For more information on the Junior Invasive Inspectors Program, visit our website at clemson.edu/invasives.

CLEMSON UNIVERSITY

JUNIOR INVASIVE INSPECTORS

A partnership to protect your natural resources.

Sherry Aultman and **Sarah Morrison** developed the Junior Invasive Inspectors Program to engage the community in the fight against invasive species. Please feel free to contact them with any questions or comments at **invasives@clemson.edu** or **864-646-2128**.

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Cover photo credit John J. Dreyer.
John Dreyer shoots photos of wildlife and landscapes in the Low Country.

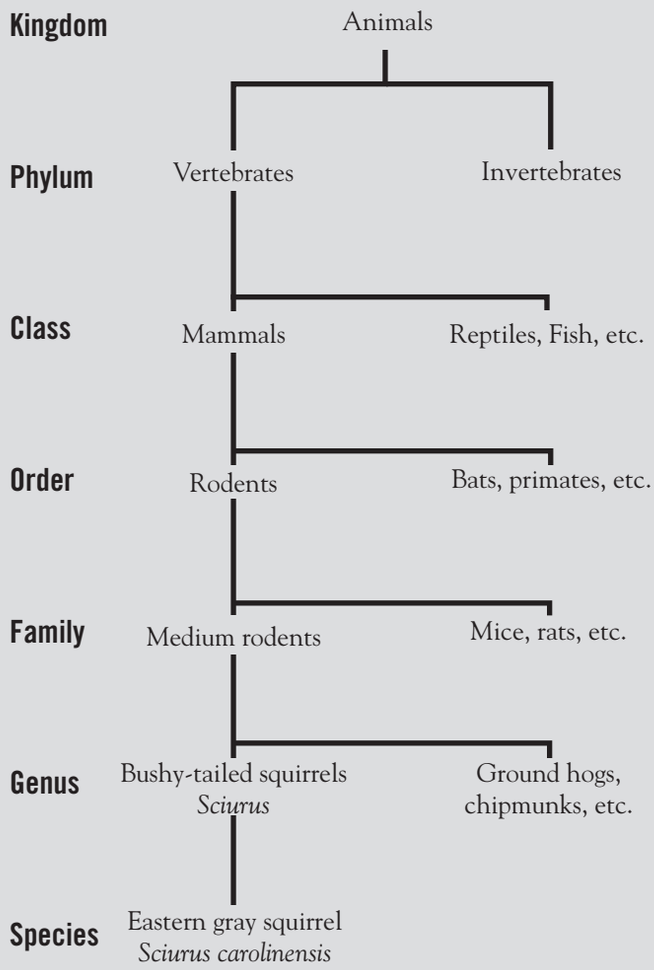
What is an *invasive* species?

While all living organisms on Earth impact the environment in some way, certain organisms are considered invasive because of the damage they cause. In this section, Junior Inspectors will gain an understanding of why some species are considered invasive and the ways invasive species are introduced and cause damage to an area.

A ***species*** is a group of organisms that are very closely related and share many of the same characteristics. The exact definition of a species has changed over time as science continues to evolve and our knowledge of the natural world grows.

Originally, biologists grouped organisms by their size, shape and color, but the appearance of an organism doesn't always tell us the whole story. Generally, two organisms that can produce fertile offspring are considered the same species. However, there are many exceptions to this rule, too.

Taxonomists, biologists who specialize in classifying different forms of life, can now analyze the genetic makeup of organisms to determine how closely related they are. This genetic analysis often confirms the way we have been classifying species, but sometimes it results in the creation of a new species or the combination of several former species into a larger species.



This diagram shows how the Eastern gray squirrel fits within each level of classification. As you go down the tree, the groups have fewer, more closely related animals.

WHAT'S IN A NAME?

Each distinct species is given a two-part scientific name, often in Latin. The first word is the ***genus***, or generic name. This tells us to whom the species is most closely related, much like your last name. The second, more specific name, is the ***species*** name and often describes something about the species. In our example, the genus name *Sciurus* comes from the Latin words *skia* and *oura* meaning "shadow" and "tail," referring to the bushy-tailed squirrels of this genus. The species *Sciurus carolinensis* is named after its native range in the Eastern U.S. including the Carolinas.

Ecosystems are what we call "the environment" or "nature." In the same way that we live in neighborhoods, towns or cities, animals, plants, and even microorganisms live in ecosystems. Many different species live together and each one has an important role to play in the ecosystem. There are many kinds of ecosystems that can be all shapes and sizes.

Can you name some species that would live in these ecosystems?

We don't realize it, but we see many different species every day. Scientists have named approximately 1.7 million species so far, and add about 13,000 more each year. Currently there are over 350,000 known species of flowering plants and over 900,000 known species of insects in the world.

Native species are organisms that are in their place of origin or where they have evolved to their current form. Some species have a very small geographic range, while others may be found over multiple states or even multiple countries. The native range of Eastern gray squirrels is shown in red on this map. Normally, these species are limited in their distribution by natural barriers such as mountains or cold weather, but occasionally they can overcome these barriers and spread to new areas.

Non-native, or ***exotic***, ***species*** are organisms that are living outside of their place of origin and have expanded their range into areas where they would not normally be found. This expansion can be accomplished on their own or with help from other natural processes. However, when humans transport a species, on purpose or by accident, it is then considered an ***introduced species***. Many of the foods that we eat like peaches, tomatoes and apples, or cows and pigs are introduced from other parts of the world.

bi·o·di·ver·si·ty *n.*
The variety of living things in one area.

WHAT MAKES A SPECIES INVASIVE?

An ***invasive species*** is defined as a non-native species that damages the economy or the environment, or causes harm to humans, animals or plants. Invasive species can be plants, fish, insects, mammals, birds and even diseases. They can change or destroy ecosystems by competing with, and sometimes replacing, native species. This can cause some threatened and endangered species to go extinct, resulting in a loss of ***biodiversity***.

Invasive species can destroy the crops or animals we depend on for food. They can damage the forests that we camp in and the lakes that we swim in. One of the biggest concerns is the threat to human health. Some invasive species bite or sting people; others are poisonous or carry deadly diseases.

Gray squirrels were introduced to Europe many years ago and have spread all over the United Kingdom. The native European red squirrel (at right) is disappearing as the gray squirrels invade and take over.

Invasive species all have some common characteristics that allow them to be so successful and damaging in their new homes:

They **outcompete** native species for resources like food, water or shelter.

Invasive species often replace a similar native species because of direct competition for vital resources. The invasive may be more aggressive or just better suited for survival than the native.

Squirrels stash their food in random places and then return to eat later, but Eastern gray squirrels are known to be sneakier than most. Gray squirrels will pretend to bury food while hiding it in their cheeks if they sense a competitor watching.

Invasive species grow and **reproduce very quickly,** allowing them to survive and spread. They also often **carry diseases** that kill native species.

The faster an introduced population grows, the harder it is to control. A female gray squirrel can have up to two litters in one year. Gray squirrels also carry and spread "squirrelpox," a disease that kills red squirrels.

They can tolerate a **wide variety of habitat conditions** such as cold, heat, drought, or flooding which means that they can successfully live in many different types of areas.

For an invasive species to succeed in a new environment, it must be able to tolerate the climate. The Eastern gray squirrel puts on extra weight to insulate during cold, wet European winters.

Gray squirrels have also adapted quite well to live among humans. While other animals struggle with habitat destruction and urban sprawl, these squirrels tend to thrive.

Invasive species have **few natural predators**, enemies or pests in their new home that can help to keep their populations under control.

The new environment may not have the predators or diseases an invasive species faces in their native range. Hawks eat gray squirrels in the U.S., but not in the U.K. Eastern gray squirrels were also introduced to South Africa, but they are not considered invasive because native birds of prey keep populations in check.

How do Invasive Species Travel?

Some invasive species may move or migrate on their own by flying, walking or crawling to new areas. While the native range of any species can change naturally with fluctuations in climate and landform, this happens very slowly and can take a long time. Invasive species tend to move from one place to another through pathways.

Natural pathways are not aided by humans and can include weather events like storm winds and flood waters. Animals often act as natural pathways, spreading invasive plant seeds after eating them or accidentally carrying seeds in their fur. Other pathways are either created by humans or enhanced by human activity.


Johan van Rensburg

Globalization has led to increased trade between countries that were once very far apart. Livestock and agricultural products are being ***imported*** and ***exported*** in large numbers around the world. Invasive species can stowaway or hitchhike on cargo in trucks, ships, trains or airplanes.

glob·al·i·za·tion *n.*
Process enabling markets to operate internationally.

People accidentally move invasive species in their cars and on their boats. Insects that attack and kill trees can be carried to new areas by moving firewood, Christmas trees and lumber.


Dave Barker

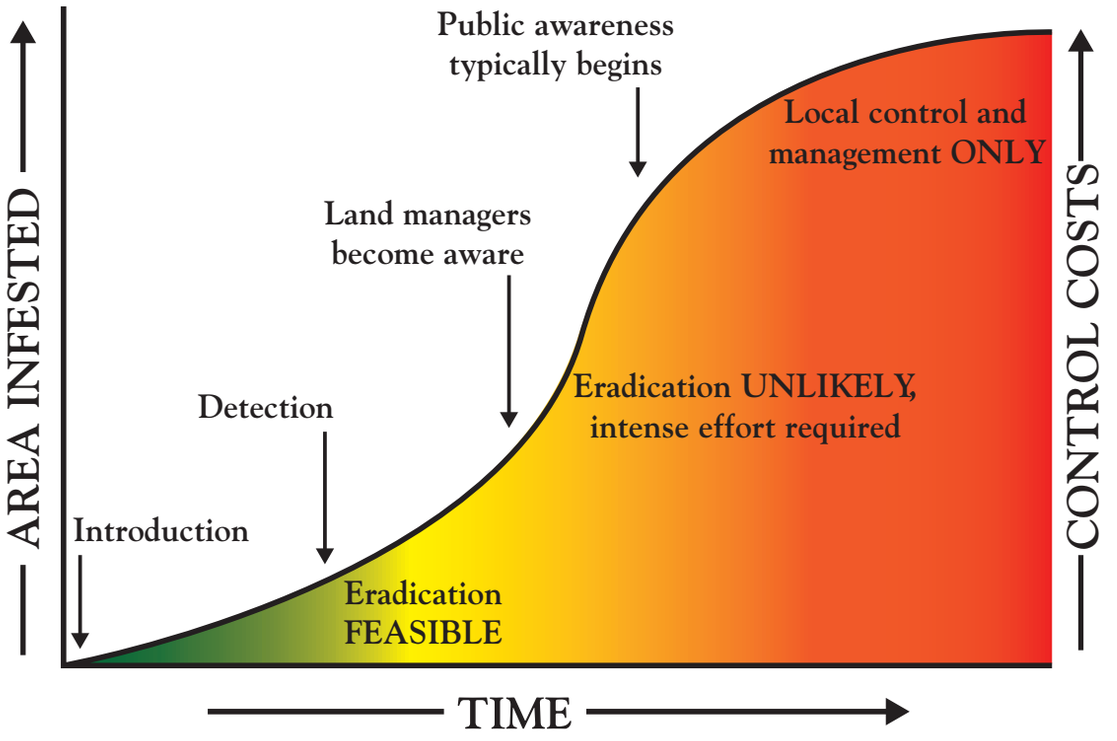
Sometimes introductions are intentional, such as people bringing in new plants for gardens or food. Non-native amphibians, fish, snails and reptiles that were once pets, like the Burmese python, have been released into the wild because their owners could no longer care for them, and now they are invasive.

Although there are natural pathways for species to spread, most invasive species introductions are caused by humans or their belongings moving quickly over very long distances.

Many people are working hard to prevent invasive species from spreading, becoming established and causing damage. Federal government agencies like the United States Department of Agriculture (USDA) and state governments like the Clemson University Department of Plant Industry (DPI) use laws and regulations to help prevent the accidental or intentional introduction of invasive species. Certain ***high risk*** species and their vectors are not allowed to be moved around, and people who try to break the laws may face fines or jail time.

At the shipping ports and airports, government officials like the U.S. Customs and Border Protection (CBP) conduct checks on people traveling and inspect shipments of cargo to prevent smuggling or stowaways.

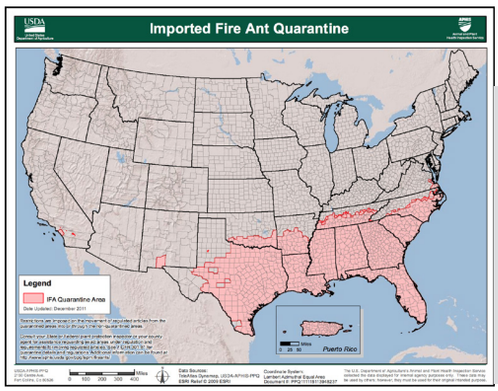
Prevention, or keeping invasive species out, is the most effective method of defense. This is the first step in combatting the problem of invasive species. It is cheaper and easier to keep them out than to try to get rid of them once they are here. The next step is ***early detection and rapid response*** (EDRR). Careful monitoring through ***surveys*** can help detect an invasive species as soon as it arrives and before it becomes established.



Regulatory agencies use EDRR programs to catch invasions while they are in the green phase of the graph above. Unfortunately, without the public's help, many invasions go unnoticed until it's too late.

How do we get rid of an invasive species?

Eradication is eliminating an invasive species from an area. As the invasion curve shows, the longer an invasive species is left alone to establish, the harder and more expensive it is to eradicate. Discovering the infestation early and taking quick action is very important. The first step of eradication is ***containment***. Regulatory agencies may try to contain the infestation through quarantines. Quarantines can restrict the movement of an invasive pest and any host material or activity that may contribute to the spread of the pest.



The **red imported fire ant** is an invasive species from South America that we have in South Carolina. Our entire state is under quarantine for fire ants, along with the other red states and counties on this map. Host material, like soil and hay, in quarantined areas must have proper documentation to show that they have been treated before shipping into non-quarantined areas.

Control is the attempt to reduce the numbers of invasive species below an acceptable level. Usually, if their numbers can be controlled, the damage will be minimal and native species can fight for themselves. There are several options for control including mechanical, chemical and biocontrol. Can you think of some controls we use for fire ants?

Mechanical	Chemical	Biocontrol
_____	_____	
_____	_____	
_____	_____	

The **phorid fly** is a tiny fly that lays her eggs inside living fire ants. The young hatch and mature inside the heads of ants until new phorid flies emerge, popping the ants' heads off and killing them. This parasitic fly has been introduced to kill fire ants through this natural, biological process.

If eradication, containment and control are not options or haven't worked, the last option available is ***mitigation***. The goal of mitigation is to live with the invasive species and try to reduce the impacts on the environment and the economy.

There are many ways that you, your friends, and your family can help prevent the damage caused by invasive species. It is important to learn about and understand which organisms threaten your area. By knowing and being able to recognize invasive species, you can help detect them as soon as they find their way here. Additionally, there are a few rules that you and your family can follow that will help prevent the introduction of new species that may become invasive:

Plant Natives

It is always a good idea to plant native plants in your yard whenever possible. If you decide to plant exotic plants, be sure that you know what they are and how they grow. You can also help eradicate or control invasive species by getting rid of any damaging plants that are currently growing in your yard. You could even join a community group that is removing non-native, invasive plants and restoring native habitats in state parks, botanical gardens and national forests.

If you like to camp, hike, boat or fish, be sure to not accidentally move invasive species from one location to another. After leaving the forest, campground or water, inspect your shoes, clothes, boats and other accessories to be sure that there are not seeds, plant parts or soil attached to anything. Wash everything really well and dispose of anything that you find by placing them in the garbage. Don't move firewood long distances. Instead, buy your firewood where you plan to burn it. Don't bring home any plants, animals, fish, reptiles or amphibians not native to your area.

Don't Dump

Never empty aquariums into rivers, lakes, or other waterways, including storm drains. Check with your pet store for information on safe disposal. Don't ever buy and release other types of pets like rabbits, ferrets, lizards, snakes or snails outside. If you and your family travel to other states and countries, don't bring back animals, seeds, fruit, live plants or soil.

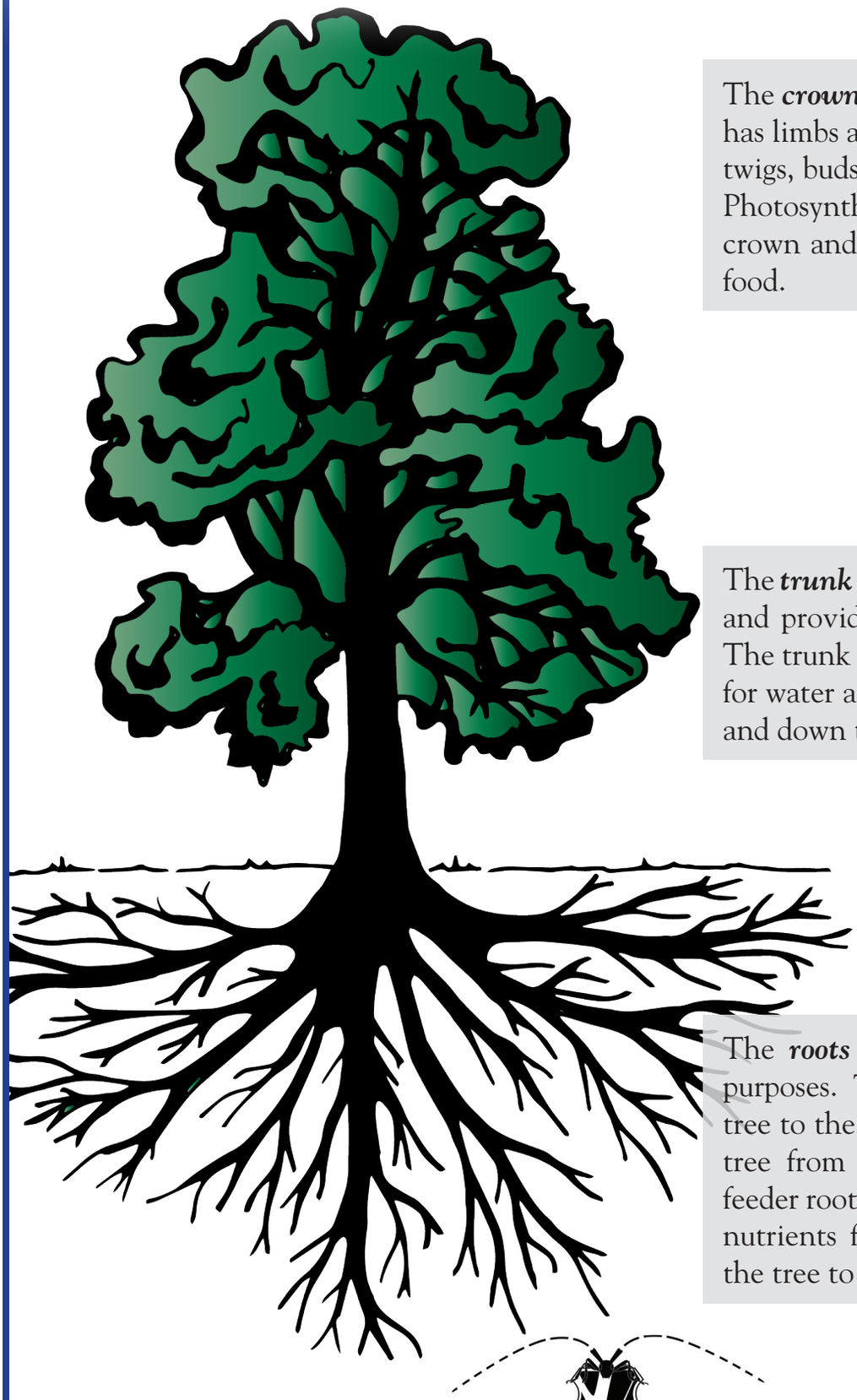
Most Importantly...

Tell everyone you know about the danger and damage that invasive species can cause, and encourage all your friends and family to learn and help prevent invasive species from spreading.

How do we *protect* our trees?

Trees are a very important part of the environment and provide many benefits for humans and other organisms. They consume carbon dioxide and give off the oxygen that we breathe. They purify the air and moderate the temperature of the earth. Trees provide food and shelter as well as many other products that humans and other animals depend upon. In this section, Junior Inspectors will learn how to identify trees so they can find and inspect trees that may fall victim to the targeted invasive insects.

Trees are a type of woody plant that usually has a single stem or trunk. They are more than 20 feet tall and have a well-defined crown when fully grown. Shrubs are different in that they normally have two or more stems, are less than 20 feet tall and form a clump when mature. Although there are many different types of trees, they all have three main parts or sections:



The ***crown*** is the part of the tree that has limbs and branches including the twigs, buds, leaves, flowers and fruits. Photosynthesis takes place in the crown and provides the tree with its food.

The ***trunk*** is the main stem of the tree and provides support for the crown. The trunk also acts as the passageway for water and nutrients that move up and down the tree.

The ***roots*** of the tree serve several purposes. The large roots anchor the tree to the ground and help keep the tree from falling over. Very small feeder roots absorb water, oxygen and nutrients from the soil, which help the tree to make food.

The tree trunk is made up of many important parts.

The ***outer bark*** protects the tree from injury.

The ***phloem*** or inner bark carries the food made in the leaves to the rest of the tree. Dead phloem cells become part of the bark.

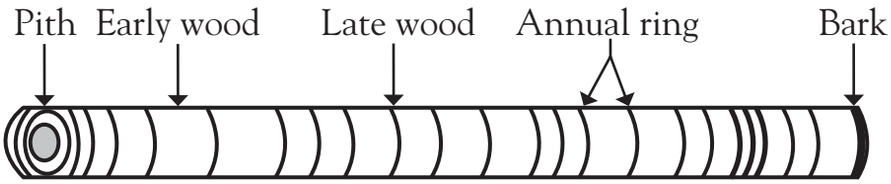
The next layer, called ***cambium***, is made of living cells. This layer creates new phloem and xylem.

The ***xylem*** or sapwood carries water and nutrients from the roots to the leaves. Older xylem becomes part of the pith.

The ***pith*** is the soft center section and is important for storage and structural support.

WHAT THE WOOD TELLS US

The cambium adds layers of wood to the tree as available resources allow. In the spring, the tree usually gets plenty of light, water, and nutrients, and the cambium adds a thick layer of growth, while the summer season is much drier, resulting in a thin, dense layer of growth. These layers are added all the way around the tree and make the tree rings we see in a cross section of wood. Instead of cutting down a tree to count the rings, scientists will core out one narrow sliver through all of the rings and analyze the lines in the core.



Count the annual rings to determine the age of this tree:

_____

How old is this tree?

_____

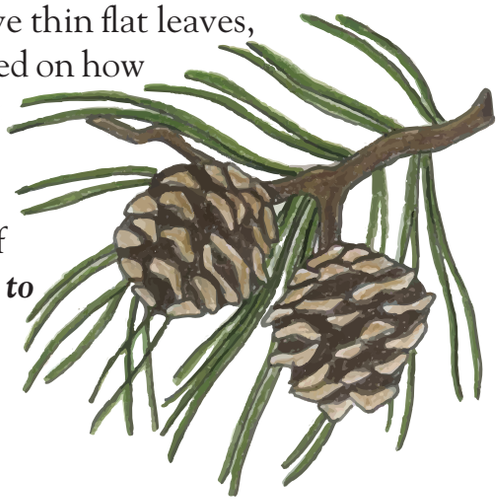
Why is the second tree smaller than the first? What do the annual rings tell you about the second tree's growing conditions in the past 12-13 years?

_____

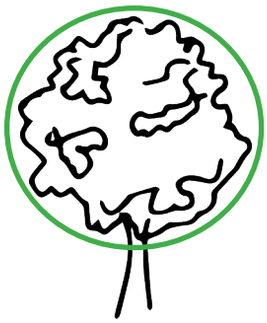
_____

Answers: 23; 23; The second tree lives in harsher conditions than the first, suffering from drought the past 12 years.

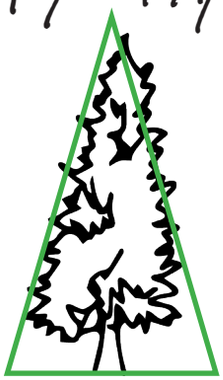
There are over a thousand species of trees in the U.S., and South Carolina has over 300 different species. All trees are divided into two types based on their leaves. ***Conifers*** have cones and needle or scale like leaves, like pine trees. ***Broadleaf*** trees have thin flat leaves, like maple trees. Trees can also be divided into two groups based on how they hold their leaves during the changing seasons. Trees that keep their foliage through the winter are called ***evergreens***, and most conifers are evergreens. Trees that drop their leaves in the fall and winter are called ***deciduous*** and most broadleaf trees fit into this category. ***All of the trees that we will learn to identify will be deciduous broadleaf trees.***



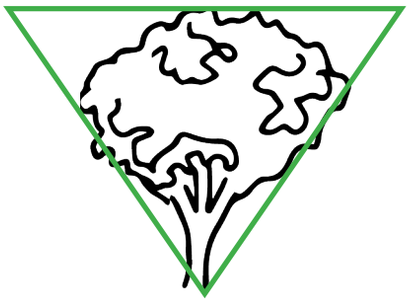
CHARACTERIZED BY SHAPE



Round trees are as wide as they are tall.

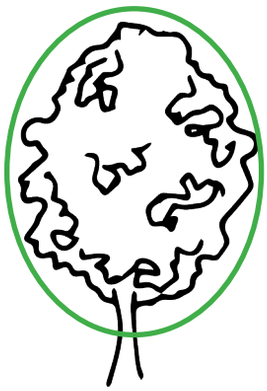


Conical trees have triangular canopies: wider at the base and narrower at the top.

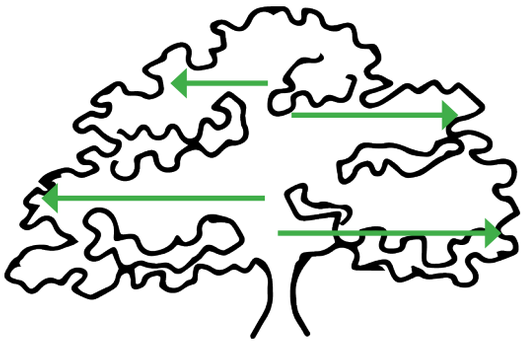


Vase shaped trees are upside down triangles with a wide top and a narrow bottom.

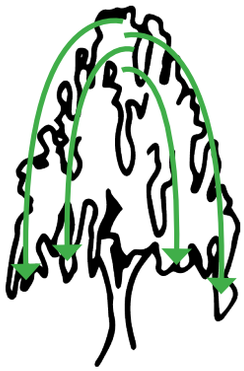
Columnar trees are shaped like cylinders with branches that are all the same length.



Oval trees are taller than they are wide with the widest part in the middle.



Spreading trees have limbs that primarily grow horizontally, even at the top of the crown.



Weeping trees have branches that droop downward.

COMMON TYPES OF TREE BARK

Many trees have characteristic patterns or textures of bark. If you know how to identify a tree by its bark, you can identify it in any season.

Smooth bark is usually very thin, with no peeling or ridges. Beech trees, because of their soft, smooth bark, are easy targets for vandalism. Carving your initials into a tree is not nearly as romantic when you know that you're strangling the tree!

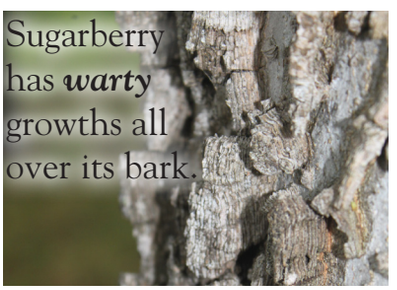
Furrowed bark has deep, rough ridges that typically form a diamond pattern. Black walnut has chocolatey brown furrowed bark, while green ash has lighter furrowed bark with a more pronounced diamond pattern.

Scaly bark is made up of small to medium 4-sided blocks. You can find this pavestone texture on dogwoods.

Plated bark is very similar to scaly bark, but the blocks, or plates, are larger. Plated bark is commonly seen on various pine species and white oak.

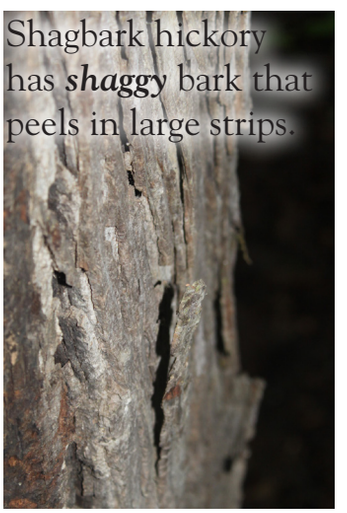
There are other ***rough*** types of bark that have irregular ridges and scales, but we try to use the most specific terms to describe tree bark. Bark often changes in appearance as a tree matures, so be sure to read bark descriptions carefully.

Check out these more unusual barks:



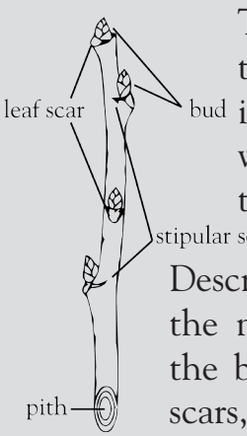
Sugarberry has ***warty*** growths all over its bark.

River birch has ***papery*** bark that peels off in large sheets.



Shagbark hickory has ***shaggy*** bark that peels in large strips.

TWIGS AND BUDS



Twigs are an excellent tool to identify trees in the winter, but we won't cover them in this workbook.

Descriptions usually focus on the most apparent features: the buds, leaf scars, stipular scars, and pith.

LEAF CHARACTERISTICS

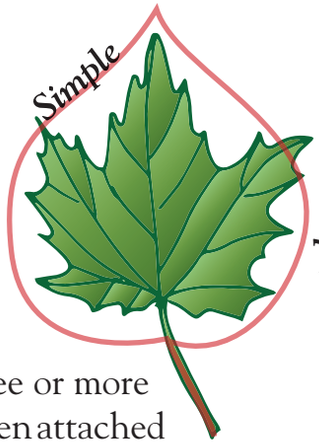
Arrangement refers to how leaves and branches arise from the tree.

Maples, ashes, dogwoods, and buckeyes all have ***opposite*** arrangement, meaning leaves and branches occur in pairs, directly across from one another.

Most other trees, such as oaks, birches, hickories, and poplars, have alternate leaf and branch arrangement. ***Alternate arrangement*** means there is only one leaf attached on one side of the stem and another leaf on the other side of the stem some distance away.

The last type of leaf arrangement is called ***whorled***. This means that there are three or more leaves connected at one point in a circle around the stem.

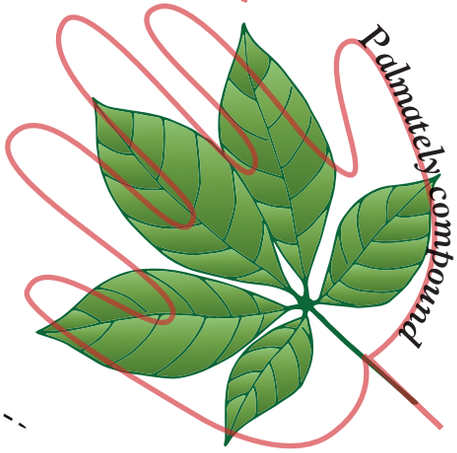
There are several different leaf types that can be very helpful in identifying trees. The most common type, a ***simple leaf***, has a single leaf blade attached to the stem.



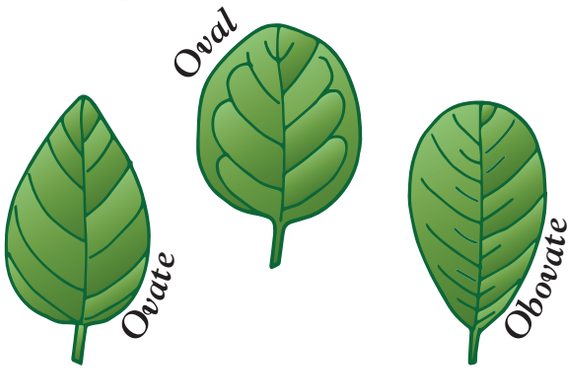
Some trees, like walnut and ash, have three or more small leaf blades attached to a stalk that is then attached to the stem. This type of leaf is called ***compound***, and the individual leaf blades are called leaflets.

Pinnately compound leaves have leaflets that are attached along the stalk.

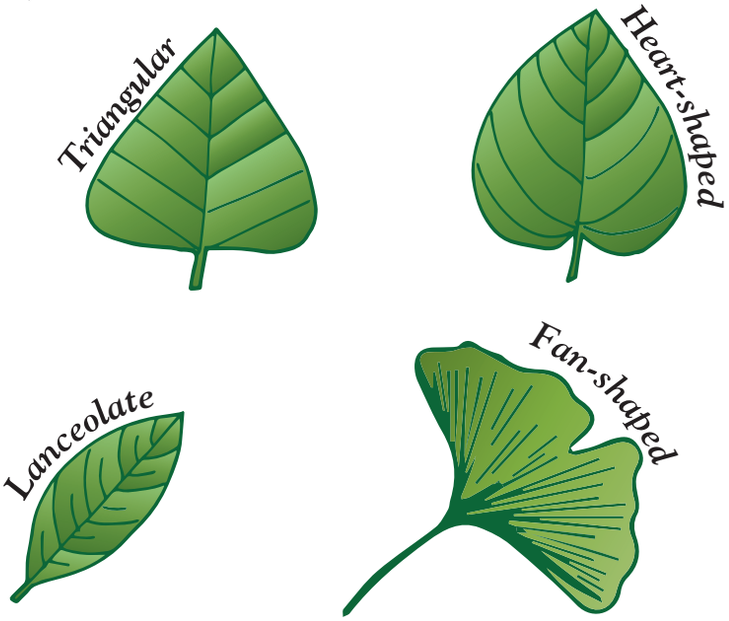
Palmately compound leaves have leaflets that join at a single point, much like your fingers join at your palm.



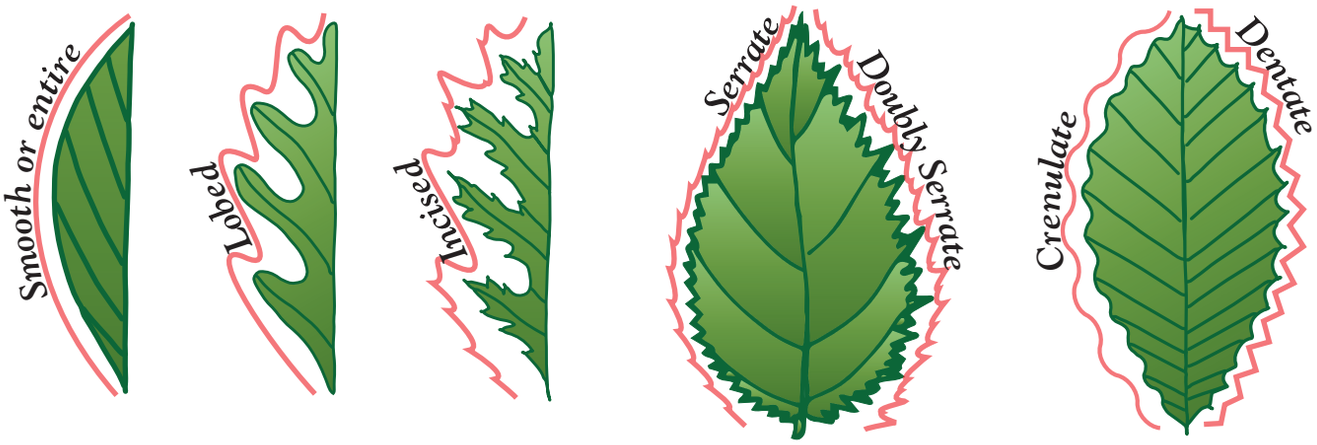
The ***shape*** of the leaf blade can be described as a familiar shape like an oval, triangle or heart. Leaf shapes can also be named after objects, like a lance or fan.



The widest part of an oval leaf is in the center, while ovate leaves are widest at the base and obovate leaves are widest at the tip.



The edge of the leaf blade, called the ***margin***, can be very helpful in tree identification.



Describe the leaves you see to the left. What type and shape are they? What kind of margin do these leaves have?

_____

_____

_____

_____

Flowers and Fruit

Flowers come in all shapes and colors, depending on how the flower has evolved to be pollinated. Typical flowers with brightly colored petals attract bees, ants and butterflies looking for nectar. While the insect is feasting on the sweet nectar, its legs and body are coated in pollen to be transported to the next flower. White flowers are usually associated with night-time pollinators like bats, beetles and moths.

Some trees have two kinds of flowers: male flowers with pollen and female flowers that are pollinated and develop into fruit. The male flowers shown to the left (yes, those are flowers!) are called ***catkins***. The female catkins usually look like small pinecones. All of the trees we will target in our surveys have catkins and are pollinated by wind.

Once a flower is pollinated, the new seed forms inside of the developing fruit. The type of ***fruit*** a tree produces has evolved for certain ways of moving and planting the new seeds. Some seeds are enclosed in tasty, fleshy fruits like an apple to attract hungry animals. Some animals hide their food and the buried fruits they forget about end up sprouting into a new tree. Squirrels are particularly fond of the fruit that comes from oaks. You may know these better as ***acorns***.

The walnuts you buy in the grocery store are the seeds inside walnut fruits. The fruit is actually a fleshy green ball, shown here. Walnuts are a great snack, but they are notoriously hard to harvest from the fruit and you will stain everything brown in the process!

Maples and ash have a type of fruit called a ***samara***. Some people call these helicopter seeds because the seed is in a hard covering on one end with a wing on the other. The shape of the fruit helps the seeds disperse by wind. The wing makes the samara spiral when it falls to the ground.

Once an inspector has identified a host tree, the next step is to evaluate the health of the tree. There are some common ***symptoms*** that sick trees may display in response to stress, much like sick people often have a fever.

Leaf Wilt

When leaves do not have enough nutrients, they begin to yellow, droop, wilt and eventually die.

Crown Dieback

The upper and outer branches of the tree are known as the crown. Dieback is the death of branches, starting at the top and working its way down. If there are leaves on these branches, they are typically thin and yellow in color.

Epicormic Shoots

When trees are really stressed or sick, they try to grow new branches and leaves to replace the dead ones. These epicormic shoots grow wherever they still can, often at the base of the tree and on the trunk.

Bark Splits

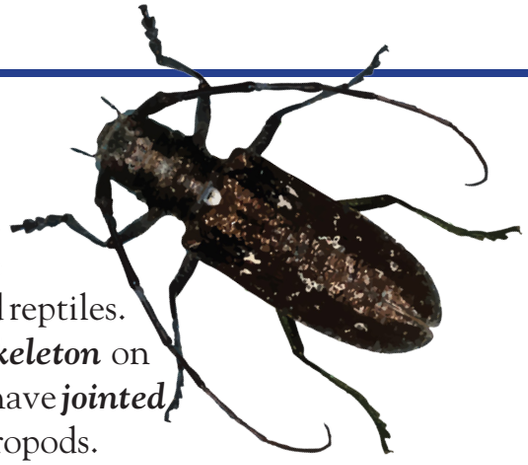
Vertical splits in the bark are caused by calluses or "scar" tissue that develops around the infested areas. If you peel back the bark in these areas, you may find signs of a pest.

Some vertical splits are caused by woodpecker scratching, but this is another sign that a pest may be present and you should investigate further.

How do invasive *insects* kill trees?

Over half of all known species of animals on the earth are insects! Insects fill important roles in *almost every* ecosystem such as pollinator, predator, and prey. Some insects are economically important, like silk worms and honey bees. Like other exotic animals and plants, insects can cause damage when introduced to new ecosystems and become invasive. In this section, Junior Inspectors will learn to identify insects and recognize the signs and symptoms associated with five targeted species of invasive insects.

ANIMALS > ARTHROPODS > INSECTS



Insects belong to the phylum of animals called arthropods. ***Arthropods*** are invertebrates, which means that they do not have a backbone or skeleton inside their bodies like mammals, birds and reptiles. Instead, arthropods have a hard, protective case called an ***exoskeleton*** on the outside of their bodies. Arthropod bodies are ***segmented*** and have ***jointed legs***. Spiders, centipedes, lobsters, ticks and insects are all arthropods.

A few characteristics separate ***insects*** from other arthropods. Most importantly, all insects have ***six legs*** and almost all insects have ***wings***. They also have ***compound eyes*** and one pair of ***antennae***. The word insect actually means "in sections" and all adult insects have a body that is made up of ***three main sections***. By knowing and learning to recognize the different parts of an insect, it is possible to identify them.

CIRCLE THE INSECTS!

Describe how you know which ones are ***not*** insects.

Black widow spider
CAUTION: venomous!

Lone star tick
CAUTION: carries diseases!

Dog-day cicada

DID YOU KNOW?

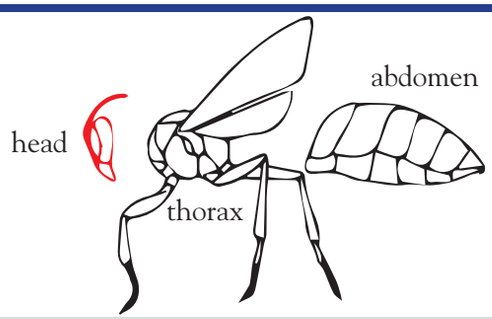
Not all insects are bugs.

True bugs are a specific order of insects called Hemiptera that have piercing and sucking mouthparts. Stinkbugs are true bugs, but beetles are not!

Eastern tiger swallowtail

Greenhouse millipede

INSECTS: IN SECTIONS

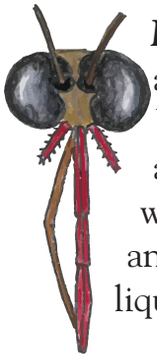


The **HEAD** is usually the smallest section and carries the eyes, the mouth and the antennae.

Compound eyes are made up of hundreds of smaller eyes all packed together. This allows the insect to see things that move really quickly, like predators or flowers blowing in the wind.

Insect mouthparts are adapted to the particular way each species eats:

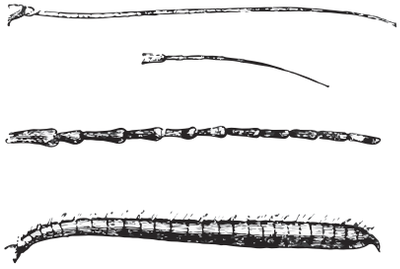
Chewing mouthparts are used for biting and grinding solid food like plant leaves and stems. Beetles, ants, caterpillars and grasshoppers have ***mandibles*** that bite and chew like jaws.



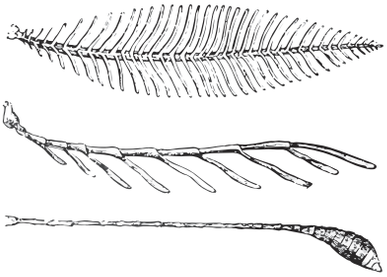
Piercing/sucking mouthparts are used by mosquitos and stink bugs. These bugs usually have a feeding tube and a ***stylet***, which is used to penetrate plant and animal tissue and suck the liquids from them.

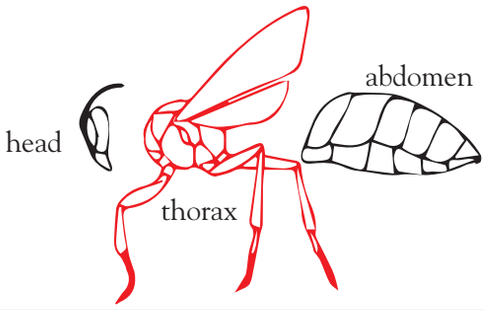
Siphoning mouthparts are elongated feeding tubes called the ***proboscis,*** and they are adapted to suck nectar from long, tubular flowers. Butterflies and moths have this type of mouthpart and it is often curled up like a coil when not being used.

Sponging mouthparts are used by house and fruit flies to sponge and suck. The flies often use an enzyme to turn the food into a liquid that can be sponged up more easily.



Some people call ***antennae*** "feelers" because insects use them to feel their surroundings, but antennae can also hear, smell and taste.





The *THORAX* is the middle part of the insect body, which carries the three pairs of legs and wings.

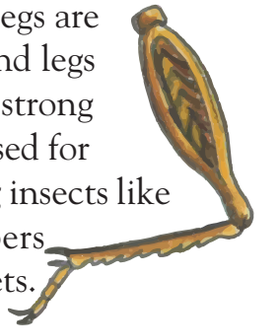
Most insects have ***wings*** but wings can come in all shapes and sizes. Insect wings have rigid ***veins***, which support the wing in flight. These veins can be used for identification in some species, like honey bees. Wings can also do more things than just fly. Sturdy wings called ***elytra*** can help protect the insect. Colorful wings can be used to attract mates or scare away predators. Some wings help to collect heat or make sounds.

These wings can...

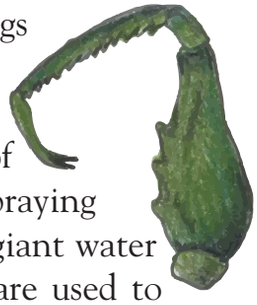
Each pair of ***jointed legs*** can be different in size and shape, adapted to special tasks:

Running legs are long and narrow to help insects like cockroaches and tiger beetles move very quickly.

Jumping legs are usually hind legs that have strong muscles used for propelling insects like grasshoppers and crickets.

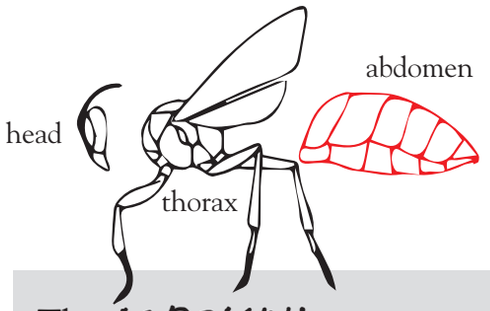


Predatory legs are large and strong legs at the front of insects like praying mantis and giant water bugs. They are used to grab and hold prey while the insect eats.



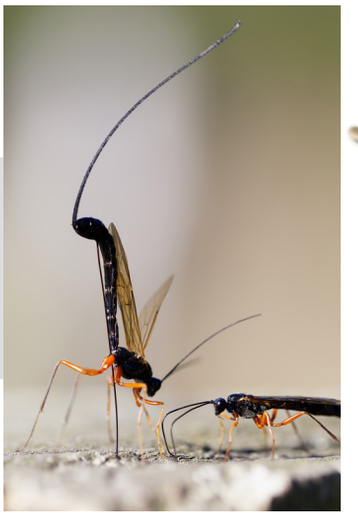
Swimming legs are usually flat and fringed with hair. These legs act like flippers and allows water bugs to move quickly through water.

Digging legs are modified forelegs that mole crickets and cicada nymphs use to live underground.



The **ABDOMEN** is usually the largest section of the body and contains the insect's digestive system, heart and reproductive organs.

If an insect has developed the capacity to sting, the ***stinger*** will be located at the tip of the abdomen.



In female insects, the ***ovipositor***, or egg-laying organ, is also located here.

The abdomen contains all of the important functions of the insect body including its nervous system, digestive system, circulatory system and respiratory system. Some of these systems are very different in insects than they are in humans and other mammals.

Insects don't have lungs like we do. Instead they have tubes and sacs that are spread throughout their body. Small openings along the insect's abdomen called ***spiracles*** take in oxygen and release carbon dioxide. The oxygen is delivered directly to the parts of the body that need it through the small tubes and sometimes stored in the sacs.

Since an insect doesn't need blood to move oxygen around its body like humans do, it doesn't need the same kind of circulatory system that we have. Insect blood or ***hemolymph*** is usually pale green or yellow and transports nutrients, hormones and waste. In some insects the hemolymph is also used for defense by smelling or tasting bad to predators. Have you ever seen hemolymph on the windshield of a car?

Circle of Life

Unlike people and other mammals that are birthed by their mother, insects begin life outside their mother's body as eggs. All insects go through a process of change from egg to adult that is called ***metamorphosis***, meaning "change of form." We will explore two types of metamorphosis: complete and incomplete.

The female parent usually lays her ***eggs*** on a food source such as a plant or even a dead animal.

When the change is complete, the case splits open and the ***adult insect***, wings and all emerges. The adult insect usually doesn't grow any more. Many live for weeks or months, and during this stage they reproduce.

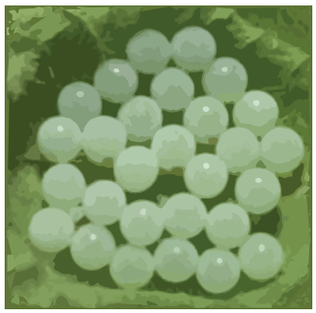
Complete Metamorphosis

has 4 distinct stages:
egg > larva > pupa > adult

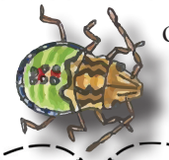
During this resting stage the ***pupa*** is ready to undergo the final change into an adult. Most pupae build some sort of case, called a chrysalis or coccoon, for protection. Other pupae may burrow into the soil for protection. Inside the case, the pupa's body is disassembled and reassembled into the adult form.

Incomplete Metamorphosis

has 3 gradual life stages: egg > nymph > adult



Instead of a larva hatching out, a ***nymph*** emerges from the egg. The nymph does not have wings and is usually a different color, but other than that, it looks just like a very small adult. The nymphs will grow and molt and each time it sheds its skin...

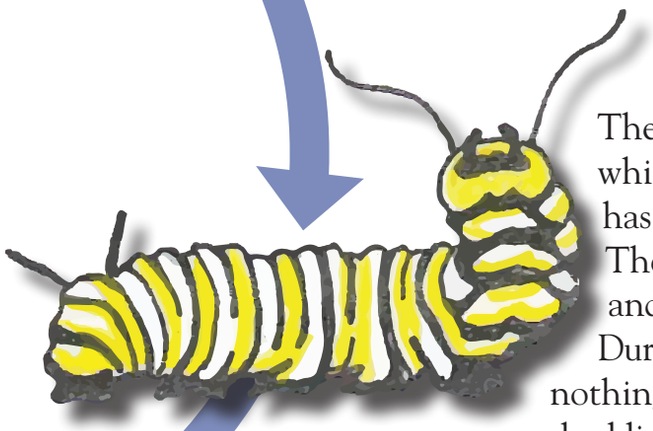


Sometimes insects lay a group of eggs called an ***egg mass*** for strength in numbers; at least a few of the eggs will survive this stage.

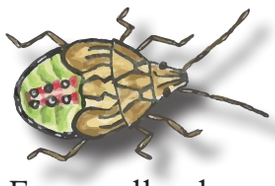
The Monarch butterfly, pictured here, lays ***solitary eggs***, meaning only one egg at each place. A larva from a solitary egg does not have to compete with its siblings for food.

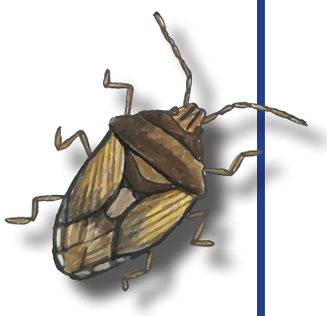
YOU ARE WHAT YOU EAT

During the different stages of metamorphosis, more than just the shape and appearance of an insect changes. Each life stage has a different diet so there is plenty of food for everyone.

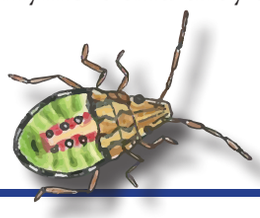


The egg then hatches into a ***larva***, which resembles a segmented worm, has many small legs and no wings. The larva immediately begins eating and will feed for several weeks. During this time, the larva does nothing but eat and grow, by molting, or shedding its skin. Once the larva has had enough to eat and has matured enough, it will stop eating and begin the pupal stage.





...it gets bigger and bigger and bigger. Eventually, the nymph finishes maturing and it sheds its skin for the last time and emerges into a full adult with wings. The adult insects usually don't grow anymore and they are ready to reproduce.



Insects are extremely important to the world and can be both helpful and harmful. Can you make a list of ways that insects can help (Pros) and hurt (Cons) our ecosystems?

Pros	Cons
_____	_____
_____	_____
_____	_____

Many of the fruits, nuts and vegetables that we eat are pollinated by insects. Bees produce honey and beeswax. Insects clean up dead plants, dead animals or animal manure, helping to keep the environment clean. Insects are also an important link in the food chain because people eat the animals that eat the insects and in some places people even eat the insects!

Invasive Insects Kill Trees

Unfortunately, some do more harm than good. Insects can feed on, damage and destroy our gardens, our trees and even our houses. They can sting or bite people and animals and sometimes they transmit diseases that can kill people, animals and plants. One of the biggest problems is the invasive insects that damage or kill plants, especially the trees in our forests.

Many invasive insects are bark beetles that feed on the tissue just below the bark surface. Some insects are ***vectors*** that carry diseases that can spread and further damage the tissue. The damage to the ***phloem*** disrupts the movement of nutrients in the tree and the tree will essentially starve to death.

1. The emerald ash borer lays an egg on the bark of an ash tree.
2. A larva hatches from the egg and eats through the bark.
3. Once in the phloem, the larva eats and matures, leaving behind zig-zag tunnels called ***larval galleries***.
4. The larva pupates and matures into an adult. The adult beetle exits the ash tree through a D-shaped ***exit hole*** to mate and continue the cycle.

SIGNS AND SYMPTOMS

When trees are infested with harmful insects, they become stressed and display ***symptoms*** such as crown dieback, bark splits, leaf wilt and epicormic shoots. A walnut infested by walnut twig beetle may have ***cankers***, patches of rotting and dead tissue. The cankers are a symptom of thousand cankers disease which is caused by a fungus the tiny walnut twig beetles carry under their elytra.

Gypsy moths lay brown, fibrous ***egg masses*** that can look like wet paper.

The Asian longhorned beetle chews craters into bark before she ***oviposits*** her eggs. The large, round hole in the bottom right is an ALB ***exit hole***.

An adult emerald ash borer emerges from a D-shaped ***exit hole***. At right, EAB feeds on a leaf as an adult.

When you see a sick tree with symptoms of stress, look for ***signs*** of insect activity. Signs of insects can include oviposition damage, eggs, larval galleries, frass, exit holes, feeding marks on leaves, and flying or crawling adult insects.

Emerald ash borer larvae leave zig-zag ***larval galleries*** just below the bark surface.

The Asian longhorned beetle chews the wood and leaves behind bug poop called ***frass***.

Abdomen	Body section with the heart, digestive and reproductive organs
Acorn	The fruit or nut of an oak tree and their close relatives
Adult	The final mature reproductive stage of an insect
Alternate Arrangement	An arrangement is where leaves are staggered along the stem
Antennae	Movable sensory organs located on the head of most arthropods
Arrangement	The positions in which leaves grow on a stem
Arthropod	An invertebrate animal with a segmented body such as an insect, spider, or crustacean in the family Arthropoda
Bark Split	The common response to various environmental conditions where a tree's bark cracks open, allowing entry of secondary pests
Biocontrol	The introduction of a species to help control and manage an invasive pest
Biodiversity	The variety of life in a particular habitat or ecosystem
Broadleaf Tree	A tree with flat broad leaves
Cambium	Layer of the tree that makes new bark by adding living cells
Canker	An area of rotting and dead tissue on woody plants
Catkin	A dense and drooping cluster of small, male or female flowers found in willows, birches, and oaks
Columnar Trees	Trees with narrow, single trunks
Compound Eyes	Eyes composed of many simple lenslike facets each receiving a seperate image
Compound Leaf	A leaf containing mutiple leaflets
Conical Trees	Trees that are cone-shaped: narrow at the crown and more broad at the base
Conifers	Cone-bearing woody plants (pines, cedars, cypresses, firs, etc.)
Containment	The process of preventing the expansion of something harmful
Control	Reducing numbers of invasive species below an acceptable level
Crenulate Margin	Very small, rounded teeth on the edge of a leaf
Crown	The top portion of the tree that includes the limbs, branches, twigs, flowers, and fruits of the tree
Crown Dieback	The severe loss of leaves and limbs in the top of a tree
Deciduous	Trees that lose their leaves seasonally
Dentate Margin	Triangular, tooth-like edges along the side of a leaf
Doubly Serrate Margin	Many saw-like teeth along the leaf edge
Ecosystem	A community made up of both non-living and living factors
Egg	The first stage of most insects

Egg mass	A group of eggs laid by an insect
Epicormic Shoots	Small branches that grow in clumps on the trunk of the tree, and usually indicate branch dieback and other problems
Eradicate	Successfully removing and eliminating an invasive species from an area or region
Evergreen	A plant that retains its green leaves throughout the year
Exoskeleton	A rigid external covering for the body in arthropods
Exit Hole	The hole that is formed when the adult insect leaves a tree
Export	Shipping goods and/or services out of a country
Fan-Shaped	A leaf shaped like an old-fashioned fan (as seen on gingko trees)
Flowers	The reproductive part of plants; can be male, female, or both; are often adapted to attract pollinators
Frass	Solid excrement of insects resembling fine sawdust
Fruit	The mature ovary of a fertilized flower that contains the seed
Furrowed Bark	Bark that has deep grooves
Genus	The first word of a scientific name and the second lowest level of classification, linking the most closely related species together
Globalization	The process of interaction and integration between different countries
Heart-Shape Leaf	Round on both sides of the stem, this leaf shape resembles a heart
High Risk Species	Species that have invasive characteristics and are expected to damage a certain region if introduced
Hemolymph	The fluid in the circulatory system of insects similar to blood
Import	To bring goods and/or services into a country from other locations
Incised Margin	Leaf margins that are cut deeply, sharply and irregularly
Insect	A small arthropod animal that has six legs, three main body sections, antennae and generally one or two pairs of wings
Introduced Species	Species living outside its natural habitat due to human interaction
Invasive Species	A non-native species that causes harm to an environment, humans, animals, or plants
Jointed Legs	Arthropod legs that have many joints for easier movement
Lanceolate	Long and skinny leaves that resemble a spearhead
Larvae	The wingless, feeding stage of an insect that undergoes complete metamorphosis
Larval Galleries	The winding tunnels carved under tree bark as beetle larvae feed, girdling the tree; usually filled with frass and sawdust

Leaf Shape	The overall shape and geometry of a leaf
Leaf Wilt	The loss of rigidity in non-woody parts of plants
Lobed Margin	The rounded, deep indentation of a leaf edge
Mandibles	Mouthparts of insects and anthropods used for biting and chewing
Margin	The structure of the leaf's edge
Metamorphosis	The process of transformation an insect or amphibian will go through into an adult form
Mitigation	Reducing the severity of the damage caused by invasive species
Native Species	Organisms in a particular region that evolved there over a long period of time
Non-Native Species	Organisms introduced to an environment or region in which they did not evolve
Nymph	An immature stage of incomplete metamorphosis; resembles adult
Obovate	An oval leaf that is narrow at the bottom and broad at the top
Opposite Arrangement	The arrangement in which leaves emerge from the stem in pairs
Outer Bark	The outermost part of a tree that protects against injury or damage
Oval Leaves	Leaves that are generally rounded and shaped like an oval or egg
Oval Trees	Trees with a short trunk that branches into a dense, round crown
Ovate	An oval leaf that is narrow at the top and broad at the bottom
Ovipositor	An organ used by arthropods for the laying of eggs
Palmately Compound	A leaf that has multiple leaflets radiating from the leaf stem
Papery Bark	Bark that is very thin and peels easily off the tree in large sheets
Pathway	A method through which a pest is introduced into an area
Phloem	Inner bark that carries food from the leaves to the rest of the tree
Pinnately Compound	A leaf with multiple leaflets arranged to look similar to a feather
Pith	The soft middle section of the tree used for storage and support
Plated Bark	Bark that has large, thick chunky scales
Prevention	Keeping invasive species out of a region
Proboscis	A long thin tube that forms part of the mouth of some insects (butterflies) used for sucking up food
Pupa	The life stage of some insects characterized by a hard protective coating such as a chrysalis in butterflies
Root	Section of tree primarily underground that anchors the tree to the ground and absorbs water and nutrients
Rough Bark	Bark that is furrowed and rough to the touch
Round Tree	A stocky tree with branches that form a circular crown shape

Samara	A type of fruit that is winged with a papery tissue
Scaly Bark	Bark that has small thin scales that often peel away
Segmented Body	The division of some animal and plant bodies into segments
Serrate Margin	A leaf having edges notched like a saw
Shaggy Bark	Bark that peels off in large, thick strips
Simple Leaf	A single leaf blade attached to a stem
Sign	The observation of an actual pest or part of a pest; the evidence a pest leaves behind (for example: beetles, larvae, frass, galleries)
Smooth Bark	Bark that has no raised texture, ridges or crests, giving it an almost skin-like appearance
Smooth Margin	A leaf margin that has no teeth or lobes
Species	The smallest unit on the Tree of Life; members of a species all share the same common and scientific name
Spiracles	The openings in an insect's exoskeleton that allow air to enter
Spreading Tree	A tree whose limbs primarily grow horizontally
Stinger	A sharp organ that is usually connected with a poison gland
Stylet	A piercing mouthpart used to help suck liquids from tissue
Survey	Collecting information about the presence or absence of a target pest and its native host plants; often through trapping or visual inspections of host material
Symptom	A physical feature of the host tree that indicates pest infestation and damage (for example: leaf wilt, bark splits, branch dieback)
Taxonomist	A biologist that organizes species by evolutionary relationships
Thorax	The part of the arthropod body between the head and abdomen that includes the circulatory and respiratory systems
Triangular	A tree with a broad base and narrow crown, like a pyramid
True Bug	Insects with piercing and sucking mouthparts
Trunk	The main stem of the tree that provides support for the crown
Vase Tree	Trees that are wider at the crown than at the base of the branches
Vector	An organism that carries and spreads a disease
Warty Growth	Trees that contain abnormal growths that look like bubbles
Weeping Tree	A tree with soft, limp branches that bend towards the ground
Whorled Arrangement	More than two leaves or branches radiate from a single point
Wings	A number of specialized, paired appendages that enable some animals to fly; sometimes adapted for defense or finding a mate
Xylem	The tree layer that carries water and nutrients from the roots to the leaves