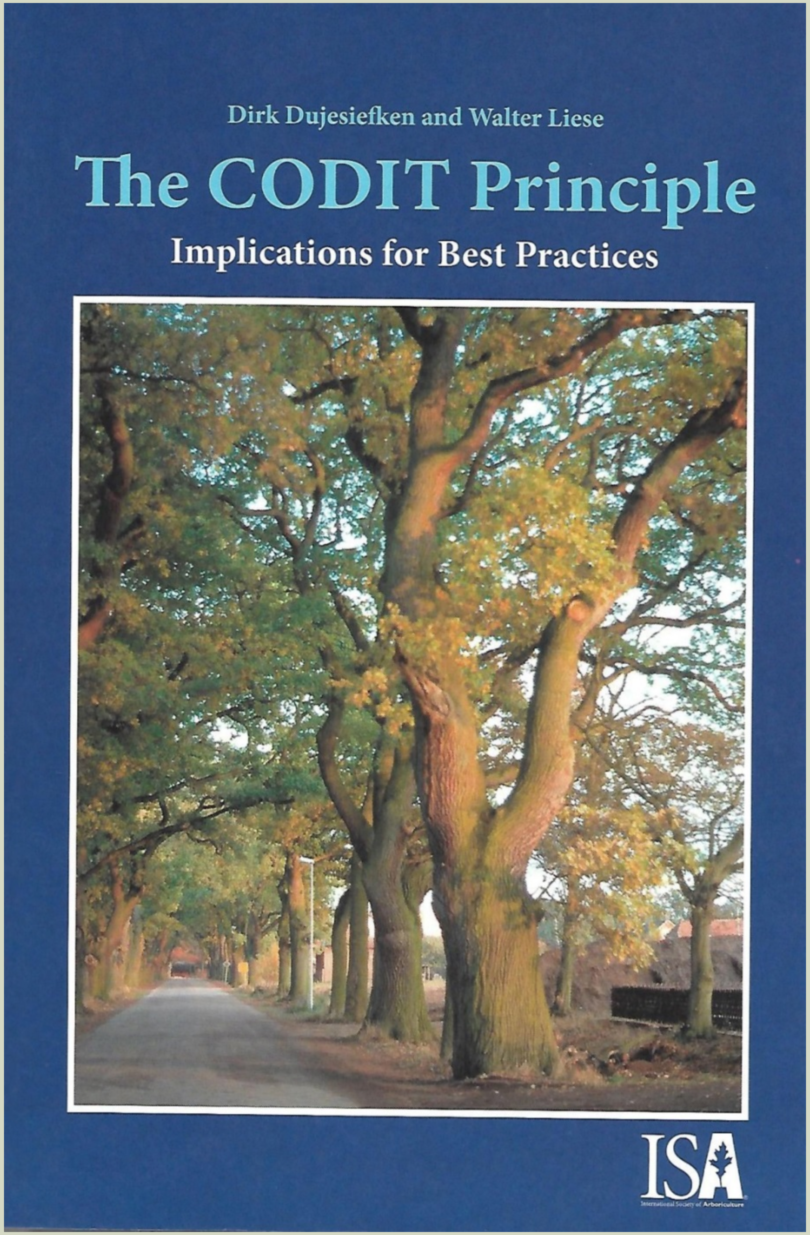


PHOTO CREDIT ;

Unless otherwise noted, images were taken from The CODIT principle

ALEX SHIGO AND CODIT

Photo Credit: Modern Arboriculture

HOW TREES HANDLE DAMAGE: DAMAGE PREVENTION STRATEGIES

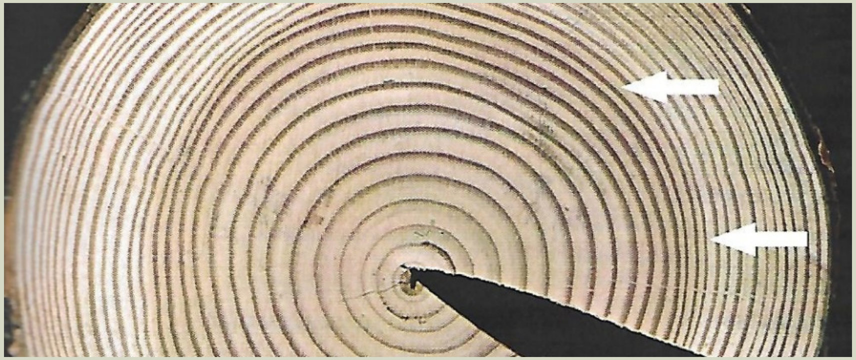
- Changes to the directly affected tissue
  - For example: compartmentalization
- Forming new tissues or entire organs
  - Secondary shoots
  - Adventitious roots

DAMAGE PREVENTION STRATEGIES

- Passive Defense
- Active Defense

DAMAGE PREVENTION STRATEGIES

- Passive Defense
  - A healthy plant already has certain protective structures or substances
    - For example: periderm and ryhtoderm
  - Some plants form heartwood as they age. Heartwood is filled with substances such as toxic phenols that protect against decay



PASSIVE DEFENSE
TRUE HEARTWOOD VS. FALSE HEARTWOOD

- Trees that form true heartwood:
  - Douglas fir
  - Yew
  - Oak
  - Pine
  - Cherry
  - Larch
  - Walnut
  - Locust
  - Elm

PASSIVE DEFENSE
TRUE HEARTWOOD VS. FALSE HEARTWOOD

- Trees that form false heartwood:
  - Maple
  - Birch
  - Beech
  - Ash
  - Linden
  - Poplar
  - Horsechestnut
  - Willow

PASSIVE DEFENSE
TRUE HEARTWOOD VS. FALSE HEARTWOOD

- In practice, any dark colored area within the trunk is called heartwood.

However

- False heartwood differs considerably from the colored heartwood of heartwood forming species in both origin and properties
- False heartwood does little to increase wood’s resistance to harmful organisms

ACTIVE DEFENSE

- Triggered by damage
- Aims to protect inner bark, cambium, and the water conducting system in the sapwood
- Only living cells can mount active defense
- Examples of active defense
  - Transport growth substances
  - Form resins
  - Synthesis of phenolic substances

WOUND PREVENTION STRATEGIES

- Only living cells (phloem, cambium, sapwood) can mount active defense
  - Inner bark converts cells to form the wound periderm as new boundary tissue
  - Cambium forms completely new tissue (callus and the barrier zone) near the wound
  - In wood, formation of new cells in not possible
  - Instead, the reaction is to seal off damaged tissue from healthy tissue by sealing off water-conducting elements and forming embedded substances

THE WOUND REACTIONS OF TREES
STRATEGIES OF THE BARK

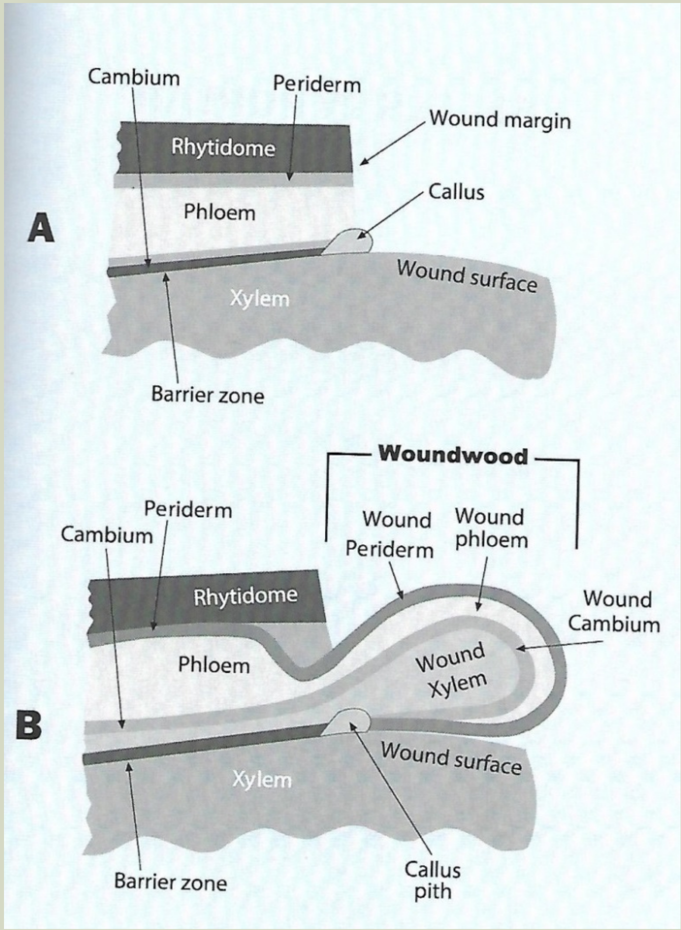
- For minor injuries where the injury is confined to the inner bark and where the cambium remains intact
  - Parenchyma cells die off near the injury
  - Farther away, substances such as suberin are deposited on cell walls
  - Tree is able to minimize discoloration in the phloem (inner bark) compared to the damage in the wood

THE WOUND REACTIONS OF TREES
STRATEGIES OF THE CAMBIUM

- Injuries that extend into the wood, for example: pruning cuts, drill holes, or severed roots also affect the cambium
- **Strategy 1: Callus and Woodwood**
  - First a callus develops at the wound margin followed by the formation of woundwood
- The Tree Begins the process of covering (sealing the wound). This process may take years.

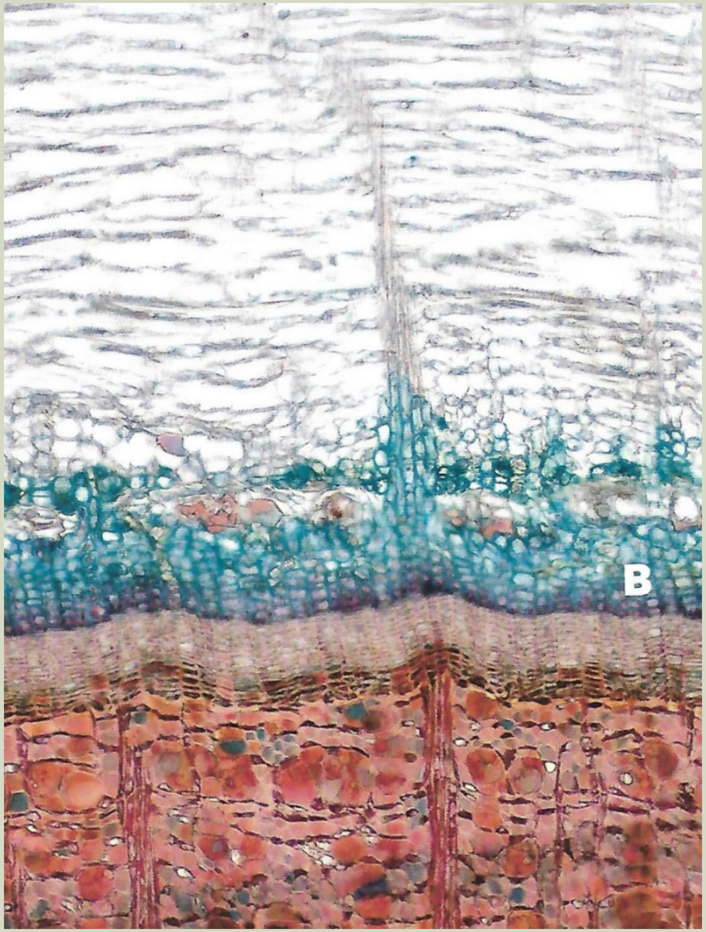
THE WOUND REACTIONS OF TREES
STRATEGIES OF THE CAMBIUM

- The Strategies of the Cambium:
- 1. Callus and Woundwood Formation



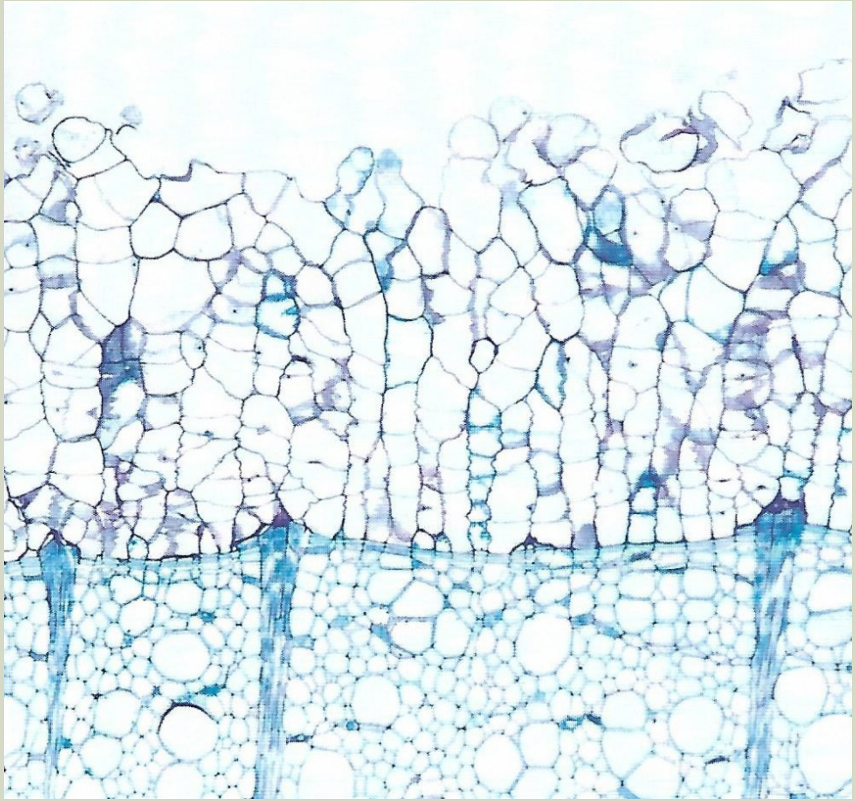
THE WOUND REACTIONS OF TREES
STRATEGIES OF THE CAMBIUM

- **Strategy 2 Barrier Zone**
- Near to the wound, the cambium forms a new layer of living cells, the barrier zone, capable of reacting to spreading microorganisms
- Barrier Zone separates new wood from all wood that existed at the time of the injury



THE WOUND REACTIONS OF TREES
STRATEGIES OF THE CAMBIUM

- **Strategy 3: Surface Callus**
- A "special" form of wound reaction
- If cells capable of division are left on the wound surface (collision damage) they can form a layer of callus on the wound surface

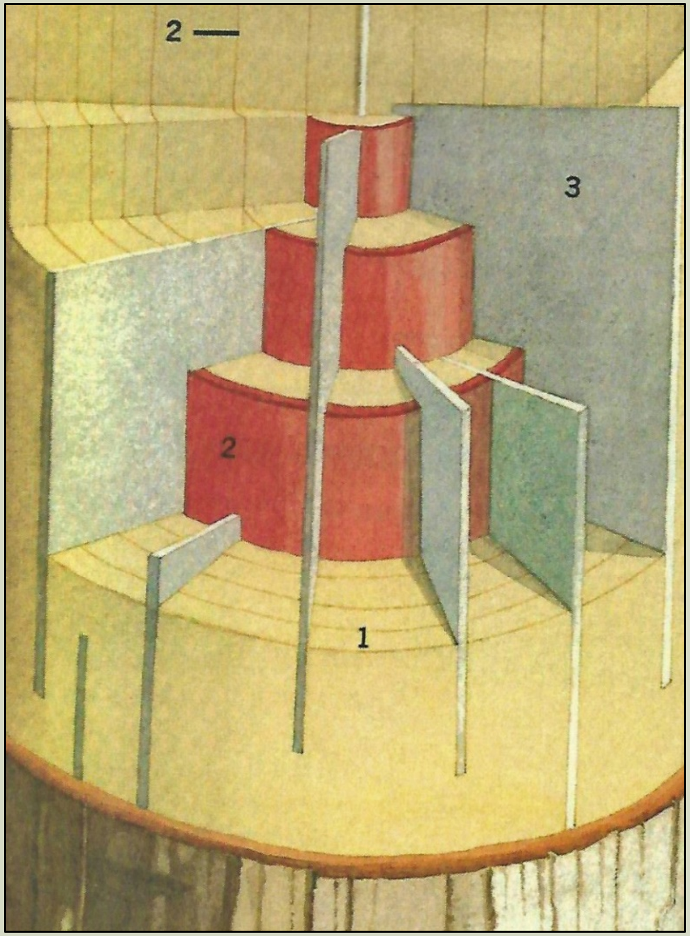


THE WOUND REACTIONS OF TREES
STRATEGIES OF THE WOOD

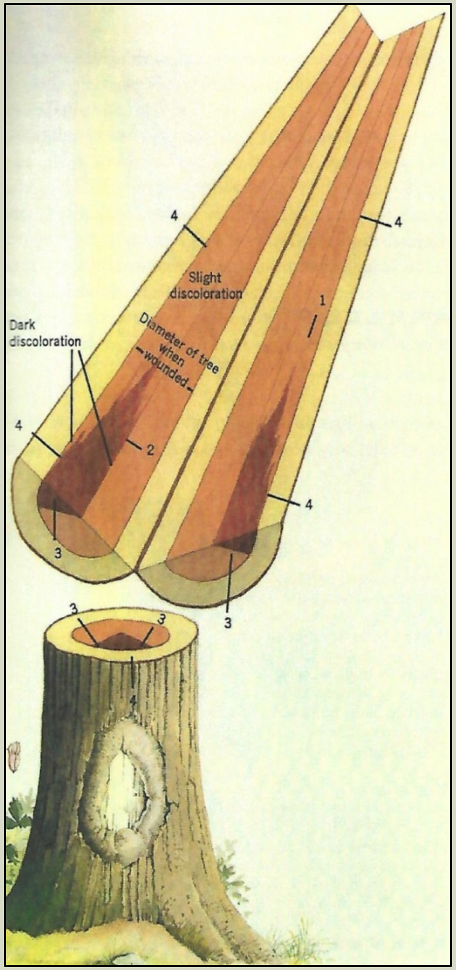
- Summarized as “Compartmentalization”
  - Air enters the wound and spreads in water-conducting tissue
  - Vessels no longer function to transport water; water conducting tissue is rapidly closed
  - Parenchyma cells die off
  - Dead and nonfunctional tissue becomes discolored
  - Dead tissue becomes colonized by harmful organisms

CODIT FROM MODEL TO PRINCIPLE

- Shigo and Marx developed the CODIT model (Compartmentalization Of Decay In Trees) in 1977 and over time it revolutionized the way trees were pruned and the way wounds to trees were treated



THE CODIT MODEL



4 is the Boundary Layer

THE CODIT PRINCIPAL

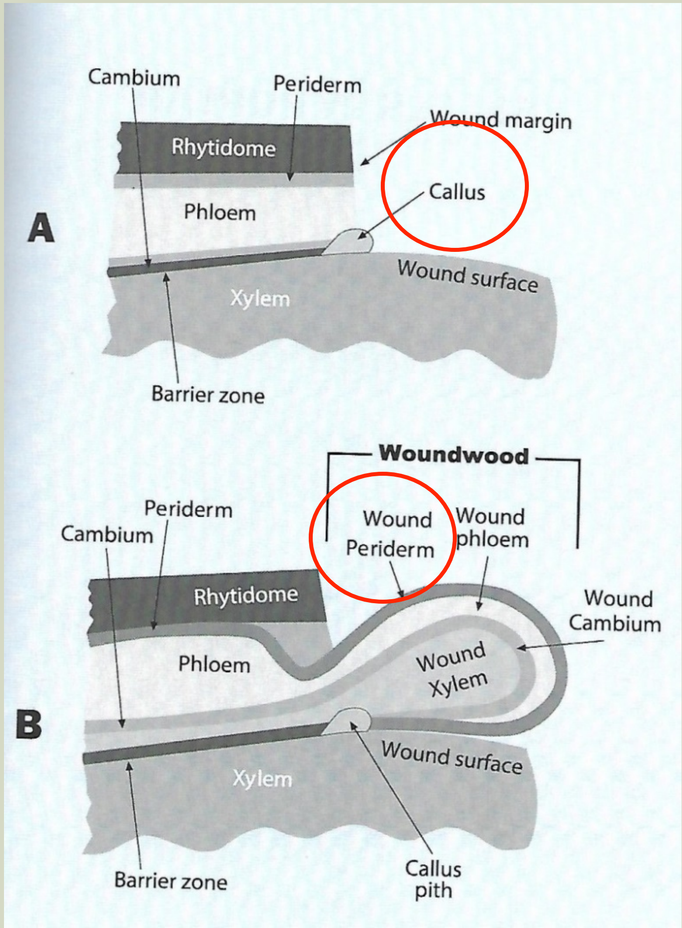
- A more comprehensive view describing compartmentalization of damage in trees as well as the formation of woundwood in **chronological** sequence
- The principal is always recognizable:
  - Compartmentalization and encapsulation of damage take place in sequential phases

PHASES OF A TREE'S REACTION TO INJURY

- 1 Entry of Air
- 2 Entry of harmful organisms (e.g. wood destroying fungi)
- 3 Spread of harmful organisms
- 4 Encapsulation of harmful organisms

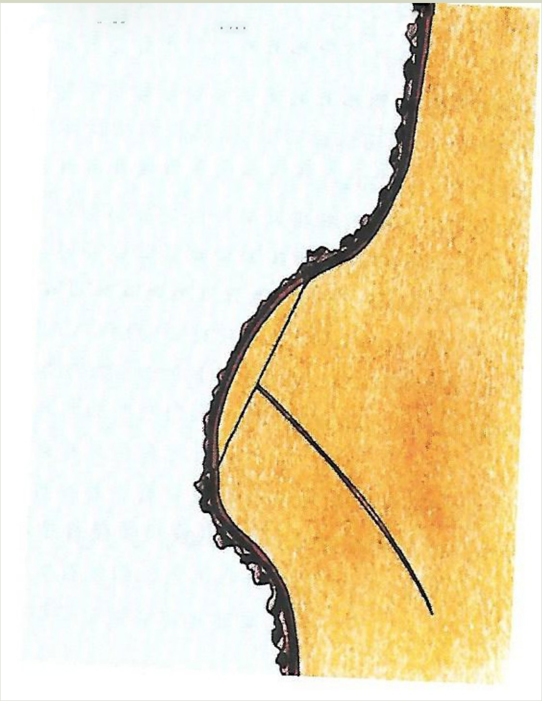
PHASES OF A TREE'S REACTION TO INJURY

- **Phase 1: Entry of Air**
  - As a consequence: nearby tissues die
  - As a reaction:
    - Bark forms a wound periderm
    - Cambium forms callus at the wound margin and a barrier zone nearby
    - The wood forms a boundary layer for compartmentalization



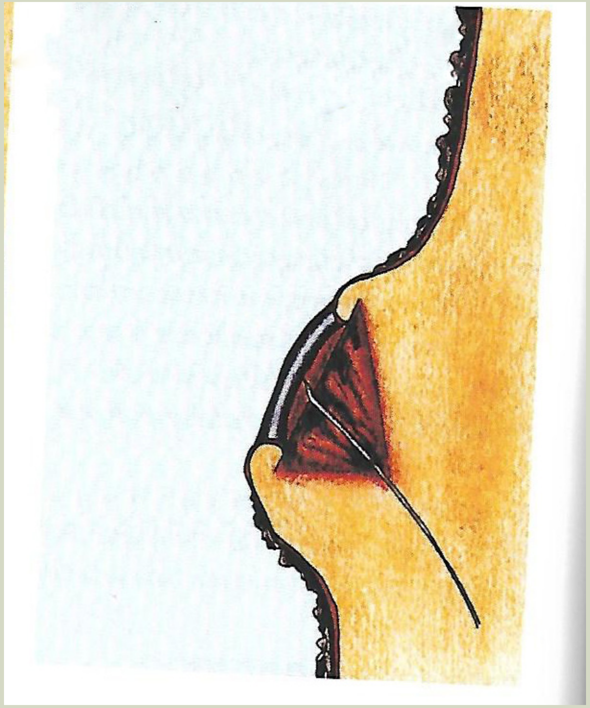
PHASES OF A TREE'S REACTION TO INJURY

- Entry of Air
  - (Another view)



PHASES OF A TREE'S REACTION TO INJURY

- **Phase 2: Entry of harmful organisms**
  - Into the bark up to the wound periderm
  - Into the wood up to the boundary layer
  - A woundwood is formed from the original callus (beginning the closing of the wound)

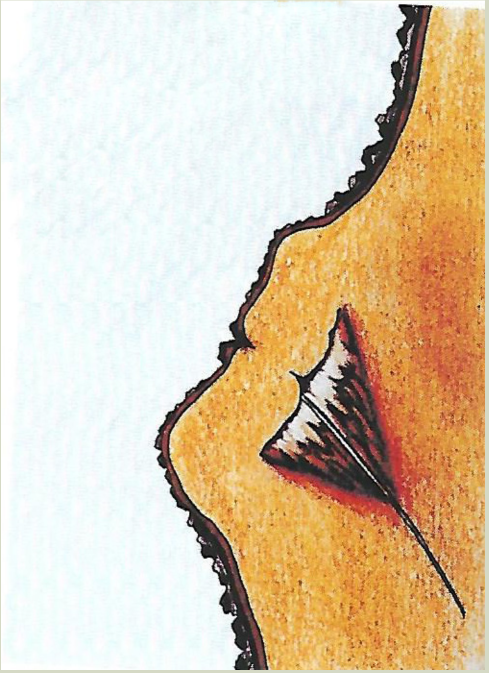


PHASES OF A TREE'S REACTION TO INJURY

- **Phase 3: Spread of harmful organisms**
  - The boundary layer can be breached, especially in older woody tissue (more likely with large wounds)
  - As a reaction:
    - The wood then forms a new boundary layer
    - If harmful organisms reach the barrier zone, more accessory substances (preservatives) are formed in the wood as a means of defense
    - Simultaneously, woundwood continues to grow to cover the wound

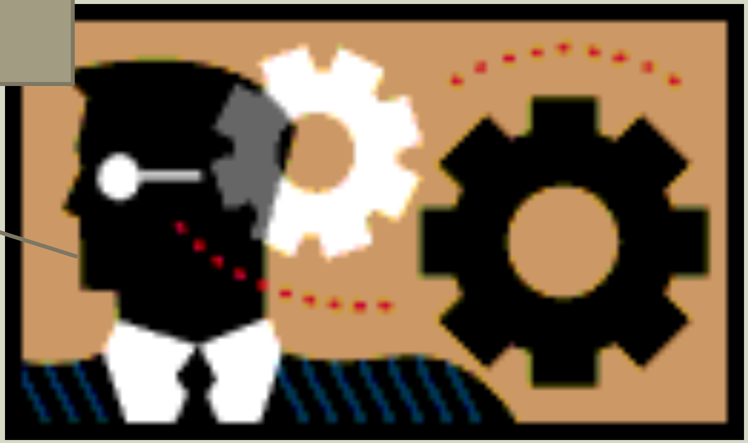
PHASES OF A TREE'S REACTION TO INJURY

- **Phase 4: Encapsulation of harmful organisms**
  - Woundwood closes the wound and encapsulates the damage, causing the wood-decay fungi to die off. The harmful organism cannot expand further into the tree.



CONSIDERATIONS AND IMPLICATIONS FOR TREE CARE

Something to think about



FACTORS THAT AFFECT COMPARTMENTALIZATION

- Tree species
- Wound type
- Time of year (seasonality) of injury
- Wound treatment
- Wound size, tree age, and tree vitality

TREE SPECIES AND COMPARTMENTALIZATION

- Weak Compartmentalizers
  - Ash, birch, horsechestnut, poplar, willow, fruit trees, spruce, hemlock.
  - Of these, birch, poplar, willow, and fruit trees respond most weakly while ash may compartmentalize more strongly by comparison

Horsechestnut: Note spread of discoloration frpm a pruning wound into the trunk

TREE SPECIES AND COMPARTMENTALIZATION

- Strong Compartmentalizers
  - Beech, elm, hawthorn, honey locust, hornbeam, sycamore, pine, and yew

TREE SPECIES AND COMPARTMENTALIZATION

- Genera which contain both weak and strong compartmentalizers
  - maple
  - Linden
  - oak

Linden: Note strong compartmentalization with no discoloration in the trunk

FACTORS THAT AFFECT COMPARTMENTALIZATION

- Wound type
  - Pruning cuts and broken crowns
  - Bark damage (collision or logging)
  - Root severance

WOUND TYPE AND COMPARTMENTALIZATION

- Pruning cuts or crown failures (most destructive)
  - Both expose wood across the fibers – exposing water conducting tissue
  - Both also expose older wood near the center of the stem – older wood is less physiologically active and contains fewer reserve substances – weakly compartmentalizing cells
  - The discoloration in the branch base is cone shaped and may develop into funnel shaped discoloration into the trunk

WOUND TYPE AND COMPARTMENTALIZATION

- Size of pruning wounds
  - When pruning, to minimize the possibility of creating wounds which cannot be encapsulated
    - In weak compartmentalizing species do not make cuts in excess of 2 inches
    - In effectively compartmentalizing species do not make cuts in excess of 4 inches

SEASONALITY AND COMPARTMENTALIZATION

- Effectiveness of wound reactions is affected by the time of year in which wounds are made – especially for deciduous trees.
- Tree reactions to injury are determined by living cells which depend on stored reserve substances and the ability of the tree to mobilize them
- These factors are subject to pronounced seasonal variations

SEASONALITY AND COMPARTMENTALIZATION

- Best time to prune for maximum compartmentalization:
  - April to August
- The most unfavorable time to prune:
  - September to February
- German Best practices for tree care 2006 states: “To minimize possible tissue damage and to facilitate compartmentalization and rapid callus growth, pruning should be completed during vegetative periods

April June August November

WOUND TREATMENT

- In general, the use of wound dressings is not considered beneficial to compartmentalization.
- A more recent innovation for trees affected by collision damage is to cover fresh damage on the trunk with opaque plastic wrap.
- This allows any living cells on the wound surface to form surface callus.
- Studies show that results in significantly more effective wound reaction than painting the wound or doing nothing.

OPAQUE PLASTIC WRAP OVER COLLISION DAMAGE

SURFACE CALLUS ON COLLISION DAMAGE

FACTORS THAT AFFECT COMPARTMENTALIZATION

- Tree species
- Wound type
- Time of year (seasonality) of injury
- Wound size, tree age, and tree vitality