

Trophic Levels

Insect ecology is the branch of entomology that focuses on the **interrelationships** between insects and their environment. To an ecologist, the concept of "environment" encompasses both the **abiotic world** (non-living things like climate and geology) as well as the **biotic world** (all living organisms including plants, animals, microorganisms, etc.). All of these components interact within a framework called the **biocenose** (a natural community).

Communities are groups of organisms (populations) that maintain persistent associations with each other. The members of a typical community include plants, animals, and other organisms that are biologically interdependent through predation, parasitism, and symbiosis. The structure of a biotic community is largely characterized by the trophic (feeding) relationships among its member species. These relationships are often represented simplistically as a **food chain**. Each link in the food chain represents a **trophic level** encompassing either producers or consumers.



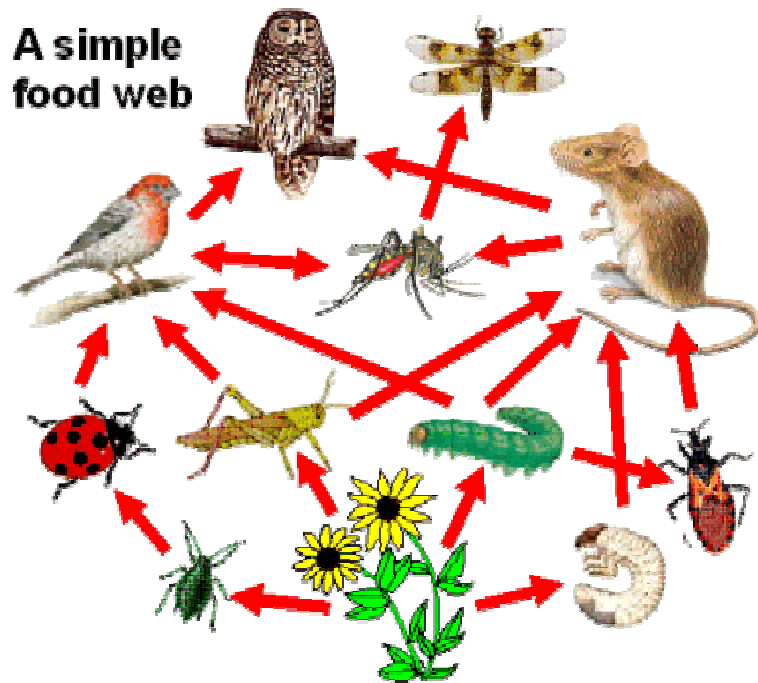
In most communities, green plants are the dominant **producers**. They represent the [first link](#) in a typical food chain. Plants capture kinetic energy from sunlight and, through the process of photosynthesis, manufacture organic molecules (*e.g.* simple sugars) from carbon dioxide and water. The captured energy is "stored" in the chemical bonds of these molecules. Some of the stored energy is used by plants for their own survival and growth, some is lost as heat, and some passes on to **consumers** when the plant is eaten, or to **decomposers** when the plant dies.

Primary consumers occupy the [second link](#) of a food chain. These animals, often called **herbivores**, survive by feeding exclusively on plants or plant products. The [third link](#) includes **primary carnivores**, secondary consumers that live as predators or parasites of herbivores. Any [remaining links](#) in the food chain are occupied by secondary or tertiary carnivores (predators or parasites of other carnivores). Since energy becomes limiting at the uppermost trophic levels, there are seldom more than four or five links in a terrestrial food chain.

**All insects
are
consumers**
They may be
found in all
levels of a
food chain
except the
first

Food Webs

Very few animals have a diet that is restricted to only a single food source, so the concept of a linear food chain is rather simplistic. In reality, trophic relationships within a community are more like a **food web** in which dozens of plant species support a wide variety of herbivores which in turn are consumed by numerous predators and parasites. If one species within a food chain becomes scarce (perhaps due to bad weather or over-exploitation), there will be serious repercussions on all other species in



the chain. But in a complex food web, changes in individual populations have a smaller impact because they are buffered by the availability of an alternative prey or host species.

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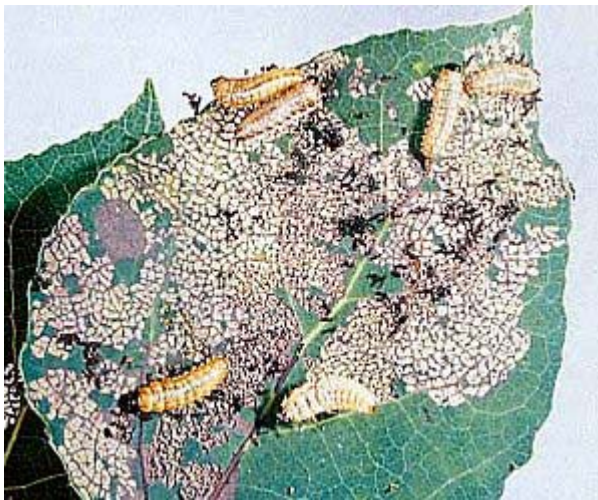
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2005

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Insect Herbivores



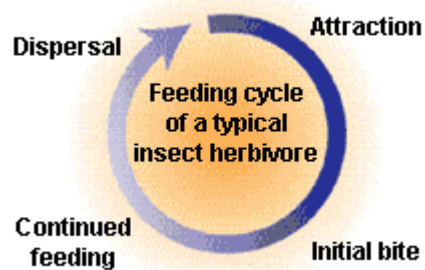
Animals that feed on plant tissues or plant products are often called herbivores. This term applies not only to insects that injure a plant by chewing leaves or sucking sap but also to more benign species who only collect pollen, nectar, or plant resins. Entomologists frequently use the noun "**phytophagy**" and the adjective "**phytophagous**" when referring to any of these nutritional strategies. Both words are derived from Greek roots: "*phyton*" meaning plant and "*phagein*" the verb to eat or devour.

Phytophagous insects generally use visual or olfactory (odor) cues to locate a host plant. Visual cues may be as simple as the vertical silhouette of a tree or the contrast of white flowers against a dark background of foliage. Some insects are strongly attracted to certain shapes or colors which they evidently associate with "food". Red spheres, for example, attract adult apple maggots, white pans of water attract aphids, and bright yellow sticky traps attract leafhoppers. Odor cues are plant volatiles such as the saponins in alfalfa, the mustard oils in crucifers, or the terpenes in conifers. Sometimes these attractants are **primary plant compounds** such as sugars (*e.g.* glucose), nucleotides (*e.g.* adenine), or amino acids (*e.g.* alanine) that a plant needs for its own survival and growth. But in other cases, the attractants are **secondary plant compounds** that have no nutritional value to

either the plant or the insect. These substances may be manufactured by the plant as a chemical defense against herbivores but they unwittingly serve as **token feeding stimulants** to a select group of specially adapted species.

Milkweed plants, for example, produce cardenolides that deter feeding by most phytophagous insects. These chemicals, however, attract monarch butterflies, oleander aphids, milkweed beetles, and a few other species that have the ability to digest or detoxify the compounds.

Insect herbivores often have a cyclical pattern of feeding behavior. After an initial phase of attraction to the host plant, appropriate tactile (touch) and olfactory (odor) cues trigger the impulse to take a first bite. Additional gustatory (taste) stimuli must be present in order for continued feeding to occur. After a bout of feeding is complete, the insect may leave the host plant to engage in other activities.



Since many plants conduct chemical warfare against insect herbivores by manufacturing repellents or deterrents, it is common for insects to be rather narrow and specialized in their choice of host plant. A **monophagous** insect restricts itself to a single host species -- it is a consummate specialist, adapting its behavior and physiology to a single nutritional resource. Some of these insects must rely on intestinal symbionts to supply essential dietary components that are not supplied by their host (see [Insect Nutrition](#)). **Oligophagous** insects have a slightly broader host range -- often adopting any plant within a close circle of related genera or the members of a single taxonomic family. These insects are less likely to starve if a preferred host plant is unavailable. A few insects are **polyphagous**. These species are equipped with "broad-spectrum" detoxification enzymes that can overcome a wide range of plant defenses. It can be

metabolically "expensive" to produce these enzymes, but on the other hand, there is no shortage of available food!

Some of the more polyphagous insects (like grasshoppers and armyworms) will consume every part of their host plant. But most insect herbivores are more selective: they specialize as leaf chewers, sap suckers, stem borers, root pruners, gall makers, leaf miners, collectors of pollen or nectar, etc. Each of these feeding strategies represents a separate ecological **niche**

and all of the species that feed on the same plant in the same way are known as members of a **feeding guild**.

True or False???

1. Stem borers and leaf miners are in the same feeding guild.
2. Katydid and plant bugs are in the same feeding guild.
3. Grasshoppers and aphids are in the same feeding guild.
4. Leafhoppers and aphids are in the same feeding guild.

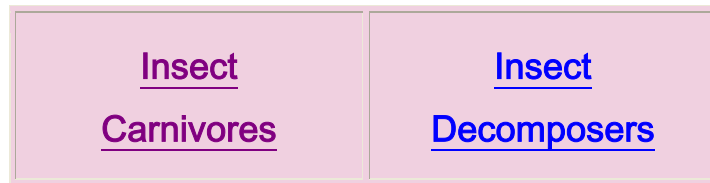
guild. Within a feeding guild, all species compete directly with each other for exactly the same resource. Between members of different guilds, competition is usually less direct and less severe. As a result, there is strong selective pressure limiting the number of species within each guild. Direct competitors usually are not closely related to each other (phylogenetically) and their association tends to be relatively recent in origin and short-lived in duration compared to more symbiotic (mutualistic) interactions. Natural selection tends to favor adaptations that minimize competition between species within a feeding guild.



Herbivory has had both positive and negative impacts on plants over evolutionary time. Flowering plants (the Angiosperms) have certainly benefited by attracting insect herbivores and exploiting them as pollinators.

These plants often provide nectar (or other nutritional "rewards") to their insect accomplices. Bright colors, distinctive odors, geometrical patterns, and in some cases even subterfuge are tactics used by plants to attract specific pollinators and maintain their interest from blossom to blossom (pollinator fidelity). On the other hand, insects are also vectors of plant diseases. Aphids and leafhoppers (Hemiptera: Homoptera) are notorious for spreading plant viruses and mycoplasmas as they feed. Bark beetles (Coleoptera) invade

the woody tissues of living trees, inoculating them with fungal pathogens that weaken and eventually kill the tree. Bacteria, protozoa, and nematode pathogens are also carried from plant to plant by insect herbivores. Pathogens may be carried externally on an insect's feet, mouthparts, or ovipositors, or internally in the salivary glands, digestive tract, or reproductive system. Some plant diseases like fire blight (a bacterium) and mummy berry (a fungus) are collected and spread by insect pollinators that are attracted to sticky-sweet exudates produced by the infected plants.



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Insect Carnivores



Carnivores eat meat! Some insect carnivores catch and kill other insects (or non-insect arthropods) as food, some parasitize the bodies of other animals, and some feed by sucking blood. **Zoophagy** is a term for all these feeding strategies. It is derived from the Greek words "*zoion*" meaning animal and "*phagein*" the verb to eat or devour.

Predators are zoophagous insects that kill and eat numerous prey individuals in the course of their growth and

development. They are generally larger than their prey and must often immobilize or overpower it before feeding. Some predators are generalists or opportunists: they attack a wide variety of prey species. Others are more narrow in their selection of prey. Agile, fast-moving predators (like hornets and tiger beetles) can easily overtake and subdue their prey. But other predators (like ambush bugs) blend in with their environment. They wait quietly for prey to approach and then grab it. Doodlebugs, the larval stage of ant lions, dig a shallow pit in loose sand, bury themselves at the bottom, and wait for prey to slide down into their trap. A few predators release an attractive chemical bait that lures prey within range. Predators are often regarded as useful insects when they serve as natural enemies of pest species. An Asian lady beetle, for example, may eat as many as 5000 aphids during its life cycle.

Parasites are usually much smaller than their prey (or host) and may complete their development on the body of a single host individual. Endoparasites live inside the host's body, whereas ectoparasites live in the host's nest or on the surface of its body.

A "true" parasite does not kill its host, but it may spread disease pathogens or cause other disability such as skin irritation, intestinal blockage, organ failure, or allergic reactions. Blood feeding (hematophagy) is a common practice among insects that parasitize vertebrate animals. Fleas (order Siphonaptera), sucking lice (order Phthiraptera), bed bugs and conenosed bugs (order Hemiptera), and numerous members of the order Diptera (including mosquitoes, deer flies, black flies, sand flies, and others) seek vertebrate blood meals throughout all or part of their life cycles.



Many zoophagous insects live in or on the body of a single host individual during their larval stage but become free-living as adults. These insects do not fit the classical definition of a "parasite" because they feed on the internal organs and tissues of the host individual and eventually kill it. Entomologists call these insects **parasitoids** to distinguish them from "true" parasites such as fleas and mosquitoes. Most parasitoid species are members of the orders Diptera and Hymenoptera. Adult females use chemical cues to locate their hosts for oviposition. After hatching, young parasitoid larvae feed on non-vital tissues within the host's body (*e.g.* fat body). As the larvae grow, their nutritional demands increase until they eventually consume their hosts from the inside.

The term "parasite" also encompasses several groups of zoophagous insects that have been given special names because they have distinctive ecological characteristics :

Hyperparasites are parasites (or parasitoids) of another parasitoid species.

Autoparasites are species in which the females feed on males to obtain a nutritional advantage.

Brood parasites are insects that live in the nests of social insects and feed on the juveniles.

Social parasites are insects that steal food or other resources from the nests of social insects.

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Insect Decomposers

The dead bodies of plants and animals are a rich source of organic matter that provides nutrition for many insects called **saprophages** (from the Greek words "*sapros*" meaning rotten and "*phagein*" the verb to eat or devour. Insects adapted to this lifestyle are an essential part of the biosphere because they help recycle dead organic matter.



Within the ranks of saprophagous insects, entomologists recognize several major groups:

- those that feed on dead or dying plant tissues
- those that feed on dead animals (carrion), and
- those that feed on the excrement (feces) of other animals.

The dead plant feeders include a wide variety of soil- and wood-dwelling species that shred leaves or tunnel in woody tissues. They accelerate decay by increasing the surface area exposed to weathering and the action of other decomposers. They are largely responsible for creating a

layer of **humus** that often covers the soil. This layer serves as an incubator for the fungi, bacteria, and other microorganisms that release carbon, nitrogen, and mineral elements for uptake by living plants.

Carrion feeders include numerous beetles, fly larvae (maggots), wasps, ants, mites, and others. Each species colonizes the dead body for only a limited period of time but, as a group, they rapidly consume and/or bury the decaying flesh. Blow flies, usually the first to arrive on a carcass, are also the first to complete development and depart. Other species follow over time in a relatively predictable sequence as the body decomposes. This change in the species composition of saprophages is called **faunal succession**. It provides a reliable way to determine the time elapsed since death and has become a useful tool for police, medical examiners, and other practitioners of [forensic entomology](#).



Tumblebug rolling dung

Many species of manure flies and dung beetles are attracted to the odor of animal excrement. Adults lay their eggs on fresh feces and larvae feed on the organic matter in these waste products. Many dung-

feeders exhibit distinct preferences for particular types of manure: the species associated with horse manure, for example, may be quite different from those found on the same farm in cattle manure. One group of dung beetles, called **tumblebugs**, form the excrement into a small ball and roll it into a hole that was previously dug in the soil. They lay an egg on the ball of dung and cover it with soil to serve as a nursery for their larvae.

In addition to their role as decomposers, some saprophagic insects also serve as pollinators for plants like skunk cabbage

More about
[Stinking Flowers](#)

and wild ginger. These plants produce drab colored, foul smelling flowers that attract the attention of blow flies or carrion beetles. The insects crawl around in the flowers looking for food and unwittingly pick up pollen. Finding nothing to eat, the insects leave and continue to forage for food, perhaps visiting another blossom and transferring pollen.

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