UNIT 3
CYCLES AND GROWTH
HOW A FOREST WORKS

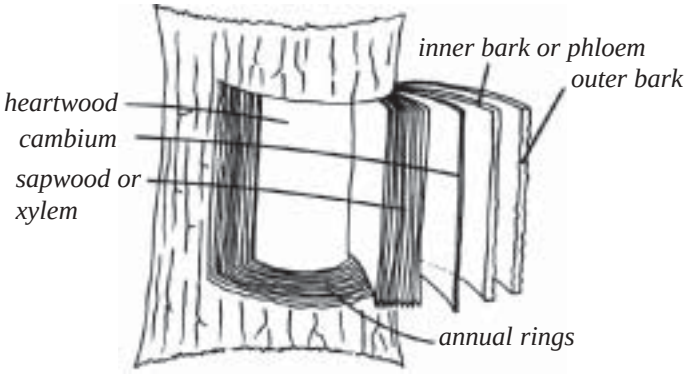
Tree Biology

Each part of a tree has a special function. Working together these parts help the tree survive, grow, and reproduce.

Photosynthesis

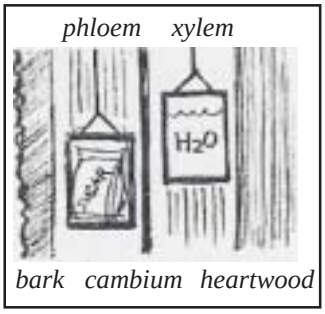
Leaves make food for the tree. **Chlorophyll** is the green chemical in the cells of leaves. Leaves use chlorophyll to capture energy from the sun in a process called **photosynthesis**. They make simple sugars and oxygen using carbon dioxide from the air and water from the soil. These simple sugars can be used as food energy or as building blocks for more complex products such as starch, carbohydrates, and cellulose. Carbon dioxide enters and oxygen exits through small pores or openings in the leaf surface called **stomata**. The tree maintains internal temperatures by losing water through its stomata (**transpiration**).

Transport



A tree's upper branches and leaves make up the **crown**. The **trunk** supports the crown. The trunk and branches have transport systems. Water and nutrients from the **roots** must go to the leaves. Food from the leaves must go to the roots or to other parts of the tree for storage or for energy for growth. The cells in the trunk and branches are lined up end to end to form transport tubes. A trunk's cross-section reveals most of its structures.

The **outer bark** is very different in texture than other parts of the trunk. It can be thick and cork-like, smooth, rough, shaggy, or spiny depending on the type of tree. Bark protects the tree from insects, diseases, fire, and sometimes even lawn mowers.



Just inside the outer bark is a layer called the **phloem** or **inner bark**. The phloem carries **sap** (sugar and nutrients dissolved in water) from the leaves to the roots or to the rest of the tree. In some types of trees, at certain times of the year, the phloem also carries sap from the roots to the leaves (e.g., Sap moves upward in sugar maples in late winter-early spring to nourish the buds and new and growing leaves. People tap trees and boil the sap down into maple syrup.)

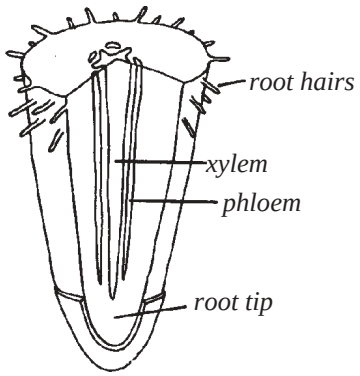
The inside of the trunk is made up of **xylem** or **sapwood**. Xylem brings water and nutrients up from the roots to the leaves. As new xylem is formed, older xylem becomes clogged with particles. This clogged xylem is called **heartwood** (dense dead wood that gives the trunk strength) and forms the central core of the tree. Deposits in the heartwood make it naturally resistant to decay, in some species.

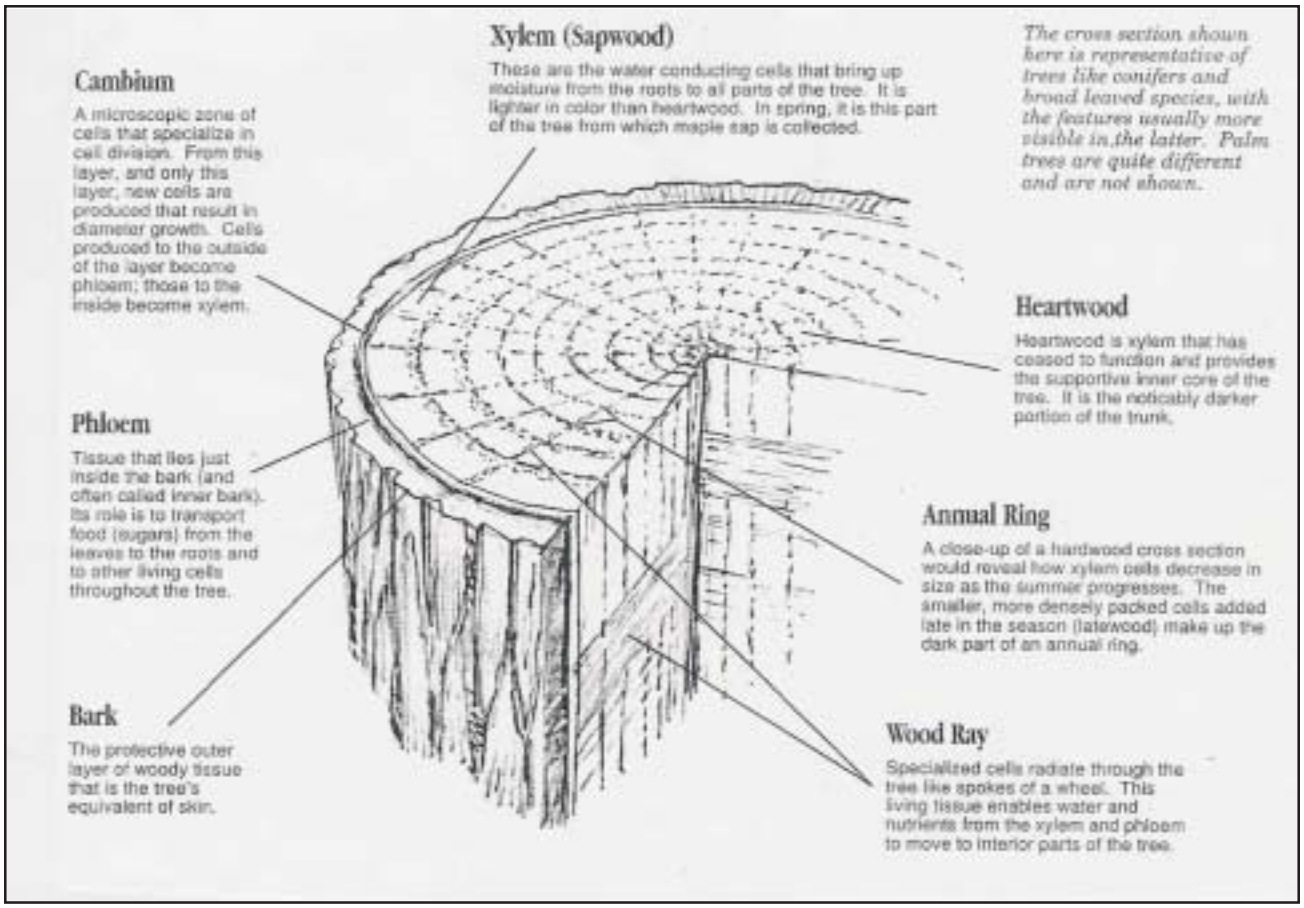
Growth

The **cambium** (very thin layer of cells seen only with a microscope) is between the phloem and the xylem. It is where growth occurs in the trunk. Cambium produces new phloem to the outside, new cambium in the middle, and new xylem to the center of the trunk. This growth increases the tree's girth each year.

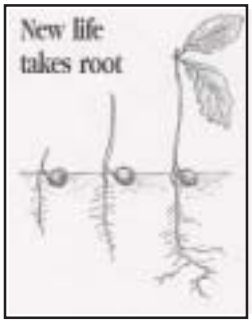
Two types of wood are produced each year to make up an **annual ring**. The band of lighter colored wood is **springwood** and the dark colored band is **summerwood**. The springwood band usually is wider than the summerwood band. The tree puts on more growth in the moist spring and slows down during the drier summer. Count either the light or dark rings when aging a tree. One light ring and one dark ring together make up one year's growth.

Only three parts of the tree actually grow: **root tips**, cambium, and **buds**. Growth in the root tips makes the roots longer–able to spread out in search of more water and nutrients. Cambium is present in the trunk, branches, and roots. When cambium cells divide the trunk, branches, or roots get wider. Cells forming to the outside of the cambium become phloem cells and old phloem cells form new bark. Cells forming to the inside of the cambium form the xylem or wood of the tree. Growth at the buds makes branches longer, making the crown taller and wider. Once a branch is formed it never gets any higher on the tree!

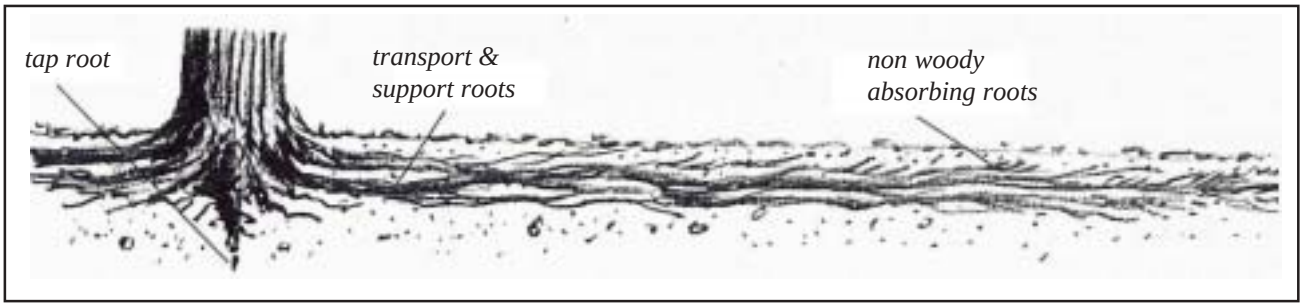




Underground



Roots are the tree's anchor and tool for getting water and necessary nutrients from the soil. A seedling's first roots grow straight down. **Lateral roots** spread out from the base of the trunk and may extend out further than the width of the crown (**dripline**). As roots grow they branch into finer and finer roots called **rootlets**. Rootlets are covered by even finer **root hairs** that absorb the water and nutrients the tree needs from the soil. Approximately 90 to 95 percent of a tree's root system is in the top three feet of soil, and more than half is in the top 12 inches.



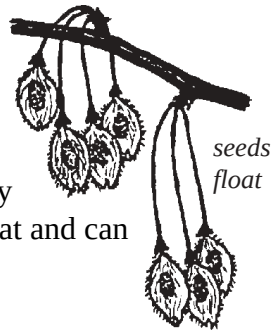
Reproduction

Most trees reproduce by **seeds**. Seeds are formed in pollinated flowers. Wind, insects, birds, or bats carry pollen from flower to flower. Each species of flower usually is adapted for a specific pollinator. Cottonwoods, oaks, walnuts, and hickories have **catkins**, designed for pollination by wind. They are pendulous shaped flowers that move easily in the wind. Most catkin-bearing trees flower before the leaves unfold, so pollen movement is unhampered. Flowers pollinated by animals use nectar to attract the insect, bird, or bat to the flower. Pollen clings to the animal's body as it reaches inside the flower for the nectar. As it moves from flower to flower it pollinates them.

seed carried by wind

Some trees reproduce **vegetatively.** They may sprout from the base of the trunk or roots, or have branches that form roots and grow into new trees under the proper conditions (e.g., Willow trees will grow from branch cuttings.) These trees also usually produce seeds.

Trees disperse seeds in many ways. Ash and maple seeds have wings that help them travel on the wind. Willows and cottonwoods produce tiny seeds attached to downy fluff that may float on the wind for miles. Other trees form fruits that can be food for birds and other animals. Animals may travel long distances after eating cherries, mulberries, or dogwood berries before depositing the seeds in a new location in their droppings.



seeds that float

Oaks, walnuts, and hickories produce seeds high in nutrients (acorns and nuts). Squirrels, chipmunks, and mice store these for their winter survival. Some are buried, forgotten, and left to sprout. Oak trees often do not produce acorns every year, but have a very large acorn crop when they do. This strategy may have evolved so that some seeds will be left uneaten. Many seeds will float and can be carried for miles in streams and rivers.

Winter Adaptations

In winter, the **photoperiod** (length of daylight) is short, temperatures are low, and liquid water may be unavailable. Tree growth requires a lot of energy or is impossible. Deciduous trees in Iowa become dormant to cope with these conditions. Transport systems to the leaves are interrupted. The leaves die and fall from the tree. As cells die the green pigment, chlorophyll, breaks down, making other pigments visible. This creates the fall show of colors–brilliant yellows, reds, and oranges. Conifers have a waxy coating on their leaves or needles. This conserves water in the leaf so photosynthesis can occur when temperatures are high enough.

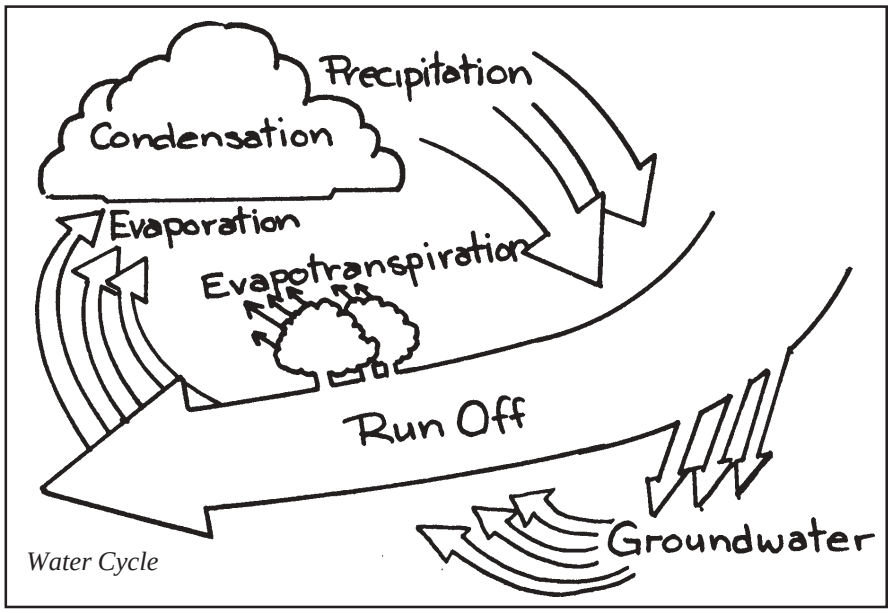
Forest Cycles

Water Cycle

Just as energy is cycled through the forest in food webs, other forest elements have cycles. We may think of water as an inexhaustible resource. Actually, there is a finite supply of water on earth and it constantly cycles. That is why it is so important to protect our water supplies from becoming polluted.

Water can be a liquid, solid, or vapor, depending on the temperature. The transition of water between these forms is called the **water cycle**. When atmospheric conditions are right, water vapor in clouds **condenses** (changes to liquid form) and may fall as rain. If temperatures are below freezing (0° Celsius) somewhere on the water's route, it may fall as hail or snow. This water may fall into an ocean, lake, river, or stream; or run off land into a body of water; or soak into the ground and become **groundwater**.

An **aquifer** is an underground area saturated with water. Aquifers are important sources of water for human use. Forest plants absorb water in the soil, on it's way to an aquifer. Water returns to the atmosphere by evaporation from surface water, transpiration from plants, and respiration from animals. The cycle continues. No new water is formed.



Water Cycle

diagram from Project WILD Aquatic, © Council for Environmental Education

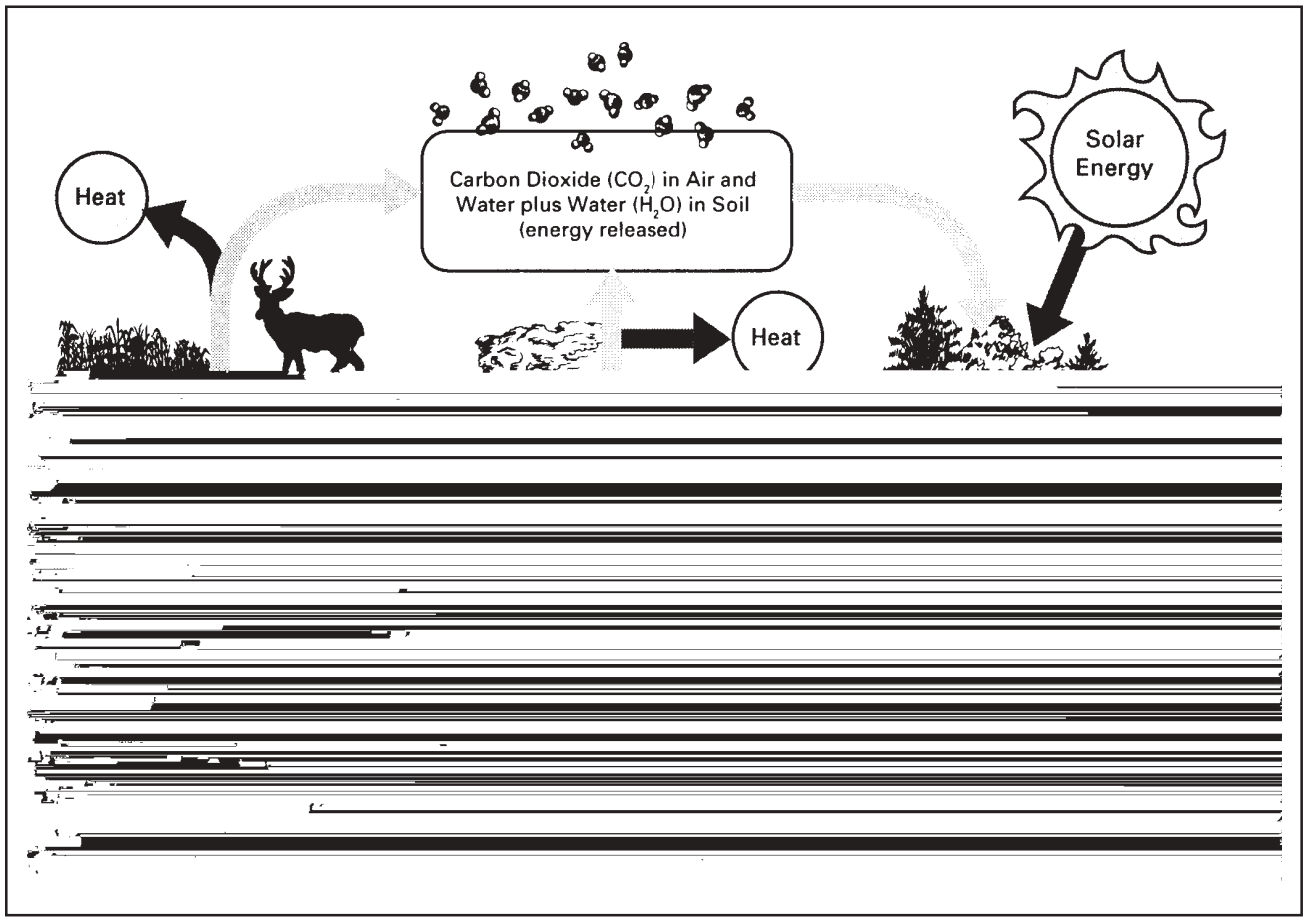
Carbon Cycle

Carbon, the main element in all **organic molecules** (molecules from a living or once-living thing), also cycles through the forest. One reservoir of carbon is the atmosphere. Most carbon in the atmosphere is in the form of carbon dioxide.

Plants use carbon dioxide to make food through photosynthesis. When a deer browses on a woody plant its body converts the carbon stored in the plant into deer tissue. If a person hunts and eats the deer, the carbon stored in the venison becomes part of the person.

Through each one of these carbon transfers, some carbon is lost through **respiration** (process that breaks down food into usable energy). Carbon dioxide is released through the pores of a plant's leaves when it breaks down stored food for energy to grow. As the deer uses energy to run, it releases carbon dioxide through its lungs. Bacteria and fungi decompose plants and animals when they die. This releases carbon into the soil and the atmosphere.

Plant and animal bodies may escape decomposition (by being buried in sediments) and become fossils. If buried deep enough and long enough, these bodies may form fossil fuels such as oil, coal, or natural gas. Carbon is stored in the fossils or fossil fuels.



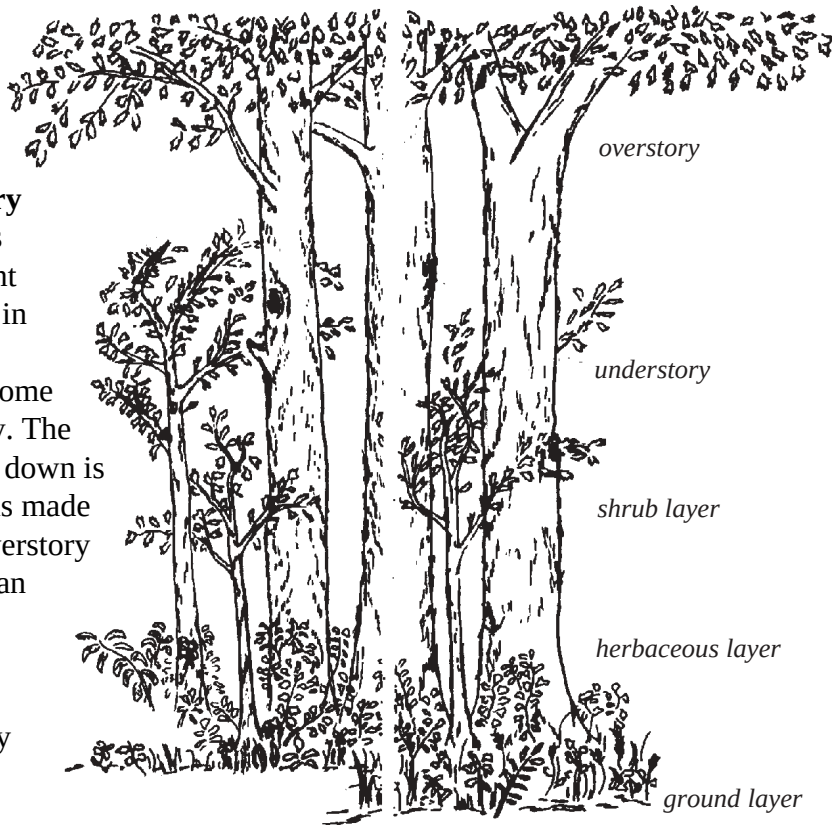
For millions of years the carbon cycle was in equilibrium. The amount of carbon entering the atmosphere was approximately equal to the amount plants used. Burning of fossil fuels for heat and power has increased the carbon in the atmosphere by an estimated 25 percent since pre-industrial times (300 years ago).

This additional carbon dioxide may cause the earth to warm up. Carbon dioxide does not allow **infrared** (heat) energy reflected from the earth to dissipate back into space, creating a **greenhouse effect**. Nearly all scientists agree this accelerated accumulation of greenhouse gases will make the earth get warmer, but no one knows how much warmer, or how it will affect plant and animal life.

Studies measuring atmospheric carbon dioxide show a steady increase over the last 25 years. These data also show fluctuations throughout the year, with large increases in atmospheric carbon when temperate forests go dormant in the winter and decreases when they are photosynthesizing in the spring and summer.

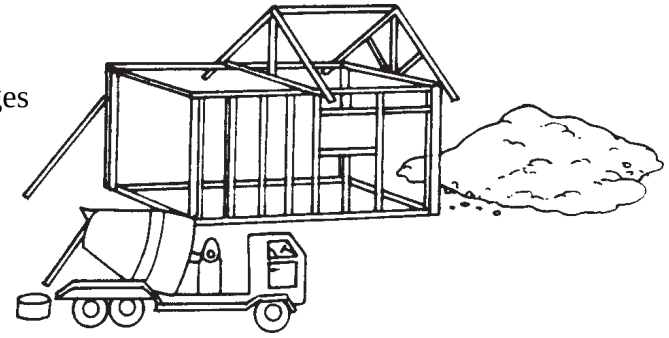
Forests also help prevent the increase of carbon in the atmosphere by acting as **carbon sinks** (holding carbon in organic molecules, preventing it from circulating back into the atmosphere). Long-lived forest vegetation holds carbon in its wood and leaves. **Deforestation** (cutting down forest tracts) has contributed to the acceleration of the greenhouse effect.

Forest Layers



Forest plants form several layers. The **overstory** (canopy or topmost level) is composed of large, dominant trees that usually grow best in full sun. Oaks, hickories, maples, and basswood are some trees that form the overstory. The **understory** or second level down is shaded by the overstory. It is made up of smaller versions of overstory trees and **shade-tolerant** (can grow well under low light conditions) species such as dogwood or hornbeam. The **shrub layer** contains woody shrubs such as gooseberry, coralberry, and highbush cranberry. The **herbaceous layer** is the most diverse and has mostly nonwoody species–grasses, sedges, and wildflowers. Vines (e.g., Virginia creeper, poison ivy) climb from this layer to the overstory to reach sunlight. The **ground layer** (forest floor) holds the soil builders and stabilizers–fungi, mosses, liverworts, and lichens.

Forest Succession



Succession can be defined as a process of changes in species composition of an area over time. Succession is ongoing. It is easiest to see after a disturbance in an area leaves open ground. This disturbance may be natural–fire, flood, storm, or glacier. Humans also cause disturbances by clearing land for agriculture or urban development.

If disturbed areas are left to re-establish on their own, the first plants to appear are **pioneer species**. They have colonizing characteristics such as rapid growth, abundant seed production, and seeds that are dispersed easily. Pioneer species do not grow well in shade or where other plants are established.

Pioneer species add organic matter to the soil and stabilize the site. This creates the right conditions for shrubby vegetation to grow. **Shade-intolerant** (do not grow well under low light conditions) tree species (e.g., black cherry) may grow with the shrubby vegetation.

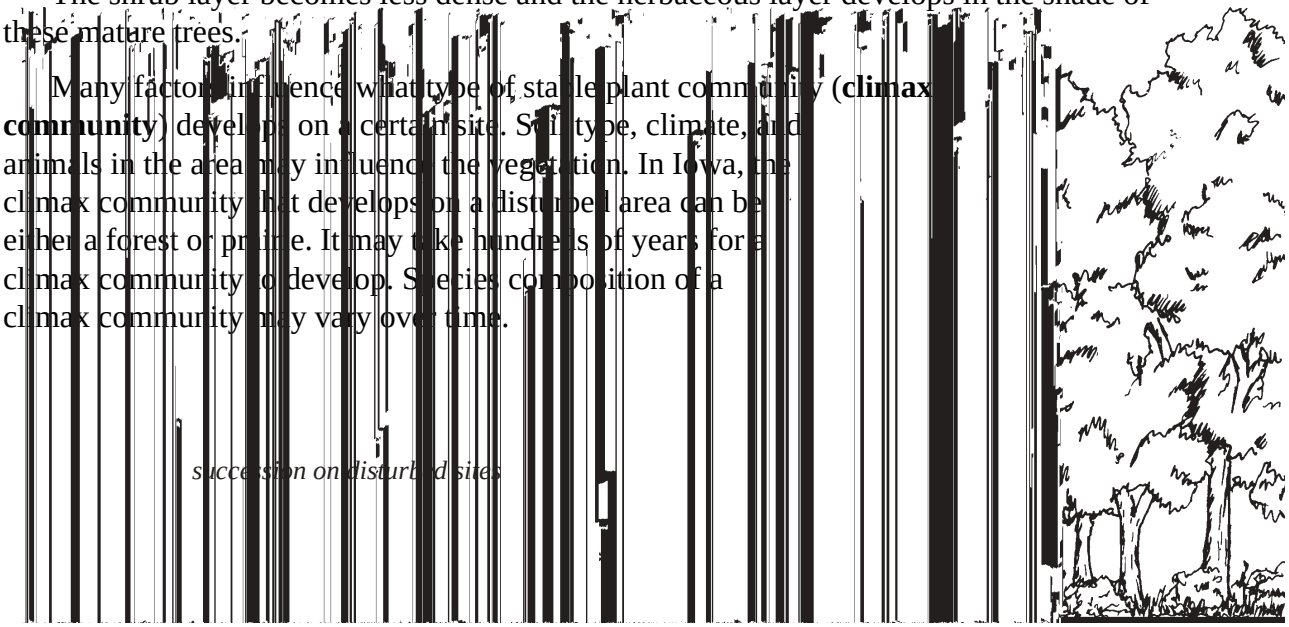
Elm, ash, and juniper seedlings (more shade tolerant tree species) begin to appear under the shrubs. Their seeds and seedlings are kept moist and protected by the litter layer produced by the shrubs and sun loving trees.

Oaks, hickories, and other hardwoods begin to appear. They are **semi-shade tolerant** (can grow in low light conditions, but do better in full sun). Sugar maples and basswoods are shade tolerant. Both groups are considered **mature forest** species or a climax community. Mature forest species usually are long-lived. They produce seeds that are not easily dispersed, but contain extra energy for seedlings growing under an established canopy.

The shrub layer becomes less dense and the herbaceous layer develops in the shade of these mature trees.

Many factors influence what type of stable plant community (**climax community**) develops on a certain site. Soil type, climate, and animals in the area may influence the vegetation. In Iowa, the climax community that develops on a disturbed area can be either a forest or prairie. It may take hundreds of years for a climax community to develop. Species composition of a climax community may vary over time.

succession on disturbed sites



annual weeds *perennial weeds &grasses* *shrubs* *elm/boxelder/ cottonwood* *oak/hickory* *sugar maple/basswood*

Other Materials

Bennett, C.F. 1983. Conservation and Management of Natural Resources in the United States. New York: John Wiley & Sons.
Dorros, A. 1997. A Tree is Growing. New York: Scholastic Press.
Iowa Association of Naturalists. 1994. Iowa's Trees. (available from: ISU Extension, www.extension.iastate.edu/pubs, 515/294-5247)
Iowa Association of Naturalists. 1994. Iowa's Shrubs and Vines. (available from: ISU Extension, www.extension.iastate.edu/pubs, 515/294-5247)
Iowa Association of Naturalists. 1994. Seeds, Nuts, and Fruits of Iowa Plants. (available from: ISU Extension, www.extension.iastate.edu/pubs, 515/294-5247)
Jackson, J. 1984. Ecology of Missouri Forests. Jefferson City: Missouri Department of Conservation.
Jasperson, W. 1980. How the Forest Grew. New York: Scholastic, Inc.
Maestro, B. 1999. Why Do Leaves Change Color? Harper Collins Publishers.
Minckler, L.S. 1980. Woodland Ecology: environmental forestry for the small landowner (2n ed). Syracuse, NY: Syracuse University Press.
Overbeck, C. 1982. How Seeds Travel. Minneapolis: Lerner.
Owen, O.S. 1980. Natural Resource Conservation: An Ecological Approach. New York: Macmillan Publishing Co., Inc.
Richberger, W.E. and R.A. Howard Jr. Understanding Forest Ecosystems. Ithaca: Cornell University Cooperative Extension.
Tree Growth. 1999. (available from: ISU Forestry Extension, www.forestry.iastate.edu/ext/pubs.html, 515/294-5247)
Understanding Trees & Woodlands. 1993. (available from: ISU Forestry Extension, www.forestry.iastate.edu/ext/pubs.html, 515/294-5247)
Zim, H.S. and A.C. Martin. 1956. A Golden Guide to Trees. New York: Golden Press.

PLT Activities (grade level)

Adopt a Tree (3-8)
Air Plants (3-6)
Bursting Buds (K-6)
Every Tree for Itself (K-8)
Fallen Log, The (4-8)
Have Seeds, Will Travel (K-8)
How Big is Your Tree? (3-8)
How Plants Grow (4-8)
Living With Fire (4-8)
Name That Tree (2-8)
Nothing Succeeds Like Succession (3-6)
Plant a Tree (1-8)
Signs of Fall (K-5)
Sunlight and Shades of Green (2-8)
Tree Cookies (see Every Tree For Itself)
Tree Factory (3-6)
Trees In Trouble (1-8)
Tree Lifecycle (3-6)
Water Wonders (4-8)

** Supplemental information provided for italicized activities.*