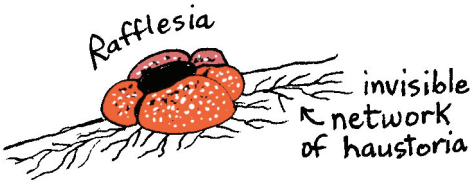
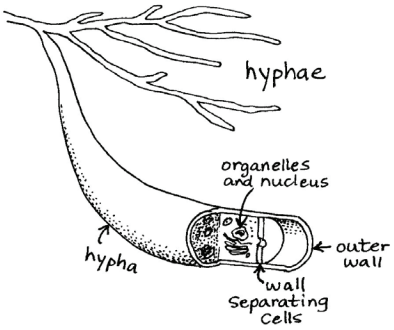
LESSON 8: PLANT DISEASES

LEVEL ONE

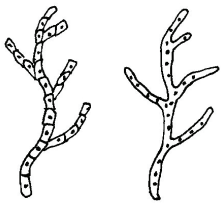
Just like people and animals, plants can get sick. They can catch viruses, get bacterial and fungal infections. About two thirds of all plant disease is caused by fungi, so let's take a look at this category first.

Fungi are a bit like the Rafflesia plant. (If you read level 2 of lesson 7, you've already met this plant.) This parasitic plant has no roots, no stems and no leaves. The main "body" of the plant is an invisible network of fibers running through the host plant (the plant to which it is attached). You'd never know the Rafflesia even existed if it didn't produce flowers once in a while. Seemingly out of nowhere (but actually from that network of fibers) a flower appears. Rafflesia flowers grow to be the largest flowers in the world. But there sit the flowers, with no plant in sight!

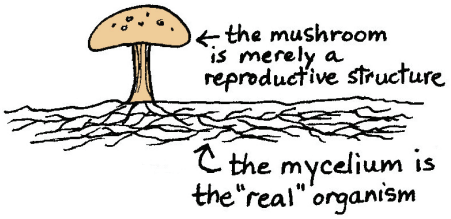


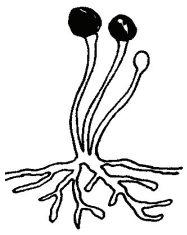


Fungi work in much the same way. The "body" of a fungus is a network of fibers called a ***mycelium***. (The word "mycelium" is Greek for "fungal body". Not much translating needed there.) The individual strands that make up the mycelium are called ***hyphae*** (meaning "filaments"). If you are talking about just one strand, you call it a ***hypha***. That's the basic structure of a fungus. Pretty simple. The hyphae can be separated into individual cells with walls in between, or they can be like one very long cell, with nuclei and organs dotted here and there along the way. Fungal cells are similar to plant and animal cells in that they have a nucleus and the usual assortment of organelles—mitochondria, endoplasmic reticulum, ribosomes, Golgi bodies, and storage vesicles.

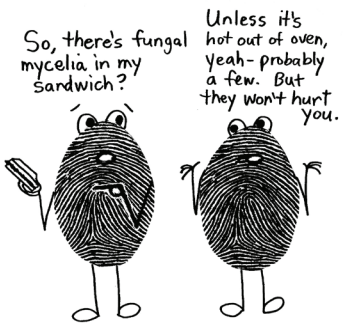


Mycelia are creeping around all the time and you are not even aware of it. It's only when the fungus decides to reproduce that you notice it. Certain fungal cells are able to produce what are generally called "fruiting bodies." The fungal fruiting bodies you are most familiar with are mushrooms. You might think of a mushroom as a little plant, but it's not. The mushroom is only the reproductive structure. The main body of the organism we call a mushroom is actually the hidden mycelium under the dirt. You can't see the main body of the organism. The mushrooms come and go along with the wet and dry seasons, but the mycelia are there all the time.





Another type of fruiting body you recognize is the blue, green or black fuzz that grows on breads and fruits when they've been sitting too long. If you could look at the fuzz under a magnifier, you'd see that the fuzz is made of thousands of tall filaments with balls on their ends. The balls are similar to those sporangia we saw on moss plants. The sporangia break open and release zillions of spores into the air. The spores can float in the air for a long time. Eventually they may land on a fresh slice of bread where they can grow into mycelia.



Fungi get their nutrition by using enzymes to dissolve the plant or animal tissue they are growing on. The hyphae release digestive enzymes into the immediate environment around them. The enzymes break down the tissues into tiny molecules that the fungal cells can then absorb. It's like external digestion. Fungi are very important to the environment because their digestion helps to recycle dead plant and animal material. Fungi, along with bacteria, are ***decomposers***. We'd be buried miles deep in dead plants and animals if it were not for our tiny decomposing friends! However, there are certain members of the fungi kingdom who are not so helpful.

Fungi can attack plants. You've seen mushrooms and shelf fungi growing on trees. Other types of fungi cause black or brown spots on leaves.

Any time you see large, round, dark spots on leaves, it's probably a fungal infection. The spots are round because the fungus starts out as a single dot then grows at the same rate in every direction.

Powdery mildew is another common fungal infection. It is often seen on lilac bushes and on garden plants such as squash and cucumbers.

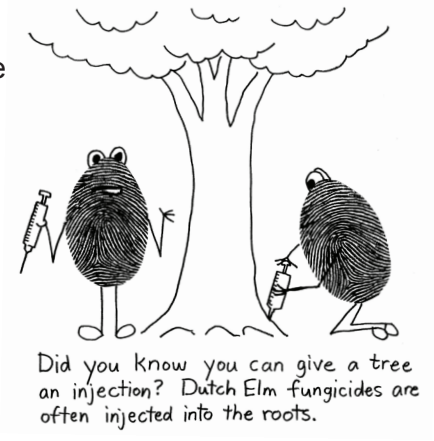
"Rust" is the common name for a fungus that causese leaves to turn reddish-brown, as though they were rusting.

Cankers are infections that cause "open wounds" on trunks.

Another well-known fungal infection is called ***Dutch Elm Disease***. This fungus has devastated the population of beautiful old elm trees in public parks and college campuses across Europe, the UK and North America since the 1930s. (An estimated 25 million trees died in the UK alone!) The fungus is carried from tree to tree by a beetle that eats elm tree bark. When the fungus gets into the xylem tubes, the tree reacts and tries to protect itself by sealing off that area. The xylem tubes begin making a gummy substance that intentionally clogs them up. This effectively stops the fungus from travelling up through the xylem tubes, but it also cuts off the water supply for the connected branches. Those affected branches will die not as a result of direct contact with the fungus but because they are not getting enough water. As the beetle bites into more parts of the trunk, more xylem becomes clogged. As more and more branches are affected, the entire tree will start to die.

One way to fight the disease is to try to get rid of the beetles. ***Insecticides*** (insect-killing sprays) were used during the 1950s and 1960s until these chemicals were proven to be harmful to other forms of life, not just beetles. ***Fungicides*** (fungus-killing chemicals) have also been used, but the results have been disappointing. The fungicides have not been able to get rid of the disease.

The most successful approach has been to find plants that are naturally resistant to it. Remember back in those lessons about plant reproduction we learned that one reason plants need to trade DNA (by using egg and sperm) is to produce offspring that are slightly different from the parents. Yes, all the baby elm trees will all look and act like elm trees, but each plant will have minor differences. One of these differences is their ability to survive attacks by various diseases. ***Arborists*** (professional tree growers) have found some elm trees that are more resistant to the Dutch Elm Disease fungus, and they've started to breed these hardy trees. Sick trees are destroyed and are replaced by these more resistant ones.



If a plant in your yard or garden comes down with a fungus, the first thing you need to do is cut off all the parts that are sick. Trim off every leaf, stem and branch that looks even slightly affected. Dispose of the diseased parts in a way that won't spread the fungus around any more. (Many gardening books and websites can tell you how to do this.)

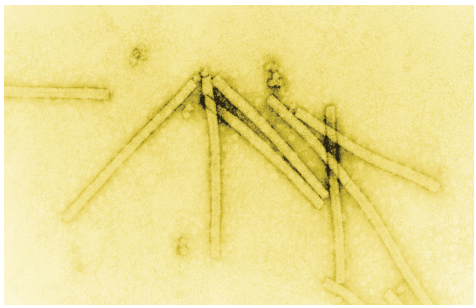
Sometimes you can use a spray to slow down the fungus. (Sprays don't work for Dutch Elm Disease, but they are effective on other types of fungi.) Two very safe sprays you can make are baking soda spray (made from baking soda, vegetable oil, and a little dish soap) and compost tea spray. To make compost tea, you soak compost in water and pump air bubbles into it. The result is a solution full of good bacteria that will kill fungi without harming your plants. There are also sprays you can buy that contain sulfur and copper, but you have to be careful with these since they could be toxic to animals.

Perhaps the best thing you can do for plants that are fighting fungal infections is to try to keep them dry, if possible. You can't control the weather, but if you water your plants, don't spray the whole plant. Pour the water on just the roots. The extra water on the leaves only serves to help the fungi grow.

The next most common infection seen in plants is viral infection. Human viruses you may be familiar with include rabies, polio, chicken pox, influenza and the common cold. The most well-known plant virus is called mosaic virus. It was first discovered on tobacco plants, so sometimes it is called ***tobacco mosaic virus***.

Mosaic virus gets its name from the mottled pattern it makes on leaves. It mainly attacks members of the nightshade family (which includes tobacco, potatoes, tomatoes, eggplants and peppers), but it can also attack cucumbers and some types of garden flowers. The virus rarely kills the plant, but causes enough damage that the plant becomes useless to farmers who are looking to make money from their harvests.

The virus was discovered in the late 1800s, though at that time there were no electron microscopes, so the scientists who discovered it never knew what it looked like. They knew it was extremely small, much smaller than a bacteria. They put juice from infected plants through strainers that could filter out even the smallest bacteria. After the juice had been through the strainer, they could be sure that it had no bacteria in it. When this bacteria-free strained juice was applied to healthy plants, they got sick. Obviously, some infectious agent was slipping through.



In 1939, the first electron microscope picture of the mosaic virus was taken. Then, in the 1950s, Rosalind Franklin (the scientist who produced the images of DNA for Watson and Crick) was able to gather enough information from her x-ray images of the virus to be able to make a model of it for the 1958 World's Fair. She figured out that the virus was long and hollow, like a drinking straw, and contained a single strand of RNA. The piece of RNA contains instructions that can tell a plant cell how to make mosaic viruses.

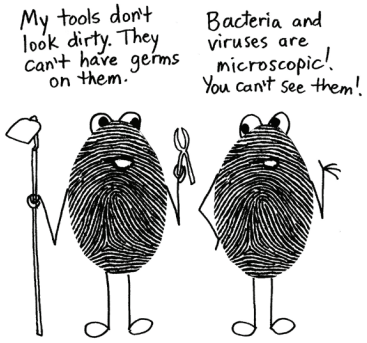
Viruses are like pirates—they land on a cell and take it over. They inject their RNA instructions into the cell. The cell's organelles then stop what they are doing and begin to follow these new instructions instead. The plant organelles begin to manufacture and assemble new mosaic viruses. Soon the cell is so full of viruses that it bursts open, releasing all the new viruses. Each one of those new viruses goes to another plant cell and takes it over. When the viruses get into the xylem and phloem tubes, they are quickly transported to other areas of the plant. As you might guess, it doesn't take too long before the plant is overwhelmed with viruses.

Plants don't have immune systems like animals do, but they aren't totally helpless, either. We've already seen how a Dutch Elm clogs its infected xylem cells to keep the fungus from spreading. Plants can also make chemicals that will interfere with the ability of a ***pathogen*** (a disease-causing fungus, virus or bacteria) to live and reproduce. Plants that are more successful at producing large volumes of protective chemicals, or better quality chemicals, will be the ones that survive the infection. Weaker plants die off and the stronger ones go on to reproduce and pass along these strong genetics to their offspring. Plant scientists have been able to speed up this natural process and breed plants that are more resistant to disease.

There are many other types of plant viruses besides mosaic virus. Most are long and thin like mosaic viruses, but some look more round. No matter what they look like, they all work the same way, taking over the cell's "machinery" and forcing the organelles to make viruses.

Once a plant is infected there isn't much you can do. Usually infected plants need to be destroyed so they won't infect other plants. Anything that has touched the plants (tools, gloves, etc.) will need to be washed with soap and water, or possibly even with bleach. Metal tools that might rust can be heated with a blowtorch.

Insects and worms can transfer viruses from plant to plant. (The viruses don't harm the bugs at all.) It's not possible to kill all the bugs that have touched the infected plant. The best you can do is to try to cut down the insect population as much as possible and hope for the best.



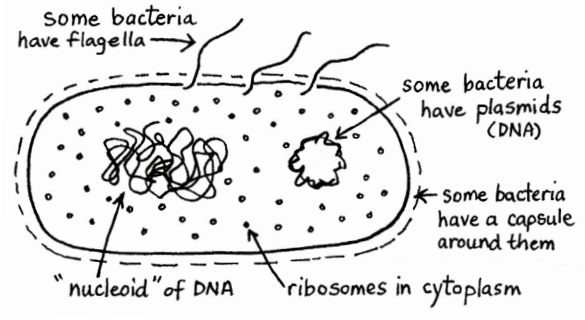
When we think about bacteria we should not think of them as "bad guys." Judging by all the advertisements for anti-bacterial soap, you'd think that a world without bacteria would be ideal. Not so! Most bacteria are friendly and are essential to the health of every type of organism on the planet.

We met some nice bacteria back in lesson 6—the nitrogen-fixing bacteria who live in nodules on the roots of legume plants and take the nitrogen out of the air and put it into a form that plants can use. Without these bacteria the soil would run out of nitrogen. Other types of bacteria can protect plants against insect and fungal invaders. The bacteria found in compost piles break down dead plants (and animals) and turn them into fresh soil that is rich in nutrients.

Relatively few species of bacteria are considered to be pathogens (causing disease). It is estimated that about 70 percent of all bacteria are not harmful. However, the remaining 30 percent can be a problem. Perhaps you have come down with strep throat or pneumonia or some other illness that had to be treated with antibiotics. (Strangely enough, do you know where most antibiotics come from? They are made by fungi!) Plants can have unfriendly bacteria attack them and damage their leaves, fruits and stems. Sometimes the bacteria live in the soil and get into the plant through the roots. Other bacteria are carried by insects. When the insect bites the plant, the bacteria get in.

Unfortunately for plants, there are no antibiotic medicines you can give them. Once again, the best you can do is to get rid of all diseased plants and plant parts. Don't put them in the compost pile, though. Burn them if you can, or dispose of them into the trash. Clean any tools that have touched the diseased plants.

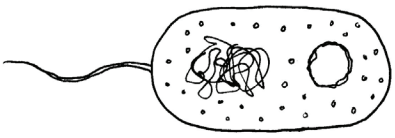
Bacteria are very simple—they don't have all the fancy organelles that plant cells do. They don't even have a true nucleus. They've got a clump of DNA (the nucleoid), and thousands of ribosomes floating around in cytoplasm. Most bacteria have a cell wall outside of their membrane and many bacteria have some kind of protective capsule. Some have flagella that allow them to move around, but many do not. Some have plasmids.

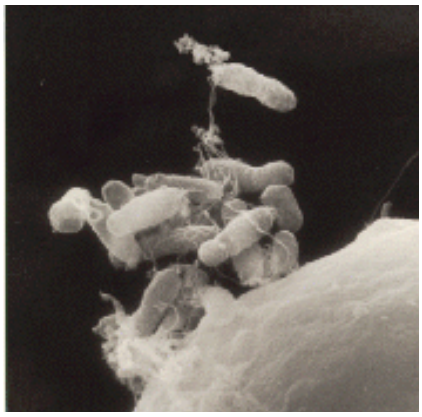


Crown galls on a willow tree

The most well-known example of a bacteria that attacks plants is the species of bacteria that causes ***crown gall***. A gall is a bit like a callus on your skin. If something irritates your skin for long enough, your skin will make a thick lump in that spot. A gall is what a plant does when it gets irritated. In the case of crown gall, a big ugly, wrinkly lump forms. The crown gall doesn't outright kill the plant, though, as you can see from this picture. If the tree died, the bacteria would be homeless and hungry. The main problem with crown gall is that it likes to attack fruit and nut trees and grape vines. This causes problems for farmers who rely on these crops for their income.

The crown gall bacteria is an unusual species. It has a flagella (tail) and can swim over to the roots of a plant and burrow in. Then it injects a piece of DNA into the cell. The bacterial DNA is taken into the nucleus of the plant cell and attaches the plant cell's DNA. The added bacterial DNA causes the cell to do two things: 1) make too much auxin, and 2) make special food for the bacteria. The extra auxin causes the infected plant cells to grow too much and the result is a large lump, almost like a tumor. (The species name for crown gall is *tumefaciens*.)





Crown gall bacteria attacking plant cell

Recently, scientists have discovered ways to use the crown gall bacteria to do some genetic engineering. They took out that piece of transferrable DNA (contained in the plasmid) and put in some DNA from a firefly instead. What did they get? A plant that glowed in the dark! Seriously, it worked! The plant cell's ribosomes (little protein factories) had the information for how to make glow-in-the-dark chemicals, so they started making some. After that, the scientists tried putting in DNA that had instructions for how to make chemicals that kill bugs. The engineered plants started producing their own insecticides. Pretty cool, eh? But...wait a minute. What if people ate these plants? What would happen? There is a lot of controversy about this right now.

When you see a label on a food package that says "No GMOs" (Genetically Modified Organisms) this means that the plants and/or animals used to make the food did not ever have this type of genetic engineering done to them. Genetic engineering of plants is so common today that most foods you eat already contain genetically modified plants. (Corn and wheat are some of the most modified plants you eat.) Is this okay? Some scientists say it is perfectly harmless. Others aren't so sure. Would you want to know if your food had be genetically modified? Some governments are considering passing laws requiring food companies to put labels on all their products, stating whether or not they contain GMOs.

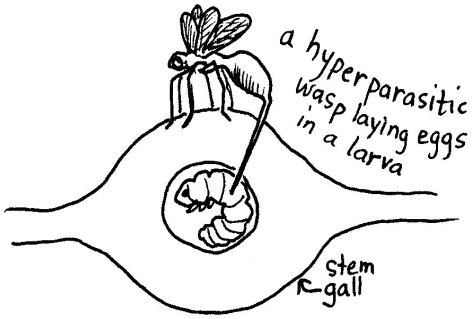
An "oak marble" gall

Galls can be caused by other things, too, not just bacteria. A gall is a plant's version of a skin callus, so anything that irritates a plant's epidermis can cause a gall. Fungi, viruses and insects can also cause galls.

The most well-known gall forming insect is the gall wasp. It's a tiny harmless wasp, not the big kind that can give a painful sting. (It looks more like a fly than a wasp.) In the spring or early summer, the female wasp deposits eggs into a leaf or stem. For reasons not entirely understood, the plant cells around the egg

start to change their growth pattern, making a gall. This gall-forming process is similar to the crown gall in that the cells' DNA is changed. The cells follow molecular instructions for how to build a perfect home a gall wasp larva. By the time the larva hatches, it is surrounded by a very cozy room filled with food. The larva munches away on the cells that line the inside of the gall. When it is mature enough, the larva will escape from the gall and fly off to enjoy its adult life out in the fresh air and sunshine. Some gall wasps spend the entire fall and winter in their galls and don't come out until spring. They live as adult wasps for only a few months—just long enough to find a mate and lay eggs (if they are female). Then the cycle starts again.

Some species of gall wasps lay their eggs inside already-formed galls. The females of these species have very long and sturdy ovipositors (with metal [zinc] tips) that can drill into every large, solid galls. The female's target is the larva in the center. She deposits one or more eggs in or near the larva. When these new wasp eggs hatch, they will eat the larva as their food source. These wasps are called "hyperparasites" because they are parasites of parasites. (And, believe it or not, there are other types of gall wasps that deposit their eggs onto these parasitic larva. That's hyper-hyperparasitism!)



Galls are very common and in some places they have even become part of human folklore. In medieval England, the custom was to open a gall as part of the St. Michaelmas festival (September 29) and use the contents of the gall to predict the coming seasons. If a "worm" (insect larva) or a fly was found, then the upcoming year would be pleasant. If a spider was found, the coming year would bring hardships with ruined crops. If the gall was empty it spelled disaster for the community, possibly even plagues. Obviously, there is no science behind these customs and if the year turned out as the gall predicted, it was just a coincidence. (Hopefully, some observant person discovered how to check for small holes in the sides of the galls. A small hole would indicate that the occupant of the gall had already escaped.)

Galls can occur on any part of a plant. Most are brown or green, but a few kinds are bright red.

Cola-nut gall on oak leaf

Nail galls on lime leaf

Spangle gall on oak

"Pineapple" gall on pine branch

Leafy goldenrod gall

Goldenrod stem gall cut in half

ACTIVITY 1: WATCH GALL WASPS IN ACTION

There is a fantastic video about gall wasps posted on the Botany playlist. Also, see some of the strangest galls in the world—they jump!

ACTIVITY 2: A WEBSITE ABOUT GALLS

Want to see a "poop gall"? This and many other strange galls are featured at this web address: http://waynesword.palomar.edu/pljuly99.htm

If you'd like to look at pictures of galls (without more info) here is a gallery of just photos: http://www.british-galls.org.uk/gallery.htm

ACTIVITY 3: A THREE-ANSWER QUIZ

This quiz only has three possible answers: fungus, virus, bacterium. However, you will have to use these answers more than once. (You can just abbreviate with F, V or B.) Sometimes only one of these will be the right answer, but other times two of them or all three of them will be correct. We are going to make the blank lines all the same size so you won't have any clues as to how many correct answers there are. (Note: We are using the word "pathogen" here in our clues, but remember that some types of fungi and bacteria are beneficial. We're just focusing on the pathogenic species.)

1) This type of pathogen attacks plants: _____

2) This type of pathogen contains DNA: _____

3) This type of pathogen sometimes has a tail-like thing called a flagella: _____

4) This type of pathogen doesn't qualify as being truly "living." _____

5) This pathogen is so small you need an electron microscope to see it. _____

6) This pathogen sometimes contains a plasmid (extra ring of DNA). _____

7) This type of pathogen can act as a decomposer, recycling dead plants. _____

8) This pathogen is often compared to a pirate because it takes over cells. _____

9) Some plants are naturally more resistant to this type of pathogen. _____

10) This type of pathogen can be used to do genetic engineering of plants. _____

11) This type of pathogen has organelles. _____

12) This type of pathogen makes reproductive structures. _____

13) Garden tools should be sterilized after contact with this type of pathogen. _____

14) This type of pathogen can cause a plant to form a gall. _____

15) Plants and plant parts affected by this type of pathogen need to be destroyed. _____

16) This type of pathogen can be discouraged by using "compost tea." _____

ACTIVITY 4: A SYLLABLE PUZZLE

The answers to all these questions have been chopped up into individual syllables, then arranged alphabetically. All you have to do is put the words back together again! The number at the end of the line is a helpful hint, telling you how many syllables to use. You might want to circle or cross out the syllables one you use them, so you don't get confused.

A, AN, AR, BAC, BI, BOR, CAN, CEL, CIDE, CO, COM, COM, DE, DEN, DER, DEW, ER, GEN, GOL, HY, I, I, I, I, IC, IC, IC, IL, IN, IST, IZE, KER, LEG, MID, MIL, MO, MY, O, OT, OV, PAR, PATH, PHA, PLAS, POS, POS, POST, POW, RE, ROD, SA, SECT, SIS, SITE, STER, TANT, TI, TO, TOR, UM, UME, US, VIR, Y

1) This microorganism can't reproduce on its own. ___ ___ ___ ___ ___ (2)
It must "borrow" the organelles of a cell.

2) This is a pile of rotting plants, rich in friendly bacteria. ___ ___ ___ ___ ___ ___ ___ (2)

3) This describes the pattern on leaves infected with this virus. ___ ___ ___ ___ ___ ___ (3)

4) This chemical kills bugs. ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (4)

5) Both fungi and bacteria help to break down dead plants and animals. An organism that does this job is called a ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (4)

6) This is the main "body" of a fungus. ___ ___ ___ ___ ___ ___ ___ ___ (4)

7) This is one single strand of the answer to number 6, above. ___ ___ ___ ___ ___ (2)

8) This fungus likes to attack lilac bushes. ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (5)

9) This infection looks like an open wound on a tree trunk. ___ ___ ___ ___ ___ ___ (2)

10) This is a person who specializes in taking care of trees. ___ ___ ___ ___ ___ ___ ___ ___ (3)

11) Some plants are natually more ___ ___ ___ ___ ___ ___ ___ ___ ___ to diseases than others. (3)

12) This is the body part of a female gall wasp that she uses to deposit eggs into a plant or a larva.
___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (5)

13) This type of plant lives in symbiosis with nitrogen-fixing bacteria. ___ ___ ___ ___ ___ ___ (2)

14) This is an extra ring of DNA found inside some bacteria. ___ ___ ___ ___ ___ ___ ___ (2)

15) The first virus ever discovered was found in this type of plant. ___ ___ ___ ___ ___ ___ ___ (3)

16) This type of chemical is used to fight bacteria. ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (5)

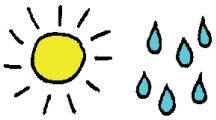
17) Any microorganism that causes disease can be called a ___ ___ ___ ___ ___ ___ ___ ___ (3)

18) A common weed that often gets stem galls (both leafy and ball-shaped) is the
___ ___ ___ ___ ___ ___ ___ ___ ___ (3)

19) This is what you should do to tools that have been used to cut out diseased plants.
___ ___ ___ ___ ___ ___ ___ ___ ___ (3)

20) This kind of organism must live in or on a host organism. ___ ___ ___ ___ ___ ___ ___ ___ (3)

LEVEL TWO



Although plants sometimes get sick, their biggest problem isn't pathogens, it's their environment. A plant with healthy growing conditions—the right amount of light, water and minerals, and the absence of toxins—will be much less susceptible to infections than a plant that is struggling with drought or malnutrition. It's the same with people; nutrition is very important to maintaining good health.

What are ideal growing conditions for a plant? It depends on the plant. We've already seen that some plants thrive in desert conditions while others are adapted to watery environments. Also, not every plant needs a lot of sunshine—some do better in shady areas. All plants need minerals from the soil, but some plants need more of one thing and less of another. So the best we can do is to offer some very general information that will apply to as many plants as possible.

Did you know that plants can get sunburn? In general, leaves are really good at soaking up sunlight with no harm done to them, but they can only do this if they have an adequate water supply. Even the hardiest leaf will start to burn if it runs out of water. Plants that are designed for shady environments don't even have to get dry to experience sunburn. The author of this book found this out the hard way, with an indoor palm and an outdoor fern.

One day I looked over at my palm and noticed that there were several leaves right in the middle of a frond that had gone brown. Some of the tips were also brown. I didn't immediately figure out what had happened because the plant had been moved away from the lamp. But as part of my investigation, I moved the plant back over near the lamp. It became obvious what had happened. These leaves had gotten more than their recommended daily allowance of light. No amount of watering could restore these leaves.

Sunburn lesson number two occurred outdoors just a few months after the indoor palm incident. I had a huge, lovely fern growing very happily under this pine tree. It had been surrounded by some other plants, including weedy vines growing all over the wire mesh fence behind it. Thinking to improve the landscape, I spent hours taking the vining weeds off the fence. The area looked very nice when I was finished. However, a few weeks later, my fern started to turn brown. The weather was not unusually dry, so I couldn't blame it on lack of water. Then one day, late in the day, I went out and discovered that the sun's rays were shining directly on the fern from behind the fence. It was now possible for the fern to receive several hours of direct sunlight. Previously, the vines must have shaded the fern. Apparently, what I wanted my yard to look like was not compatible with the needs of the fern. In trying to showcase my fern, I had made it sick. (I suspect that the rhizome of the fern (under the soil) is still alive, so I might get a second chance in the spring. I could move my fern to a better location, or perhaps plant some new vines on the fence.)

Fruits can also get sunburn. If you stop to think about the location of fruits on trees and vines, you'll notice that they are mostly sheltered by leaves. (Think about fruit trees, berry bushes, or even bean plants. You have to reach in or under leaves to pick the fruit, don't you?) Sunburned areas on fruits are discolored and acquire a hard texture. Though not toxic, they won't sell very well at a store, so fruit growers have to keep a watchful eye on their plants as the fruits ripen.

So how do you know if your plant is experiencing problems with its growing conditions? A good place to start is to look at the leaves. As we just discovered, if they are dry at the tips (A), your plant probably needs more water. If the leaves at the tips are okay but the leaves at the base of the branch are dry (B), your plant might be experiencing salt burn. This can be a result of too much plant fertilizer or because the plant is receiving run-off water from roads or sidewalks that is high in salty chemicals.

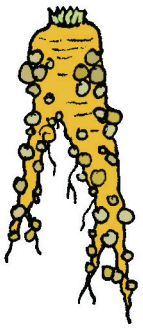
A B C D E

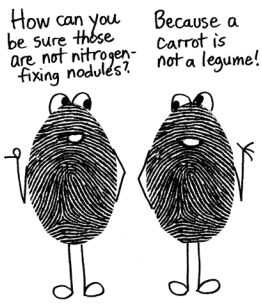
If the leaves are too yellow, look carefully at the veins. If the veins are still fairly green and the yellow is mainly between the veins (C), your plant is probably suffering from a lack of nitrgoen or magnesium. Adding some plant fertilizer to the soil can fix this problem. If yellow leaves appear only at the tips of the branches (D), the plant might be getting too much light. If the yellow leaves are near the bases of the branches (E), the plant could be getting too much water.

For indoor plants, keep the soil moist but not soggy. To estimate how much water is in the middle or bottom of the pot, tap the the pot. If you hear a solid “thud” sound, this indicates that there is still water in the pot. If you hear a hollow sound, your pot is dry and you need to add water.

If your plant’s leaves are wilted, are they still green or are they shades of brown, black, or gray? If they are green, you might just need to water your plant. If watering the plant doesn’t revive it, it may have a bacterial disease called, appropriately enough, “wilt.” Cucumbers and squashes are especially susceptible to “wilts.” This type of bacteria is usually transmitted by beetles. You’ll need to get rid of infected leaves and stems first, then deal with the beetles.

If the wilted leaves are not green, they could be infected with a fungus (if the leaves are fuzzy or powdery), a bacteria (if the leaves are brown and either crispy or gummy), or by insects (if the stems have telltale holes or chew marks). If you suspect a pathogen is the problem, trim off the infected leaves immediately. If the plant in question is an outdoor plant and you want to know exactly what is wrong, you might want to consult a diagnostic website like this one: www.extension.umn.edu/gardeninfo/diagnostics/





If an outdoor plant appears to be struggling to survive for no apparent reason, you might want to look at the roots. A tiny round worm called a ***root-knot nematode*** can take up residence in roots, causing root galls. Unlike the nitrogen-fixing nodules, these nematode galls hinder the plant’s growth. The roots can’t do their job effectively and the plant parts above the soil have trouble getting enough water and minerals. You need to remove the plant from that area and either burn it or throw it out. Don’t compost the plant, as the nematodes will be able to survive for a long time in the compost and will infect any soil you put the compost on. You can reduce the nematode population in the soil by covering the area with black plastic for a few weeks (cooking the worms to death), or by planting some marigolds in that area. Before the marigolds start making seeds, chop them up and plow them into the dirt. The rotting marigold stems and leaves will release chemicals into the soil that will kill the nematodes.

If your plant looks way too tall and skinny, it is probably not getting enough light. Remember, lack of light makes plant cells produce more auxin which causes more growth, enabling the plant to grow towards a light source. You might have to move the plant to a sunnier location, but do a little research first to find out how many hours of sun per day are best for this type of plant. You'll also have to observe your yard or garden on a sunny day and figure out which areas get full sun, partial sun, or full shade.

If your leaves have holes of any kind, they are probably being eaten by some kind of small animal. Insects are the most common leaf eaters, but slugs and mites will also damage leaves. There are hundreds of thousands of different kinds of tiny critters that eat plants, but we've boiled the list down to just eight. So here is our "top eight" list of bugs whose destructive behavior is infamous.

THE LOCUST

This member of the grasshopper family is famous for its tendency to form swarms. The largest swarm ever recorded was estimated to have over 12 trillion locusts in it! Swarms this large can sweep across farmland and consume every single green leaf in their path, leaving nothing but sticks and stubble behind. (Exactly the scene described by Moses in Egypt, and by Laura Ingalls in the American midwest.)

Oddly enough, locusts don't form swarms all that often. Usually, they exist as individuals minding their own business. When conditions get crowded and they start bumping into each other a lot (several times per minute) that's when they switch over to "swarm mode."

In ancient times there was little anyone could do to stop a swarm of locusts. Nowadays, farmers can use an insecticide made from a fungus. This particular type of fungus loves to attack grasshoppers, eating right through their hard outer shell. The fungus won't harm the crops.

THE BOLL WEEVIL

This beetle migrated up from South America into North America in the late 1800s and early 1900s. By the 1920s it was devasting cotton crops in the southern American states. Up through the 1970s it was costing cotton farmers crop losses totalling over 300 million dollars every year.

In the 1950s and '60s, DDT insecticide was sprayed on cotton fields, but this chemical was eventually banned in 1972. Now, a milder chemical is used: malathion. They also use environmentally-friendly traps baited with pheromones (the chemicals insects use to communicate with each other.) These traps are especially effective in the spring when the weevils are first emerging. For every 2 weevils you trap in the spring, you've prevented their potential 134 million off-spring! (They have a very short life cycle of only three weeks so they do a lot of reproducing over the summer.)

THE GYPSY MOTH

This pest is native to Europe and the UK. It was brought to America in the 1860s by a Frenchman named Professor Trouvelot. He thought this moth might be good for silk production so he started a little moth farm in his backyard in Boston. By the time he figured out that they were worthless for silk production, the moths had already escaped from his yard and had infested all the trees in his neighborhood.

The moths spread out quickly and within a few decades the forests of neighboring states were covered with them. A century later, the moths were destroying forests as far west as Wisconsin and as far south as Virginia.

At first, toxic insecticides were sprayed on the forests, but now they use sprays containing viruses and bacteria that attack only gypsy moth caterpillars. Sounds a little strange to intentionally spread viruses and bacteria, but apparently it's safer than using the chemical sprays.

THE WHITE CABBAGE BUTTERFLY

Sometimes mistaken for a moth, this little white butterfly lays eggs on the undersides of cabbage and broccoli leaves. Why it prefers the members of the cabbage family is unknown, but it does show a marked preference for plants related to cabbages.

When the eggs hatch, the baby caterpillars start munching on the leaves. As the caterpillars grow, so do the sizes of the holes in the leaves. The caterpillars rarely kill the plant, however. The problem with these caterpillars is that they make their way into the part of the plant that will end up on your dinner table. Most people don't like worms in their broccoli. However, these insects are very easy to defeat without causing any harm to the environment. You can spray the plants with a friendly bacteria that kills only these caterpillars, not other forms of life.

APHIDS

We met some aphids briefly when we were studying the vascular system. They have a specialized mouth part that drills into a stem until it hits a phloem vein. The aphid then stays put, letting the sap from the phloem fill up its stomach. Usually aphids don't take enough sap to kill their host plant. The biggest problem is that aphids transmit viruses and bacteria from one plant to another. The pathogens get sucked up along with the sap so that when the aphids move along to another plant, the pathogens go along, too.

Fortunately, there is a natural way to control aphids. Get yourself a big supply of ladybugs. (Yes, you really can buy ladybugs from online suppliers.) Parasitic wasps and lacewing insects will also eat aphids. Some gardeners just hose down their plants once a week to control aphids. You can also use natural oils or insecticides made from fungi.

JAPANESE BEETLES

You have to admit, this villain is kind of pretty. If it were not for its appetite for our garden plants, we might like it as much as we do ladybugs and fireflies.

As their name suggests, Japanese beetles are from Japan. They came to the US in 1939 in a packet of iris bulbs. Once they were loose, they spread all over North America.

The Japanese beetle is not a picky eater and will munch on a wide variety of plants. Unfortunately, their favorites happen to be the same ones that we humans like to eat.

These beetles are called "skeletonizers," because they eat the soft parts of a leaf, leaving the veins. The leaf ends up as nothing but a network of veins—a leaf skeleton.

Many gardeners buy "bag traps," to hang in their gardens, but studies have shown that this can backfire and actually attract more beetles than they kill. The best bet is to use a natural (fungal) insecticide called "milky spore."

SLUGS

This creature is very different from most other garden pests. It's not even remotely related to an insect. Its closest relatives are snails and squids. Slugs must stay moist, so they are generally nocturnal. You'll never see them on your plants unless you go out with a flashlight after dark.

Slugs have big appetites. In one night a few slugs can do some pretty serious damage to a small plant. Other types of critters can eat holes in leaves, too, but only slugs leave slime trails. Yeah, it's yucky, but if you look carefully at a leaf and see a trail, you can bet there are slugs nearby. Just pick up the nearest big rock and you'll likely find the criminals hiding from the sun.

Chemicals that harm slugs can also harm humans, pets and wildlife. A non-toxic remedy is to go out at night and just start putting the slugs into a plastic bag. It's safe and cheap.

MITES

Mites are tiny relatives of spiders. Mites that live on plants are often called spider mites. They are super small—even smaller than the head of a pin. You can't see their body parts without using a magnifier. They look like tiny moving dots.

Like aphids, mites like to sip sap. They are so small, though, that a tiny vein in a leaf is big enough for them. Colonies of mites live on the underside of leaves, sipping sap and hiding inside web tents they've constructed.

Fortunately, mites aren't the worst pests you could have. Unfortunately, they are very resistant to insecticides. You can spray your plant with neem oil (a natural oil from the neem tree) or find an online supplier who can sell you bigger mites. Truly! You can buy predator mites that will eat spider mites. (We're betting you'll go with the neem oil.)

ACTIVITY 1: THE LAST VIDEOS

If you have not watched them already, watch the last few videos on the playlist. They are about how to solve some disease and pest problems in non-toxic, environmentally friendly ways.

* *

If you are interested in more specific information about plant diseases (a lot more detail than we went into in this chapter) try some online resources such as these:
1) Free downloadable fact sheets with color photos: http://ohioline.osu.edu/hyg-fact/3000/index.html
2) An online resource (not downloadable): http://www.extension.umn.edu/gardeninfo/diagnostics/

These sites feature plants that live in temperate climates (US, UK, Europe). If you live in a place where the climate is more like subtropical, tropical, or dessert, don't worry—the Internet is a big place and the information you need is certainly out there somewhere. Search for "plant diseases" and also add key words about your climate (such as "tropical" or "desert"). There are plant experts all over the world, and they love to put information online to help people with sick plants.

ACTIVITY 2: "DEAR DR. GREEN"

In a quaint little town called Garden City, the newspaper runs a weekly advice column called "Dear Dr. Green," in which a local expert answers readers' questions about plants. Here are some recent questions that readers sent in. Can you impersonate Dr. Green and give these folks the answers they need? Write your answers in the blank spaces below the questions.

Dear Dr. Green,

I am 9 years old and just planted my first garden this summer. I am trying to take care of it and water it a lot. I have a problem, though. My watermelon vine looks really wilted no matter how much I water it. Can a plant be so thirsty that it can't get enough water? Will I have to water it day and night? Is there something wrong with the vine?

Sincerely,
Ollie Ocksenfree

Dear Ollie,

Dear Dr. Green,

I am a college student at Garden City College. Recently I saw men cutting down some of the big beautiful elm trees that line the main entrance to the campus. I was really mad. Those trees are historic. I think the maintenance crews need to be taught to respect history. However, my roommate

said that there might be a practical reason for them doing this. He said to write to you before I start my petition to the college agasinst this tree cutting. Could there be any good reason for destroying beautiful historic trees?

Sincerely,
A political science student

Dear student,

Dear Dr. Green,

The bushes next to my driveway are starting to turn brownish-yellow. The first leaves to lose their green color were the ones down at the base of the stems. The leaves out at the end of the branches look the best. Our rainfall has been very good for this time of year so I think the bushes are getting enough water. The bushes even get extra water as it runs off our driveway. I am mystified as to why only some of the leaves are affected. What could be going on here?

Sincerely,
Ima Knotshure

Dear Ima,

Dear Dr. Green,

My lilac bush looks like someone dusted it with powdered sugar. Is a neighborhood kid playing a prank on me, or is this some kind of natural phenomenon? (And is there anything I should do?)

Mr. I. V. Grohsonmywahls

Dear Mr. Grohsonmywahls,

Dear Dr. Green,

I've been watching my next door neighbor's gardening habits for several years now. I've noticed that his garden looks different every year. He never plants the same thing in the same place two years in a row. Is he an organization freak, or does he know something about plants that I don't know? Why would someone do this?

An anonymous resident of Maple St.

Dear anonymous resident,

Dear Dr. Green,

I am having trouble with aphids on my roses. I can't spray insecticides on my plants because some of my kids have problems with chemical sensitivities. Help! What can I do? Am I doomed to be plagued by aphids?

Sincerely,
Gertrude Plotz

Dear Gertrude,

Dear Dr. Green,

My cousin, Egbert, says that if you touch a diseased plant, you'll catch the disease. Is he right?

Sincerely,
Billy

Dear Billy,

BIBLIOGRAPHY

The bibliography at the back of a book lets you see how much reading and research the author had to do in order to write the book. Just think—these are books and websites you did NOT have to read! You only had to read the condensed version of all these research. Not so bad, eh? (But if you are interested in reading them yourself, the ISBN number is given so that you can find them easily. (If you type that number into Amazon, for example, it will show you a copy of that book.)

Books intended for adults:

Biology of the Cell (Fourth Edition) by Sylvia S. Mader. Published by Wm. C. Brown Publishers, © 1993. ISBN 0-697-20857-5.

Biology (Tenth Edition) by Sylvia S. Mader. Published by McGraw Hill Higher Education, © 2010. ISBN 978-0-07-352543-3

What's Wrong With My Plant (And How Do I Fix It?) by David Deardorff and Kathryn Wadsworth. Published by Timber Press in Portland and London, © 2009. ISBN 978-0-88192-961-4

Botany for All Ages by Jorie Hunken. Published by Globe Pequot Press, © 1993. ISBN 978-1564402813

Books for young people:

100 Flowers and How They Got Their Names, by Diana Wells. Published by Algonquin Books of Chapel Hill, © 1997. ISBN 1-56512-138-4

Ferns: Plants Without Flowers, by Bernice Kohn. Published by Hawthorn Books, Inc., New York. © 1968.

How Did We Find Out About Photosynthesis? by Isaac Asimov. Published by Walker and Company, New York, © 1989. ISBN 0-8027-6886-5.

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Looking at Plants by David Suzuki. Published by John Wiley & Sons, © 1991. ISBN 0-471-54049-8

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General info:
Wikipedia.com (many, many articles)
http://universe-review.ca/R10-34-anatomy2.htm#ferns

Mosses:
http://umanitoba.ca/Biology/BIOL1030/Lab7/biolab7_2.html

Mosses, Ferns, cross sections:
http://people.bethel.edu/~johgre/bio114d/lowervasculars.html

Ferns:
http://www.deanza.edu/faculty/mccauley/6a-labs-plants-02.htm
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Stem cross section, including fern:
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