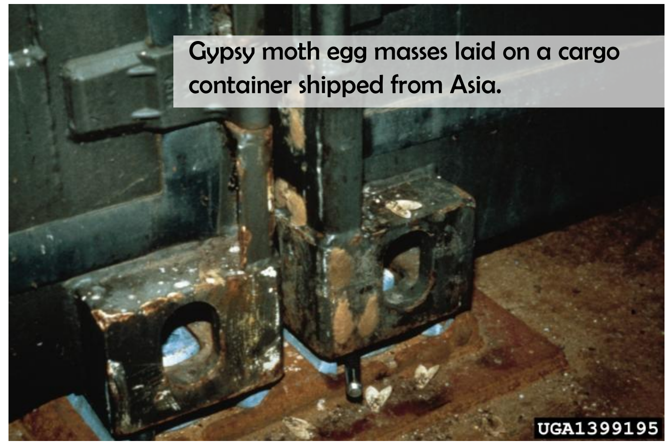
Forest Insects

Forest Entomology

Insects kill more trees in the U.S. each year than any other forest stress agent. In addition, they can cause significant growth loss, degrade lumber, make trees vulnerable to attack by secondary insects and diseases, spread tree pathogens, and can be a serious nuisance. However, most insects that feed on trees do not cause serious harm. For instance, many of our native moths and butterflies feed on tree foliage in their larval stage. Trees have evolved along with these insects and under normal circumstances are tolerant of such activity. Many insects play important roles in the forest ecosystem including pollination, nutrient cycling, eliminating sick or weakened trees from the forest, and are even an important food source for many animals, especially birds. Many insects found in our forests are predatory and feed on some of our more serious forest insect pests and keep their populations in check.

Under normal circumstances, insect populations are highly suppressed by predators and disease. In addition, trees have evolved effective defense mechanisms against insect pests, and therefore serious or widespread damage or mortality caused by insects is rare. However, when trees become stressed or when predators fail to keep insect populations under control, the tremendous reproductive potential of insects can lead to large outbreaks and serious infestations resulting in tree damage or death. When outbreaks occur, they are often difficult or impossible to control. Therefore proper forest management, early detection of infestations, and practices that promote predatory populations are key components of minimizing the impact of serious forest insect pests.

During the last few decades, there have been dozens of introductions of exotic insects from other countries. Because our tree species have not adapted defense mechanisms against these insects, and predators adapted to feed on these exotic species are often lacking, exotic insect populations have the potential to increase rapidly and cause serious damage to the forest ecosystem. The first serious exotic forest insect to arrive in the U.S. was the gypsy moth (*Lymantria dispar*). Since its introduction in Massachusetts in the late 1860's, the gypsy moth has defoliated and killed millions of acres of



hardwood trees. Since that time, other insects such as the European elm bark beetle, hemlock woolly adelgid, beech scale, balsam woolly adelgid, Asian longhorned beetle, emerald ash borer, and the redbay ambrosia beetle, along with many others, have done serious and irreparable damage to our nation's forests. Exotic insects are now some of the biggest and most serious threats to our forest ecosystems.

Entomology is the study of insects, and ***forest entomology*** is the study of forest insects, particularly those insects which feed on or do damage to trees or lumber. Forest entomologists study insect biology, life cycles, classification, interactions with their host plants and other organisms, and control/management strategies.

The first insects appeared around 340 million years ago. Since that time, they have spread across our planet to occupy virtually every habitat imaginable. Their adaptations and modifications are nearly endless and often bizarre. The smallest insects are some species of parasitic wasps that are less than 1/16 inch long; the largest include moths with 12 inch wingspans, giant walkingsticks almost a foot and a half long, and goliath beetles that are 3 inches wide! Scientists predict that there are at least 10 million different species of insects worldwide, of which only about 1 million are currently known to science. Insects are so plentiful, in fact, that they represent approximately 85% of all known animal

The eastern Hercules beetle is the largest beetle found in North Carolina

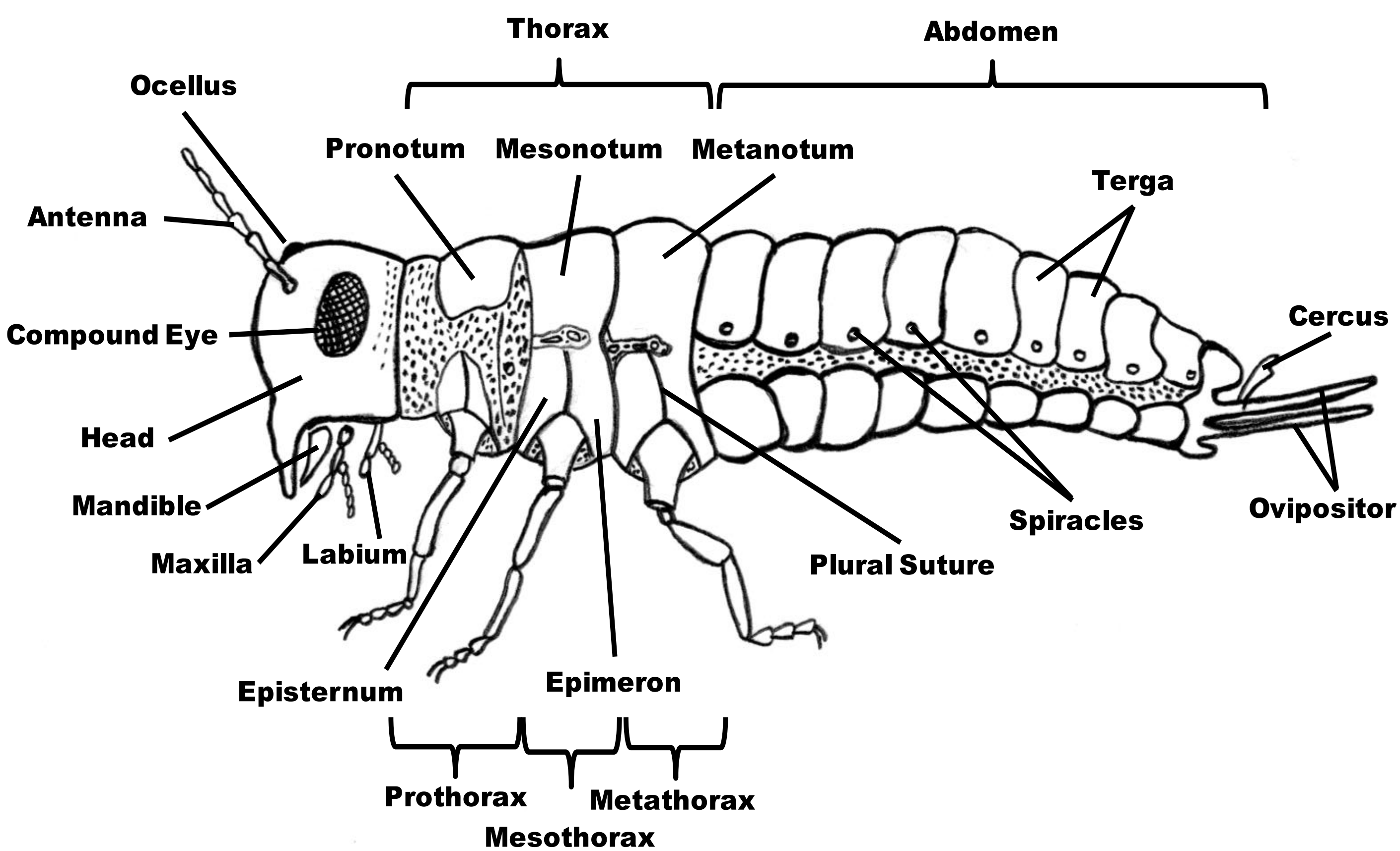
species on the planet. In the U.S. there are about 92,000 described insect species and an estimated 73,000 yet to be described. World-wide, there are more beetles than any other insect.

Insects are in the phylum Arthropoda which includes all animals with ***exoskeletons*** and segmented bodies. Entomology typically encompasses the study of two classes of arthropods: Class Insecta which are of course the insects; and Class Arachnida which includes the spiders, mites, scorpions, and ticks. There are approximately 30 insect orders, however not all orders include forest pests. The most common insect orders encountered in forest entomology include:

Coleoptera……. ………….	Beetles
Diptera………...................	Flies
Hymenoptera……………..	Ants, Bees, Wasps
Lepidoptera……………….	Moths and Butterflies
Orthoptera…………………	Grasshoppers, Katydids, Crickets
Phasmida……………..…..	Walkingsticks
Isoptera……………………	Termites
Hemiptera…………………	Cicadas, Leafhoppers, Aphids, Scales

All adult insects (with only a few exceptions) have the following characteristics: 1) a hardened external skeleton; 2) three distinct body regions (head, thorax, and abdomen); 3) one pair of segmented antennae; 4) one pair of compound eyes; 5) three pairs of segmented legs; and 6) one or two pairs of wings. Immature insects may resemble miniature adults or may have a completely different body shape and appearance. Arachnids differ from insects in that they have only two body segments and eight legs.

The ***head*** is the hardened region of the insect body that bears sensory organs such as eyes and antennae, and the mouthparts used for feeding. The large eyes that occur in most adult insects are called ***compound eyes***

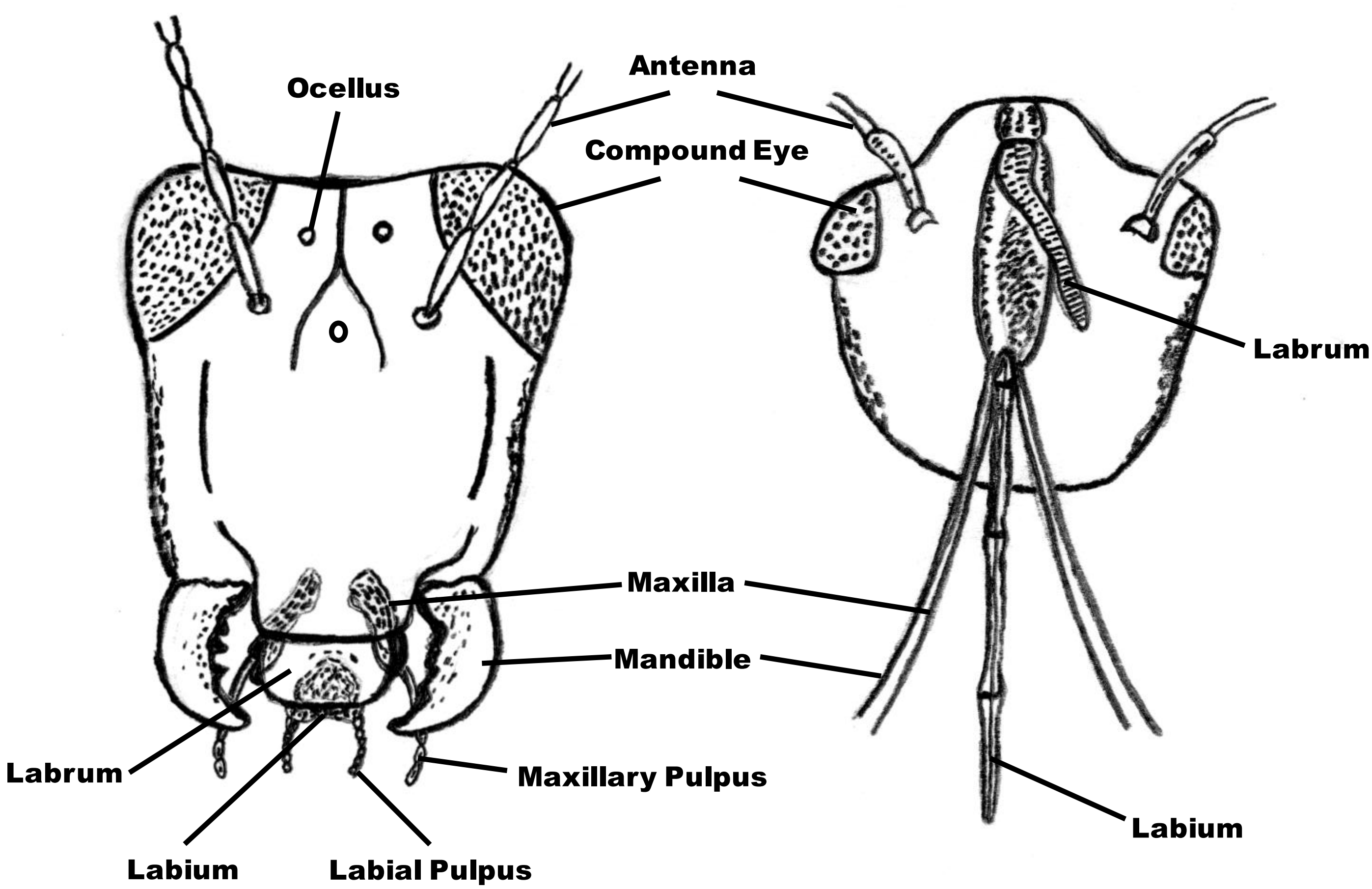


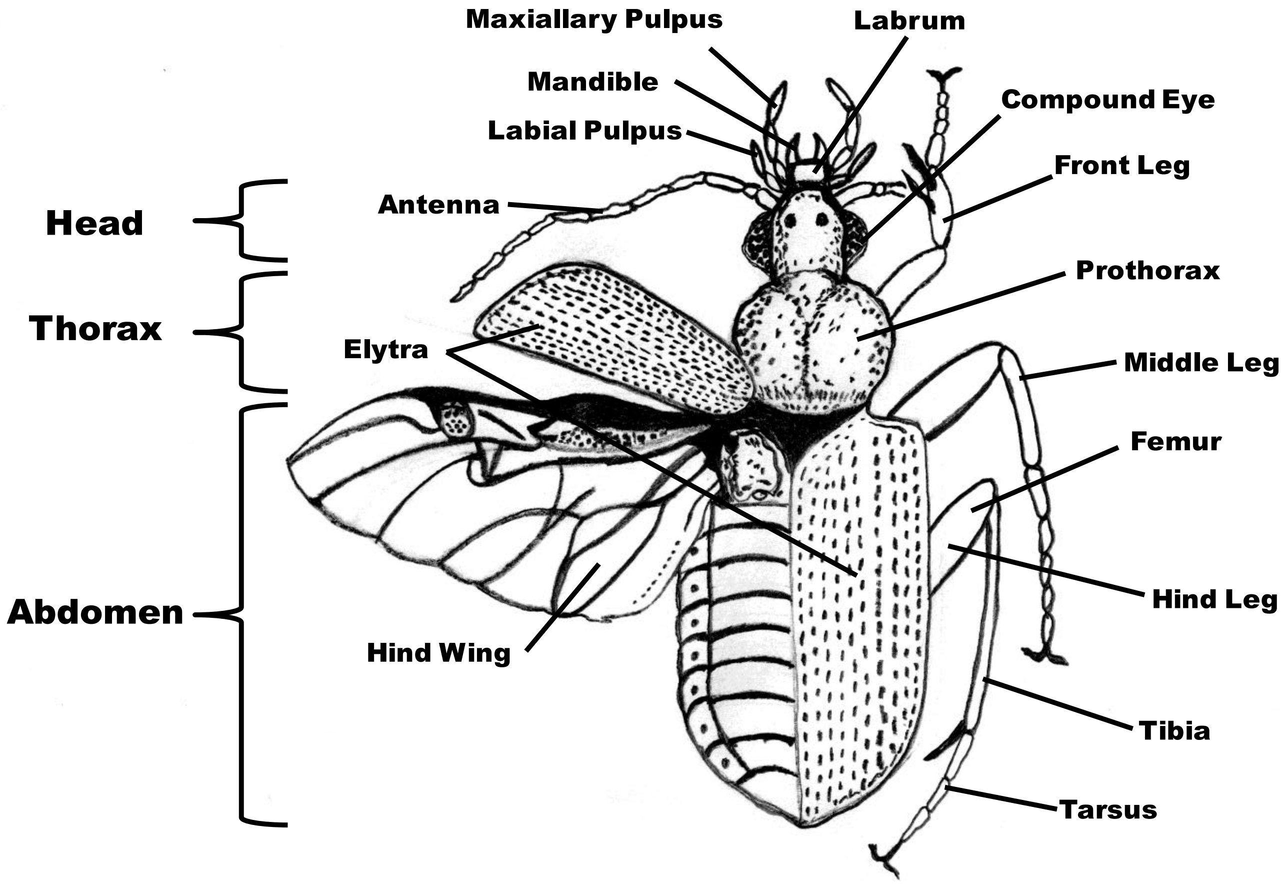
because they are made up of many individual light sensing units (up to several thousand per eye). Most adult insects also have three ***ocelli*** (simple eyes) located on the top of the head. ***Antennae*** are long, segmented sensory appendages that can be used to detect odors and sounds and to touch and taste objects. The function and appearance of the antennae varies with the insect species and can be useful for identification purposes.

The mouthparts are among the most varied of insect body parts and are specially adapted to accommodate their diverse diets. Therefore, mouthparts are often critical to classifying insect species. Mouthparts consist of an upper lip called a ***labrum***, a pair of jaw-like ***mandibles***, sometimes a tongue-like organ called a ***hypopharynx***, and a lower lip or ***labium***. In addition, the mouthparts contain a pair of elongated organs called maxillae that serve as sensory organs or are modified for piercing/sucking purposes. In general, insect mouthparts can be classified by their function: either ***chewing***, ***piercing-sucking***, or some other variation of these two categories including rasping-sucking, sponging, siphoning, etc. In chewing insects, the mandibles may be stout, curved, and toothed with special adaptations for cutting, crushing, or grinding. The labium and labrum are used to guide food into the mouth, and the maxillae have antenna-like appendages that touch and taste the food. In piercing-sucking insects, the mandibles and/or maxillae are modified into long, needle-like appendages; the labium/labrum may be somewhat flattened and elongated to surround, guide, and protect the mandibles/maxillae. In piercing-sucking insects, the elongated mouthparts are also known as the ***beak*** or ***proboscis***.

The ***thorax*** is the second body segment (located between the head and abdomen) and is made up of three individual segments known as the ***prothorax***, ***mesothorax***, and ***metathorax***. The segments of the thorax often contain grooves and ridges, and in addition to the arrangement of hardened scale-like plates that cover the thorax, can be useful for identification purposes. Each of the three segments of the thorax has a pair of segmented legs that may be specially adapted for

Chewing Mouthparts ***Piercing – Sucking Mouthparts***

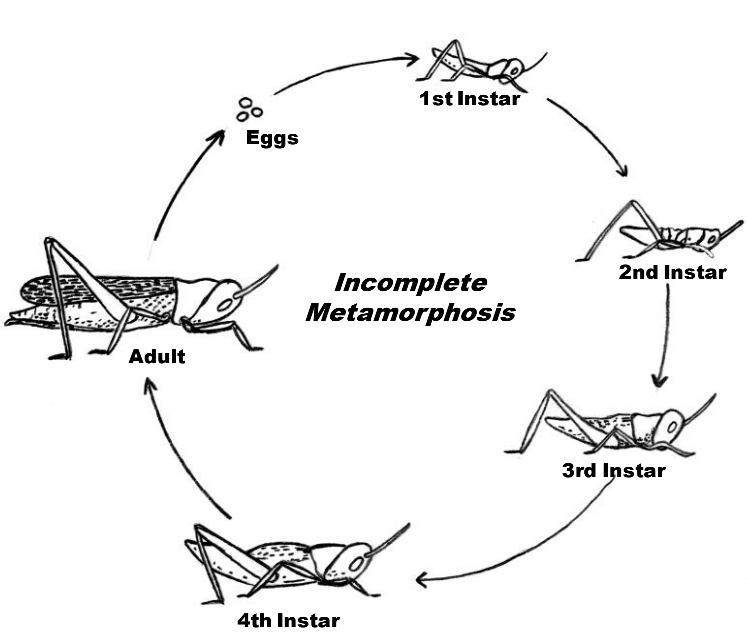


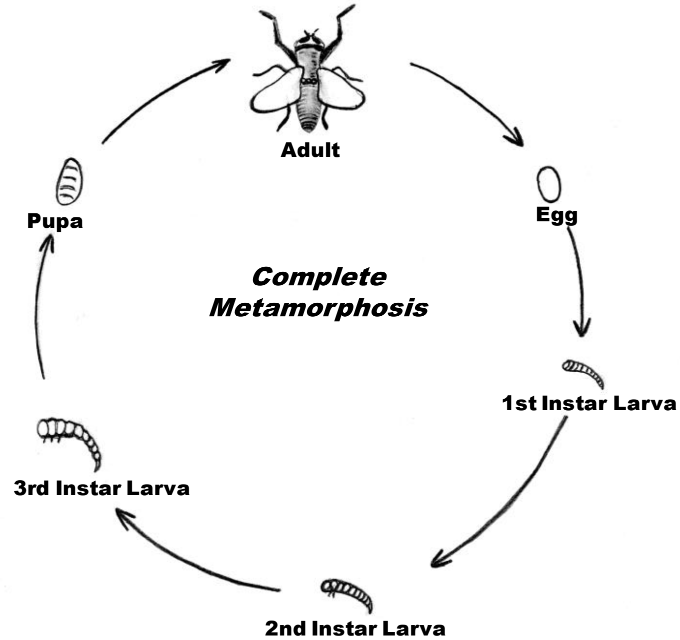


running, jumping, grasping, swimming, etc., depending on the insect. Each leg is made up of six segments, the last of which is a pair of claws. Insect larvae such as caterpillars may have additional pairs of fleshy legs on the abdomen known as ***prolegs***, but these legs do not have six segments and disappear in the adult stage of the insect. Most adult insects also have one or two pairs of wings that reside on the thorax, although some insects lack wings altogether. The wings vary in shape, color, size, thickness, texture, and even function. Beetles for instance, have two pairs of wings: one pair is elongated, thin, transparent, and often used for flight; the other pair known as ***elytra*** are thicker and hardened, and serve as protective covers for the underwings.

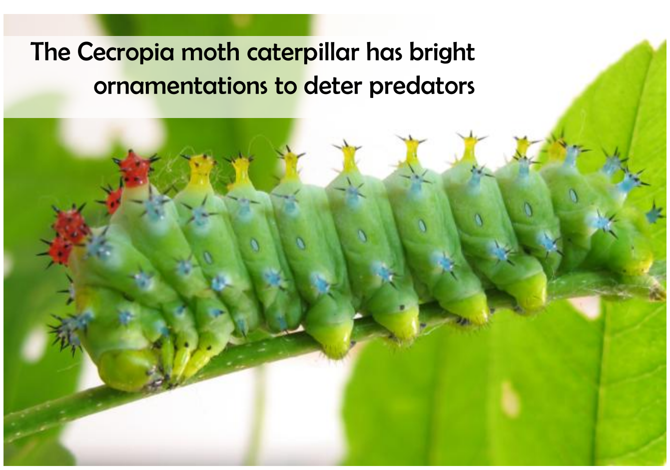
The last body segment, which tends to be softer and more flexible than the head and thorax, is the ***abdomen***. The abdomen contains most of the insect's internal organs, and usually consists of eleven distinct segments. Most adult insects lack any appendages on the abdomen, but exceptions include some male genitalia and the female ***ovipositor*** which can be specially adapted for egg laying, digging, sawing, piercing, or stinging. The abdomen of larvae may contain prolegs or ornamentations (that may be hairy, spiked, colorful, or even toxic) to deter predators.

Insects undergo dramatic changes in appearance and behavior during the course of their lives. Immature forms may differ so significantly from adults that they may not even be recognized as the same species. During their development, insects undergo a drastic change in form known as ***metamorphosis***. There are two basic types of metamorphosis: incomplete and complete. ***Incomplete metamorphosis*** is characterized by immature insects that resemble adults and change mostly in size and the development of wings and genitalia. Immature life-stages typically have compound eyes and mouthparts; they generally have the same feeding habits as adults. Insects that undergo ***complete metamorphosis*** have immature life stages that do not resemble the adults, are generally worm like, have simple eyes, no visible wings, short antennae, and mouthparts that often differ greatly from the adult stage.

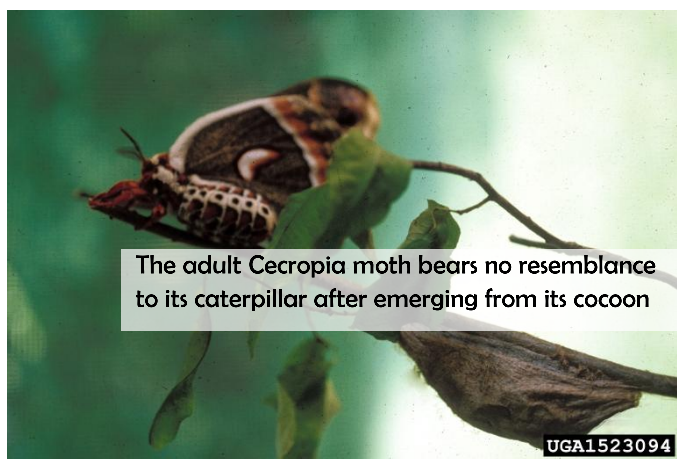




All insects begin their life as an egg. Immature insects which hatch from eggs are known as ***nymphs*** (incomplete metamorphosis) or ***larvae*** (complete metamorphosis). All immature insects grow in size by a process known as ***molting***, which is periodic shedding of the skin and expansion of tissues before the new underlying skin hardens. The number of times an immature insect molts before becoming an adult ranges from four to eight and varies with species and even gender. Between molts, the immatures are known as ***instars***. Insect development is often monitored by knowing what stage or instar the insect is currently in. Management recommendations such as pesticide applications are often timed to target certain instar stages (e.g. an insecticide must be sprayed before the 3rd instar).


The Cecropia moth caterpillar has bright ornamentations to deter predators

Following the final instar stage, insects that undergo incomplete metamorphosis become adults. For insects that undergo complete metamorphosis, the final instar stage is followed by an additional life stage known as the ***pupa***. The pupa does not feed nor move, and is usually covered in a protective coating that may be silken, hairy, or hardened. During ***pupation***, the structure of the insect completely changes from the larval form to the adult. In the pupal stage, the insect's tissues are broken down, reorganized, grow, and differentiate into their adult form. New mouthparts, digestive systems, reproductive organs, wings, compound eyes, and other dramatic additions and changes take place.



The adult Cecropia moth bears no resemblance to its caterpillar after emerging from its cocoon

The pupal stage may last for days, weeks, or even months. When the fully formed adult is ready, it emerges from the pupal skin and its new body begins to quickly dry, harden, and develop pigmentation. Some adults feed on completely different hosts or host tissues than their larvae; others do not feed at all and may only live for a few hours or days: just long enough to mate and lay eggs.

Many insects feed on and breed within trees and other forest plants. Forest insects cannot attack any plant species; instead, insects tend to be host-specific. A ***host*** is a plant that can be utilized for an insect to complete its life cycle. Most insects have only one or a few suitable host species; however some insects can attack a wide range of host plants. The mechanisms that determine which insects can attack which plants are very complicated and result from complex interactions and signals between the two organisms.

Trees have evolved structural and chemical defenses such as thick bark, waxy leaf coatings, root secretions, and even toxins that prevent or deter insect attacks. A plant that possesses the ability to prevent attack is completely ***resistant*** to that insect. Some plants may be attacked by insects, but because of defensive adaptations they are able to limit damage and are considered to be resistant compared to more susceptible plants. ***Susceptible*** plants are vulnerable to insect attacks that result in severe damage or death. Resistance and susceptibility form a continuum that ranges from completely resistant to highly susceptible. A plant can be resistant to one insect, but susceptible to another: each interaction is unique.

Forest insect pests are generally grouped by the type of damage they cause to their hosts. These insects fall into one of five categories: defoliators, bark beetles, wood borers, sapsucking insects, and meristem feeders.

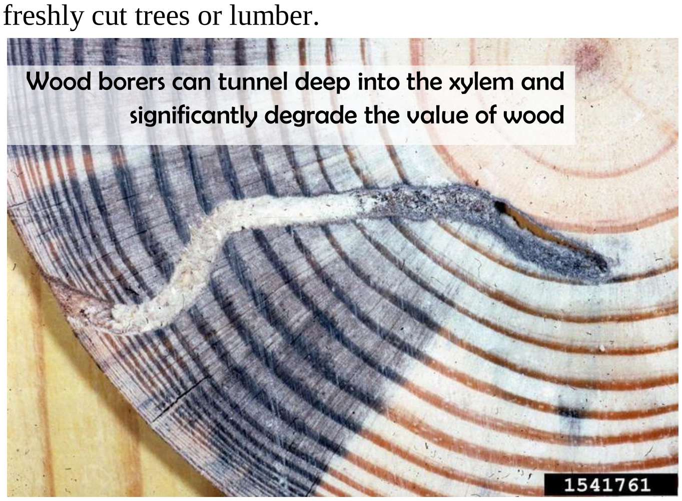
Defoliating insects feed on the foliage of trees, which are the main tissues responsible for photosynthesis. Although most defoliating insects are harmless or tend to be merely a nuisance, when outbreaks occur they can become highly destructive. For example, the gypsy moth is a highly damaging defoliator because its populations can grow rapidly, each larva can eat over a square foot of leaf surface per year, and a heavily infested tree can be completely defoliated year after year. Most other defoliating insects do not have such destructive potential. For instance, many of our native moth and butterfly larvae feed on tree leaves. Because only a few larvae feed on any given tree, little or no damage occurs. Any time a tree is partially or completely defoliated during the growing season there is a general decline in the health of that tree. This decline can cause the tree to grow slower, make the tree more susceptible to secondary pests, and can even cause tree mortality in some cases. If a tree is defoliated early in the growing season, it may refoliate, but this dramatically decreases the tree's energy reserves. Defoliation that occurs later in the growing season typically does less harm to the tree because the tree has already had ample time to build up energy reserves before the onset of winter.

Eastern tent caterpillars feed on the foliage of a variety of hardwoods during the spring

Bark beetles are a highly destructive group of forest pests. The southern pine beetle, the most destructive forest insect in the South, falls into this group, as do the *Ips* engraver beetles. Adult bark beetles bore into the inner bark of susceptible host trees to lay eggs in long tunnels known as ***egg galleries***. When larvae hatch from these eggs, they begin to bore through the inner bark and

Galleries formed by southern pine beetle adults and larvae girdle a tree's vascular system feed on the nutrient-rich cambium and phloem tissues, and even the outer sapwood. The tunnels created by feeding larvae are known as ***larval galleries***. If a tree is heavily infested by bark beetles, the cumulative effect of the galleries is ***girdling***, which occurs when the nutrient conducting tissues of the phloem are completely severed and destroyed. In addition, if the outer sapwood is damaged, the tree may be unable to transport water and will wilt. Healthy trees resist attack by bark beetles by producing sap or pitch to push adult beetles out of entrance holes. When trees are in a weakened state or are attacked by large populations of beetles, they may be unable to generate enough sap to prevent beetles from entering. Therefore, when bark beetles do gain entrance to a tree, the most common result is tree mortality. Many of the bark beetles carry fungi, such as blue stain fungi, that can degrade wood quality and plug the tree's vascular tissue accelerating the host's decline.

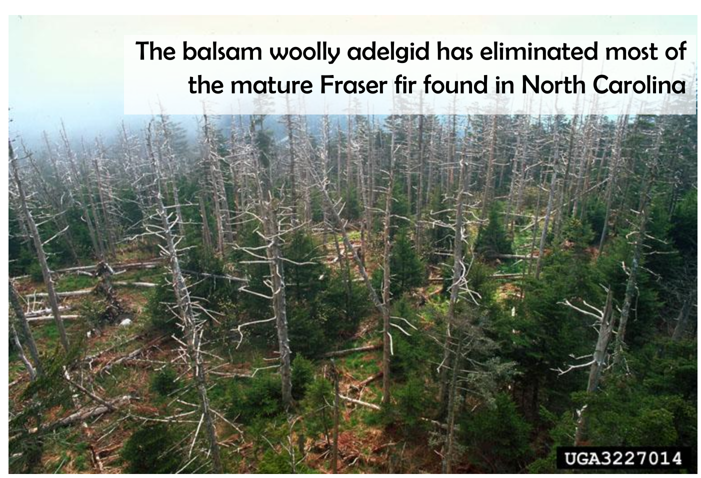
Wood borers differ slightly from bark beetles in that their activity is not strictly confined to the cambium and phloem tissues of the inner bark. Wood borers will also bore into and feed on the sapwood. Damage from wood borers includes girdling of the water and nutrient conducting tissues of the vascular system, and usually results in death. Many devastating non-native invasive insects, such as the emerald ash borer, redbay ambrosia beetle, and Asian longhorned beetle belong to this group. Many secondary insect pests also fall into this group, including the twolined chestnut borer and the southern pine sawyer. Wood borers that feed on dead or dying trees require sufficient wood moisture; trees that have been dead for a prolonged period of time (e.g. when the bark falls off) are no longer suitable for wood borer activity. However, as long as wood moisture remains sufficient, wood is susceptible to attack. Therefore, many wood boring insects are a significant threat to freshly cut trees or lumber.



Wood borers can tunnel deep into the xylem and significantly degrade the value of wood

Sap-sucking insects are those insects that possess piercing-sucking mouthparts and are able to penetrate the nutrient conducting tissues to feed on the plant's sap. Most sap-sucking insects are only able to feed on soft, succulent tissues where the vascular system is close to the plant surface; others possess mouthparts which can penetrate tree bark. Though most are not, piercing-sucking insects can be highly damaging to trees. For instance, the hemlock woolly adelgid is a sap-sucking insect that feeds at the base of hemlock needles and is responsible for nearly wiping out both eastern and Carolina hemlocks in North Carolina. The balsam woolly adelgid, which created the ghost forests of high elevation Fraser fir in North Carolina, also are highly destructive. Piercing-sucking pests include scales, aphids, adelgids, pysillids, leafhoppers, and related species such as mites. Under the right conditions, piercing-sucking insects can cause serious damage resulting in tree decline or mortality. Some of these insects, such as aphids, can also cause a distortion of plant parts and unsightly galls.

Aphids are sap-sucking insects that are commonly found on both conifers and hardwoods



The balsam woolly adelgid has eliminated most of the mature Fraser fir found in North Carolina

Meristem-feeding insects feed on those tissues of a plant known as ***meristems***, which are responsible for plant growth. Meristems include shoot tips (which account for increases in tree height and branch length) and the cambium (which accounts for increasing tree diameter). An example of a meristem feeder would be the Nantucket pine tip moth which lays its eggs on the shoots of young pines. Upon hatching, larvae bore into the young, rapidly growing shoots to eat the nutrient rich tissue. When populations are high enough, meristem feeders can kill trees (especially seedlings and young trees), but more often they only disfigure trees or cause reduced growth. Feeding by these insects can cause the terminal shoots to die, resulting in increased lateral branch growth that gives rise to trees with poor form and multiple stems. Damage from these insects also reduces tree growth and vigor, and may make them more susceptible to secondary pests.

The Pales weevil feeds on the secondary meristem tissue (cambium) of young pine seedlings

The Nantucket pine tip moth feeds on the primary meristem tissue (growing shoots) of young pines