📄 1 – Secondary Growth in Dicot Stem 🌳

🔹 Definition

- **Secondary growth** = increase in **girth/diameter** of stem due to activity of **vascular cambium** and **cork cambium**.
- Occurs in dicotyledons & gymnosperms (absent in most monocots).

🔹 Vascular Cambium Activity

- Cambium = **lateral meristem**.
- Forms a continuous ring:
  - **Fascicular cambium** (within vascular bundle).
  - **Interfascicular cambium** (between bundles).
- Cambial ring cuts:
  - **Secondary xylem (inward)**.
  - **Secondary phloem (outward)**.

🔹 Wood & Phloem Development

- More **xylem** formed than phloem → bulk of wood.
- **Annual rings** formed due to seasonal activity:
  - **Spring wood (early wood)** → larger vessels, less thick walls.
  - **Autumn wood (late wood)** → narrow vessels, thick walls.

🔹 Heartwood vs Sapwood

- **Sapwood** → outer, lighter, active conduction.
- **Heartwood** → inner, darker, non-functional, impregnated with tannins/resins.

🔹 Rays

- **Medullary rays** → lateral transport of food & water.

🔹 Periderm Formation (Cork Cambium)

- **Phellogen (cork cambium)** arises in cortex.
- Produces **phellem (cork, outwards)** & **phelloderm (secondary cortex, inwards)**.

- Replaces ruptured epidermis.

🔹 **Mnemonics** 💡

- **Cambium Products → "X-in, P-out"**
  - Cambium cuts **Xylem inwards** and **Phloem outwards**.
- **Periderm Layers → "COP"**
  - **C**ork (phellem)
  - **O**rigin (phellogen)
  - **P**helloderm

🔹 **Exam Capsule** 🎯

- Secondary growth due to **vascular cambium + cork cambium**.
- Produces **annual rings** (basis of dendrochronology).
- **Heartwood** = dark, durable, non-conducting; **Sapwood** = light, conducting.
- Periderm replaces epidermis (phellem, phellogen, phelloderm).

📄 2 – Secondary Growth in Dicot Root 🌱

🔹 **General Features**

- Occurs in dicot roots like *Sunflower, Pea, Bean*.
- Initiated by **cambium formation from pericycle + vascular tissues**.
- Leads to increase in **girth** of root.

🔹 **Steps in Secondary Growth**

1. **Cambium Formation**

- Cambium originates from:
  - **Parenchyma between xylem and phloem (intra-fascicular)**.
  - **Pericycle opposite protoxylem poles (extra-fascicular)**.
- These join to form a **wavy cambial ring**, later becomes circular.

2. **Cambium Activity**

- **Secondary xylem** → cut towards inner side.
- **Secondary phloem** → cut towards outer side.
- Xylem more abundant than phloem → concentric growth.

3. **Medullary Rays**

- Cambium cuts ray initials → form **secondary medullary rays** for lateral transport.

4. **Periderm Formation**

- Cork cambium (from pericycle) produces:
    - **Phellem (cork)** outward.
    - **Phelloderm (secondary cortex)** inward.

◈ Anatomical Results

- Root shows **radial arrangement** → secondary xylem and phloem form concentric rings.
- Central pith gets reduced due to massive secondary xylem.
- Cork replaces epidermis for protection.

◈ Mnemonics 💡

- **Origin of Cambium in Root → "PP"**
    - **P**ericycle
    - **P**arenchyma (between xylem & phloem)

◈ Exam Capsule 🎯

- **Cambium in roots** arises partly from **pericycle**.
- Produces **secondary xylem inward & phloem outward**.
- Rays provide lateral conduction.
- **Periderm (phellem, phellogen, phelloderm)** replaces cortex & epidermis.
- Pith reduced/obliterated due to xylem growth.

📄 3 – Secondary Growth in Gymnosperms 🌲

🔹 General Features

- Gymnosperms (e.g., *Pinus, Cycas*) undergo **secondary growth** by vascular cambium.
- Similar to dicots, but **wood anatomy differs**.

🔹 Cambium Activity

- **Cambium ring** produces:
  - **Secondary xylem (inward)** → forms the bulk of wood.
  - **Secondary phloem (outward)** → narrow zone.
- **Annual rings** form due to seasonal activity.

🔹 Wood Structure in Gymnosperms

1. **Tracheid Dominance**
   - Main water-conducting cells = **tracheids** (not vessels).
   - Bordered pits for conduction.
2. **Xylem Rays**
   - Mostly **uniseriate** (one cell wide).
   - Aid in radial transport.
3. **Resin Canals**
   - Present in many gymnosperms (*Pinus*).
   - Lined by **epithelial cells** secreting resin.
4. **Phloem**
   - Consists of **sieve cells + albuminous cells**.
   - No companion cells or sieve tubes (angiosperm feature).

🔹 Heartwood vs Sapwood

- Similar distinction as dicots:
  - **Sapwood** → functional, lighter.
  - **Heartwood** → dark, durable, non-functional.

🔹 Special Features

- Gymnosperm wood = **non-porous** (no vessels).
- Called **softwood** (though mechanically strong).
- Resin canals aid defense & healing.

🔹 **Mnemonics** 💡

- **Gymnosperm Xylem Features → "T-R-N"**
  - **T**racheids dominant
  - **R**esin canals
  - **N**on-porous wood

🔹 **Exam Capsule** 🎯

- Secondary growth in gymnosperms via **cambium ring**.
- Wood made of **tracheids (not vessels)** → bordered pits.
- Rays mostly **uniseriate**.
- Phloem = sieve cells + albuminous cells.
- Resin canals → diagnostic of *Pinus* and related species.

📄 4 – Anomalous Secondary Growth 🌱🔄

🔹 **Definition**

- Secondary growth that **deviates from the normal pattern** of cambial activity.
- Common in **dicot stems (Boerhaavia, Achyranthes)** and **monocot stems (Dracaena, Yucca)**.

🔹 **1. Boerhaavia (Dicot Stem)**

- Has **three types of cambia**:
  1. **Normal cambium** → produces regular secondary xylem & phloem.
  2. **Accessory cambia** arise successively from pericycle/parenchyma.
  3. Accessory cambia cut **conjunctive tissue + secondary bundles**.
- Results in **concentric rings of vascular bundles**.

◈ 2. Achyranthes (Dicot Stem)

- Successive cambia arise in **conjunctive tissue**.
- Each forms **xylem on inner side, phloem on outer side**.
- Leads to formation of **secondary medullary bundles** in concentric fashion.

◈ 3. Dracaena / Yucca (Monocot Stem)

- Monocots usually lack secondary growth.
- Here, a **secondary thickening meristem (STM)** arises outside the vascular bundles.
- STM cuts off **secondary vascular bundles & ground tissue**.
- Produces **anomalous secondary thickening** in monocot stems.

◈ Key Features

Plant	Peculiarity
Boerhaavia	Rings of vascular bundles by accessory cambia
Achyranthes	Secondary medullary bundles
Dracaena	Secondary thickening meristem in monocots

◈ Mnemonics 💡

- **“BAD” Anomalous Growth**
  - **B**oerhaavia → concentric bundles
  - **A**chyranthes → medullary bundles
  - **D**racaena → monocot thickening meristem

◈ Exam Capsule 🎯

- **Anomalous secondary growth** = irregular cambium activity.
- **Boerhaavia** → successive cambia → concentric vascular rings.
- **Achyranthes** → successive cambia → medullary bundles.
- **Dracaena** → monocot → secondary thickening meristem produces bundles & ground tissue.

📄 5 – Annual Rings & Dendrochronology 🌳⏳

🔹 Annual Rings

- Produced by **seasonal activity of vascular cambium**.
- **Spring wood (early wood)** → formed in favorable season (spring/summer).
  - Large vessels, thin-walled, lighter color.
- **Autumn wood (late wood)** → formed in unfavorable season (winter/autumn).
  - Narrow vessels, thick-walled, dark color.
- One cycle of spring + autumn wood = **Annual Ring**.
- Each annual ring = **1 year of plant's age**.

🔹 Factors Affecting Ring Formation

- Climate (temperature, rainfall).
- Soil conditions.
- Availability of nutrients.
- Internal genetic control.

🔹 Dendrochronology (Tree-Ring Dating)

- **Science of dating past events using annual rings**.
- Uses overlapping tree-ring series from old trees/fossil woods.
- Applications:
  - Age determination of trees.
  - Paleoclimatic studies (rainfall, drought, temperature records).
  - Archaeological dating of wood used in ancient constructions.

🔹 Special Cases

- **Tropical trees** may not show distinct rings (uniform growth).
- Distinct rings common in **temperate regions** with clear seasonal variations.

🔹 Mnemonics 💡

- **Annual Ring Parts → "SL"**
  - **S**pring wood → Soft, light, large vessels.

- **L**ate (autumn) wood → Dark, dense, lignified.

🔹 **Exam Capsule** 🎯

- **Annual ring = spring wood + autumn wood**.
- Each annual ring = **1 year of growth**.
- **Spring wood** = larger vessels, lighter.
- **Autumn wood** = smaller vessels, darker.
- **Dendrochronology** = study of annual rings to date tree age & past climate.

📄 6 – Heartwood vs Sapwood 🌳🍪

🔹 **Sapwood (Alburnum)**

- **Outer lighter zone** of secondary xylem.
- Living xylem → actively conducts **water & minerals**.
- Contains functional tracheids/vessels.
- Rich in starch, sugars, other nutrients.
- Softer, less durable.

🔹 **Heartwood (Duramen)**

- **Inner darker zone** of secondary xylem.
- Non-conducting → vessels/tracheids blocked by **tyloses** or deposits.
- Contains resins, tannins, oils, gums → give durability & color.
- Provides mechanical strength.
- Hard, dense, resistant to pathogens.

🔹 **Structural Differences**

Feature	**Sapwood** 🌿	**Heartwood** 🍪
Position	Outer	Inner
Function	Conducting	Non-conducting
Color	Light	Dark

Feature	Sapwood	Heartwood
Storage	Starch, food	Tannins, oils, gums
Durability	Less durable	Highly durable

Functional Significance

- Sapwood → essential for tree's survival (water transport).
- Heartwood → provides durability & strength (timber value).

Mnemonics

- **"S-H" Rule**
  - **S**apwood = **S**ervice (conduction).
  - **H**eartwood = **H**ard (strength).

Exam Capsule

- **Sapwood** = functional xylem (light-colored, conducts water).
- **Heartwood** = non-functional xylem (dark, durable, mechanical strength).
- **Tyloses & deposits** make heartwood impermeable.
- Heartwood gives **economic timber value**.

7 – Periderm Formation

Why Periderm Forms?

- As stem/root thickens due to secondary growth, **epidermis ruptures**.
- Replaced by **periderm** → protective tissue formed by **cork cambium (phellogen)**.

Components of Periderm

1. **Phellogen (Cork Cambium)**

- Secondary lateral meristem.
- Origin: hypodermis, epidermis, cortex, or phloem parenchyma.
- Produces cork outward & secondary cortex inward.

2. **Phellem (Cork)**

- Produced **outwards**.
- Dead, suberized cells, impermeable to water.
- Protective barrier against injury, pathogens, desiccation.

3. **Phelloderm (Secondary Cortex)**

- Produced **inwards**.
- Living, parenchymatous cells.
- Stores food, performs limited photosynthesis.

◈ Sequence of Formation

Epidermis ruptures → Phellogen arises → Cuts off Phellem (outer) + Phelloderm (inner) → Together form Periderm.

◈ Functions

- Provides mechanical strength.
- Prevents water loss.
- Barrier against microbes, physical injury.
- Phelloderm → storage & photosynthesis.

◈ Mnemonics 💡

- **Periderm layers → "POP"**
  - **P**hellogen
  - **O**utward → Phellem
  - **P**helloderm inward

◈ Exam Capsule 🎯

- **Periderm** = secondary protective tissue (phellogen + phellem + phelloderm).
- **Phellogen** → lateral meristem, forms cork cambium.
- **Phellem** = cork, dead, suberized.
- **Phelloderm** = secondary cortex, living.
- Collectively replaces ruptured epidermis.

8 – Lenticels

Definition

- **Lens-shaped openings** in periderm that allow **gaseous exchange**.
- First observed by **Maluighi (1686)**.

Structure

- Formed in **periderm** at places where phellogen is more active.
- Consist of:
    1. **Complementary cells** → loosely arranged, thin-walled, living.
    2. **Closing layer** → compact cells formed periodically.
    3. Surrounded by **cork cells**.

Development

- **Phellogen** in localized regions cuts cells loosely instead of compactly.
- Loose **complementary cells** break through cork layers → lenticel forms.
- Remains open for exchange → covered by closing layer during unfavorable season.

Functions

- Allow **exchange of gases** (O_2 , CO_2 , water vapor) between inner tissues & atmosphere.
- Maintain respiration when stomata are closed (e.g., night, winter).
- Help in transpiration to some extent.

Special Notes

- Common in **woody stems & roots**.
- Well visible as raised spots on bark (e.g., Mango, Apple, Potato tuber surface).
- Complementary cells may dry & shed seasonally.

Mnemonics

- **Lenticel Parts → "3C"**

- **C**omplementary cells
- **C**losing layer
- **C**ork boundary

🔹 **Exam Capsule** 🎯

- Lenticels = **aerating pores in periderm**.
- Formed by phellogen → complementary cells.
- Enable gas exchange even when cork is impermeable.
- Found in **woody stems, roots, potato tubers**.

📄 9 – Bark (Types & Uses) 🌳🪵

🔹 **Definition**

- Bark = all tissues **outside vascular cambium** (secondary phloem + periderm).
- Protective outer covering in woody plants.

🔹 **Types of Bark**

1. **Early Bark**

- Formed at early stages of secondary growth.
- Thin, smooth.

2. **Late Bark**

- Formed in older stems.
- Thick, rough.

3. **Ring (Complete) Bark**

- Encircles the stem completely.

4. **Scaly Bark**

- Shed in scales or flakes.
- Example: *Guava, Syzygium*.

5. **Furrowed (Ridge) Bark**

- Deep cracks and ridges.

- Example: *Mango, Neem*.

6. **Rhytidome**

- Outermost dead bark formed by successive periderm layers.

◈ Functions of Bark

- Protection from physical injury, desiccation, microbes.
- Reduces water loss.
- Insulates against temperature extremes.
- Stores secondary metabolites.

◈ Commercial Uses

- **Cork** → bottle stoppers, insulation, flooring (*Quercus suber*).
- **Tannins** → leather industry (*Acacia, Rhizophora*).
- **Spices & Medicines** → *Cinnamomum zeylanicum* (cinnamon), *Cinchona* (quinine).
- **Fibres** → ropes, mats (*Tilia*).

◈ Mnemonics 💡

- **Bark Uses → "CTS-F"**
  - **C**ork
  - **T**annins
  - **S**pices/medicines
  - **F**ibres

◈ Exam Capsule 🎯

- Bark = **phloem + periderm** outside cambium.
- Types → scaly, ring, furrowed, rhytidome.
- Functions → **protection, storage, insulation**.
- Economic importance → cork, tannins, spices (cinnamon), drugs (quinine).

📄 10 – Secretory Tissues 🌿💧

🔷 Definition

- Special tissues that secrete **latex, resins, oils, nectar, mucilage, gums**.
- Found in many higher plants for **defense, attraction, storage, wound healing**.

🔷 Types of Secretory Tissues

1. Laticiferous Tissues (Latex Secreting)

- Contain **milky fluid (latex)** – emulsions of proteins, alkaloids, rubber, resins.
- Two types:
    - **Non-articulate (simple)** → unicellular, branched, multinucleate; originate from a single cell. (e.g., *Calotropis, Nerium*).
    - **Articulate (compound)** → multicellular, formed by series of cells with dissolved walls (e.g., *Papaver, Hevea brasiliensis* → rubber plant).

Functions:

- Defense against herbivores (toxic/bitter).
- Healing of wounds.
- Commercial products: **rubber, opium, chicle, gutta-percha**.

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2. Glandular Tissues

- Secrete **oils, resins, nectar, mucilage**.
- Types:
    - **Oil glands** → Citrus (oil glands in peel).
    - **Resin ducts** → Pinus (defense).
    - **Nectaries** → secrete nectar (floral attraction for pollinators).
    - **Salt glands** → halophytes, excrete salts.
    - **Hydathodes** → secrete water by guttation.

Functions:

- Attract pollinators (nectar).
- Defense (resins, oils).
- Salt regulation (halophytes).
- Removal of excess water (hydathodes).

🔹 Mnemonics 💡

- **Secretory Tissues → "LaGONRHS"**
  - **La**tex (laticifers)
  - **G**lands
  - **O**ils
  - **N**ectaries
  - **R**esin ducts
  - **H**ydathodes
  - **S**alt glands

🔹 Exam Capsule 🎯

- **Secretory tissues** = laticifers + glandular.
- **Laticifers** → simple (Calotropis), compound (Papaver, Hevea).
- **Products** → rubber, opium, gutta-percha.
- **Glands** → oils (Citrus), resins (Pinus), nectar (pollination), hydathodes (guttation).
- Role in **defense, attraction, wound healing, excretion**.

📄 11 – Anomalous Secondary Thickening in Monocots 🌴🌱

🔹 General Background

- **Monocots** usually lack secondary growth (no vascular cambium).
- But some (Palm, Yucca, Dracaena, Agave) show **anomalous thickening** by special meristems.

🔹 Mechanism

1. **Secondary Thickening Meristem (STM)**

- A **meristematic zone** forms outside primary vascular bundles.
- Cuts off:
  - **Secondary vascular bundles** (inward).
  - **Ground tissue (parenchyma/fibers)** (outward).

2. **Successive Vascular Bundles**

- New vascular bundles keep forming in concentric rings.
- Embedded in conjunctive tissue.
- Leads to increased girth.

◈ Examples

- **Dracaena**
  - STM produces secondary vascular bundles & conjunctive tissue.
  - Bundles = xylem (with vessels) + phloem.
- **Yucca & Agave**
  - Similar pattern; vascular bundles embedded in parenchymatous ground tissue.
- **Palm**
  - Shows **diffuse secondary growth** → parenchyma and vascular bundles added irregularly by STM.

◈ Structural Features

- Secondary vascular bundles are **collateral, closed**.
- Wood is **fibrous**, not forming rings.
- No cambium ring, no typical annual rings.

◈ Mnemonics 💡

- **"DYP"** → **Dracaena, Yucca, Palm** = monocots with anomalous thickening.

◈ Exam Capsule 🎯

- Normal secondary growth absent in monocots.
- **STM (secondary thickening meristem)** produces secondary bundles & ground tissue.
- **Dracaena/Yucca** → concentric vascular bundles in conjunctive tissue.
- **Palm** → diffuse thickening.
- Explains why some monocots develop tree-like girth despite lacking cambium.

📄 12 – Special Structures in Plants 🌿✨

🔹 1. Hydathodes

- **Pores at leaf margins/apex** connected to vein endings.
- Surrounded by thin-walled **epithem tissue**.
- Exude water drops by **guttation** (when transpiration is low, e.g., night, humid morning).
- Example: *Colocasia, Nasturtium, Tomato*.

🔹 2. Trichomes (Hair-like Outgrowths)

- Outgrowths of **epidermal cells**.
- Types:
  - **Non-glandular** → unicellular or multicellular hairs, cotton fibers.
  - **Glandular** → secrete sticky substances, essential oils.
- Functions: reduce transpiration, defense, absorption (root hairs).

🔹 3. Nectaries

- Specialized glands that secrete **nectar** → attract pollinators.
- Located inside flowers (**floral nectaries**) or outside (**extrafloral**, e.g., cotton).
- Nectar = sugars, amino acids, volatiles.

🔹 4. Resin Ducts

- Tubular canals lined by **epithelial cells** secreting resin.
- Found in gymnosperms (*Pinus*) and some angiosperms.
- Function: defense, sealing wounds.
- Products: **turpentine, resins**.

🔹 5. Oil Glands

- Contain essential oils (volatile).
- Examples: *Citrus* (oil in peel), *Eucalyptus* (oil for medicine).
- Function: defense, aroma, pollinator attraction.

◈ Mnemonics 💡

- **Special Structures → "H-T-N-R-O"**
  - **H**ydathodes
  - **T**richomes
  - **N**ectaries
  - **R**esin ducts
  - **O**il glands

◈ Exam Capsule 🎯

- **Hydathodes** → guttation (leaf tips).
- **Trichomes** → absorption, defense, transpiration control.
- **Nectaries** → nectar secretion for pollination.
- **Resin ducts** → resin secretion in *Pinus*.
- **Oil glands** → Citrus, Eucalyptus → essential oils.