LESSON 7: PLANT ADAPTATIONS

LEVEL ONE

Life is seldom ideal. We all live with situations that are difficult for us in some way. Some people face severe problems such as not being able to find enough food or clean water, living in extremely hot or cold climates, or having to deal with a chronic illness. Others of us live with milder limitations having to do with our age, our size, our family situation, the neighborhood where we live, the work our parents do, the personalities of our siblings, and so on.

We don’t think of plants as having the same problems that we do, but to a large extent, they really do. They can experience malnutrition, extreme temperatures, unfriendly neighbors, competition for territory, “parents” who overshadow them, “siblings” who are more or less successful than they are, chronic and acute illnesses, and problems due to aging. Obviously, they can’t think about their problems like we can. All of their responses come not from their brains (which they don’t have) but from their pre-programmed DNA that allows them to adapt and survive.

Let’s take a look at two of the most basic problems a plant might face. We could introduce these problems as a silly “Would You Rather...?” question. In the “Would You Rather...?” game, players are forced to choose between two bad options. For example, “Would you rather be trapped in outer space or at the bottom of the ocean?” No matter which you choose, the outcome will not be good. You must choose what you feel to be “the lesser of two evils,” and then explain your choice. The game is intended to encourage interesting discussions and hopefully bring some laughter along the way. If plants were playing this game, one of them could ask this question: “Would you rather have almost no water at all, or so much water that you are drowning in it?”

Assuming that a plant had a brain and could think about this question, it would ponder the consequences of each option. Not having enough water would mean that as transpiration occurred, there would be no way to replace the water lost through the leaves. The plant would dry out and probably die. Being immersed in water would mean that the stomata (holes) in the leaves would be filled with liquid water, preventing the plant from “breathing,” causing the plant to die. Too much water might also encourage the growth of harmful bacteria. So which option is worse? It’s like choosing between dying of thirst and drowning. Two bad options!

Some plants would definitely choose the “too little water” option. In fact, they live out that scenario every day and manage to survive. Desert plants have special adaptations that allow them to live in places that get less than 10 inches (25 cm) of rain a year. In deserts, rain is often seasonal, and months can go by with no rain at all. How is it possible for a plant to survive that long without water? Garden plants start wilting if they don’t get rain every week.

A normal plant growing in a place with adequate rainfall has a constant flow of water going in through its roots, up through its stems, and out through its leaves. (Remember, the beginning of this process is actually the “out through the leaves” part. The loss of water in the leaves causes water to flow up through the stems, and finally come in through the roots.) If there is not a constant source of water available, this mode of living doesn’t work. What changes would have to be made to a plant’s anatomy in order to prepare it for life in a desert?
LEAVES: This is where the water loss problem starts. That pesky transpiration process is constantly allowing water molecules to go flying off into the atmosphere. Can this be prevented? Could we just get rid of the leaves? Maybe, but leaves are where photosynthesis occurs, so the plants would starve without photosynthesis. If a plant did not have leaves, it would have to have photosynthesis occurring somewhere else. Or maybe we could just reduce the size of the leaves instead of getting rid of them altogether. Smaller leaves would mean less water loss.

STEMS: What changes could be made to the stems? Could photosynthesis occur here? Could the stems be adapted for water storage instead of simply holding tubes for water transport? If so, the stems might have to become very large at times.

ROOTS: Is there any way to make roots more efficient at gathering water? Should the roots go deeper? Or would it be better to keep them shallow and near the surface so that they can quickly soak up rain when it comes? Would having more tiny root hairs help?

The most famous of all desert plants is the cactus, of course. Cactus plants look like they have no leaves. Technically, their sharp spines are actually leaves, but these leaves are so thin that they lose almost no water at all. We saw a similar adaptation in pine trees. Pine needles are actually very thin leaves. However, since pine needles are green, it is easier to think of them as leaves. Cactus spines just don’t seem like leaves, but botanists assure us that spines are indeed highly adapted leaves.

What could possibly be the purpose of a leaf that can hardly do photosynthesis and doesn’t initiate transpiration? What are cactus spines good for? The main thing they do is hurt like crazy if you get them in your skin. Sharp spines help to protect cacti from thirsty desert animals who might want to quench their thirst with a big bite of juicy cactus stem. Some botanists think the spines might also help to collect water at night. Little droplets of dew form on the spines. These droplets run down the spines toward the stems, then they flow down the stems, ending up at the base of the plant where the roots near the surface can absorb the moisture quickly before the sun comes up.

The body of a cactus is technically a stem. Most cacti are green (or at least green-ish), which tells you that these bulky stems contain chlorophyll. Wherever there is chlorophyll, photosynthesis is occurring. Cacti must use adapted forms of photosynthesis, however. Regular photosynthesis requires a constant supply of water and carbon dioxide from the air. The “downside” of not having regular leaves is that you can’t use regular photosynthesis. The types of photosynthesis desert plants use are called “C4” and “CAM.” (Regular photosynthesis is known as “C3” since it produces 3-carbon sugars. C4 produces 4-carbon sugars. “CAM” is an abbreviation for a gruesomely complicated word that even scientists don’t like to use because it’s too long. They just say “CAM.”)

Cactus stems have the ability to store a lot of water—enough water to keep the cactus alive during dry seasons that last for many months. The body of a cactus usually looks like it is made of “pleats” that go in and out. This shape allows for easy expansion and contraction without any disruption of the roots at the base of the plant. The root system of a cactus is often very shallow and
extends outward from the plant quite a distance. When rain comes, the cactus has thousands of root hairs waiting and ready right near the surface. Large cacti can take in over 100 gallons (400 liters) during a single rain storm.

A few types of cacti have very long tap roots in addition to lots of surface roots. The long central tap root can be twice as long as the body (stem) of the cactus. This deep root can store a lot of water.

Cactus stems have a structure that other plants do not have: bumps called areoles. Botanists guess that areoles are most closely related to the branches of regular plants. It is from the areoles that both spines and flowers grow.

One last important cactus survival strategy is to grow slowly. Cacti don’t need to be in any hurry. Growth takes energy. A plant’s energy comes from sugars made during photosynthesis. Desert plants are already at a disadvantage when it comes to photosynthesis because they have to keep their stomata shut all day to prevent loss of moisture. Growing slowly reduces the need for sugar.

Cacti are not the only type of plants that can survive in dry climates. Plants called succulents are similar to cacti in many ways, though they have actual leaves, not spines. The leaves of succulent plants feel thick and “juicy.” The stems are often very thick and can store water. Some succulents have stems and leaves that are filled with a gooey substance called mucilage (MEW-sell-ahj). The mucilage acts like a sponge and holds water. A common succulent plant that many people recognize is the aloe vera plant. Some people call it the “burn plant” because you can break open the leaves and use the mucilage to soothe burned skin. The mucilage may feel slimy and weird, but it does make your skin feel better.

Succulent leaves feel like they are covered in a waxy substance. This is because they are covered in a waxy substance. We met this waxy substance back in lesson five when saw the cross section of a leaf. The thin top layer was called the cuticle. All leaves have at least a tiny bit of cuticle, but succulent leaves have a lot of it. Cuticle is fairly waterproof, so it keeps moisture from getting out of (or going into) the leaf.

Another characteristic of succulent leaves is a reduced number of stomata. Those little stomata holes are where air and moisture get in and out of a leaf, so if you have fewer holes you have less of a problem with water molecules escaping. Succulents have fewer stomata than regular plants. Also, succulents tend to close their stomata during the day when the sun is hot and evaporation (and therefore dehydration) will occur quickly. They open their stomata at night, when the air is cooler and evaporation is less of a problem.

These stomata tricks are pretty slick, but there’s a downside to them. The reduced number of stomata and the daytime closings also mean that a succulent leaf can’t take in as much carbon dioxide as a normal leaf can. Like cacti, succulents need to use those alternative forms of photosynthesis: “C4” and “CAM.” In these forms of photosynthesis, carbon dioxide is brought in at night and the carbons are snipped off and stored in the form of an acid. (You could think of it like canning food, perhaps?) The succulent cells have to be very efficient with their carbon atoms because there is a limited supply of carbon dioxide.
One last succulent survival trick worth mentioning is hair. Some plants grow hairs on their leaves or stems in order to provide some extra protection from the wind and sun. The hairs act like a layer of insulation, slowing down the rate of evaporation. On cold desert nights, dew can condense on the hairs and perhaps a small trickle of water will reach the roots by morning.

A really thick layer of hairs probably also functions as a way to deter insects from biting into the plant. The insect can’t get its mouthparts close enough to the stem because the hairs get in the way. This feature can be seen on plants in temperate (not so hot) areas of the world, not just in super dry climates. You might have some plants with hairy stems and leaves growing right near you. Sunflowers, for instance, have very hairy stems. The plant called “Lamb’s Ear” has leaves so fuzzy they feel like animal ears, not plant leaves.

Plant hairs are not made from the same stuff that animal hairs are. Animal hair is made of “dead” protein molecules. Plant hairs are made of living plant cells. Plant hairs are properly called trichomes, and they are extensions of epidermis cells. (Remember the upper and lower epidermis cells from the leaf cross section?) These specialized epidermis cells can grow to be very long and thin. Some have specialized cells at the tip that can secrete strong-smelling substances. The strong smell of most herbs (such as mint) come from smelly oils produced by gland cells on the tips of trichomes.

Let’s turn now to the other terrible option for plants: drowning in water. Too much water will kill most plants, but there are some plants that are adapted for living in water all the time. What adaptations would a plant need to have in order to survive being in water all the time? Would the stomata be a problem? Would water still flow up the xylem tubes? Would the roots need to be in dirt?

There are many types of aquatic plants and their adaptations are just what they need for their specific environment. Some plants have their roots submerged in water all the time while their leaves stay out of the water. Other plants have roots and stems under the water and leaves that float on the surface. The most extreme water plants live completely submerged all the time.

What adaptations would a plant need to have in order to be able to live submerged in water all the time? Would it need stomata or cuticle? What about roots? Would it be able to make flowers?

Seagrasses spend their entire life under the water. They look and act very much like regular grass. They even have those pesky rhizomes that let them use vegetative reproduction to spread very quickly. This is annoying in your garden when the grass starts taking over your strawberry patch, but along seashores this ability to spread quickly is a very good thing. Seagrasses are a very important part of shoreline ecosystems. Seagrasses reproduce using flowers and seeds, too. The pollen is carried by water instead of wind.

Seagrass leaves have neither cuticle nor stomata. It’s pointless to try to keep water in or out when you are surrounded by it all the time! The cells in the leaves are okay with being saturated with water all the time and the cells have micro-adaptations that let them take carbon dioxide right from the water. Like all leaves, seagrass leaves need sunlight for photosynthesis. This means that seagrasses can only grow in relatively shallow water. If the water becomes cloudy because of pollution, the deeper seagrasses will start to die out. Dying grass might not sound like a big deal, but seagrasses occupy a very important place in many aquatic ecosystems. Seagrass beds are filled with all kinds of animal life. If the grasses disappear, so do the animals.

Seagrasses have another adaptation that helps them to survive in the water. They have
microscopic air sacs in their leaves and stems that act like little floaties, keeping the leaves upright in the water. (If you take seagrass out of the water, it droops over your hand like a wet noodle. The leaves don’t have stiff central veins like regular grass blades do. Seagrasses need to be able to bend and flex and “go with the flow” in the water. If their leaves were stiff, they’d get torn apart by the motion of the water.) The tiny air sacs in the leaves and stems provide just the right amount of buoyancy so that the leaves stay upright in the water, reaching toward the sunlight.

Water plants are surrounded by water, so transpiration is not necessary. Cells can get whatever they need by osmosis. (Remember, osmosis is when molecules go right through the cell’s membrane.) The carbon dioxide, water, and nutrients are abundant all around the cells, so xylem tubes aren’t really necessary. In most water plants, the vascular bundles are very much reduced, and in some cases they are almost absent.

A slightly less drastic situation is when a plant is only partly submerged in water. The bottom half of the plant stays in the water while the top part is allowed to touch the air. A great example of a plant adapted to this situation is the water lily. Let’s take a close-up look at a lily that holds the world record for the largest leaf in the plant kingdom: the Amazon lily.

Found in the Amazon River in South America, this lily can grow leaves that are up to 8 feet (2.5 meters) across. These giant leaves are almost perfectly round and look like floating plates. They are quite stable and can support the weight of small birds and animals. Their strength is due to a network of strong veins on the underside of the leaf. Their ability to float is due to small air pockets inside the veins. In addition to being strong, these veins can also be deadly—they are covered in sharp spines. Fish learn very quickly that nibbling lily veins is a bad idea!

The undersides of the lily leaves have two other features that are worth mentioning. Like seagrasses, the undersides of lily leaves have no stomata and no cuticle. Unlike seagrasses, these undersides have lots of red pigment in them. The red pigment molecules help to catch wavelengths of light that the green chlorophyll pigments on top might miss.

The top side of a lily leaf is nothing like the bottom side. It’s green, is covered with waxy cuticle, and contains stomata. The top side is adapted to living in air, the bottom side to water.
The life cycle of the Amazon water lily sounds like something from a fantasy story. Its flowers bloom for only two days. The first night it blooms, the flower is female. It’s white and smells like fragrant perfume, an odor that scarab beetles find irresistible. Once the flower has attracted beetles, it closes up, trapping the beetles inside. During the night, the flower changes its gender from female to male, and its color from white to pink. It also stops making perfume. When the flower opens up at the end of the second day, the beetles are freed from their flowery prison but are covered with pollen grains. The flower no longer smells good, so they fly off to find another white lily flower, carrying the pink pollen grains with them.

Once fertilized, the flower closes and falls to the bottom of the river where it forms a seed. The seed does not begin to grow until the next year. Lily seeds usually germinate right as the Amazon River is reaching its annual flood stage, with the water rising several inches a day. The newly sprouted water lily stem must grow at an unbelievably fast rate in order to keep its “head” above the rising water. The stem is capable of growing up to 20 feet (7 meters) tall in just a few weeks. When the waters stop rising, the lily starts growing giant leaves (lily pads).

It’s then a battle of lily versus lily, with each plant attempting to dominate its area. (Sibling rivalry happens even among plants!) Once a giant leaf has spread itself out over the water, any plant underneath it will die from lack of sunlight. A side benefit of this situation is that algae is also prevented from growing. This is why water lilies (usually varieties other than Amazon) are planted in outdoor water gardens. People would rather look at lily leaves than algae “scum.”

One of the smallest aquatic plants on earth is called “duckweed” or “water lentils.” Duckweed looks like tiny green dots floating on the surface of a lake or pond. They are bright green and look very clean. True to its name, ducks love duckweed. Other water birds eat it too, as well as people in some parts of the world. It’s a great source of protein, even better than soybeans, and it produces more starch per acre than corn! It’s possible that duckweed could be turned into ethanol fuel, just like corn is. Some day our cars might run on fuel made from duckweed!

A duckweed plant consists of just a tiny leaf, with no visible stems or roots. (In some species, the leaves have very small root hairs dangling from the underside.) If duckweed doesn’t have stems or roots can it still be classified as a plant? We decided way back at the beginning of lesson one that there are only two requirements for being a plant: 1) you must do photosynthesis, and 2) you must be made of more than one cell. Duckweed qualifies on both counts. In fact, it’s even classified as an angiosperm since it occasionally produces flowers—the tiniest flowers in the plant kingdom, no larger than the width of a piece of thread!
ACTIVITY 1: SIT LIKE A LUMP ON YOUR CHAIR OR COUCH AND WATCH VIDEOS

This activity should not be too difficult. Log on to www.YouTube.com/TheBasementWorkshop and enjoy the videos about desert plants and water lilies.

ACTIVITY 2: PLANT PUZZLE

Fill in the missing words in the clues, then transfer the letters to the numbered slots underneath the pictures. Assuming you’ve filled in the clues correctly, you’ll find out the names of the succulent plants in the pictures. (We’re counting cacti as succulents. Sometimes the word succulent is used as a more general term, with cacti being a subcategory.)

1) Succulents have fewer ___ ___ ___ ___ ___ ___ and more ___ ___ ___ ___ ___ ___.
   They also have gooey stuff called ___ ___ ___ ___ ___ ___ in their stems and leaves.
2) Cacti have bumps called ___ ___ ___ ___ ___ ___ on their ___ ___ ___ ___ ___.
3) Desert plants must use two other forms of photosynthesis: “___4” and “_____5.”
4) The water plant called ___ ___ ___ ___ ___ ___ looks like tiny green dots. Even though
   it does not have stems or roots, it is still a ___ ___ ___ ___ ___ because it does photosynthesis and
   is made of more than one cell.
5) Duckweed is very nutritious. Like soy, it is a good source of ___ ___ ___ ___ ___ ___ ___ ___,
   and like corn, it is a good source of ___ ___ ___ ___ ___ ___ ___ ___.
6) Like all plants, when a duckweed flower is pollinated, a ___ ___ ___ ___ ___ is formed.
7) This type of animal loves to eat seagrass: ___ ___ ___ ___ ___ ___ ___.
8) Plant hairs are called ___ ___ ___ ___ ___ ___ ___ ___ and originate from the
   ___ ___ ___ ___ ___ ___ ___ ___ layer.
9) The ___ ___ ___ ___ ___ side of an Amazon lily ___ ___ ___ ___ is the color ___ ___ ___ ___ ___ and
   has sharp ___ ___ ___ ___ ___ ___ ___ ___ on the veins.
10) When water evaporates out through the leaves, causing an upward flow of water from the roots,
    this is called ___ ___ ___ ___ ___ ___ ___ ___.
11) The aloe plant is sometimes used to treat this type of injury: ___ ___ ___ ___ ___ ___ ___ ___.
12) ___ ___ ___ ___ ___ ___ ___ plants have very ___ ___ ___ ___ ___ ___ stems. This lets
    them store water so they can ___ ___ ___ ___ ___ ___ in desert climates.
13) This word root means “naked” in Greek: ___ ___ ___ ___ ___ ___ ___ ___.