Unit 1 · Plant Anatomy

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Plant Anatomy (Unit 1): 5 of 75 marks; 1 MCQ and 1 short question (4 marks: knowledge 1, understanding 1, application 2); no long question from it
- **The paper:** Botany 37 + Zoology 38; each part: MCQs × 1 (5 Botany, 6 Zoology) · 4 short × 4 · 2 long × 8; one OR in each short and long group; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ: a bundle with centripetal protoxylem (exarch); short: a section given: features of layer Y; draw it, label the tissue for secondary growth, its activity up to the cambium ring
- **MCQ (1 mark)**
  - father of plant anatomy; heterogeneous tissue
  - which meristem does what; idioblast; aerenchyma
  - collenchyma's wall; living mechanical tissue; lumen
  - parts of xylem and phloem; the dead cell in phloem
  - radial, amphicribal bundles; exarch, endarch
  - tyloses; periderm; heartwood and sapwood
- **Short and long (in parts)**
  - meristem: features; kinds by position
  - parenchyma and its kinds; fiber vs sclereid
  - xylem vs phloem; types of bundle, with diagrams
  - dicot vs monocot root; monocot root, three features
  - a section to name; monocot stem diagram
  - dicot vs monocot leaf; periderm; early vs late wood
  - secondary growth of the stele, with diagrams

Key terms

Tissue: group of cells of common origin doing one function, with any matrix between them.

Plant anatomy: internal structure of plant parts, mainly their tissues; father: **Nehemiah Grew**.

T.S., L.S., V.S.: section across, along, and (leaf) from top surface to bottom.

Meristem: actively dividing, undifferentiated cells in growing parts.

Permanent tissue: cells that have stopped dividing and **differentiated** for a job.

De-differentiation: permanent cells regain the power to divide (→ secondary meristem).

Simple tissue: one kind of cell (homogeneous); **complex**: several kinds (heterogeneous).

Stele: everything inside the endodermis: pericycle, vascular tissue, pith.

Casparian strip: band of suberin and lignin round the **radial and transverse** walls of endodermal cells.

Passage cells: thin-walled endodermal cells opposite the protoxylem; let water into the stele.

Vascular bundle: strand of xylem and phloem, with or without cambium.

Secondary growth: increase in girth by the lateral meristems.

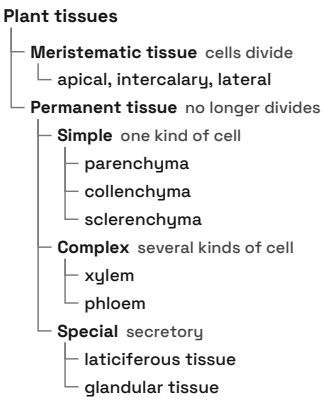
Periderm: phellem + phellogen + phelloderm.

Tyloses: balloon-like outgrowths of parenchyma into vessels through pits; plug them.

Dendrochronology: finding a tree's age from its annual rings; **dendroclimatology**: past climate from ring widths.

Plant tissues

- levels: cell → tissue → organ → organ system → organism
- organ systems: **shoot system** (stem, leaves; flowers, fruits) and **root system**
- **tissue systems**: epidermal; ground (cortex, pith, mesophyll); vascular (xylem, phloem)
- by division: **meristematic** and **permanent** (simple, complex, special)



Plant tissues: a flow chart.

Meristems

Features

- young, living, undifferentiated
- small, isodiametric; thin cellulose walls
- closely packed, **no intercellular spaces**
- large nucleus, dense cytoplasm

- vacuoles small or absent; no stored food or inclusions
- high metabolic rate; divide by **mitosis**

By origin and growth

- **promeristem**: first cells of the embryo and extreme tips; gives all other meristems
- **primary**: from the embryo, never stopped; **primary growth** (length); apical, intercalary, intrafascicular cambium
- **secondary**: from permanent cells that de-differentiate; **secondary growth** (girth); cork cambium, interfascicular cambium

By position

- **apical**: root and shoot tips → **length**
- **lateral**: sides, a cylinder → **girth**; vascular and cork cambium
- **intercalary**: base of internodes and leaves; left behind by the apex → internodes longer; lodged cereals stand up; grasses, bamboo, maize, sugarcane, mint; absent in rosette plants (cabbage)

By planes of division

- **rib (file)**: one plane → rows of cells; pith, cortex
- **plate**: two planes → sheet; leaf blade
- **mass**: all planes → volume; embryo, endosperm, young fruit

Layers behind the tip

- modern: **protoderm** → epidermis; **ground meristem** → cortex, endodermis, pericycle, pith; **procambium** → xylem, phloem, cambium
- **histogen theory** (Hanstein, 1868): **dermatogen** → epidermis; **periblem** → cortex, endodermis; **plerome** → stele; **calyptrogen** → root cap
- **tunica–corpus** (Schmidt, 1924), shoot tip: tunica (1–2 layers, anticlinal division) round corpus (all planes)

Shoot apex	Root apex
bare tip, under young leaves	covered by root cap
makes leaves and buds (nodes)	no leaves, no nodes
tunica–corpus	histogen theory

Simple permanent tissues

Parenchyma (most common, least specialized)

- living; round, oval, many-sided; thin cellulose walls; intercellular spaces
- cortex, pith, fruit flesh, mesophyll; stores food and water; heals wounds
- kinds
  - **epidermis** (root: **epiblema**): one outer layer; protects
  - **chlorenchyma**: chloroplasts; photosynthesis
  - **aerenchyma**: big air spaces; buoyancy (lotus, water hyacinth, *Hydrilla*)
  - **prosenchyma**: long, tapering, thickish walls, living; support (pericycle)
  - **idioblasts**: large single cells storing tannins, oils, crystals, mucilage

Collenchyma (*kolla*, glue): **living mechanical tissue**

- elongated, living; walls thickened **unevenly**, cellulose, hemicellulose, **pectin**; strong but flexible
- hypodermis of young **dicot stems**, petioles, pedicels, midrib; absent in monocots and roots
- **angular** (corners: *Datura*, tomato); **lacunar** (next to spaces: *Salvia*, *Cucurbita*); **lamellar** (tangential walls: sunflower)
- jobs: flexibility, bending; keeps herbs upright; leaves don't tear; strength while growing; some photosynthesis

Sclerenchyma (*skleros*, hard)

- thick **lignified** walls; **dead** when mature; empty **lumen**; pits; no spaces
- monocot hypodermis, bundle caps and sheaths, bast fibers, seed coats, nut shells
- **fibers**: long, narrow, pointed; bast (jute, flax, hemp, लोक्ता, अल्लो), wood (xylem), surface (coir)
- **sclereids** (stone cells): short, isodiametric or odd shapes; even more lignified; nut shells, fruit stones, seed coats (legumes), grit in pear and guava

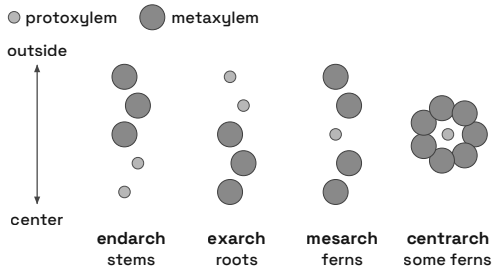
	Parenchyma	Collenchyma	Sclerenchyma
cells	living	living	dead
wall	thin, cellulose	uneven, cellulose + pectin	thick, lignified
spaces	present	few or none	none
job	storage	flexible support	rigid support

Fiber	Sclereid
long, narrow, tapering	short, isodiametric or irregular
lumen wider	lumen tiny, wall layered, branched pits
support, strength	hardness, protection

Complex permanent tissues

Xylem (wood, hadrome): water and minerals **upward**, one way; support

- **tracheids**: dead, long, closed tapering ends, pits; main in pteridophytes, gymnosperms
- **vessels**: vessel elements end to end, end walls dissolved (**perforation plate**); main in **angiosperms**; absent in most pteridophytes and gymnosperms (*Gnetum* has them)
- **xylem parenchyma**: the **only living** xylem cells; storage, sideways flow
- **xylem fibers**: dead; support
- thickenings: **annular**, **spiral** (stretch; protoxylem), **scalariform**, **reticulate**, **pitted** (strongest)
- **protoxylem**: first, narrow, annular/spiral; **metaxylem**: later, wide, reticulate/pitted
- **secondary xylem**: from vascular cambium = wood; none in monocots



Endarch, exarch, mesarch, centrarch.

- **endarch**: protoxylem towards the center: **stems**, leaves

- **exarch**: protoxylem towards the periphery: **roots**
- **mesarch**: protoxylem in the middle: fern stems, cycad leaves
- **centrarch**: protoxylem at the very center: *Rhynia*

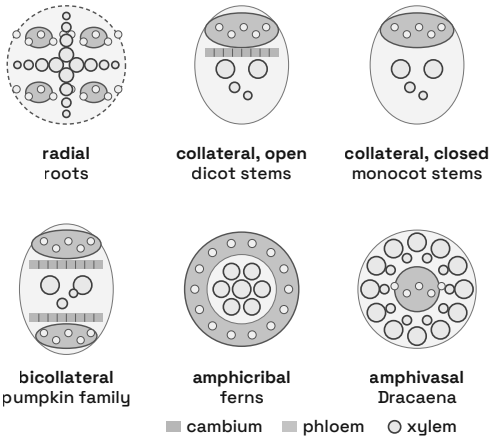
Phloem (bast, leptome): food from **source to sink**, both ways; all living except fibers

- **sieve tubes**: living, no nucleus when mature; **sieve plates** with pores
- **companion cells**: sister cells of the sieve element; large nucleus, many mitochondria; control it; load and unload sugar
- **phloem parenchyma**: storage; absent in most monocots
- **phloem fibers**: dead; jute, flax, hemp
- pteridophytes, gymnosperms: **sieve cells** with **albuminous cells**

	Xylem	Phloem
carries	water, minerals	food (sucrose)
direction	upward	both ways
conducting cells	dead	living
living cells	xylem parenchyma only	all but fibers
walls	thick, lignified	thin, cellulose

Vascular bundles

- **radial**: xylem and phloem on **different radii**: roots
- **conjoint**: on the **same radius**: stems, leaves
  - **collateral open**: phloem outside, **cambium** between: dicot stems (sunflower)
  - **collateral closed**: no cambium: monocots, dicot leaves
  - **bicollateral**: phloem outside **and** inside, two cambia: *Cucurbita*
  - **concentric amphicribal**: xylem in center: ferns
  - **concentric amphivasal**: phloem in center: *Dracaena*, *Yucca*

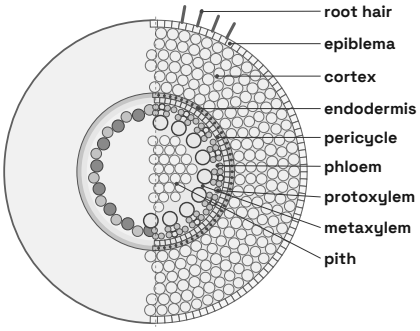


Types of vascular bundle.

Roots

- order, outside in: epiblema → cortex → endodermis → pericycle → bundles, conjunctive tissue → pith
- **epiblema**: one layer, **no cuticle, no stomata**, unicellular root hairs
- **cortex**: many layers of parenchyma, spaces, no chloroplasts; stores starch
- **endodermis**: barrel-shaped cells, **Casparian strips**; passage cells; the **biological check post**
- **pericycle**: one layer; lateral roots
- **radial** bundles; **exarch** xylem

	Dicot root	Monocot root
xylem strands	2–6 (diarch–hexarch)	many, over 6 (polyarch)
vessels	angular	round, metaxylem large
pith	small or absent	large
pericycle makes	lateral roots, cambium, cork cambium	lateral roots only
exodermis	absent	in older roots
conjunctive tissue	parenchyma → cambium	may become sclerenchyma
secondary growth	yes	no



T.S. of a monocot (maize) root.

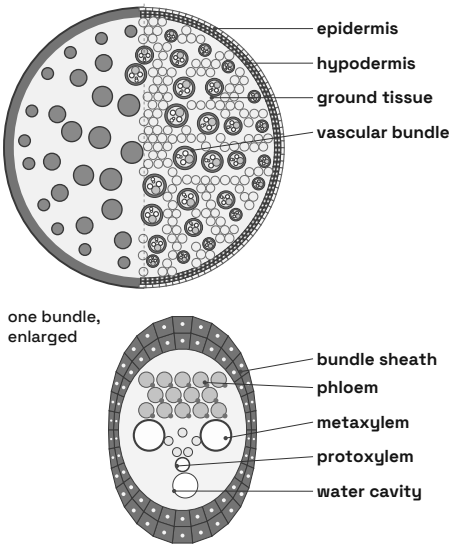
Stems

Dicot stem (sunflower)

- epidermis with **cuticle**, **multicellular hairs**, stomata
- hypodermis: 3–4 layers of **collenchyma**
- general cortex: parenchyma, chloroplasts outside; **resin ducts** lined with glandular cells
- endodermis: wavy, **starch sheath**; no Casparian strips
- pericycle: **heterogeneous**: sclerenchyma **bundle caps** + parenchyma
- bundles in a **ring** (eustele), **conjoint, collateral, open**, wedge-shaped; **endarch**; intrafascicular cambium
- **medullary rays** between bundles; large **pith**

Monocot stem (maize)

- thick cuticle, no hairs, **dumbbell-shaped** guard cells
- hypodermis: 2–3 layers of **sclerenchyma**
- **ground tissue** undivided (no cortex, endodermis, pericycle, pith, rays)
- bundles **scattered** (atactostele), **conjoint, collateral, closed**; small at the edge, large inside; **sclerenchyma bundle sheath**
- xylem in a **V or Y**: 2 metaxylem outside, protoxylem inside (endarch); **protoxylem lacuna** (water cavity, lysigenous)
- no phloem parenchyma



T.S. of a monocot (maize) stem.

	Dicot stem	Monocot stem
hypodermis	collenchyma	sclerenchyma
ground tissue	divided	undivided
bundles	ring, equal	scattered, unequal
bundle	open	closed, with sheath
phloem parenchyma	present	absent
pith, rays	present	absent
secondary growth	yes	no

- thick monocots: thick from the start (primary thickening meristem); *Dracaena*, *Yucca* thicken by a cambium of their own

Leaves

Dicot leaf: **dorsiventral**

- upper epidermis: thick cuticle, few or no stomata; lower: many stomata, **kidney-shaped** guard cells
- mesophyll: **palisade** (columns, many chloroplasts) + **spongy** (loose, air spaces, **substomatal cavity**)
- bundles conjoint, collateral, **closed**; parenchyma sheath; **xylem towards upper**, phloem towards lower
- bundle sheath extension: **collenchyma** at the midrib

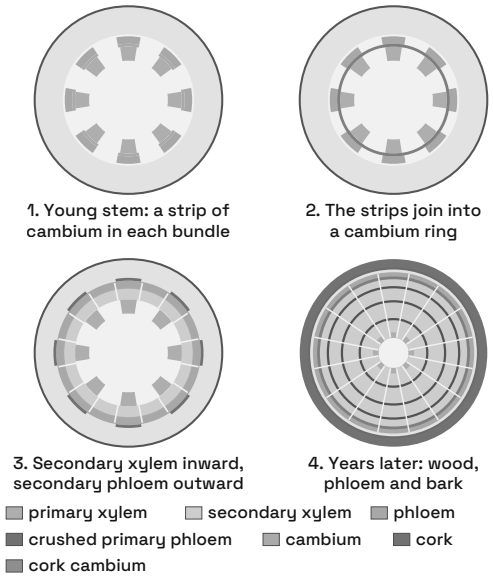
Monocot leaf: **isobilateral**

- stomata on **both** surfaces; **dumbbell-shaped** guard cells
- **bulliform (motor) cells** in the upper epidermis: leaf rolls in dry weather
- mesophyll **undifferentiated**
- parallel bundles, large and small; xylem in a V, metaxylem towards the lower side
- bundle sheath extension: **sclerenchyma**

	Dicot leaf	Monocot leaf
sides	dorsiventral	isobilateral
stomata	mostly lower	both, equal
guard cells	kidney	dumbbell
mesophyll	palisade + spongy	one kind
bulliform cells	absent	present
sheath extension	collenchyma	sclerenchyma

Secondary growth

- **primary growth**: length, all plants; **secondary**: girth, dicots and gymnosperms; not in most monocots, pteridophytes, leaves
- **vascular cambium** → secondary xylem and phloem (**intrastelar**); **cork cambium** → bark (**extrastelar**)



Secondary growth of a dicot stem.

Vascular cambium

1. **cambium ring**: intrafascicular cambium (primary) + medullary ray cells de-differentiate → **interfascicular** cambium (secondary) → complete ring
2. initials: **fusiform** (long → xylem, phloem); **ray** (short → rays)
3. fusiform initial divides: one stays cambium; **inner** cell → secondary xylem, **outer** → secondary phloem; far **more xylem**; cambium pushed outward; primary phloem crushed, primary xylem stays by the pith
4. **secondary medullary rays**: living parenchyma, radial; food inward, water outward

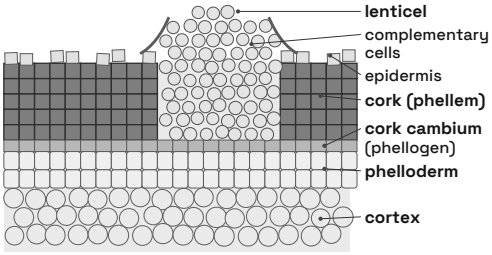
5. **annual rings**: spring (early) wood: active cambium, **wide** thin-walled vessels, pale; autumn (late) wood: **narrow** vessels, thick walls, dark; one of each = one year's ring
6. **heartwood** (duramen): central, dead, filled with tannins, resins, gums, oils; vessels plugged by **tyloses**; dark, hard, durable; only supports
7. **sapwood** (alburnum): outer, pale, living parenchyma; conducts, stores; inner sapwood → heartwood each year

Spring (early) wood	Autumn (late) wood
spring, cambium very active	cool or dry season, slow
many, wide vessels	fewer, narrow vessels, more fibers
thin walls, light, pale	thick walls, dense, dark

- same climate all year (tropical rainforest): no distinct rings; CDC calls it **diffuse-porous**; strictly, ring-porous (oak, teak) and diffuse-porous (maple, sal) describe where vessels lie in a ring
- increment borer: core from bark to center, rings counted

Cork cambium (phellogen)

- from outer cortex (or epidermis, hypodermis) as the epidermis tears
- outward: **phellem (cork)**: dead, rectangular, **suberin**, waterproof; protects
- inward: **phelloderm** (secondary cortex): living parenchyma; stores food
- **bark** = everything outside the vascular cambium
- **lenticels**: loose **complementary cells** → gas exchange, lenticular transpiration



Periderm.

Significance

- timber, furniture, paper, firewood
- girth and support (heartwood)
- age from rings; past climate
- bark protects from injury, heat, cold, infection
- lenticels: gas exchange
- new xylem and phloem each year

COMMON MISTAKES

✗ Casparian strip on radial and tangential walls
✓ on the **radial and transverse** walls.

✗ Monocot roots have no passage cells
✓ they do, opposite the protoxylem.

✗ Root xylem is endarch
✓ roots **exarch**; stems and leaves **endarch**.

✗ Amphicribal: phloem in the center
✓ **xylem** in the center (ferns); amphivasal: phloem in the center.

✗ Collenchyma is dead
✓ **living** mechanical tissue; sclerenchyma is dead.

✗ Vascular bundle of a monocot stem is open
✓ **closed**: no cambium.

✗ In the leaf the phloem faces up
✓ **xylem towards the upper** epidermis.

✗ Heartwood conducts water
✓ only supports; **sapwood** conducts.

✗ Cork cambium makes more cells inward
✓ more **outward** (cork).