DISEASES AND PESTS OF TREES

Insects, pests and diseases have always been part of the forest environment. There was no real effort to manage these disruptive influences in the forests, however, until long after European settlers arrived in North America. During this period in history, the forests of this continent seemed much too vast to raise concerns over shortages. Even damage to the forests caused by insects, pests and diseases seemed insignificant. Today we see these forests as finite resources that may be depleted if careful oversight and management practices are not used to protect and maintain them.

OBJECTIVES

After completing this chapter, you should be able to

- distinguish between biotic and abiotic diseases
- describe symptoms of heart-rot diseases and explain their significance to the forest products industry
- explain the roles that fungi play in causing diseases of trees
- describe symptoms of the canker diseases and identify some control methods used in the forest industry
- describe symptoms of the rust diseases and identify some control methods used in the forest industry
- name and describe some forms of abiotic diseases in trees
- identify symptoms of vascular wilt infections in trees and recommend a method for controlling these diseases
- name the most important classes of destructive forest insects, and describe the nature of the damage they inflict upon trees
- distinguish between biological control and chemical control of insects and list some examples of each control method
- discuss merits of integrated pest management (IPM) and genetic engineering as insect control methods for the future
- identify other pests that damage or kill trees, and suggest methods for controlling them.

TERMS FOR UNDERSTANDING

abiotic disease
biological control
biotic disease
brown rots
canker
chemical control
conk
cutting cycle
depredation hunt
disease
fruiting body
fungi
genetic engineering
heart-rot
insecticide
IPM
mechanical control
parasites
parthenogenesis
recombinant DNA technology
rhizomorphs
rodents
root graft
rotation age
rust
saprophytes
vector
white rots
wilt

DISEASES

All living organisms are affected by destructive disorders that interfere with health or cause illness. When a particular disorder occurs that can be traced to a specific cause with consistent symptoms, it is called a **disease**. A disease has predictable symptoms, and causes of the disease are the same in each occurrence. A disease caused by living agents of infection such as bacteria, fungi, viruses, microplasmas, parasites or nematodes is described as a **biotic disease**. A disease caused by a non-living factor or condition is an **abiotic disease**.

The most destructive agents of disease in the forest are the **fungi**. These organisms are thread-like plants that lack chlorophyll. Since they cannot make their own food, they obtain their nourishment from other organic materials. Fungi that obtain nourishment from living

organisms are called **parasites**. These are organisms that live in the tree and obtain their nourishment from the tree, but they do not contribute to the good of the tree. Fungi that obtain their nutrients from dead organic materials are called **saprophytes**. These organisms perform the useful function of converting dead vegetation to humus, but they also invade the heartwood and other mature tissues of living trees. Nearly all fungi that affect trees are saprophytes.

Biotic Diseases

Wood rots are diseases that occur when fungi cause decay in trees. Two types of wood rot are known to occur, and each type utilizes a different decay process. The least damaging are the **white rots**. The fungi that cause white rots break down both the cellulose and lignin components of cell walls. The **brown rots** occur when decay fungi break down the cellulose in the cell walls. It is estimated that over 70% of all timber losses due to forest diseases is caused by heart-rot which is a form of brown rot.

Heart-rot

Fungi are responsible for **heart-rot** which is the decay of the core of deadwood that accumulates at the center of mature trees. This disease occurs when fungi invade the heartwood. The sapwood of young trees is usually resistant to wood rot fungi; however, the heartwood no longer sustains the flow of sap, and it becomes vulnerable to infection. As this disease progresses, the trunks of affected trees become hollow and weak. Many of these trees are blown down by wind in the later stages of heart-rot. Timber harvested in the early stages of heart-rot requires trimming to eliminate diseased wood, but entire sections of badly infected logs must be discarded because the diseased wood is of little or no value. This disease causes greater losses in North American forests than any other.

The presence of a fungus infection in a tree is sometimes difficult to detect on the outside of a tree. There are some external indicators which indicate that decay is present in a live tree. One of these is the presence of a specialized growth on the trunk of a tree. A **conk** is a growth that arises from an infection caused by fungi inside the tree. It is a fruiting body filled with the reproductive spores from a growth of fungus.

Science Profile: Fungi

A fungus is an organism consisting of specialized cells, but it lacks chlorophyll for making its own food, and it has no way to eat the nutrients needed to sustain life. All fungi are parasitic organisms that derive their nutrients by absorbing them from other living things or from dead organic material. These organisms release their digestive juices on the materials in their environment, and these food sources are digested outside the cells of the fungus. When digestion is complete, the fungus absorbs the nutrients released by this process. Mushrooms and molds are examples of common fungus forms. A fungus reproduces by forming a **fruiting body**, a reproductive structure that releases spores into the environment. A spore is capable of growing into a complete fungus.

The most effective way to deal with decay in timber is to try to prevent infections that cause decay. Fire prevention is important in preventing decay and rotting of trees, because the scars sustained around the bases of trees during a fire become entry points for fungi infections. Other silviculture practices for dealing with rot in trees include reducing the **rotation age** or maturity stage at which a stand of trees is harvested. For example, if a serious problem exists with heart-rot in a stand of timber harvested at 80 years of age, a reduction to a rotation age of 65-70 years in the next generation of trees may solve the problem.

Another strategy to reduce rot in a forest is to increase the frequency of harvesting in forests of mixed ages. Reducing the **cutting cycle** from 25 to 20 years could result in immature problem trees being removed from the stand during the regular harvest cycle along with mature timber. This improves the chances for forest managers to prevent the spread of fungi infections in the forest.

Root Rots

The most important disease agents associated with root rots are fungi. Root rots are hard to control because they are difficult to detect. Some fungi attack the succulent roots of young trees, while other fungi destroy the woody tissues of mature roots. Destruction of any part of the root system of a tree will cause the tree to decline in vigor and in health. When a large part of the root system of a tree is damaged or destroyed, the tree is likely to be killed. The shoestring root rot

fungus is a common forest disease in many forests of the world. This fungus becomes established in a stump or in the roots of a tree and then, using the stump or the plant roots as a food source, the fungus sends out thin strands of tissue called **rhizomorphs**. These strands enter into the surfaces of any tree roots they encounter where they establish new colonies of fungi. It is also possible that new trees become infected when their roots touch the roots of infected trees.

Butt rot and root rot are caused by fungi of many kinds. Infection spreads when fungal spores become wind-borne and land on freshly cut tree stumps. When conditions are favorable, the stumps become colonized by the spores, and a new cycle of infection begins. Each individual fungi causes specific symptoms, and in some instances a particular fungi is more harmful to one kind of tree than it is to another. Among the methods of control used is the treatment of freshly cut stumps with applications of borax or other similar materials. Some attempts have been made to reduce fungal infections by removing stumps from the area. Some fungi do not appear to damage trees. These organisms are sometimes intentionally introduced to colonize stumps in competition with more harmful fungi.

Some fungi cause the wood to become stained and discolored. This usually happens when moisture is present and temperatures are warm. This is a problem with logs that have been cut and stored to await processing. Logs stored in ponds of water or kept wet by sprinkler systems are less affected by these fungi than logs that are allowed to dry quickly. This is because less oxygen is available to the fungi when a log is wet. Wet logs also tend to produce lumber with fewer cracks due to the center of the log drying out at a similar rate to the outer layers of the log. Cracks occur in the logs as the outer tissues shrink faster than the inner core. Cracks in the log surface provide points of entry into the log for fungi.

Some fungi attack soft tissues of the tree such as the cambium and bark causing them to die. An infection that kills patches of tissue on the trunk or branches of a tree is called a **canker**. The cankers affect trees of both the conifer and hardwood varieties.

Cankers

Two general types of cankers, annual and perennial, are known to infect trees. The fungi that cause most cankers enter the tree through wounds in the bark injuries to the tree trunk or branches from any source make the tree susceptible to canker infections. Annual cankers move rapidly through the bark and cambium of a tree. When the tree is girdled by the infection, it soon dies.

Perennial cankers persist in the tree for several years. They cause lesions along the edges of the infected areas that produce callus tissue. This tissue causes damaging growths to develop that extend into the woody tissue causing it to decay and become weakened. These growths also result in large lesions on the outside of the tree. The best known control method for most cankers is to remove infected trees from the stand, eliminating the source of infection.

Rusts

A class of plant diseases that results in spotted red or brown discoloration of the stems and leaves is known as **rust**. The discoloration comes from the spores of the fungi that cause this disease. These diseases attack trees in different ways. For example, rust infections may invade the cones, needles and stems of some conifer trees, but they may infect only the leaves of certain hardwoods.

All fungi that cause rust diseases spend part of their life cycles on two different unrelated host plants. In addition to tree hosts, the fungi that cause white pine blister rust also infect cullant and gooseberry bushes. An intense effort was made over a period of many years to eliminate fungal infections by destroying gooseberry and currant bushes throughout the forests where this fungus is a problem. This proved to be impossible, and the effort was later abandoned.

White Pine Blister Rust

Fungi organisms that cause this disease produce up to five different spore stages. Some of these stages infect trees, and others infect currants and gooseberries, the secondary plant hosts. This disease was introduced in the U.S. nearly 100 years ago on white pine planting stock imported from Europe. It is of Asian origin, and now infects trees in many regions of the world. The North American white pine tree varieties proved very susceptible to this disease. The best hope for control is to use resistant strains of plants to regenerate white pine forests.

Fusiform Rust

The fusiform rust disease organisms infect southern pines such as the loblolly and slash pines. The fungi that cause this disease also infect oak trees. When the original pine forests containing fusiform rust resistant populations of longleaf pine were cut, the oak trees increased in abundance, and the loblolly and slash pines were planted to speed forest recovery. These management choices favored the increase of the disease. Current efforts to control this disease include the use of fungicides in forest nurseries, and restoring forests with resistant planting stock.

Vascular Wilts

Fungi of some types invade and grow in the vessels of the xylem tissue where they block the flow of water in the trunk and branches of the tree. This kind of disease is called a **wilt**. The Dutch elm disease that destroyed many of the American elm trees in North America is this kind of disease. Oak wilt is similar to the Dutch elm disease; however, it is a native disease to which oak trees are vulnerable.

Some wilts are highly infectious diseases that easily spread from tree to tree. It is believed that beetles and other insects that eat tree sap play roles in spreading this disease. The disease also spreads through root connections that occur naturally between trees when roots grow together. Such a connection between roots is called a **root graft**.

The class of diseases known as wilts is of greatest importance in angiosperms (flowering trees). The leaves of affected trees tend to show symptoms of water loss such as limpness. This is due to the blockage of the vessels that carry water and nutrients to the foliage of the tree. The most important of the wilts are Verticillium wilt, Dutch elm disease and oak wilt.

Control methods for vascular wilts include using care to avoid injuries to trees that allow fungi to infect them. Other control efforts include the removal of affected trees, and trenching or fumigating with chemicals between trees to break root connections. Some success has been observed when trees are injected with fungicides, but the best long-term solution is probably the development of disease resistant trees.

Other disease organisms also affect the trees in North American forests. Among them are infections caused by bacteria, nematodes, fungi and viruses. Some insects and disease organisms even work together to invade trees. For example, some wood wasps are known to carry fungal spores in their egg sacs that are deposited in the tissues of trees along with the eggs of the wasp. In this manner, the fungus invades the tunnels created inside the tree by the wasp larvae. Still another disease agent is the seed of the dwarf mistletoe, a parasitic plant.

Dwarf Mistletoe

Dwarf mistletoe is a plant that grows out of the branches of conifer trees. Despite the ability of the mistletoe plant to engage in photosynthesis, a tree that is host to mistletoe is seriously stunted in its growth, and sustains high losses in timber production. This disease ranks second behind heart-rot in the damage it causes to conifer forests in the western United States. It also affects the black spruce in eastern forests and in the Great Lakes region. Dwarf mistletoe spreads by seeds. These plants are parasites that grow directly into the tissues of the tree branches and stems from which they draw nourishment. Control of this forest disease is mostly done by physically removing or burning affected trees or their parts.

Abiotic Diseases

Abiotic diseases include conditions that cause damage to trees such as drought, heat, cold, poisons, nutrient deficiencies, or weather related factors. These conditions are not contagious, although they may affect large numbers of trees in an area.

Sunscald is a condition in which the bark of trees is damaged by direct sunlight. This condition may follow logging or thinning operations that allow direct sunlight to penetrate below the foliage of the forest canopy. Damage can be severe enough to interfere with the function of the bark. Similar damage can occur due to freezing temperatures following a few warm days in the late winter or spring seasons.

Long periods of drought are known to cause declines in deposits of hardwood in the annual rings of a tree. A condition that causes the loss or death of plant tissue is called blight or dieback. Symptoms include wilting of foliage that may be severe enough to cause branches or even the entire tree to die.

Trees require nutrients of the proper kinds and in the right amounts. When nutrients such as phosphorous are missing or too little is in the soil, trees suffer deficiency symptoms, and they are unable to sustain normal growth and development. Too much of a particular nutrient can poison the tree. Both of these conditions are nutritional diseases.

Air pollution is a source of abiotic disease. Sulfur and nitrogen compounds are often given off as exhaust fumes by motor vehicles and by industrial factories. When these materials combine with raindrops, weak acids are formed. These acids are destructive to all kinds of plants, especially trees. The foliage of affected plants is sometimes damaged so badly that a decline in photosynthesis appears likely. One serious effect of abiotic diseases is that trees become weak enough that biotic disease agents are able to invade and become established in them.

INSECTS

Bark Beetles

The mode of action of the bark beetles is to bore an entrance hole through the bark of a tree. Tunnels are cut through the area between the bark and the woody part of the tree trunk. After mating, the females lay their eggs inside the entrance tunnels or in a series of tunnels that have been excavated beneath the bark to form galleries. The larvae feed upon the phloem and xylem tissues of the tree. Sometimes they completely girdle the tree beneath the bark interrupting the flow of nutrients through the tree. These trees eventually die.

Trees that are healthy and vigorous have a defense mechanism against beetles. Resins and sap floods the tunnels of the adult beetles causing them to drown. Trees that are past maturity may not have enough sapwood to combat these pests. They are more vulnerable than the young trees to the bark beetles.

Some beetles carry disease organisms in their bodies, and they distribute them as they move between trees. An insect or other organisms that spreads disease organisms in this manner is a **vector**. One example of the spread of a deadly disease by a vector is the Dutch elm disease that has been spread by bark beetles. This disease has killed nearly all of the American elm trees in many regions of North America.

Defoliators

Some insects do damage to trees by feeding on the leaves and needles. A large population of defoliators such as caterpillars, webworms, sawflies or tussock moths can completely remove the foliage from a tree. Sometimes many of the trees in an area are defoliated by insects.

The loss of leaves or needles affects different trees in different ways. Complete defoliation of some species of pines with needles that persist from year-to-year may be killed by defoliation. This is partly due to their dependence for plant food on foliage that was accumulated for several years. Some broad-leaved trees, such as the Yellow Birch, Black Maple and Sugar Maple, may also be killed in a single season if they are defoliated during midsummer. Most other broad-leaved trees and deciduous needlebearing trees are able to withstand defoliation for several seasons before they are killed.

Some defoliating insects eat only the tissue inside leaves. Some damage leaves by chewing tunnels through the internal leaf tissue. Others, such as the skeletonizers, eat all of the soft tissue inside the leaves. All that remains of these leaves are the leaf veins.

Defoliators often weaken trees enough that they can no longer resist deadly diseases and other insects. Sometimes the secondary invasion of the tree by disease organisms or insects is fatal.

In many instances, terminal and radial growth of trees is seriously reduced. When such factors as temperature, light, moisture and wind are favorable to defoliating insects, they are capable of rapid and massive population growths. When this happens, large areas of forest land may be defoliated by these insects.

Root-Feeding Insects

Insects that feed on tree roots cause death to trees, or stunt their growth by causing damage to their root systems. These insects consist mostly of wire worms and white grubs, both beetle larvae. The wire worms are immature forms of a group of insects

known as click beetles and the white grubs are larval forms of May beetles and June beetles. These insects feed on the roots causing young plantings of trees to be stunted or killed.

Another type of root insect is the weevil. Mature Pale weevils lay eggs in the stumps of freshly harvested pine trees. When the adult weevils emerge from the stumps, they eat the bark off the roots and stems of young seedling trees. Entire plantations of young trees have been killed in this manner.

The pine root collar weevil infests the trunks of some pine species in the area of the root collar where roots are attached to the tree trunks. It feeds upon this tissue causing it to become weak. Damaged trees sometimes break off level with the ground during wind storms, and others are often severely stunted in their growth. All of the root insects are capable of killing trees.

Terminal-Feeding Insects

The terminal feeding insects cause serious deformities to trees by killing the meristem tissue located on the tips of growing branches and the tips of the central leaders on the main tree trunks. A tree that sustains this kind of damage usually responds by sending up a lateral shoot to take its place. This results in tree trunks that are crooked, and the quality and value of the lumber they produce is poor in comparison with lumber produced from straight tree trunks. These insects seldom kill a tree, but they sometimes cause the main trunk of a tree to fork, producing two leaders or trunks.

Insects responsible for damage to shoots and buds include the pine tip moths and the white pine weevil. They cause their worst damage in stands of trees that are about the same age. They are especially destructive in freshly planted and immature tree plantations. This is probably because an abundant food supply is available to terminal feeding insects when all of the trees are in the early stages of growth.

Sucking Insects

Sucking insects that infect trees include the aphids, mites, leafhoppers, plant lice, scales, cicadas and spittlebugs. All of these insects are equipped with mouth parts that penetrate young immature shoots, twigs and foliage to feed upon the resin and sap of the tree. Large concentrations of these insects can cause the growth rates of trees to be reduced due to the continual loss of plant nutrients. The balsam wood aphid is an exception. It frequently kills the balsam fir tree.

Aphids and plant lice tend to feed upon the softer plant tissues. They eat sap, and they secrete a sticky, sweet liquid called honeydew. The honeydew falls down beneath the feeding area attracting ants, wasps and flies to the area. The honeydew also provides nutrients for a fungus that grows rapidly and produces black spores. The black colored spores soon cover the surface of the tree interfering with light absorption by the leaves. In the case of the white pine and some other trees, many of the leaves eventually shrivel, die and fall off.

Science Profile: Parthenogenesis

Aphids are a type of sucking insect that has an unusual mode of reproduction. Adult males and females mate in the fall and the females lay their shiny black eggs on the individual needles of white pine trees. The eggs hatch in the spring, and all offspring are females that have no wings. These aphids give birth to live young throughout the spring and summer seasons. Many generations of aphids are produced with no males present. This kind of reproduction in which females do not mate with males to produce offspring is called **parthenogenesis**. As the fall season progresses, both male and female aphids are produced. These insects mate and the females lay eggs to preserve the species until the next growing season.

The scale insects are unusual in that the female secretes a large round scale made of wax. The insect lives beneath this scale where she eats and reproduces live offspring called crawlers. Some of these crawlers are carried to new trees by strong winds; others remain on the tree where they were born. These insects feed by inserting their mouthparts into a tree branch, and drawing nutrients from the tree through a long hollow tube. Female scales lose their legs when they molt, and they are permanent residents of the tree where they live. They also excrete honeydew, and the fungus that feeds on the honeydew eventually causes leaves to die and fall from the tree in a similar manner as was observed with the aphids.

Mites infest leaf surfaces where they suck the cell contents out of leaf cells. The loss of

chlorophyll eventually causes the leaves to become brown in color. Some kinds of mites spend part of their lives inside of tree leaves where they eat leaf tissue. These mites are sometimes grouped in a distinct grouping of their own. In most instances, trees sustain more damage from fungus infections and loss of chlorophyll than they do from the loss of fluids.

Wood Borers

Wood boring insects attack the heartwood and sapwood of trees weakened by stress or that are overly mature. Sometimes they even destroy wood in harvested trees not yet processed. They are the most damaging insect pests in North American forests. They damage trees by tunneling through the mature wood as they eat. Most of these insects hatch from eggs deposited in cuts in the bark of the tree. After they hatch, they burrow or mine in the phloem tissue. Eventually they work their way through the woody tissue to the center of the tree. Their tunnels become quite large, and the wood of affected trees is seriously damaged.

Among the wood boring insects are two types: the long-horned-round-headed borers and the short-horned-flat-headed borers. The antennae of the long-horned variety are extremely long. These insects can also be identified by the round holes they make in a tree. The short-horned-flatheaded borers leave and enter their tunnels through oval-shaped holes.

The white spotted sawyer is a long-horned-round-headed borer that feeds on pine, spruce and fir trees. The bronze birch borer is a short-horned-flat-headed borer that is a serious threat to birch trees throughout North America. There are many other kinds of wood boring insects in North America. Some of the most serious of these forest pests are the mountain and southern pine beetles, Ips engraver beetle, Carolina pine sawyer, and the flat-headed apple tree borer.

One problem that impacts the control of insect pests is the vast amount of territory and the rugged terrain that some forests occupy. It is sometimes very difficult to get equipment to insect infested trees. Another problem that forest managers face is the tendency of some citizen groups to file legal proceedings to prevent the use of pesticides and other control measures on public lands. Some people believe that nature will seek its own balance, and that the results will be superior to management efforts by humans.

Career Option: Entomologist

An entomologist is a person who specializes in the branch of biology that deals with insects. A career in this field usually requires an advanced degree in biology or a related science, and a specialty in entomology. The work of an entomologist will require gathering research data through fieldwork, and using the data to learn more about the relationships of insects to the environments in which they live. Entomologists use their knowledge of insect anatomy, feeding habits, and life cycles to discover ways of strengthening populations of useful insects while controlling or reducing populations of harmful insects.

Management of the forest environment to minimize insect damage to trees can be done in several ways. One form of forest insect control is the removal of dead or dying trees for timber or firewood. This is a form of **mechanical control** of insect pests. It is not very effective at reducing harmful insect populations because most of their damage is done before the tree dies or becomes weakened. It is useful, however, in reducing localized pockets of insect infestations. Perhaps the greatest potential value that can come from removing trees that have sustained serious insect damage is that removal of weakened trees will reduce the risk that a serious disease will gain a foothold in the area. Many serious tree diseases get started in trees that have first become weakened by insect damage. Trees in a weakened condition do not have as much natural resistance to disease as they do when they are healthy.

Checks and balances are part of nature, and the forest environment is no exception. Birds provide the most valuable form of insect control in forests. Huge numbers of forest insects are eaten every day by birds. Of particular importance as insect predators are the woodpeckers, chickadees, nuthatches and creepers. Each of these birds lives in the forest and eats insects as a major component of its main diet.

Profile in Nature: Woodpeckers

The woodpeckers are important in forest environments as natural predators of wood-boring insects. They are well adapted to this role with chisel-like beaks and strong skulls

that allow them to hammer out holes in tree trunks as they search for insects or prepare cavities in trees for nesting. Woodpeckers also have long thin tongues with which they extract insects from their holes in the trunks of trees. Most woodpeckers have feet that are adapted to clinging to tree trunks. Two toes face forward and two toes face backward. Their stiff tail feathers are used as props against the tree trunks. This bird has evolved into a highly specialized insect predator.

Some forest insect pests are killed and eaten by other insects. These insect predators may be natural to the environment or they may be introduced to forest environments by forest managers in attempts to control problem insects. The use of this kind of control practice is usually not disruptive or dangerous to other creatures in the environment. Some examples of predatory insects include the ladybugs and ants.

One kind of insect helpful in reducing harmful insect populations is the parasitic wasp or fly. These insects lay their eggs within or on the bodies of specific insect hosts. When a natural enemy of a harmful insect can be identified and introduced into a forest environment, some control of the harmful insect species can usually be attained. In most cases this kind of insect control does not harm the populations of beneficial insects. Harmful insects can sometimes be controlled by introducing microorganisms to forest environments that cause diseases. Pathogenic or disease causing organisms include viruses, bacteria, fungi, protozoa and others. The use of predators and disease organisms to control insect pests is a **biological control** method.

Chemical control is accomplished by applying chemicals to the environments infested by harmful insects. A chemical used to kill insects is called an **insecticide**. This type of control is very effective at reducing insect populations. The weakness in this insect control method is that chemical controls often kill the beneficial insects along with the harmful ones.

Some political action groups contend that any use of chemicals is unsafe for birds, humans and wildlife species that live or work in the treated area. Insecticides used in the United States require rigorous testing under a variety of conditions before manufacturers are allowed to market them. The burden of proof that they can be safely used is on the company that owns the patents, and millions of dollars must be invested in scientific testing before these materials are approved for use.

Chemicals used according to the directions provided by the manufacturer can be used effectively and safely. This should not be interpreted to mean that insecticides are safe to use and that there are no hazards involved. Almost any substance can be abused when used in excess or under conditions for which it has not been tested. Good judgment and careful attention to detail is required of those who apply insecticides and other chemicals to forest environments. Any real or perceived danger due to the use of chemical insecticides and similar materials can generally be traced to their misuse . . . not their use.

Despite known hazards that accompany the use of insecticides, such as the potential destruction of populations of useful insects, the use of insecticides in forests is sometimes the best choice among insect management options available to forest managers. For example, when populations of pine beetles or gypsy moths reach epidemic levels, the use of insecticides is the only known method of insect control that can immediately reduce the insect population to a level that can be managed in other ways. It is also possible to apply insecticides in remote areas or in forests located on steep or rugged terrain by applying the insecticide with airplanes or helicopters. It is important to make sure that the amount and type of chemical material applied to the forest is well within the guidelines for safe use of that particular product.

A relatively new approach to control of insects and other pests is gaining acceptance in the agriculture and natural resource industries. It is called integrated pest management or **IPM**. It is a method of controlling harmful insects and providing protection to useful insects. It is proving to be a more practical approach to insect control than mechanical, chemical or biological control methods when they are used separately.

An integrated pest management program makes use of all pest control strategies available including the use of limited applications of chemicals. IPM depends mainly on the use of natural insect enemies and other forms of control to reduce harmful insect populations. Total destruction of harmful insects is not the objective of IPM. The objective of this kind of control is to keep some of the pests alive as a food source for their natural enemies. IPM

strives to establish a natural balance between harmful insects and their natural enemies at population levels low enough to minimize insect damage.

Future insect control is likely to include the use of genetic engineering techniques to modify the genetics of trees making them resistant to insect pests. This is accomplished using **recombinant DNA technology**. This procedure makes it possible to transfer a resistant gene to a particular kind of pest from a naturally resistant plant to a plant vulnerable to the pest. This is done by cutting a desired gene resistant to an insect pest from the chromosome of the resistant plant and inserting it into the chromosome of a nonresistant plant. Many years will be required to research the genetics of different species of trees and to create insect resistant strains of each different kind of tree. It will also take a long time to produce enough genetically altered trees to make large plantings in the vast forests found in North America and around the world. The use of science principles and technologies to modify the genetics of a plant causing it to express genetic resistance to pests and diseases is part of a growing science known as biotechnology. The process by which plant genetics are changed is called **genetic engineering**.

PESTS

In addition to the insect pests, other creatures sometimes cause serious damage to forests. Among the gnawing mammals that injure trees are mice, voles, gophers, rabbits, beavers and porcupines. These animals are also classed as **rodents** by most scientists. Other animals that sometimes become pests in tree plantations are members of the deer family because they eat the young shoots and twigs found on the growing tips of tree branches and central leaders.

Most of the damage inflicted on trees by mice, voles and rabbits occurs as they gnaw on the bark in plantings of young trees. During this stage of development, the tree can easily be killed if the cambium and phloem areas beneath the bark are damaged around all or most of the trunk. Gophers inflict damage by eating the roots of young trees. One of the most obvious methods of controlling rodents in tree plantations is to remove the plant cover from the area that these rodents require for shelter. Another method of control is to place poison baits in the tunnels of gophers or in strategic areas where the intended pests will find and eat them. It is important to be as selective as possible in the placement of baits to avoid deaths and injuries to birds and animals other than those for which the poison is intended.

Rodents such as porcupines cause extreme damage to most coniferous forests by eating the bark of trees. This is a climbing animal best known for its protective covering of sharp quills, but a porcupine can and does cause serious damage and death to trees. During the summer season, porcupines feed on a variety of plants, but during the winter season much of their diet consists of the bark of trees.

The beaver is a rodent that is destructive to the trees in the immediate vicinity of its territory. It is generally conceded, however, that the environmental value of the dams and ponds that it creates more than makes up for the trees it uses for food and structures. The stored water behind a beaver dam raises the water table in the area contributing to an environment favorable to many species of wild plants and animals.

Deer and other large game animals can cause problems in nurseries and young tree plantings when they enter sensitive areas in large numbers. In some instances it is possible to discourage these animals from entering or feeding in an area. Small muslin bags of blood meal, tied among the branches of young trees, emit an odor offensive to deer. This practice can be effective in plantation plantings when there is an adequate food supply available to the animals in other locations. During times of drought or short supplies of food due to natural disasters such as fires, the only effective control methods for deer are high fences or depredation hunts.

A **depredation hunt** is a legal hunting season established by a state fish and game agency to reduce a herd of browsing animals causing serious damage in an area. Fences for deer, elk and other large animals are usually too expensive to be considered as control measures unless the tree plantings they are intended to protect are high value species.

LOOKING BACK

Diseases of trees are of two types known as biotic and abiotic diseases. Biotic diseases are caused by living organisms and abiotic diseases are caused by non-living factors in the environment. Fungi are the most harmful disease organisms in forest environments, because they cause many of the diseases found in trees. The worst of these fungal diseases is heart-rot. Other important tree diseases include cankers, rusts, rots, wilts and dwarf mistletoe.

Insects are serious forest pests that cause heavy timber losses. Forest insect infestations are managed using mechanical, biological and chemical control methods. Integrated pest management (IPM) along with insect resistant varieties of trees are considered to be the best insect control methods of the future. Other pests that affect forest production include rodents and sometimes deer.

QUESTIONS FOR DISCUSSION AND REVIEW

Essay Questions

1. How are biotic diseases of plants different than abiotic diseases?
2. Describe the symptoms of the heart-rot diseases, and explain their significance to the forest products industry.
3. What roles do fungi play in causing diseases of trees?
4. What are the disease symptoms of canker diseases in trees? How are these diseases controlled?
5. Describe the symptoms of the rust diseases, and identify some control methods that are used in the forest industry.
6. Identify the symptoms of vascular wilt infections in trees, and recommend a method for controlling these diseases.
7. Name and describe some forms of abiotic diseases in trees.
8. What classes of insects are harmful to forests, and what kinds of damage does each class inflict on trees?
9. Describe and give examples of biological and chemical control methods for forest insects.
10. How are genetic engineering and integrated pest management practices used to control insects?
11. What other kinds of pests damage or kill trees, and how can they be controlled?

Multiple Choice Questions

1. A disease caused by a living organism is:
   a. organic
   b. abiotic
   d. pollution
   e. biotic

2. Wood rots are diseases that occur in trees due to organisms called:
   a. fungi
   c. rhizomorphs
   b. cankers
   d. rusts

3. Fungi are organisms that lack chlorophyll to make their own food, so they obtain nourishment from other living things. For this reason fungi are known as:
   a. endomorphs
   c. parasites
   b. rhizomorphs
   d. cankers

4. When the roots of trees touch each other, they sometimes grow together creating connections between their roots that are known as:
   a. rusts
   c. wilts
   b. root grafts
   d. rhizomorphs

5. An example of a disease known as a wilt is:
   a. White Pine Blister Rust
   c. heart-rot
   b. Dutch Elm Disease
   d. Dwarf Mistletoe

6. A fruiting body is:
   a. a structure that produces spores that develop into fungi
   b. a fleshy structure that surrounds the seeds of a plant
   c. a thin strand of fungal tissue that enters tree roots infecting them with disease organisms
   d. a structure on a tree leaf in which sap becomes fermented to produce honeydew

7. A canker is a plant infection that:
   a. causes red or brown discoloration
   c. kills patches of tissue on the trunk or branches
   b. affects only conifer trees
   d. a painful infection of the gum of a tree

8. An example of an abiotic disease in a tree is:
   a. canker
   b. Verticillium wilt
   c. Mistletoe
   d. sunscald

9. An entomologist is:
   a. a person who studies relationships between living and non-living things
   b. a student of the fruiting habits of trees
   c. a hollow beak-like mouthpart with which sucking insects obtain sap for food
   d. a person who studies the branch of science related to insects

10. Which of the following is not a destructive type of forest insect?
    a. defoliator
    b. terminal feeder
    c. bark beetle
    d. pollinator

11. To which of the following types of destructive forest insects does the scale insect belong?
    a. sucking insect
    b. defoliator
    c. wood borer
    d. root feeder

12. Which of the following animals is not classed as a rodent?
    a. gopher
    b. mink
    c. mouse
    d. porcupine

LEARNING ACTIVITIES

1. Take a walking field trip around the neighborhood and collect insect specimens suspected of causing damage in forest environments. Identify each of the insects collected, and study how each interacts with the forest environment. Suggest ways that each of these insects might be controlled to prevent damage to trees. Assign students to repeat this exercise by gathering and displaying their own insect specimens.

2. Invite the county extension educator or a forest or park service official to discuss local forest and ornamental tree problems with members of the class. Discuss procedures for gathering plant materials from diseased plants that will prevent the diseases from spreading to new areas.