What is a Tree?

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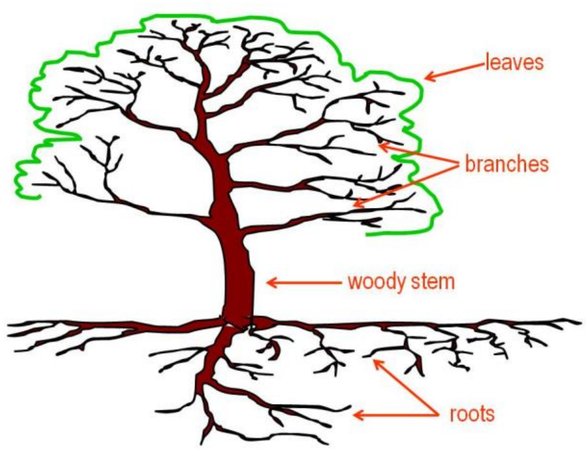
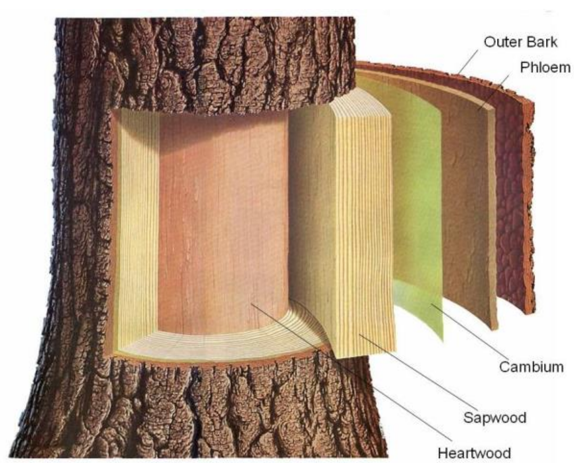
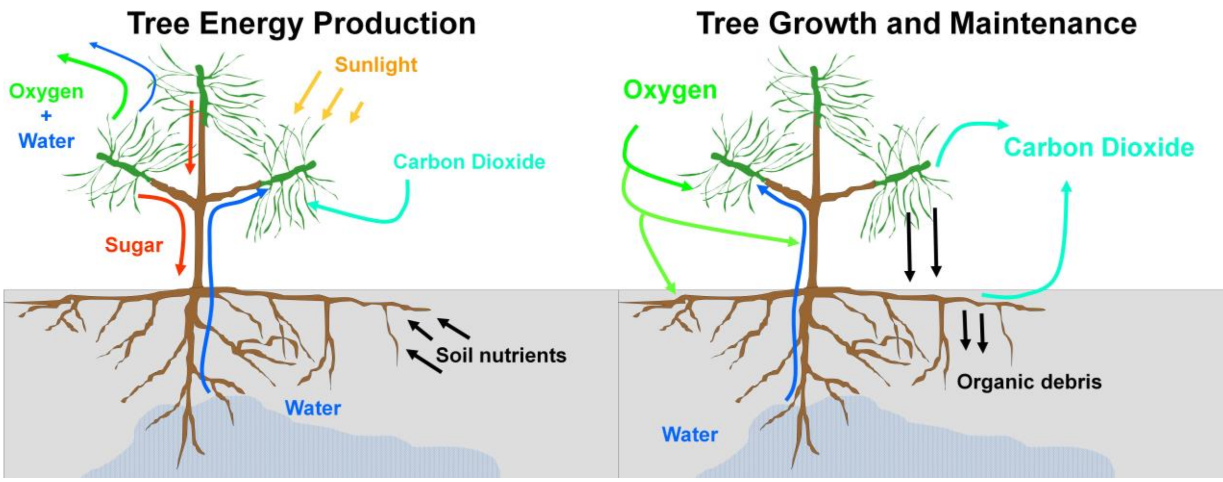
A tree is a plant with a tall structure comprised of a **stem** and **branches** to support **leaves**, and a **root system** than anchors the stem as well as procures and stores essential growth elements such as water and nutrients. **Trees** are unique from other plants because they can and usually do **live for decades** and **up to several millennia** (the oldest known single-stem tree is a baobab in South Africa measured to be 6000 years old), grow successive layers of woody vascular tissue that is added from growth just under the bark to develop **woody stems**, and in most parts of the Earth **grow taller than surface vegetation, ranging in height from several meters up to 115.55 meters** (the tallest recorded tree is a giant redwood in northern California). A tree stem is unique from other plant forms in that its woody stem growth occurs from a thin strip of cells called the **cambium** located just under the outer bark. Each year the cambium produces layers of new growth to the outside and inside. Growth to the outside is called the **phloem** and consists of large diameter cells designed to conduct sugar water from the leaves down the stem to the rest of the tree. Because of their large diameter, phloem cells are structurally weak and collapse after a year or two and are pushed outwards in compacted layers to become the **outer bark**. Growth to the inside is called the **sapwood** and functions as a living water transport system from the roots to the leaves and a storage site for surplus sugar and starch. As sapwood ages it becomes a depository for secondary metabolite materials such as phenols and terpenes. Eventually older sapwood dies and becomes the dead central core of tree called the **heartwood**. Deposited materials also make the heartwood of many tree species toxic to fungi and microorganisms which is why lumber cut from tree heartwood is often more durable than the nutrient rich sapwood. All trees have these key characteristics, although their stem shapes, wood composition, leaf shape and overall form can vary significantly.





Tree Physiology

Tree physiology functions much as in all other plants: their leaves absorb carbon-dioxide (CO_2) from the atmosphere through little pores in their leaves called stomates and use the energy of the sun in a biochemical process called **photosynthesis** that converts CO_2 and water into the 1carbon-2hydrogen-1oxygen molecule known as sugar. Oxygen is also produced as a byproduct of photosynthesis and is released in gaseous form back into the surrounding air. A primary use of photosynthesized sugar is consumption by all the living tree cells to stay alive in a process called **maintenance respiration.** Respiration is the chemical reaction between sugar and oxygen that fuels cell function and cell division and is a basic process used by most living cells (plant and animal). Surplus sugar is converted into starch for storage, which is then used to fuel growth of leaves, roots, branches and the tree stem. Tree growth occurs when optimal temperatures, water supply and energy reserves (starch and sugar) allow for cell division and the production of cellulose, hemi-cellulose and lignin, which are the major components of woody cell walls, in a process known as **growth respiration**.

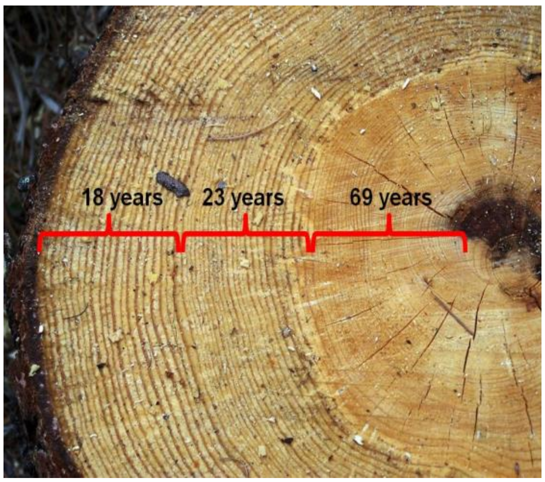


Respiration is a consumptive process as opposed to photosynthesis, and carbon dioxide is a byproduct that is released into the surrounding air. Maintenance respiration occurs all the time and is a function of temperature – the warmer it is the higher the rate - whereas growth respiration only occurs when new tree leaves, branches, stem or root cells are being produced. In most regions primary tree growth occurs in the spring when temperatures warm for optimal photosynthesis and water and nutrients are abundant. Growth slows during the summer and fall when resources become more limited and sugar is directed towards seed/fruit production. When temperatures cool to freezing, growth stops and trees go into dormancy.

In general, the sugar produced by a tree is allocated and used in the following order of importance: 1-Respiration, 2-Structure, 3-Storage, 4-Defense, and 5-Reproduction. A healthy and vigorous tree consumes about 10% of its produced energy for respiration alone.

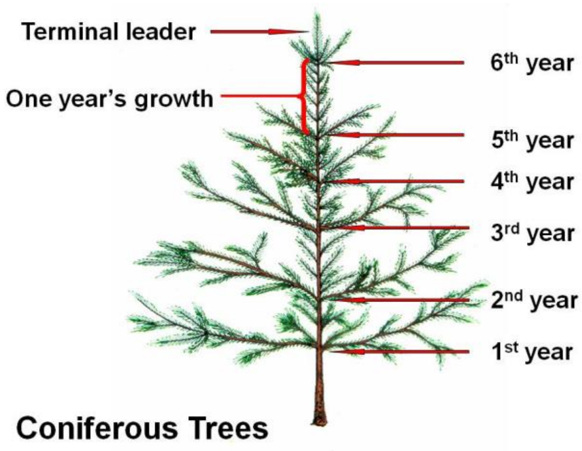
Tree Growth

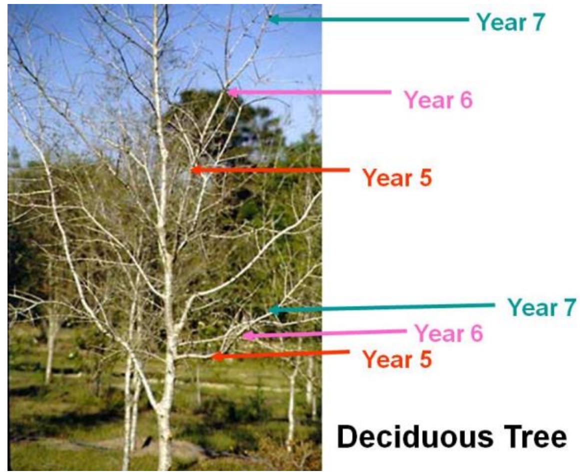
Tree growth is determined by a tree species ability to obtain sunlight, water, nutrients, and air in a specific climate. Each tree species has evolved over time to have a particular growth and reproductive advantage for a specific range of variability of climatic and soil conditions. Tropical trees for example do not expend energy for becoming cold hardy and thus outcompete any tree that puts aside energy for that purpose. Alternatively a tropical tree planted in a climate where freezing occurs will grow tall at a phenomenal rate during the summer only to die from the first frost, and the slower growing trees that allocated energy for winter hardiness will survive. Similar adaptations occur for climates with low versus high humidity, summer rain versus summer drought, and a range of soil conditions and nutrient availability.



Where the climate has distinct seasons, tree stem and branch growth can be seen as rings in the woody (xylem) tissue on a cross section of a tree stem. Light rings are formed in spring when a tree has abundant water, starch is metabolized into sugar and cell growth is rapid. This produces larger diameter vascular cells for better water transport. As water becomes more limited during the summer, cell growth slows and denser dark rings are produced. A trees age can be determined by counting either light or dark rings. Ring width is a reflection of resource availability – wide rings show periods of abundance of resources and thus better growth, narrow rings periods of resource limitation and thus poorer growth. Trees growing in more tropical climates may produce rings that correspond to rainy and dry periods, or may not produce rings if the differences between seasons are not very pronounced.

Tree height growth occurs when the meristematic tissue in terminal buds at the ends of branches starts to grow and divide. This can be seen in spring as elongating buds – often called "candle" growth on conifers since the elongating buds have not yet developed needles and thus resemble actual wax candles. All trees grow taller only from the tips of branches. Conifers typically grow taller from one main terminal creating a single stemmed tree versus most broadleaf and deciduous trees grow taller from multiple terminal branches creating a multi-stemmed tree. Once the woody xylem tissue of the stem and branches is formed it cannot elongate anymore, thus the basic shape of a tree is fixed by the growth that occurs from the branch tips.





Tree growth is determined by the ratio of sugar production in leaves during warm sunlight day light hours to continuous sugar consumption by the branches, stem and roots to stay alive and grow. During the daylight hours of the growing season the amount of atmospheric carbon dioxide absorbed and converted into sugar (and oxygen released) by a tree is much greater than the amount of sugar consumed by respiration (and carbon dioxide released back into the air). However, during the night when photosynthesis stops due to lack of light, a tree's respiration rate exceeds photosynthesis, more energy is consumed than produced and a tree is a net carbon dioxide producer. A tree that is considered healthy and vigorous will produce 8 to 10 times more sugar than it consumes and show wide growth rings averaging 2-5 growth rings per radial inch. Prolonged periods of drought or heat stress can cause a tree to close leaf stomates during the day to conserve water, which results in stopping or slowing of photosynthesis, though respiration must continue to keep tree cells alive. Under these conditions a tree may produce only enough energy to keep its cells alive and thus measurable growth almost stops and more than 200 rings per radial inch of stem cross section are not uncommon. Trees that are overcrowded and thus competing with each other for light, water and nutrients can create the same conditions as drought. Such prolonged stress can result in a tree depleting its energy reserves, poor subsequent growth, predisposition to pests and pathogens and eventual tree death.

A tree height growth is also determined by its energy surplus as well as its genetic programming. A taller tree may simply be growing on better soil conditions than its neighbor, or it may have the genetic commands to commit more energy to height growth may have a competitive advantage over its shorter neighbor in obtaining more sunlight for photosynthesis. Alternatively growing taller may occur at the expense of using that same energy for defense compounds, or root growth and that tree may be more readily attacked by pests and pathogens or suffer drought stress. Some species that grow tall in optimal environments for that species, may develop into very short prostrate "shrubs" under the harsh conditions of polar regions or mountain tops. Trees that have been cultured into "bonsai" trees can be tall growing trees that are pruned and purposefully stressed so they grow stunted. It is a very difficult art to stress a tree so it stays small without killing it, which can make true bonsai trees very valuable.

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