche.

My final example strays from insect/plant interactions to a recent innovative development of an insect/bird/human combination. Recently, the Zoo held a seminar on common terns by Dr. Jennifer Arnold, who now works at the government's wildlife research facility in Pawtuxent, MD. For her research she needed to obtain blood samples from nesting terns to measure stress, without disturbing them. She had been a Humboldt Fellow in Berlin where, in the laboratory of Christian Voigt, she learned an imaginative procedure to obtain blood samples without disturbing the birds. She imported from Europe bloodsucking beetles (*Dipetalogaster maximus*) that normally parasitize birds by sucking their blood. After emptying a tern egg, Arnold inserted a single beetle through the small hole used for extracting the egg contents. She then fastened a small piece of gauze over the hole to keep the beetle inside, but through which the beetle could poke its long proboscis. After the modified egg is slipped, hole-side up, among the real eggs being incubated, the beetle does its work on the brooding tern by engorging its blood. Dr. Arnold then removed the modified egg; in her laboratory she released the beetle and with a tiny hypodermic needle carefully drew four milliliters of tern blood from its stomach. The beetle is evidently not the worse for wear and can carry out its duties several times. The beetles can also obtain blood samples from bats to test them for rabies. Bats are particularly hard to sample otherwise. Voigt has also used these beetles on constrained animals to gain larger blood samples by removing blood from the beetle's abdomen while it is sucking blood through its proboscis. Like most bloodsucking insects (and vampire bats), it releases an anticoagulant anesthetic when it bites so that the victim does not feel anything. Finally, unlike ticks, which bury their head in the victim's skin to gain blood, this beetle can easily be picked off when full.

Bark beetles, carnivorous plants and bloodsucking insects at first glance seem to have little in common, but they are all good examples of the almost unbelievable way evolution enables living organisms to exploit every niche on our globe. Still waiting to be discovered are endless new miracles of mind-boggling behavior. We humans are fortunate to be sentient beings who can share our discoveries with one another. As Robert Louis Stevenson wrote, "The world is so full of a number of things, I'm sure we should all be as happy as kings."

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P.S. Details for this letter came from the Xerces Society booklet "Wings" (Fall 2005) and from a short piece on the bloodsucking insect in *New Scientist*, Nov. 19-25, 2005, pg. 4.