COURSE CODE: FRM 513

COURSE TITLE: Forest Diseases, Pests and Forest Protection

NUMBER OF UNITS: 2 Units

COURSE DURATION: Two hours per week

COURSE DETAILS:

Course Coordinator: **Dr. Adetogun Adekunle Clement** *B.Sc; M.Sc; PhD*

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Office Location:

Other Lecturers:

COURSE CONTENT:

Introduction to tree disease concepts ;Historical perspective of plant diseases ;forest pathology in relation to plant pathology ;role of tree diseases in natural ecosystems ;importance of tree diseases ;disease in relation to other disorders of plants ;symptoms of tree diseases as a reflection of disturbed physiological function ;proof of pathogenicity ; ;categorizing types of tree diseases; recognition of biotic, abiotic, and decline diseases; specific diseases; forest insects; Forest fire

COURSE REQUIREMENTS:

This is a compulsory course for all Forestry Option students in the University. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

Nakasone,K.K.1990.*Cultural Studies and Identification of Wood-Inhabiting Corticiaceae and Selected Hyphomycetes from North America.* Mycologia Memoir No. 15. Cramer.

Nobles, M.K. 1965. *Identification of cultures of wood-inhabiting hymenomycetes.* Can. J. Bot. 43:1097-1139.

Overholts, L.O. 1953. *The Polyporaceae of the United States, Alaska, and Canada.* Univ. of Michigan Press, 466 pp.

Schwarze, F.W.M.R., J. Engels and C. Mattheck. 2000. *Fungal Strategies of Wood Decay in Trees.* Springer-Verlag. 200 pp.

Stalpers, J.A. 1978. *Identification of wood-inhabiting Aphyllophorales in pure culture.* Centraalbureau voor Schimmelcultures, Baarn. Institute of the Royal Netherlands Academy of Arts and Sciences. Studies in Mycology No. 16.

Zabel, R.A. and J.J. Morrell. 1992. *Wood Microbiology: Decay and Its Prevention.* Academic Press. San Diego. 476 pp.

Beal, R.H. 1967. Formosan invader. Pest Control. 35(2): 13–17.

Beal, R.H.; Maulderi, J.K.; Jones, S.C. 1983. Subterranean termites, their prevention and control in buildings. Home & Garden Bull. 64 (rev.). Washington, DC: U.S. Department of Agriculture. 30 p.

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Ebeling, W. 1975. Wood destroying insects and fungi. In: Urban entomology. Berkeley, CA: University of California, Division of Agriculture Science: 128–216.

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LECTURE NOTES

Plants interact with their environment and other organisms in a wide range of ways. The plants most fit to survive are in balance with their environment. In the short run, imbalance caused by the presence of disease agents may produce serious economic and ecologic effects. These are the concerns of the plant pathologist. Therefore, forest pathology is the study of tree diseases and methods of controlling these diseases.

DISEASE IN RELATION TO OTHER DISORDERS OF PLANTS

Disease involves disturbance in the normal physiologic functioning of a plant, has many causes, and exhibits an array of appearances. Plant pathologists do not agree on a precise definition of plant disease. A useful concept of disease should distinguish it from plant injury, from disease symptoms, and from disease incitants (pathogens). There is a major difference between the pathogen-host interaction of a rust fungus and a white pine tree compared to the interaction of a camper-wielded hatchet and the same tree. One is considered disease, the other injury. These are two extremes in a continuum of plant-incitant interactions that are damaging to the plant.

Disease will be defined here as any deviation in the normal functioning of a plant caused by some type of persistent agent. How long must an agent persist in its interaction with a plant to cause disease? This is where the continuum comes in. The hatchet blow is a very short interaction. An air pollutant such as fluoride released suddenly in large amounts as a result of an industrial accident also causes injury. The same pollutant continuously released in small quantities as the result of an ongoing industrial process causes disease. The boundary line between when something causes injury only or results in disease is not particularly important, since the problems that fall into this area can be handled as specific cases. The more important point is to recognize that disease is generally caused by a persistent biotic or abiotic agent.

Any agent that causes disease is called a pathogen. As we shall see, pathogens may be either biotic agents such as fungi or abiotic agents such as air pollution. Some pathogens are parasites, but not all parasites are pathogens. Any organism that lives on and derives nutrients from another organism is a parasite. Only those parasites that cause a disruption in the normal physiological function of the host are called pathogens.

SYMPTOMS OF TREE DISEASES AS A REFLECTION OF DISTURBED PHYSIOLOGICAL FUNCTION

Disease symptoms resulting from the interaction of specific pathogens and hosts are characteristic signatures of the pathogen and host. The plant pathologist can often readily recognize the presence of a specific pathogen based on symptoms alone. Why are symptoms so characteristic?

The symptoms of diseases are expressions of disturbed or abnormal physiology of the host plant. The woody plant has evolved a complex structure to separate and yet tie together various functions necessary for competitive survival. In Fig. 1-1, an elementary understanding of the structure and function of the woody plant is superimposed on the diagrammatic tree. There is a division of function, and therefore a limit to the range of expression, which various parts of trees can produce in response to invasion by pathogens.

Along the right and left columns of the diagram are listed the various abiotic and biotic agents of disease. At the center top a third category of diseases, declines, is tied to both biotic and abiotic agents. The center portion of, the diagram relates the physiological functions of various parts of trees with the general categories of disease.

The biotic pathogens have evolved to fit into specific niches. A fungus that has evolved the capacity to survive by competing with soil microorganisms and the responses of tree roots is most likely to be found causing a disease of the roots. If we recognize the function of roots, we see why root problems produce characteristic symptoms of decay and necrosis of the root system and an overall appearance of mineral deficiency in the rest of the tree. Pathogens that disrupt DNA-directed meristematic cell division result in cancerous-like growths called galls.

Pathogens that parasitize the cambium, phloem, and sapwood xylem cells for available sugars and other nutrients result in the death of the invaded area. Death of a localized stem area prevents secondary growth in the affected area. The bark may change color. A depressed area on the stem results from the lack of stem enlargement in the diseased area. As the stem is being completely girdled by the invasion of an aggressive canker fungus, the roots are the first remote part of the tree to deteriorate. The canker interrupts the production and maintenance of functional phloem.

Heart rot pathogens have evolved the capacity to utilize the cell-wall materials of woody plants (i.e., cellulose and lignin). They differ from saprobic decay fungi in that the heart rot fungus is able to tolerate the dynamic chemical and morphological defense mechanisms of the living stem. The saprobic decay fungi do not compete well against the chemical and morphological defenses of a vigorous living stem. Therefore, they successfully invade dead or dying branches, large wounds" and eventually the dead or dying tree. The effects of decay or rot fungi are to weaken the structural integrity of the stem, roots, or branches.

Vascular wilt pathogens are adapted for survival in vessels of the sapwood xylem. Disruption of xylem vessels by wilt pathogens reduces the capacity of the vessels to translocate water from the roots to the top of the transpiring tree. During hot, dry periods, insufficient water is translocated to the leaves, causing them to wilt and die.

Foliage diseases affect the photosynthetic activity of trees. Viruses induce subtle color changes such as mottling and chlorosis, as well as other morphological and metabolic abnormalities. Obligate parasites such as rust and mildew fungi disrupt photosynthetic activity without causing serious mortality of leaves. Other fungi and bacteria cause necrosis of invaded portions, thereby reducing the effective area of the leaf. Abiotic toxicants, including salt, pesticides, and air pollutants, accumulate in leaves, disrupting or reducing photosynthetic activity.

Chlorosis (yellowing) of foliage may result from the direct effects of biotic and abiotic factors on leaves or the indirect effects of biotic and abiotic factors on roots. The most common symptom of mineral deficiency in plants is chlorosis.

Shoot blight is caused by microorganisms that aggressively parasitize succulent, rapidly growing shoots. These fungi and bacteria are also foliage and canker pathogens. They may gain access to shoots through infection of foliage, flowers, or succulent shoots, and may persist as stem cankers at the base of the infected shoot. The effect of shoot blight on young seedlings is more pronounced because killing the terminal shoot may destroy a great deal of the aboveground portion of the plant. As trees get larger, the killing of a shoot or shoots induces lateral buds to take over and compete for dominance as the new leader. A bushy-crowned tree may result from the inability of one lateral to gain dominance, or from the successive deaths of new leaders.

Reduced growth may occur as a consequence of the effects of anyone or a combination of the problems discussed above. Reduced growth is also a characteristic symptom of decline diseases. Reduced growth may be the only aboveground symptom of some destruction of the root system. But reduced growth is a very subjective symptom, which may not be caused by disease agents. One must keep in mind that the capacity to grow is a combination of the age, genetic makeup of the tree, environmental effects on those genes, and possible pathogen~.

Although the profile of a tree has been emphasized in developing this introduction to disease symptoms as a reflection of disturbed physiological functions, it is appropriate also to think of the functions of a tree in cross section. The tree stem is a complex structure consisting of (1) inner xylem (heartwood), functioning basically for structure; (2) outer xylem (sapwood), for storage and translocation of water; (3) cambium, as the meristematic layer of cells which, by mitotic division, produces xylem cells on one side and phloem cells on the other; (4) phloem, as a region where photosynthetic~ products, produced in the leaves, are translocated down to the stem and roots; and (5) bark, as a protective envelope of dead cells surrounding the living cells and providing a physical as well as a chemical barrier to invasion by microorganisms. Bark cells are produced from a cork cambium (phellogen) layer between the phloem and the bark. As the tree enlarges the cork cambium becomes interrupted. The interrupted cork cambium produces the rough or platy bark characteristic of older trees. This is a rather simplified characterization of the stem cross section, but it gives a framework on which one can impose the activity and effects of various diseases of the stem and branches.

This quick survey of disease as a reflection of disturbed physiologic function is meant simply as an overview. Subsequent chapters provide details regarding the interaction of pathogens and hosts.

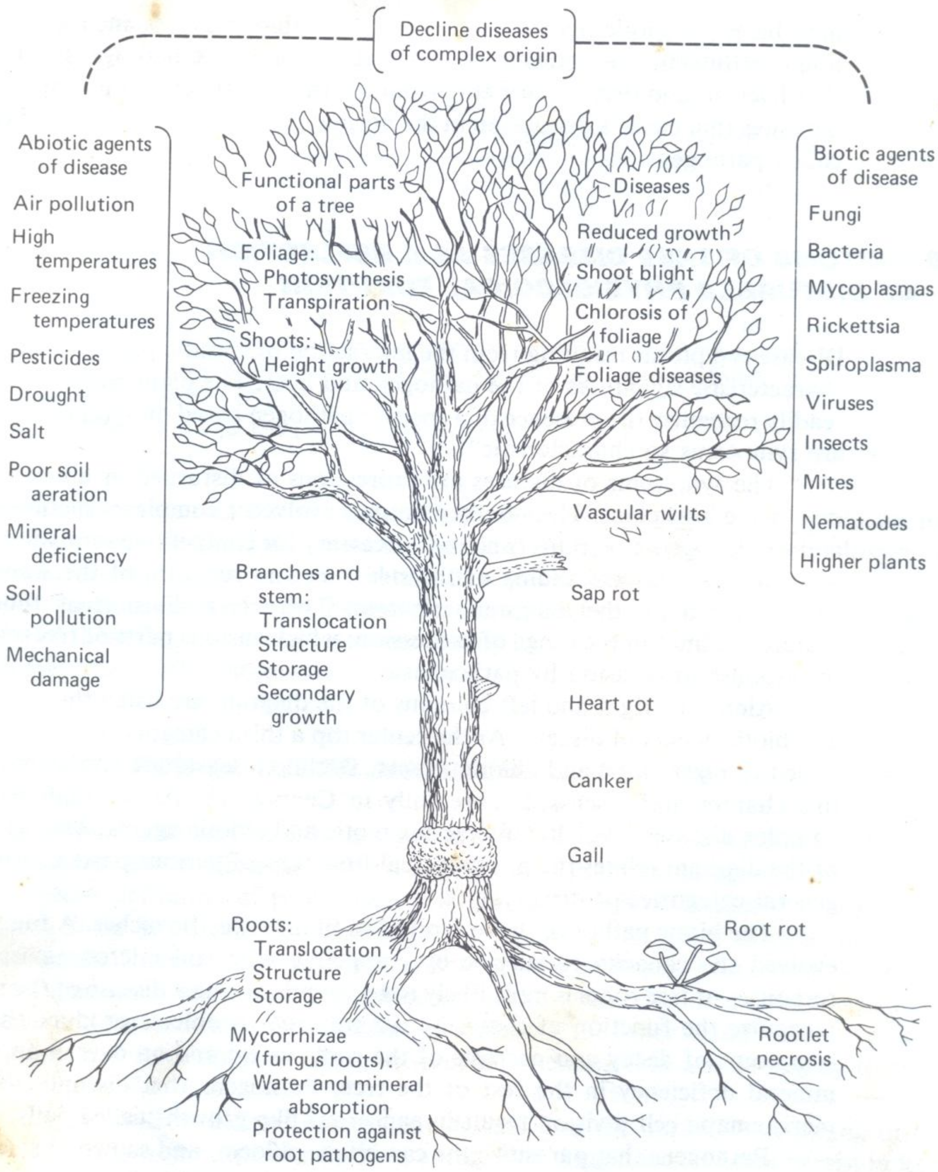


Figure 1–1. Summation of abiotic and biotic agents involved in diseases of trees, types of diseases, and functional parts of the tree. Decline diseases are caused by a combination of biotic and abiotic agents.

PROOF OF PATHOGENICITY

Proof of the pathogenicity of specific biotic agents has generally been accomplished by the following set of procedures originally proposed by Robert Koch (1843-1901). The modified procedures are as follows:

1. There must be constant association of the suspected causal agent and the disease.

2. The suspected causal agent must be isolated and grown in a pure culture.

3. When inoculated into healthy plants, the agent that has been isolated must induce the disease.

4. Re-isolation from the disease-induced plants must yield the same causal agent.

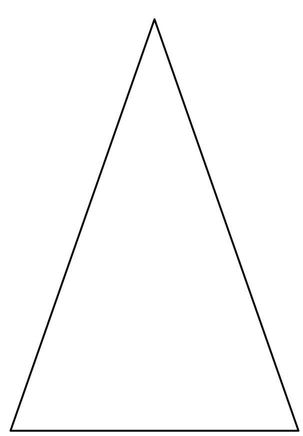
Certain modifications of the procedures are necessary for specific types of disease agents that cannot be cultured - viruses, nematodes, mycoplasms, and some fungi.

. CATEGORIZING TYPES OF TREE DISEASES

Biotic Plant Disease

Biotic plant disease is the product of the plant, the pathogen, and the environment (Fig. 1-2) interacting over time. It is important to recognize that all three factors interact to produce diseases and that we may therefore prevent or control diseases by manipulating anyone of the three. It is also important to recognize the time factor. Some diseases develop quickly within a plant; others develop slowly. There is also a time factor related to the spread and increase of the pathogen population within the host population.

By tradition, plant pathology is concerned with all diseases of plants except those caused by insects. This is a very artificial separation of an important group of pathogens. In actual practice, a useful plant pathologist liust also recognize and understand insect-plant interactions.



Host Pathogen

Environment

Figure 1-2: Biotic plant disease is the product of three interacting factors over time.

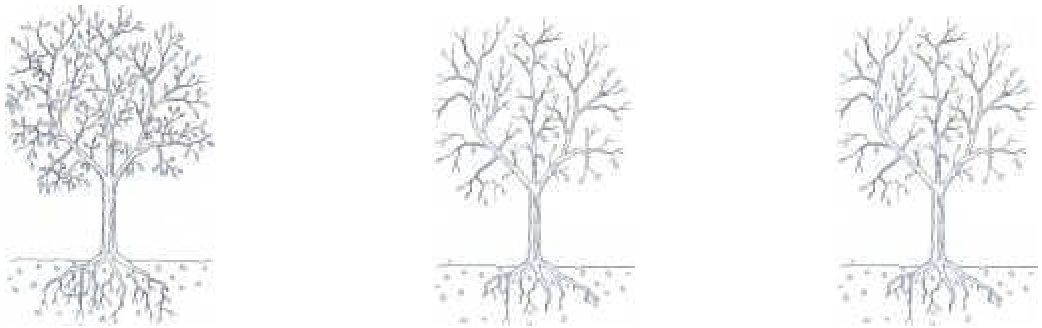
Abiotic Plant Disease

Diseases can also be caused by abiotic agents such as high or low temperature, phytotoxic gases, nutritional imbalance, soil-oxygen deficiency, moisture stress, and other abiotic factors. Abiotic diseases are sometimes very similar to injury, so that separation of disease from injury is often more academic than practical.

Decline Plant Disease.

Major emphasis in plant pathology has been directed toward single biotic or abiotic primary-causal-agent diseases. There is a third category of diseases, called declines, which result not from a single causal agent but from an interacting set of factors (Figure 1-3). Terms that denote the symptom syndrome, such as dieback and blight, are commonly used to identify these diseases.

PREDISPOSING INCITING CONTRIBUTING



Long-term factors:	Short-term factors:	Long-term factors:
Genetic potential	Insect defoliation	Bark beetles
Age	Air pollutants	Canker fungi
Viruses (interacting with) Climate	Drought	Root-decay fung
Soil factors	Salt	
Air pollution	Mechanical injury	

Figure 1-3 Factors influencing declines.

RECOGNITION OF BIOTIC, ABIOTIC, AND DECLINE DISEASES

The reasons for separating disease into three groups will become more evident once an understanding of each of the three types has been developed, but a few generalizations may be helpful at this point. If we shift from the theoretical concept that three types of disease exist to the practical question of how a person involved in the management of trees recognizes the three types, the concept should be more understandable.

One must look at both the diseases of individual trees and the diseased trees in a population to recognize differences among the three categories of disease. The biotic, abiotic, and decline diseases will be compared using four criteria: symptoms, signs, host specificity of disease, and spatial distribution.

Symptoms

Biotic agents of disease produce symptoms on specific plant parts. The affected parts are usually not randomly distributed on the plant; more often. only a portion of a plant is affected. Environmental or inoculum dispersal factors Day account for the unevenness of disease symptoms. A progressive invasion of tissues is also a good symptom of biotic-induced disease.

Abiotic disease may or may not be plant-part-specific but is usually uniform in its symptom expression on the plant. There may be exceptions to a general distribution throughout the plant, caused by portions of the plant not being exposed. For example, the lower branches of a tree may be covered with snow and therefore not exposed to salt spray or the desiccating effects of winter winds. Abiotic disease does not generally occur as a progressive invasion like biotic infection, so that evidence of callous ridges on stem infection, or necrosis of leaves surrounded by chlorotic or other colored tissue, is usually not seen.

The most characteristic symptom of decline disease is the progression of symptom expression on individual plants and between plants. Another characteristic symptom is a reduction in growth. Some trees show very slight symptoms, others are dead, and others are intermediate in condition. A range of symptom expression may also occur with biotic diseases as a result of genetic variation and the spread patterns of the pathogen.

Signs

Signs are fruiting or other structures of biotic causal agents of diseases. Signs are most useful with fungal-induced diseases. The fungus can be identified and recognized as a causal agent of disease by the presence of specific fruiting structures.

With abiotic diseases, a confusing array of fungal structures may be seen. These can be identified and recognized as known saprobic organisms and are therefore not signs of tree pathogens.

Signs associated with decline diseases are not uncommon either. Some of these may be the confusing saprobes such as those often found on trees suffering from abiotic diseases, and others are facultative or weak parasites that contribute to the decline. Identification of a specific organism as a known contributor to declines is a good indication of decline disease.

Host Specificity

Biotic diseases are usually host-specific or occur on limited numbers of related or unrelated hosts. This concept fits best for fungal and bacterial pathogens. The most characteristic feature. of abiotic disease is the occurrence of similar symptoms on two or more totally unrelated hosts. Decline diseases are host-specific problems, but more than one tree species in a region may have its own specific, decline syndrome.

Spatial Distribution

Biotic diseases, because they are caused by infectious agents, usually show a clumping distribution pattern of diseased individuals. Inoculum produced by diseased individuals is most concentrated around the diseased individuals, thereby contributing to a higher incidence of disease in localized areas. Only with initial infection caused by inoculum dispersed from a distance does the distribution of disease approach randomness. Topographic features that produce moisture or temperature conditions favorable for inoculum production, dispersal, and infection may contribute to clumped disease distribution patterns typical of biotic disease.

Abiotic disease is usually random in a population except when the agent is distributed in a nonrandom fashion. For example, a point source of pollution will produce a progressive intensification of symptoms as one nears the source. Over distance, the distribution of symptoms is progressive, but at a given distance the individuals affected will be randomly distributed. Decline diseases have a random symptom distribution pattern within a given location.

All three types of diseases occur nonrandomly if one looks at a region as a whole. Thus, differences from one stand to another can be caused by many factors - site, environmental, and genetic factors of the host, to name just a few.

Damping-off

Damping-off of seedlings is caused by fungi in the genera *Phytophthora*, *Pythium*, *Fusarium* and *Rhizodonia.* Damage can be extensive in wet springs or poorly drained soils. Damping-off results in death of succulent seedlings and root rot with associated stunting in older seedlings.

Hosts: Conifer seedlings.

Recognition: Pre-emergent damping-off is characterized by failure of seedlings to emerge due to the infection and decay of the young radicals. Post-emergent damping-off is characterized by infection and decay of succulent stem tissue at or just below the ground line causing seedlings to fall over. At the point of infection, the stem is watersoaked and necrptic. Root infections of slightly older seedlings may also occur causing partial or total decay; in these cases seedlings may remain upright after dying. No visible signs of fungi are seen on damped-off seedlings.

Fungi are easily cultured from infected seedlings and can be separated from one another by differences in spore and mycelium characteristics.

Disease Spread: Damping-off fungi are soil inhabitants, surviving either as dormant spores or mycelium in organic matter. After the seedlings are infected, additional mycelium or spores are formed within seedling tissue so that the population of damping-off fungi increases with each successive crop of trees. Generally, high moisture and high soil pH favor damping-off. Infection by damping-off fungi is usually most severe in very young, succulent seedlings, but these fungi may attack roots of older woody seedlings as well. The disease can be spread by movement of infested soil and seedlings.

Management: Nursery beds with high damping-off fungi populations should be fumigated prior to sowing. Avoid excessive movement of soil between fumigated and nonfumigated areas. Provide good drainage. Maintain acid soil (pH 5.5). Seed treatments have not proven to be consistently effective in preventing damping-off losses. Soil drenches with registered fungicides may be effective if applied soon after sowing.

May be Confused With: Heat injury, wind injury, non-germinating seeds.

Armillaria Root Rot

Armillaria root rot, also called shoestring root rot, is caused by the fungus Armillaria mellea. This is the most common conifer root rot. Infection results in growth loss, root and butt rot, uprooting, and tree killing.

Hosts: Virtually all trees and other woody species.

Recognition: Decline in growth increment, foliage yellowing, distress cone crop, heavy resin flow at tree base, tree death; early decay appears as a watersoaked area with tiny pockets; advanced decay is a yellow stringy rot; butt rot sometimes develops in non-resinous hosts, especially hardwoods.

Disease centers contain numerous stubs, snags, and dying

trees. White mycelial sheets often shaped like fans developed under bark of roots and lower bole; rhizomorphs (black or brown shoestring-like structures) form in the same areas; mushrooms are golden-yellow with a ring on the stem and grow from infected material in the fall.

Disease Spread: The fungus survives and grows in old stumps or dead trees; rhizomorphs are formed and grow through the soil to infect the roots of new hosts; spread also occurs across root contacts and grafts; spread by spores is negligible. Conifers develop resistance to the disease at age 20- Disease centers usually occur around infected stumps of the former overstory. Secondary attack by bark beetles is common. Frequently occurs on trees affected by other root diseases.

Management: Maintain vigorous growing stock. In severely diseased areas, plant or favor species that appear only lightly or not affected; remove stumps of infected trees to sanitize severely infected sites. Do not thin severely infected areas**.** Precommercial thinning or harvesting and stump removal may be necessary to sanitize severely infected sites. Normal tree harvesting does not reduce or prevent infection and may aggravate the problem. Infected trees should be treated in recreation areas.

May be Confused With: No other disease or insect if mycelia fans are present.

Insects

Several kinds of insects attack living trees, logs, lumber and finished wood products for food and/or shelter. These pests include various termites, ants, and beetles.

Termites - Termites use wood for food and shelter and are the most destructive of all wood insects.

Ants cannot use wood for food, but they are often confused with termites because the two look somewhat similar. However, there are several distinct differences in their physical appearance. Ants have 'elbowed' antennae; termites do not. Ants have narrow waists whereas termites' bodies are broad. Ants' wings have few veins and the hind wings are smaller than the front wings. Both pairs of termite wings are similar in shape and size and have very small veins.

Termites are divided into three major groups.

* Subterranean or ground-inhabiting termites

* Drywood Termites

* Dampwood Termites

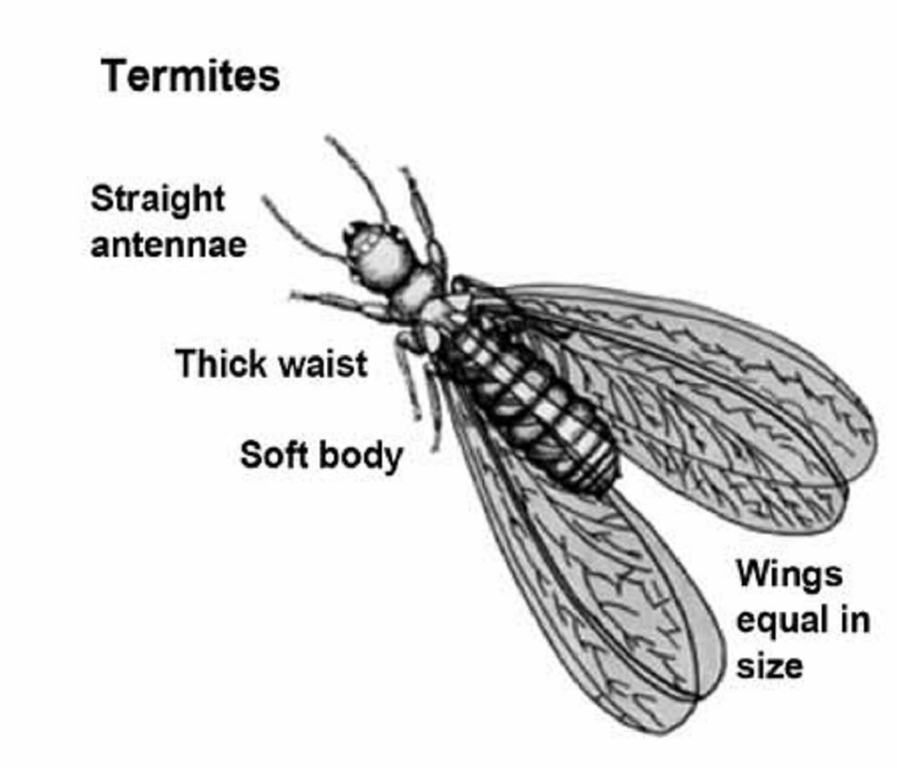
Subterranean Termites - These termites attack wood products in buildings and other wood products throughout most of continental United States, but most damage occurs in the warm, southern coastal regions along the Atlantic Ocean and Gulf of Mexico. At certain seasons of the year, winged males and females are produced by the termite colony. They swarm, mate, lose their wings, and attempt to begin a new colony in the soil. Termites build tunnels through earth and around obstructions to get to a source of food (either sound or decaying wood). They also require a constant source of moisture – usually obtained from the soil.

The presence of subterranean termites may be noted by: * the swarming of winged, ant-like insects and the discarded wings observed after swarming * earthen shelter tubes built over masonry or other foundations to a source of wood * the presence of white workers when termite shelter tubes are broken open * the hollowed-out condition of badly infested wood products

Drywood Termites - Drywood termites are found naturally only in Hawaii, Puerto Rico, and in a narrow

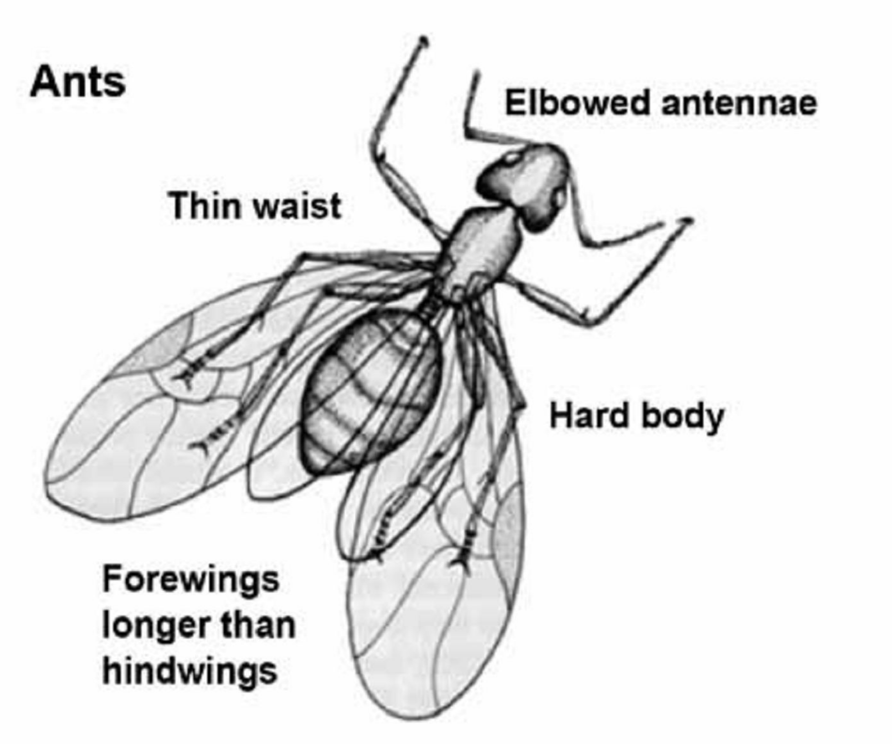
strip of land extending from southern California and Texas to Florida and along the Atlantic coast to Virginia. After swarming, drywood termites enter cracks and crevices in dry, sound wood. In excavating their galleries, they occasionally discharge oval-shaped fecal pellets through temporary openings in the wood surface. The ability of the drywood termite to live in dry wood surface. The ability of the drywood termite to live in dry wood without direct contact with the soil increases its menace. However, it reproduces slowly and does not destroy wood as quickly as the subterranean termite.

Dampwood Termites - Dampwood termites are a serious pest along the Pacific Coast. They do not require contact with the soil, but do need wood with a high moisture content.



Ants

Carpenter ants may be black or red. They usually live in stumps, trees, or logs, but often damage poles ar structural timbers set in the ground. Elevated portions of buildings, such as windowsills and porch columns, are susceptible to damage. Carpenter ants use wood for shelter not for food. They usually prefer wood that is naturally soft or has been softened by decay. The galleries are large, smooth and, unlike those of termites, are free of refuse and powdery wood. Mounds of sawdust indicate their presence.



Beetles

***Powder Post or Lyctus Beetles* -** Powder post beetles attack both freshly cut and seasoned hardwoods and softwoods. They attack the sapwood of ash, hickory, oak, and other hardwoods. Adults lay eggs in the wood pores. The larvae burrow through the wood, making tunnels form 1/16- to 1/12-inch in diameter, packed with a fine powder. after a larval period (from a few months to a year, or longer - depending on the species) and a much shorter pupal stage, newly formed adults chew holes through the wood surface and emerge to lay eggs for another brood. Signs of damage by powder post beetles are: * small round 1/16' holes in the surface of the wood made by emerging adults, and * fine powder that falls from the wood.

***Anobiid beetles* -** may attack softwoods in damp and poorly ventilated spaces beneath buildings. Eliminating the source of moisture will cause the colony to slowly die out.

***Roundheaded Borers* -** A longhorn beetle, commonly known as the old house borer, damages seasoned pine timbers. The larvae bore through the wood. Over many years their tunneling can weaken structural timbers, framing members, and other wooden parts of buildings. Contrary to its name, the old house borer most often infests new buildings. It is found in the Eastern and Gulf Coast States. Larvae reduce sapwood to a powdery or sawdustlike consistency. They may take several years to complete their development. While working in the wood, they make a ticking or gnawing sound. When mature, the adult beetle makes an oval emergence hold about 1/4 inch in diameter in the surface of wood.

Flatheaded Borers **-** Flatheaded borers infest live trees as well as recently felled and dead, standing softwood trees. They can cause considerable damage in rustic structures and some manufactured products by mining into sapwood and heartwood. Typical damage consists of rather shallow, long, winding galleries that are packed with fine powder. Adults are often called metallic wood-boring beetles because of their color. They are about 3/4 inch long, with wing covers usually rough, like bark.

Marine Borers

Extensive damage is done to submerged portions of marine pilings, wharf timers, and wooden boats by a group of animal organisms known collectively as marine borers. In the United States they are especially active in the warm waters of the Pacific, Gulf, and South Atlantic coasts. Untreated timbers can be destroyed in less than a year. The major marine borers are the **shipworm** and **pholad** mollusks (related to the clams and oysters), and the **crustacean borers** (related to the crabs and lobsters).

Forest Fire

A forest fire is any uncontrolled fire in combustible vegetation that occurs in the countryside or a wilderness area. Other names such as brush fire, bushfire, forest fire, desert fire, grass fire, hill fire, squirrel fire, vegetation fire, and wildland fire may be used to describe the same phenomenon depending on the type of vegetation being burned. A forest fire differs from other fires by its extensive size, the speed at which it can spread out from its original source, its potential to change direction unexpectedly, and its ability to jump gaps such as roads, rivers and fire breaks. Wildfires are characterized in terms of the cause of ignition, their physical properties such as speed of propagation, the combustible material present, and the effect of weather on the fire.

Forest fires occur on every continent except Antarctica. Fossil records and human history contain accounts of forest fires, as forest fires can occur in periodic intervals. Forest fires can cause extensive damage, both to property and human life, but they also have various beneficial effects on wilderness areas. Some plant species depend on the effects of fire for growth and reproduction, although large forest fires may also have negative ecological effects.

Strategies of wildfire prevention, detection, and suppression have varied over the years, and international wildfire management experts encourage further development of technology and research. One of the more controversial techniques is *controlled burning*: permitting or even igniting smaller fires to minimize the amount of flammable material available for a potential forest fire. While some wildfires burn in remote forested regions, they can cause extensive destruction of homes and other property located in the *wildland-urban interface*: a zone of transition between developed areas and undeveloped wilderness.

The spread of forest fires varies based on the flammable material present and its vertical arrangement. For example, fuels uphill from a fire are more readily dried and warmed by the fire than those downhill, yet burning logs can roll downhill from the fire to ignite other fuels. Fuel arrangement and density is governed in part by topography, as land shape determines factors such as available sunlight and water for plant growth. Overall, fire types can be generally characterized by their fuels as follows:

- **Ground** fires are fed by subterranean roots, duff and other buried organic matter. This fuel type is especially susceptible to ignition due to spotting. Ground fires typically burn by smoldering, and can burn slowly for days to months, such as peat fires.
- **Crawling** or **surface** fires are fueled by low-lying vegetation such as leaf and timber litter, debris, grass, and low-lying shrubbery.
- **Ladder** fires consume material between low-level vegetation and tree canopies, such as small trees, downed logs, and vines.
- **Crown**, **canopy**, or **aerial** fires burn suspended material at the canopy level, such as tall trees, vines, and mosses. The ignition of a crown fire, termed *crowning*, is dependent on the density of the suspended material, canopy height, canopy continuity, and sufficient surface and ladder fires in order to reach the tree crowns. For example, ground-clearing fires lit by humans can spread into the forest, damaging ecosystems not particularly suited for heat or arid conditions.

Costs and Benefits of Wildland Fire Management Tools

	Costs	**Benefits**
Suppression	Labour intensive Requires high level of planning Can be very expensive Particular strategies can be very inefficient (i.e. aerial retardant drops) Can increase intensity and likelihood of future wildfires. Inhibits natural ecological processes in many cases	Can reduce human health impacts Can protect forest and agricultural resources Can save private dwellings and commercial buildings
Prescribed fire	Can be expensive to implement Requires skilled workforce to implement Requires high level of planning Can impact human health (e.g. smoke and its effect on those with asthma or allergies)	Can provide habitat for wildlife Can improve forest and agricultural resources Can reduce hazardous fuel loading Mimics natural processes but under more controlled circumstances

Mechanical Fuels Reduction	Requires use of heavy machinery (resulting in fossil fuel consumption, compaction, etc.) Can be expensive to implement Does not mimic natural processes	Can provide habitat for wildlife Can improve forest and agricultural resources Can reduce hazardous fuel loading Does not produce large amounts of smoke

FIRE PREVENTION

Most forest fires result from human carelessness or deliberate arson. Fewer fires are started by lightning. Weather conditions influence the susceptibility of an area to fire; such factors as temperature, humidity, and rainfall determine the rate and extent to which flammable material dries and, therefore, the combustibility of the forest. Wind movement tends to accelerate drying and to increase the severity of fires by speeding up combustion.

By correlating the various climatic elements with the flammability of branch and leaf litter, the degree of fire hazard may be predicted for any particular day in any locality. Under conditions of extreme hazard, forests are closed to public use.

Although organizations involved with fire control have traditionally fought all fires, certain fires are a natural part of the ecosystem. Complete fire exclusion may bring about undesirable changes in vegetational patterns and may also allow accumulation of fuel, with increased potential for feeding catastrophic fires. In some parks and wilderness areas, where the goal is to maintain natural conditions, lightning-caused fires may be allowed to burn under close surveillance.

FIRE DETECTION AND FIGHTING

One of the most important aspects of forest-fire control is a system of locating fires before they are able to spread. Land-based forest patrols and lookouts have been largely replaced by surveillance aircraft, which detect fires, map their locations, and monitor their growth.

Ground fires, once established, are difficult to extinguish. When the humus layer is not very deep, a ground fire may be extinguished with water or sand. Most ground fires, however, are controlled by digging trenches around the burning area and allowing the fire to burn itself out. Surface fires are limited by clearing the surrounding area of low vegetation and litter, or digging emergency furrows to confine the area. Crown fires are difficult to extinguish. They may be allowed to burn themselves out, they may be halted by streams, or they may be limited by backfired areas. Backfiring consists of carefully controlled burning of a strip of forest on the leeward side of the blaze, so that when the fire reaches the burned area it can go no farther.

FIRE IN LAND MANAGEMENT

Foresters may purposely ignite prescribed fires under carefully controlled conditions to remove unwanted debris following logging, to favor tree seedlings, or to keep fuels from accumulating. Since most grasses and shrubs grow well after fires, and animals are attracted to the tender and nutritious new growth, prescribed fires often benefit both wildlife and livestock. The mosaic of vegetation of different ages that results from frequent small fires favors a rich diversity of plant and animal life.

Forest fires are often set deliberately to clear forested areas for grazing or agricultural purposes. In *slash-and-burn cultivation*, subsistence farmers burn small plots of forest for space to grow crops. After two or three years, when the nutrients in the soil have been depleted, the plots are abandoned and other plots are cleared by fire. Large-scale agricultural operations use similar methods to clear forested areas.