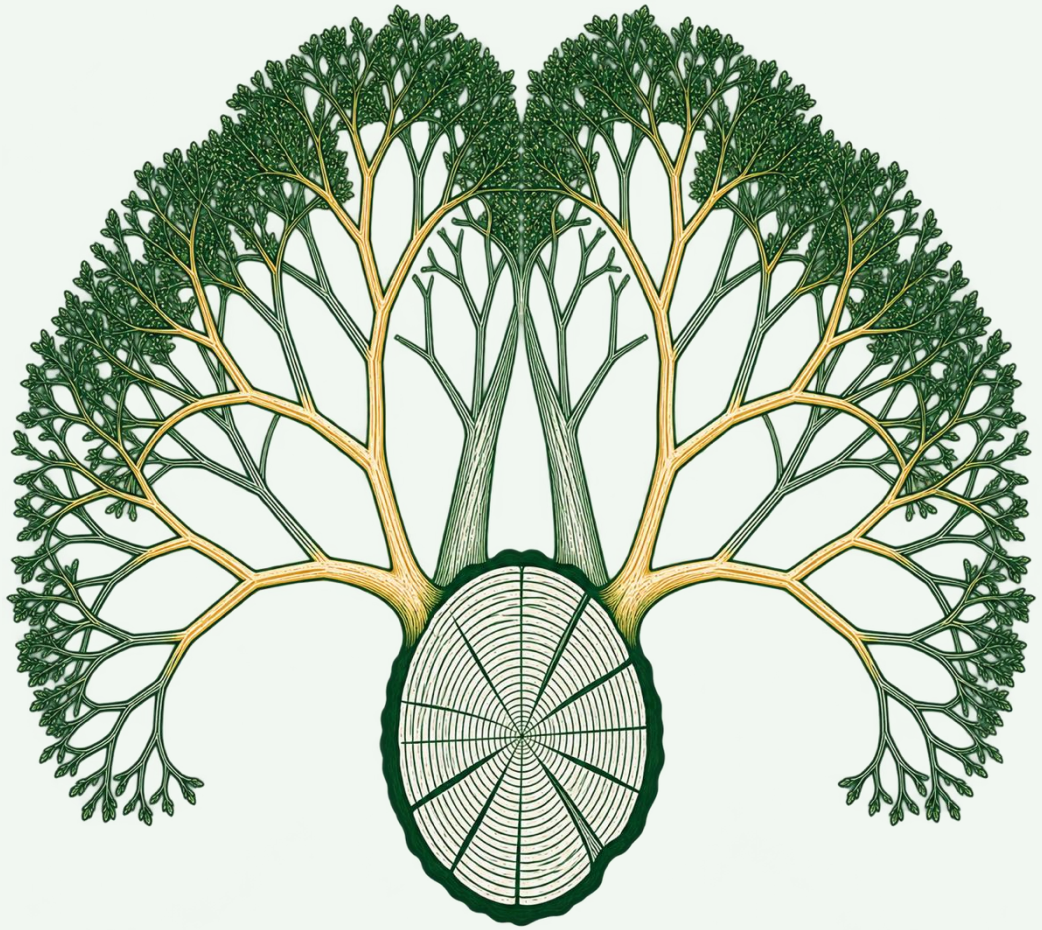
The Architecture of a Forest Stand

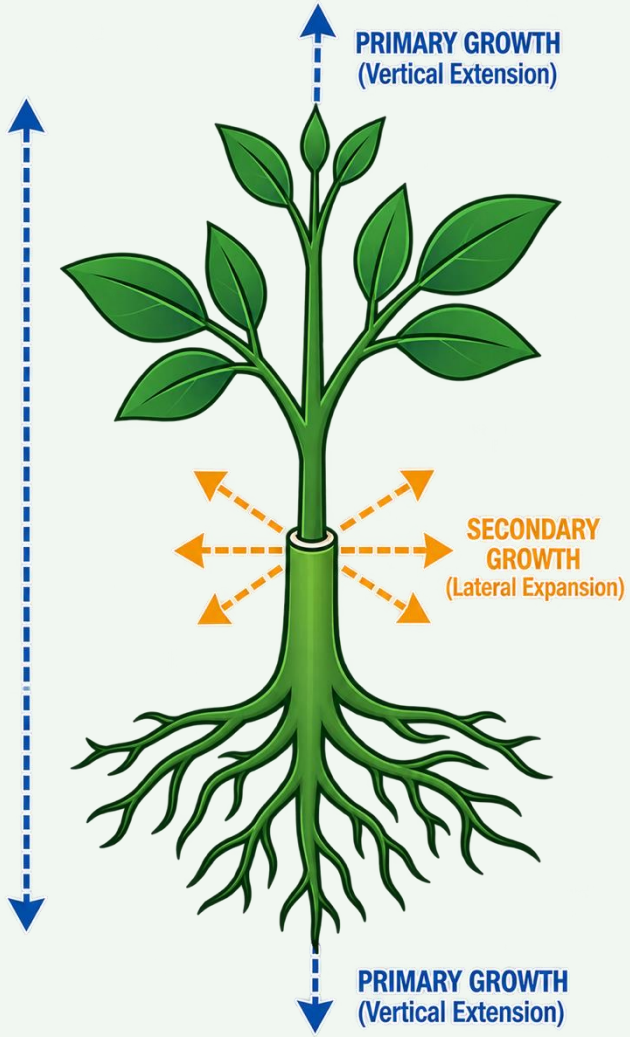
How tree growth shapes forest structure, competition and self-thinning.

In this topic, we connect individual tree growth with changes across the whole forest.



Trees grow in two main directions

Height growth and diameter growth work together.



1. Primary growth — Height

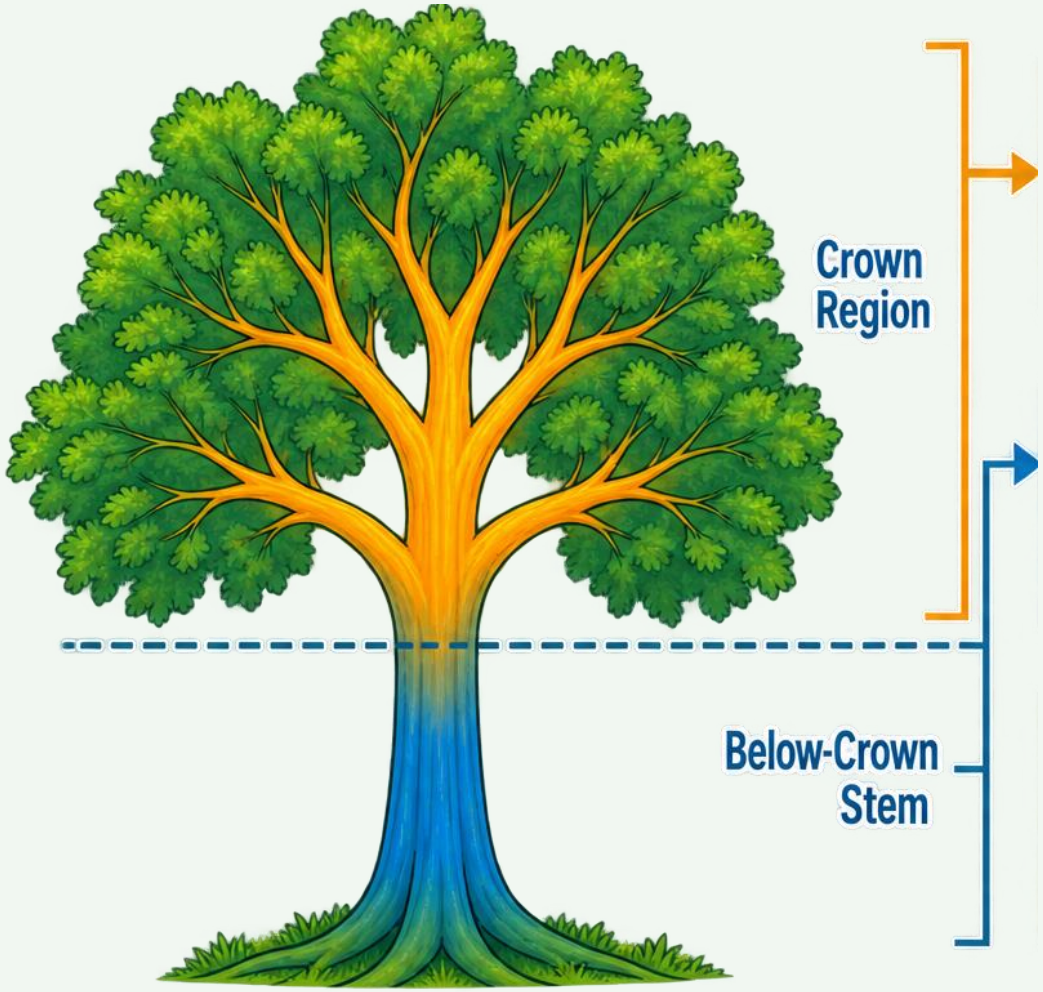
- Driven by growing tips at the shoot and root apical meristems.
- Helps trees reach sunlight & water.
- Shapes future canopy position.
- Vertical expansion

2. Secondary growth — Diameter

- Adds new wood around the stem.
- Strengthens the tree. Builds secondary xylem (wood) for structural thickness.
- Increases biomass and support (structural stability).
- Lateral expansion

Where does diameter growth stay active?

The crown and leaf supply influence where a tree invests in growth.



Inside the crown (Active)

New shoots (primary height growth) and leaves need water, nutrients and conducting tissue (secondary height growth). Diameter growth remains active.

Below the crown (Inactive)

Lower stem/trunk diameter growth at breast height may slow or drop to near zero when the tree is shaded or stressed.

Key idea

Trees prioritise living foliage and the tissues that support it to survive

Canopy closure increases competition

As crowns touch, light and space become limited.

Step 1: Free growth

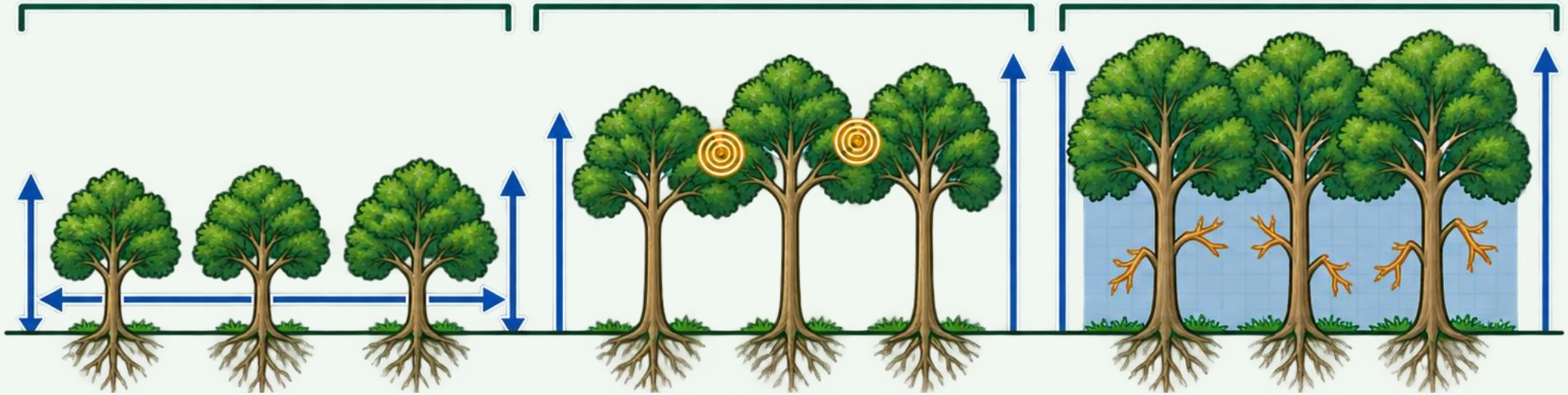
Tree saplings expand upward and sideways while light is available.

Step 2: Crown contact

Lateral branches meet. Horizontal space becomes limited.

Step 3: Canopy closure

Upper leaves capture light, & the understorey becomes heavily shaded. Lower branches lose light and may die (self-pruning).



Canopy closure forces the forest from the Stand Initiation phase into the Stem Exclusion phase, initiating a vertical race for survival.

Why does the crown base rise?

Lower branches die as the canopy becomes crowded.

Self-Pruning

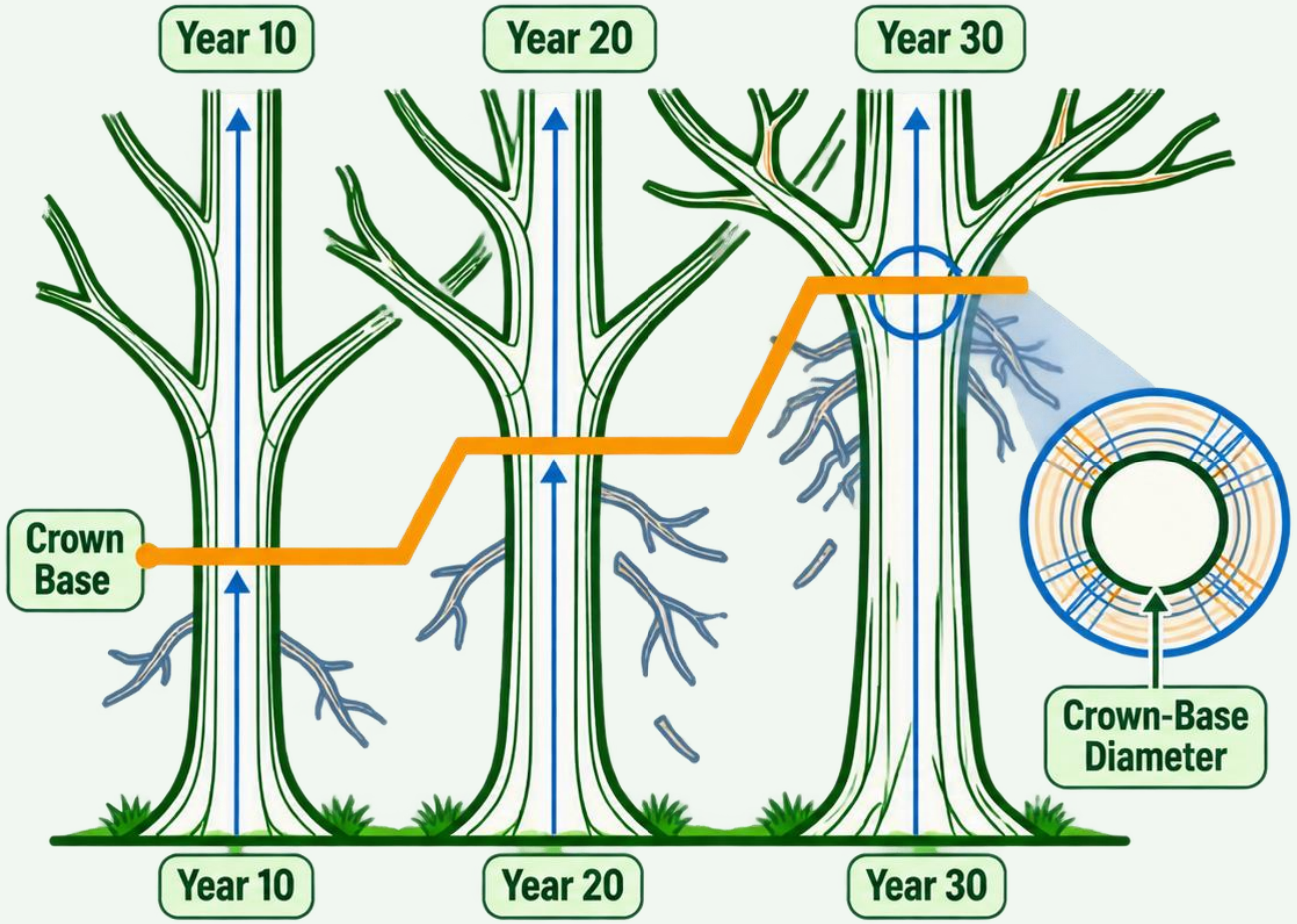
Shaded lower branches die and fall away. This can create a cleaner, knot-free lower stem.

Pipe Model Theory

The tree maintains conducting tissue to support its living leaves. More foliage (mass of leaves) needs more support (trunk diameter).

Balance

Tree height growth rates pushes the crown upward, while self-pruning removes lower branches (killing lower crown).



Four stages of forest stand development

Forest structure changes as trees grow, compete and die.

1. Stand initiation

New trees establish. Canopy closure begins.

2. Stem exclusion

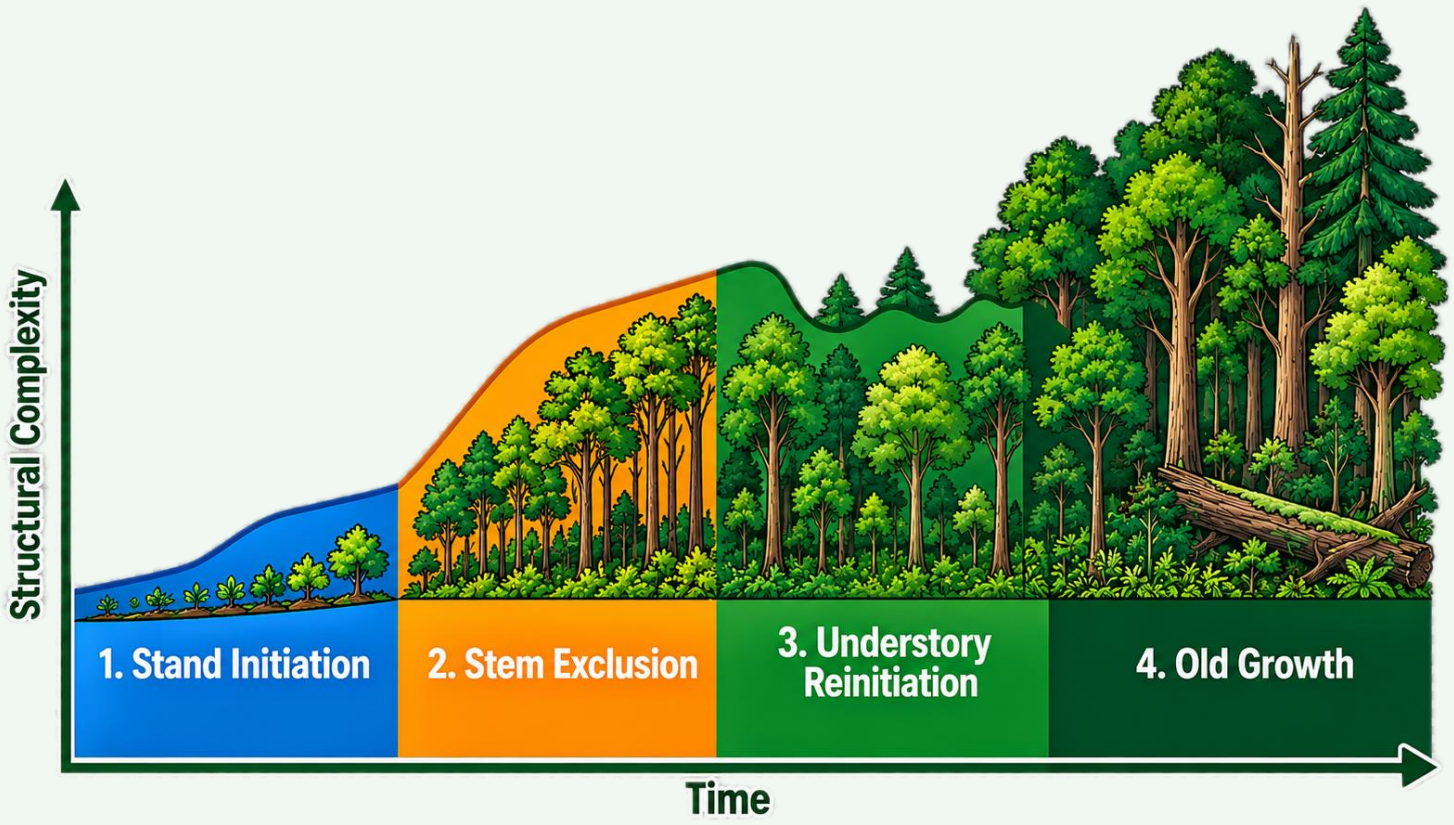
Competition is intense. Some trees die. No new individuals appear.

3. Understory reinitiation

Gaps allow understory plants and new trees to return.

4. Old growth

The stand develops varied layers, canopy strata, gaps and massive woody debris.

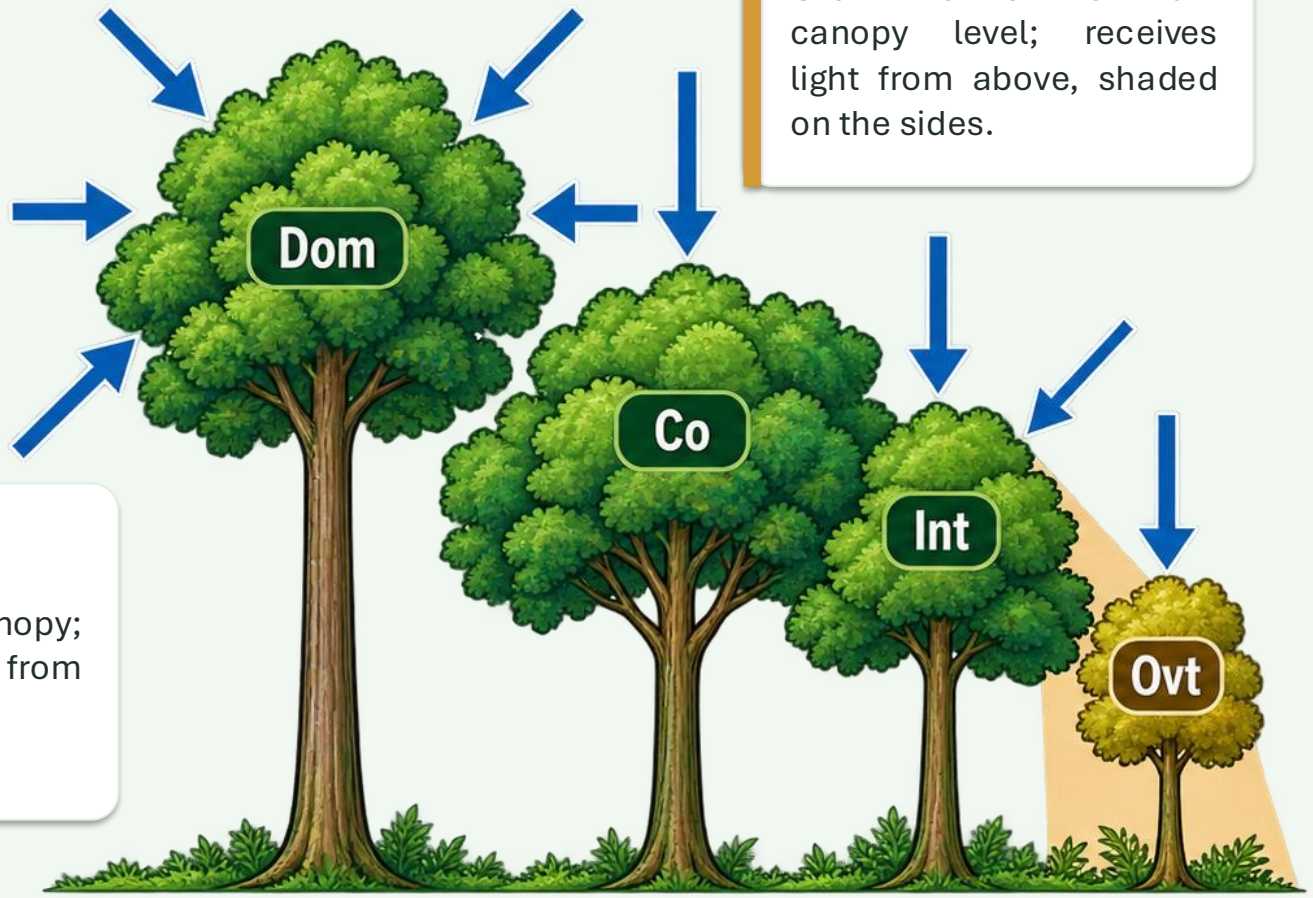


Competition creates different crown classes

Not all trees receive the same amount of light.

Codominant (Co)

Crown forms the main canopy level; receives light from above, shaded on the sides.



Intermediate (Int)

Below the main canopy; receives little direct light from above, heavily shaded on sides.

Dominant (Dom)

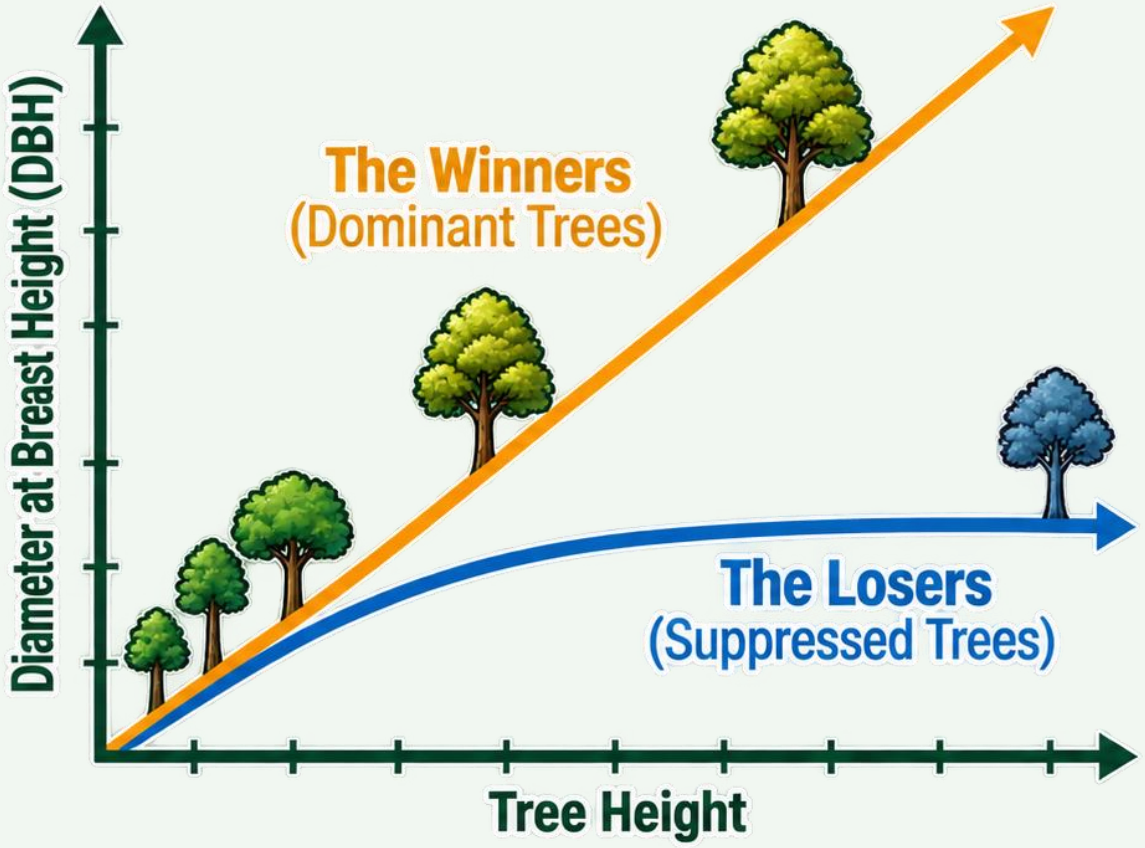
Above the main canopy; receives full light from above and sides.

Suppressed/Overtopped (Ovt)

Completely shaded; growth slows and mortality risk rises.

Winners and losers grow differently

Light access affects both height and diameter growth.



Dominant trees — the winners

Height and DBH usually continue to increase as the crown expands its canopy and structural support.

Suppressed trees — the losers

Trees may still grow slowly in height to seek light or turn over leaves, but DBH growth can approach zero.

The stand-level effect over time, suppressed trees may die, raising the average size (height and DBH) of surviving trees.

Self-thinning: trees compete for limited space

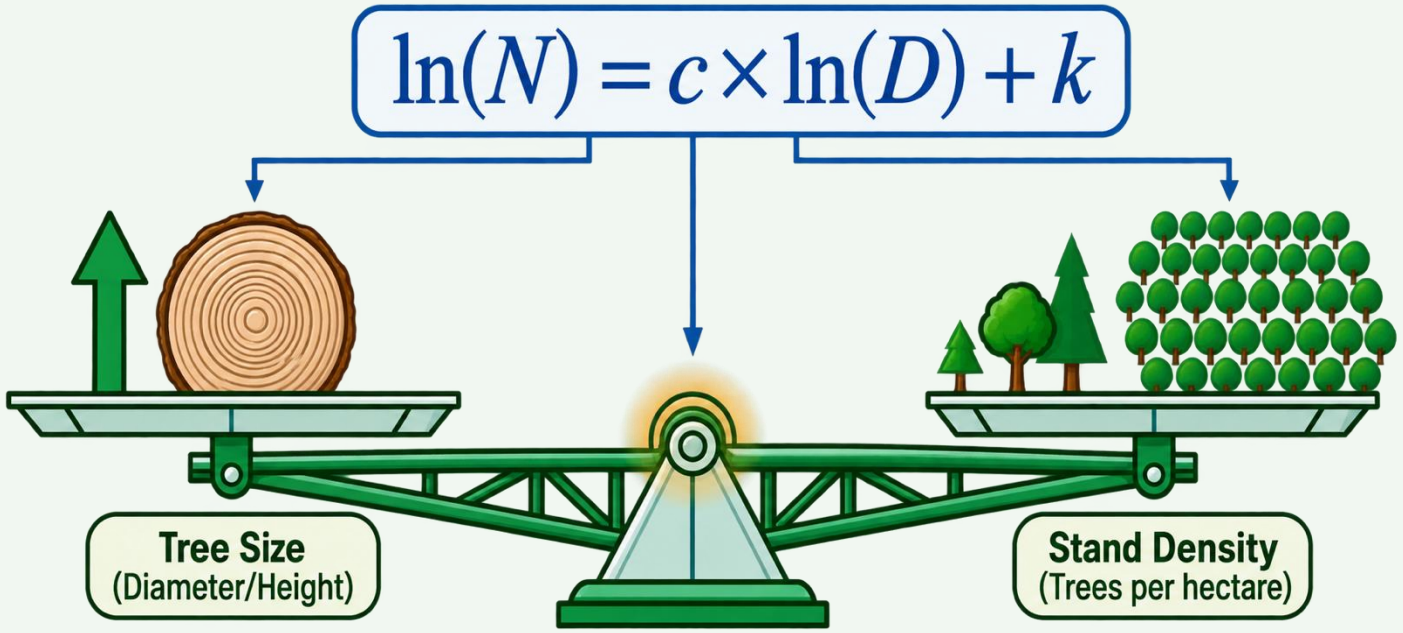
As trees become larger, a stand cannot hold the same number of trees.

Maximum density

A site has a practical limit to how many trees it can support at a given site size (carrying capacity).

The trade-off

When surviving trees grow larger, some individuals must die or be removed. The forest's capacity accommodate with stem decreases.



Reineke's idea

Tree size and stand density are mathematically linked.

- Modeled with a universal slope (c) of -1.605, showing that density (N) and mean diameter (D) are inextricably mathematically linked.

Tracking stand density with basal area and height

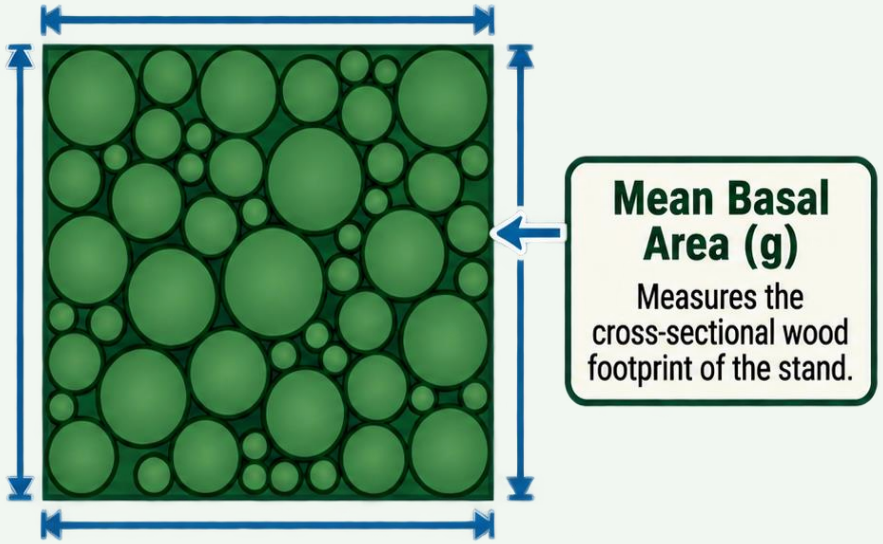
These measurements help describe how a forest uses space.

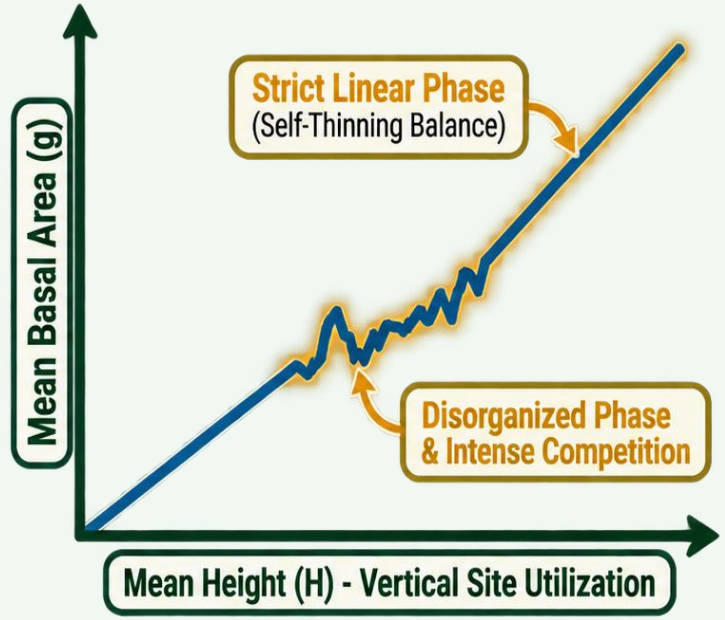
Basal area

The cross-sectional area of tree stems. It represents the stand's wood footprint.

Mean height

Shows how trees use vertical space and reach the canopy.





Why it matters

Stable growth phases may show a clear relationship between basal area and height.

- **The Discovery:** 18 years of plantation data reveal that forests possess self-regulatory mechanisms maintaining a strict linear balance between Basal Area and Height during specific, stable phases of development.

Three stages of the self-thinning process

The relationship between basal area, height and density changes over time.

Stage I — Canopy closure

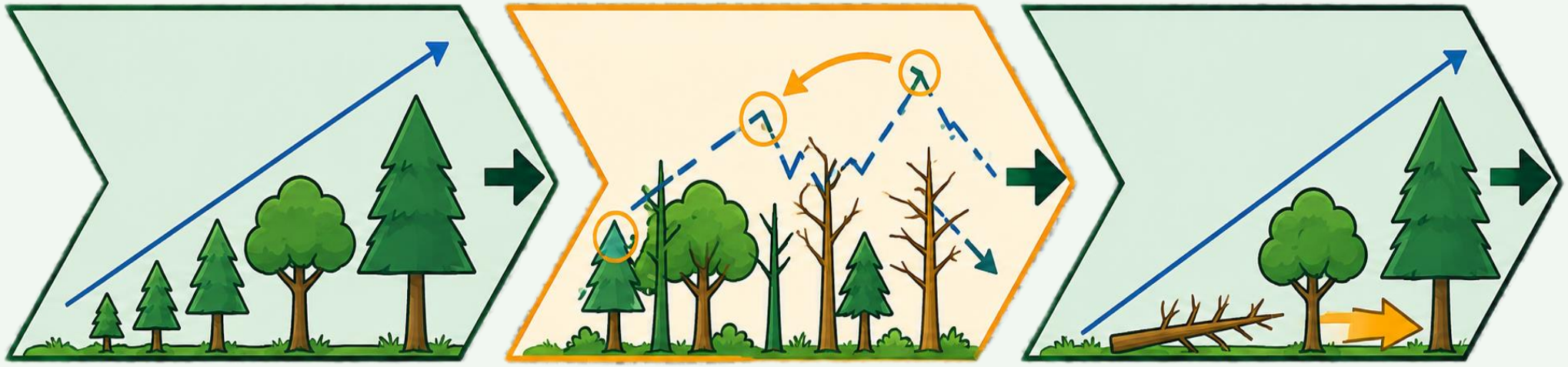
Tree number stays fairly stable. Basal area and height show a clear linear relationship.

Stage II — Early self-thinning

Competition increases, linear relationship breaks down. Density begins to decline irregularly.

Stage III — Late self-thinning

Maximum density is reached, strong relationship. Regular density-dependent mortality allows survivors to grow.



Self-thinning is a natural process of adjusting tree numbers as stand size increases.

Constructing a maximum density line

Use data to identify the stage where density becomes self-regulating.

The challenge

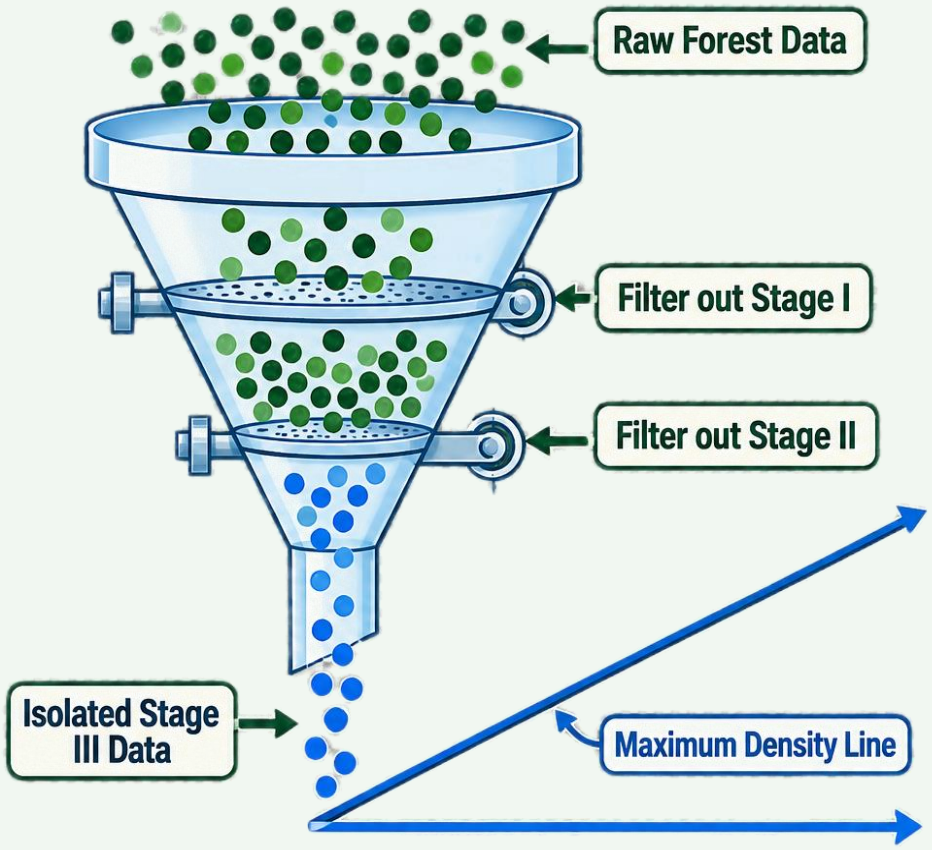
Traditional approaches may use fixed thresholds, such as a selected mortality percentage.

The approach

Examine the basal area–height relationship. A strong linear pattern can indicate late self-thinning.

Application

Use the Stage III data to build site- or species-specific density models.



The Problem

Traditional methods for finding the maximum density line rely on arbitrary thresholds e.g., waiting for 15% mortality or specific relative densities).

Solution

Use the Basal Area/Height relationship. When the tight linear relationship reappears in the data, the stand has officially entered Stage III.

Application (C3)

Foresters can objectively extract tree density and mean diameter data only from Stage III to build highly accurate, species-specific carrying capacity models.

Synthesis: from growing cells to forest density

Small changes inside trees can shape the whole stand.

1. Biological drive

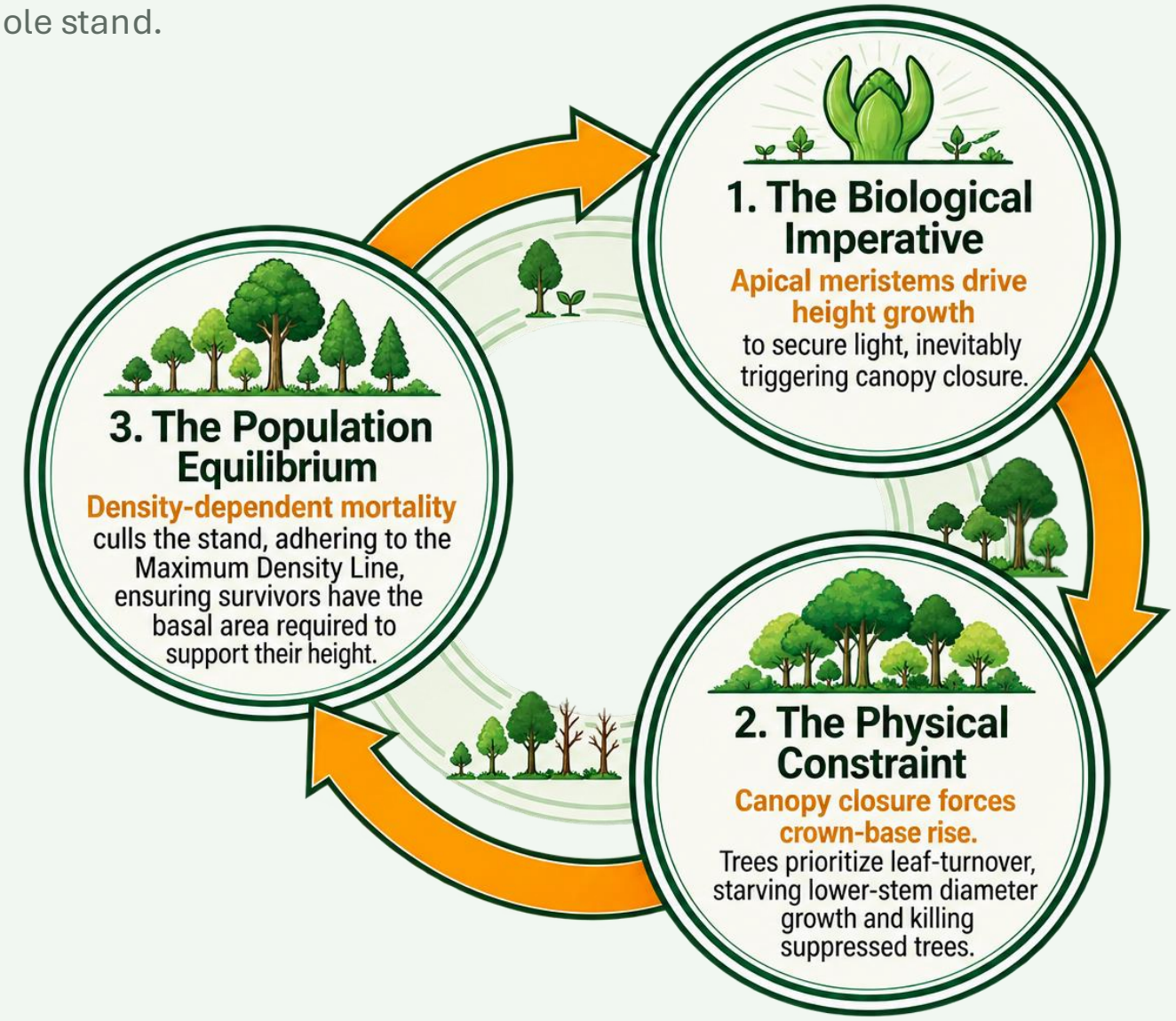
Growing tips help trees reach light and establish canopy position.

2. Physical constraint

Canopy closure increases competition and pushes the crown base upward.

3. Population response

Density-dependent mortality leaves fewer trees with more space to grow.



Quick reflection

Check your understanding before moving to the next topic.

1. Explain

What is the difference between primary growth and secondary growth?

2. Apply

Why does canopy closure increase competition among trees?

3. Connect

How does self-thinning affect stand density and average tree size?

KEY TAKEAWAY

Forest structure is shaped by:

- **Tree growth**
- **Light competition**
- **Crown development**
- **Self-thinning**

Grow to yield and manage with evidence.