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Woody Plant Physiology

Unit Code: A/602/3922

UNIT GUIDE 2023-24

LO 6 Understand what is meant by tree biomechanics

6.1. Identify what is meant by the term biomechanics

Physics and biology are the two sciences that are combined to form biomechanics. It is the study of living things from a mechanical standpoint. The study of motion in objects is known as mechanics, and it is founded on Newton's three laws of motion.
The three laws are:

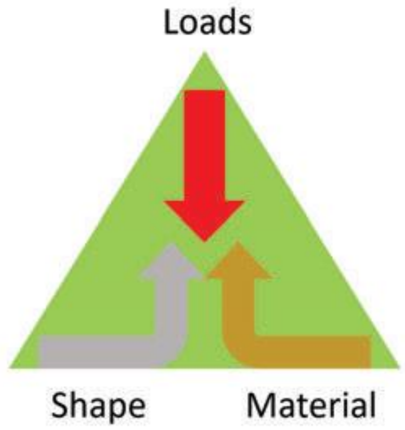
Unless a force acts upon an object, it will usually remain in motion; conversely, an object that is not in motion will likely remain so until a force acts upon it.

An object's mass (m) and acceleration (a) are related to the forces (F) acting on it in the following way: $F = ma$.

An object exerts an equal force in the opposite direction when a force is applied to it.

The environment in which trees grow shapes them. We can offer better management recommendations if we better understand and describe the effect of the environment on tree shape, wood physical and mechanical qualities.
From the perspective of an arborist, biomechanics mostly pertains to estimating the probability of tree failure.
This entails evaluating the consequences' severity, impact, and chance of failure.

The "static triangle" can be used to illustrate the fundamental idea of static in trees.



This shows that the tree has two ways to stand loads, the material of the tree can have the proper conditions, of the shape of the tree can be load-bearing.

LOAD

A tree's ability to support its own weight as well as the loads it encounters determine how likely it is to fail. A portion of the tree or the entire tree will fail when the loads exceed the load-bearing capability.
A load is a force that pushes or pulls on an object. Gravity pulls a tree down, and the ground pushes against it in the opposite way to keep it in place. The two forces (gravity and the ground) work equally on the tree (in this case, the tree's weight), but in opposite directions. This is why the tree does not move with respect to the ground. If the forces were not balanced, the tree would sink into or lift away from the soil. The two forces also align with one another, indicating that they are on the same side of the battle.

WIND / BENDING Moment

Another force that affects trees is wind. It presses against the crown, while the earth pulls back in the opposite direction, keeping the tree in place. If the forces were not balanced, the tree would either slide horizontally through the earth or topple. However, unlike in the preceding example, the force of the wind (known as drag) and the force applied by the ground to keep the tree in place against the wind do not act along the same imaginary line. The perpendicular distance is known as a lever, and you need to know that to calculate the second type of load, which is called a bending moment. For the calculation of a bending moment, multiply the applied force (such as wind drag) by the length of the lever. If the centre of a tree's crown is 50 feet above the ground, the lever is also 50 feet. If the wind creates 1,000 pounds of drag, the bending moment is 50,000 foot-pounds. Drag affects the entire tree crown, not simply a single spot in the centre.

LOAD-BEARING CAPACITY

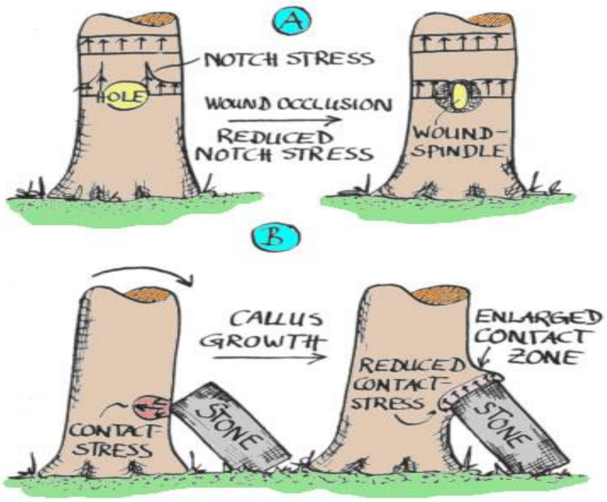
A structure's (like a tree's) or a portion of a structure's (like a tree branch's) load-bearing capacity is determined by two primary criteria. The first is the dimensions and form of the tree stem's cross section. The wood's strength in the cross section is the second. The size and shape are more important than the wood strength. Consider attempting to snap off two branches—one from a tree whose wood is extremely weak and the other from a tree whose wood is very strong. It will be simpler to break a branch with weaker wood if all of the branches have the same diameter. However, it will be simpler to break the smaller branch if the weaker branch has double the diameter of the stronger branch.
The diameter of the cube has a direct relationship with the load-bearing capacity. This indicates that the load-bearing capacity doubles eight times if one branch has twice the diameter of another, for example, 1 inch vs. 2 inches. 23 is equal to 2 x 2 x 2. The load-bearing capacity increases 27 times if one branch is three times as large as another branch (1 inch vs. 3 inches): 33 is 3 x 3 x 3. While some stems have an elliptical cross section, most stems are round. Depending on which way a bending moment works on a cross section that is more elliptical than circular, it will have a varying load-bearing capability.
Defects are commonly evaluated by arborists as a component of failure probability analysis. It is important to explain how faults lower load-bearing capacity. The most straightforward example is decay, a prevalent flaw in a lot of trees. Because decay lowers the load-bearing capacity in one of two ways, it raises the chance of failure. Compared to sound wood, decayed wood is far weaker. Second, there is less wood in the cross section to support the imposed load(s) if the decay process has hollowed out a stem.

We have gone over some of the fundamental mechanics, such as how arboriculture techniques affect failure probability. For instance, a tree that has been pruned will have less drag since its crown has fewer leaf areas. However, if you prune to lengthen the lever by removing only the lowest branches from the crown, the longer lever may make up for the reduced drag. This indicates that the wind-induced bending moment will not be significantly less than it was prior to the tree's pruning.
Gaining additional knowledge about mechanical concepts helps boost your confidence while planning projects and estimating the risk of tree failure.

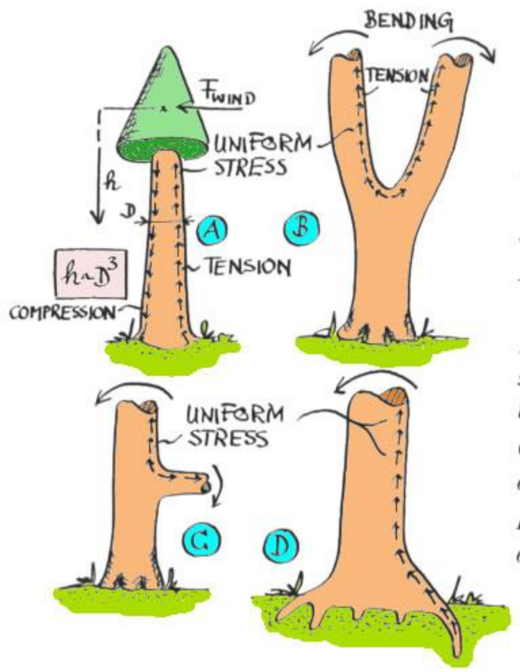
<u>6.2. Define a minimum of four key terms associated with tree biomechanics</u>

Mechanical self-optimisation mechanisms of trees.
Due to the permanent competition in nature and the survival of the fittest, trees are highly optimised structures.

<u>Axiom of uniform stress</u>
The tree is a self-optimizing structure because the growth of new wood tends to eliminate any stress concentrations, maintaining a uniform stress distribution. Adaptive growth lessens surface stress concentrations. The surface of a tree bears an equitable distribution of inevitable stresses.
The uniform distribution of stress throughout the surface of trees is a distinguishing feature. They develop so as to prevent both locally minor strains (overuse of material) and locally large stresses (possible locations of rupture).



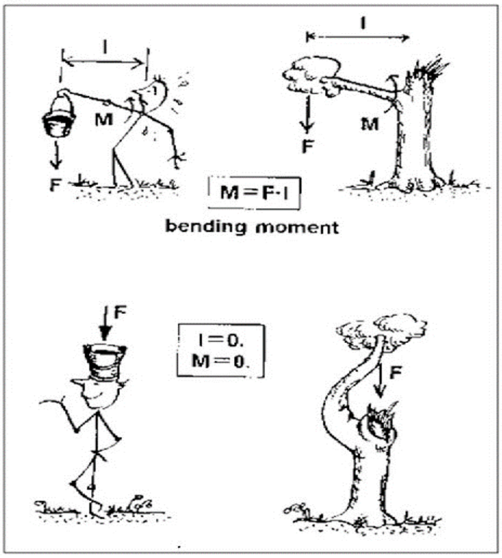
Examples of the tree's self-repair in accordance with the axiom of uniform stress.
A: Greatest wood formation at the point of greatest stress.
B: Levelling out contact stresses by enlargement of the contiguous surfaces.



Examples of the development of the tree's shape in accordance with the axiom of uniform stress.
A: Height/diameter h(D) formula for the stem.
B: Fork without notch stresses (double stemmed tree).
C: Branch junction free of notch stresses.
D: Root junction free of notch stresses.

Lever arm (body language of trees)
The length of a structure free to move at one end in the manner of a lever, such as a branch, and the distribution of weight along that length affecting loading at the base.

Reduction of the lever arms. By shortening the length of the loaded lever arm, trees reduce stress. Reaction wood, which forms when rigid portions of trees actively bend themselves, or the passive yielding of flexible tree components are two ways that length reduction can be accomplished. The ideal angle between the branch and stem is continuously adjusted by balancing apical dominance and negative geotropism. As long as the ruling-leading shoot remains intact, it suppresses the urge of the potential successor to straighten. The extended, lateral following branch straightens to replace its predecessor once the leading shoot is lost. Then, this branch, though not always the highest branch, declares its apical dominance and stifles the remaining leading shoot candidates.



A lateral branch straightens after the loss of the leading shoot, thus minimizing the bending load that acts on the branch joint and in the stem.

Minimisation of the bending load by rising up of a lateral branch after deterioration of the leading shoot.

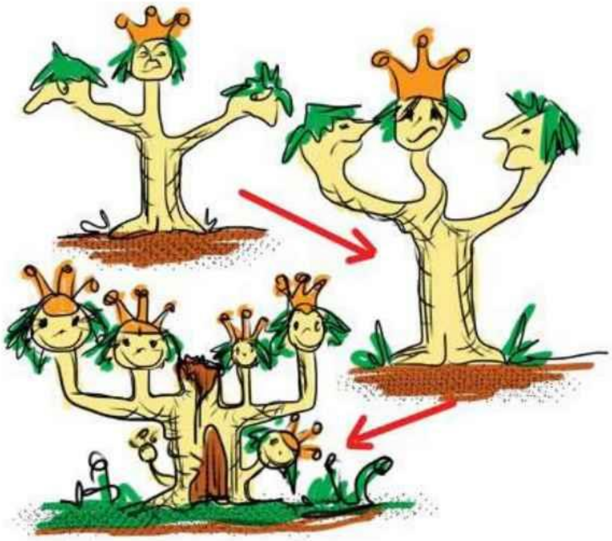
Compression and tensile forks

There are two biomechanically distinct types of tree forks described: the "compression fork," in which reaction wood presses the two jointed stems against one another at the contact face, and the "tension fork," in which gravity or wind action bends the two connected stems apart, creating tensile stresses in the connective zone.
It is common knowledge that trees always strive to maintain a condition of continual mechanical stress at the tree surface by adapting their development to better suit their own plans. In the case of these two distinct tree fork types, adaptive development also adopts distinct strategies to steer clear of high localised stress peaks that could cause the tree to fail when subjected to wind loading.
It is demonstrated that the tensile fork is perfectly shaped to prevent any hazardous localised stress peaks, or notch stresses, which might cause the tree to fail.

Trees develop a root system that can sustain the current crown and supply leaves with water in an appropriate manner. The crown, on the other hand, is large enough to support both the organism and the rest of it, including the roots and collaborating soil creatures. The trunk's dimensions and form match the requirement to both steadily sustain the crown and compete for light. Like any other portion of the tree, it strengthens itself in vulnerable places. The density, strength, and structure of the wood in the trunk and branches vary. Where the most strain is placed, at the bases of the trunk and branches, is where it shows the most strength. Furthermore, these regions are reinforced by dense growth, as seen by the thickness of the branch bases and buttresses. The bottle-shaped base of a rotting trunk or the "ears" formed by a cracked fork are examples of how trees strengthen additional wood growth zones that have been damaged by mechanical damage or fungal decay.

The tree tried to fix a fractured fork by adding extra wood on both sides of included bark – but it failed.

Wood is anisotropic, meaning that its properties differ in various directions.
The apex of the tree controls the activity of branch meristems in apical dominance, also known as apical control. Auxin, a hormone released by the main leader's apical meristem, causes branches to grow horizontally and keeps them from fighting with the main stem for light. Dormant buds are likewise inhibited by auxins. Damage to the apex results in the loss of apical control, the vertical growth of lateral branches, and the activation of latent buds.



The loss of apical dominance was humorously illustrated by Claus Mattheck, one of tree assessment's classical authors.
The apex rules over branches like a king over vassals. However, as soon as his rule is weakened, the lesser lords raise their heads and take over control of the tree.

Dissipation of the hormonal control can result from damage to the apical bud by wind, animals, diseases, or its decline due to environmental stress. Often, it is water stress induced by drought, lowering of the groundwater table, flooding, or damage to roots through excavations or soil compaction.
Impairment of apical dominance also characterises ancient trees.

Here is an example of the loss of apical dominance: particular branches assume vertical growth and begin to compete for light as if they were separate trees.

Where there is continuous or recurring tension, reaction wood forms. Its job is to keep the strain going and let the tree to follow its inherited pattern while adapting to its surroundings, especially light. Conifers often have compression wood, whereas broad-leaved trees exclusively have tension wood.

On the squashed side of a trunk or branch, compression wood forms. Compared to typical wood, these cell walls have a higher lignin content and a lower cellulose content. The arrangement of microfibrils, or bundles of cellulose chains, is about 45 degrees from the cell axis; the broader the angle, the greater the strain. Because compression wood can swell, it can regulate the way a trunk or branch grows.

On the stretched side of a branch or trunk, tension wood forms. Microfibrils are oriented nearly along the longitudinal axis of the cell, and the cellulose content in cell walls is higher than in ordinary wood. Depending on the situation, the tension wood's ability to shrink allows it to change its growth direction.

Within a fork, axillary wood is generated. Grain patterns that intricately connect offer a junction exceptional strength. Axe struck from above: try splitting a fork. If the presence of cork prevents the correct development of axillary wood, the tree will try to strengthen the fork by growing more wood on the exterior (called "ears," as mentioned above). If this attempt is unsuccessful, the junction gets weaker.

Axillary wood

Axillary wood forms when the independently moving parts of a fork experience strain, just like other changes in wood structure. A ridge in the bark is one of its outward signs. Nevertheless, the fork will not be strengthened, and the likelihood of bark inclusion will rise if the movement is prevented, for example, by branch graft above (natural bracing in the crown). Therefore, it is not advised to remove the natural bracing because doing so could weaken the fork below and increase the chance of failure.

Bark ridge in the fork indicates that axillary tissue is properly formed, and the strength of the junction is appropriate

A fork with limited movement of leaders, due to natural bracing. Bark inclusion has formed and in the lower part of the fork extra wood tissue is laid to reinforce it. The picture on the right presents the other side of the fork.

<u>Hazard beam cracks</u>
When wood growing in tension and compression collide and move in separate directions along the neutral plane in the centre of the branch, it might result in hazardous beam splits. The branch begins to split in two as a fracture develops at the centre, where the two forces converge due to shear stress.

6.3. Identify what is meant by the term thigmomorphogenesis

The prefixes "thigmo-" denotes touch, "-morpho-" denotes appearance, and "-genesis" denotes origin.

One adaptation characteristic linked to enhanced fitness in a variety of environmental contexts is a plant's capacity to perceive and react to mechanical inputs. Natural mechanical stimulation can come from the wind, rain, nearby plants, or predatory animals. This mechanical stimulation can cause a variety of morphogenic reactions, which are grouped together under the name thigmomorphogenesis.

The aboveground portions of plants are the ones where mechanical stimulation has been studied the most. Jaffe (1973) first used the term "thigmomorphogenesis" to refer to the process by which mechanical forces affect plant organogenesis. According to Jaffe wind action causes developmental changes in trees that result in a more compact form with increased stem taper, shorter branches, and smaller leaves.
Plants can react to mechanical perturbation in two ways: primary and secondary effects. The mechanical movement of the tree that causes the stem to be displaced and eventually fail is one of the immediate repercussions. roots, branching, and leafy flapping. Secondary stresses include variations in the air conditions surrounding leaves and the gravitational pull of wind-induced lean. The stressors that come with higher wind speeds can cause a wide range of physiological reactions. The leaves gather on the lee side when foliage is blown away from the direction of the predominant wind. Due to this clustering, net photosynthesis may decrease as effective photosynthetic area decreases. Young foliage may be mechanically abraded by rubbing leaves against one another, and at greater wind speeds, leaves may become twisted and torn, leading to water stress. Additionally, wind can enhance the absorption of airborne contaminants such as SO2. It is well known that wind decreases leaf area. Originally, it was believed that a decrease in leaf size resulted from dehydration brought on by increased transpiration. However, research has revealed that wind has no direct impact on stomata conductance. Plants react similarly to wind, shaking, flexing (two-directional movement), brushing, and rubbing. As one of the most reliable plant reactions to mechanical disturbance, reduced foliar enlargement is regarded as a direct thigmomorphogenetic response. A tree blown by the wind will sway back and forth, and the displacement of the stem is determined by the wind velocity. After the wind has stopped, if the wind loading forces have not exceeded the tree's strength, the tree will return to its vertical position. However, system failure, such as a wind snap or windthrow, may happen if the stem fails to return to its vertical position as a result of sustained wind exposure. The tree needs to be given as much time as possible to return to its upright position to respond. To elicit a reaction, the tree needs to be stressed for a specific amount of time, referred to as the "presentation time." Gymnosperm stems will respond to wind by forming irregular woody growth, or "flexure" wood, on the lee side of the tree if they are allowed to stand upright again after a period of swaying. An increase in tracheid count causes flexure in wood by changing the internal compressional strain. Additionally, flexure wood has been seen at the nodes and bases of branches on flexed trees. On the other hand, "reaction" wood also forms on the leeward side of wind-stressed gymnosperms if a tree experiences protracted displacement. Compared to regular wood, reaction wood has a different kind of cell. The reddish-coloured cells have spherical shapes, strongly lignified cell walls, and intercellular gaps. Reaction wood is tough, which has been known to cause chainsaw blades to jam. To maximise the effective photosynthetic leaf area as much as possible, the displaced tree can return to its upright position through the creation of irregular growth and response wood. Although the exact mechanisms of perception that can cause these modifications in woody development are

unknown, experts from several domains have offered some insights into the signals responsible for stimulating secondary growth.

This conifer, significantly deformed by the strong winds associated with open and exposed surrounds, is classed as a 'flag tree'

Resources

https://core.ac.uk/download/pdf/14343231.pdf
"C:\Users\skust\Desktop\BTP DONE\Module 6\Basic Understandings of Structure & Load.pdf"
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