MASTER GARDENER TRAINING
BASIC PLANT PATHOLOGY

This handout goes with the Basic Plant Pathology presentation and is to be used in conjunction with the more comprehensive NY Master Gardener Manual.

I. General Information.

Casual Agents of Disease:

> **Living** = fungi, bacteria, nematodes, viruses, and phytoplasmas = microplasma-like-organsisms.
>
> **Non-living (environmental)** = nutrient deficiencies, mineral toxicities, lack/excess soil moisture, too low/too high temperature, lack/excess of oxygen, air pollution (ozone), soil acidity/alkalinity (pH).

Plant Disease: any alteration in the physiological processes of a plant, caused by living organisms or non-living agents, which negatively affects the plant.

Plant Pathogen: a pathogen is an organism that is capable of changing the physiological processes of a plant, thus causing disease.
Pathogenic: means disease causing.

Plant Pathology is the study of:

1. the living entities and the environmental conditions that cause disease in plants.
2. the mechanisms by which these factors produce disease in plants.
3. the interactions between disease causing agents and the diseased plant
4. the methods of preventing or controlling and alleviating the damage it causes.

History of Plant Pathology.

700 B.C.- The Romans celebrated the holiday "Robigalia" that involved sacrifices of reddish colored dogs and cattle in an attempt to appease the rust god Robigo.

470 B.C.- Pliny was the first to use a fungicide, amurce of olives, to control blight.

1844-1845- The Irish Potato Famine, caused by the Late Blight fungus *Phytophthora infestans*, struck Ireland and prompted the birth of modern plant pathology. The average adult male ate 15 lbs. of potatoes a day. The Famine killed 1.5 million people and forced another 1.5 million to immigrate between 1845-1850. The population of Ireland was 8.5 million in 1840, it decreased to 4 million by 1900.

1885- Bordeaux mixture. Downy Mildew of Grape was a great problem in the growing fields in France but there was no known ways of controlling it. The vineyards were also troubled with pilferers. They began applying a mixture of copper sulfate and lime to the plants along edges of the fields. The bluish-white mixture deterred people from helping themselves to a snack. It was also observed that these plants held onto their leaves throughout the season.

1900- White Pine Blister Rust caused by *Cronartium ribicola*. The pathogen was introduced on seedlings from European nurseries. White pines, especially young trees, and plants belonging to the genus *Ribes* (currants and gooseberries) are susceptible to the disease. Although WPBR is occasionally a severe foliar disease on *Ribes* plants, on white pines it is lethal if allowed to spread from an infected branch into the trunk. This disease caused the first US quarantine in 1912.

******"Current" information: Within the blister rust hazard areas, all susceptible *Ribes* should be removed from the vicinity of valuable white pines. *Ribes* are not allowed to be planted in nine northern counties of New York and parts of 6 others (see http://www.dec.state.ny.us/website/regs/part192.html for more information). If you wish to plant *Ribes* in New York State, contact Robert Mungari (Phone 518-457-2087) at the NYS Dept of Agriculture & Markets *before purchasing or planting* to determine **if** you can plant in your area.

1904-1940- Chestnut Blight caused by *Cryphonectria (Endothia) parasitica*. Chestnut seedlings imported from the orient brought with them the pathogen that killed off all the mature chestnuts in eastern North America. The disease devastated the people who relied on the chestnut tree for their livelihood. There are still some sprouts left in the forests, put up by the living root systems, but they too eventually succumb to the blight.

1910- Citrus Canker caused by *Xanthomonas axonopodis pv. Citri,* was discovered near the Georgia border and was eradicated in 1931. The pathogen was found 400 miles away in Dade County in 1912. The pathogen spread throughout the Gulf States and as far north as South Carolina. It took more than 20 years to eradicate that outbreak of citrus canker and $2.5 million in State and private funds (the equivalent of $28 million in 2000 dollars). In 26 counties, over 250,000 grove trees and over 3 million nursery trees were destroyed by burning. Subsequent outbreaks occurred in 1986 and 1995.

1930-present- Dutch Elm Disease caused by *Ophiostoma ulmi*. This disease devastated mall and roadside planting of American elm trees throughout much of the United States.

1941-present- Golden Nematode, *Globodera rostochiensis,* was discovered in 1941. It entered the country on the tracks of WWI equipment returning from Europe. It caused a slow decline in potato plants that eventually lead to death. As of 1955, the distribution was believed to be located only in Nassau and Suffolk counties in NYS. After decades of building their population levels, the GN was capable of reducing the potato yield up to 70%. For over 60 years, an effective Federal and State quarantine program has confined the pest to nine counties in New York.

1970- Southern Corn Leaf Blight caused by *Helminthosporium maydis*. Originally considered a minor disease, a change in the genetics of seed corn caused an epidemic. In 1970, the disease was reported in every state east of the Mississippi River, also in several states west of the Mississippi River. The epidemic received enormous press coverage with over 37 articles printed in the Chicago Tribune alone. Losses due to the epidemic were officially estimated at nearly $1 billion nationally. Reduction in yield was greater in the South versus the min-west corn belt states. In some areas damage caused losses of 50-100%. Nationally losses averaged 20-30%.

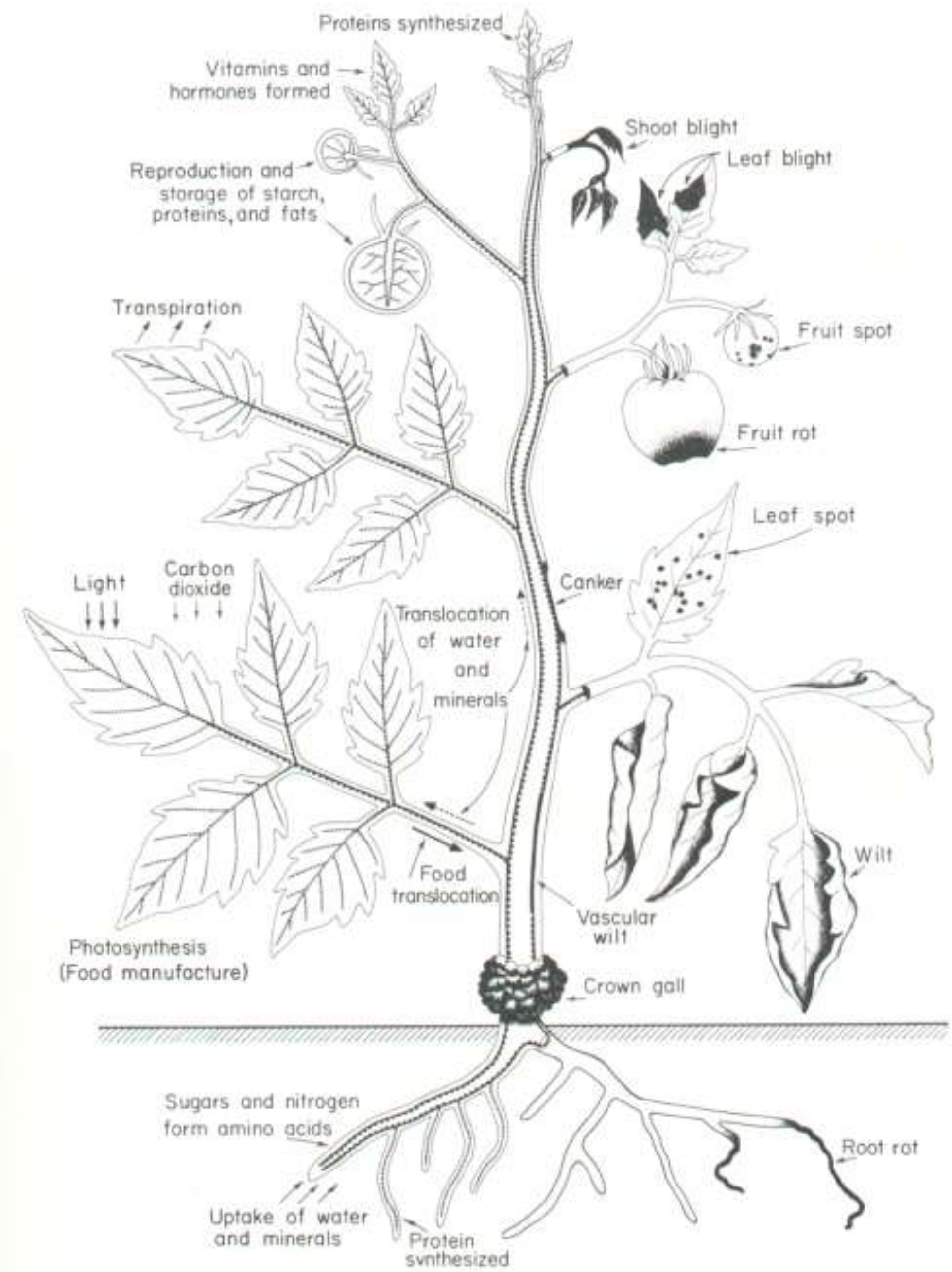
1995- Sudden Oak Death, caused by *Phytophthora ramorum*, was discovered in California. A large number of tanoaks were found to be declining with no known cause. It took five years to isolate and identify the causal agent. Also called ramorum blight and ramorum dieback. Although the disease was first observed in the United States in tanoaks, it is also found to infect **many, many** other plant species.

1999- Southern Wilt/Brown Rot, caused by *Ralstonia solancearum* R3 B2. Southern Wilt is a disease of Geranium and Brown Rot is a disease of Potato. *Ralstonia solanacearum* Race 3 Biovar 2 has appeared on Geranium a few times in recent years but it appears to be confined to greenhouse crops and there is no evidence of spread to potato, tomato, or eggplant.

1999- Plum Pox, caused by *Plum Pox Virus*, is a disease of stone fruits caused by a viral pathogen called the Plum Pox Virus, also known as "Sharka". It was first discovered in an Adams County, Pennsylvania Orchard in 1999. It is a member of the Agricultural Bioterrorism Select Agent Listing of 2002. It was removed from the listing in April 2005 due to its limited ability to spread easily.

2004-Soybean Rust, is caused by two fungi named *Phakopsora pachyrhizi* and *Phakopsora meibomiae.* It is a member of the Agricultural Bioterrorism Select Agent Listing of 2002. It was removed from the listing in April 2005 due to its established presence in the US. *P. pachyrhizi* appeared in the US in November 2004, apparently entering on winds of Hurricane Ivan. It was found in 9 States shortly thereafter. Detected by a NPDN exercise participant. It was found in Florida early in 2005 on Kudzu and volunteer Soybean and new detections for this season remained in the South.

Plant Disease Symptoms:



Examples = root rot, leaf spot, gall, fruit rot, blossom blight, canker, shoot blight, leaf blight

Points to keep in mind=

1) No single plant pathogen can cause many different symptoms on a plant
2) More than one pathogen or disease can occur on a plant at one time
3) There are some symptoms that may appear identical for two different diseases

Pay particular attention to the roots of a plant when evaluating it for disease. Anything that affects the roots will have some effect on the growth and function of all parts of the plant above ground.

Symptoms produced by plant pathogens include:

Wilts: Verticillium Wilt on Watermelon.
Fusarium Wilt on Cyclamen corm. Notice the red/brown discoloration of the vascular tissue.

Blights: Diplodia (Sphaeropsis) Tip Blight on Pine.
Late Blight on Tomato caused by *Phytophthora infestans*.

Leaf Spots: Leaf spot on Fiddle leaf Fig caused by the fungus *Glomerella*.
Leaf spot on Ivy caused by a bacterium.

Fruit Rots: Black Rot of Pumpkin caused by the *Didymella* sp.
Late Blight of Tomato caused by *Phytophthora infestans*.

Cankers: Cytospora Canker on Spruce, overall branch dieback.
Cytospora Canker on Hemlock, a close-up of a canker.

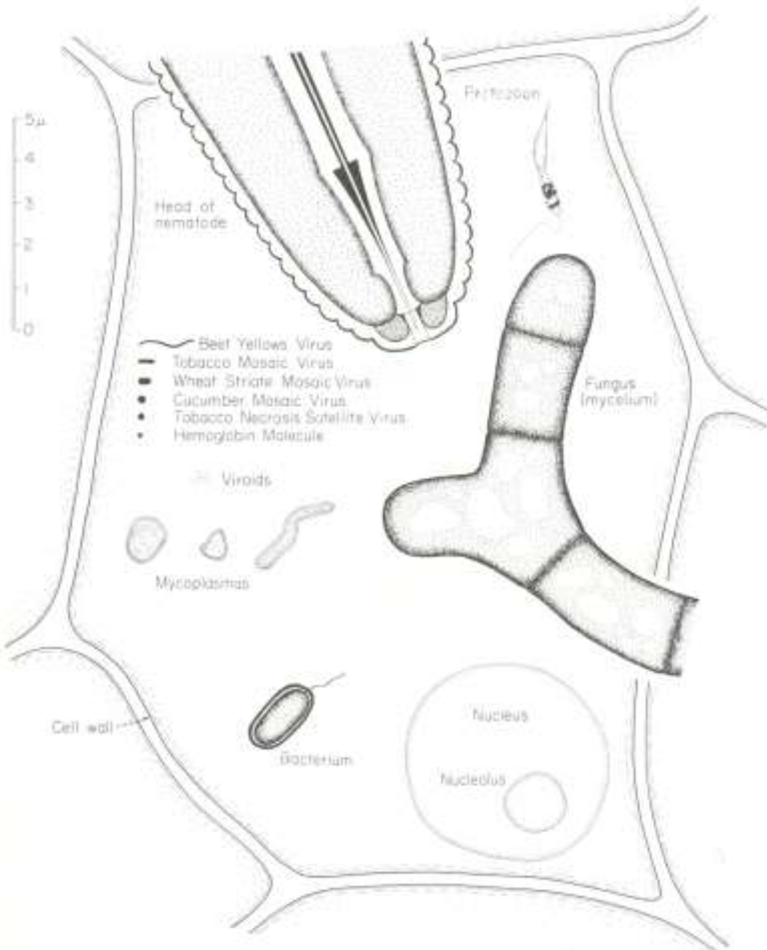
Root Rots: Root Rot on Spinach caused by the fungus *Fusarium*.

Damping Off: Damping Off of Pepper caused by the fungus *Fusarium*. Note the narrowing of the stem right at the crown area.

Reduced Growth, Development, and Yield: Ranunculus plants with and without Impatiens Necrotic Spot Virus.

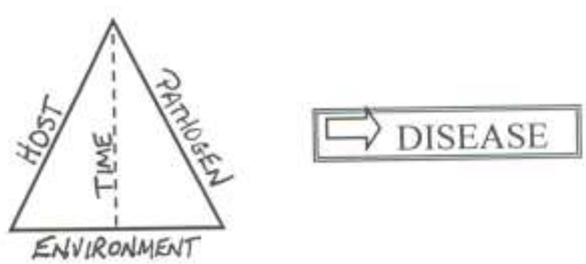
Symptoms:	Bacteria	Fungi	Viruses	Nematodes	Phytoplasmas
Wilts	√	√		√	√
Leaf Spots & Blights	√	√	√		
Fruit Rots	√	√			
Root Rots	√	√		√	
Damping Off		√			
Distorted Growth	√	√	√	√	√

Plant Cell with various plant pathogens present:

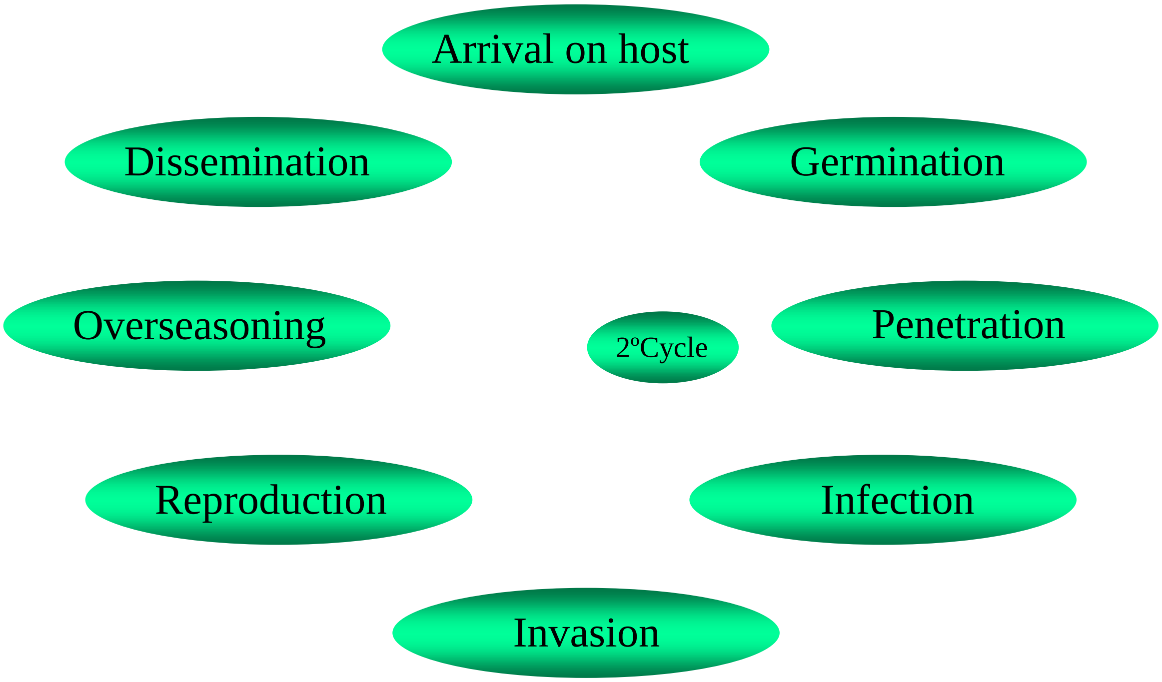


Parasite: an organism that invades and consumes another living organism; a plant pathogen is a parasite.
Saprophyte: an organism that derives its food from dead, organic matter. Ex: Birds Nest Fungus growing on a dead log.
Some plant pathogens may be able to live as both a saprophyte and a parasite. A parasite and saprophyte can often coexist together (part of tree branch is alive and part is dead).
Often saprophytes overgrow parasites so the real cause of the symptom cannot be determined.

Disease Pyramid: 1) susceptible host plant, 2) virulent pathogen, 3) favorable environment (moisture, temperature) 4) time for the interaction to occur.
All these factors must be present for disease to occur.



Disease Cycle:



Spread of Plant Pathogens: rain, dew irrigation, drainage water, wind, soil; insects, crop debris, seeds & propagating materials, man, animals, machinery.

Generally microorganisms cannot move themselves from one plant to another due to their extremely small size. Thus they rely on elements in the environment for movement (rain, dew, wind, etc.). Microorganisms also must produce very large numbers of reproductive bodies so that at least a few will happen to land in the right place and survive.

A Broader Description of the Disease Cycle based on Calendar Year:

The disease cycle usually occurs during the growing season of the plant (April to September). For a fungus, the first spores produced during the spring are called **primary spores** (or primary inoculum); those produced in successive lifecycles of the fungus are called **secondary spores** (or secondary inoculum). These secondary spores are generated throughout much of the growing season and allow the fungus population to really build up.

A pathogen must **survive (overwinter)** during plant dormancy (October to March).

A pathogen must also survive other unfavorable environmental conditions (i.e. drought, heat, lack of food). Examples of overwintering structures for fungi are tarspots on maple leaves. These allow **Rhytisma** sp., the cause of tarspot, to overwinter. “Shoe strings” on tree trunks allow **Armillaria** sp., a fungus that causes root rots of woody plants, to survive unfavorable conditions. A virus can survive the winter in the affected plant itself (if perennial) or in nearby perennial weeds.

II. The Fungi.

Fungus: (singular = fungus; plural = fungi) is a non-photosynthesizing eukaryote that produces enzymes and absorbs its food; usually producing and living inside a network of apically extending, branching tubes called hyphae. It produces reproductive structures called spores.

Properties of fungi:

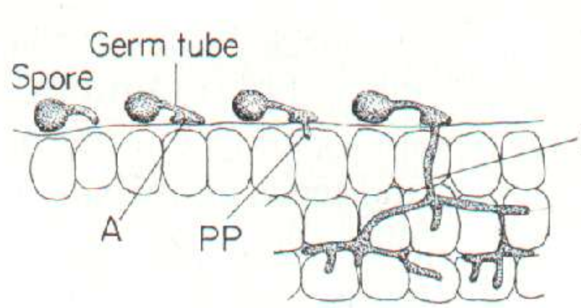
- •Cause nearly all of the economically important diseases.
- •Characterized by a mycelial (filamentous) growth habit.
- •Live on organic matter.
- •Identified on the basis of the morphology of their reproductive structures.
- •Reproduce primarily by means of spores.
- •Perennial inhabitants of all ecosystems.

Fungi are responsible for **85%** of all plant diseases.

The string-like filaments of a fungus body are called **hyphae** (hypha = singular). Bread mold is composed of many hyphae. Some fungi that are plant pathogens produce mushrooms. Mushrooms also are masses of hyphae. Most fungi that produce mushrooms are not plant pathogens.

Spores are to fungi what seeds are to plants. They function in the reproduction and dispersal of the fungus. A mushroom produces billions of spores. **Pycnidia** are small, black "dots" that are formed by many fungi to produce spores (ex. The fungus that causes black rot of pumpkin). Mushrooms and pycnidia are also called "fruiting bodies" because spores are produced in them (much like a fruit holds seeds).

A spore **germinates** and can infect a plant through natural openings between plant cells (stomates) or it may penetrate directly into the plant cell by digesting the cell wall. Wounds are ideal ports of entry for fungi. Once inside the plant the fungus forms hyphae which grow through the plant and absorb nutrients.



Direct with appressorium (A), penetration peg (PP), and intracellular mycelium (IM)

Disease Slides Shown:

- Snow mound on turf, the fuzzy material is fungus hyphae.

- This picture was taken with a high power electron microscope and shows fungal hyphae on the surface of a plant. The football shaped structures are the **spores** and function similar to seeds in plants, they reproduce the fungus and help it spread around. Millions of spores are produces on a relatively small area of the plant and are released into the air or into splashing water.

- This slide shows a reproductive structure called a **conidiophore**. These lollipop shaped structure produce asexual spores, conidia, in large numbers. The fungus is an *Aspergillus* that is growing directly off an onion seed.

- This is a close-up of a single conidiophore of the *Aspergillus* fungus. The very small dots around the outside of this head are all conidia, asexual reproductive spores.

- A few plant pathogenic fungi produce large structures that bear spores like this honey mushroom. The spores are produced in the cap of the mushroom and are caught in the wind when they are released. Billions of spores are produced during the relatively short life of a mushroom. Fungal structures that contain spores are called **fruiting bodies**.

- Black Rot of Pumpkin. Other plant pathogenic fungi produce spores from less conspicuous, more microscopic fruiting bodies. Here is a pumpkin affected by the black rot fungus, *Didymella*.

- If we take a close-up view not of the spots on the fruit but of the stem, tiny black dots called *pycnidia* thrive. Each "dot" will produce hundreds of spores. Some pycnidia are also in spots on the fruit. This fungus can also cause spots on the leaves.

- *Atropellis* canker on Douglas Fir. In this overall shot you can see some stem swelling.

- In this close-up of the *Atropellis* canker you can see saucer-shaped or cup-like fungal fruiting bodies. These are sexual structures called apothecia.

- Coral spot *Nectria* canker on Japanese Maple. Note the red/pink fruiting bodies on the stem. These are called perithecia, flask shaped sexual structures. Each perithecia will ooze hundreds of spores.

- After a spore makes contact with a susceptible host plant (blown, rain splashed, spread by pruning shears, etc.), it may begin to grow and invade the plant. It must have the correct environment (remember the disease pyramid)- food, moisture, temperature, etc.- however to be successful.

- The spore germinates by producing a "germ" tube. This tube may: (1) force its way into the plant, some can digest the plant cell wall with enzymes, (2) find a natural opening between plant cells for entry, and/or (3) enter through a wound, wounds are often ideal ports of entry. This is similar in humans, remember the last time you had an infected cut. Fungus hyphae will eventually grow around and through the plant cells and absorb nutrients. In many cases this will be a destructive process resulting in the death of the attacked cells. Thus, a leaf spot fungus will produce brown, dead spots on the leaves.

- **Moisture** can affect disease in various ways. For example, a rainy period early in the season can help the fungi by promoting four processes (see slide).

- **Role of Moisture in Fungal Plant Diseases:**

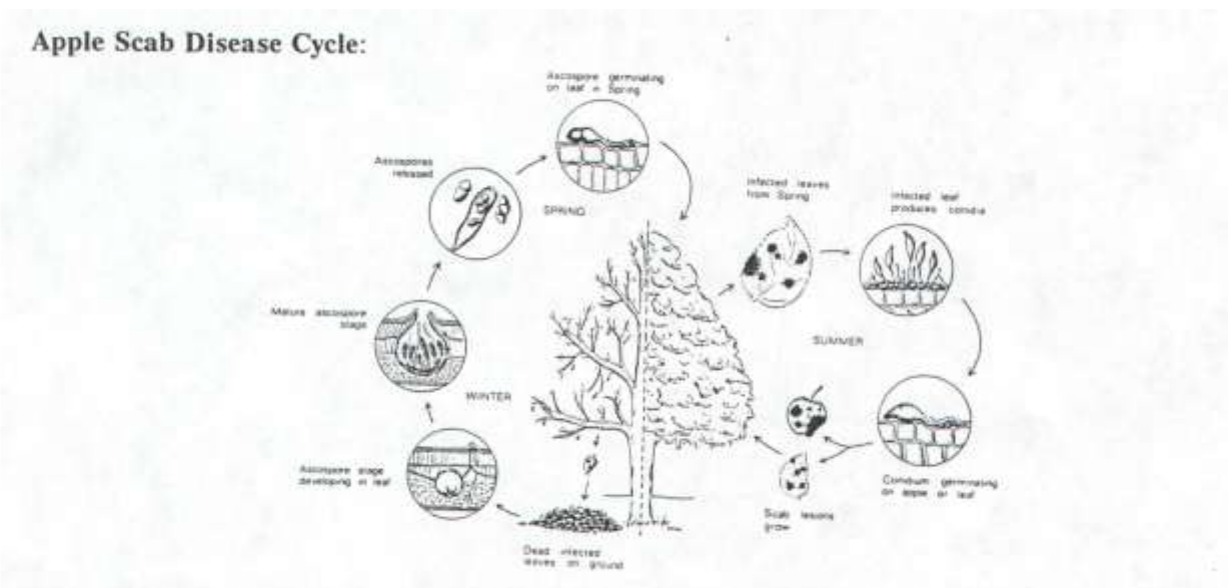
    1) favors fungal growth
    2) favors spore production
    3) favors pore germination
    4) favors the spread of spores

    Moisture is important to many diseases caused by fungi. It is also particularly important for bacterial diseases.

    Let's examine the apple scab disease closely and use it as a model for fungal diseases. Note the spots on the leaves and fruit. The fruit spots make the apples unappealing. Controlling the disease is necessary in most years if top quality fruit is desired.

The disease cycle of the apple scab pathogen, *Venturia inaequalis*.

1= the fungus overwinters in the fallen foliage, **2=** new spores arise in the spring from these leaves, **3=** new foliage is infected in the spring, **4=** several secondary cycles develop during the growing season.



Where might control practices be useful? Dead, infected leaves that fall off in the autumn are the overwintering sites for the fungus; thus (1) **cleaning up and burning or burying these leaves** will help get rid the initial inoculum. A HOT compost pile would also work.

Even in a completely clean orchard you may not be able to completely escape the disease. Why? Because the spores produced by this fungus are air-borne and can travel long distances from other orchards or plantings. The intensity of the infections on your trees won't be as great because less spores, overall, will be around due to your leaf clean-up in the fall.

Another way of controlling the disease is prevention via (2) **resistant varieties** of apple, especially crapapple.

If no resistant varieties are used, then one can protect the new foliage from infection by the fungus by using a (3) **fungicide**. There are two basic types of fungicides.

1) **Protectants:** The spray, applied to the foliage, will kill spores as they attempt to germinate. These fungicides must be applied before any fungal spores land on the foliage. Several applications are required in a growing season.

2) **Systemics:** A few fungicides have what are called "systemic" properties. They penetrate the plant tissue and kill the fungus. These can "cure" infections that have already occurred. Most available fungicides fall into the "protectant" category.

Today's fungicides are inactivated after a relatively short exposure to outdoor conditions (sun, wind, heat…). Also, rain may wash these chemicals off of plant parts. This is the reason for spraying at regular intervals and more often during rainy weather.

********* ALWAYS FOLLOW RECOMMENDATIONS ON PESTICIDE LABELS FOR CORRECT USAGE *********

Fungal Spread:

- Environmental Conditions
  - Slight Air Movement to Wind, Splashing Rain
- Vectors
  - People, Animals, Insects
- Planting Material
  - Vegetative parts
- Mechanical Means
  - Tools, Equipment, Plant Contact

Fungal Management:

- Fungicides
- Exclusion
- Eradication
- Resistant Varieties
- Clean Tools and Materials
- Avoid Wounds, Stress

III. The Bacteria.

Bacterium: (singular = bacterium; plural = bacteria); a single celled microscopic organism which multiplies by division. Bacteria are composed of individual bacterial cells (vs. spores for fungi).

Properties of bacteria:

•Tiny rod-shaped single celled microorganisms.
•0.5-3.5 microns in length and 1.5-1.0 microns in diameter.

•Nearly 200 species cause diseases in plants.
•Identified on the basis of their physiology.
•Reproduce primarily by means of cell division.
•Perennial inhabitants of all ecosystems.

Many bacterial cells have tails called **flagella** that help move them around in water.

Spread of Bacteria:

1) spread by streams of water produced by rain, misting, etc.
2) spread by the use of bacteria-infected plant parts (propagation)
3) spread via tools used on infected plants (pruning)

Bacteria multiply very quickly (1 cell can lead to 17 million cells after 24 hours). They require moist, warm environments to survive and reproduce.

Bacteria need a wound or natural opening (stomate in a leaf, nectarthode in a flower) for entry into plant.

Disease Slides Shown:

- Crown Gall caused by *Agrobacterium tumefaciens*. Many woody and herbaceous plants can be attacked by this widespread bacterial pathogen. In this slide wintercreeper is affected. The bacteria gain entry into the plant primarily through wounds and cause abnormal growth of the plant tissue called galls. Avoiding wounds will reduce the chances for infection.

  Removal and destruction of galls or badly galled plants can reduce the spread of the disease, but the bacteria can survive for long periods (years) in the soil.

  Avoid replanting susceptible plants in a site where this bacterial disease has occurred.

  A relatively new control measure involves dipping transplants in a solution with *Agrobacterium radiobacter*, trade name=Norbac/Galltrol, to protect the new transplants for *Agrobacterium tumefaciens*.

- Soft Rot of Potato caused by *Pectobacterium carotovorum,* causes the tissue to liquefy and collapse. The pathogen works quickly and a rather strong odor is often associated with soft rot infections.

- Fireblight of Apple caused by *Erwinia amylovora*. Rain, splashing water, and insects can spread the bacteria. As with fungi, water is important in both the spread and invasion of the plant by bacteria. Anytime you can limit contact of water with plant foliage (adjusting irrigation periods, using ground drip system), you can help control a bacterial or fungal plant disease problem.

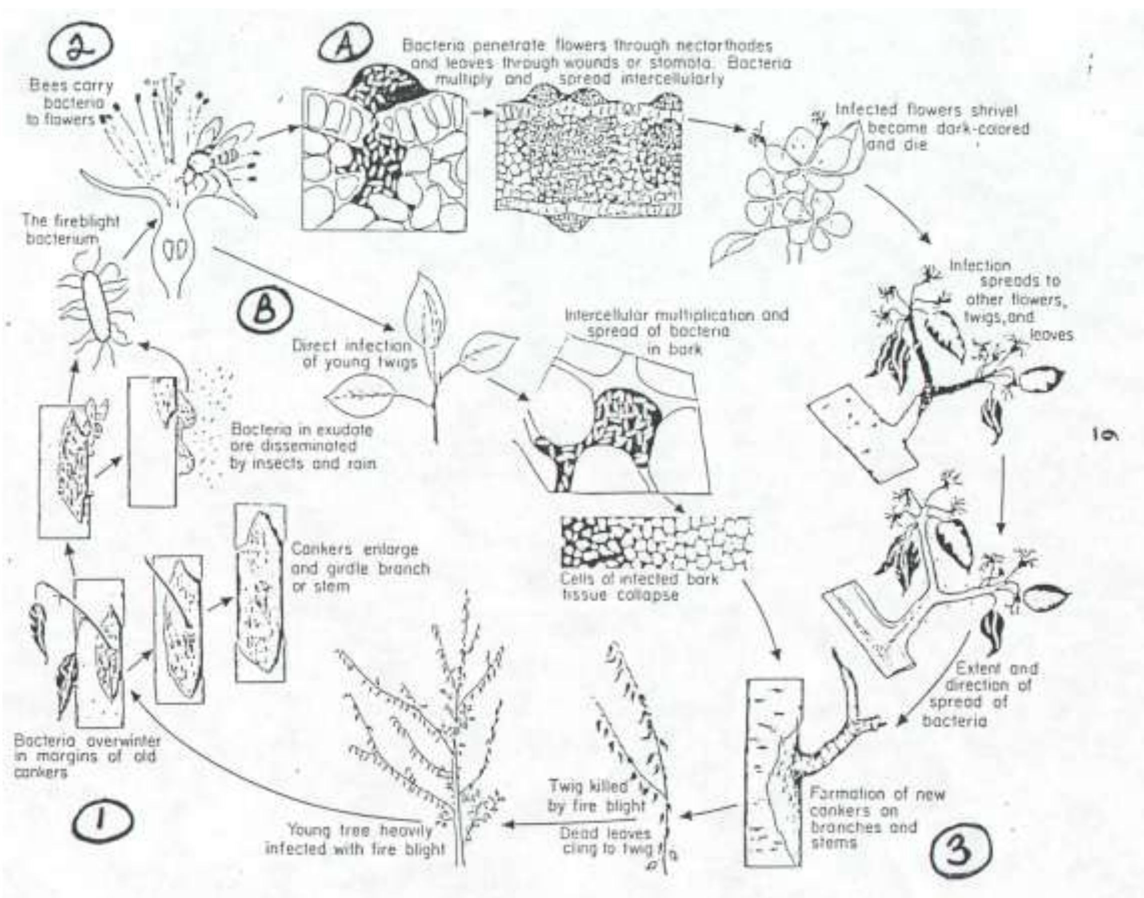
- Diagnostic Techniques include looking for bacterial strings when pulling sections of stem apart and bacterial streaming when tissue is placed in water.

Fireblight Disease Cycle:

1) Overwintering Cankers
2) Bacteria spread via insects and rain to
    a) leaves and flower-penetration through stomata, wounds, or nectarthodes; bacteria multiply and spread into twigs and, eventually, larger branches where they cause cankers (#3).
    b) Bacteria directly infect twigs later in the season; they multiply and spread into larger branches to form cankers.
3) Bacteria in cankers on larger branches. Tree can be heavily blighted.

Management of Fireblight:

1) Prune out cankers in the winter.
2) Removal of infected blossoms and twigs.
3) Antibacterial sprays to protect blossoms.



FIREBLIGHT DISEASE CYCLE

IV. The Viruses.

Virus: (singular = virus; plural = viruses); a very small particle that consists of genetic material encased in a protein capsule and can reproduce only within a living organism. Plant viruses become <u>systemic</u> in their host plants.

Viruses are some of the smallest pathogens known. There are not any pesticides that are effective against a virus. Viruses are particularly helpless outside of a living cell and so require special means for spread and infection.

Disease Slides Shown:

- A Kwanson Cherry with a viral infection. A single plant cell can contain many virus particles, when the cell dies and breaks open, all of the virus particles are released and may spread through the plant. Thus once a virus infects a plant, the whole plant will likely be invaded. Another was to say this would be to say that the virus becomes systemic.

  If there are viral symptoms on any part of the plant you must assume that all parts contain the virus.

- This is a view of virus particles through an electron microscope. The particles here are round. Other common plant pathogenic viruses consist of long rods.

- The following slides show symptoms that are common among virus disease. These yellow squash have been infected with **Cucumber Mosaic Virus** (CMV). This virus causes the green molting on the fruit and the distorted leaf yellowing.

- Here is a virus disease that is sometimes touted as a new variety of tulips. The disease is called **tulip breaking** and results in this white streaking. There are some bonifed tulip varieties with a color break but the pattern is different than this.

- Unfortunately, the virus can be spread by aphids and soon all the tulips in a planting could be infected. The disease can also result in the decline of the plants, so rogueing infected plants as soon as the are noticed is recommended.

- The yellow lines and ring spots on this foliage is caused by **Rose Mosaic Virus**. This is actually a complex of Prunus Necrotic Spot Virus and other viruses. This disease is not very damaging to roses and often goes undetected. The virus is not spread by an insect vector. It is only spread via propagation. Roguing infected plants is required for control. This is seldom recommended, however, since little immediate damage is done by the virus (es) and any rose grower knows that roses require substantial time for establishment. Viral infection can, however, affect vigor/winter hardiness, so infected plants should be given extra winter protection.

- This plant has a very serious virus problem that is especially of concern in commercial greenhouses, **Tomato Spotted Wilt Virus (TSWV)** and **Impatiens Necrotic Spot Virus (INSV)**. The two viruses cause symptoms that are indistinguishable from each other. New Guinea Impatiens are especially hit hard. The main insect that spreads the virus is the

western flower thrips. This insect is very elusive and difficult to see on plants. Yellow or blue sticky cards are used to monitor for its presence.

- This impatiens plant has one side healthy-looking and one side diseased-looking, yet we must assume that the entire plant is affected (remember that viruses are often systemic). The virus produces different symptoms on the various plants it can infect; This makes it very difficult to identify. Ornamental such as impatiens, gloxinia, cyclamen, petunia, etc. are commonly infected as are vegetables like tomato and pepper. Viruses are usually named for the first host they are detected on (Tomato Spotted Wilt Virus) but they can infect a variety of different species.

TSWV/INSV has a large host range including Impatiens, Double Flowering Impatiens, New Guinea Impatiens, Cineraria, Tomato, and Begonia.

The virus can eventually lead to death of plants, especially if plants are infected when young (as with these cuttings). At this point, root rot and other disease are also involved with the decline of these plants, but early viral infection, the cuttings were taken from an infected mother plant) was no doubt a significant stress.

Most viral problems in the home garden will have to be diagnosed by visual symptoms alone. Much time and money are necessary for appropriate tests to determine the specific virus involved. Unlike fungi and bacteria, it is difficult to see viral particles and identify them as a specific virus.

- **Dahlia with Cucumber Mosaic Virus (CMV).** This is an example of a very severe infection, this is not real typical of virus infections.

- **Aphid.** Viruses are especially helpless outside of a living plant cell and so require special means for spread and infection. Insects with sucking mouthparts such as aphids (see Slide) and leaf hoppers, are particularly adept at spreading viruses. As these insects pierce the plant surface to feed, their needle-like mouths are inserted into plant sap. If the sap contains virus particles, the insects may ingest them. When they fly to uninfected plants and feed again, they can transfer the virus directly into the new plant cells.

- **Leafhopper.** Because insects can have a major role in the spread of virus diseases, virus controls often involve insecticides. However, insecticides can sometimes be ineffective because the insects may be able to infect the plant with a virus before the chemical kills it. Many insecticides operate slowly when compared to the movement of insects.

- **Border Rows in the Garden.** One wat to help get better control of the insect population (and viral infections) is to plant a special border row of somewhat tall plants to attract insects. Treat this with insecticide so that the insects are killed before they spread into the rest of the garden. In this case, tall marigolds are being used. Ornamental grasses are another good possible border row.

- **Weeds at the edge of a yard.** Another approach is to apply an insecticide to any perennial weed patches near the garden to kill the insects. Often, insects will be found first around the perennial weeds because this was where they spent the winter. Out right removal of the perennial weeds will remove this overwintering site.

Spread of Viruses:

- Insects
  - Aphids
  - Leafhoppers
- Planting Material
  - Vegetative parts
- Mechanical Means
  - Tools
  - Plant Contact

Management of Virus Diseases:

- Insecticides
- Border Plantings/Removal of Weeds
- Rogueing Infected Plants
- Resistant Varieties
- Clean Tools and Materials
- Avoid Wounds.

V. The Nematodes.

Nematode: (singular = nematode; plural = nematodes); are microscopic, worm-like animals that live saprophytically in water or soil OR as parasites on plants.

Properties of nematodes:

•Belong to the Animal Kingdom.
•Most nematodes are beneficial organisms that do not harm plants.
•Approximately 12 genera of nematodes are known parasites of turfgrasses.
•Obligate root parasites.
•Identified on the basis of their morphology.
•The greater the populations, the greater the damage.
•Perennial inhabitants of all ecosystems.
•Need to learn more to understand damage capabilities.

Disease Slides Shown:

- This slide compares the size of a plant parasitic nematode with a single cotton thread.

- This slide compares feeding nematodes with root hairs of the host plant.

- This slide shows the damage caused by root knot nematodes. Swellings on the roots are very obvious on the swiss chard, beet, and carrot. These galls are caused by substances released by the nematode during feeding. The growths help to protect and feed the nematode but are harmful to the plant. Infected plants often show stunting and wilting above ground.

  If a wilting plant is dug up, you may find these knots and guess that you have a nematode problem. There are other diseases that can be confused with this type of injury (crown gall bacteria, nitrogen fixing nodules of legumes) thus you may want to consult with a plant pathologist to be sure of your diagnosis.

- This slide is a cartoon of the sausage-shaped, **sedentary females of root knot nematodes** imbedded in the "knots" of the plant roots. The egg mass is extruded outside the knot to allow for spreading into the soil. The best means of control is to avoid introducing the nematode into the garden. Infected transplants are a prime means of introduction. Also, movement of infected soil into the garden can introduce the nematodes. Use only high quality transplants and clean soil.

- **Nematode Overwintering**. Most plant parasitic nematodes live in the **soil (C)** and many can survive the winter in the soil. However. the cold winter temperatures here limit the survival rate. Warmer areas of the U.S. have much more severe nematode problems than we do.

  Nematodes can also survive the winter in the **roots (A)** or **tubers (E)** of the infected outdoor crops, or indoors in **greenhouse plants (B)**.

  Nematode populations may begin at low levels but can increase over several seasons and become high enough so that the plants become unthrifty and may die. Nematode feeding can also wound and stress plants thus making them more susceptible to disease such as Pythium Root Rot and Verticillium Wilt. Some nematodes can even be vectors of viruses.

  Crop Rotation with plants that are not attacked or only lightly attacked can help control nematodes by limiting their population growth. Unfortunately, the root knot nematode has a wide host range. Susceptible plants include most garden vegetables and flowers. However, corn, cabbage, beans, and related crops are not good hosts for the nematode. Grasses and grains are generally resistant and could be left fallow or used as a cover crop on problem soils.

- Several studies indicate that marigolds produce materials that are toxic to root knot and other parasitic nematodes. Planting these in spots where the nematodes occur in high populations can reduce their numbers. However, marigolds will not protect other crops in the garden from attack, they only reduce numbers around their own root systems. Mass plants would be necessary to control nematodes in the entire garden, (see slide) the number of marigolds and tomatoes in the garden should be reversed. One could also try planting sections of a garden to solid marigolds on a rotating basis.

- Other nematodes- The female body of the **Cyst nematode** becomes the house to protect the eggs and immature (J2) forms of the nematode.

- This slide shows a dissecting microscope view of the cyst, J2s, and eggs.

- This is a close-up view of a cyst split open with eggs pushing outward.

- This is an image of a single egg with the juvenile nematode curled up inside.

- **Masterwort with a foliar nematode**. This is an example of a nematode that affects the foliage of plants.

Chrysanthemum is especially affected by foliar nematode. V-shaped lesions on mums are diagnostic of infection by these organisms. Remember that must nematodes affect roots not foliage.

- **Creeping Phlox with foliar nematode.** This slide shows an infected plant on the right and a healthy plant on the left.

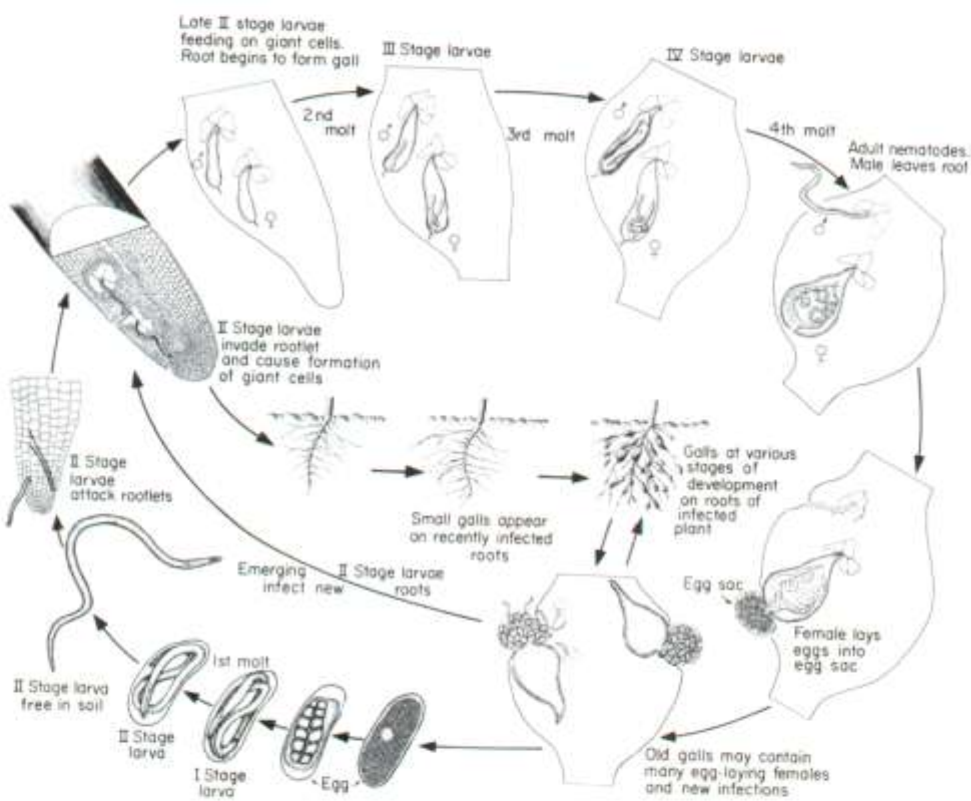
- One leaf was removed from the plant and was cut under water in a glass petri dish. You can see a few nematodes swimming out of the leaf.

- After just a few minutes there are hundreds of foliar nematodes seen around this single leaf. The leaf itself was approximately ¾ of an inch in length. The populations in this plant were extremely high.

Control of foliar nematode is difficult. Once established it is recommended to rogue out any plants showing symptoms, not to use any plants for propagation purposes, and to spray with a nematicide. Currently there are no nematicides registered in NYS for the control of foliar nematodes on ornamentals.

Nematode lifecycles are similar to those of insects (eggs hatch into juveniles which molt into adults).

Root-Knot Nematodes: Meloidogyne



A single nematode can do little harm to a plant root; but when large numbers build up in the soil (over several seasons) many root areas are attacked at once and significant damage can result.

Not all nematodes are plant parasites; many nematodes are saprophytes. Some nematodes are even insect parasites.

Nematode Spread:

- Environmental Conditions
  - Splashing Rain, can swim short distances
- Vectors
  - People and Animals moving soil and plant parts, Insects within their bodies
- Planting Material
  - Vegetative parts

Nematode Management:

- Nematicides
- Exclusion
- Eradication
- Resistant Varieties
- Clean Tools and Materials
- Avoid Wounds, Stress

Another option is using biological control methods to manage nematode populations. This slide shows a nematode trapping fungus at work.

VI. Phytoplasmas.

Phytoplasmas are Mollicutes that cause plant disease and that cannot be cultured. Phytoplasmas cause the disease known as "Yellows" diseases.

Mollicutes are very similar to bacteria in that they are prokaryotes but they lack a cell wall. In some older literature these will be called Mycoplamas Like Organisms or MLOs. Diseases caused by these organisms were originally thought to be caused by viruses. Not until 1967 was the distinction made.

A little information about Phytoplasmas.

- Cause over 300 plant diseases.
- Obligately parasitic and not yet culturable.
- Among the smallest organisms known.
- Vectored by phloem-feeding insects such as leafhoppers.
- May also be transmitted by grafting and dodder.

Phytoplasma History.

- 1967-Japan-Some MLO's associated with Yellows diseases.
- MLO's occupy the sieve tubes of angiosperms.
- Graft and insect transmittable.
- Tetracycline causes a remittance of symptoms and temporary disappearance of MLO's.

Some Phytoplasmal diseases.

- X-disease of peaches and cherry.

- Lethal Yellowing of Palms.
- Pear Decline.
- Elm Yellows.
- Ash Yellows.
    - Lilac Witches Broom.
- Aster Yellows.
- Blueberry Witches Broom.
- Bunch disease of pecan and walnut.
- Grapevine yellows.

Phytoplasma-induced symptoms.

- Slow to feeble growth.
- Loss of apical dominance.
- Witches broomes.
- Dwarfing.
- Sterility.
- Yellowing.
- Rootlet necrosis.
- Phloem necrosis.
- Phloem hyperplasia.
- Leaf malformations.
- Impaired gas exchange.

Slides of Phytoplasma Diseases:

- A phytoplasma found inside an insect. Note the shape of the organism.

- Phytoplasmas in the sieve element of Vinca.

- Known host range of Ash Yellows in 1998.

- Example of a healthy *Echinacea purpurea*, Purple coneflower. Example of an *Echinacea purpurea*, Purple coneflower, with Aster Yellows.

- Healthy and Aster Yellows infected Chrysanthemum cv. Bright Golden Ann.

- Coconut Palm infected with Lethal Yellows of Palm.

- Phytoplasmal witches broom on Willow.

- Witches broom caused by Ash Yellows on an Ash seedling. Witches broom caused by Ash Yellows on the trunk of a mature Ash tree.

- Example of Dodder growing over Vinca.

Phytoplasma Vectors.

- Primarily Leafhoppers.
- Others include Planthoppers, Psyllids, a froghopper and stickbugs.

- Phytoplasmas circulate and multiply within their vector.

Management of Phytoplasma Diseases:

1) use of **chemotherapy** with tetracycline. This procedure is very expensive. Other antibiotic such as penicillin are not effective. The tetracycline provide a remission of symptoms, this is not a cure.
2) use of **heat treatments**. Plants grown at 30-37C for long periods of time OR hot water treatments(45-50C) of dormant plants for 20-30 minutes.
3) **Insecticides** used to control insect vectors.
4) **Weed Control.**
5) **Resistant Varieties.** Either resistance to the insect vector or to the pathogen is effective.

VII. Abiotic Symptoms.

About 50% of the samples that some into the diagnostic clinic have symptoms that are caused by an abiotic agent not by a plant pathogen.

Abiotic symptoms can be caused by:

1) Salt Injury.
2) Herbicide Injury.
3) Chemical Spills.
4) Soil Compaction.
5) Freezing Injury.
6) Chilly Water injury.
7) Nutrient Deficiency.
8) Ozone Injury.
9) Genetic Abnormalities.
10) Oedema.
11) Snow Damage.
12) Car Exhaust.
13) Vandalism.
14) Lightning.

VIII. Reference Section.

References for Further Reading and Use:

Ball Field Guide to Diseases of Greenhouse Ornamentals. M. Daughtrey and A. Chase. 1992. Ball Publishing. Geneva, Illinois. 218 pp. (around $60)

Brooklyn Botanic Gardens Handbooks. Brooklyn Botanic Garden, 1000 Washington Ave. Brooklyn, NY 11225 (around $9.00)

Some of the titles available:

- Hummingbird Gardens: Turning Your Yard Into Hummingbird Heaven
- Wildflower Gardens: 60 Spectacular Plants and How to Grow Them in Your Garden
- Bird Gardens: Welcoming Wild Birds to Your Yard
- Going Native: Biodiversity in Our Own Backyards
- Invasive Plants: Weeds of the Global Garden
- The Natural Water Garden: Pools, Ponds, Marshes and Bogs for Backyards Everywhere
- Woodland Gardens: Shade Gets Chic
- Gardening with Wildflowers and Native Plants
- Natural Disease Control: A Common-sense Approach to Plant First Aid

Compendia are published by the American Phytopathological Society (APS), 3340 Pilot Knob Road, St. Paul, MN 55121-2097. They currently cost $55-59, with discounts to APS members. Each compendium covers common diseases found on the various plants listed.

The color photographs in the center of each publication are helpful although the language in the body of the text is somewhat technical. Here is a listing of the compendia available.

Compendium of Alfalfa Diseases.
Compendium of Apple and Pear Diseases.
Compendium of Barley Diseases.
Compendium of Bean Diseases.
Compendium of Beet Disease and Insects.
Compendium of Brassica Diseases
Compendium of Chrysanthemum Diseases.
Compendium of Citrus Disease.
Compendium of Conifer Diseases.
Compendium of Corn Diseases.
Compendium of Cotton Disease.
Compendium of Cucurbit Diseases.
Compendium of Elm Diseases. (not available)
Compendium of Flowering Potted Plant Diseases.
Compendium of Grape Diseases.
Compendium of Hop Diseases and Insect Pests.
Compendium of Lettuce Diseases.
Compendium of Nut Crop Diseases in Temperate Zones.
Compendium of Onion and Garlic Diseases.
Compendium of Ornamental Foliage Plant Diseases.

Compendium of Pea Diseases.
Compendium of Peanut Diseases.
Compendium of Pepper Diseases.
Compendium of Raspberry and Blackberry Diseases and Insects.
Compendium of Rhododendron and Azalea Diseases.
Compendium of Rice Diseases.
Compendium of Rose Diseases.
Compendium of Sorghum Diseases.
Compendium of Soybean Diseases.
Compendium of Stone Fruit Diseases.
Compendium of Strawberry Diseases.
Compendium of Sweet Potato Diseases.
Compendium of Tobacco Diseases.
Compendium of Tomato Diseases.
Compendium of Tropical Fruit Diseases.
Compendium of Turfgrass Diseases.
Compendium of Umbelliferous Crop Diseases.
Compendium of Wheat Diseases.

Christmas Tree Pest Manual. 2nd ed. 1998. Edited by J. Benyus. USDA-Forest Service, Michigan State University Extension Service Bulletin E-2676.
(Available online at: http://www.na.fs.fed.us/spfo/pubs/misc/xmastree/tbl_contents.html.)

Cornell Commercial Recommendations for Pest Control (available for Trees and Shrubs, Turf, Tree Fruits, Small Fruits, Vegetables and Potatoes, etc.)

Diseases and Pests of Ornamental Plants. 5th ed. P.P. Pirone. 1978. John Wiley & Sons, Inc., New York, New York. 566 pp.

Disease of Forest and Shade Trees of the United States. USDA Agriculture Handbook 386 658 pp.

Disease of Herbaceous Perennials. Mark L. Gleason, Margery L. Daughtrey, Ann R. Chase, Gary W. Moorman, and Daren S. Mueller. 2009. APS Press. 296 pp.

Diseases of Trees and Shrubs, 2nd ed. W.A. Sinclair and H.H. Lyon. 2005. Cornell University Press. Ithaca, NY. 660 pp.

Diseases of Ornamental Plants. J.L. Forsberg. 1975. Special Publication No. 3. Revised, Univ. of Illinois at Urbana-Champaign, College of Agriculture. 220 pp.

Disease of Woody Ornamentals and Trees in Nurseries. Ronald K. Jones and D. Michael Benson. 2001. APS Press, St. Paul, Minn. 482 pp.

Essential Plant Pathology. Gail L. Schuman and Cleora J. D’Arcy. 2006. American Phytopathological Society (APS Press), 338 pp.

Foliage Plant Diseases: Diagnosis and Control. A. R. Chase. 1997. American Phytopathological Society (APS Press), 169 pp.

Guide to Pest Management Around the Home, Parts I and II. 2005-2006. Misc. Bulletin 74. Cornell Cooperative Extension. 135 pp. [To be replaced by IPM Manual; pending]

Herbaceous Perennial Plants: A Treatise on their Identification, Culture, and Garden Attributes, 3rd edition. Allan Armitage. 2008. 1224 pps.

Identifying Diseases of Vegetables. A.A. MacNab, A.F. Sherf, and J.K. Springer. 1983. Pennsylvania State University, University Park, PA. 62 pp.

Landscape Plant Problems: A Pictorial Diagnostic Manual. Ralph S. Byther, Carrie R. Foss, Arthur L. Antonelli, Raymond R. Maleike, Van M. Bobbitt, and Jenny Glass. 2006. Cooperative Extension, Washington State University. 160 pp.

Magical Mushrooms, Mischievous Molds. George W. Hudler. 1998. Princeton University Press, Princeton, NJ.

Pests of the Garden and Small Farm: A Grower's guide to Using Less Pesticide. 1990. M.L. Flint. Statewide IPM Project, Univ. of California, Div. Of Agriculture and Natural Resources, Publication 3332, ISBN 0-931876-89-3. 276 pp.

Phytophthora Diseases Worldwide. Donald C. Erwin and Olaf K. Ribeiro. 1996. American Phytopathological Society (APS Press), 562 pp.

Plant Diseases: Their biology and social impact. Gail Schumann. 1991. American Phytopathological Society (APS) Press, 397 pp.

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Resource Guide for Organic Insect and Disease Management. Brian Caldwell, Emily Brown Rosen, Eric Sideman, Anthony Shelton and Christine Smart. 2005. NYSAES (Geneva) and Arnold Printing (Ithaca) 169 pp.
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The Healthy Indoor Plant: A Guide to Successful Indoor Gardening. C. Powell and R. Rossetti. 1992. Rosewell Publishing Inc., Columbus, Ohio. ISBN 0-9631767-6, 297 pp.

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Turfgrass Problems, Picture Clues and Management Options. Eva Gussack and Frank S. Rossi, PhD. 2001, NRAES-125, Ithaca, NY.

Vegetable Diseases: A Colour Handbook. Steven T. Koike, Peter Gladders, and Albert O. Paulus. 2007. Academic Press, Mansion Publishing Ltd. London. 448pp.

Wescott's Plant Disease Handbook. 7th edition. R.K. Horst. 2008. Springer Verlag Berlin Heidelberg NewYork, 1317 pp.

Useful Web Sites:

Cornell University's Plant Disease Diagnostic Clinic, http://PlantClinic.cornell.edu
Cornell University's Home and Grounds Pest Fact Sheets, www.cce.cornell.edu/factsheets/home/pests
Cornell University's Gardening Program, http://www.fvs.cornell.edu/Gardening/index.html
Cornell University's EcoGardening Fact Sheets, http://www.fvs.cornell.edu/extserv/MES/EcoGardFS.html
Cornell University's Composting Home Page, http://cfe.cornell.edu/wmi/#anchor9523120
National Plant Diagnostic Network, www.npdn.org
Northeast Plant Diagnostic Clinic, www.nepdn.org
Ohio State Yard & Garden Fact Sheets, http://www.ag.ohio-state.edu/~ohioline/lines/hygs.html
Penn State University-Woody Ornamental Plants, http://ento.psu.edu/extension/trees-shrubs
Purdue University, http://www.ppdl.purdue.edu/ppdl/Reference_links.html#Gardening_Landscapes
Missouri Extension Service, http://muextension.missouri.edu/xplor/agguides/hort/index.htm

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