Introduction to Botany

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Lecture 25

Outline

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Stem and shoot

Plant body

Structure of plant body: the first glance

- Shoot system (aboveground part: stems, leaves, buds, flowers, fruit)
- Root system (below-ground part: main roots and branches)
- Exceptions:
  - Some mosses and even ferns have only shoot system
  - Liverworts and hornworts frequently have only leaf-like thallus

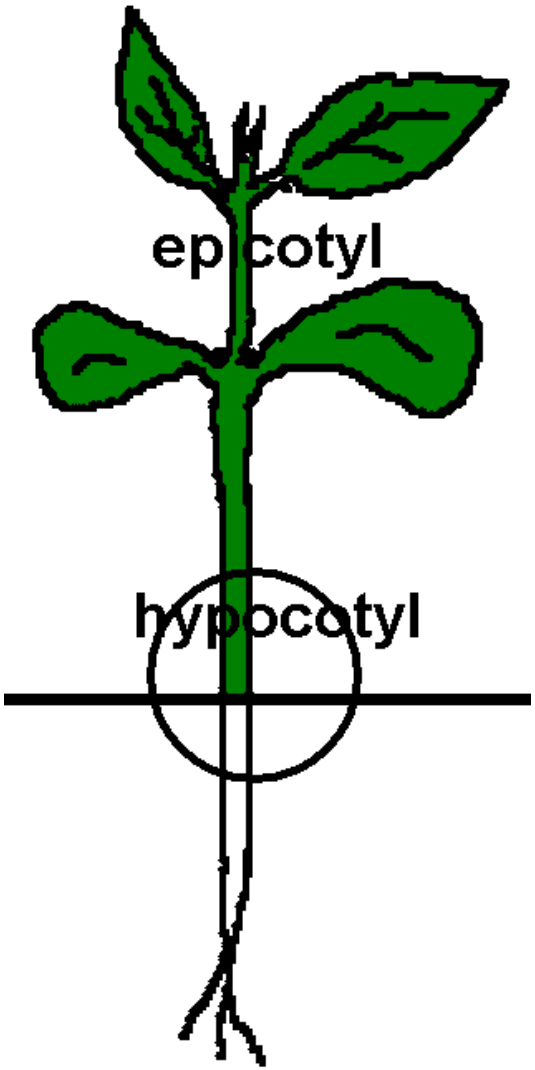
Types of plant body

- **Thallus** (flat, with non-differentiated organs)
- **Shoot** body (roots are absent)
- **Bipolar** body (root and shoot systems)

Organs of bipolar plant

- **Leaf**: flat lateral organ with restricted growth
- **Stem**: axial aerial organ with continuous growth
- **Root**: soil organ modified for absorption
- **Floral unit** (FU): stable element of generative system

Non-organs



- *Hypocotyl*: transition between stem and root
- *Epicotyl*: first internode of plant
- *Bud*: shoot “embryo”
- *Fruit*: temporary structure, ripe FU
- *Seed*: chimeric structure, has two or three genotypes

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Organ systems: final

- Shoot system: vegetative and generative
- Root system

Origin of tissues and organs of plants

- Land colonization. Challenge: drying. Response: **epidermis** and **parenchyma**. Thallus body plan.
- New level of competition. Response: shoot body plan. Problem: big weight. Solution: **collenchyma**.
- Competition grows again. Respose: grow higher. Weight grows. Response: use dead cells in **sclerenchyma**.
- Competition grows again. Response: grow faster. Solution: **meristems**.
- Size of plant is too big for plasmodesmata transportations. Solution: vascular tissues, **xylem** and **phloem**. Here plants with sporophyte dominance win the competition.
- Size of plant is too big for osmotic absorption of water. Solution: **absorption tissues**, roots, bipolar body plan. Now they are independent from water as much as possible—with an exception of generative system...
- Shoot system make leaves, stems and **branches**. Plants are facing new challenge!

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Summary

- Water deficit results in either sclerophyte or succulent adaptations
- Water excess results in hygrophyte or even hydrophyte adaptations

Shoot

Stem

Stem: definition and functions

- Axial vegetative organ of shoot with functions of support and transportation
- Other functions:
  A. Photosynthesis
  B. Storage
- Features:
  A. Radial structure
  B. No root hairs
  C. Continuous growth

Shoot
Development of stem tissues

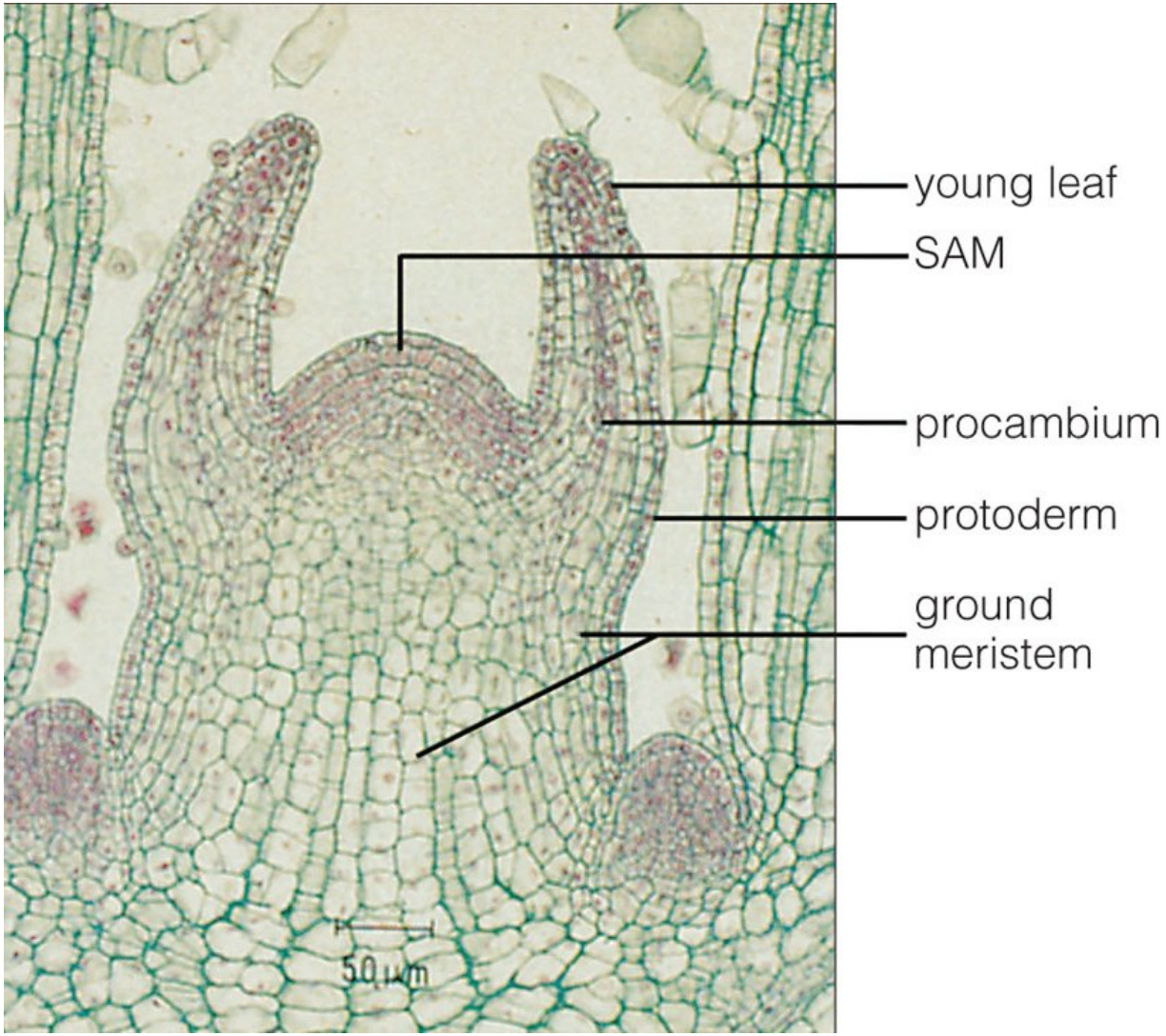
Protoderm to epidermis

- Stem apex meristem (SAM) produces **protoderm**
- Protoderm cells differentiate into epidermal cells

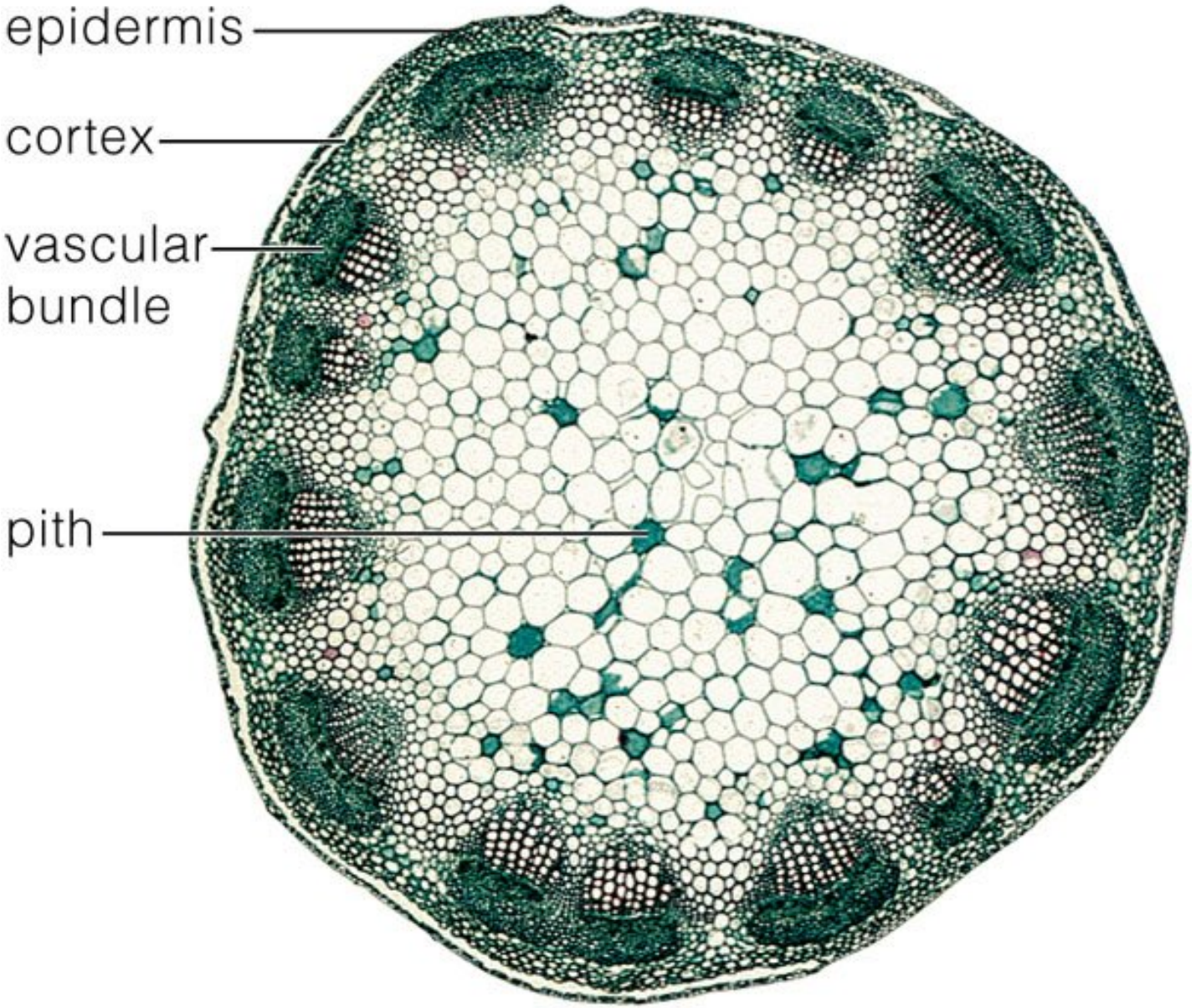
Ground meristem to cortex and pith

- SAM produces also **ground meristem**
- Ground meristem differentiates into **cortex** and **pith**
- Procambium raises between cortex and pith, it forms vascular bundles or vascular cylinder

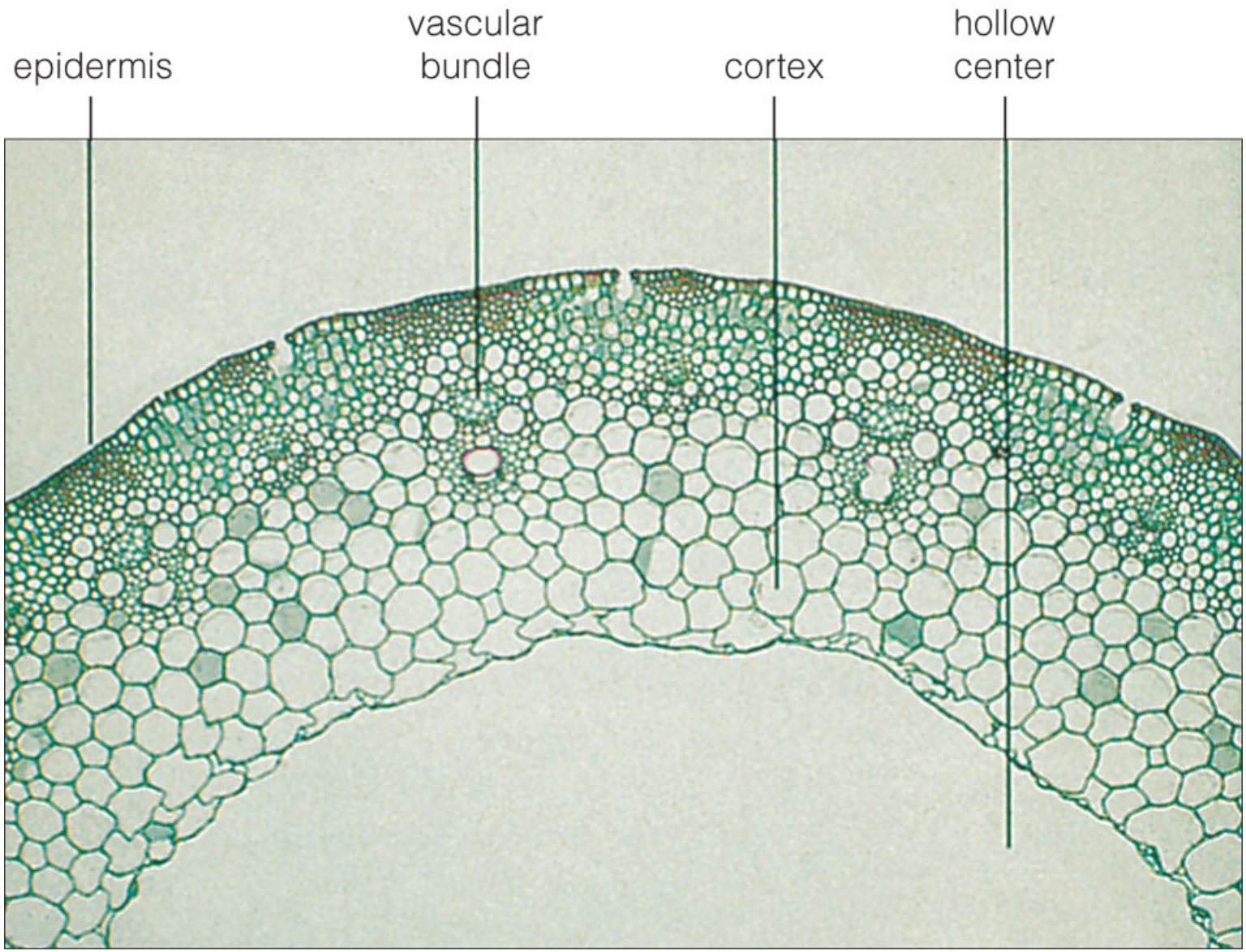
Three primary meristems: procambium, protoderm and ground meristem



Young stem with primary tissues



Older stem with hollow in the center

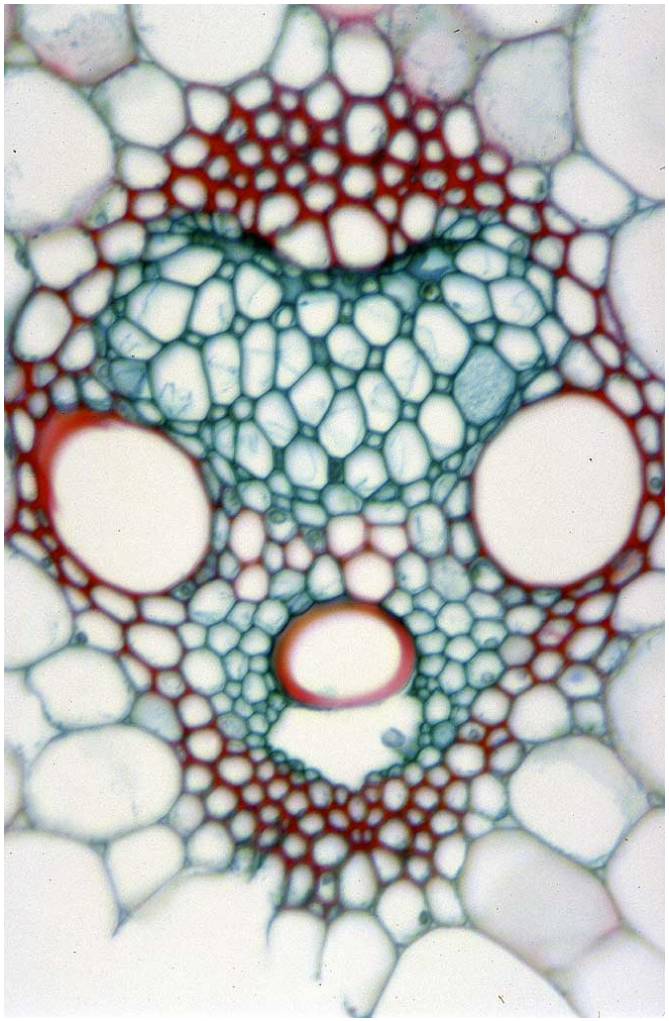


Procambium to xylem and phloem

- Outer layers of procambium form **primary phloem**
- Inner layers become **primary xylem**
- Middle layer could be completely spent **or** will make cambium for the secondary thickening
- Sometimes outermost layers of procambium form **pericycle** (parenchyma cells)
- In some cases, inner layers of cortex could form **endoderm**

Shoot
Anatomy of the primary stem

Vascular bundle (monocot)



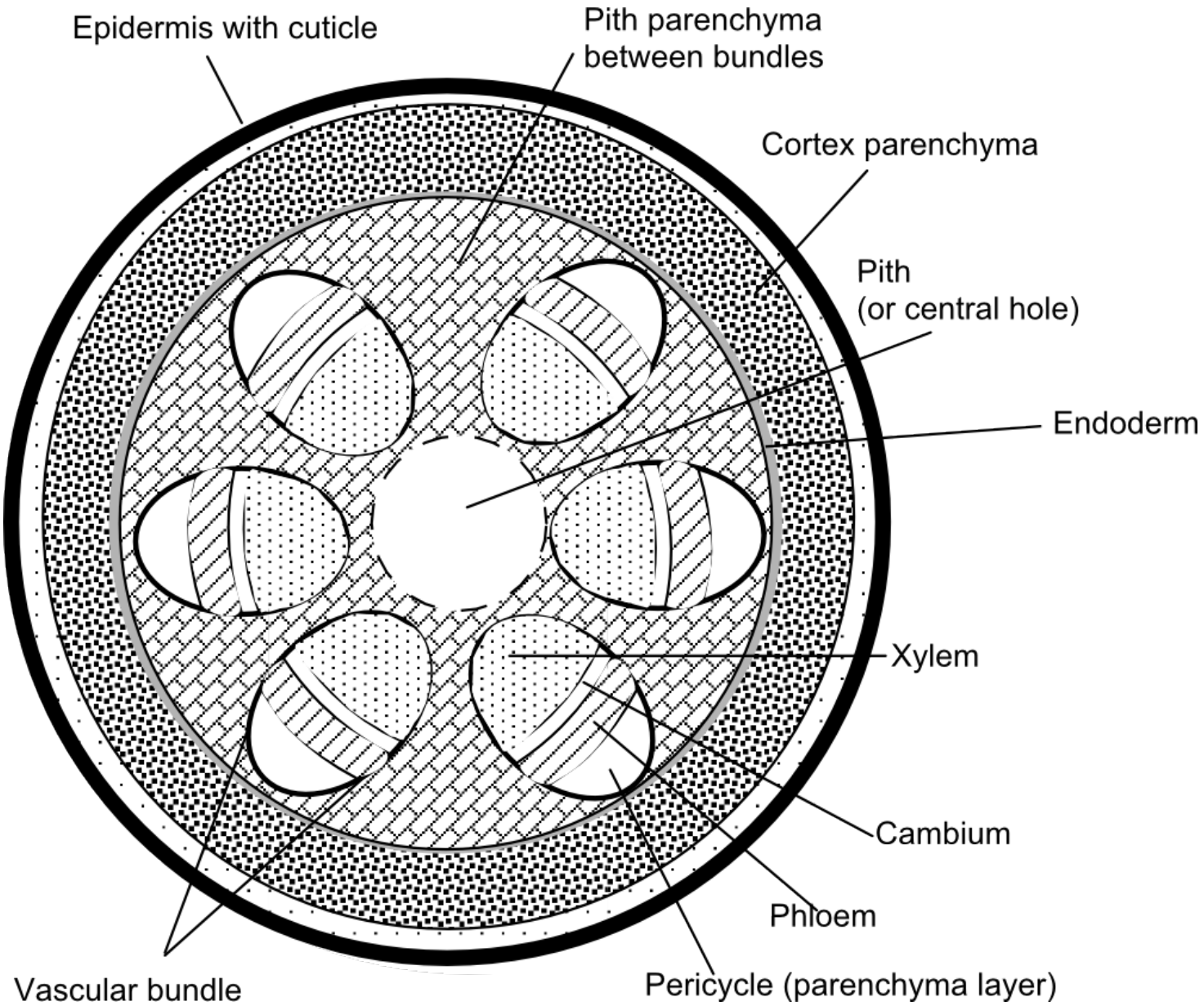
Corn (*Zea mays*) mature stem cross-section showing single vascular bundle, Brightfield (LM $\times$400)

Summary

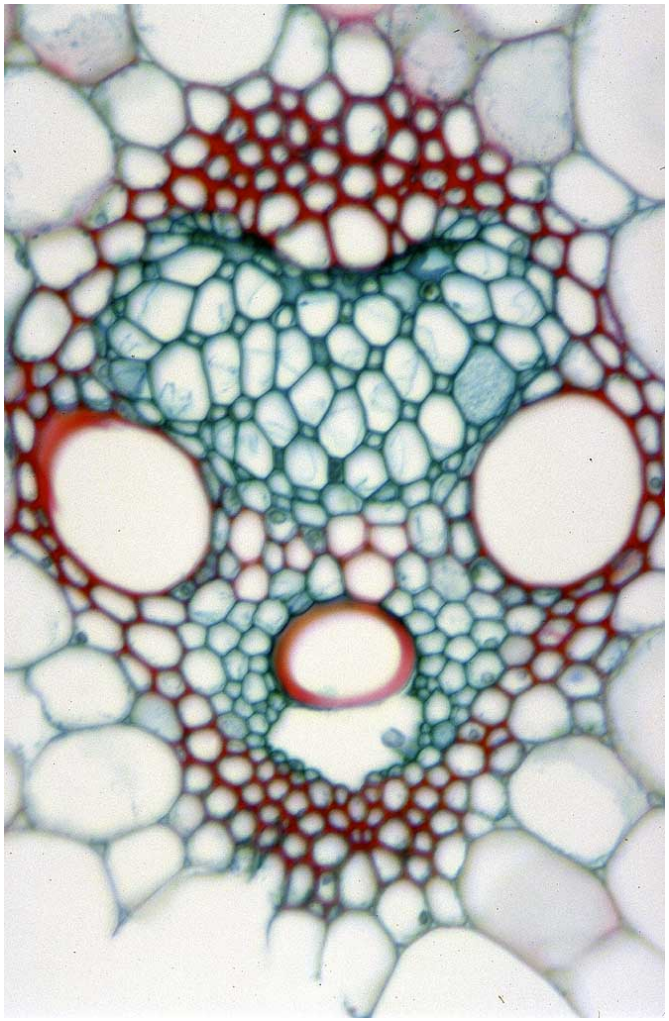
- SAM produces **protoderm** and **ground meristem**, ground meristem differentiates into **cortex** and **pith**
- Procambium forms **vascular bundles** or vascular cylinder

Shoot
Anatomy of the primary stem

Primary structure of stem

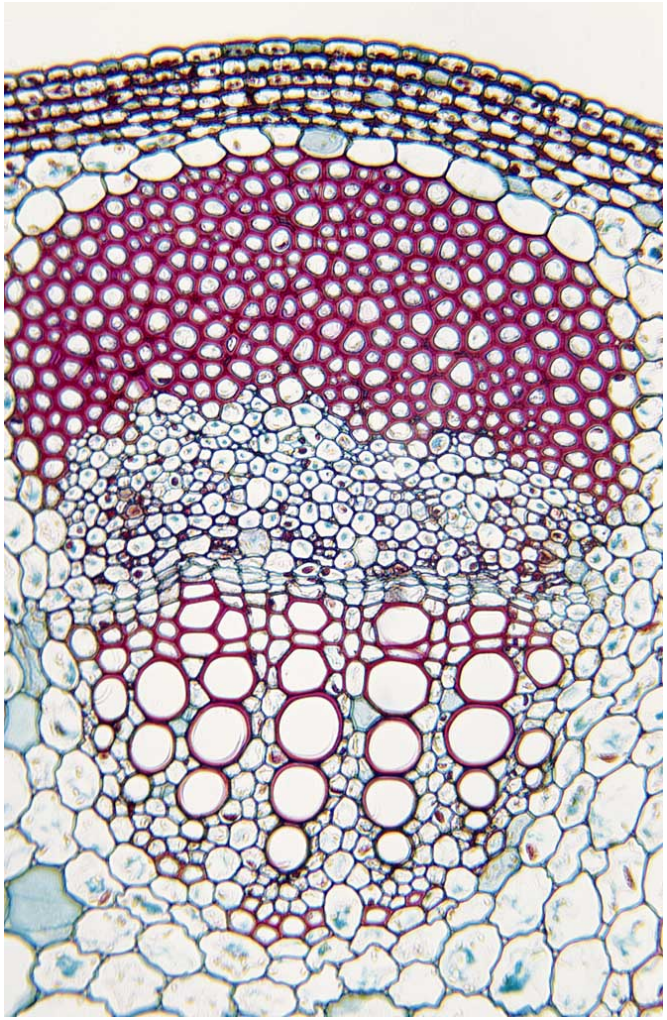


Vascular bundle (monocot)



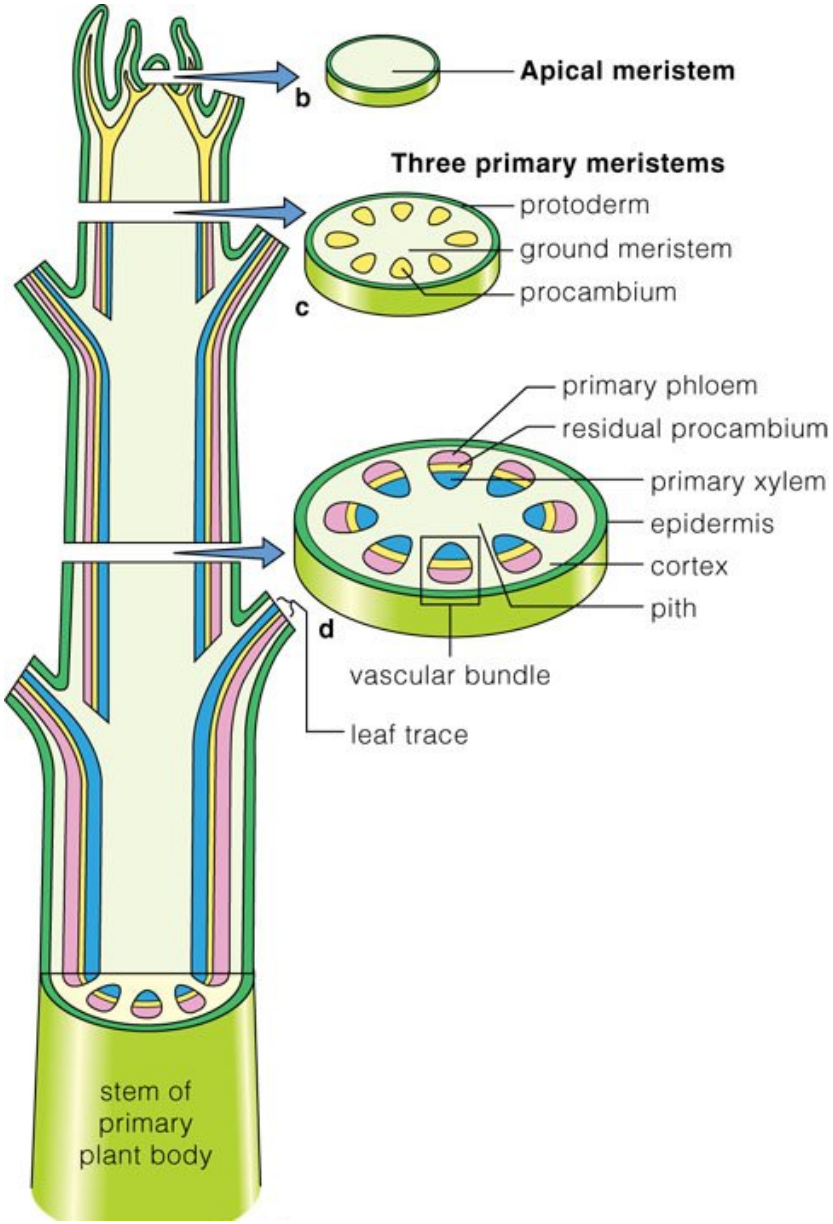
Corn (*Zea mays*) mature stem cross-section showing single vascular bundle, Brightfield (LM $\times$400)

Vascular bundle (asterid)



Wild Sunflower (*Helianthus* sp.) with nearly mature vascular bundle (LM $\times$35)

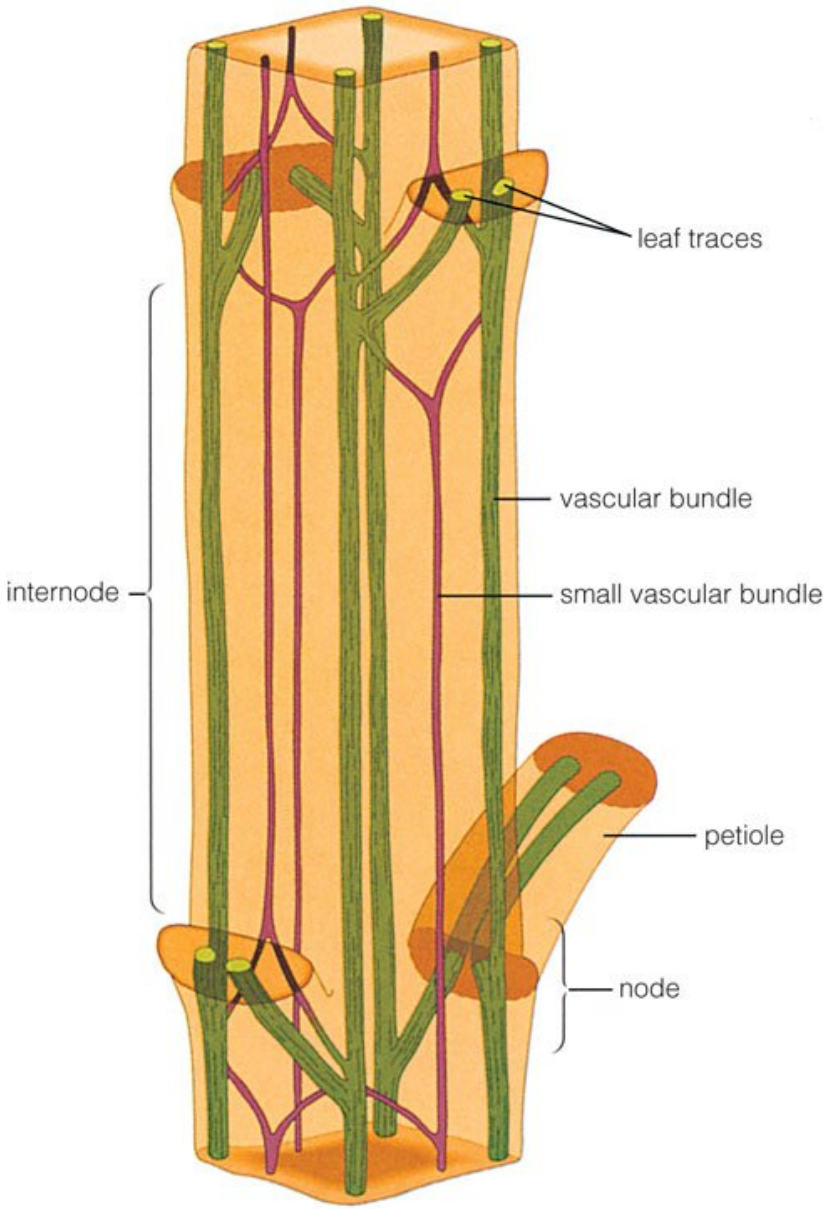
Origin of vascular bundles



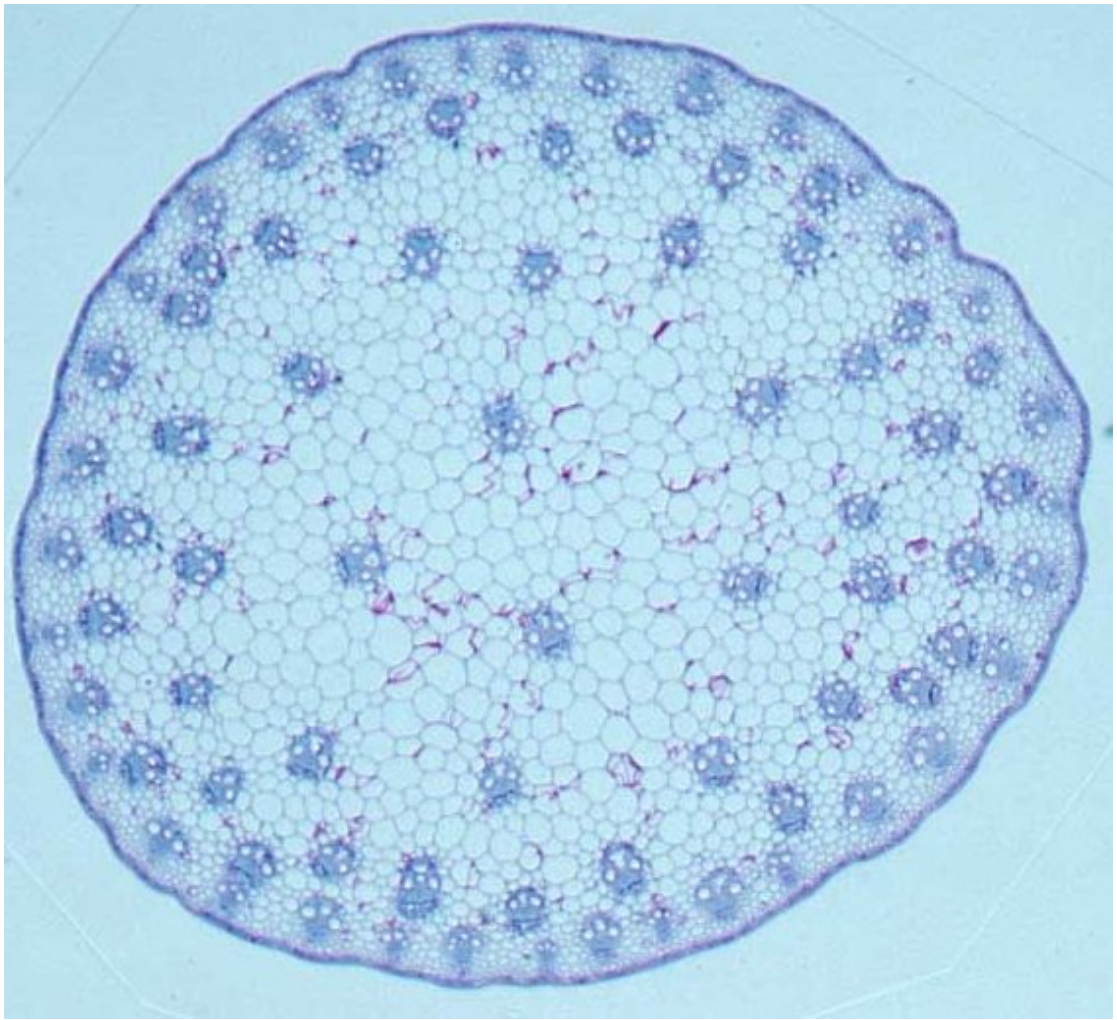
Vascular bundles

- Vascular bundles connect leaves and stems
- In many plants, they form **ring** on the cross-section of stem (“dicot” stem)
- Monocot stems usually have **dispersed** vascular bundles

Vascular bundles and leaf traces



Monocot stem

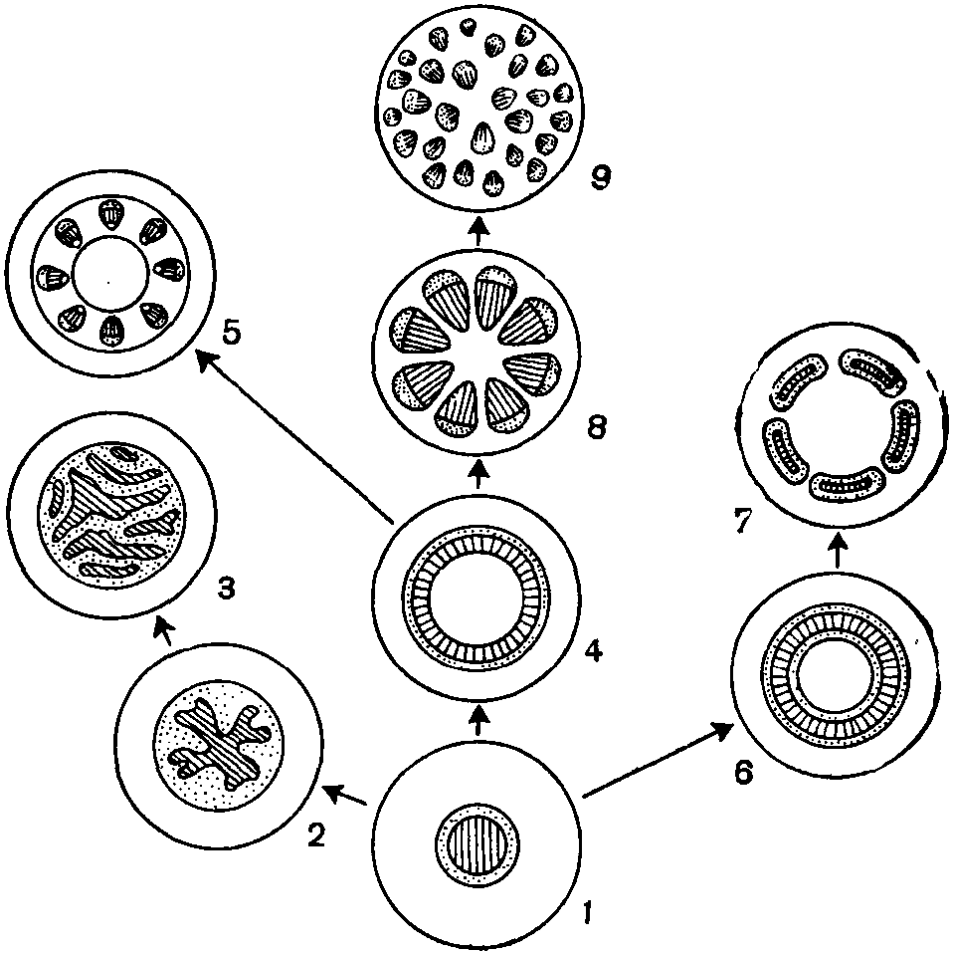


Corn (*Zea mays*) stem (LM $\times 4$)

Steles

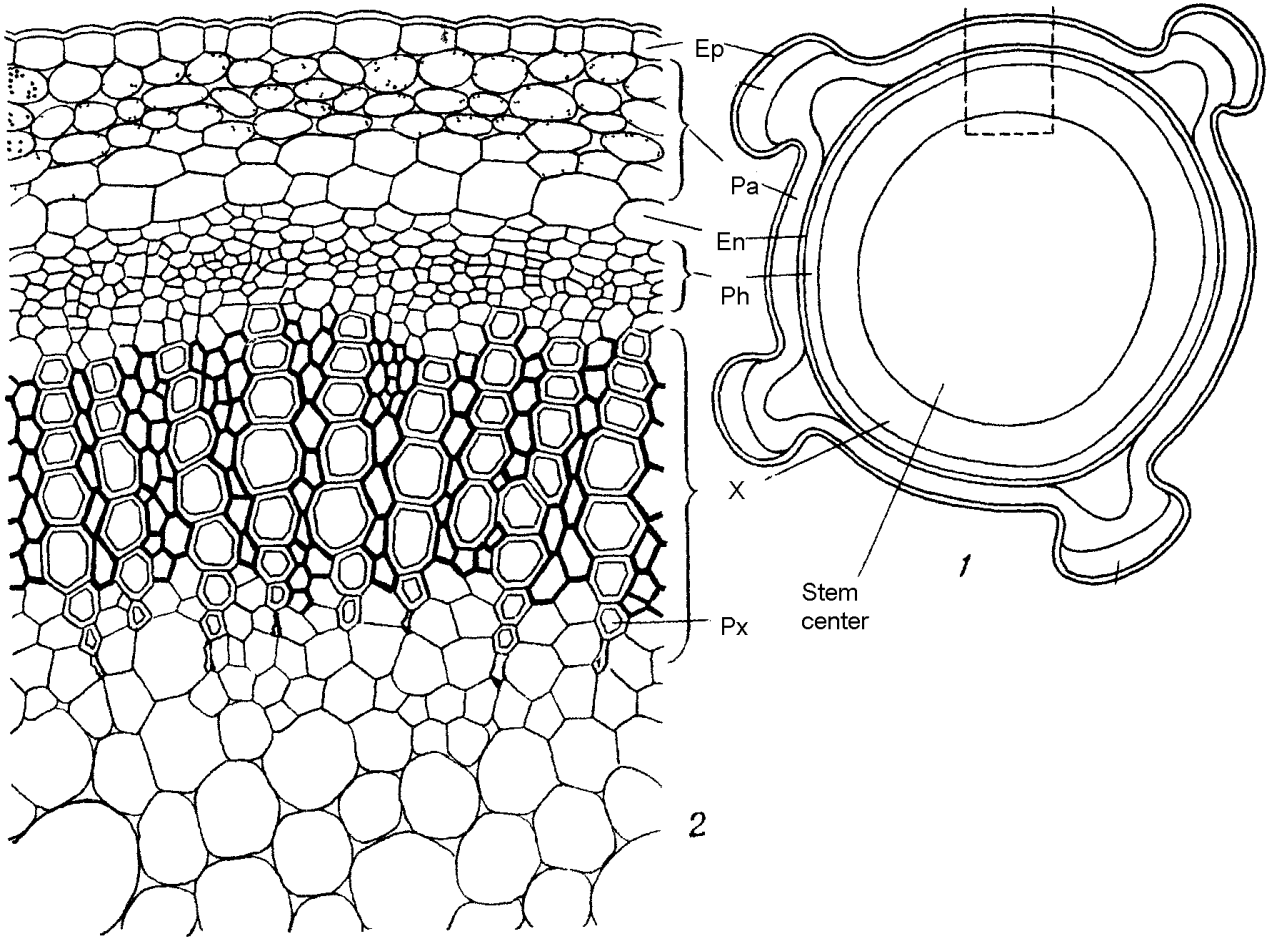
- **Stele** is an overall configuration of primary vascular system of plant stem
- The most important kinds of steles are: **protostele**, **solenostele**, **eustele** and **ataktostele**

Diversity of steles



(1) is protostele, (4) solenostele, (8) eustele (“dicot” stem), (9) ataktostele (monocot stem)

Vascular cylinder: alternative to ring of bundles



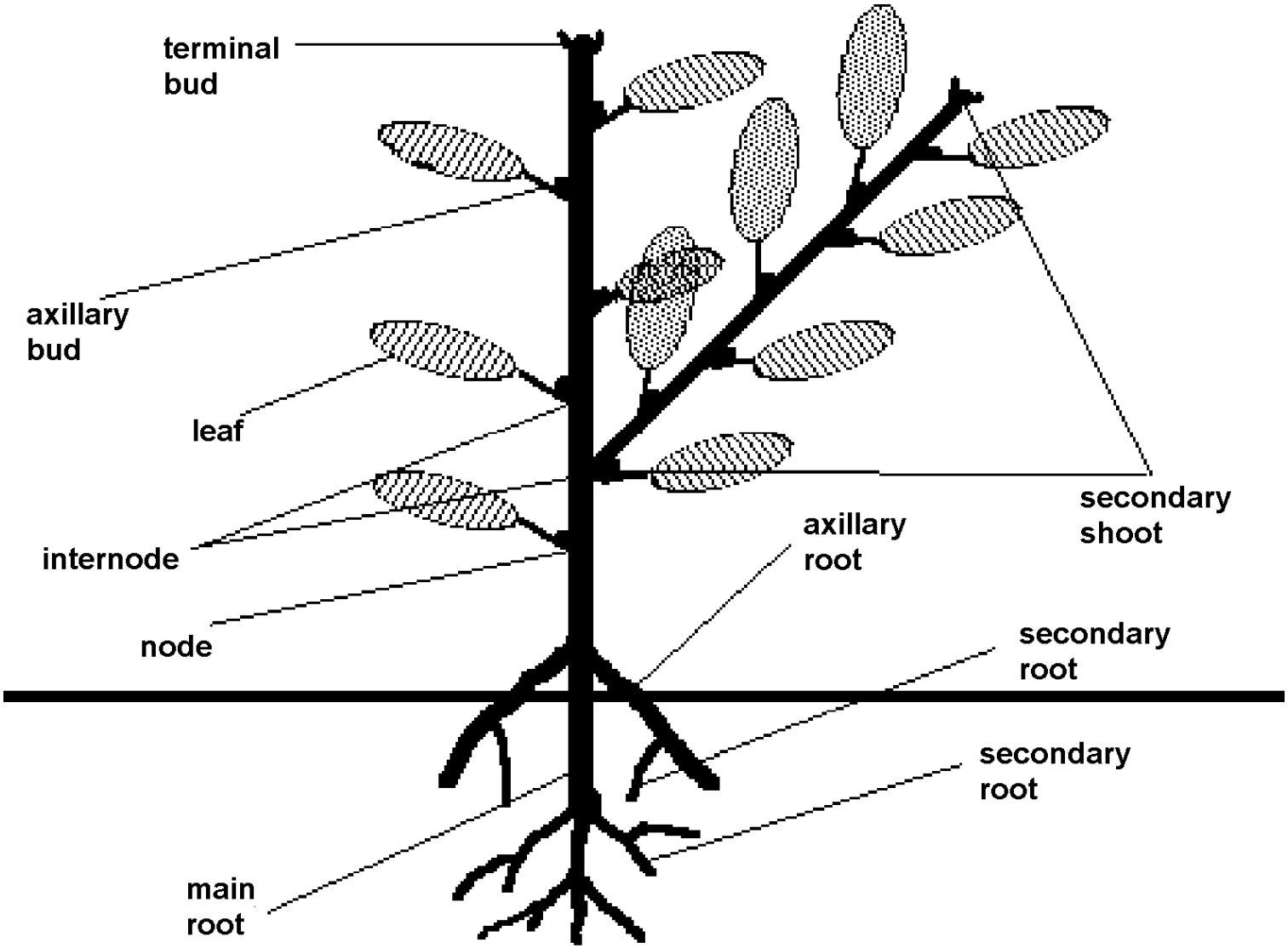
Sometimes, vascular bundles are so dense that they form almost a cylinder. We may call this vascular cylinder “solenostele” (#4 on the scheme of steles)

Shoot
Components of shoot

Components of vegetative shoot system

A. Main and secondary shoots
B. Terminal and axillary (lateral) buds
C. Nodes and internodes
D. Leaves

Components of shoot

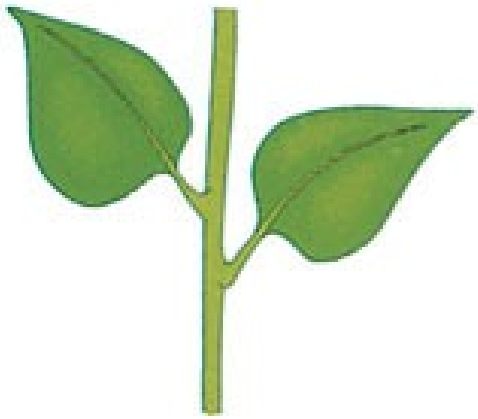


Shoot
Phyllotaxis

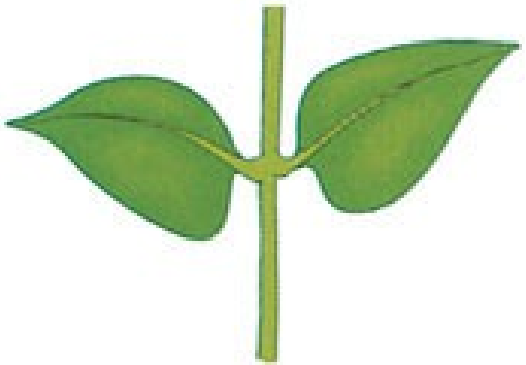
Arrangement of leaves: phyllotaxis

- One leaf per node: **spiral**, or **alternate** arrangement
- Two leaves per node: **opposite** arrangement, they may be:
  - All in same plane
  - Each pair will rotate on 90°
- $>$ 2 leaves per node: **whorled** arrangement (each whorl can also rotates)
- Each type of phyllotaxis has its own *angle of divergence*

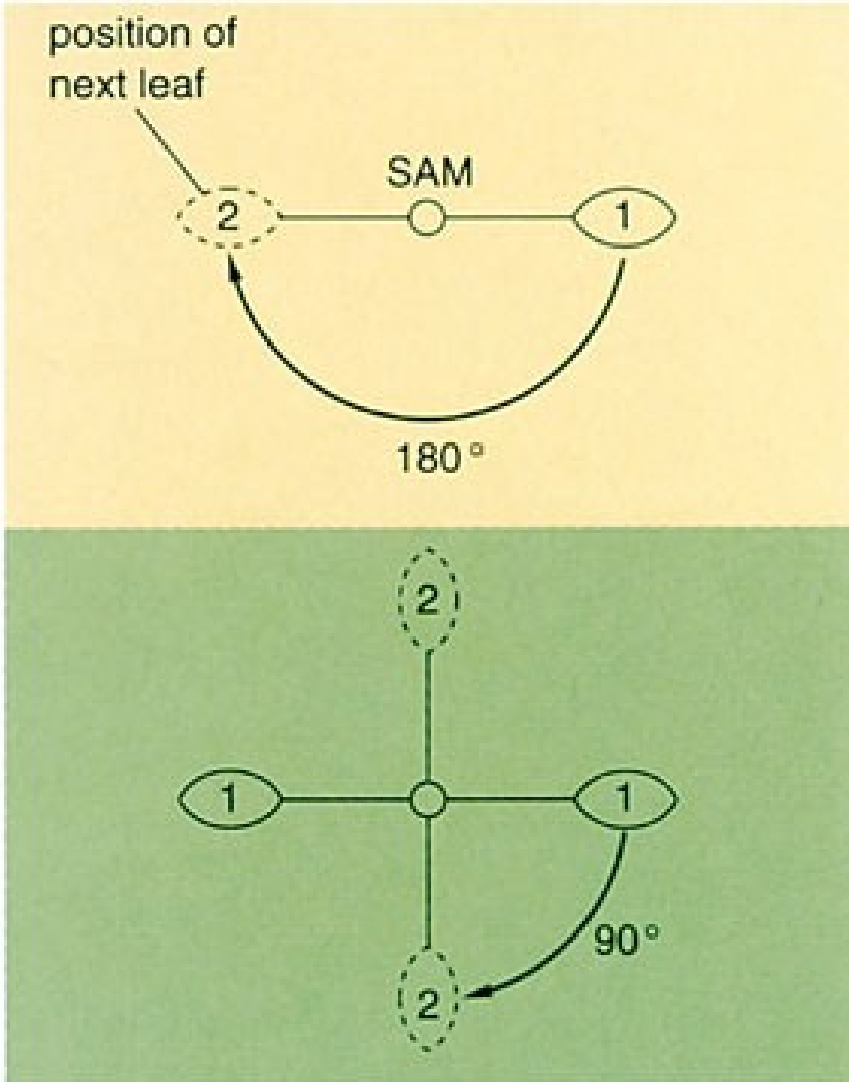
Alternate and opposite phyllotaxes



alternate



opposite



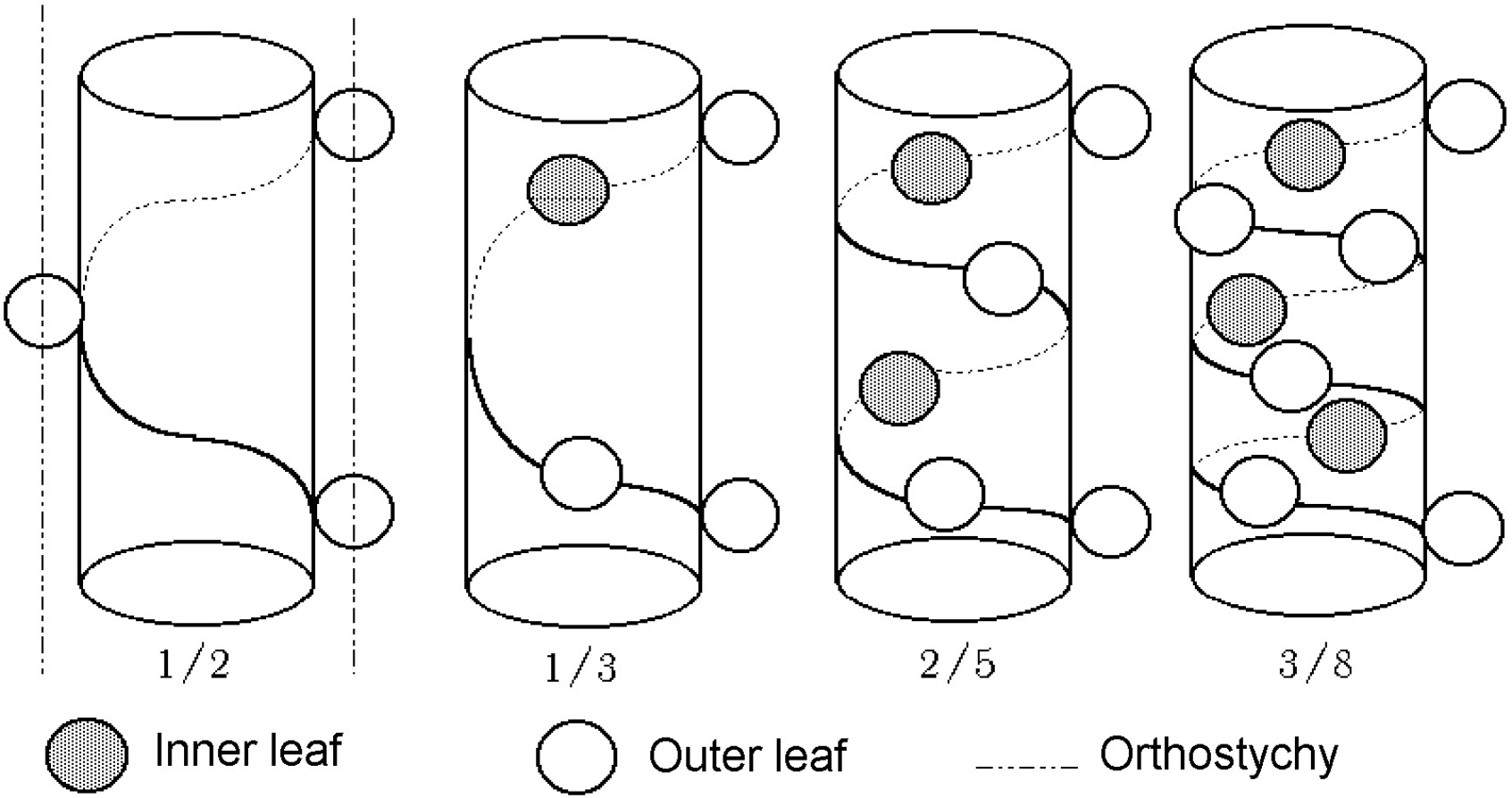
Spiral phyllotaxis: Fibonacci rule

- Multiple types of leaf spiral leaf arrangement mostly follow **Fibonacci rule**
- Formulas of leaf arrangements is very similar to Finobacci fractions: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, *et cetera*
- Numerator is number of spiral circulations, denominator is number of leaves in a series (counted from zero)
- Denominator gives the number of **orthostychy** (this is plural)

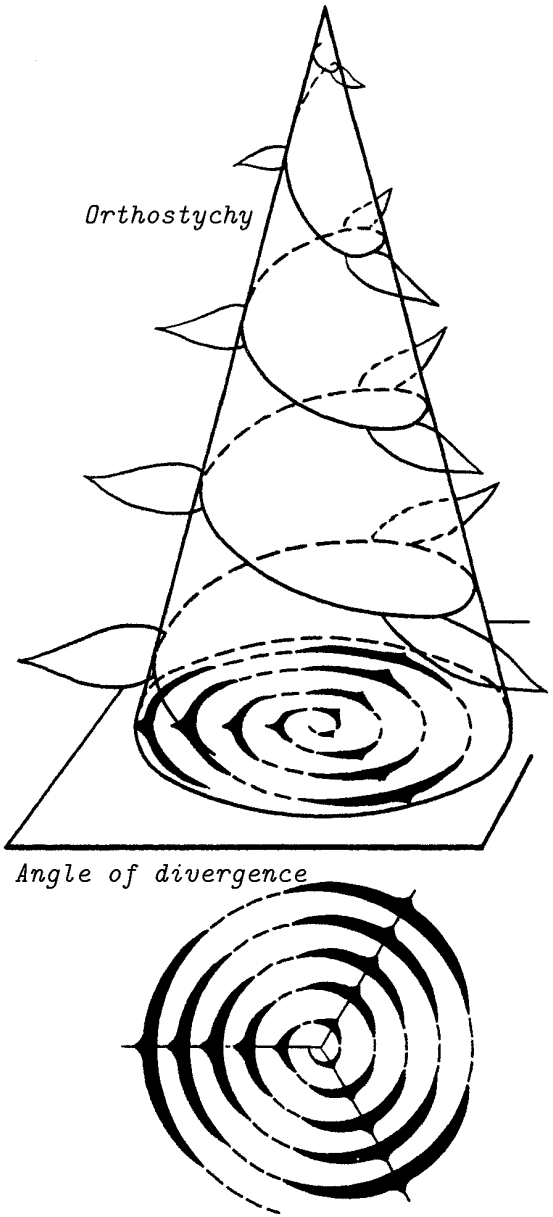
Spiral phyllotaxis: how to make a formula

- Take a branch, find any leaf (it will be leaf #0)
- Find the second one which is located in the same position (exactly above or exactly below leaf #0)
- Count how many leaves are in this series (start from 0), this will be a denominator
- Imagine (or use a real thread) a spiral which go from leaf #0 to the last leaf of series, count how many times this spiral circulate the stem—this is a numerator

Spiral phyllotaxis: orthostychy



Spiral phyllotaxis: angles of divergence for 1/3



Final question (2 points)

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What is procambium?

For Further Reading

A. Shipunov.
Introduction to Botany [Electronic resource].
Mode of access:
http://ashipunov.info/shipunov/school/biol_154