What is a Tree?

“A tree may be defined as a woody plant reaching 20 feet or more at maturity, with a single trunk and a definite crown”

Harlow, Harrar, Hardin and White; Textbook of Dendrology
All Trees Fall into Two Categories

Angiosperms
(flowering plants)
Contain petals, sepals, pistil, and stamen. *Not always on the same flower or plant.

Gymnosperms
(flowerless plants)
Contain pollen-producing cones and seed-producing cones.
*Not always on the same plant.
Main Components of a Tree

The Leaves
- Sunlight energy is converted into fuel that the plant needs to live. This process is called photosynthesis.

The Stem
- Main water and nutrient transport system. Supports crown and stores carbon.

The Roots
- Acts as an anchor, holding the plant in place. Water and nutrient absorption, storage, and transport.
Tree Biology

5% Leaves
15% Limbs
60% Trunk
15% Woody Roots
5% Absorbing Roots
Animal and Plant Cells
## Animals and Plants

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Animal Cell</th>
<th>Plant Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cytoplasm:</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Endoplasmic Reticulum</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Ribosomes:</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Mitochondria:</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Golgi Apparatus:</td>
<td>Present</td>
<td>Present</td>
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<tr>
<td>Microtubules/ Microfilaments:</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Flagella:</td>
<td>May be found in some cells</td>
<td>May be found in some cells</td>
</tr>
<tr>
<td>Nucleus:</td>
<td>Present</td>
<td>Present</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences</th>
<th>Animal Cell</th>
<th>Plant Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell wall:</td>
<td>Absent</td>
<td>Present (formed of cellulose)</td>
</tr>
<tr>
<td>Shape:</td>
<td>Round (irregular shape)</td>
<td>Rectangular (fixed shape)</td>
</tr>
<tr>
<td>Vacuole:</td>
<td>One or more small vacuoles (much smaller than plant cells).</td>
<td>One, large central vacuole taking up 90% of cell volume.</td>
</tr>
<tr>
<td>Centrioles:</td>
<td>Present in all animal cells</td>
<td>Only present in lower plant forms.</td>
</tr>
<tr>
<td>Chloroplast:</td>
<td>Animal cells don't have chloroplasts</td>
<td>Plant cells have chloroplasts because they make their own food</td>
</tr>
<tr>
<td>Plastids:</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Plasma Membrane:</td>
<td>only cell membrane</td>
<td>cell wall and a cell membrane</td>
</tr>
<tr>
<td>Lysosomes:</td>
<td>Lysosomes occur in cytoplasm.</td>
<td>Lysosomes usually not evident.</td>
</tr>
</tbody>
</table>
Autotrophs vs. Heterotrophs

• Trees are **photoautotrophs** that fix their own energy from sunlight using **photosynthesis**. Autotrophs are the producers in ecosystems.

• Heterotrophs (like humans) depend upon energy from other organisms. There are consumers (herbivores, carnivores, omnivores), detritivores (worms), and decomposers (fungi).
Energy and Gas Exchange

\[
\text{CO}_2 + \text{H}_2\text{O} + \text{light} \rightarrow (\text{CH}_2\text{O}) + \text{O}_2
\]

- Carbon dioxide from the air
- Water taken up by the roots
- Energy
- Carbohydrates
- Oxygen

\[
(\text{CH}_2\text{O}) + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Energy}
\]

- Carbohydrates
- Oxygen
- Carbon dioxide released into the air
- Water
- Energy
The Leaf

Top Side

Bottom Side
Leaf Anatomy

- Cuticle
- Collechyma
- Upper epidermis
- Palisade parenchyma
- Spongy parenchyma
- Lower epidermis
- Guard cells
- Xylem
- Phloem
- Vein
- Stoma
Leaf Anatomy

Sun Leaf vs. Shade Leaf
Pine Needle Leaves
Leaf Anatomy

Two stomata are visible - one on each side of this leaf section. A Stoma consists of the pore itself - (2) and the two surrounding guard cells - only 1 indicated - (1). The air space - (3) is also visible. (Image from Molcol Software)
Photosynthesis

- Overall, water, carbon dioxide, and sunlight produce glucose and oxygen.
- $6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{energy} = \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{CO}_2$
- Sunlight and water create short-term plant energy (ATP and NADH).
- This ATP and NADH energy creates “glucose” from CO2 and RuBP.
Types of Photosynthesis

- C3, C4, CAM. All three use the Calvin cycle as the final stage of photosynthesis. Plants with the added steps of C4 and CAM grow slower, but conserve water better than C3 alone.

- C3 plants include most trees and shrubs.
C3 Photosynthesis

- **Adaptive Value:** more efficient than C4 and CAM plants under cool and moist conditions and under normal light because requires less machinery (fewer enzymes and no specialized anatomy, but drought sensitive).
C4 Photosynthesis

• Adaptive Value:
  • Photosynthesizes faster than C3 plants under high light intensity and high temperatures.
  • Has better Water Use Efficiency because it does not need to keep stomata open as much (less water lost by transpiration).
CAM Photosynthesis

• Adaptive Value:
  • Better Water Use Efficiency than C3 plants under arid conditions due to opening stomata at night when transpiration rates are lower (no sunlight, lower temperatures, lower wind speeds, etc.).
Respiration

- Sugar and oxygen produce carbon dioxide, water, and plant energy.
  - $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{CO}_2 = 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy}$
- Oxygen’s main job is to bind with extra Hydrogen and let the system cycle.
The Anatomy of Respiration

• “Glucose” is broken down by glycolysis and the citric acid cycle (mitochondria) to produce short-term plant energy (ATP). CO2 and H2O can then be released or used by photosynthesis.

• 1 glucose can produce 26 to 38 ATP.
Carbon cycling

- \(6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{light} = \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2\)
- \(\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 = 6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{ATP}\)
- During good growing days, photosynthesis outperforms respiration by 40 to 70%. This allows extra sugars to be converted into the growth of wood (fixed carbon). Thus, more \(\text{O}_2\) than \(\text{CO}_2\) is released into the atmosphere.
- However, respiration occurs year round on all perennial plants. Any time a plant is not actively growing, it releases as much or more \(\text{CO}_2\) as \(\text{O}_2\).
Gas Exchange

- Stomata
- Lenticels
- Collenchyma cells
- Root Absorption
Leaf Fall

- Trees that keep their leaves are **evergreens**, trees that lose their leaves are **deciduous**.

Abscission zone—area at the base of the petiole that breaks down and causes leaf (or fruit) drop
Leaf Fall

Declining intensity of sunlight triggers the processes leading up to leaf fall in autumn.

Chlorophyll reduces, unmasking carotenoids.

Clogged phloem veins trap sugars in the leaf and promote production of anthocyanins.
From Leaves to Roots

Now that we have explored how leaves work, let’s go downstairs to the foundation and examine roots.
1. Tree roots are not an underground reflection of the crown.

2. Roots spread far and wide!
Root Structure
Root Structure
Root System
Root Development

- The most important part of the root does not have a woody covering yet.
- Single-cell root hairs provide most of the tree’s water and nutrient uptake from the soil.
Root Development
Root Function

1. Support and Anchor the Tree
2. Absorb Water and Nutrients
3. Storage of Food and Nutrients
It all starts with SOIL

- As we know, 99% of a tree’s root mass is in the top 3 feet of soil.
- This is where the tree absorbs water stored in soil from rainfall and the intake of vital nutrients (N-P-K).
Soil Types and Horizons

- **O horizon**: Loose and partly decayed organic matter
- **A horizon**: Mineral matter mixed with some humus
- **E horizon**: Zone of eluviation and leaching
- **B horizon**: Accumulation of clay, iron, and aluminum from above
- **C horizon**: Partially altered parent material
- **R horizon**: Unweathered parent material

The diagram illustrates the classification of soil types based on percentage of sand, clay, and silt.
Soil Nutrients

- Nitrogen, phosphorous, potassium, calcium, Magnesium, Sulfur, Iron, Manganese, Zinc, Copper, Boron, Molybdenum, and Chlorine are all considered essential to plant growth.
Soil Nitrogen

• Nitrogen makes up proteins and enzymes needed for photosynthesis and cell synthesis.

• Nitrogen deficiency results in chlorosis of older leaves.
Soil Phosphorus

- Phosphorous makes up energy transfer compounds ATP, ADP. It is also essential in the makeup of DNA and RNA.
- Phosphorus deficiency often causes stunting of young trees.
Soil Potassium

• Potassium is essential for the movement of water and minerals within a plant (one of the main ways to manipulate osmosis). It is also essential for protein synthesis.

• Potassium deficiency results in chlorosis followed by marginal scorching of old leaves.
Water and Nutrient Uptake
Xylem and Phloem: Tree Transportation Highways

Parts of a Tree

A tree is a woody perennial plant that usually is more than 10 feet tall and has one main stem. Although trees come in different shapes and sizes, most have the same basic parts. Each of these parts — from the highest leaves in the crown to the tiny root hairs buried in the soil — plays an important role in the tree's function and survival. Click on the parts of the tree for more information.
The Stem

- The trunk and branches of a tree provide the tree’s framework.
- They conduct water and minerals from the roots to the leaves.
- They also store energy in the form of sugars and starches.
Grow Upward and Outward
Stem Anatomy

- **Vascular Cambium**: Area of cell division that is responsible for secondary growth. Creates and separates the xylem and phloem.

- **Xylem**: Grows to the inside of the vascular cambium to transport water and nutrients from roots to leaves. Prominent cells are vessels, tracheids, fibers (Angiosperm) or tracheids (Gymnosperm).

- **Phloem**: Thin layer growing on the outside of vascular cambium to transport nutrients down from leaves. Prominent cells include sieve tubes and companion cells.

- **Cork Cambium**: Area of cell division that forms bark and lenticels to the outside. Designed to protect inner cells and allow gas exchange.
Xylem Stem Anatomy

Figure 17.4  Cross sections of stems of Pinus (A) and Tilia (B), each with periderm and several increments of secondary vascular tissues. (After K. Esau. Plant Anatomy, 2nd ed. John Wiley & Sons. 1965.)
Xylem Stem Anatomy

Xylem
Phloem
Cambium
Vascular cambium
Stem Anatomy

Vessel Element

Tracheid
Springwood, Latewood, and Heartwood

*Figure 2.20.* Variations in transition from earlywood to latewood in gymnosperms. Gradual transition of sugar pine (left) and abrupt transition in longleaf pine (right). Magnification: ×27.5. Photo courtesy of the U.S. Forest Service.
Phloem Stem Anatomy

Figure 17.4 Cross sections of stems of Pinus (A) and Tilia (B), each with periderm and several increments of secondary vascular tissues. (After K. Esau, Plant Anatomy, 2nd ed. John Wiley & Sons, 1965.)
Phloem Stem Anatomy

Vascular cambium

Xylem

Phloem

Cambium
Phloem Sieves Cells
What makes a plant a tree?

Like other plants:

- Trees are *autotrophs* - meaning they produce their own food.
- Tree cells have rigid cell walls, a large central vacuole, and chloroplasts.

The difference is **Secondary Growth**!
Secondary Growth means Wood!

Trees and shrubs grow **radially** as well as vertically.

(The difference between trees and shrubs is size.)
Cross Section of Woody Stem

- xylem
- phloem
- pith
- pith ray
Our secondary growth model:

A typical hardwood tree in cross section (transverse surface).

What can you identify?
The bark is everything outside the vascular cambium.

As you can see, there is a lot going on in the bark.
The phellogen is the region of cell division that forms the periderm tissues.

Phellogen development influences bark appearance.
The Bark: periderm: phellem (cork):

Phellem replaces the epidermis as the tree increases in girth.

Photosynthesis can take place in some trees both through the phellem and in fissures.
The Bark: periderm: phelloderm:

Phelloderm is active parenchyma tissue.

Parenchyma cells can be used for storage, photosynthesis, defense, and even cell division!
The Bark: phloem:

Phloem tissue makes up the *inner bark*.

However, it is *vascular tissue* formed from the vascular cambium.
The Bark: phloem: sieve tube elements:

Sieve tube elements actively transport photosynthates down the stem.

Conifers have sieve cells instead.
The cambium is the primary meristem producing radial growth. It forms the phloem & xylem.
The Xylem (wood):

The xylem includes everything inside the vascular cambium.
The Xylem: a growth increment (ring):

The rings seen in many trees represent one growth increment.

Growth rings provide the texture seen in wood.
The Xylem: vessel elements:

Hardwood species have vessel elements in addition to trachieds.

Notice their location in the growth rings of this tree.
The Xylem: fibers:

Fibers are cells with heavily lignified walls making them stiff.

Many fibers in sapwood are alive at maturity and can be used for storage.
The Xylem: axial parenchyma:

Axial parenchyma is living tissue!

Remember that parenchyma cells can be used for storage and cell division.
The Xylem: rays (multiserrate & uniserrate):

Rays are radial parenchyma cells.

Parenchyma cells give rise to adventitious tissues.
The Xylem: a natural compartment:

Notice that a natural compartment is formed with living tissue at its borders.

How does this support the CODIT model?
The Symplast:

The symplast is the living portion of the tree.

It is all connected via plasmodesmata (tiny passages in the cell walls.)
Vascular plants differ from us greatly when faced with wounding or infectious diseases. Unlike us, they lack IMMUNE systems. Instead, they have developed a process to cope known as: Compartmentalization.
CODIT

Compartmentalization of Decay In Trees

The 4 Walls

1. Tyloses
2. Axial parenchyma and annual growth components
3. Ray cells
4. Wound response of cambium
CODIT: Trees don’t Heal, they SEAL

• A wounded tree will NOT be capable of healing a wound by regenerating destroyed tissue.
• Instead, the wound is “walled” off from the rest of the vascular system by the formation of “TYLOSES” thus, not allowing decay to spread into the rest of the system.
• There are four walls or boundaries
CODIT

• Wall 1: Stops VERTICAL Spread by plugging vessel & tracheid cells in the xylem (weakest boundary).

• Wall 2: Stops INWARD spread toward the pith.

• Wall 3: Stops LATERAL movement by plugging cells that are primarily for food storage (strong boundary).

• Wall 4: Separates NEW wood from that which was present from the time of the damage (the strongest boundary).
Natural Branch Abscission

- Compartmentalization also occurs at branch collar and leaf collars.
- This CODIT prevents injury to the tree when it is time for a branch to go.
Wound Response in a Deciduous Tree

A wound was created through the bark, phloem, cambium, and the youngest xylem.
The cambial zone continues to form a barrier zone along the inner edge of the cambium. The barrier zone has advanced farther from the wound site along the edge of the cambium.
Tissue near the wound site (blue zone) on the interior of the barrier zone begins to darken and discolor.
What does it all mean?

- Trees can live longer than other plants.
- They can get bigger than other plants.
- They can respond to damage, disease, insects, and environmental conditions successfully.
- Trees are a long term investment.
Tree System Review

The Leaves process water and carbon dioxide (Photosynthesis) to form complex sugars (fuel), which are sent back down (Phloem) the tree for storage and use.

The Stem transports water and solutes (Diffusion & Osmosis), to the crown via the Xylem.

The Roots absorb water and nutrients with help from Root Hairs.
For More Information

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Definition of Cellular Terms

- **Cytoplasm**: the protoplasm of a cell contained within the cell membrane but excluding the nucleus: contains organelles, vesicles, and other inclusions.
- **Endoplasmic Reticulum**: an extensive intracellular membrane system whose functions include synthesis and transport of lipids and, in regions where ribosomes are attached, of proteins.
- **Ribosomes**: any of numerous minute particles in the cytoplasm of cells, either free or attached to the endoplasmic reticulum, that contain RNA and protein and are the site of protein synthesis.
- **Mitochondria**: Also called chondriosome, a small spherical or rod like body, bounded by a double membrane, in the cytoplasm of most cells: contains enzymes responsible for energy production.
- **Golgi Apparatus**: a membranous complex of vesicles, vacuoles, and flattened sacs in the cytoplasm of most cells: involved in intracellular secretion and transport.
- **Microtubules/Microfilaments**: a hollow cylindrical structure in the cytoplasm of most cells, involved in intracellular shape and transport.
- **Flagella**: a long, lashlike appendage serving as an organ of locomotion in protozoa, sperm cells, etc.
- **Nucleus**: a specialized, usually spherical mass of protoplasm encased in a double membrane, and found in most living eukaryotic cells, directing their growth, metabolism, and reproduction, and functioning in the transmission of genic characters.
- **Cell wall**: the outer layer of a cell, especially the structure in plant cells that consists of cellulose, lignin, etc., and gives mechanical support to the cell.
- **Vacuole**: a fluid-filled cavity in the cytoplasm of a cell.
- **Centrioles**: either of two rodlike bodies in most animal cells that form the poles of the spindle during mitosis.
- **Chloroplast**: a plastid containing chlorophyll and other pigments, occurring in plants and algae that carry out photosynthesis.
- **Plastids**: a small, double-membraned organelle of plant cells and certain protists, occurring in several varieties, as the chloroplast, and containing ribosomes, prokaryotic DNA, and, often, pigment.
- **Plasma Membrane**: a very thin membrane composed of lipids and protein that surrounds the cytoplasm of a cell and controls the passage of substances into and out of the cell.
- **Lysosomes**: a cell organelle containing enzymes that digest particles and that disintegrate the cell after its death.