INSECT RELATIONS WITH PLANTS*

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The insects comprise by far the great majority of animals on the face of the globe. In the evolution of life, they originated about the same time as the seed- and flower bearing plants, and since that time, the relations between the two have been of the utmost intimacy. Both insects and plants have been modified in numerous ways to sustain this relationship or to protect one or the other from the deleterious effects of such close and greedy company.

It is immediately apparent that, with the possible exception of the plant enemies of insects, either the aggressiveness of insects in their quest for food or their desire for shelter or refuge, or a combination of both, almost always is the underlying reason for relations between insects and plants.

Probably the desire for food is the most important of these two reasons since more complex and far-reaching results come from it.

No terrestrial plant, not even the dreaded poison ivy, is free from insect feeders, and some, such as our larger trees, are hosts to a thousand or more species. No part of the plant, from the deep roots to the high branches, from the tough outermost bark to the woody innermost pith, from the hardest seed, the waxiest leaf, or the spiniest branch to the daintiest flower, the softest fruit, or the most succulent shoot is free from insect attack.

Only plants in salt water are out of reach of insect depredations, for most, if not all, of the extremely few insects which venture a greater or lesser distance into salt water, are of predacious rather than phytophagous habits. Fresh water plants are often eaten or tunneled into by insects, punctured for the deposition of eggs, or otherwise utilized for protection, by a number of families of several orders of insects.

Of the terrestrial plants, those higher in the evolutionary scale probably harbor the greatest number of insects, but even the lowest forms have their characteristic species. Great numbers of insects are known to exist on the microscopic organisms which cause decay. Even the hard fungi are often riddled by small borers, usually beetles, which are limited to them as a habitat. While making botanical collections on tropical mountains I have split open fleshy mushrooms only to find more fly maggots there than plant meat. The ferns seem to be unusually free from insect attack, though by no means completely so.

Now that we have briefly indicated the extent to which insects will feed on plants, one of the next most important questions concerning this relationship, that of the specificity of relationship between the feeder and host, presents itself. This question is of interest both to the biologist who studies the evolution or bionomics of these forms and to the applied scientist who must fight the insects attacking crops.

Certain insects are known to feed on as many as 200 kinds of plants. When such an omnivorous phytophagous, or polyphagous, feeder is of importance in planted fields, as it might easily be, it may be very difficult to control because of the almost unlimited opportunities for sustinence. The corn earworm is one of the best examples, the tarnished plant bug is another.

However, it is probably more common to find that plant eating insects are more or less restricted to a certain group of plants, whether it be a single order, a single family, or a single genus, or any closely related group of any of these catagories. Insects which feed within such a restricted group are termed oligophagous feeders.

The monophagous feeders, the ones restricted to one kind of host, are frequently encountered among insects. Every school boy who tries to rear larvae knows how careful he has to be to provide just

* Exclusive of Pathogenic.

the right kind of leaves for certain of them.

Certain insects, such as the aphids and the potato leafhopper, alternate their specific hosts from season to season. The possibilities of different hosts for a single species are further increased and complicated by the different stages in the metamorphosis of insects. As a general rule, I believe, nymphs feed on the same host or hosts as the adults, but larvae may or may not feed on the same host as the adults. Larvae in most cases feed on at least a different part of the plant from the adults. For instance, the larvae of the famous Japanese beetle feeds on the roots of grass, vegetables, and nursery stock, while the adults feed on the foliage and fruits of about 250 different kinds of plants of a great taxonomic variety.

As generalized insect groups evolve into more specialized forms it is generally conceded that they also acquire more specialized feeding habits. Under pressure, a specialized feeder can adapt itself to new varieties of the preferred plant. Once an insect has been able to survive on a certain kind of plant over a period of several generations it may more or less completely refuse to consume its original food plant. Biological races of the same species, one of which will not feed on the host of the other, are known for a number of insects. These races can sometimes be distinguished by slight morphological modifications or by changes in habits or in the life cycle.

While it is true that insects can and do change their feeding habits, especially in times of stress, it appears to be the general rule in Nature that many prefer the food plant upon which they hatched. According to Hopkins Host Selection Principle, the female of a species which can breed in two or more hosts will prefer to lay her eggs on the same host on which she fed, and that this physiological attraction will tend, in the course of many generations, to develop a physiological race of insects more or less restricted to the preferred host.

Plants in Nature have evolved numerous ways of protecting themselves from insect attack, but during the selection and breeding of plants for cultivation, many of the resistant properties have been lost. Cultivated plants are not only grown in large stands favorable for the concentrated attack of insects, but they also are most attractive to insects and themselves suffer more severely from insect feeding. The plant breeder is often faced with the process of rebreeding, if such a word might be used, these resistant qualities into his crop. Imms[1] lists the factors which contribute to the resistance of a plant or lack of resistance of a plant as the thickness of the cuticle, the development of the sclerenchyma or other mechanical tissue, general hairiness or its absence, acidity or alkalinity of the cell-sap, silica content, presence or absence of certain glucosides, date of maturity, and power of recuperation. It has also been observed that the cell-sap of certain varieties or species of plants directly effects the fecundity of sap-sucking insects which feed on them.

By their feeding habits, insects sometimes perform great service to the plant and to the agriculturist. One of the most publicized of the direct benefits to the agriculturist is that of the many kinds of cactus feeding insects which have been sent from North America to Australia to combat the extensive growth of the prickly pear, itself imported from North America, which has inadvertently established itself and covered enormous areas of grazing land.

By their intimate association with certain plants a number of insects, especially bees, perform a value of incalculable immensity in the cross-pollination of flowers. Most flowering plants are strongly modified to utilize this insect service and so to produce seed which will result in vigorous and fertile offspring. The colors of the plants attract the insects to the nectar cups deep within them. As the insects press into the flower to obtain nectar or pollen, they pass by structures marvelously designed in one manner or another to leave pollen on the hungry visitor or to retain the pollen brought by him from a previous flower. By their habit of feeding mainly on plants of one species, the probability of cross-pollination by insects is greatly increased.

The modifications of flowers, besides those of color and odor, are indeed remarkable. In the flower of the common Japanese barberry the stamens are adapted so that there is a turgor move-

[1] Imms, Recent Advances in Entomology.

ment in response to the stimulus given by the touch of a visiting insect's foot. This movement appresses the anthers to the leg of the insect, so effecting pollinization. The common iris has a platform for visiting bees formed by three sepals. The anthers are just above the platform on which the bee rests to obtain nectar and are just at the proper height to leave some of their pollen on the branched hairs of the back of the insect. Then as the bee enters the next flower, some of the pollen is scraped off the back on the stigmatic surface of a flap under which it must pass to reach the platform. Pollination of the same flower from which the pollen is received is prevented because the surface of only the flap that is met while entering is receptive to pollen; that met while leaving is non-receptive.

Our common milkweeds are so designed that little pollen bearing structures are attached to the legs of visiting insects when they slip into beautifully designed grooves of the flower in their attempt to obtain nectar. These structures, called pollinia, twist on their stalks after being removed from their flower and are then in a position to remain in the stigmatic chamber of the next milkweed visited. One often finds insects which are not powerful enough to extricate their legs from these grooves hanging dead or dying from milkweed flowers. The yucca moth has specially adapted mouth parts and a strong ovipositor, such as is possessed by no other moth, with which it carries on activities upon which the yucca is entirely dependent for pollination. With these mouth parts, the female scrapes pollen from several yucca flowers and then by means of her ovipositor inserts her several eggs into the ovary of another flower after which she pushes the pollen into the stigmatic tube and departs. There is, at present, no conclusive explanation for these strange actions, for the female does not feed and the larvae which develop from the eggs eat only a few of the several seeds among which they are laid.

The shapes of the Orchidaceae, which are entirely dependent upon insect pollination, are the most fantastic of all floral developments. In some species special adaptations are formed for depositing pollen on the eyes of a visiting sphinx moth and for reclaiming this pollen when the moth visits the next individual. Some of our most valuable crops, as for instance, many of our fruits and clover, are entirely dependent upon insect visits and pollination for their continuation from season to season.

Flowers are more noticeably modified than insects for pollination because of their utter dependence upon them, while the insect's purpose is usually accomplished when it obtains the nectar or pollen that the plant has to offer. However, there are a number of structural modifications present on insects which visit flowers that are not found on other insects and which make the service of cross pollination more effective. Some flies and many bees have hairy bodies and legs which gather and hold pollen until scraped off on the next flower. The hairs of pollen-gathering bees and of some flies are branched or feathery so as to insure the adherence of pollen. For the mere gathering of pollen or nectar, honey bees and sphinx moths have extremely long tongues to reach the nectaries.

Sometimes after we have pitched our tents under trees in the semi-desert scrub of Mexico we have awakened the next morning to find the trees entirely stripped of their leaves and the ground below them littered with the cut edges of the leaves. The leaf-cutting ants of warm climates go to such great effort in order to bring these cut leaves to their nests to use them as a culture media for the propagation of fungus upon which they subsist.

Plant galls caused by insects are so common that one cannot walk into the field without seeing numerous examples of infinite variety. There is little explanation for these curious and varied shapes that the plant tissues assume when certain insects lay their eggs or feed in or on the plant. It is even more amazing to find that in many cases the insect apparently determines the shape of the gall, although the gall is entirely a plant growth. One species of insect may cause similar galls on different species of plants but the galls of different species of insects on one and the same plant may be entirely different. It is usually supposed that the gall does not develop until the larva hatches. However, some galls are completely formed between the time the egg is laid and the larva hatches. Others seem to need a continuation of stimulation from the larvae that live within them. Often galls containing healthy larvae can be distinguished from those containing sickly larvae. Galls are found on almost every part of the plant, the roots, leaves, flowers, stem, and seeds. They are caused by a great many kinds of insects and are found on many kinds of plants. The simple nodular galls of the Hessian fly and the wheat joint worm are of extreme economic importance because of the debilitation of the plant while certain foreign galls are used for fuel, food or dyes.

Seed dispersal by insects is restricted almost entirely to the ants. In the western grasslands we often see the rings of grasses that surround the subterranian nests of the agricultural ants that have brought their seeds there for storage. It is said that the seeds of a certain species of bloodroot have fleshy handles by which ants carry them. According to some authors, the seeds of another plant so closely resemble the pupae of certain ants in size, form, and odor that these ants carry them from place to place although they do not use them for food.

Of importance secondary only to feeding is the protection offered by plants to insects. The innumerable possibilities of concealment offered by plants are easy to imagine. The plant may simply offer refuge from enemies or weather. For instance, while collecting in the rain on one of the deserts of southern Mexico, we once encountered within three or four minutes almost fifty specimens of a rare family of Neuroptera huddled in the crevices of the bark of a poisonous tree, but when the rain subsided none were to be found, and indeed, we collected only one other specimen in the general vicinity during the whole month. Often feeding and protection go hand in hand. Scores of our most common insects feed on the underside of leaves where they are hidden from many of their natural enemies. Root eaters usually have little to fear from predators or parasites. It is obvious that borers into stems or wood have almost no enemies to fear, especially if they bore beyond the reach of woodpeckers and other strong beaked, hard working birds. Leaf miners, of which there are many more than the average person realizes, go about their business of eating inside of the leaf in which they are living entirely or relatively unharmed. The bagworm utilizes twigs and leaves from the plant on which it feeds to spin into its silken web, and so makes a cozy little house which it carries on its back to shield itself from at least some of its many potential enemies, although many tiny parasites may still attack it. Even the aquatic Trichopterous larvae make cases of plant material for protection, but often the larvae do not feed on the plant which protects them.

Many insects utilize the interior of plants for egg laying, thus protecting the eggs from many dangers. Sometimes the young which hatch from these eggs stay within the plant, as is the case of the larvae of the engraver beetle, but many others, such as the nymphs of cicadas, fall to the ground upon hatching, or others, such as the nymphs of treehoppers, emerge and live on the outer surface of the plant.

Leaf cutting bees cut leaves with which to line the nests in which they place honey and pollen for their larvae, and then plug these nests with more cut leaves. The solicitude with which some ants place aphids on plants so as to secure their sweet offal is well known. On the desert, we have seen neat little round "stables" for these aphids, made in the crotches of branches from pieces of gravel cemented together.

We have already noted that many plants have evolved structures or other modifications to protect themselves from insect attack. Numerous insects have been so modified as to obtain protection from their enemies because of their similarity in color or structure to the plants among which they live. The common katydid is often overlooked because its green color blends so well with the bark or leaves among which it rests. *Catocala* moths, though brilliantly colored on the under wings and under surfaces, blend perfectly with the bark as they rest there with only their upper surface visible. The undersurface of the remarkable *Kallima* butterfly of India, exposed as it rests among dead leaves, exactly resembles these leaves so that it is remarkably difficult to distinguish.

Insectivourous plants, while rare and of little importance in the economy of Nature, nevertheless are of great interest biologically. In the well-known pitcher-plants of our marshes, the leaves and petioles are modified into brilliantly colored, sweet-scented pitchers provided with nectar glands which lure sweetsloving insects into their sticky depths. Then, when the victim dies from exhaustion after its unsuccessful attempt to extricate itself, this marvelously developed plant slowly digests its unchitinized tissues. Strangely enough, the pitcher-plant is the home of a genus of Noctuid moths which oviposit in the pitcher and whose larvae feed on its tissues and even spin a web across the opening, thereby protecting themselves from spiders and other enemies.

The leaves of the sundew are provided with hairs, each with a fluid secreting gland. An insect that flies to one of these leaves is trapped when the hairs enclose over it and is digested by the secretions from the glands. When the digestion has been completed the leaves open in anticipation of the next victim. Each of the leaves of the Venus fly-trap of the coastal regions of North and South Carolina slant upward from the middle and clamp over an insect which alights on it. Sharp bristles along each margin prevent escape of the larger victims, but small insects, which contain little nourishment anyway, can escape between the spines. The trapped insect is digested by fluids on the glands on the leaf's surface.

Of great interest, especially to medical entomologists dealing with the problem of mosquito abatement for the control of malaria or yellow fever, are such aquatic plants as the common *Lemma* which often covers the surface of water so closely that mosquito larvae cannot find place to extend their breathing apparatus through the surface film to obtain air.

Some insects actually guard plants. I was made painfully aware of this relation a few years ago while walking through the tropical scrub country of southeastern Mexico. While in quest of a particularly fancy flying beetle, I brushed against the sharp spines of the bull-horn acacia, one of the most common leguminous plants of the area. I was immediately sharply bitten by a number of large ants which rushed out from holes at the ends of the spikes shaped like the horns of bulls, for which the plant is named. These hollow horns shelter the ants, which, in turn, supposedly drive off the leaf-cutting ants which are so common in the region. They also drive off innocent entomologists, which are much rarer. In addition to the shelter which the acacia offers the ants, it also offers two kinds of food which are the ants' chief subsistence, a sweet fluid which they obtain from the bases of the petioles, and also little round knobs rich in albumin which they pick from the ends of the leaflets. In the tropics there are several other such plant houses with insect guards.