📄 1 – Classification of Plant Tissues 🌿

🔹 Broad Categories

1. **Meristematic Tissues** (actively dividing)
2. **Permanent Tissues** (differentiated, non-dividing)

🔹 1. Meristematic Tissues

- **Definition**: Groups of cells that retain power of division.
- **Characteristics**: Thin-walled, dense cytoplasm, prominent nucleus, no intercellular space.
- **Types**:
    - **Promeristem** → embryonic (root & shoot tips).
    - **Primary meristem** → from promeristem, helps in **primary growth**.
    - **Secondary meristem** → from permanent tissue, causes **secondary growth** (e.g., vascular cambium, cork cambium).

🔹 2. Permanent Tissues

- Derived from meristems, **lose ability to divide**.
- **Types**:
    - **Simple tissues** → one type of cell (parenchyma, collenchyma, sclerenchyma).
    - **Complex tissues** → more than one type (xylem, phloem).
    - **Specialized tissues** → secretory, laticiferous.

🔹 Flow Chart (Summary)

Plant Tissues
→ **Meristematic** (Promeristem, Primary, Secondary)
→ **Permanent**
↳ Simple (Parenchyma, Collenchyma, Sclerenchyma)
↳ Complex (Xylem, Phloem)
↳ Special (Secretory, Laticiferous)

🔹 Mnemonics 💡

- **Types of Permanent Tissues → "PCS"**
    - **P**arenchyma

- **C**ollenchyma
- **S**clerenchyma

🔹 **Exam Capsule** 🎯

- **Meristems** = dividing tissues, responsible for growth.
- **Permanent tissues** = differentiated, structural support, transport, storage.
- **Complex tissues** = transport system of plants (xylem, phloem).

📄 2 – Parenchyma 🌱

🔹 **Structure**

- **Living cells**, thin cellulose wall.
- Large **intercellular spaces**.
- Vacuolated cytoplasm, isodiametric shape.
- Found in cortex, pith, mesophyll, endosperm, etc.

🔹 **Types of Parenchyma**

1. **Chlorenchyma** → contains chloroplasts, photosynthetic.
2. **Aerenchyma** → with large air cavities (hydrophytes, e.g., *Nymphaea*).
3. **Storage parenchyma** → stores starch, proteins, oils.
4. **Idioblasts** → contain ergastic substances (calcium oxalate, tannins).
5. **Prosenchyma** → elongated, mechanical support.
6. **Arms/stellate parenchyma** → in leaves of xerophytes.

🔹 **Functions**

- **Photosynthesis** (chlorenchyma).
- **Buoyancy** (aerenchyma in hydrophytes).
- **Storage** of food, water, secondary metabolites.
- **Mechanical support** (when turgid).
- **Wound healing & regeneration** → meristematic ability.

🔹 **Special Features**

- Can **dedifferentiate** back into meristems (secondary growth).
- In hydrophytes → aerenchyma reduces resistance to gases.

🔹 **Mnemonics** 💡

- **Types → "CAPS-I"**
  - **C**hlorenchyma
  - **A**erenchyma
  - **P**rosenchyma
  - **S**torage
  - **I**dioblasts

🔹 **Exam Capsule** 🎯

- Parenchyma = **living fundamental tissue**.
- Performs **photosynthesis, storage, buoyancy, repair**.
- Special types → chlorenchyma, aerenchyma, idioblasts.
- Can revert to meristematic → important in regeneration.

📄 3 – Collenchyma 🦾

🔹 **Structure**

- **Living cells**, elongated, unevenly thickened cell walls.
- Wall thickening = **cellulose, hemicellulose, pectin**.
- No lignin (distinguishes from sclerenchyma).
- Found beneath the epidermis (hypodermis) in dicot stems, midribs of leaves.

🔹 **Types of Collenchyma**

1. **Angular** → wall thickening at cell corners (common type, e.g., sunflower stem).
2. **Lamellar (Tangential)** → thickening on tangential walls (e.g., cucumber).
3. **Lacunar (Annular)** → thickening around intercellular spaces (e.g., Aristolochia).

◈ Functions

- Provides **mechanical support with flexibility**.
- Allows organs (petiole, stem, leaf midrib) to bend without breaking.
- Living → can store food and assist in healing.

◈ Special Features

- Occurs **just below epidermis** in dicot stems.
- Absent in roots and monocots.
- Acts as **supporting tissue in young parts** of plants.

◈ Mnemonics 💡

- **Types → "ALL"**
  - **A**ngular
  - **L**amellar
  - **L**acunar
- **Key Idea → "Collenchyma = Cushion"** → flexible support.

◈ Exam Capsule 🎯

- **Collenchyma** = living mechanical tissue.
- Uneven cell wall thickening (pectocellulosic).
- Types: Angular, Lamellar, Lacunar.
- Provides **flexible mechanical support** in young stems and leaves.

📄 4 – Sclerenchyma 🦴🧱

🔹 Structure

- **Dead cells** at maturity.
- Walls thickened with **lignin**.
- Very narrow lumen, rigid structure.
- Provides maximum mechanical strength.

🔹 Types of Sclerenchyma

1. **Fibers**
    - Long, narrow, tapering ends.
    - Thick lignified walls, simple pits.
    - Occur in xylem, phloem, pericycle, cortex.
    - Examples: **Flax fibers, Jute fibers**.
2. **Sclereids (Stone Cells)**
    - Irregular, isodiametric, highly lignified.
    - Found in hard parts of seed coats, nutshells, pulp of guava/pear.
    - Types: brachysclereids, macrosclereids, osteosclereids, astrosclereids, trichosclereids.

🔹 Functions

- Provides **rigidity & strength**.
- Forms protective layers (seed coats, nutshells).
- Supports conduction (xylem fibers).
- Economic → fibers used in **ropes, textiles, mats**.

🔹 Special Features

- Unlike collenchyma, cells are **dead at maturity**.
- Secondary wall heavily lignified.
- Sclereids cause gritty texture in guava, pear (stone cells).

🔹 Mnemonics 💡

- **Sclerenchyma Types → “Fi-Sto”**

- **Fi**bers → long, elongated, flexible strength.
- **Sto**ne cells → sclereids, hardness.

🔹 **Exam Capsule** 🎯

- Sclerenchyma = **dead supporting tissue**.
- Types: **Fibers** (elongated, flexible) & **Sclereids** (stone cells, rigid).
- Present in seed coats, nutshells, fruit pulp, pericycle, vascular bundles.
- Major **mechanical tissue** of mature plant organs.

📄 5 – Xylem (Complex Tissue) 🚰💧

🔹 **Definition**

- Complex permanent tissue → transports **water & minerals** from roots to aerial parts.
- Provides **mechanical support**.

🔹 **Elements of Xylem**

1. **Tracheids**

- Elongated, dead cells with lignified walls & pits.
- Conduct water + mechanical support.
- Present in all vascular plants.

2. **Vessels (Tracheae)**

- Tubular, multicellular structures formed by end-to-end fusion of vessel elements.
- Perforation plates at ends.
- Efficient water conduction.
- Found in **angiosperms** (absent in most gymnosperms, except *Gnetum*).

3. **Xylem Fibers**

- Thick-walled, lignified, dead cells.
- Provide **mechanical support**.

4. **Xylem Parenchyma**

- Only **living cells** of xylem.
- Store starch, fats, tannins.

- Help in lateral conduction of water.

◈ Primary vs Secondary Xylem

- **Primary xylem** → from procambium (protoxylem & metaxylem).
  - **Protoxylem** = first formed, narrow, annular/spiral thickening.
  - **Metaxylem** = later, wider, pitted thickening.
- **Secondary xylem** → formed by vascular cambium during secondary growth (wood).

◈ Functions

- Water & mineral transport.
- Provides rigidity & mechanical strength.
- Storage (xylem parenchyma).

◈ Evolutionary Note

- Water conduction evolved: **Tracheids** → **Vessels**.
- Gymnosperms → only tracheids.
- Angiosperms → both tracheids & vessels (more efficient).

◈ Mnemonics 💡

- **Xylem elements → "TV-FP"**
  - **T**racheids
  - **V**essels
  - **F**ibers
  - **P**arenchyma

◈ Exam Capsule 🎯

- Xylem = **water-conducting + mechanical tissue**.
- **Dead elements**: tracheids, vessels, fibers.
- **Living element**: parenchyma.
- Protoxylem (spiral, annular) → Metaxylem (reticulate, pitted).
- Angiosperms have vessels; gymnosperms mostly tracheids.

6 – Phloem (Complex Tissue)

Definition

- Complex permanent tissue → transports **organic food (mainly sucrose)** from source (leaves) to sink (roots, fruits, storage organs).
- Bidirectional translocation possible.

Elements of Phloem

1. **Sieve Elements**

- **Sieve cells** (in pteridophytes & gymnosperms): elongated, tapering ends, sieve areas on walls, associated with albuminous cells.
- **Sieve tube elements** (in angiosperms): cylindrical, arranged end-to-end; end walls form **sieve plates**; enucleate at maturity.

2. **Companion Cells**

- Only in **angiosperms**, closely associated with sieve tubes.
- Nucleated; regulate sieve tube function.
- Plasmodesmatal connections.

3. **Phloem Fibers (Bast Fibers)**

- Sclerenchymatous, dead.
- Provide tensile strength.
- Economically important → jute, flax, hemp.

4. **Phloem Parenchyma**

- Living cells.
- Store starch, proteins, resins, tannins.
- Absent in most monocots.

Primary vs Secondary Phloem

- **Primary phloem** → derived from procambium.
- **Secondary phloem** → from vascular cambium during secondary growth.

Special Features

- Phloem lacks tracheary elements.

- In gymnosperms → **sieve cells + albuminous cells**.
- In angiosperms → **sieve tubes + companion cells**.

🔹 **Functions**

- Translocation of sugars, amino acids, hormones, signaling molecules.
- Storage of food (phloem parenchyma).
- Mechanical support (fibers).

🔹 **Mnemonics** 💡

- **Phloem elements → "SC-FP"**
  - **S**ieve elements
  - **C**ompanion cells
  - **F**ibers
  - **P**arenchyma

🔹 **Exam Capsule** 🎯

- **Phloem = food-conducting tissue**.
- Angiosperms → sieve tubes + companion cells.
- Gymnosperms → sieve cells + albuminous cells.
- Fibers = bast fibers → jute, flax.
- Parenchyma absent in most monocots.

📄 7 – Meristematic Tissue 🌱

🔹 **Definition**

- **Meristem** = tissue of continuously dividing cells.
- Responsible for **growth in length, girth, and organ formation**.

🔹 Characteristics

- Cells **small, isodiametric, thin-walled**.
- Dense cytoplasm, large nucleus, **no vacuoles**.
- No intercellular spaces.
- High metabolic activity.

🔹 Types of Meristems (Based on Origin)

1. **Promeristem** → embryonic, found at root & shoot tips.
2. **Primary meristem** → from promeristem; causes **primary growth** (length).
3. **Secondary meristem** → formed from permanent tissue; causes **secondary growth** (girth).
    - Examples: vascular cambium, cork cambium.

🔹 Types of Meristems (Based on Position)

- **Apical meristem** → at tips of roots & shoots; elongation.
- **Intercalary meristem** → at internodes, base of leaves; regeneration (e.g., grasses).
- **Lateral meristem** → cylinders in roots/stems; thickening (e.g., vascular cambium).

🔹 Initial vs. Derivative Cells

- **Initials** → maintain meristem, divide slowly.
- **Derivatives** → daughter cells, differentiate into tissues.

🔹 Functions

- Cell division → new cells for growth.
- Differentiation → origin of permanent tissues.
- Healing and regeneration.
- Secondary growth via lateral meristems.

🔹 Mnemonics 💡

- **Meristem types by position → "AIL"**
    - **A**pical
    - **I**ntercalary
    - **L**ateral

🔹 **Exam Capsule** 🎯

- Meristematic tissue = **actively dividing cells**.
- Classified as **Promeristem, Primary, Secondary** (origin) or **Apical, Intercalary, Lateral** (position).
- Initial cells maintain meristem; derivatives → tissues.
- Responsible for **growth, differentiation, regeneration**.

📄 8 – Types of Meristems 🦖

🔹 **I. Based on Origin**

1. **Promeristem**

- Very young embryonic cells (root & shoot tip).
- Source of all meristems.

2. **Primary Meristem**

- Derived directly from promeristem.
- Responsible for **primary growth (elongation)**.
- Examples: apical meristem, intercalary meristem.

3. **Secondary Meristem**

- Arises later from permanent tissues.
- Responsible for **secondary growth (girth)**.
- Examples: vascular cambium, cork cambium.

🔹 **II. Based on Position**

1. **Apical Meristem**

- Located at **root & shoot apex**.

- Function: elongation, formation of primary tissues.

2. **Intercalary Meristem**

- Located at **base of leaves, nodes, internodes** (common in monocots like grasses, bamboo).
- Function: rapid regrowth after grazing/cutting.

3. **Lateral Meristem**

- Found along sides of stems & roots.
- Function: secondary thickening (increase in girth).
- Examples: vascular cambium, cork cambium.

◈ III. Based on Plane of Division

- **Rib/File Meristem** → cells divide in one plane (rows/columns).
- **Plate Meristem** → divisions in two planes (forms lamina).
- **Mass Meristem** → divisions in all planes (forms bulk tissue like endosperm, cortex).

◈ Mnemonics 💡

- **Meristems by Position → "AIL"**
  - **A**pical → elongation.
  - **I**ntercalary → regrowth.
  - **L**ateral → thickness.
- **Planes → "RPM"**
  - **R**ib
  - **P**late
  - **M**ass

◈ Exam Capsule 🎯

- **Origin**: Promeristem, Primary, Secondary.
- **Position**: Apical (length), Intercalary (regrowth), Lateral (girth).
- **Division plane**: Rib, Plate, Mass meristems.
- Primary growth → elongation; Secondary → thickening.

9 – Functional Classification of Meristems

Basis

- Classified according to **tissue systems they give rise to**.

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1. Protoderm

- Outermost meristematic layer at shoot/root tip.
- Differentiates into **epidermis**.
- Functions: protection, cuticle formation, stomata.

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2. Procambium

- Cylindrical meristem beneath protoderm.
- Gives rise to **vascular tissues (xylem & phloem)** and cambium.
- Functions: conduction of water, minerals, food.

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3. Ground Meristem

- Remainder of meristematic tissue between protoderm & procambium.
- Forms **ground tissues** → cortex, pericycle, pith, mesophyll.
- Functions: storage, photosynthesis, mechanical support.

Functional Role Summary

Meristem	Tissue System Formed	Major Function
Protoderm	Epidermis	Protection
Procambium	Vascular	Conduction
Ground Meristem	Ground tissues	Storage, support, photosynthesis

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Mnemonics

- **Meristem Functions → "PPG"**
  - **P**rotoderm → Protection (epidermis).
  - **P**rocambium → Pipes (vascular tissues).

- **G**round meristem → Ground tissues.

🔹 **Exam Capsule** 🎯

- Functional classification (Hanstein, 1868).
- **Protoderm** → epidermis.
- **Procambium** → primary xylem, phloem, cambium.
- **Ground meristem** → cortex, pericycle, pith, mesophyll.
- Shows how shoot apex organizes into **tissue systems**.

📄 10 – Shoot Apex Theories 🌱🌿

🔹 **1. Apical Cell Theory**

- Proposed for **pteridophytes & bryophytes**.
- Shoot apex is controlled by a **single apical cell** (pyramidal/tetrahedral).
- Each face cuts off new cells → forms plant body.
- Works well in lower plants, **not valid for angiosperms**.

🔹 **2. Histogen Theory (Hanstein, 1868)**

- Shoot apex made of **three histogens (meristematic zones)**:
    1. **Dermatogen** → epidermis.
    2. **Periblem** → cortex.
    3. **Plerome** → stele (vascular + pith).
- Limitations: strict separation not always clear, especially in angiosperms.

🔹 **3. Tunica–Corpus Theory (Schmidt, 1924)**

- Widely accepted for **angiosperms**.
- Shoot apex has **two zones**:
    - **Tunica** (outer layer): divides anticlinally → forms epidermis.
    - **Corpus** (inner mass): divides in all planes → forms bulk tissues.
- Explains layered organization of angiosperm apex.

◈ Comparative Snapshot

Theory	Key Idea	Applies To
Apical Cell	Single apical cell	Bryophytes, pteridophytes
Histogen	Dermatogen, Periblem, Plerome	Gymnosperms, some angiosperms
Tunica–Corpus	Tunica (outer) + Corpus (inner)	Angiosperms

◈ Mnemonics 💡

- **A–H–T order = Evolution of Apex Theories**
  - **A**pical cell (lower plants).
  - **H**istogen (early vascular plants).
  - **T**unica–Corpus (angiosperms).

◈ Exam Capsule 🎯

- **Apical Cell Theory** → 1 cell dominates (ferns, mosses).
- **Histogen Theory** → 3 histogens (dermatogen, periblem, plerome).
- **Tunica–Corpus Theory** → outer tunica (surface growth) + inner corpus (bulk tissue) → best explains angiosperms.

📄 11 – Advanced Theories of Shoot Apex 🌱🔬

◈ 1. Tissue Differentiation Theory (Foster, 1938)

- Shoot apex not divided into strict zones.
- **Histological differences** (cytoplasm density, vacuolation, mitotic activity) determine destiny of cells.
- Emphasis on **physiological differences**, not fixed layers.

◈ 2. Mantle–Core Theory (Popham & Chan, 1952)

- Shoot apex has **outer mantle** (like tunica) and **inner core** (like corpus).

- Mantle → epidermal tissues.
- Core → vascular and ground tissues.
- Similar to tunica–corpus, but less rigid.

🔷 3. Anneau Initial + Corpus Theory (Buvat, 1935)

- Apex has **Annular Initial Zone (Anneau Initial)** around the dome.
- Beneath it → **Corpus zone**.
- Annular initials give rise to peripheral tissues.
- Corpus produces internal tissues.

🔷 4. Cytohistological Zonation Theory (Buvat, 1955)

- Shoot apex differentiated into **zones based on cytology & function**:
    1. **Apical Initials Zone** – slowly dividing, central.
    2. **Central Mother Cell Zone** – reservoir of initials.
    3. **Peripheral Zone** – actively dividing, forms cortex & leaves.
    4. **Rib/Meristem Zone** – forms pith & central tissues.
- Explains **functional zonation** of angiosperm apices.

🔷 Comparative Table

Theory	Key Concept
Tissue Differentiation	Based on histology, not layers
Mantle–Core	Outer mantle + inner core
Anneau Initial + Corpus	Annular initials + corpus
Cytohistological Zonation	Apex divided into 4 functional zones

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🔷 Mnemonics 💡

- **Advanced Theories → "TMAC"**
    - **T**issue differentiation
    - **M**antle–core
    - **A**nneau initial + corpus
    - **C**ytohistological zonation

🔹 **Exam Capsule** 🎯

- Classical theories (Apical cell, Histogen, Tunica–Corpus) → **structural**.
- Advanced theories → emphasize **cytology & physiology**.
- **Cytohistological Zonation** most widely accepted for angiosperms.

📄 12 – Root Apex Organization 🌱🌱

🔹 **General Features**

- Root apex = **meristematic dome** protected by **root cap**.
- Growth controlled by apical meristem → elongation, differentiation of root tissues.
- Simpler than shoot apex (no leaf primordia).

🔹 **Theories of Root Apex**

1. **Apical Cell Theory**

- In ferns & some lower plants.
- Root apex controlled by a **single tetrahedral apical cell**.

2. **Histogen Theory (Hanstein, 1868)**

- Root apex has **3 histogens**:
    - **Dermatogen** → root epidermis.
    - **Periblem** → cortex.
    - **Plerome** → stele (vascular + pith).

3. **Quiescent Centre Concept (Clowes, 1956)**

- Root apex has a central zone of **inactive cells** (low mitotic activity).
- Surrounding cells = actively dividing.
- Quiescent centre acts as a **reserve meristem**; gets activated during stress/wound.

🔹 **Root Cap Formation**

- Unique to root apex (absent in shoots).
- Produced by **calyptrogen (in some plants)** or **root apical meristem**.

- Protects root tip as it penetrates soil.
- Root cap cells → **columella cells** sense gravity (gravitropism).

◈ Comparative Note

- **Shoot apex** → tunica–corpus organization.
- **Root apex** → histogen concept + quiescent centre.

◈ Mnemonics 💡

- **Root Apex Histogens → "DPP"**
  - **D**ermatogen → Dermis (epidermis).
  - **P**eriblem → Parenchymatous cortex.
  - **P**lerome → Pith + vascular system.

◈ Exam Capsule 🎯

- Root apex protected by **root cap** (absent in shoots).
- **Apical Cell Theory** valid in lower plants.
- **Histogen Theory** → 3 histogens (dermatogen, periblem, plerome).
- **Quiescent Centre** → inactive zone, acts as **reserve meristem**.
- Root cap cells → columella, graviperception.