


  
**How Trees Work**  
 (so we can let them)  
 Practical Biology & Physiology  
 (to learn how trees can thrive)

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 Agriculture & Natural Resource Agent - Morris County  
 NJ Licensed Tree Expert #692 - ISA Certified Arborist NJ1247-A

Funding for this program was provided by the USDA Forest Service

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### What is a Tree?

- Woody perennial
- Usually has a single stem
- Grows taller than 15 ft at maturity



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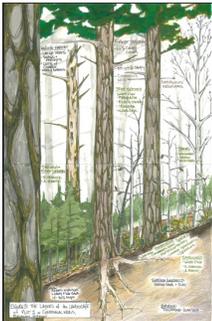
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### Trees Evolved in Forests with...

- Biotic elements
  - Other plant types: Moss, ferns, grasses, shrubs, etc.
  - Animals
  - Insects & other arthropods
  - Microbes: soil, foliar, bark, etc.
- Abiotic elements & processes
  - Bedrock & minerals in soil
  - Weather & climate



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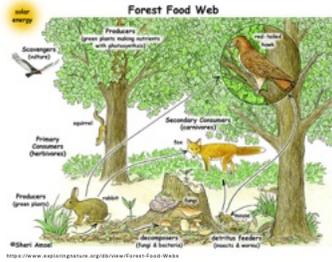
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### Connected Life of Trees

- Trees provide to ecosystem:
  - Shelter/nesting
  - Leaf litter!
  - Larval hosting
  - Forage/Food
- Ecosystem provides to trees:
  - Pollination
  - Seed dispersal
  - Communication
  - Soil health
  - Leaf litter decomposition




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### Healthy Soil is Full of Life

TREES EVOLVED TO LIVE IN HEALTH, LIVING SOIL



Figure 9- Healthy soil is full of life. 1-plant roots, 2-arthropods, 3-annelids, 4-fungi, 5-bacteria, 6-actinomyces, 7-protists, 8-plant roots, 9-plant roots, 10-plant roots, 11-plant roots, 12-plant roots, 13-plant roots, 14-plant roots, 15-plant roots, 16-plant roots, 17-plant roots, 18-plant roots, 19-plant roots, 20-plant roots, 21-plant roots, 22-plant roots, 23-plant roots, 24-plant roots, 25-plant roots, 26-plant roots, 27-plant roots, 28-plant roots, 29-plant roots, 30-plant roots, 31-plant roots, 32-plant roots, 33-plant roots, 34-plant roots, 35-plant roots, 36-plant roots, 37-plant roots, 38-plant roots, 39-plant roots, 40-plant roots, 41-plant roots, 42-plant roots, 43-plant roots, 44-plant roots, 45-plant roots, 46-plant roots, 47-plant roots, 48-plant roots, 49-plant roots, 50-plant roots, 51-plant roots, 52-plant roots, 53-plant roots, 54-plant roots, 55-plant roots, 56-plant roots, 57-plant roots, 58-plant roots, 59-plant roots, 60-plant roots, 61-plant roots, 62-plant roots, 63-plant roots, 64-plant roots, 65-plant roots, 66-plant roots, 67-plant roots, 68-plant roots, 69-plant roots, 70-plant roots, 71-plant roots, 72-plant roots, 73-plant roots, 74-plant roots, 75-plant roots, 76-plant roots, 77-plant roots, 78-plant roots, 79-plant roots, 80-plant roots, 81-plant roots, 82-plant roots, 83-plant roots, 84-plant roots, 85-plant roots, 86-plant roots, 87-plant roots, 88-plant roots, 89-plant roots, 90-plant roots, 91-plant roots, 92-plant roots, 93-plant roots, 94-plant roots, 95-plant roots, 96-plant roots, 97-plant roots, 98-plant roots, 99-plant roots, 100-plant roots.

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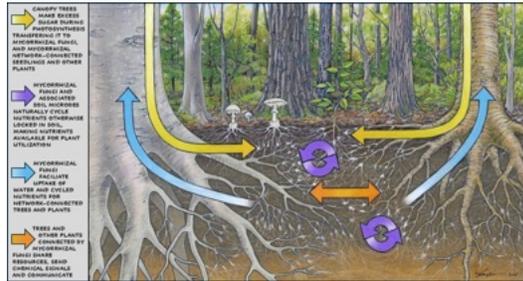
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### Trees Evolved in Communities

ABOVE & BELOW GROUND



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### What is a Tree?

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**ARBORICULTURAL DEFINITION**  
 – What arboriculture & individual tree care in developed spaces is based around




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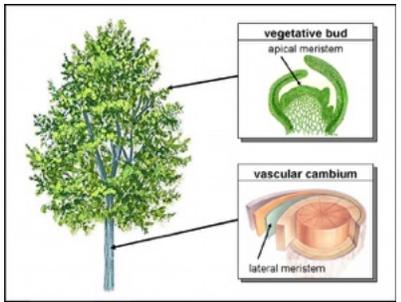
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### Tree Growth

- Apical meristem
  - Twing elongation
  - Root elongation
- Lateral meristem
  - <Girth> expansion
  - Not vertical
  - Trunk
  - Branches
  - Large roots



[https://www.researchgate.net/publication/317691416/figure/fig1/figure-pdf/317691416-vegetative-bud-494\\_fig1\\_317691416](https://www.researchgate.net/publication/317691416/figure/fig1/figure-pdf/317691416-vegetative-bud-494_fig1_317691416)

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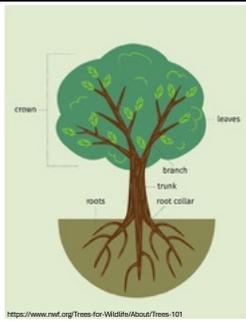
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### Tree Anatomy

#### PARTS OF A TREE

- Crown or canopy
  - Branches, twigs
    - Leaves, flowers, fruit
- Trunk or bole or stem
  - Root collar
- Root system



<https://www.mnf.org/Trees-for-Wildlife/About/Trees-101>

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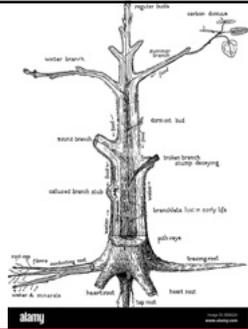
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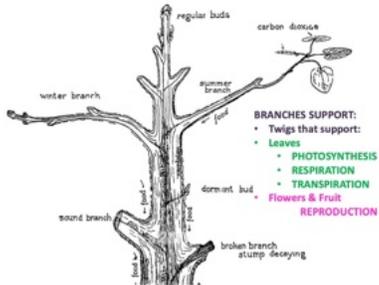
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### Crown




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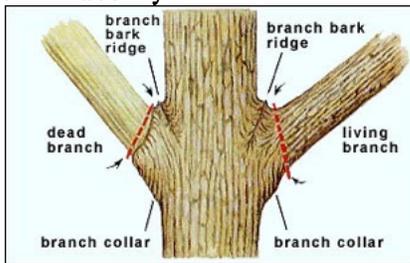
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### Branch Anatomy




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### Twig Anatomy

**Parts of the Branch**

**Terminal Bud:** The top bud at a branch tip will always grow first and largest of the leaves it has, and several buds will grow behind it.

**Leaf Bud:** Forms singly on the side of a branch. To make one grow, cut above it. Close buds pointing outward from the trunk as the growing branch will have open and light.

**Flower Bud:** Forms opposite to leaf buds and first to swell in spring. The stem from their base alone or beside leaf buds. On apple and pear they grow with a few leaves.

**Spine:** Prickles on apple, pear, plum, and apricot. They grow in older twigs, probably at flower buds, then fall. Don't scratch them.

**Leaf Scar:** A ring on a branch that marks the point where the terminal bud began growing after the dormant season. The line marks the origin of the year's growth.

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### Twig Anatomy & Physiology

Auxins in **TERMINAL BUDS** force growth upward and suppresses growth in **LATERAL BUDS**

**Terminal bud:** LENTICELS support gas exchange, water evaporation, & light penetration

**Lateral bud:** Leaf scar

**Current year's wood:** Girdle Scar

**Dormant wood bud:** Last year's wood

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### Physical Response to Pruning

- Stimulates bud break near cut
- If lateral branches are removed, more energy sent to terminal shoot (leader)
- If leader is removed, it breaks apical dominance & creates more side branches
- Many factors influence the response:
  - Age
  - Growth habit
  - Size
  - Timing
  - Species

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### Leaves / Foliage

**PHOTOSYNTHESIS**

**RESPIRATION**

**TRANSPIRATION**

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### Sugar, Water, & Air Movement in Trees

**PHOTOSYNTHESIS**  
Produces SUGAR (Food)

SUGAR is carried down through the PHLOEM

SUGAR is passed through to the rest of tree, stored, and used for growth

The leaves, roots, and sometimes bark exchange AIR

The leaves intake CO<sub>2</sub> and release O<sub>2</sub>

The roots intake O<sub>2</sub> and release CO<sub>2</sub>

WATER is absorbed by roots and moves up the tree through the XYLEM

WATER is used throughout the tree

WATER is 85-90% of growing tissue

WATER transports minerals

WATER keeps trees cool

WATER VAPOR is released by the leaves (TRANSPIRATION)

H<sub>2</sub>O and minerals

CO<sub>2</sub>

O<sub>2</sub>

Sugar

Light

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### Trunk Functions

- Support
- Storage
- Protection
- Some photosynthesis & respiration
- Mainly used by the tree for energy storage in the form of wood

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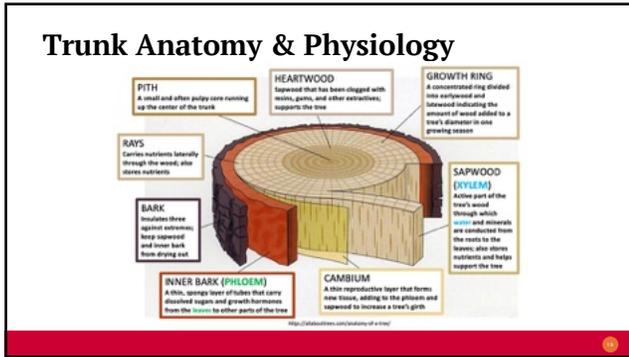
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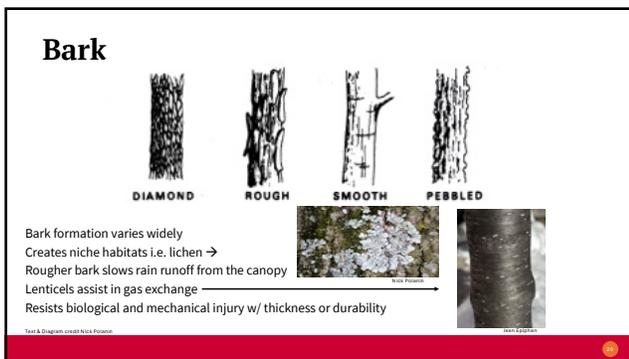
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# How do Trees Heal Wounds?

TREES DO NOT HEAL - THEY COMPARTMENTALIZE!



After wounding, the cambium forms a **barrier zone/wall**. It separates wood formed before wounding from the wood that forms after wounding.

- Compartmentalization of decay in trees (CODIT) -ALEX SHIGO

**HOST RESPONSE TO WOUNDING, CHEMICAL REACTIONS TO STOP INVASION PROCESSES BY MICROORGANISMS GO THROUGH THE BARRIERS SET UP BY THE TREE**

**INFECTION OF DEAD AND DYING TISSUES ON WOUND SURFACE DECAY PROCESS**

<https://nrcs.usda.gov/ars/forestsciences/ars/forestsciences/2021-01/0007%20800000.pdf>

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# Urban Site Tree Guards



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# Park Site Barrier Options

PROTECTION FROM DEER & WEEDWHACKERS



For single tree protection - 6ft tall is best



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### Root Collar

ALSO CALLED A ROOT FLARE

- Portion of the tree where the trunk transitions to the root system
- Has Bark unlike roots and must stay above ground
  - Not piled with mulch



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### No Volcanoes!



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### No Stone Volcanoes or Rings!



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### Root Collar Excavation Needed

Lawn w/ Convex Mound Beds for Tree

- Bed mounds should be:
  - brought down to grade, soil
  - or made into concave rain g
  - Not over-mulched year after

- If over-mulched with mounded trees..

PERFORM A ROOT COLLAR EXCAVATION



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### Flat Doughnuts, Not Volcanoes



Johnson et al. 2021. Tree Owner's Manual. USDA Forest Service Eastern Region, State and Private Forestry Milwaukee, Wisconsin. Available at: [https://nrs.fs.fed.us/eng/400/400\\_000\\_000/TreeOwnersManual](https://nrs.fs.fed.us/eng/400/400_000_000/TreeOwnersManual)

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### Removing Excess Soil from Root Ball

ROOT FLARES ARE COMMONLY BURIED IN THE ROOT BALL

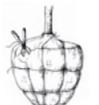
PROBE TO FIND MAIN ROOT SYSTEM



CAREFULLY REMOVE EXCESS SOIL



OFTEN THE TOP 1/3-1/4 SHOULD BE REMOVED



Johnson et al. 2021. Tree Owner's Manual. USDA Forest Service Eastern Region, State and Private Forestry Milwaukee, Wisconsin. Available at: [https://nrs.fs.fed.us/eng/400/400\\_000\\_000/TreeOwnersManual](https://nrs.fs.fed.us/eng/400/400_000_000/TreeOwnersManual)

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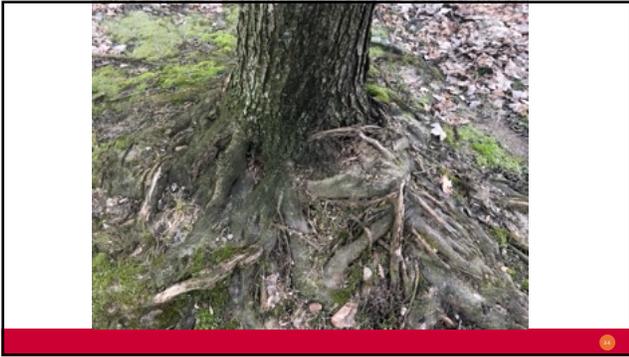
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### Prune Adventitious Roots

[https://www.cas.iastate.edu/wp-content/uploads/2022/06/14w\\_10\\_Property\\_Plan\\_3\\_Tree\\_CSE5-v1.pdf](https://www.cas.iastate.edu/wp-content/uploads/2022/06/14w_10_Property_Plan_3_Tree_CSE5-v1.pdf)

Johnson et al. 2021. Tree Owner's Manual: USDA Forest Service Eastern Region: State and Private Forestry Milwaukee, Wisconsin. Available on <https://rnrh-public.agg.ars.ars.gov/TreeOwnersManual>

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### Prune Girdling

**BEFORE ITS TOO LATE**

<https://extension.umd.edu/resources/girdling-trees>

University of Illinois Extension. 2015. Girdler's Corner: Girdling Roots on Trees. <https://www.illinois.com/learn/soil/soil-health/soil/10/10/15>

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## Raised Beds

NOT A GOOD IDEA

- Winter
  - Exposed to colder temps
  - Desiccating winds
- Summer
  - Exposed to hotter temps
  - Drier soils, more extreme drought
- Buried woody stems?
  - Rot
  - Adventitious roots



<https://www.dailymail.com/home/garden/growing-vegetables-in-your-backyard/article/when-to-build-raised-beds>

<https://www.dailymail.com/home/garden/growing-vegetables-in-your-backyard/article/when-to-build-raised-beds>

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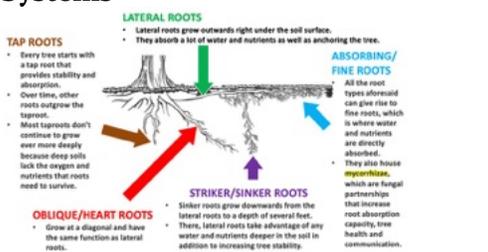
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## Root Systems



**LATERAL ROOTS**

- Lateral roots grow outwards right under the soil surface.
- They absorb a lot of water and nutrients as well as anchoring the tree.

**TAP ROOTS**

- Every tree starts with a tap root that provides stability and absorption.
- Over time, other roots outgrow the taproot.
- Most taproots don't continue to grow ever more deeply because deep soils lack the oxygen and nutrients that roots need to survive.

**ABSORBING/FINE ROOTS**

- All the root types aboveground can give rise to fine roots, which is where water and nutrients are directly absorbed.
- They also house mycorrhizae, which are fungal partnerships that increase root absorption capacity, tree health and communication.

**STRIKER/SINKER ROOTS**

- Sinker roots grow downwards from the lateral roots to a depth of several feet.
- There, lateral roots take advantage of any water and nutrients deeper in the soil in addition to increasing tree stability.

**OBLIQUE/HEART ROOTS**

- Grow at a diagonal and have the same function as lateral roots.

<https://publib.net/Project-of-tree-root-system/>

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## Root Systems

**MOST TREE ROOTS ARE FOUND IN THE UPPER 18+ INCHES OF SOIL**

**MOST ABSORBING ROOTS ARE ACTIVE IN THE TOP 6 INCHES**

Root System  
Depth in feet

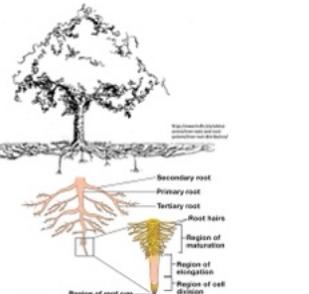
Root System Functions:

**WOODY ROOTS**

- Transport
- Anchorage/Support
- Storage

**NOT WOODY FINE ROOTS**

- Gas exchange
- Absorption (Water & Nutrients)
- Host Mycorrhizae



**Secondary root**

**Primary root**

**Tertiary root**

**Root hairs**

**Region of maturation**

**Region of elongation**

**Region of cell division**

**Region of root cap**

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### Compacted Soil & Limited Rooting Area

INCORPORATE STRUCTURAL SOILS

Fig. 3.16 How soil structure is related to plant growth. <https://www.oprecacongovernment.org/using-cu-structural-soil/6244/>

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### Soil Compaction

"I CAN'T BREATHE! I NEED AIR!"

- Oxygen, or pore space between soil particles, is *critical* in root establishment and growth
- Ideal soil is about 50% pore space, which may be filled with air or water
- Compaction reduces soil pore space; below 12%, oxygen levels are so low root growth is inhibited

Slide Credit: Nick Polanin

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### Tree Ring Expansion

WHERE POSSIBLE

- Most mulched areas below trees and shrubs "TREE RINGS" are too small
- Tree ring size should be increased over time as canopies grow
- Optimal tree ring size = drip line size or >

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## “Green Mulch” & Leaving Leaves



Christmas fern *Polystichum acrostichoides*  
Virginia bluebells *Mertensia virginica*

✓ w/ Leaves → Best option for the environment & ecosystem

- Adds nutrients to soil naturally
- Increase soil life (microbes & mycorrhizal fungi)
- Builds quality soil & reverses compaction
- **WAL** habitat for over wintering animals & beneficial insects
- Reduces transport & use of fossil fuels

**Why Leave the Leaves & How to Do It -**  
<https://njaes.rutgers.edu/fs1369/>

Green Mulch (not lawn)

- Helps rainwater capture & infiltration
- Helps reduce soil compaction
- Increase aesthetics



Common blue violet *Viola sororia*  
Cross phlox *Phlox subulata*

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## Sustainable Solutions for Urban Streets



**CURB-CUT RAIN BASINS:**  
Stop street runoff, water your trees for free



<http://www.sustainableliving.org/news/2016/04/08/green-city-the-use-of-blue-roads-in-the-urban-ecosystem/>

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## Watering

WATER WITH 2 GALLONS PER 1" DIAMETER OF TREE

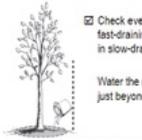
**FIRST 3 YEARS AFTER PLANTING**

- Monitor soil moisture 1-3x /week
  - Check if soil is dry 6" down
- DURING HEAT WAVES & DROUGHTS Make sure to water deeply 2-3x/week

**OLDER TREES**

- Monitor soil moisture weekly
  - Check if soil is dry 6" down
- DURING HEAT WAVES & DROUGHTS - Make sure to water deeply 2x /week

DO NOT LET SPRINKLERS HIT LEAVES OR BARK



Check every other day in fast-draining soils, weekly in slow-draining soils

Water the root ball and just beyond



Check weekly

Winters et al. 2021. Tree Owner's Manual. USDA Forest Service Eastern Region, State and Private Forestry Milwaukee, Wisconsin. Available at: <https://usfr.fs.fed.us/app-bios.com/TreeOwnersManual>

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<https://aptarree.com/?page=of-tree-root-system/>

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## Root System Types

- TAP ROOT**
  - hickory, walnut, white oak, hornbeam
- HEART ROOT**
  - red oak, honey locust, basswood, sycamore, pines
- FLAT ROOT (SURFACE)**
  - birch, fir, spruce, maple, cottonwood, hackberry

The Morton Arboretum

[https://natureresources.extension.iastate.edu/forestry/tree\\_biology/101.html](https://natureresources.extension.iastate.edu/forestry/tree_biology/101.html)

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## Physiological Response to Pruning

PRUNING CAUSES HORMONAL CHANGES

**This is why we limit pruning at planting**

**AUXINS** produced in the canopy growing tips stimulate root growth

**AUXINS affect:**

- Apical dominance
- Cell elongation
- Fruit drop or retention

**GIBBERELLINS** produced in the root growing tips stimulate canopy growth

**GIBBERELLINS affect:**

- Rate of cell division
- Flowering
- Increase of leaf & fruit size

<https://cmg.extension.colostate.edu/Gardennotes/146.pdf>

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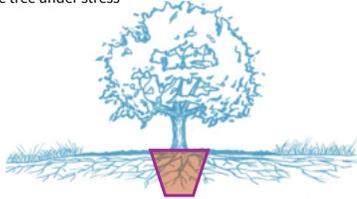
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### B&B

- 80-95% of fine roots are removed; 5-20% of the fine roots remain
- This places the tree under stress



<https://extension.colostate.edu/resource/the-science-of-planting-trees/>

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### B&B



<https://www.lsuagcenter.com/topics/soils/pages/511282789>

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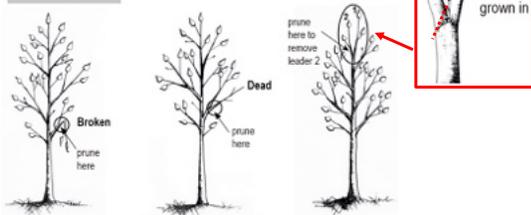
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### Minimal Pruning at Planting

See "Pruning" p. 18.



Johnson et al. 2021. The Owner's Manual. USDA Forest Service Eastern Region. State and Private Forestry Milwaukee, Wisconsin. Available at: <https://north-south-east.srs.fs.fed.us/owm/>

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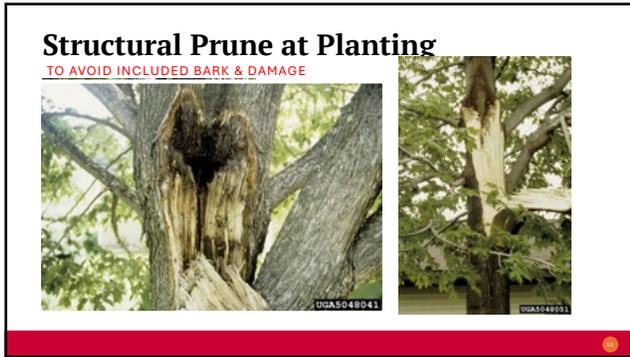
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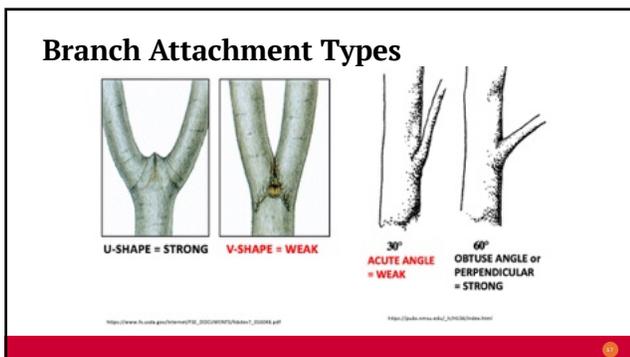
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## Crown Types

**Excurrent**  
Central leader trees



Spruce  
Firs  
Bald cypress  
American holly  
Sweet gum

**Decurrent**  
Multiple scaffold branches



Ash  
Elms  
Zelkova  
Red bud  
Mulberry

Terminal leader grows faster than lateral branches      Lateral Growth is as fast or faster than the terminal leader

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## Flower Types

**COSEXUAL** – Produces single flowers with both fully functional male and female parts (on the **SAME** tree).  
Dogwood, tulip tree, magnolia, apple, cherry

**MONOECIOUS** – Separate male and female parts on the **SAME** tree  
Oaks, walnuts, hickories, birch, beech, fir, hemlock

**DIOECIOUS** – Separate male and female parts on completely **DIFFERENT** trees.  
One tree is strictly male; one tree is strictly female.  
Willow, hickory, aspen, persimmon, red cedar, ginkgo

**POLYGAMOUS** – co-sexual male and female flowers on the same tree **OR** in different combinations on different trees  
Red & sugar maple, tupelo, sumac, mulberry



1. <https://www.watts.com.usgs.edu/story/3193/tree-sex.html>

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## Reproduction

For most trees, sexual behavior is not strictly male or female. <sup>1</sup>

Trees effectively reproduce using different combinations of functional sexual parts distributed in different types of flowers and cones. <sup>1</sup>

Woody perennials (aka trees) spend about 10-15% of resources on reproduction, but under stress will allocate 50% or more to reproduction  
- *To perpetuate the species.* <sup>2</sup>

Pollination is usually dependent on wind, insects, water, and/or animals<sup>3</sup>

Many fruit types i.e. nuts, samaras, berries, cones etc. <sup>2</sup>

Dispersal of Fruit depends on fruit/seed type.



1. <https://www.watts.com.usgs.edu/story/3193/tree-sex.html>  
2. Tree Growth & Pollination

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### Natural Dispersal

(THE BEST PLANTING METHOD)



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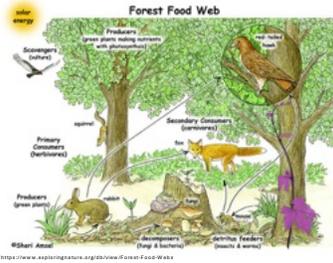
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### Connected Life of Trees

- TREES PROVIDE TO ECOSYSTEM:
  - Shelter/Nesting
  - Larval Hosting
  - Forage/Food
  - Support plant communities
    - Understory
    - Vines
- ECOSYSTEM PROVIDES TO TREES:
  - Pollination
  - Soil health
  - Seed dispersal
  - Communication



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### Remove Invasive Vines

THEY WILL HARM YOUR TREES

Native vines are benign, leave them be!

ASIATIC BITTERSWEET  
*Celastrus orbiculatus*



ENGLISH IVY  
*Hedra helix*



CHINESE & JAPANESE  
WISTERIA - *Wisteria*  
spp.



PORCELAINBERRY  
*Ampelopsis*  
*brevipendunculata*



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### Remove Invasive Vines

THEY WILL HARM YOUR TREES



DO NOT PULL VINES DOWN

WINDOW CUT METHOD

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### Abiotic Stressors

THE MOST COMMON CAUSE OF PLANT DISEASES IN THE LANDSCAPE

Facilitate instances of biotic diseases  
Speeds up tree mortality

**EXAMPLES:**

- Soil compaction/ suffocation
- Girdling roots
- Trunk damage
- Improper mulching and more

Let's work with natural tree biology & physiology to help protect trees so they can thrive!

Kennedy, M., O'Mara, J., Ruess, C., Miller, G.L. and D. Smith 2012. Introduction to abiotic disorders in plants. The Plant Health Instructor. DOI: 10.1094/PHI-1.2012-10.28201

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