Introduction to Botany: BIOL 154
Study guide for Exam 3

Alexey Shipunov

Lectures 17–26

Outline

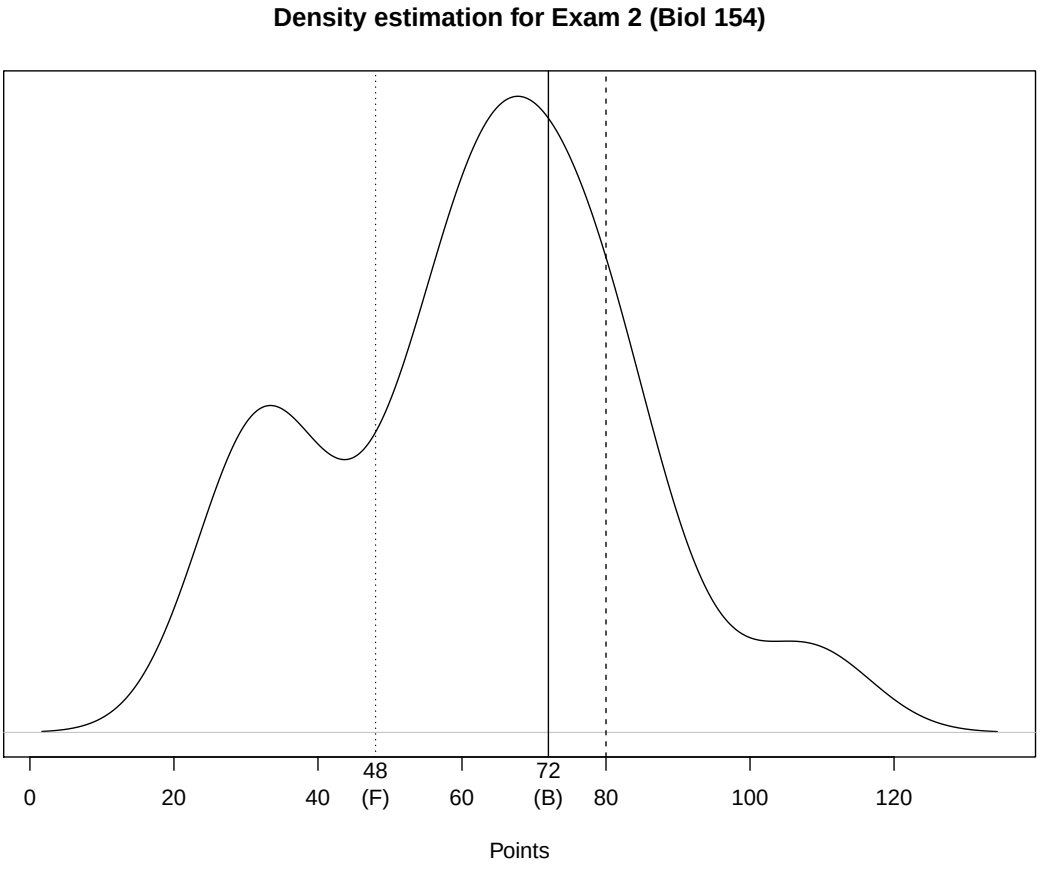
Contents

1 Questions and answers

Results of Exam 2: statistic summary

```
Summary:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
  27.00   51.75   64.50   62.69   77.50  109.00       3
Grades:
  F   D   C   B max
 48  56  64  72  80
```

Results of Exam 1: the curve



1. Two motile but unequal cells fused during syngamy. How to call these cells?

   (a) "+" and "−"

   (b) **Male and female**

   (c) Spermatozoon and oocyte

   (d) All of above

7. Which of the following is NOT associated with a chloroplast?

   (a) Double membrane system

   (b) DNA

(c) Ribosomes

(d) **Cell wall**

(e) Chlorophyll

46. Multicellular organisms:

(a) **Could function without specialized cells**

(b) Always have specialized reproductive cells

(c) Always have specialized tissues

Previous final question: the answer

Why is diplont better?

- Delaying the effect of recessive lethal mutations
- Diverse alleles (variants of one gene) increase adaptability
- In theory, better adapted for the intensive protein production

2 Tissues

2.1 Origin of tissues

Origin of tissues and organs of plants: first steps

Why did plants go to the land? Which problems did they meet and how did they resolve them? What was the plant way of acquiring tissues comparing with animals?

2.2 Tissues basics

Definition of tissues and organs

- **Tissue** is a union of cells which have common origin, function, and similar morphology
- **Organ** is a union of different tissues which have common function(s) and origin

Simple and complex tissues

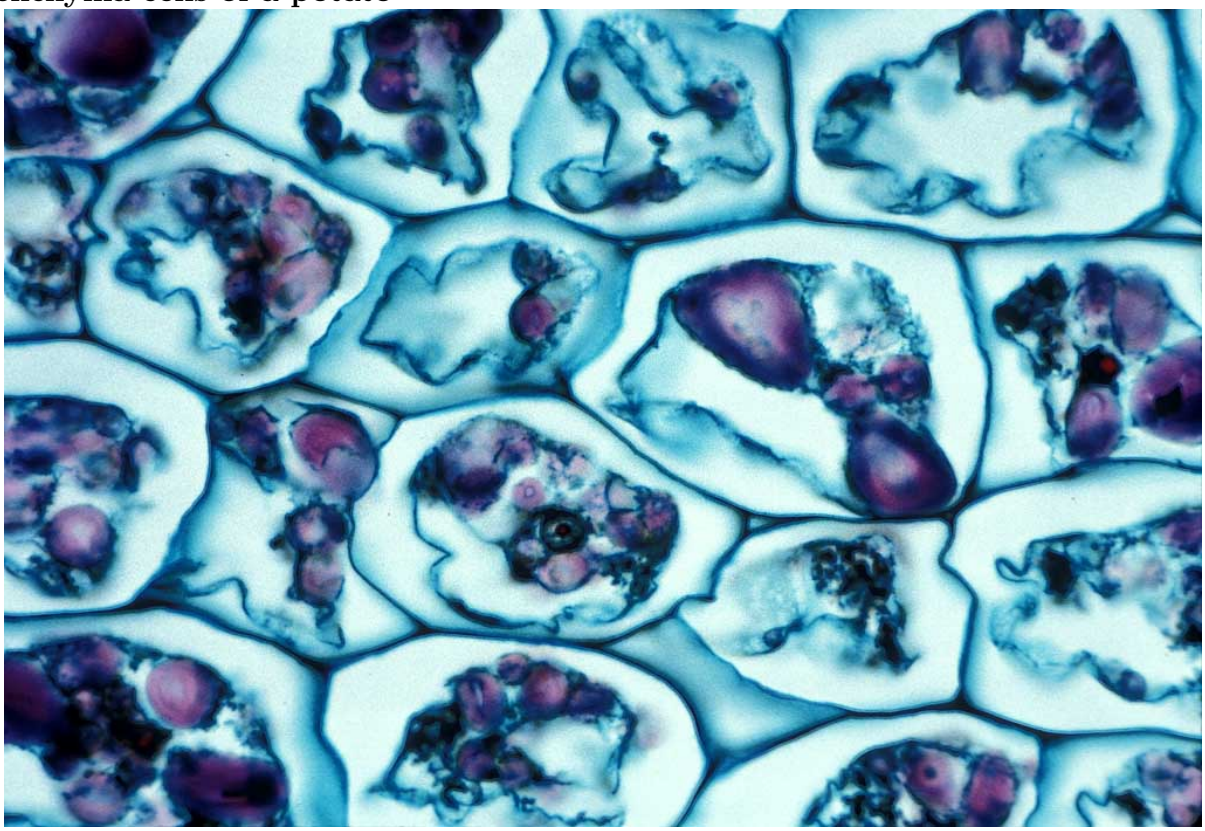
- **Simple tissues** have only one kind of cells
- **Complex tissues** have more than one cell type. This tissue type is unique for plants

2.3 First tissues: parenchyma and epidermis

Parenchyma (ground, main tissue)

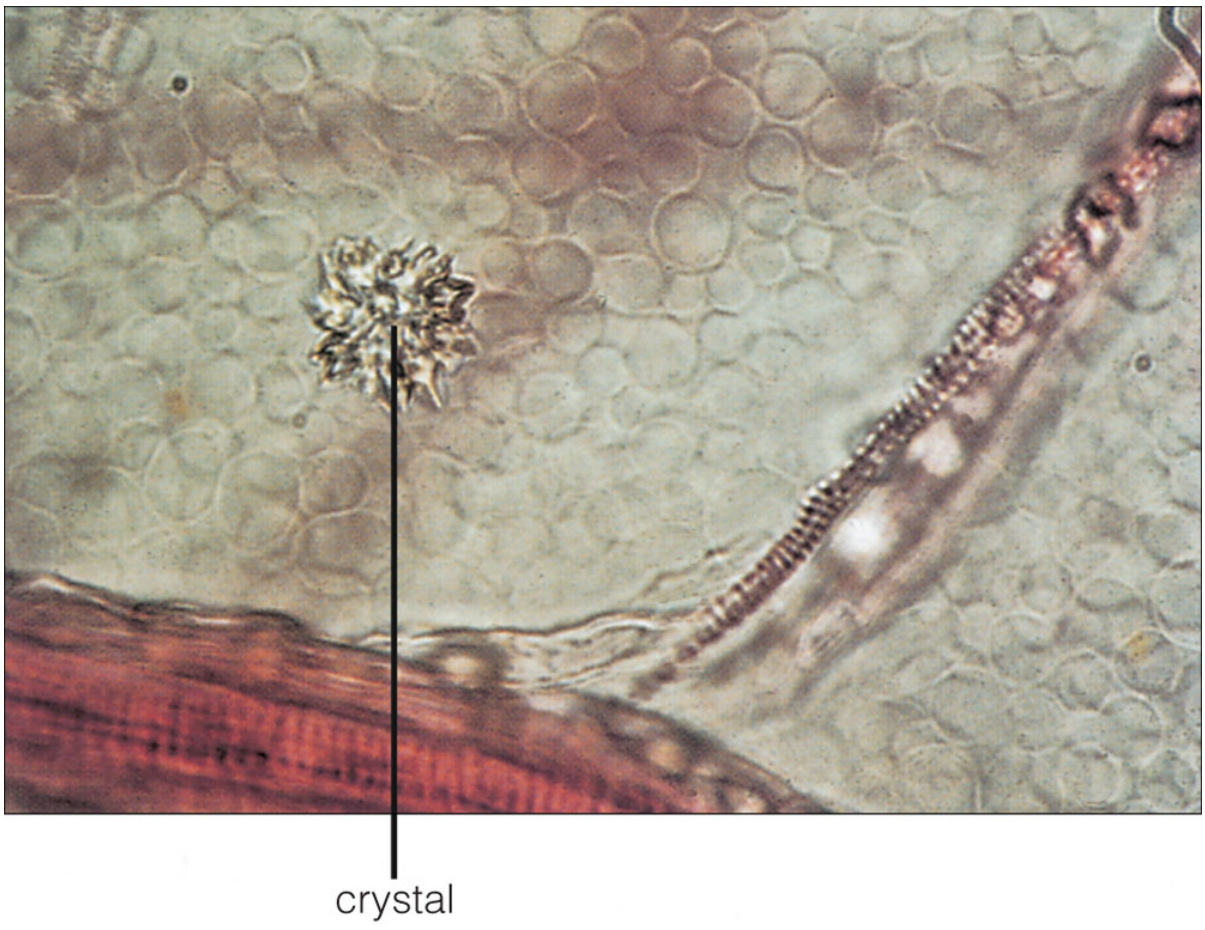
- Spherical or elongated cells
- Thin primary cell wall
- Sometimes, crystal inclusion bodies
- Main functions: photosynthesis and storage

Parenchyma cells of a potato



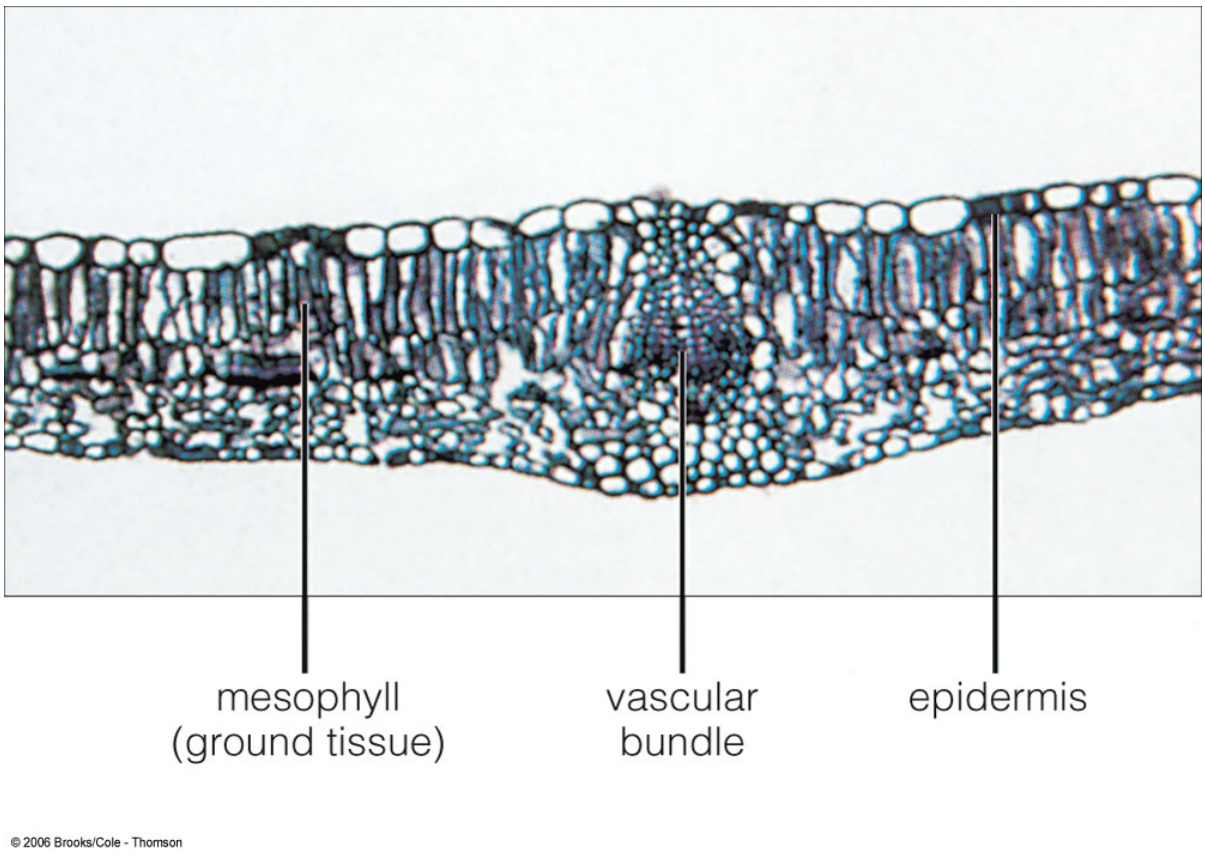
Parenchyma cells of a potato; the central cell shows obvious nucleus with starch stained purple (LM ×83)

Parenchyma with crystals



Parenchyma cells often include crystals (e.g., of calcium oxalate)

Photosynthetic parenchyma



Photosynthetic parenchyma in lilac (*Syringa vulgaris*) leaf

Epidermis: the complex tissue

- Complex tissue of different cell types:

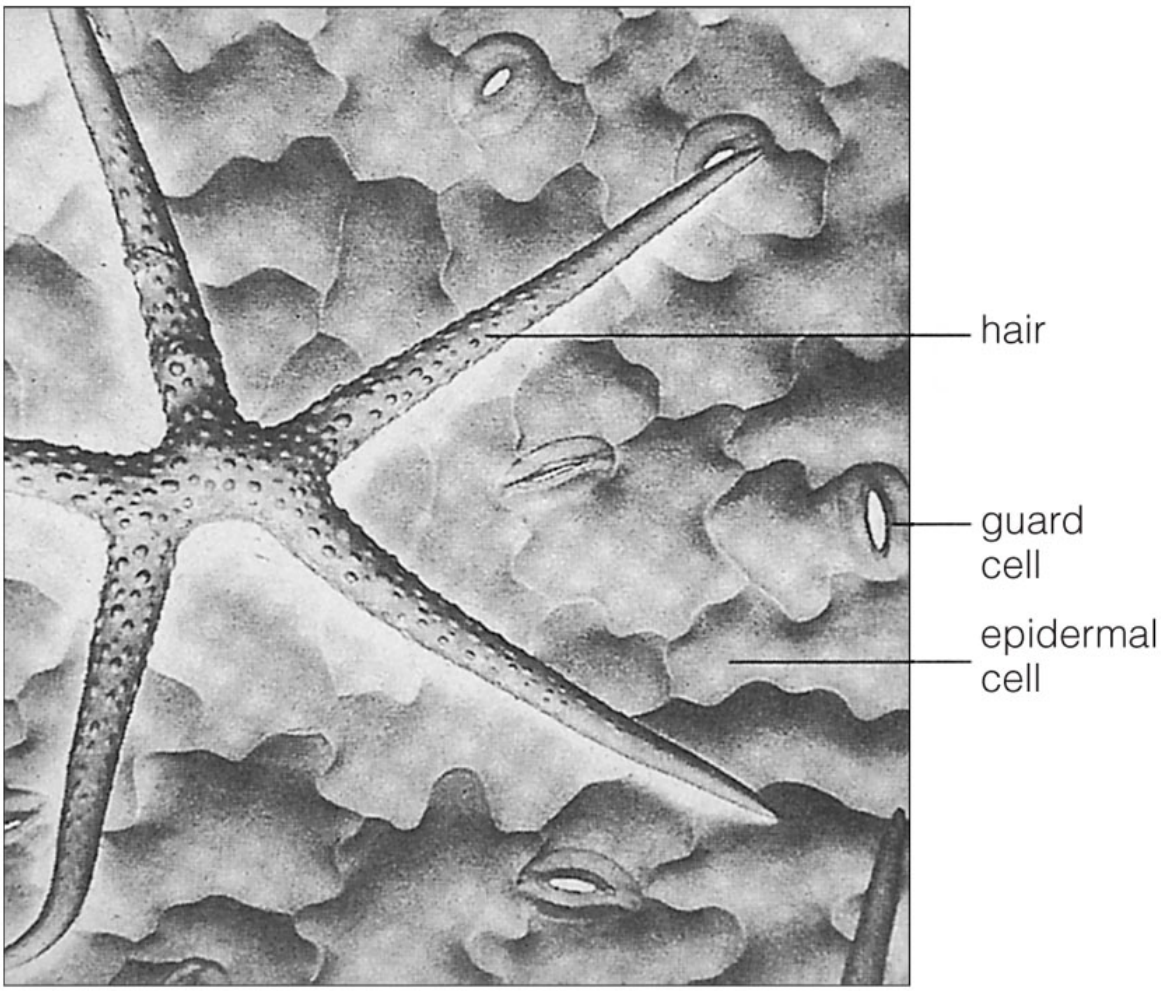
  1. Epidermal cells
  2. Stomata cells:
     - Guard cells

Subsidiary cells

Trichomes

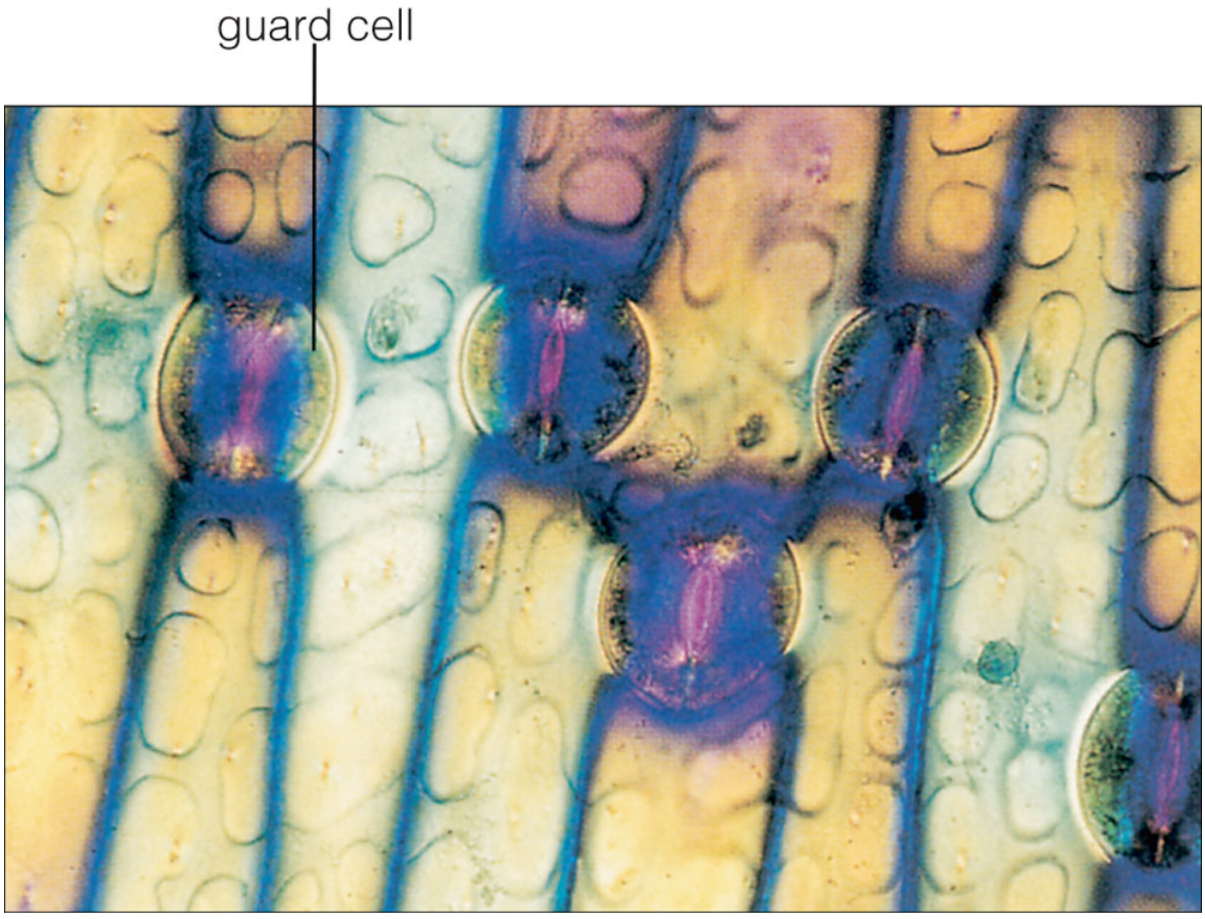
- Shapes and chemical compounds vary
- Main functions: gas exchange, transripration, defense

Epidermal cells



Three kinds of Shepard's purse (*Capsella bursa-pastoris*) epidermal cells

Stomata



Stomata with guard cells and pores (*Iris* sp.)

Final question (2 points)

How are plant tissues different from animal tissues?

Summary

- The structure of plant body, its organs and tissues is a result of land colonization
- **Complex tissues** have different cell types, **secondary tissues** originate from lateral meristems (i.e., cambium)
- **Parenchyma**, or ground tissue, is a main component of young plant organs
- **Epidermis** is a complex tissue which includes stomata

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 4*.

Outline

Contents

3 Questions and answers

Previous final question: the answer

How are plant tissues different from animal tissues?

- Live on land vs. hunting
- Epidermis with cuticle and stomata + parenchyma vs. kinoblast + phagocytoblast
- Sometimes complex vs. always simple

4 Tissues

4.1 Origin of tissues

Origin of tissues and organs of plants: first steps

- Plants went on land:
    1. To escape from competition
    2. To escape from predators
    3. To obtain several times more more light
    4. To escape from temperature-gases conflict
- To prevent drying, they develop a "plastic bag" (**epidermis** with cuticle) and regulated pore system (stomata)
- The rest of their body was parenchyma (main, or ground tissue)

More about plants$_2$ classification

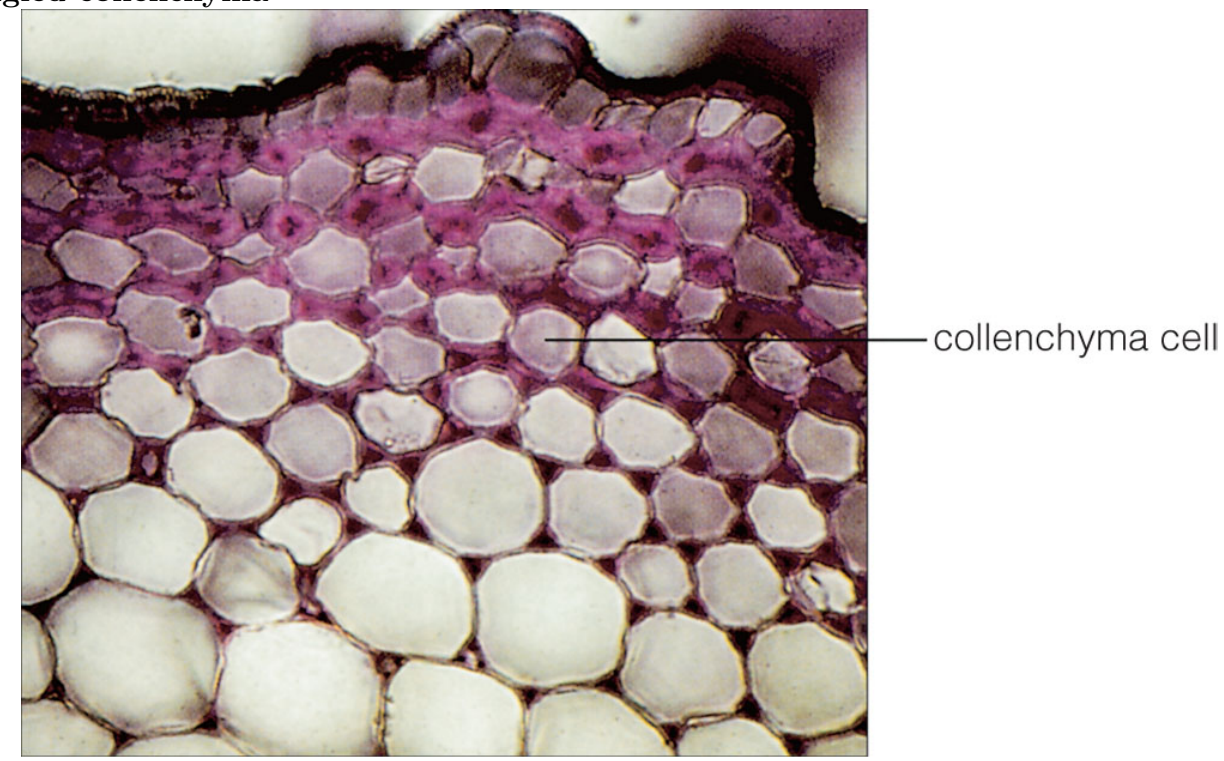
- Mosses (Bryophyta)
- Ferns and allies (Pteridophyta)
- Seed plants (Spermatophyta)
  - Conifers (Pinopsida)
  - Some other classes of seed plants
  - Angiosperms (Magnoliopsida)
    - Monocots (Liliidae)
    - Other subclasses of angiosperms (together: "dicots")

4.2 Step two: skeleton. Supportive tissues

Collenchyma: living supportive tissue

- Elongated cells
- Thick primary cell wall (pectins + cellulose)
- Main functions: mechanical support of young stems and leaves

Angled collenchyma

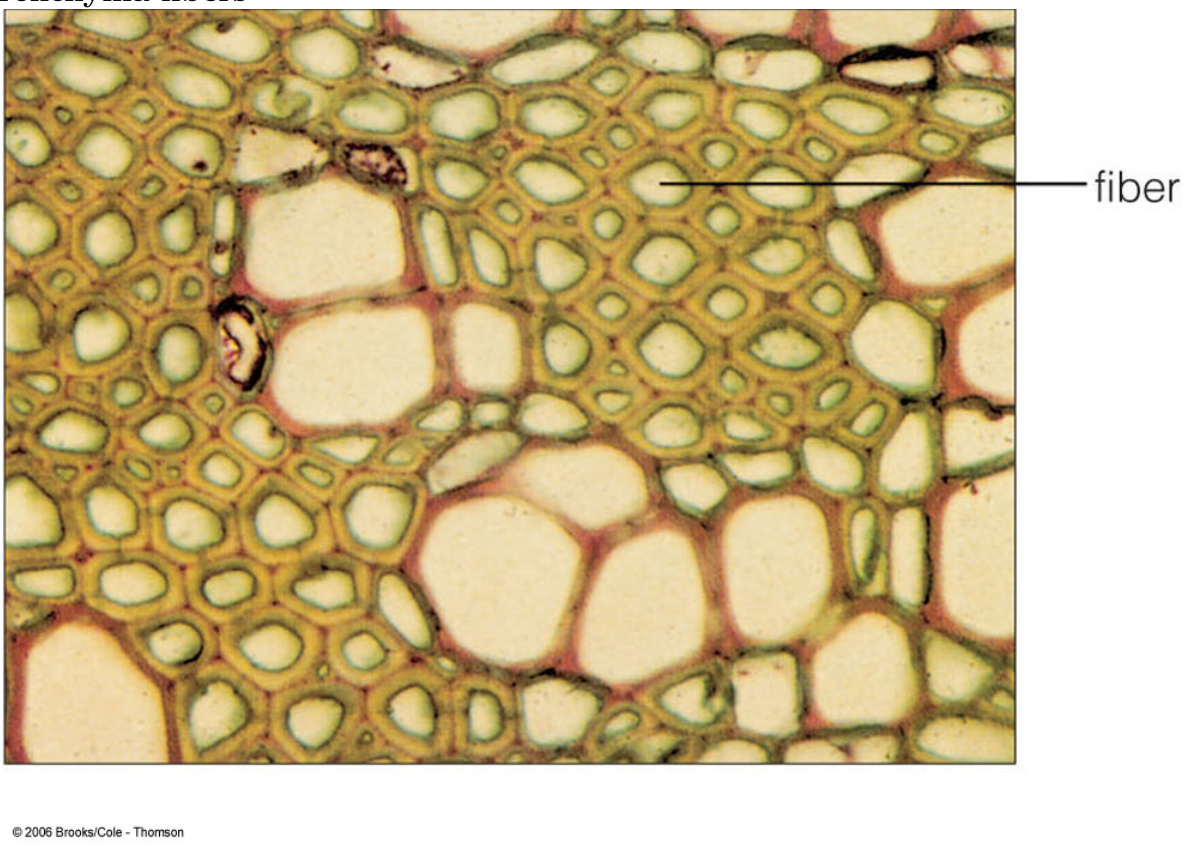


Collenchyma cells of marigold (*Calendula officinalis*)

Sclerenchyma: dead supportive tissue

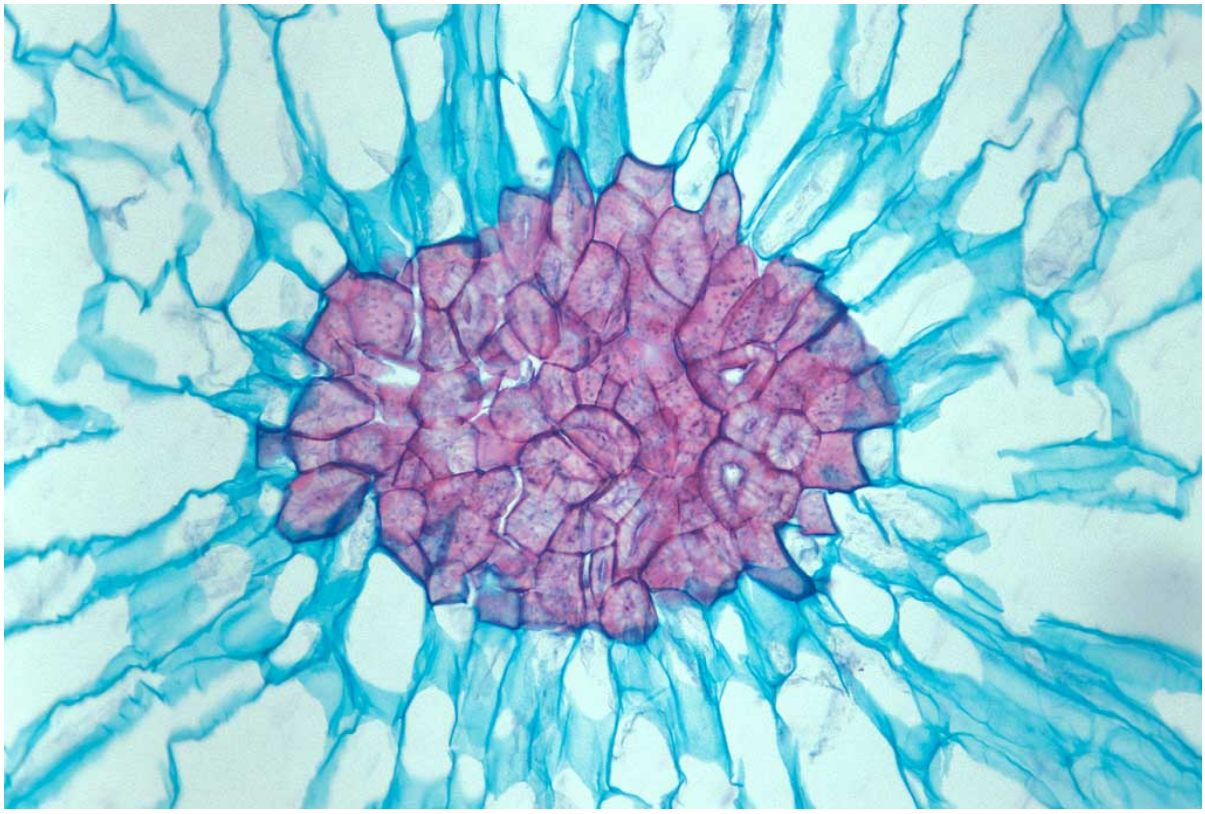
- Long cells (sclerenchyma fibers) or short crystal-like cells (sclereids)
- Dead cells with thick secondary cell wall, rich of lignin
- Supports weight of older plant organs, makes fruits non-edible before they become rip, makes stems firm

Sclerenchyma fibers



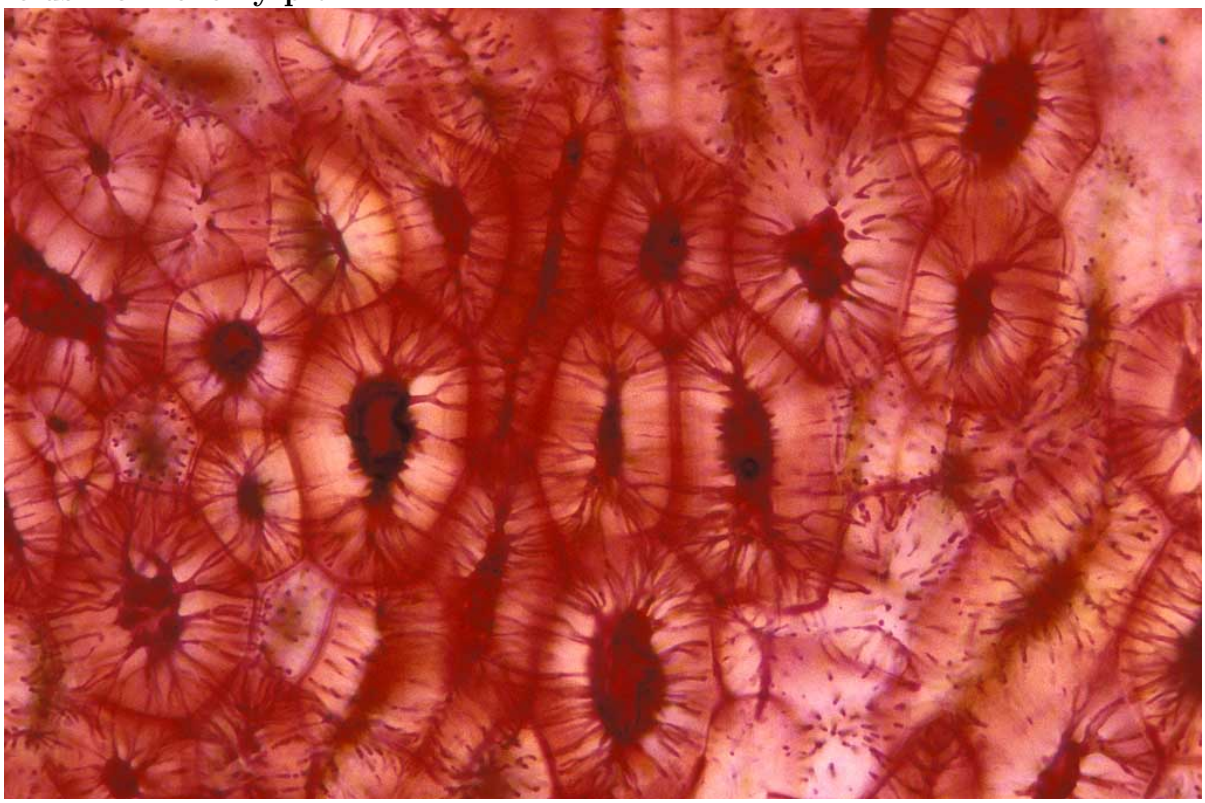
Cross-section of sclerenchyma fibers in geranium (*Pelargonium* sp.)

Stone cells



Stone cells (kind of sclereids) in pear fruit (*Pyrus communis*)

Sclereids from cherry pit



Sclereids from cherry (*Prunus* sp.) pit (LM ×400)

4.3 Step three: construction sites. Meristems

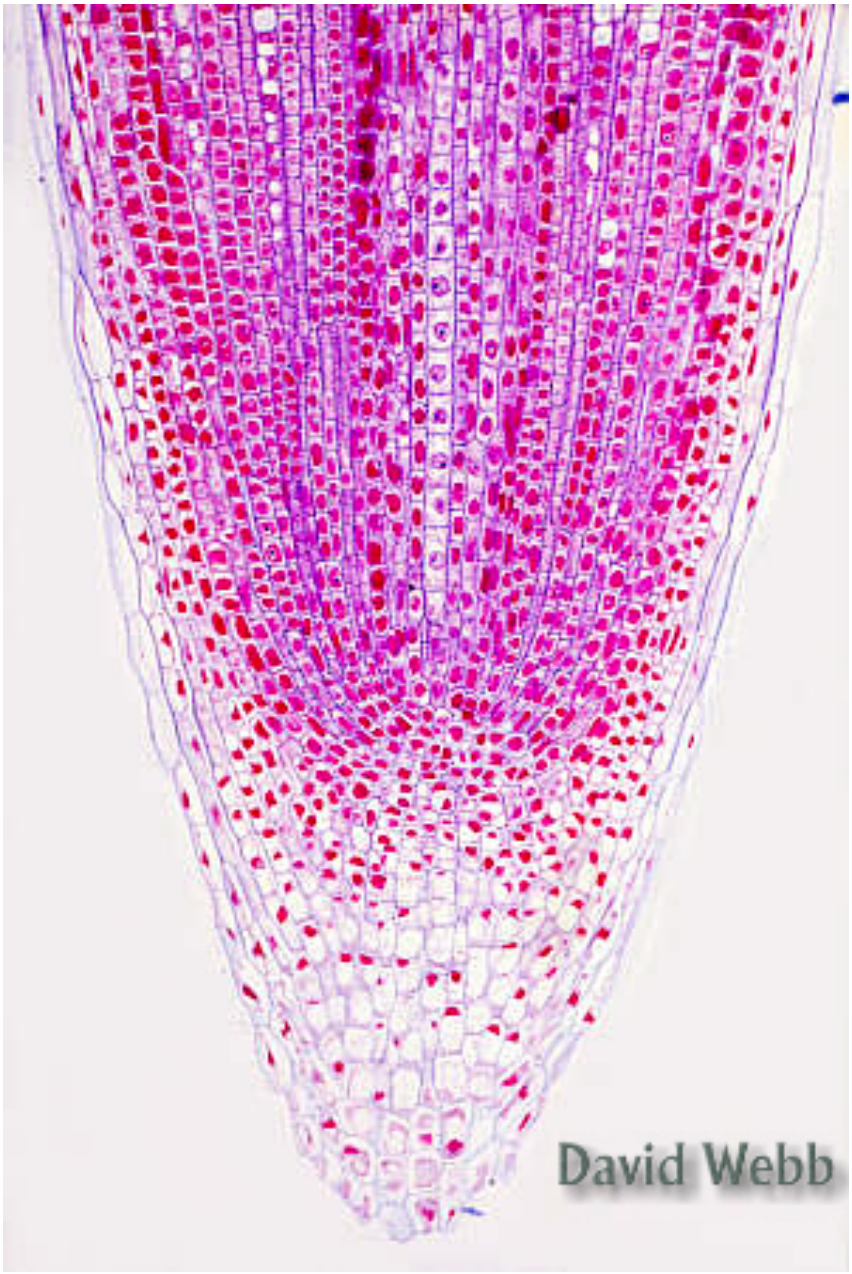
Meristems: apical

- Centers of plant development
- Locate on the very ends of roots (RAM) and shoots (SAM)
- Produce intermediate primary meristems which form all primary tissues

SAM

Coleus sp. stem apical meristem (LM ×100); primordia (embryonic leaves) are visible.

RAM



Corn (*Zea mays*) root apical meristem (© D. Webb)

Lateral meristem: cambium

- Originates from procambium which in turn originates from apical meristems
- Usually arises between two vascular tissues
- Main function: thickening. Produces secondary vascular tissues

Primary and secondary tissues

- Primary tissues originate from stem or root apex through primary meristems
- Secondary tissues originate from lateral meristems

Additional meristems

- **Intercalary** meristems: locate in stems, regulates stem elongation
- **Marginal** meristems are leaf-specific, they regulate leaf shape
- **Repair** meristems help to cure wounds, they form buds and roots in unusual places

Final question (2 points)

What is the difference between collenchyma and sclerenchyma?

Summary

- **Collenchyma** and **sclerenchyma** are simple supportive tissues
- **Secondary tissues** originate from lateral meristems (i.e., cambium)

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 4*.

Outline

Contents

5 Questions and answers

Previous final question: the answer

What is the difference between collenchyma and sclerenchyma?

- Alive vs. dead
- Primary vs. secondary cell walls

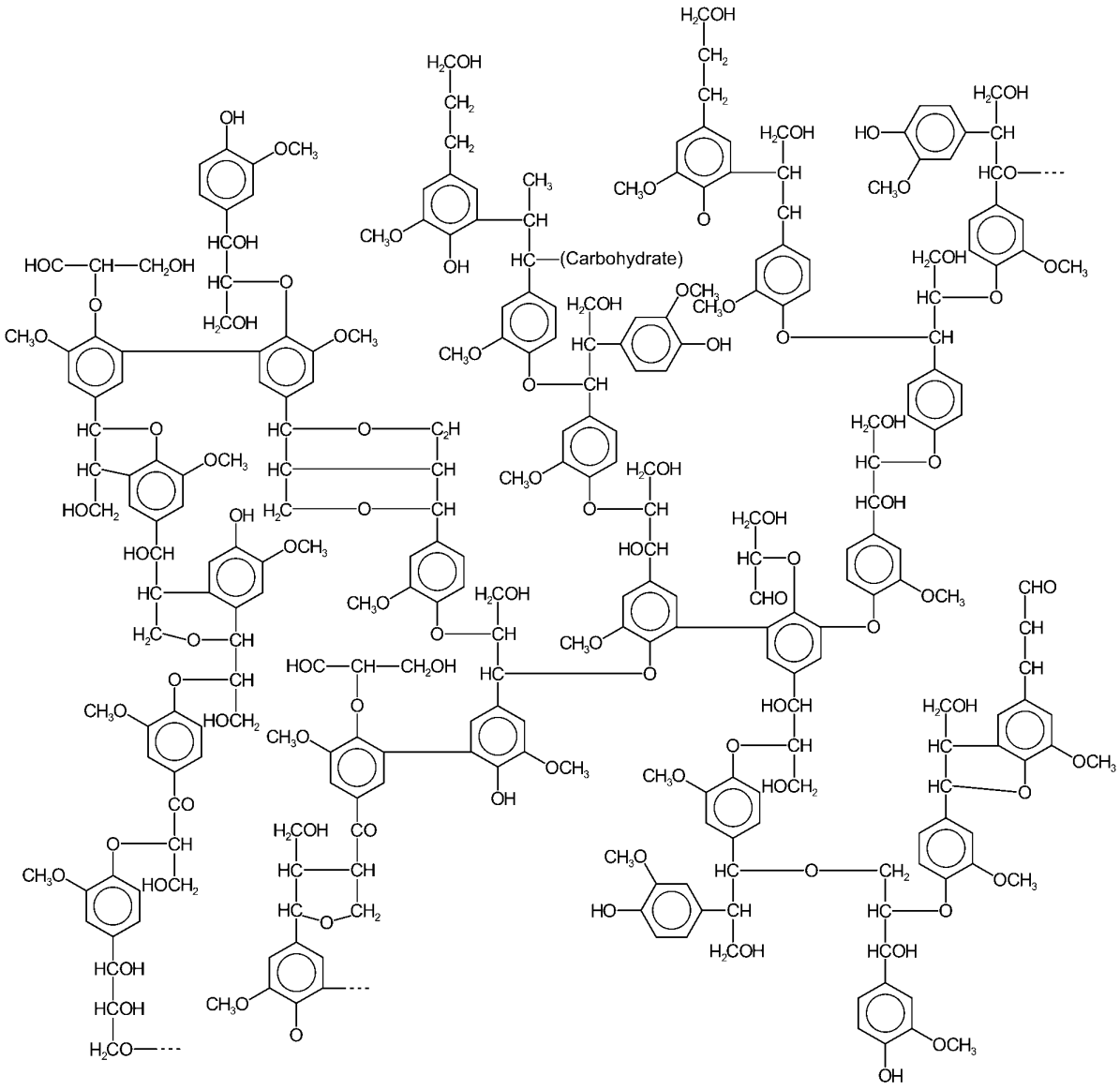
6 Tissues

6.1 Origin of tissues

Origin of tissues and organs of plants: first steps

- Plants were pushed on land for many reasons, including competition
- First challenge: drying. Response: **epidermis** and **parenchyma**.
- Second challenge: new level of competition. Response: growing up!
- Problem: big weight. Response: **collenchyma**.
- Competition grows, plants growing even higher. Weight grows. They also need to get rid of turgor dependency. Response: use lignin not only for epidermis surface (cuticle) but also for secondary cell walls—**sclerenchyma**.
- Competition grows again, plants need to grow faster. Solution: **meristems**.
- Size of plant is too big for plasmodesmata transportations. Solution: vascular tissues, **xylem** and **phloem**.

Lignin



Phenolic compounds (e.g., lignin) were initially developed for spore distribution with a wind, then used in cuticle, then in the secondary cell walls.

6.2 Step four: pipes. Vascular tissues

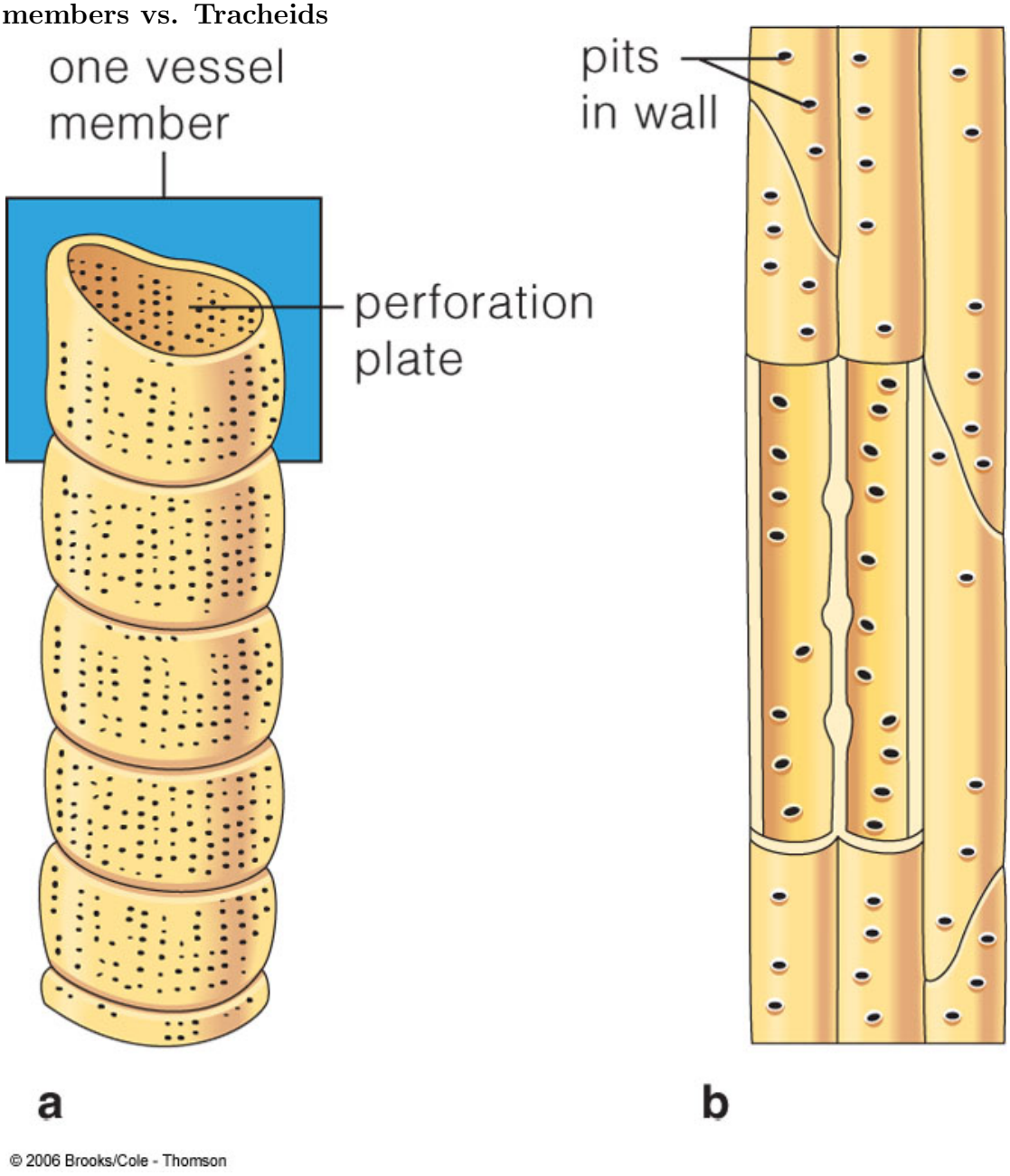
6.2.1 Xylem

Vascular tissues: Xylem

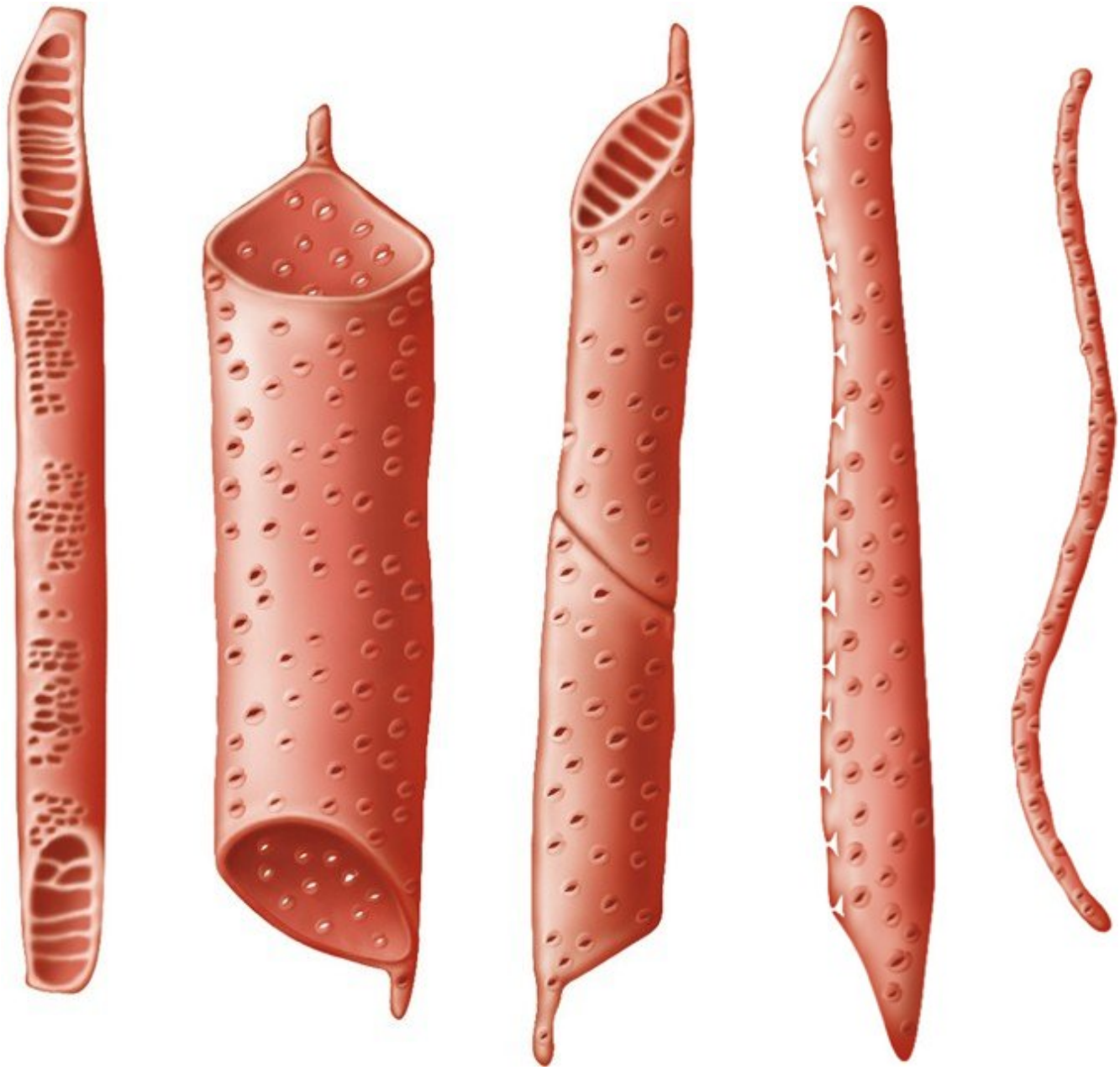
- Occurs in vascular bundles or vascular cylinder
- Types of cells: tracheary elements (tracheids and vessel members), fibers, and parenchyma
- Tracheids have pits; vessel members have perforations; all of them are dead cells
- Gymnosperms have only tracheids; flowering plants have tracheids + vessel elements together
- In flowering plants, primary xylem has mostly tracheids and vessels with scalariform perforations; secondary xylem has mostly vessels with open perforations

- Xylem elements (except parenchyma) are rich of lignin and are main components of wood
- Main functions: water transport and mechanical support

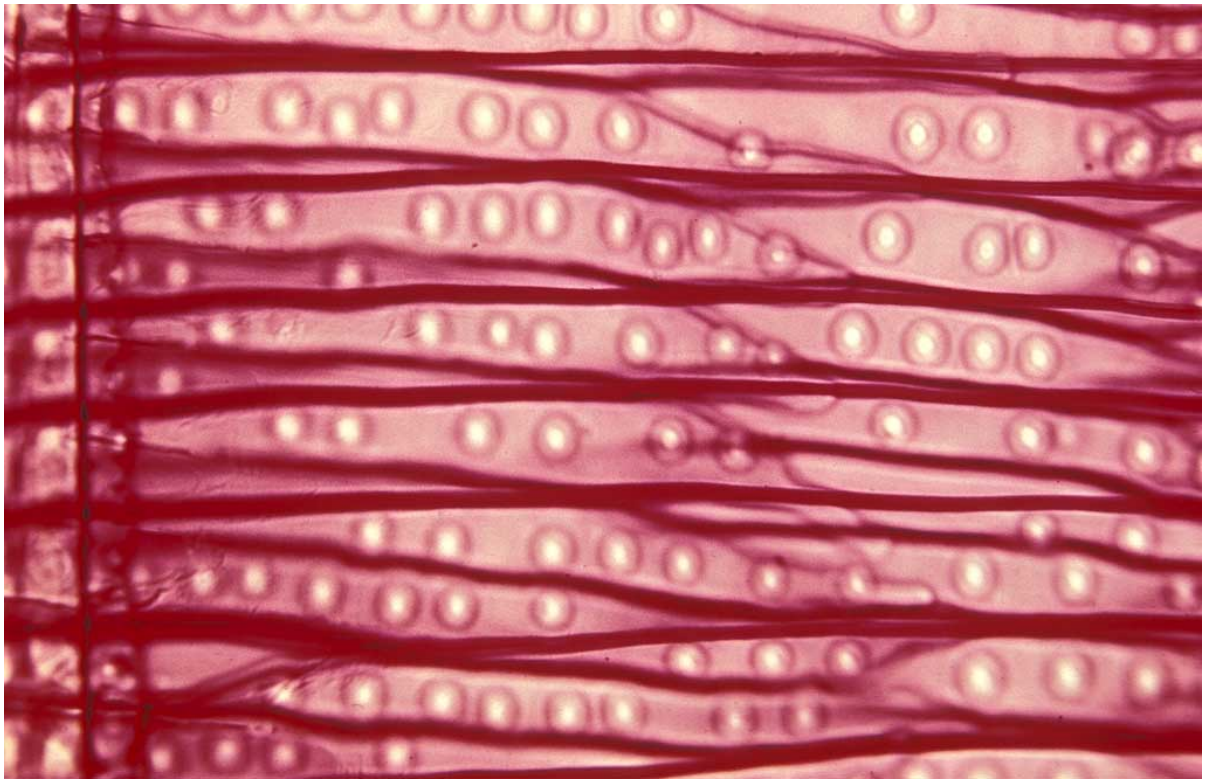
Vessel members vs. Tracheids



Vessel members vs. Tracheids

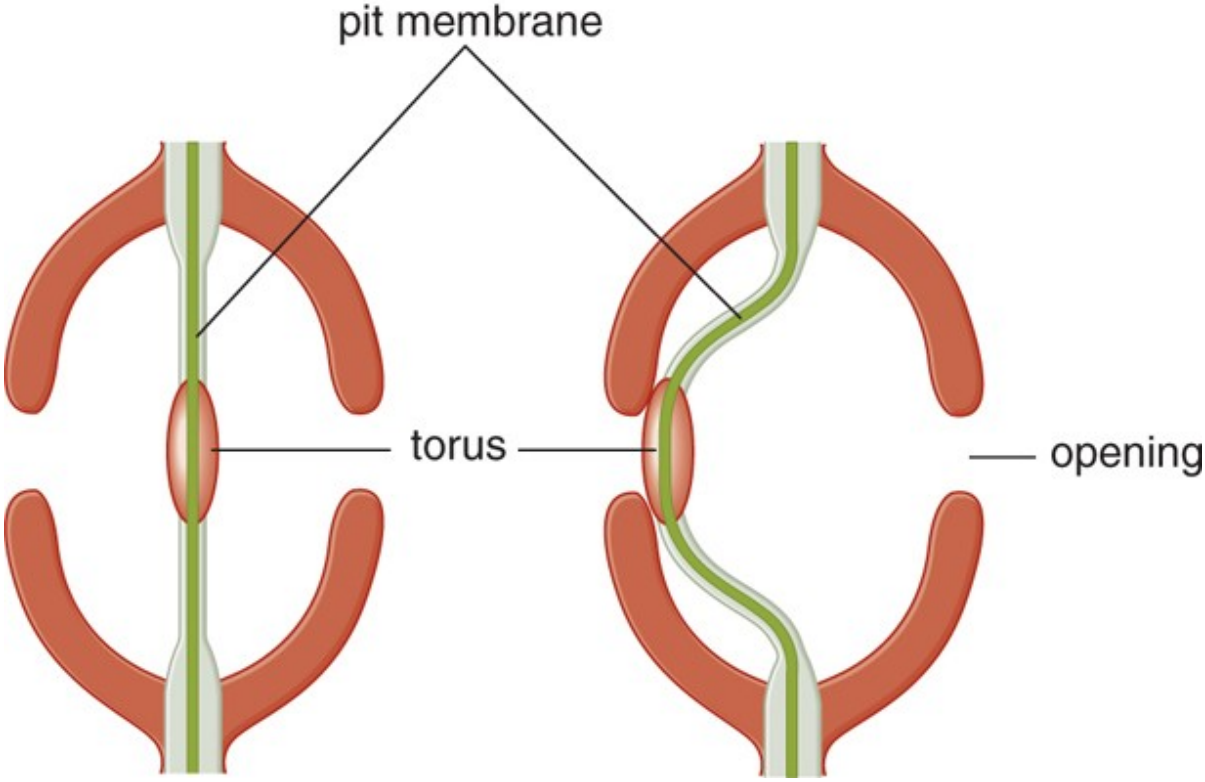


Tracheids



Pine (*Pinus* sp.) tracheids with pits

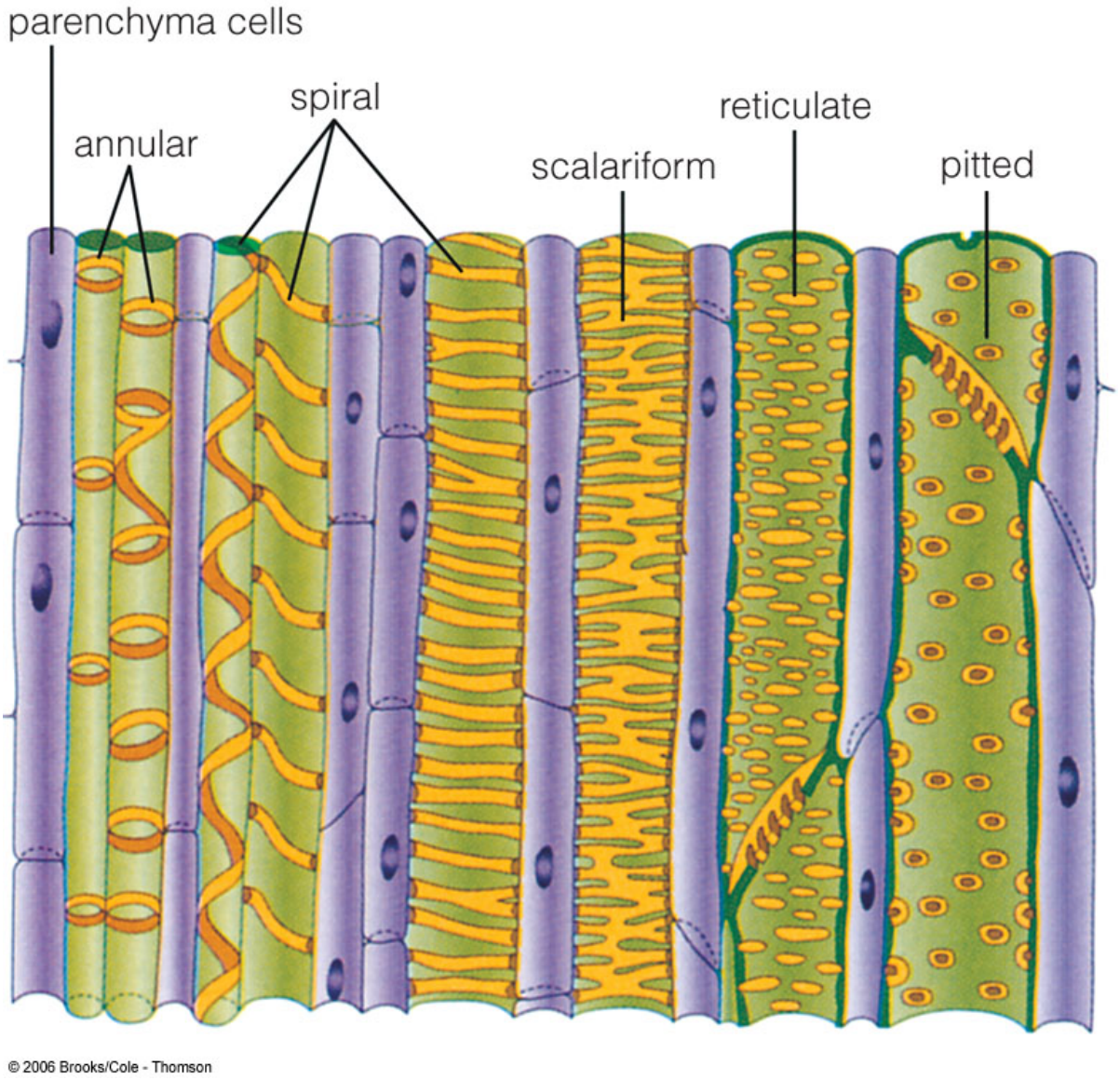
Pit is NOT a direct connection



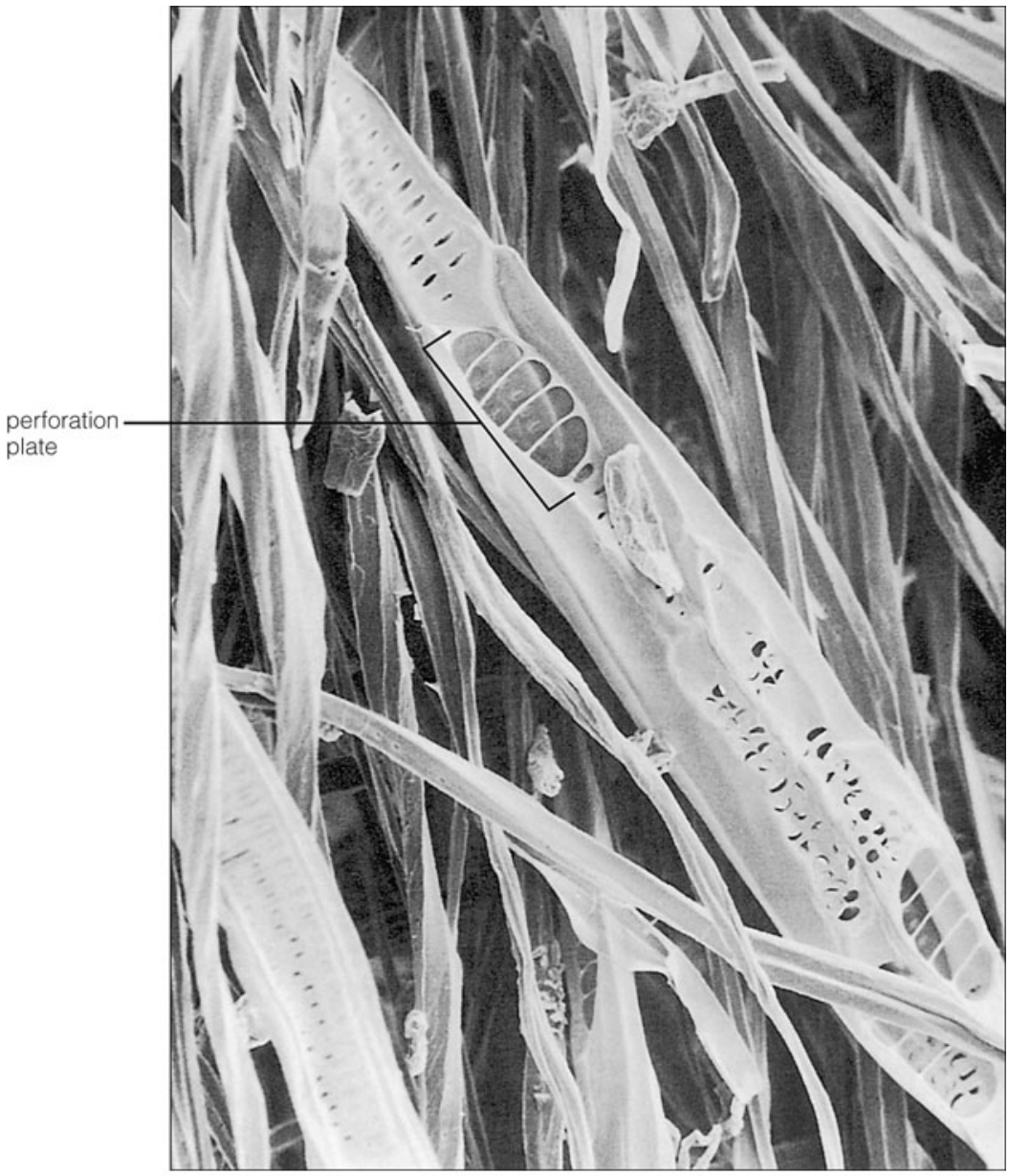
Vessels

Ash (*Fraxinus americana*) secondary xylem with vessels (LM ×26)

Perforations



Scalariform perforations: direct connections

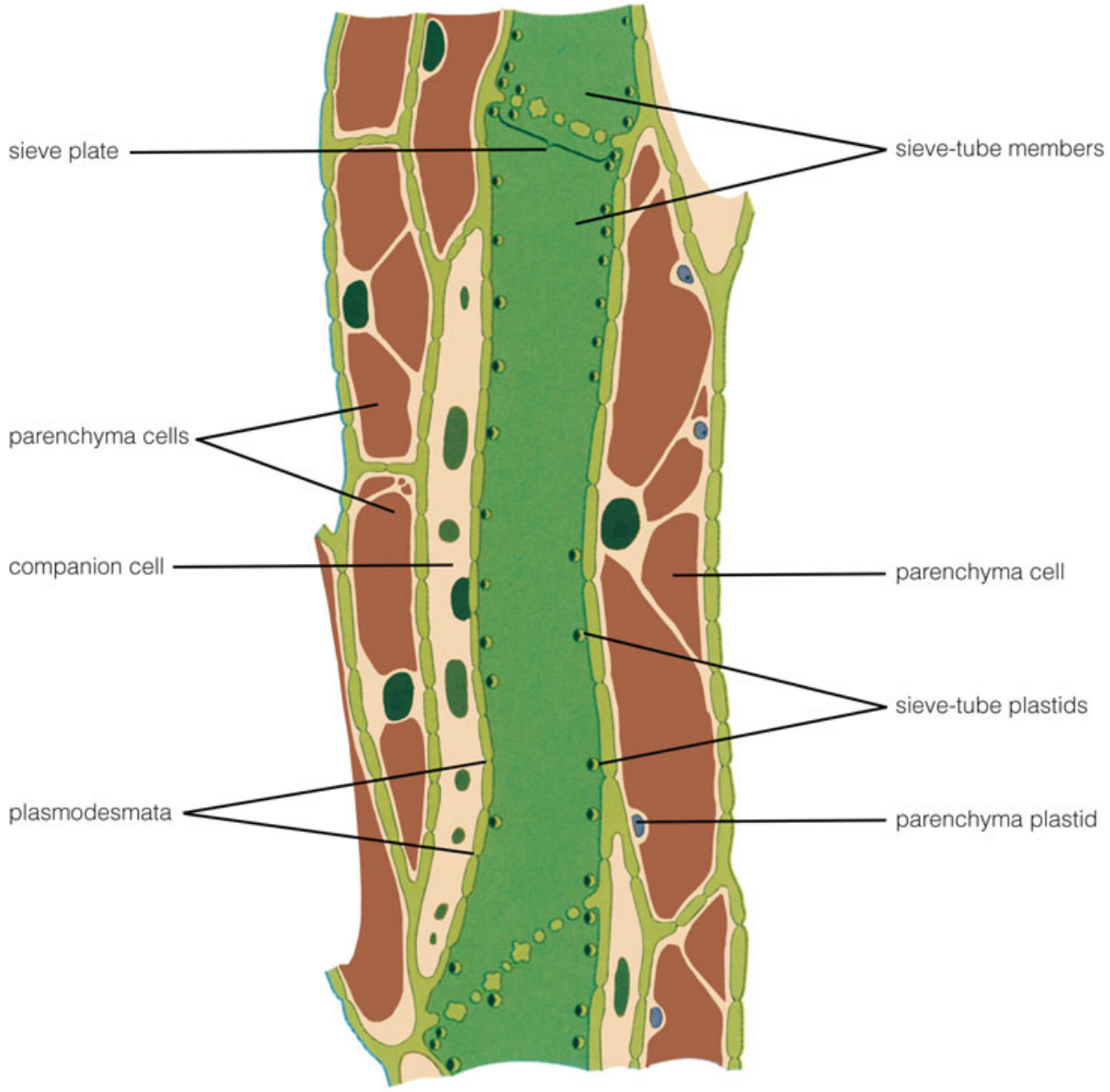


6.2.2 Phloem

Phloem

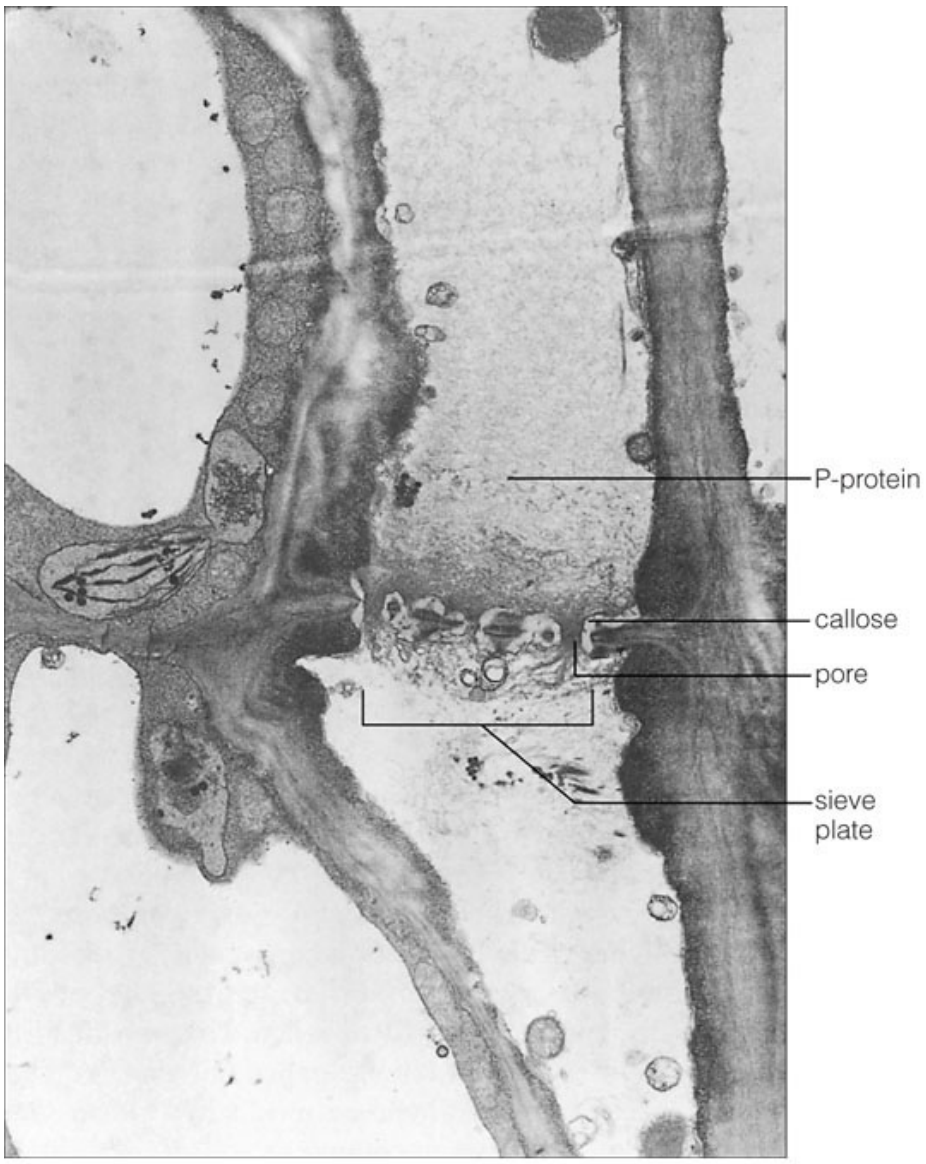
- Usually occurs adjacent to a xylem
- Types of cells: sieve tube cells, companion cells, fibers and parenchyma
- Sieve tube cells have plastids and perforation (sieve) plates between cells but no nuclei, companion cells have nuclei
- However, in gymnosperms there are *no* companion cells and sieve tube cells *have* nuclei
- Secondary phloem usually has more fibers than primary phloem
- Main functions: sugar transport and mechanical support

Phloem cell types



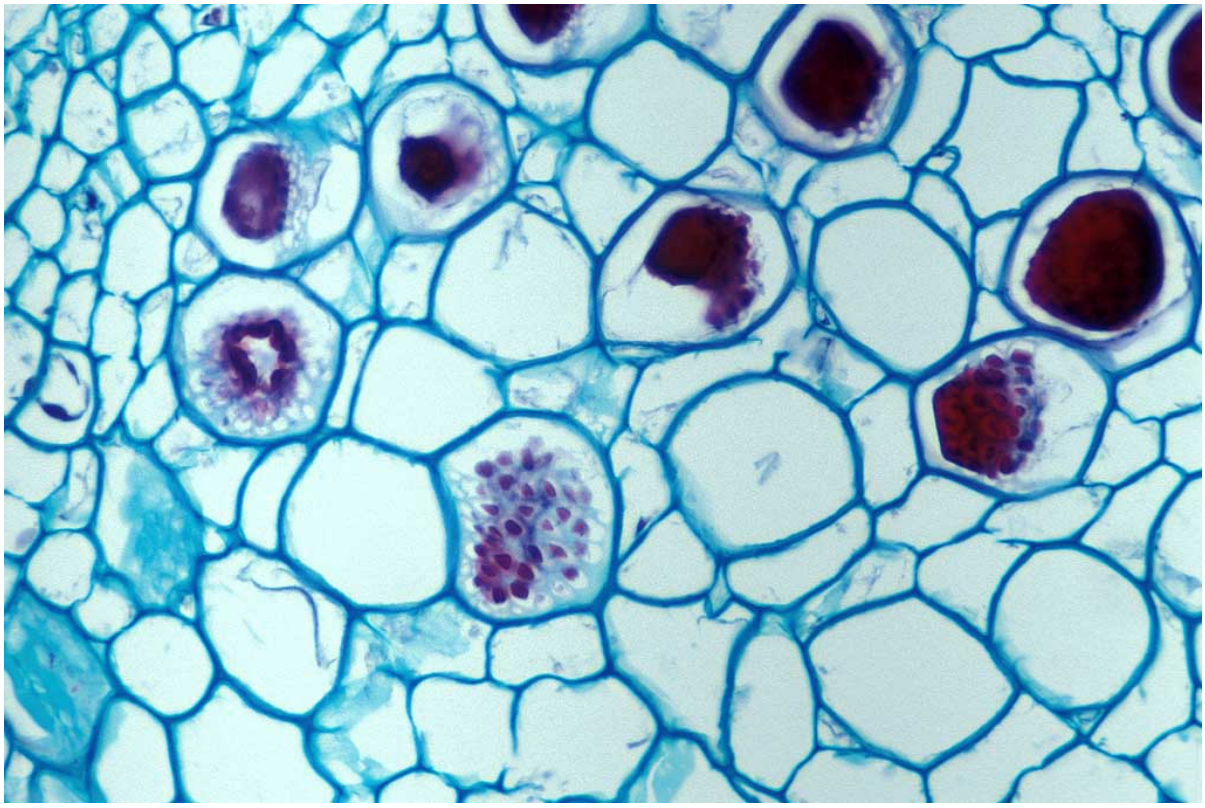
Sieve tubes and phloem parenchyma

Perforation (sieve) plate



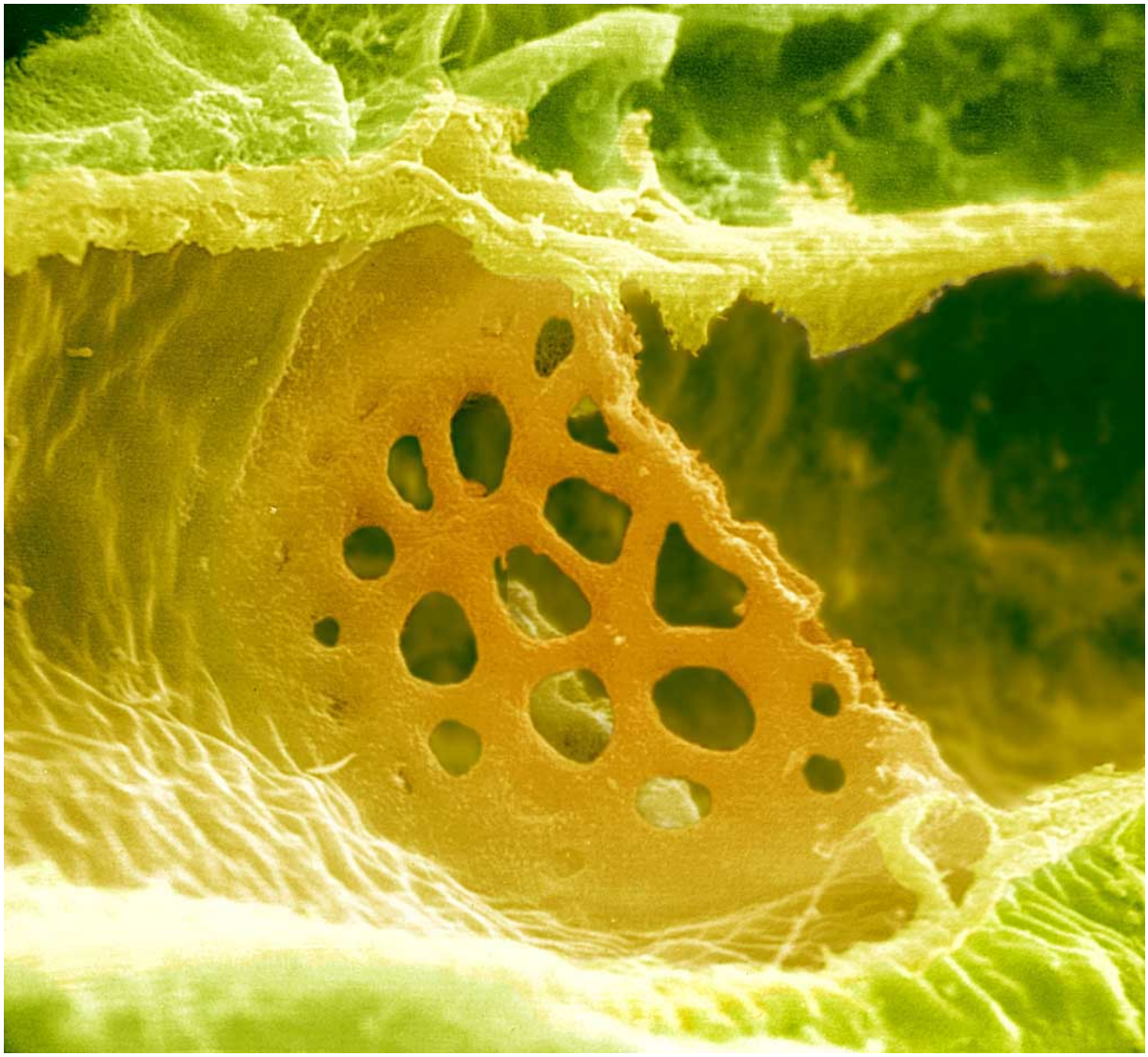
Cross-section (TEM)

Plates: frontal view



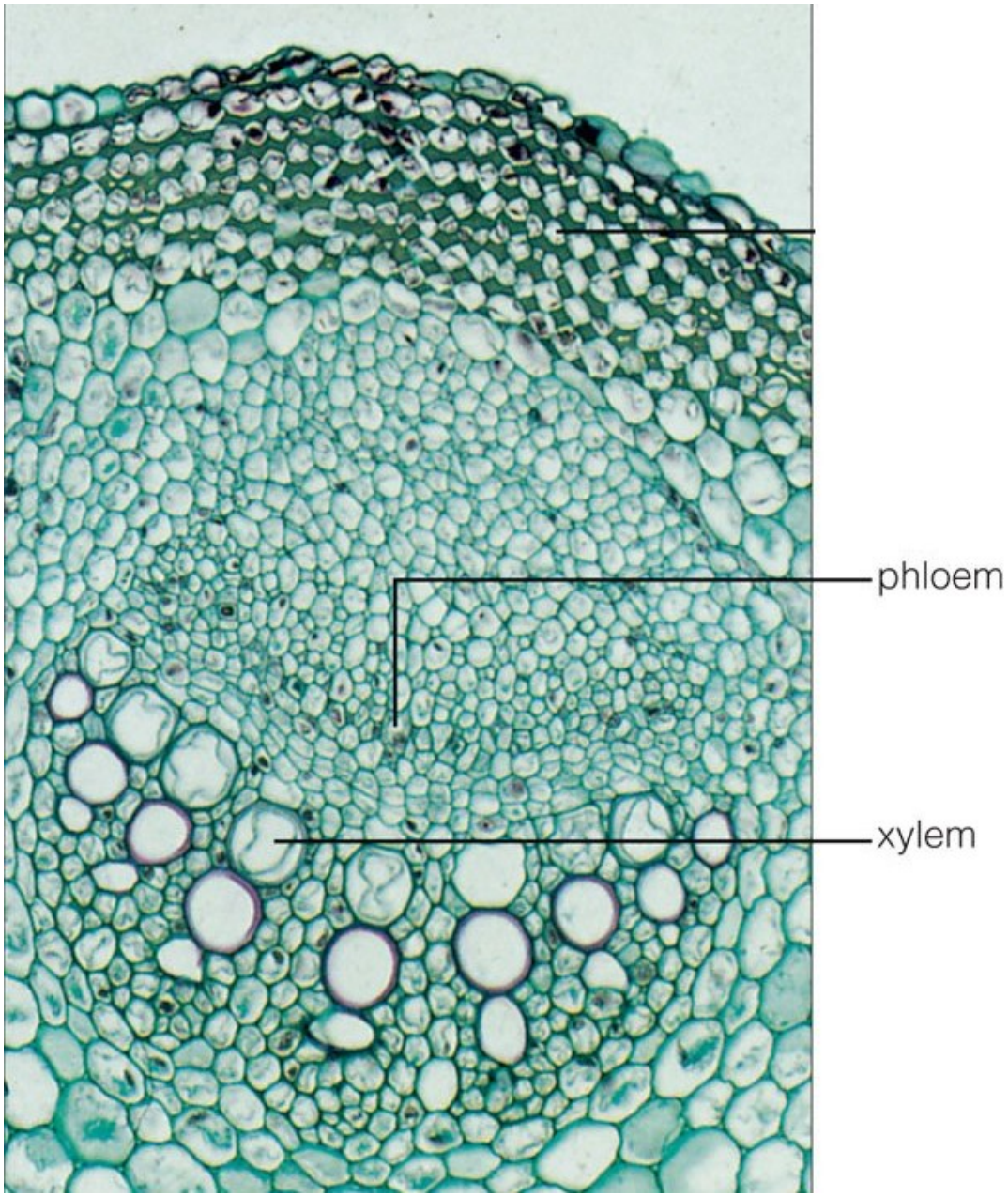
Frontal view (LM)

Plates: pores

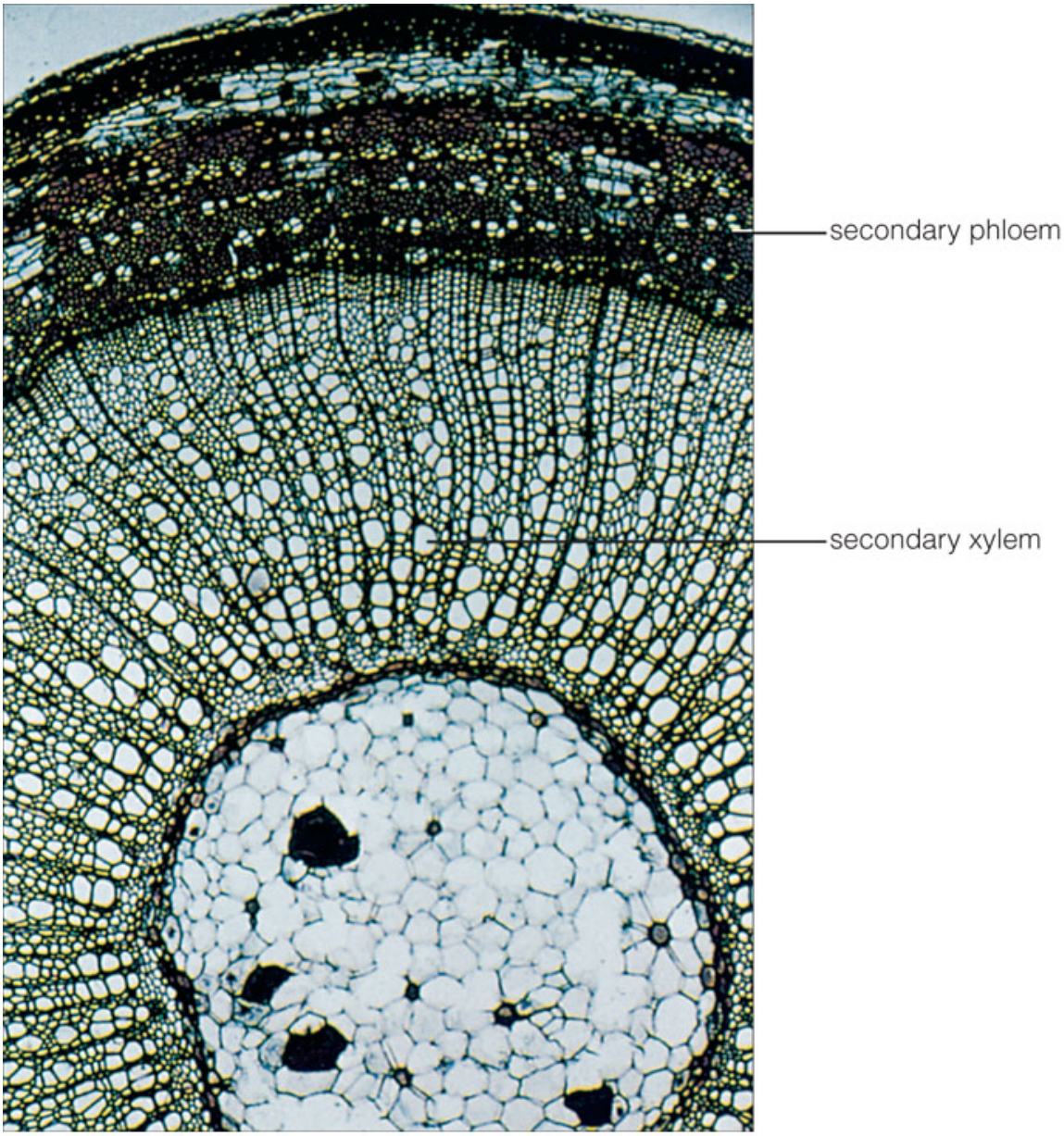


Sieve plate, a pore in the end wall of a sieve-tube member, through which phloem sap flows (SEM ×4800)

Primary vascular tissues



Secondary vascular tissues



Final question (2 points)

What are more primitive states for xylem and phloem, respectively?

Summary

Xylem vs. phloem:

- **State**: dead vs. living cells
- **Transport**: water vs. sugar
- **Direction**: up vs. down
- **Biomass**: big vs. small

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 4*.

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7 Questions and answers

Previous final question: the answer

What are more primitive states for xylem and phloem, respectively?

- Xylem: tracheids
- Phloem: sieve tubes with nuclei and no companion cells

8 Tissues

Xylem vs. Phloem

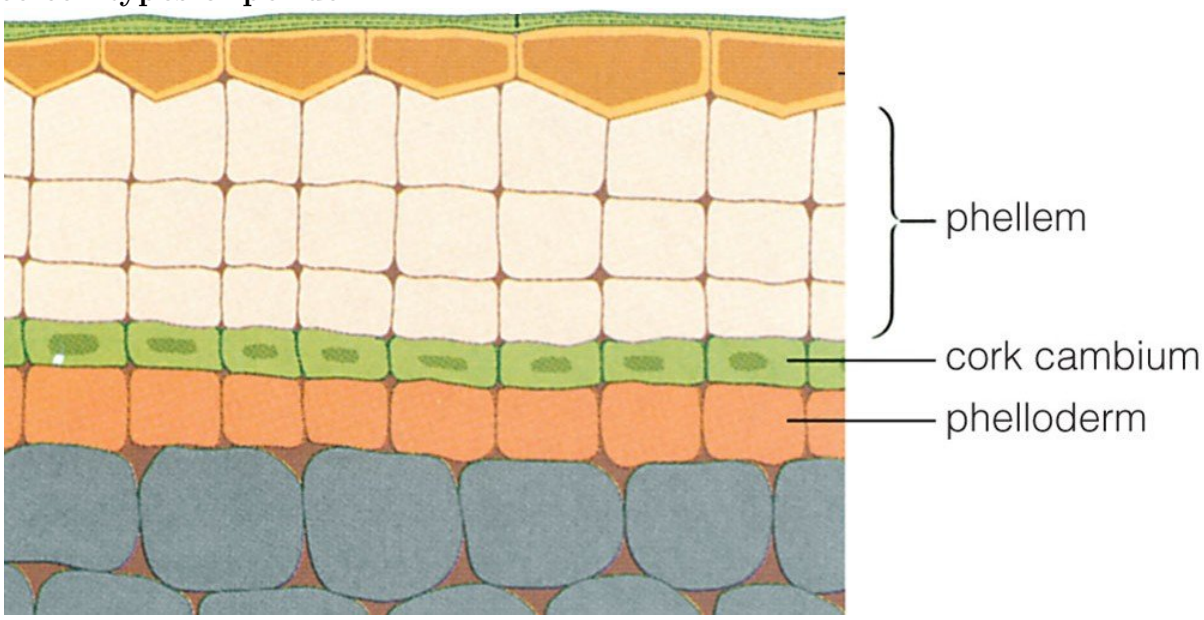
- **State**: dead vs. living cells
- **Transport**: water vs. sugar
- **Direction**: up vs. down
- **Biomass**: big vs. small

8.1 Secondary cover: periderm

Secondary dermal tissue: Periderm

- Secondary dermal tissue
- Arises inside the stem ground tissue, closer to surface (cortex)
- Complex tissue: includes phellem, cork cambium, and phelloderm
- Old periderm includes some other tissues and becomes a cork
- Cells of phellem are dead cells rich of suberin
- Main function is defense

Three cell types of periderm



Cork cambium is another lateral meristem; *phellem* and *phelloderm* are main components of periderm

8.2 Step five: pumps. Absorption tissues

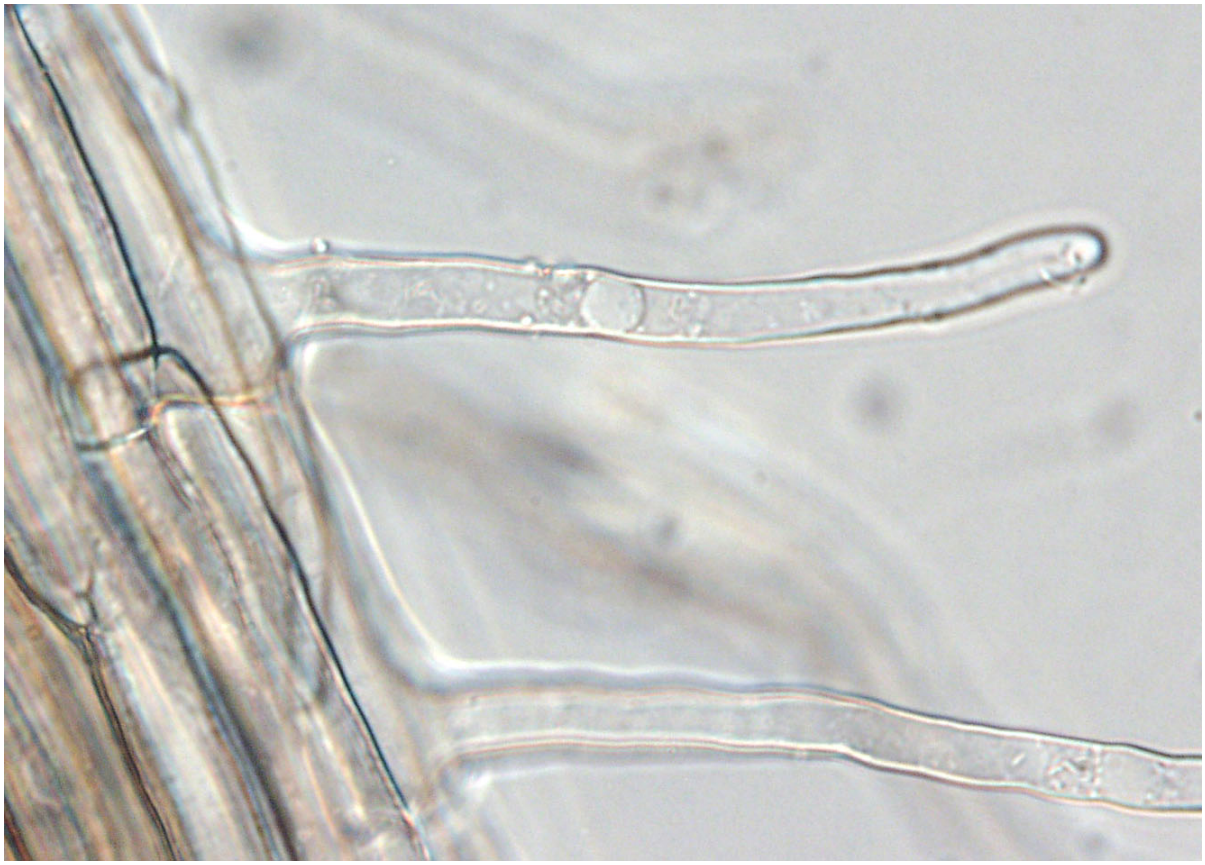
Poikilo- and homoiohydricity

- **Poikilohydric** plants do not save water, they survive even complete desiccation
- **Homoiohydric** plants save water, they always have similar water content and do not survive after desiccation
- Compare with poikilo- and homoiothermic animals (reptiles vs. mammals)

Absorption tissues

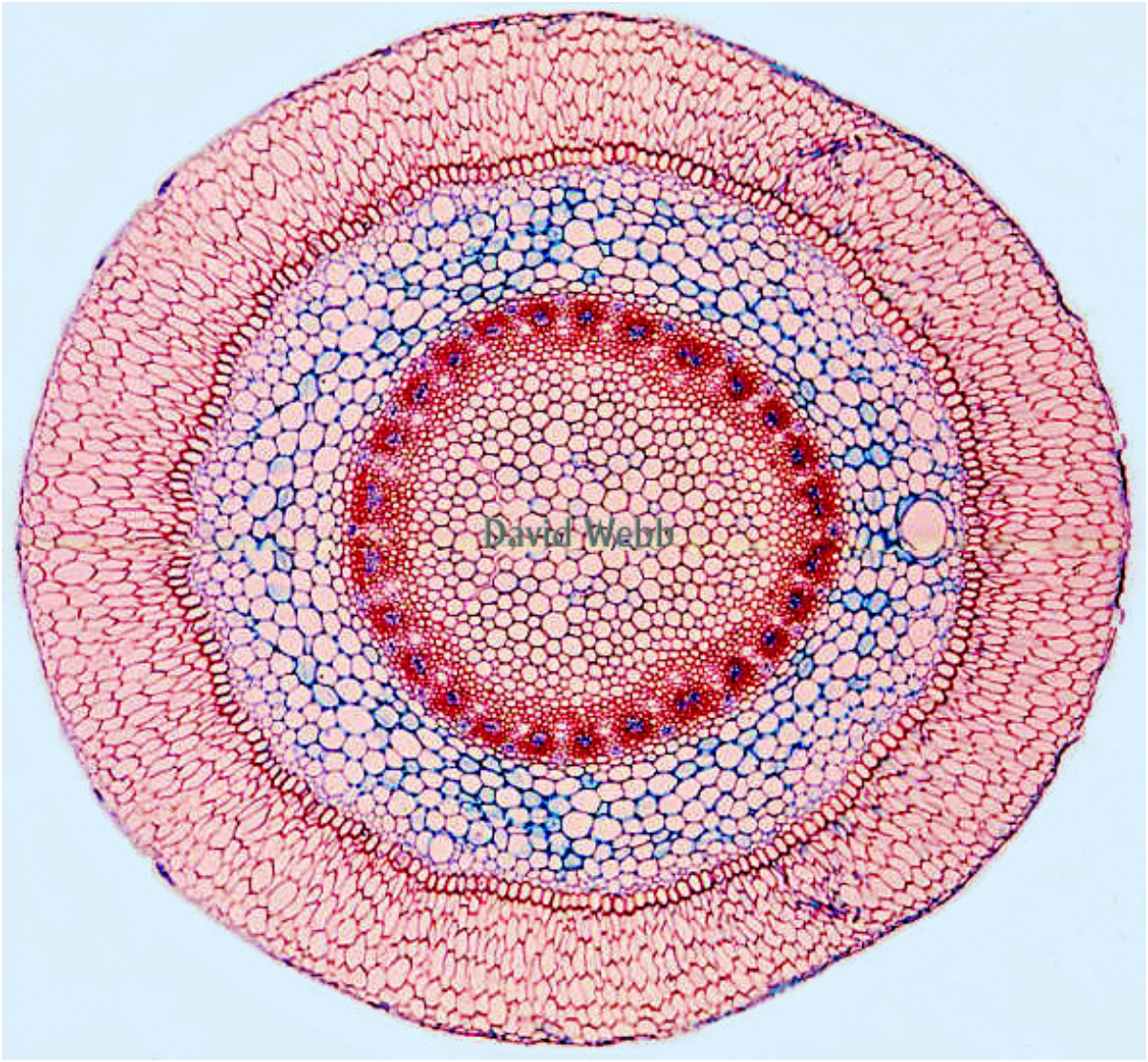
- Always primary, simple tissues
- **Rhizoderm**, or root hairs, originates from protoderm, but life span is much shorter than of epidermis
- **Velamen**, originates from root cortex

Rhizoderm



Root hairs of grass seedlings (LM)

Velamen



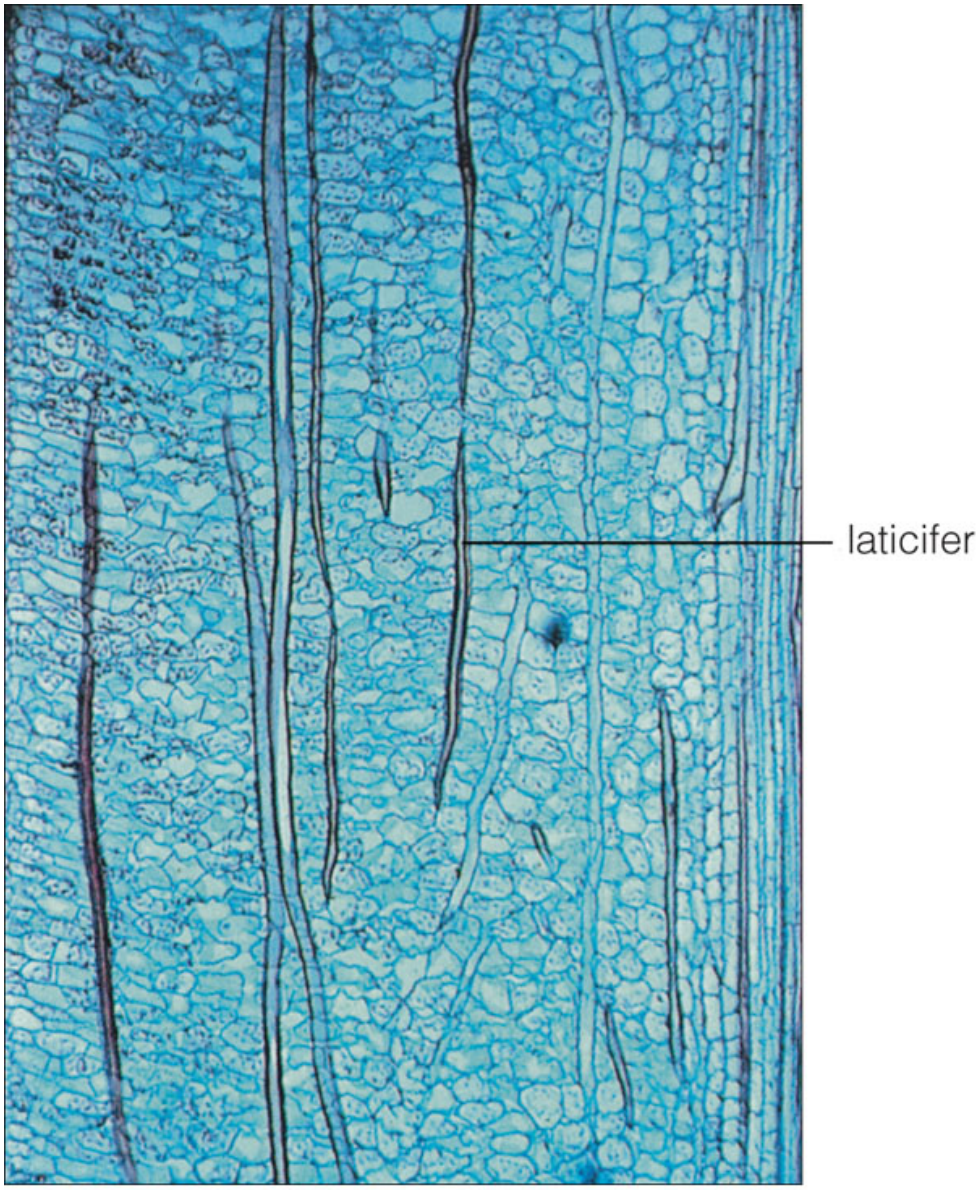
Outer cylinder is a velamen tissue of orchid root (LM, © D. Webb)

8.3 In addition: secretory tissues

Secretory tissues

- Primary, simple or complex tissues
- Spreading across plant body, concentrating in leaves and young stems
- May secrete latex, volatile oils, mucus and other chemicals
- Functions vary: attraction or dis-attraction, communication, defense etc.

Laticifers



9 Leaf

9.1 Leaf morphology

Definition, functions and features

- Lateral flattened organ of shoot with restricted growth
- Functions:
  - Photosynthesis
  - Respiration
  - Transpiration

  - Synthesis of secondary chemicals

- Features:

  - Have bud in the axil
  - Do not grow by apex
  - Do not produce new leaves
  - Have hierarchical morphology

Final question (2 points)

Please give an example of a **secondary complex** tissue.

Summary

- Xylem and phloem transport water and organic compounds, respectively
- **Secondary tissues** originate from lateral meristems (i.e., cambium)
- **Homoiohydric** plants have (among others) **absorbtion** tissues which take water from soil

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 4*.

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10 Questions and answers

Previous final question: the answer

Please give an example of the complex secondary tissue.

- Periderm
- Phloem or xylem

11 Leaf

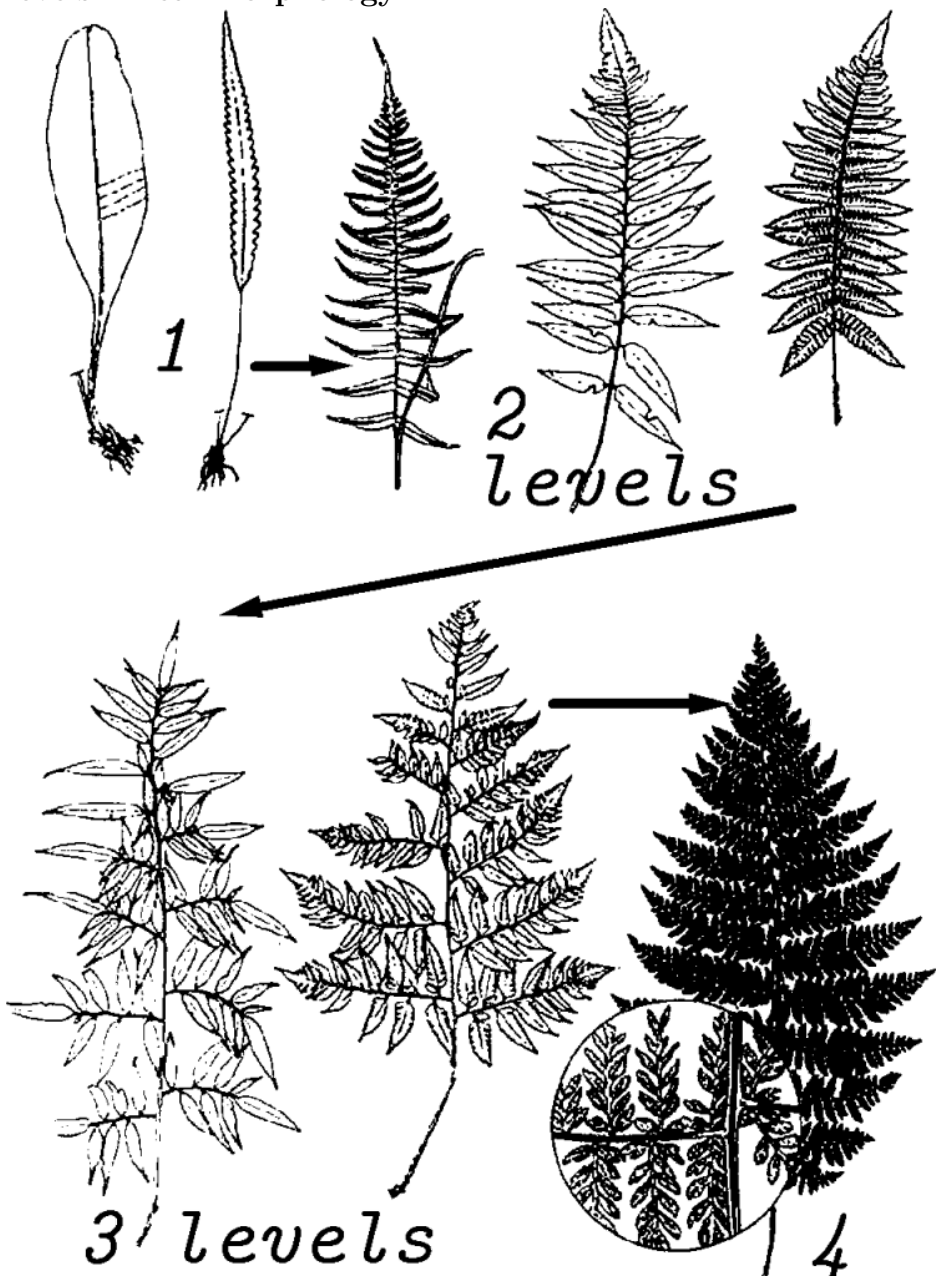
11.1 Leaf morphology

Definition, functions and features

- Lateral flattened organ of shoot with restricted growth
- Functions:
  - Photosynthesis
  - Respiration
  - Transpiration
  - Synthesis of secondary chemicals
- Features:
  - Have bud in the axil
  - Do not grow by apex
  - Do not produce new leaves
  - Have hierarchical morphology

Hierarchy

Hierarchical levels in leaf morphology



Types of leaf characters

- General: applicable only to the whole leaf
- Terminal: applicable only to the terminals (e.g., terminal leaflets)
- Repetitive: repeating on each level of hierarchy

Hierarchy in leaf morphology

- **General** and **terminal** characters do not depend on hierarchy
- **Repetitive** characters may be different on each step of hierarchy

- Therefore, leaf description should state that "on first level of hierarchy, the shape is ..., on the second level, the shape is ..."
- It is possible that each level has different repetitive characters

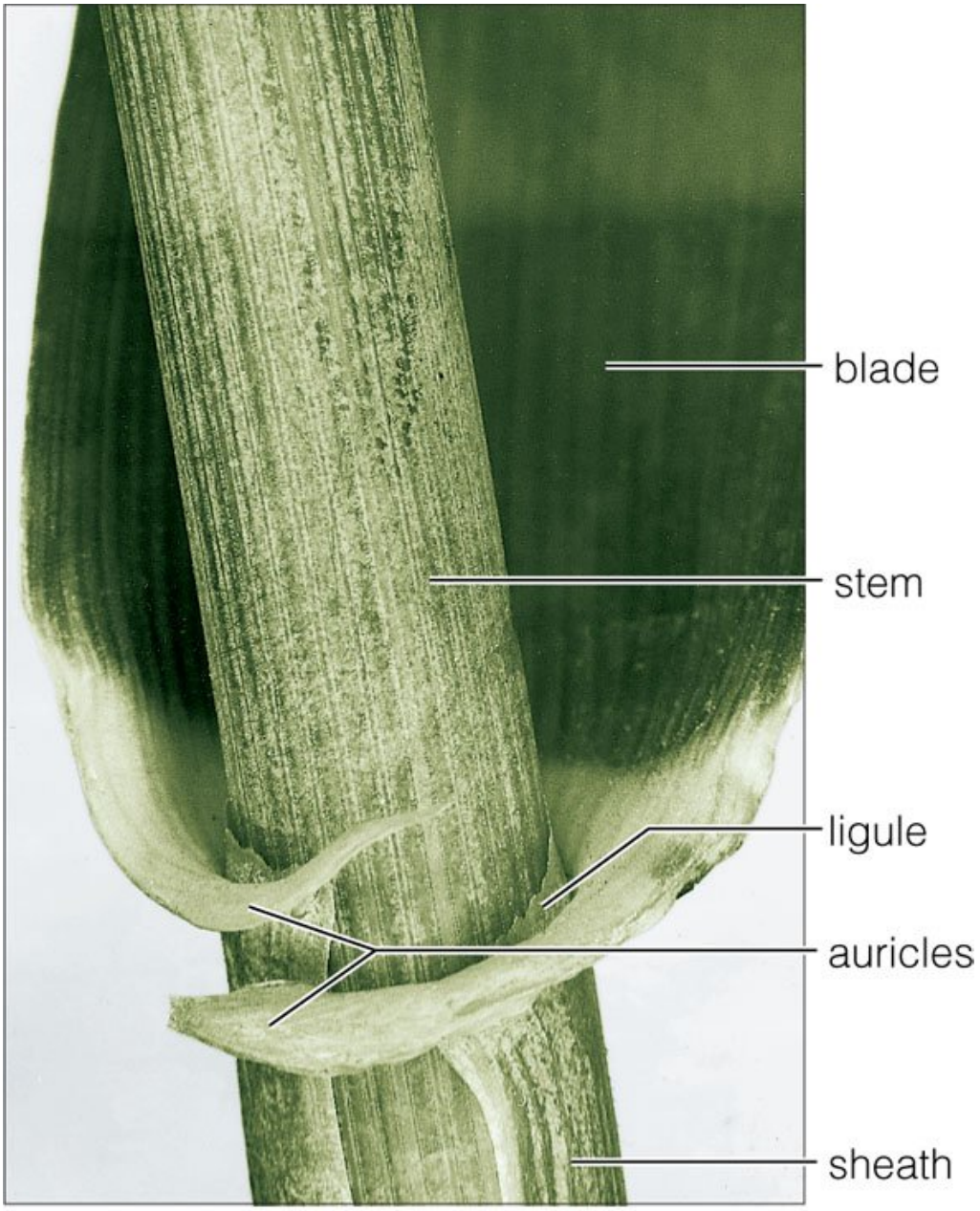
11.1.1 General characters

General characters

- General characters apply to the whole leaf
- Stipules (present or not, how many etc.)
- Other leaf base organs (sheath, ocrea, ligules etc.)

Stipules

Leaf base



11.1.2 Repetitive characters

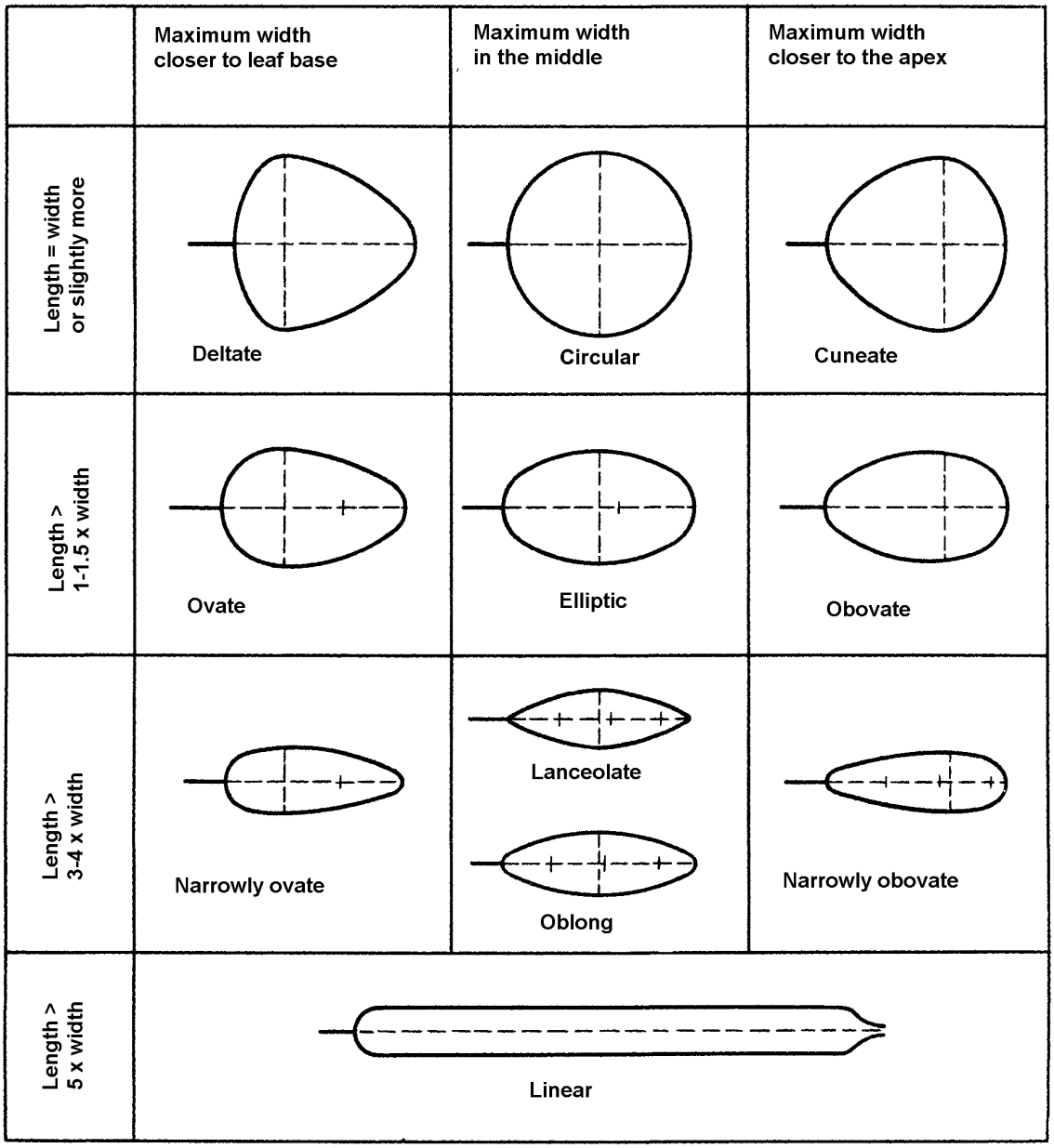
Repetitive characters

Repetitive characters are the same on each level of leaf hierarchy:

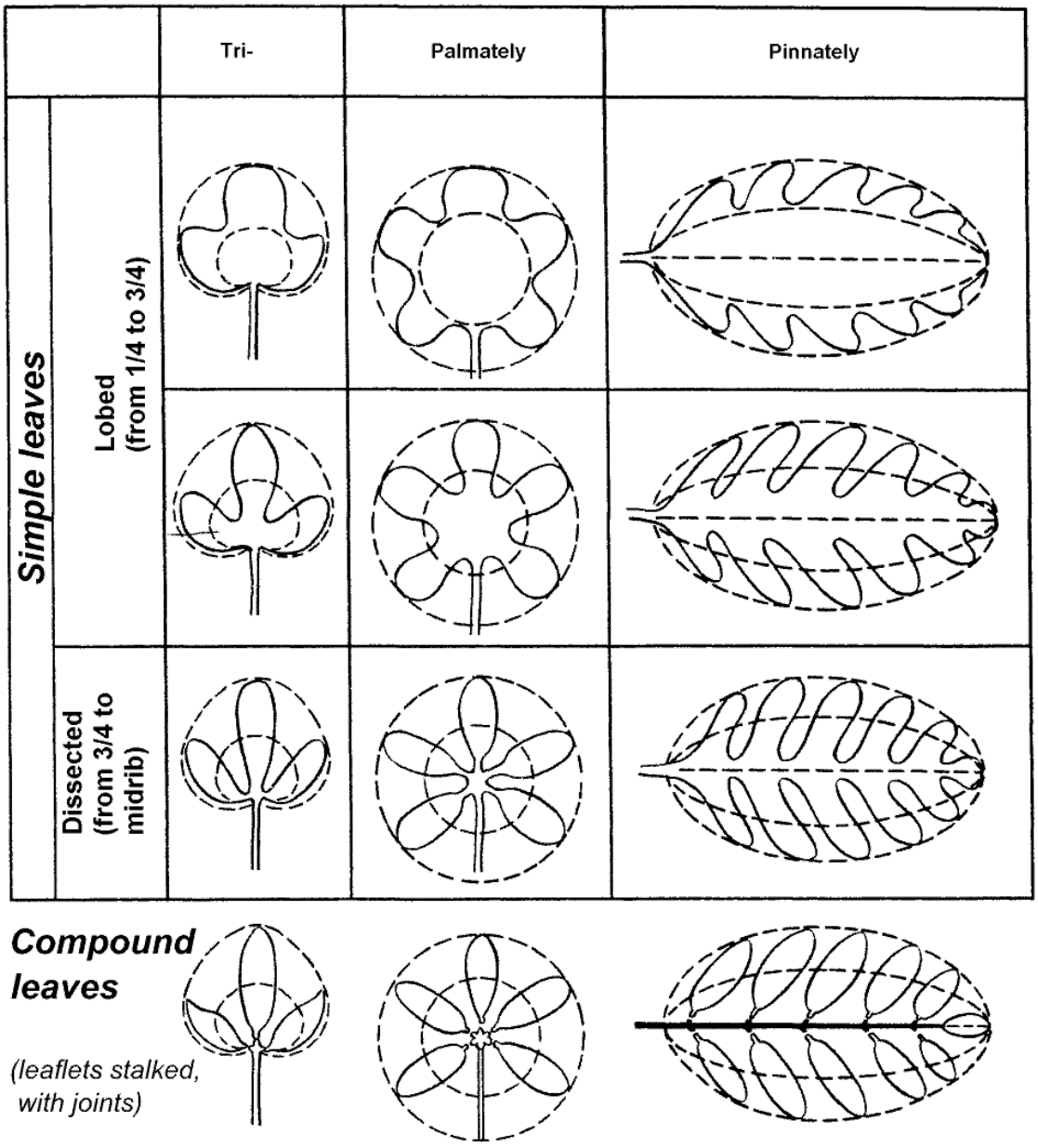
- Shape
- Dissection
- Petiole (stalked/non-stalked etc.)

Repetitive characters of same type may combine

Shape



Dissection



11.1.3 Terminal characters

Terminal characters

Terminal (leaflet) characters are applicable only to terminal parts (normally, leaflets) of leaves:

- Form of base
- Form of tip
- Type of margin
- Surface
- Venation

Terminal characters: base of leaf blade

- Rounded
- Truncate (straight)
- Cuneate
- Cordate
- Sagittate

Terminal characters: leaf apex

- Rounded
- Mucronate
- Acute
- Obtuse
- Acuminate
- Retuse

Terminal characters: leaf margin

- Without teeth: smooth
- With teeth
  - Dentate
  - Serrate
  - Crenate
- Could be double-dentate, triple-serrate etc.

Terminal characters: leaf venation

Main vein / Lateral veins	No	One	Several
No	Apodromous	Hypho-	Acro-
Several	Acrodromous	Ptero-	Actino-

11.2 Leaves in nature

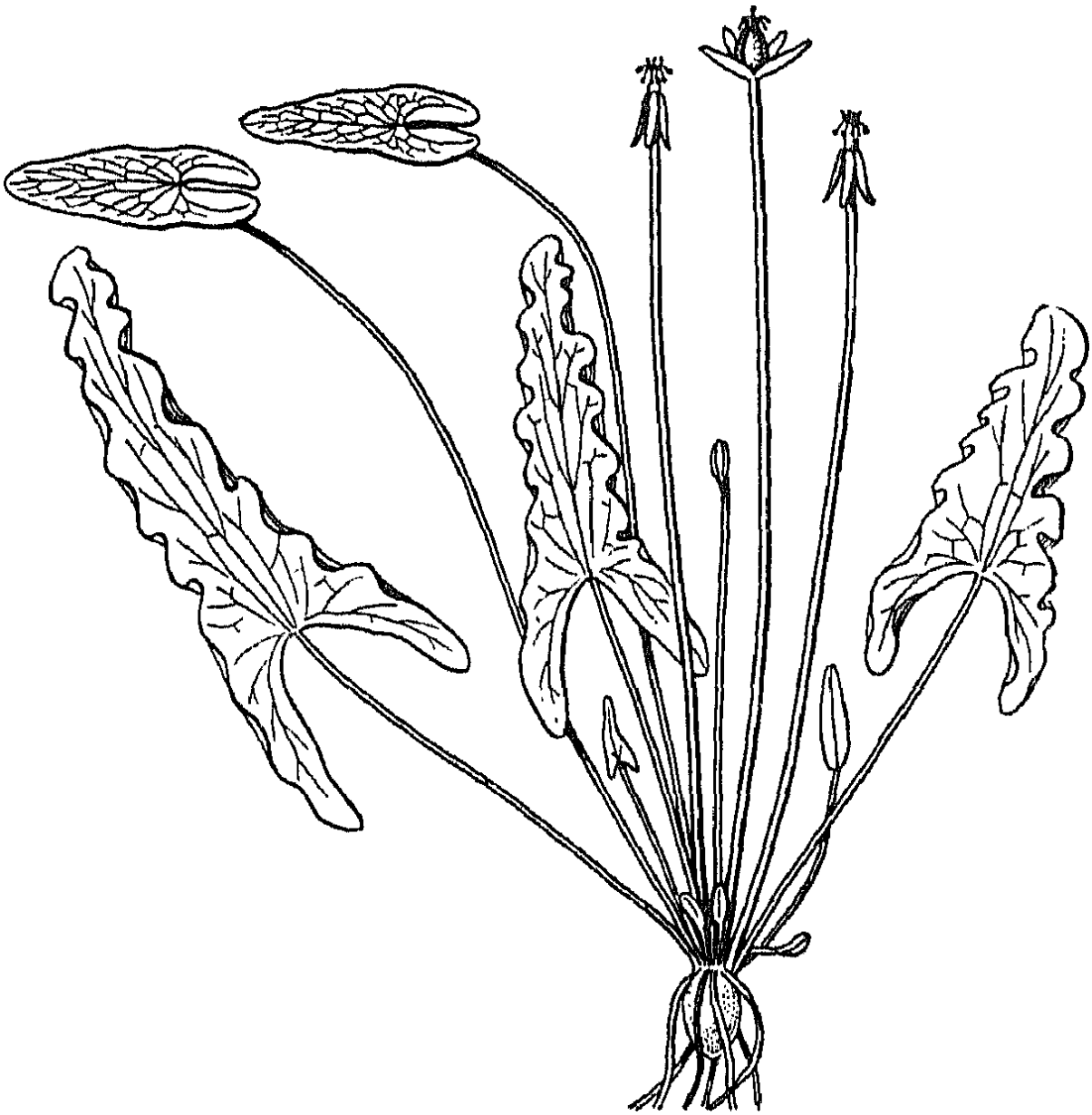
Heterophylly

- Juvenile and adult leaves
- Water and air leaves
- Sun leaves and shade leaves

Juvenile leaves of *Juniperus* sp.

Juvenile leaves of *Eucalyptus* sp.

Submerged and floated leaves of *Ondinea*



Leaf mosaic

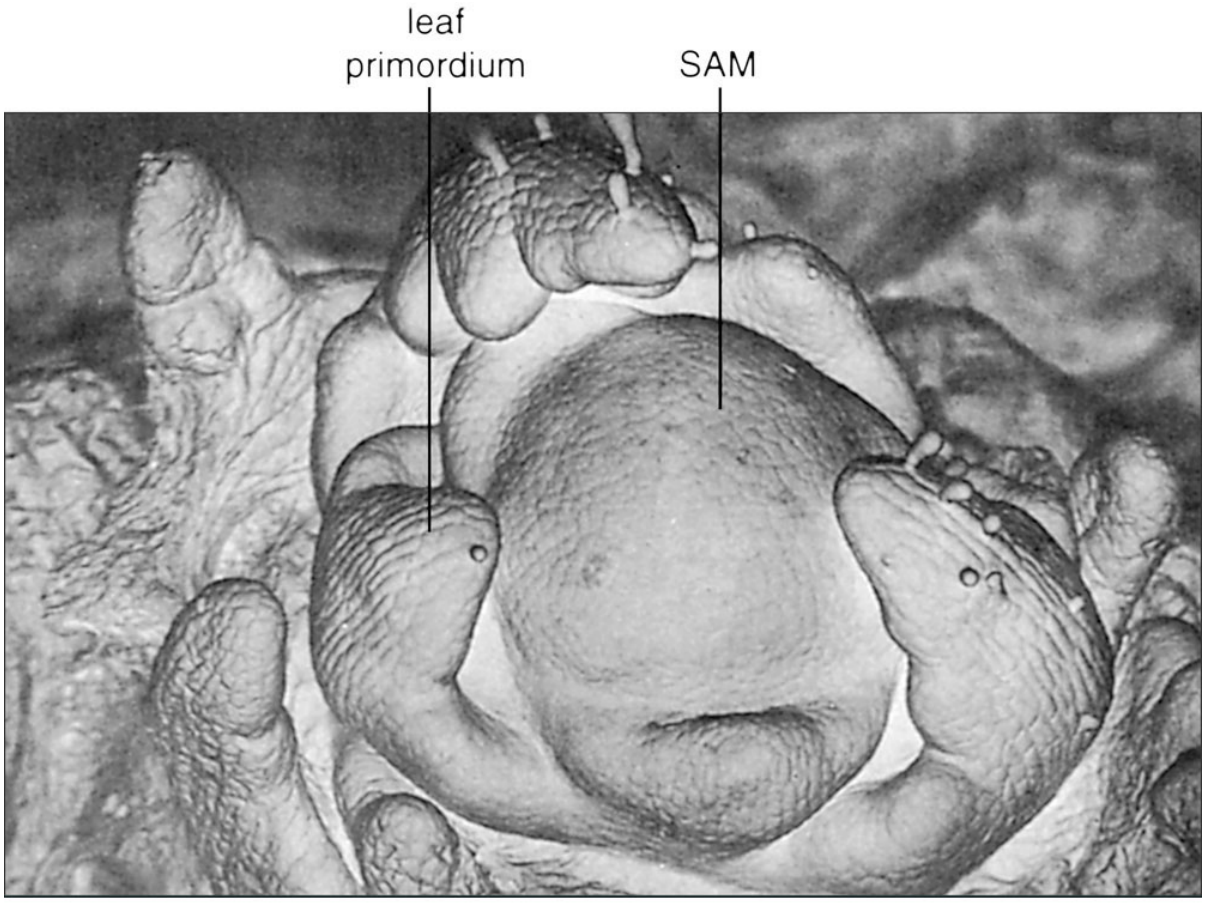
- Distribution of leaves of plants in a single plane, usually perpendicular to light rays
- Provides the least shading of leaves by one another

Leaf mosaic of red maple (*Acer rubrum*)

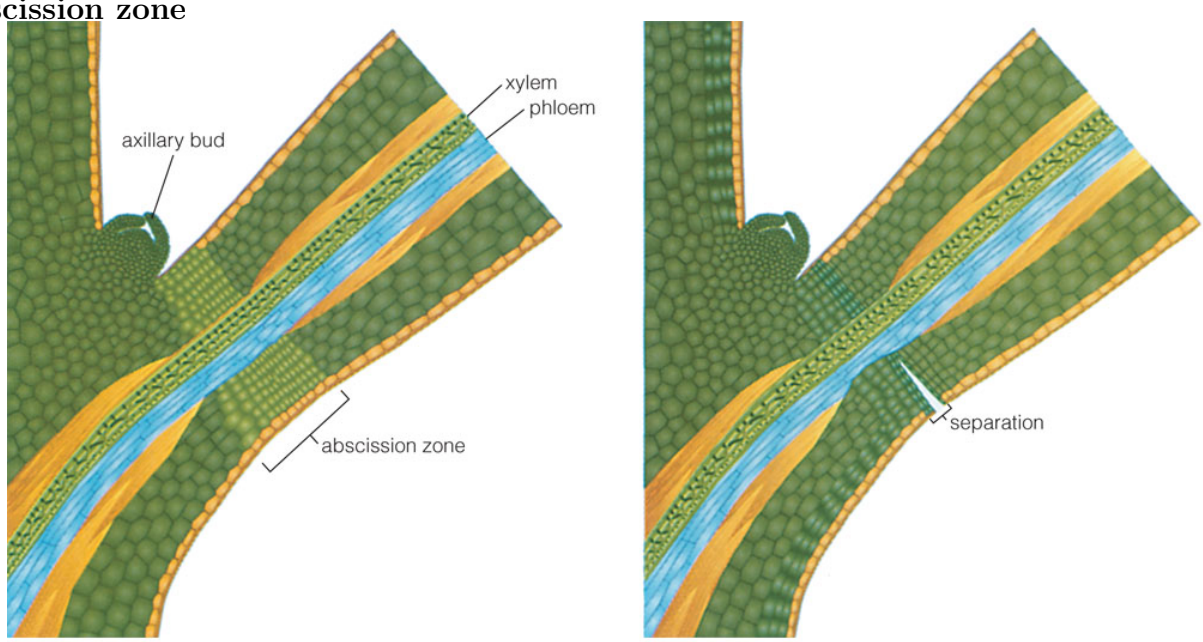
Seasonal life of leaves

- Leaves arise from SAM through leaf primordia
- Old leaves separate from plant in a region called abscission zone

Leaf primordia



Abscission zone



Final question (2 points)

How many levels of hierarchy has this leaf?

Summary

- Leaves have **general**, **repetitive** and **terminal** characters
- **Heterophylly** is a co-existence of different types of leaves on the same plant
- **Abscission zone** helps the separation of leaf at the end of season

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 6*.

Outline

Contents

12 Questions and answers

Previous final question: the answer

How many levels of hierarchy has this leaf?

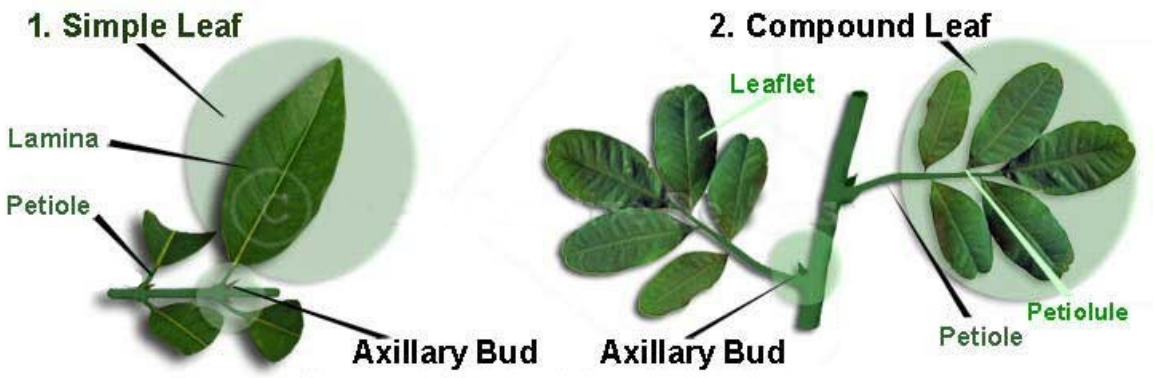
3

Lab 7

13 Leaf

13.1 Leaf morphology

Simple (one level) and compound (> 1 level) leaves



Plan of leaf description

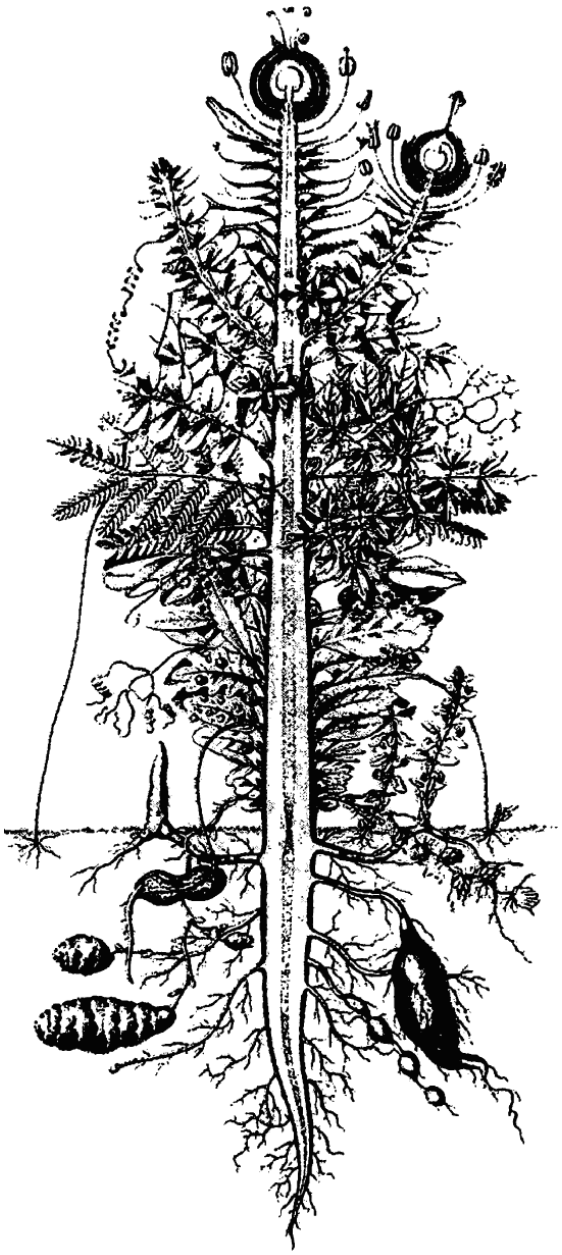
1. General characters (leaf as a whole):
   (a) symmetry (symmetrical / asymmetrical);
   (b) stipules (present / absent, deciduous / not);
   (c) base (sheath / no sheath, ligule / no ligule, auricles / no auricles)
2. First level of hierarchy: repetitive characters:
   (a) shape;
   (b) dissection;
   (c) petiole (length)
3. Second level of hierarchy
4. Third level of hierarchy and so on
5. Terminal characters (leaflets):
   (a) base [of leaf blade] (rounded, truncate, cuneate, cordate, sagittate);
   (b) apex (rounded, mucronate, acute, obtuse, acuminate, retuse);
   (c) margin (whole, dentate, serrate, crenate; degree of order);
   (d) surface (color, hairs etc.);
   (e) venation (apo-, hypho-, acro-, ptero-, actinodromous)

13.2 Modifications of leaf

Goethe's theory of modification

Famous German poet and writer Johann Wolfgang Goethe is also a founder of plant morphology. He invented an idea of "primary plant" ("Urpflanze") where all organs were modifications of one primordial organ.

Urpflanze (another interpretation)

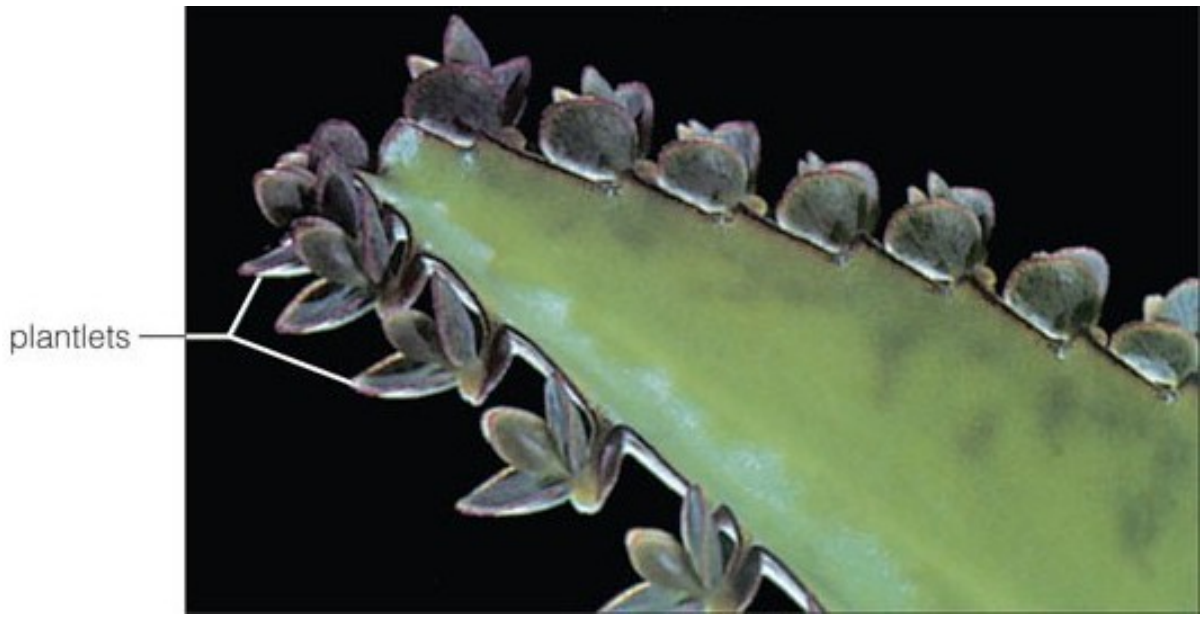


Leaf modifications

- Spines
- Tendrils
- Succulent leaves
- Traps
- Plantlets

Tendrils of sweet pea (*Lathyrus odoratus*)

Plantlets on the leaf of *Kalanchoe pinnata*



Leaf of Venus flytrap (*Dionaea muscipula*)

Everything is possible when plant needs nitrogen!

Venus flytrap in work

Urn leaf of yellow pitcher plant (*Sarracenia flava*)

***Sarracenia flava* on Buttercup Fields, Mississippi**

Prey in the urn

Urn leaf of purple pitcher plant (*Sarracenia purpurea*)

Hairs prevent insects from climbing out of leaf

"Cobra Lily" (*Darlingtonia californica*)

Sticky tape leaf of butterwort (*Pingiucula* sp.)

Leaf margins are slowly rolling

Sticky tape/trap leaf of sundew (*Drosera intermedia*)

Leaves are constantly open and close and finally digest the glued insects

Table of modifications

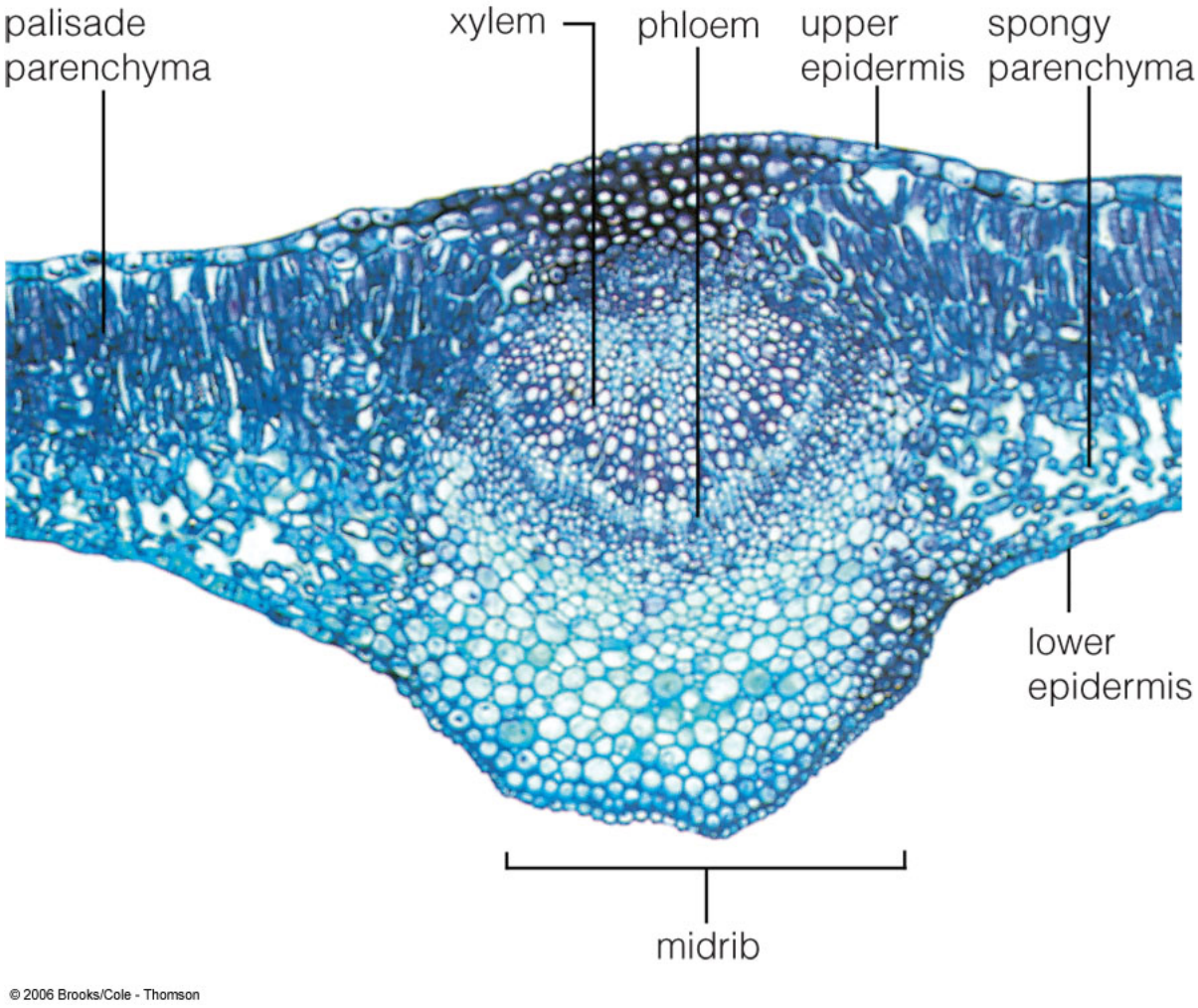
Function	Stem / shoot	Leaf	Root
Expansion		Plantets	
Storage		Succulent leaves	
Photosynthesis		DEFAULT	
Defense		Spines, scales	
Support		Leaf tendrils	
Interactions		Traps, "sticky tapes", urns	

13.3 Anatomy of leaf

General leaf anatomy

- Epidermis with stomata
- Mesophyll
- Vascular bundles, or veins

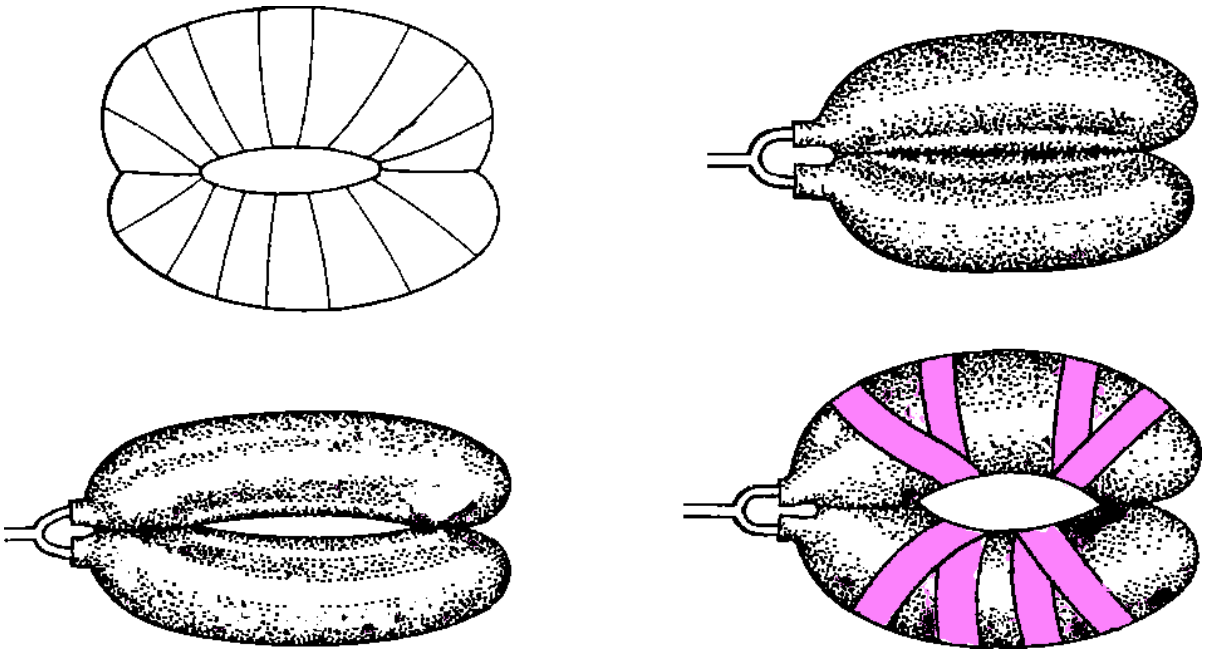
Lilac (*Syringa vulgaris*) leaf in cross-section



Epidermis and stomata

- Covered with cuticle
- Include stomata with guard cells and (often) subsidiary cells and trichomes
- Opening of stomata is a result of exchange of K^+, osmosis and uneven cell wall
- Lower epidermis in most cases contain more stomata

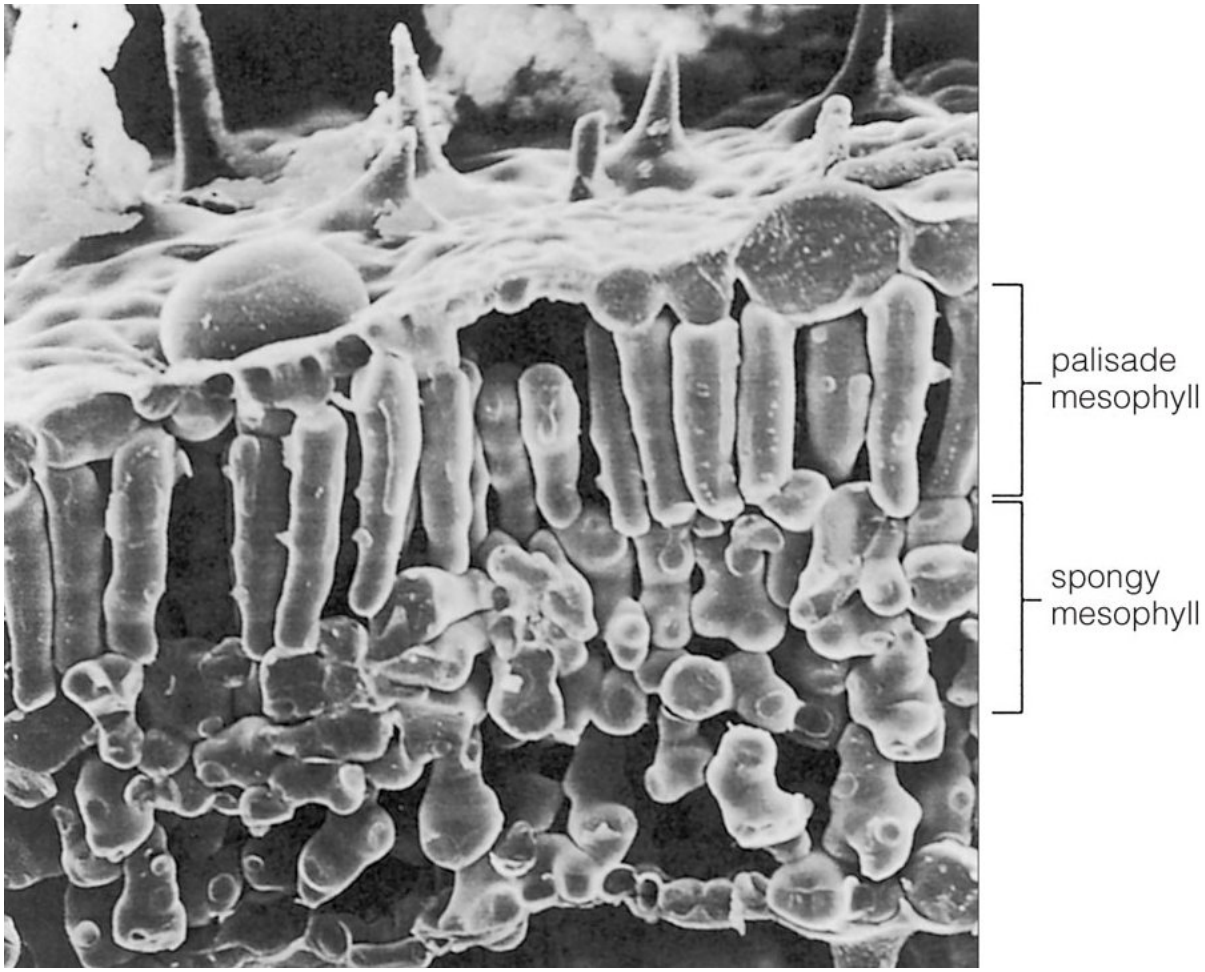
Stomata as balloons



Mesophyll

- Palisade mesophyll consists of tightly arranged elongated cells with less chloroplasts
- Spongy mesophyll consists of loosely attached cells rich of chloroplasts

Palisade and spongy cells



Final question (3 points)

Please draw the **entire** (not dissected), **ovate** leaf with **acute** apex, **cordate** base, **smooth** margin and **hyphodromous** venation.

Summary

- Internally, leaves are segregated into epidermis, mesophyll (parenchyma) and vascular bundles
- *Osmotic processes in guard cells* result in opening and closing of stomata
- The differentiation of mesophyll to **palisade** and **spongy** cells helps to acquire different types of sun rays
- Water deficit results in either sclerophyte or succulent adaptations
- Water excess results in hygrophyte or even hydrophyte adaptations

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 6*.

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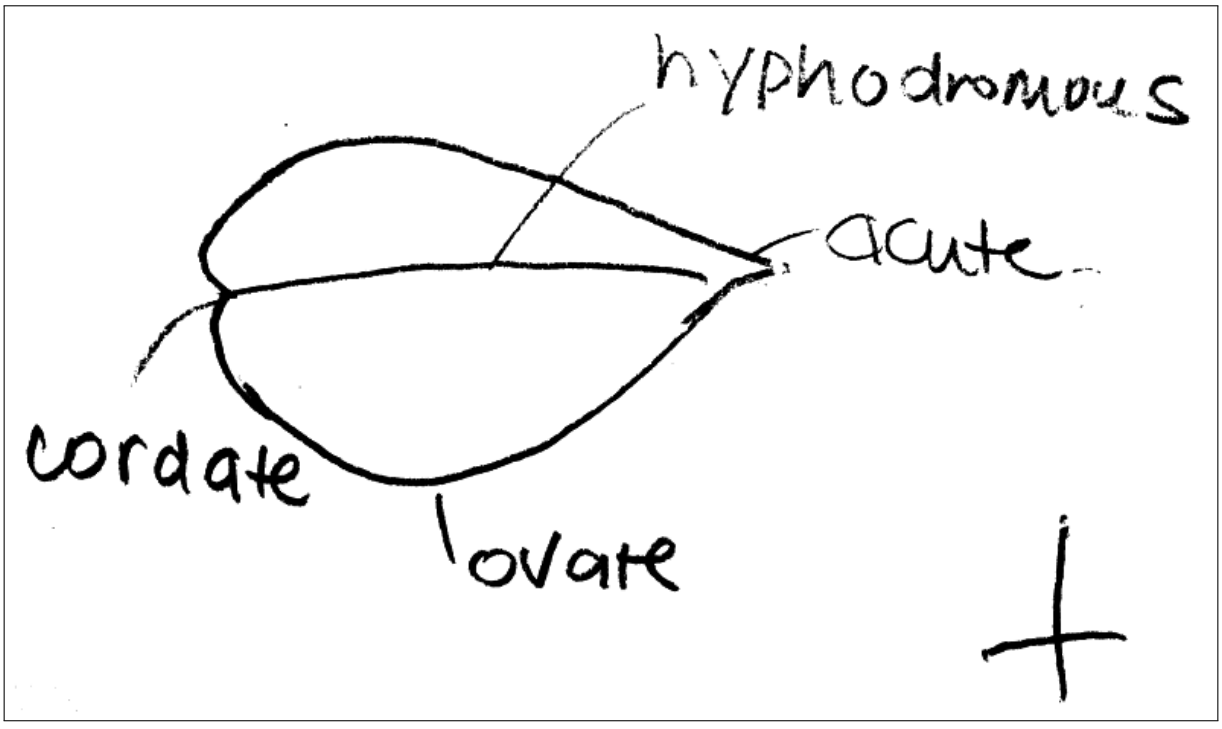
14 Questions and answers

Previous final question: the answer

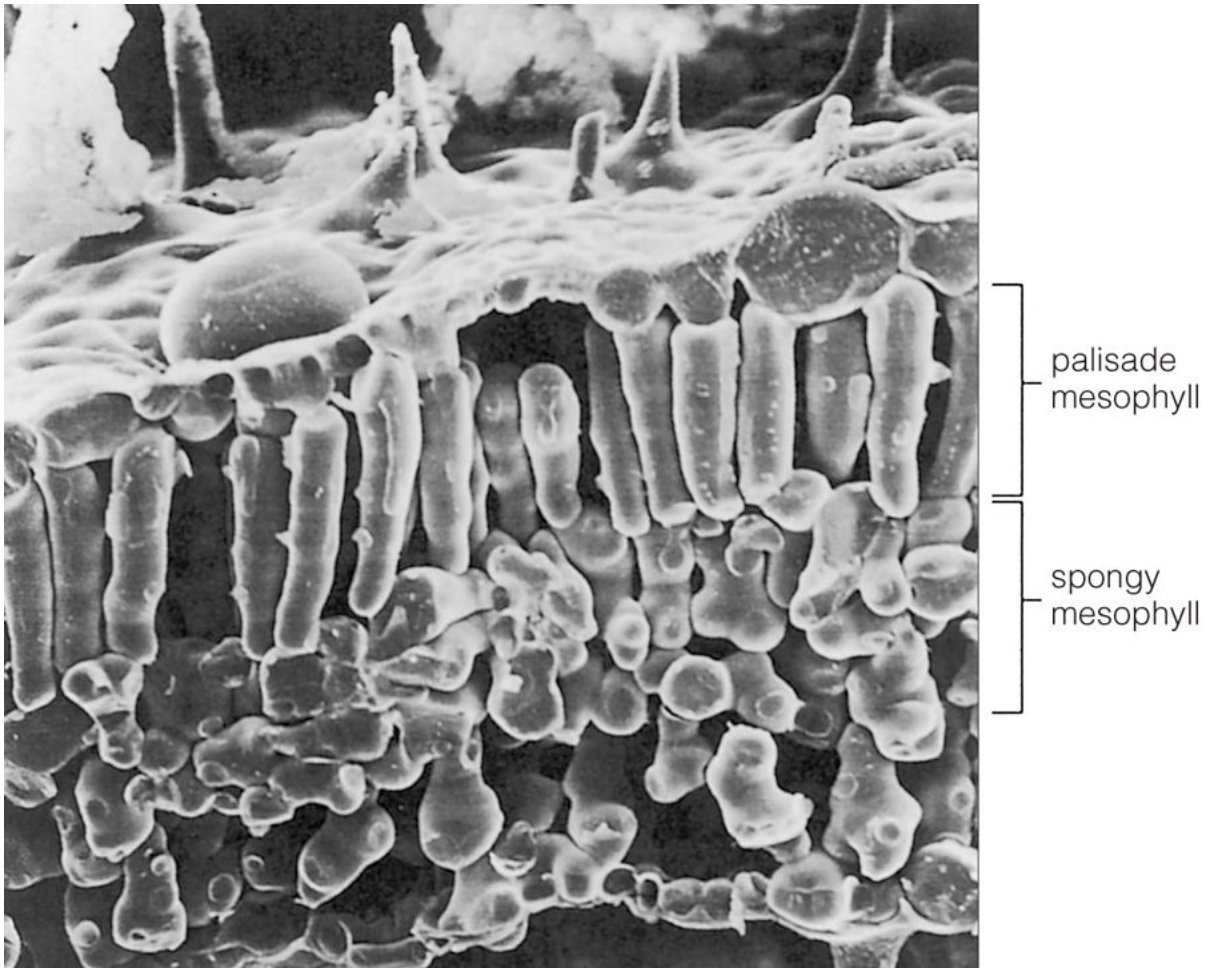
Please draw the **entire** (*whole*, not dissected), **ovate** leaf with **acute** apex, **cordate** base, **smooth** margin and **hyphodromous** venation.



15 Leaf

15.1 Anatomy of leaf

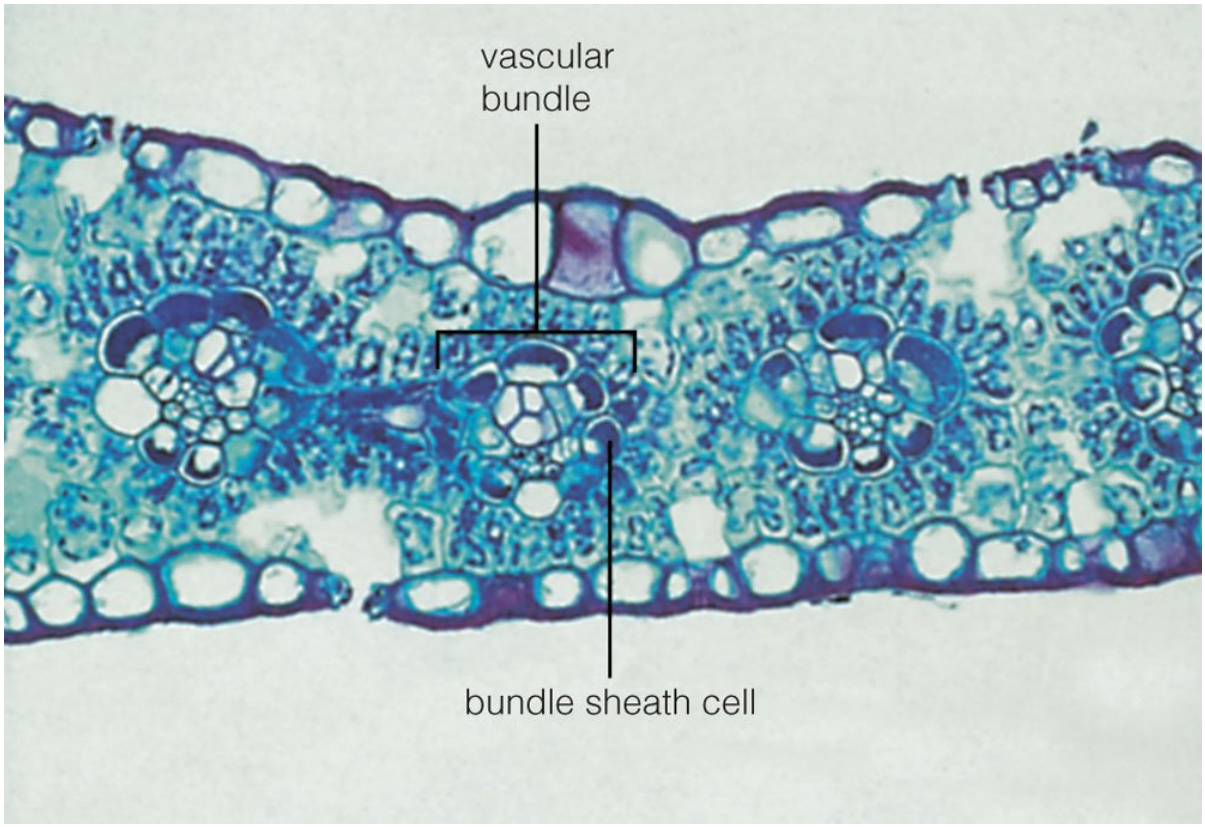
Palisade and spongy cells



Veins/vascular bundles

- Phloem typically faces downwards, xylem—upwards
- Bundles of C_4-plants have additional bundle sheath cells

Bundle sheath cells

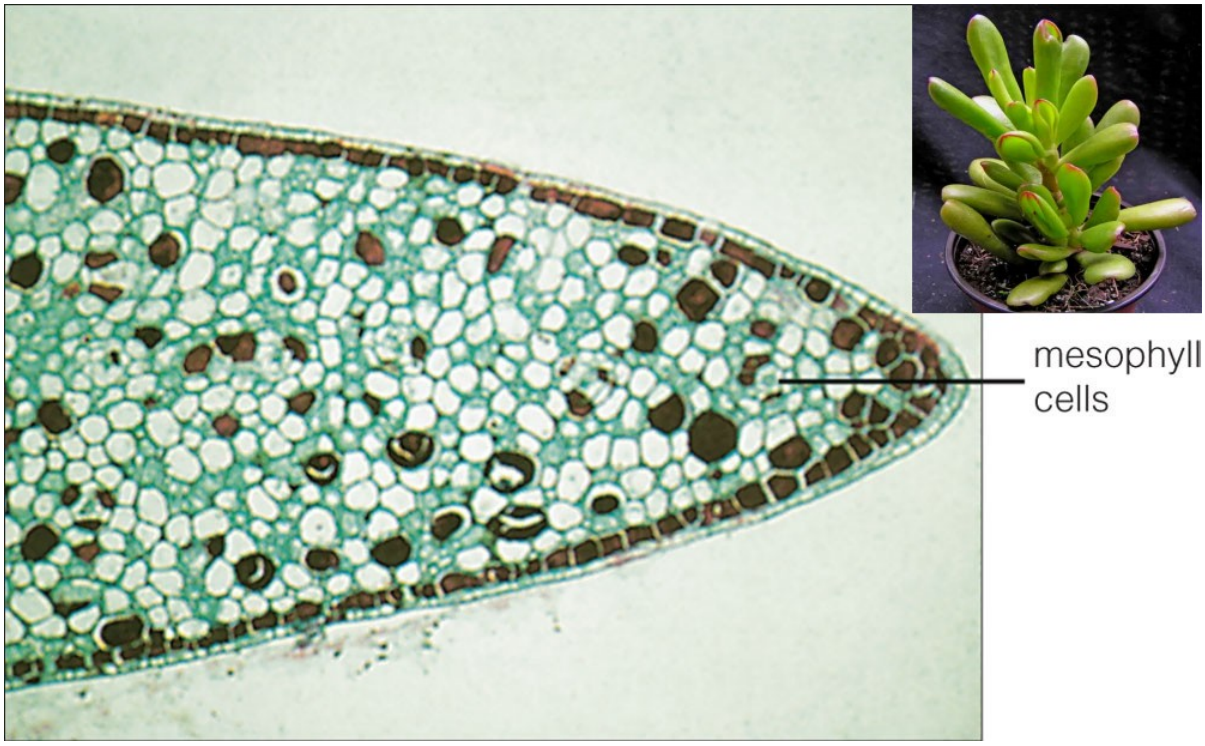


15.2 Ecological adaptations of leaves

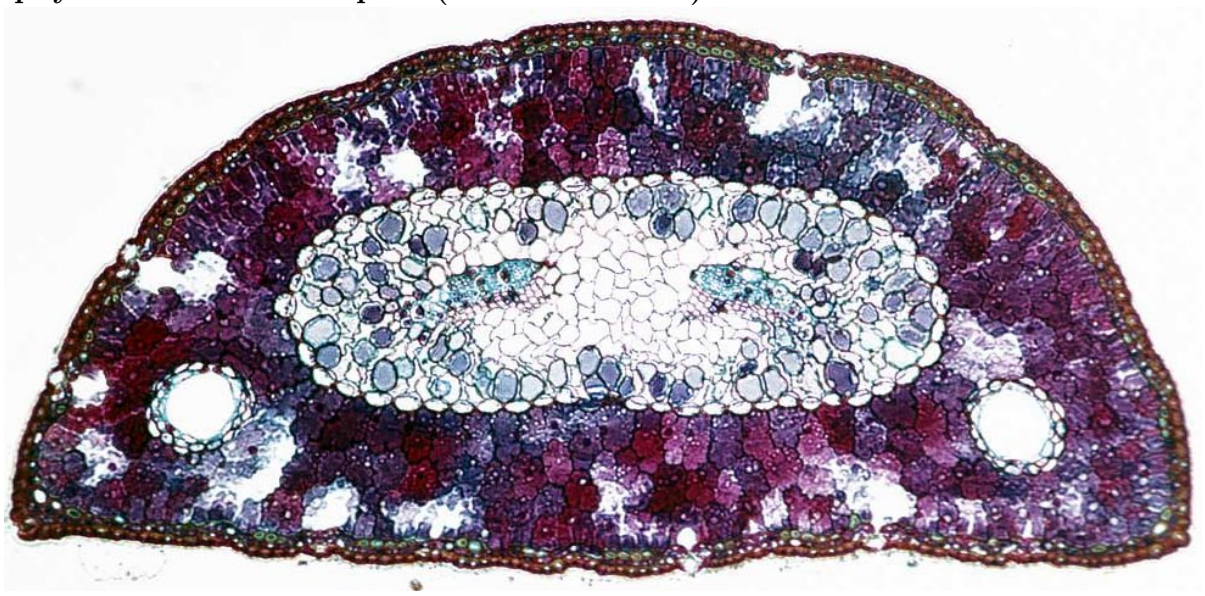
Plants and water

- Xerophytes: sclerophytes and succulents (stem and leaf)
- Mesophytes
- Hygrophytes
- Hydrophytes

Leaf succulent (*Crassula argentea*)



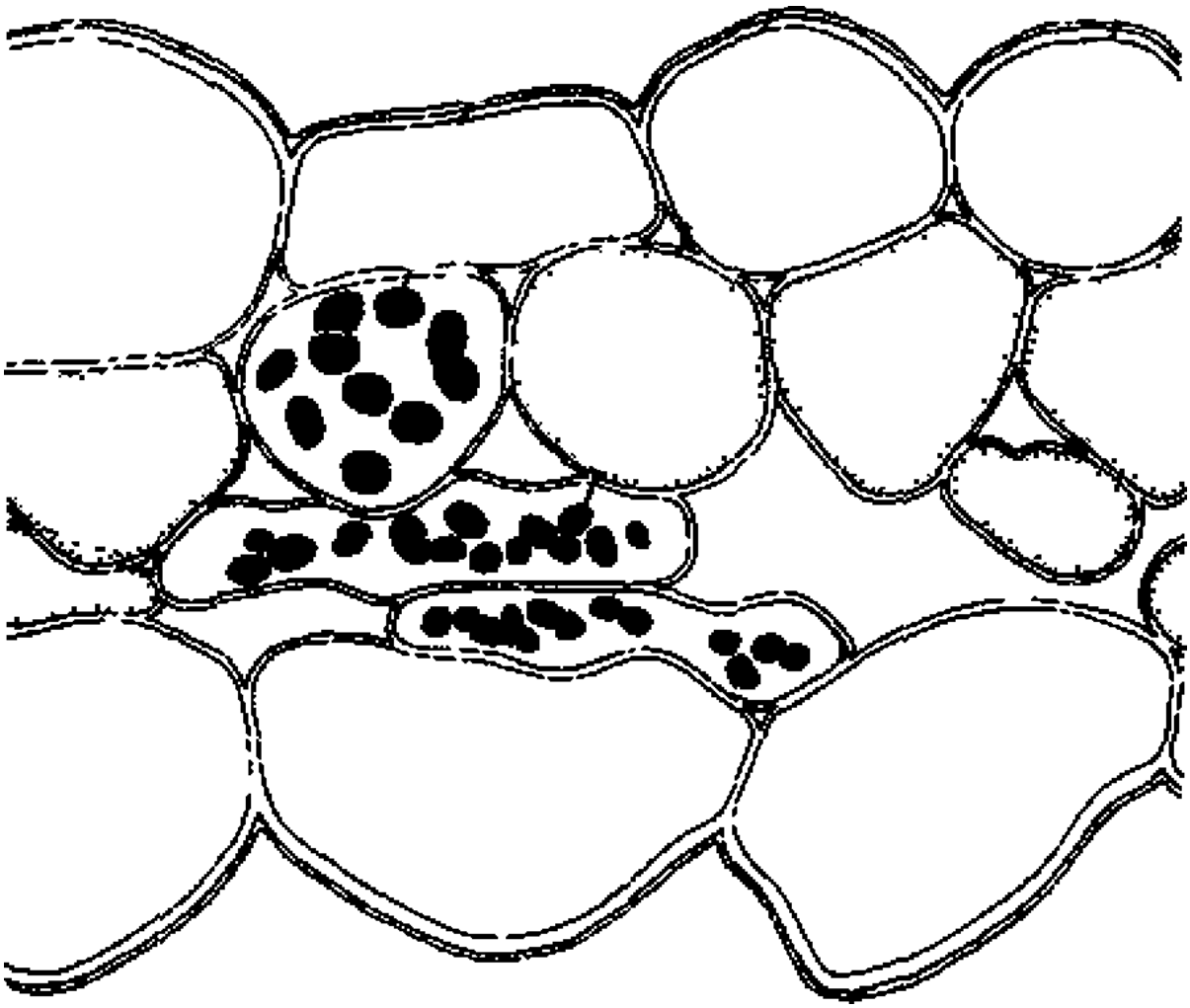
Xerophyte leaf—needle of pine (*Pinus contorta*)

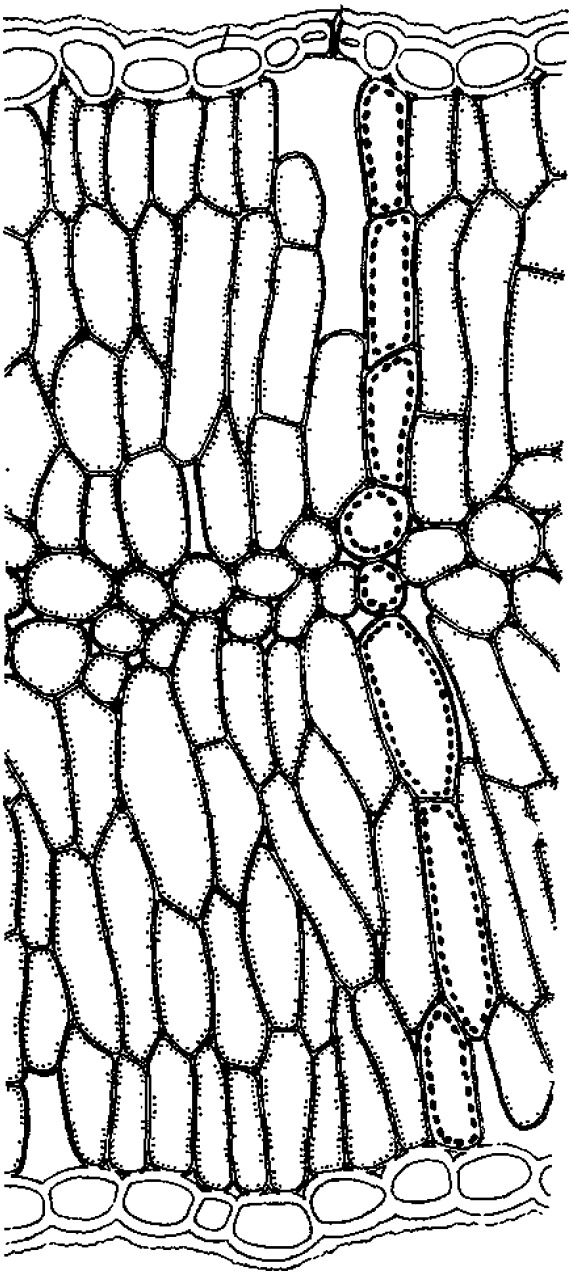


Plants and light

- Sciophytes
- Heliophytes

Sciophyte and heliophyte



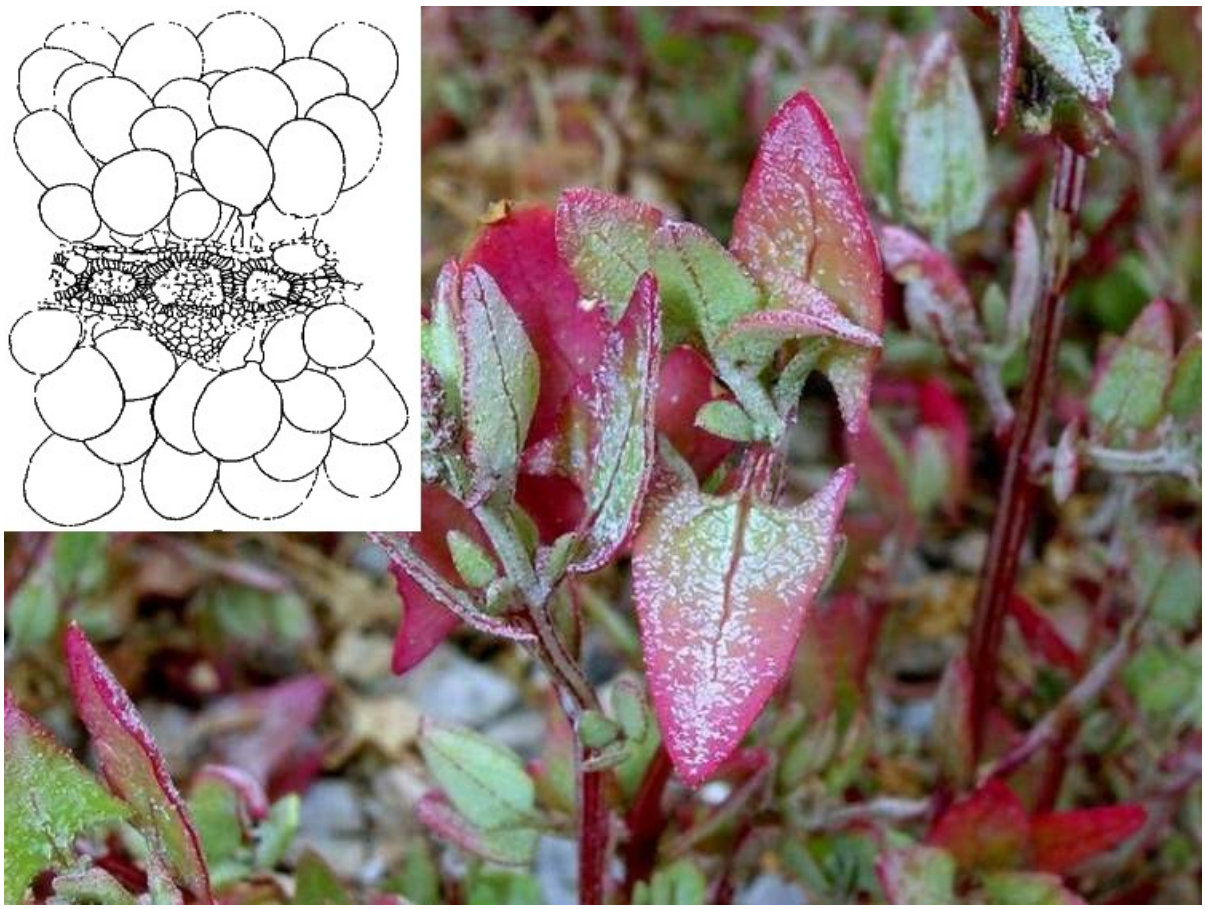


Oxalis acetosella and *Sylphium laciniatum*

Plants and soil

- Halophytes (accumulate, excrete or avoid NaCl)
- Nitrate halophytes (grow on soils rich of $NaNO_3$)
- Oxylophytes (grow on acidic soils)
- Calciphytes (grow on chalk soils rich of $CaCO_3$)

Leaf of salt-accumulating halophyte



Atriplex prostrata

Plants and substrate

- Psammophytes (grow on sand)
- Petrophytes (grow on rocks)
- Rheophytes (grow in fast springs)

Rheophyte

Macarenia clavigera from Venezuela

River with rheophytes

They are flowering, too

Podostemum ceratophyllum (may be found even in ND!)

Plants and metabolism

- Mycoparasites
- Hemiparasites
- Phytoparasites (root and stem)

Mycoparasite

Triuris hyalina from South America

Hemiparasite

Krameria parvifolia from southern Texas

Root parasite

Hydnora africana from South Africa

Stem parasite

Cuscuta europaea from Germany

Final question (2 points)

Which plants have more palisade mesophyll—heliophytes or sciophytes?

Summary

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

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 6*.

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16 Questions and answers

Previous final question: the answer

Which plants have more palisade mesophyll—heliophytes or sciophytes?

- Heliophytes (from Greek "Helios", Sun)

17 Stem and shoot

17.1 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

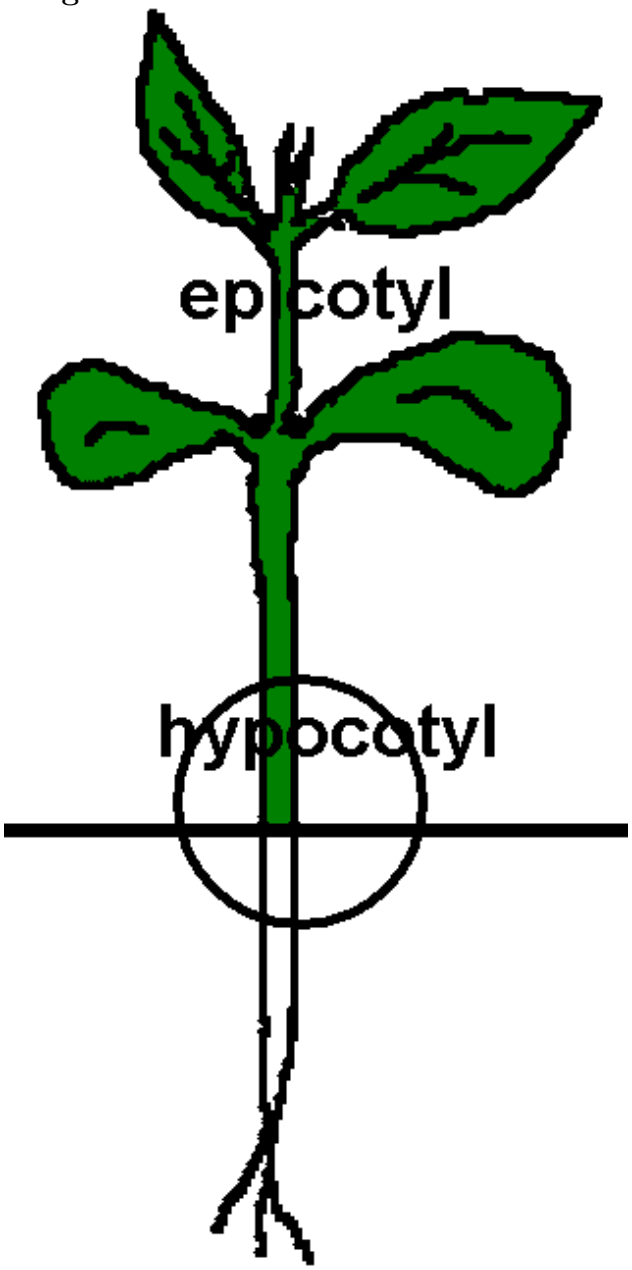
Types of plant body

- **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

Not 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

Organ systems: final

- Vegetative shoot system
- Generative shoot system
- Root system

Organs vs. organ systems

...	Vegetative shoot system	Generative shoot system	Root system
Leaf	+	+	−
Stem	+	+	±
Root	±	∓	+
FU	−	+	∓

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!

17.2 Anatomy of primary stem

Stem: definition and functions

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

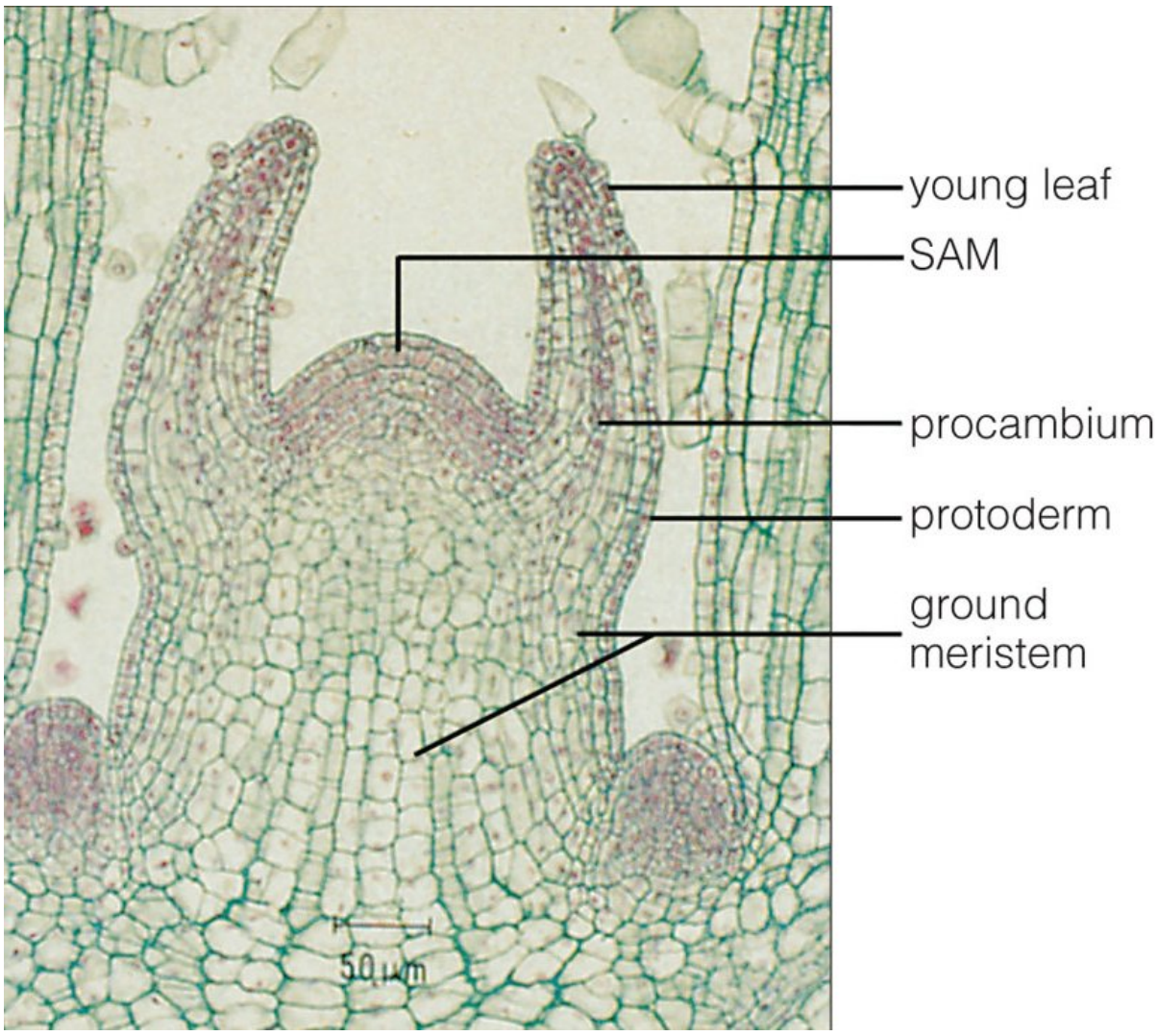
Protoderm to epidermis

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

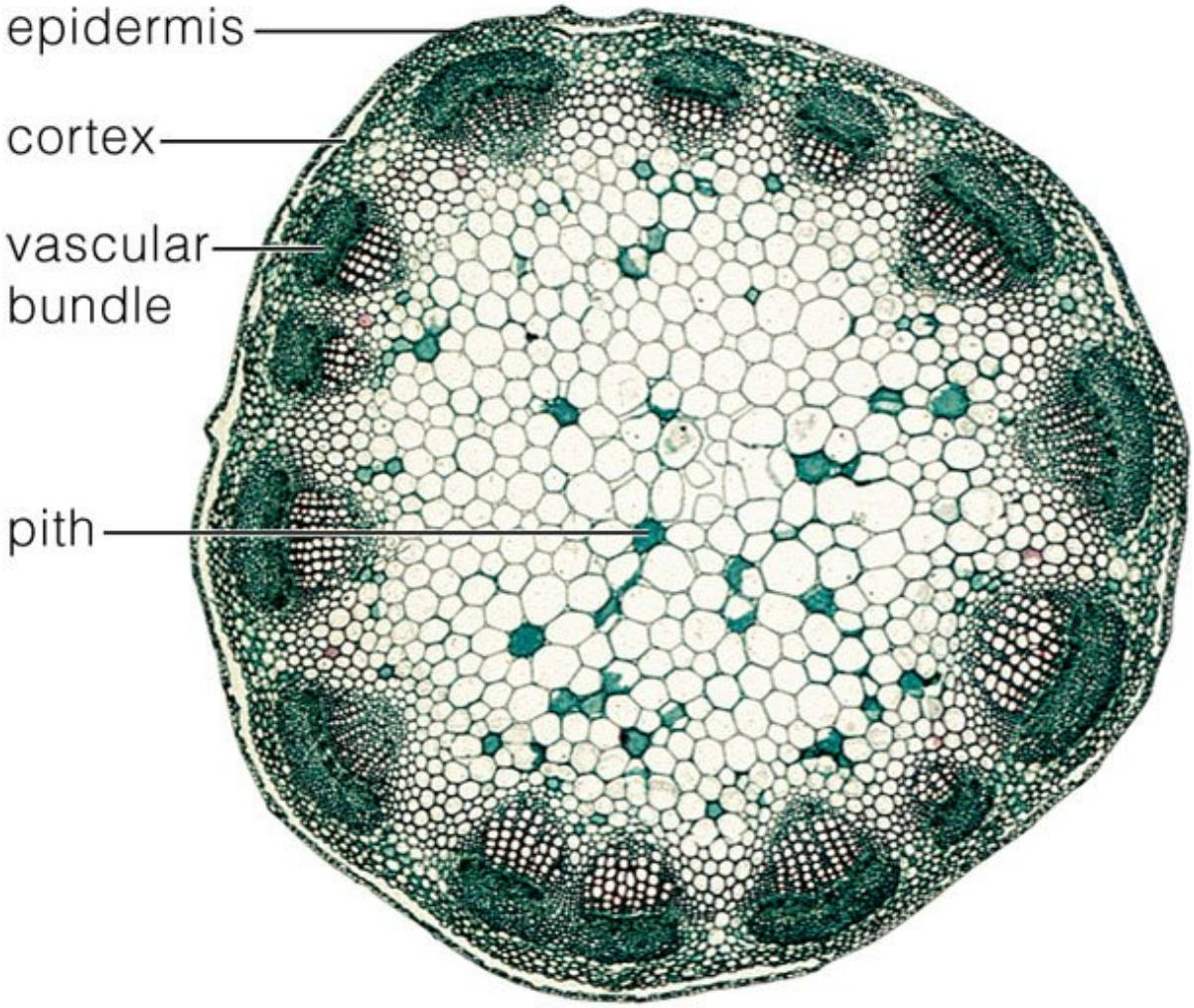
Ground meristem to cortex and pith

- 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

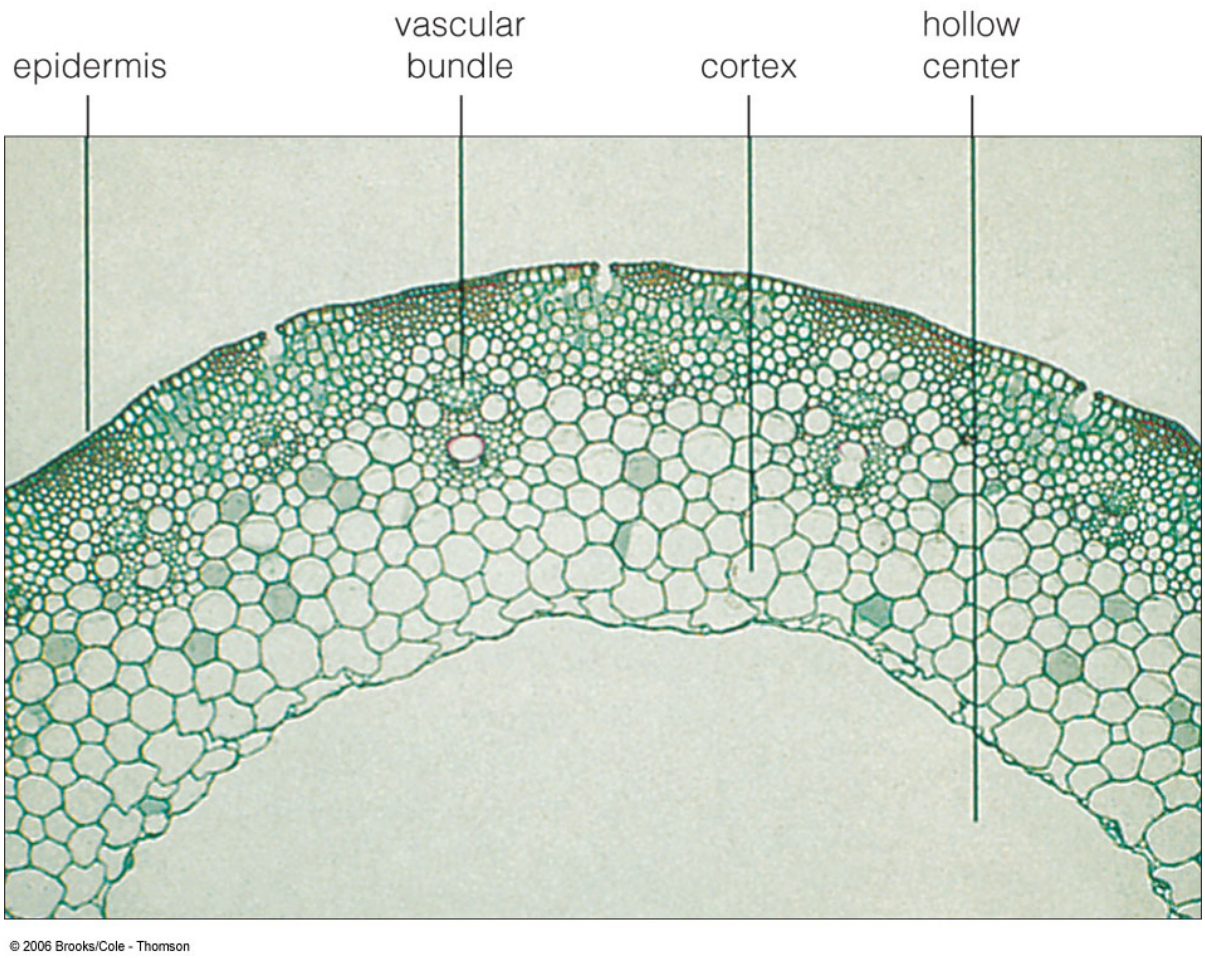
Three primary meristems: procambium, protoderm and ground meristem



Young stem with primary tissues



Older stem with hollow in the center



Final question (2 points)

Provide a list of plant organs.

Summary

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

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 5*.

18 The Private Life of Plants. Episode 2. "Growing"

[From Wikipedia]: Broadcast 18 January 1995, this programme is about how plants gain their sustenance. Sunlight is one of the essential requirements if a seed is to germinate, and Attenborough highlights the cheese plant as an example whose young shoots head for the nearest tree trunk and then climb to the top of the forest canopy, developing its leaves en route. Using sunshine, air, water and a few minerals, the leaves are, in effect, the "factories" that produce food. However, some, such as the begonia, can thrive without much light. To gain moisture, plants typically use their roots to probe underground. Trees pump water up pipes that run inside their trunks, and Attenborough observes that a sycamore can do this at the rate of 450 litres an hour in total silence. Too much rainfall can clog up a leaf's pores, and many have specially designed 'gutters' to cope with it. However, their biggest threat is from animals, and some require extreme methods of defence, such as spines, camouflage, or poison. Some can move quickly to deter predators: the mimosa can fold its leaves instantly when touched, and the Venus flytrap eats insects by closing its leaves around its prey when triggered. Another carnivorous plant is the trumpet pitcher that snares insects when they fall into its tubular leaves. Attenborough visits Borneo to see the largest pitcher of them all, Nepenthes rajah, whose traps contain up to two litres of water and have been known to kill small rodents.

Outline

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19 Questions and answers

Previous final question: the answer

Provide a list of plant organs.

- Leaf, stem, root, FU

20 Stem and shoot

20.1 Anatomy of primary stem

Protoderm to epidermis

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

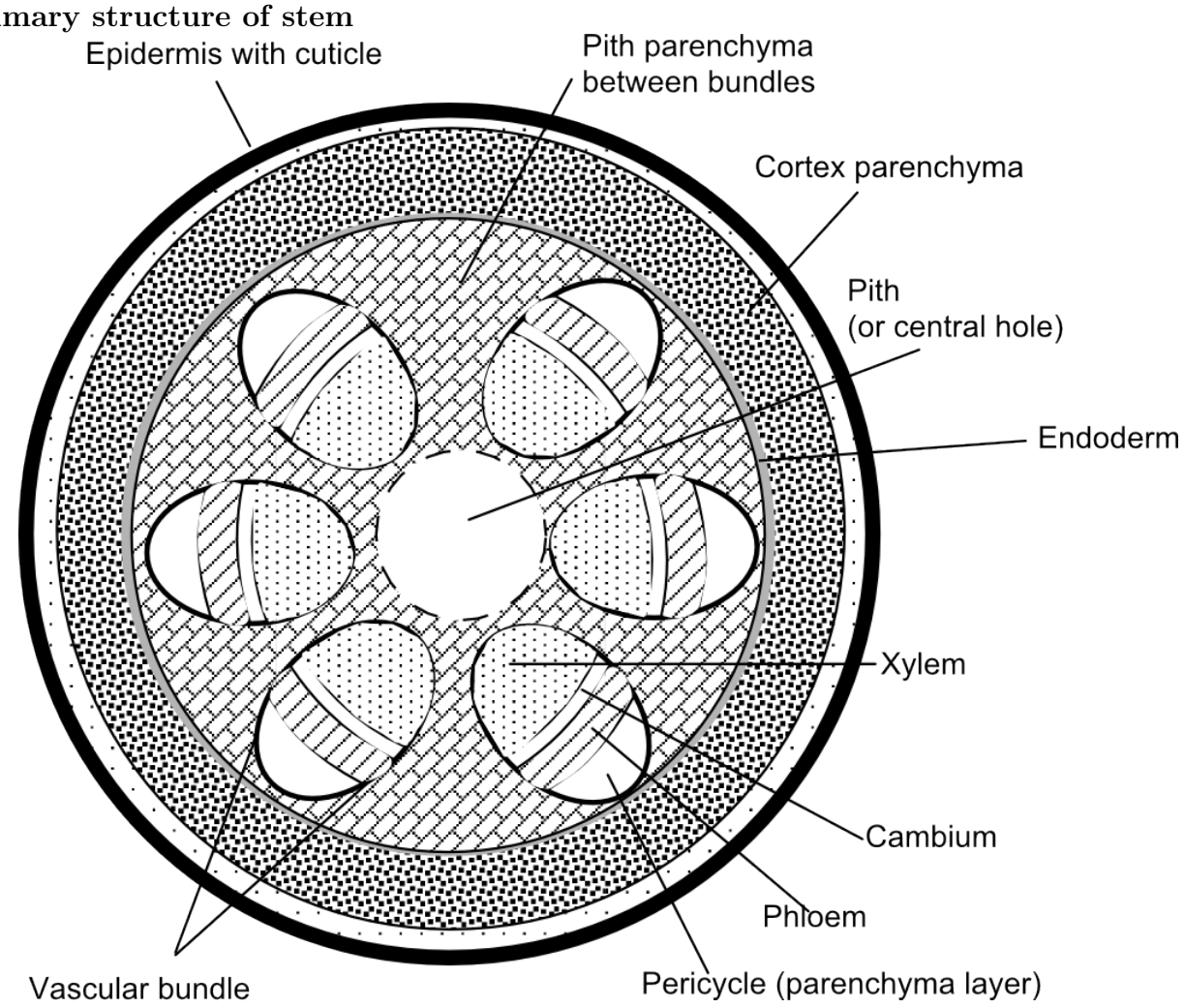
Ground meristem to cortex and pith

- 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

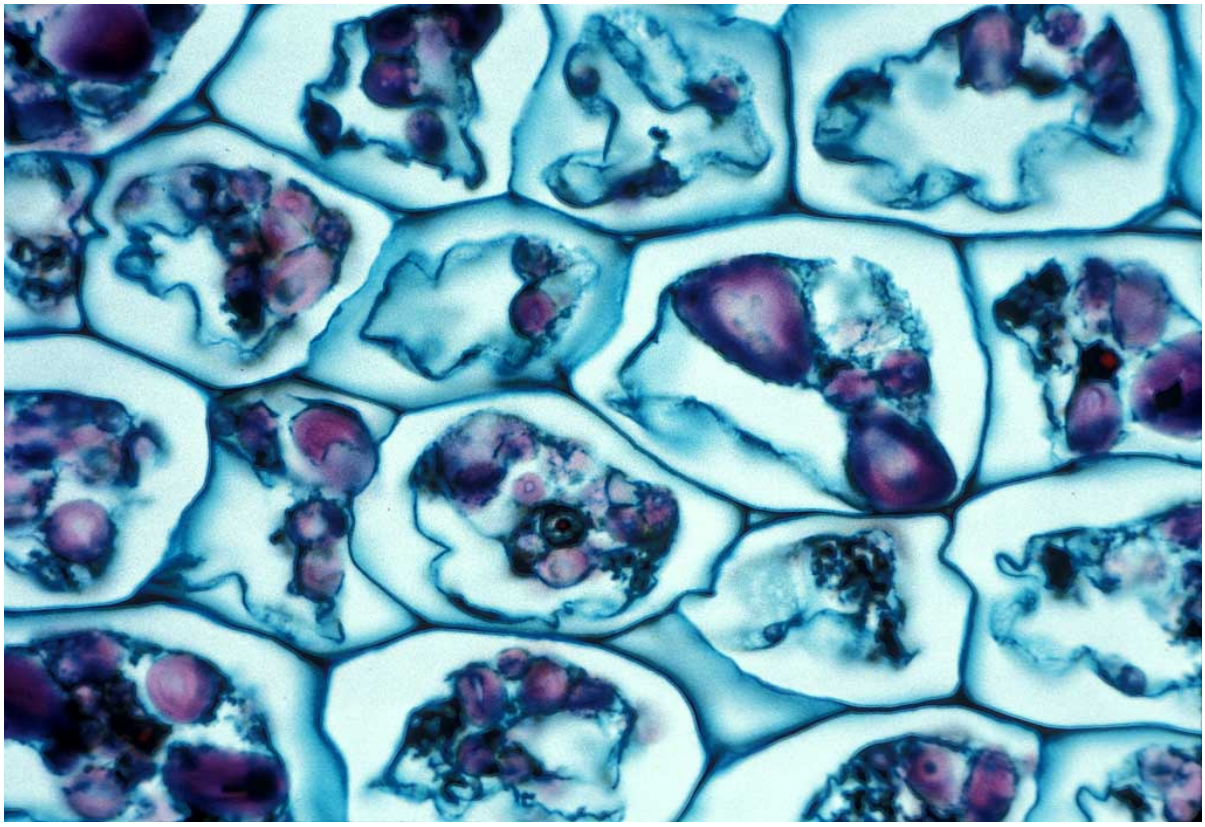
Procambium to xylem and phloem

- 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**

Primary structure of stem

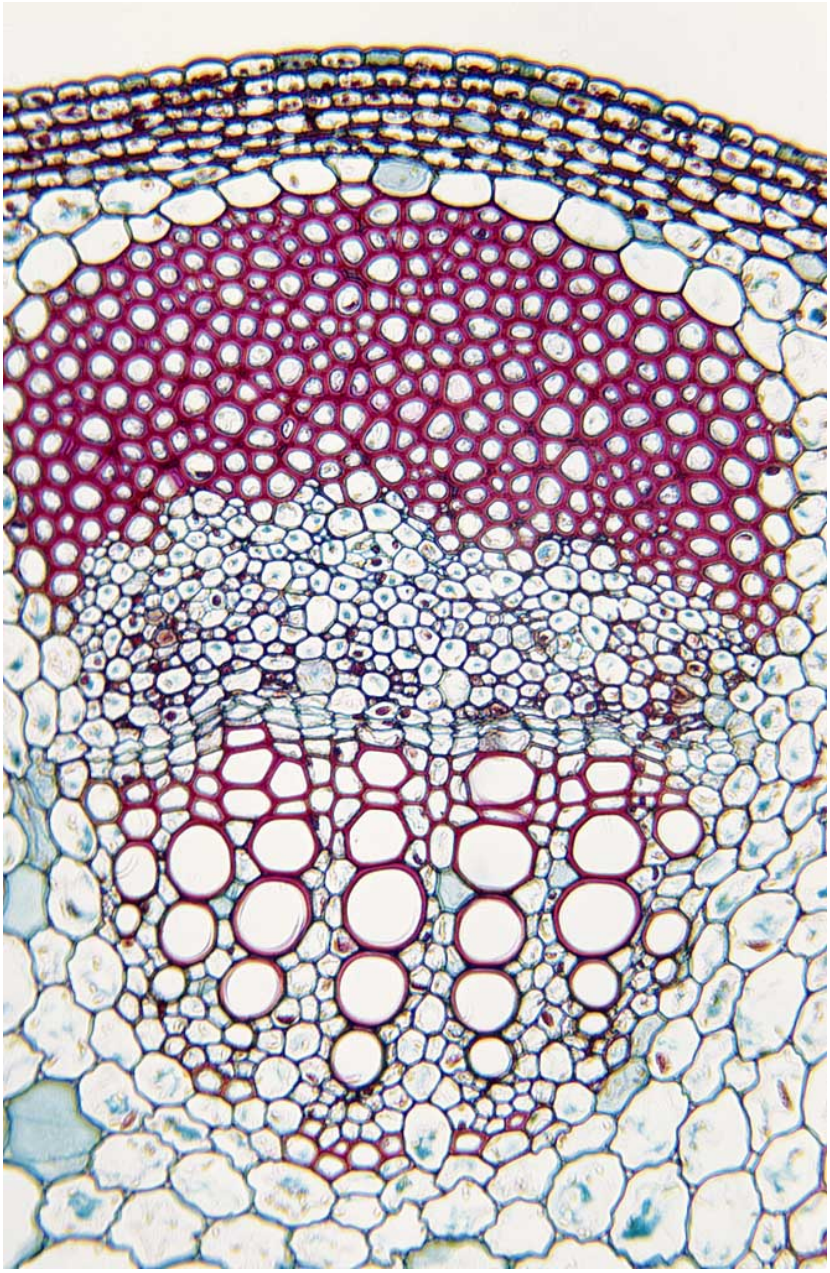


Vascular bundle (monocot)



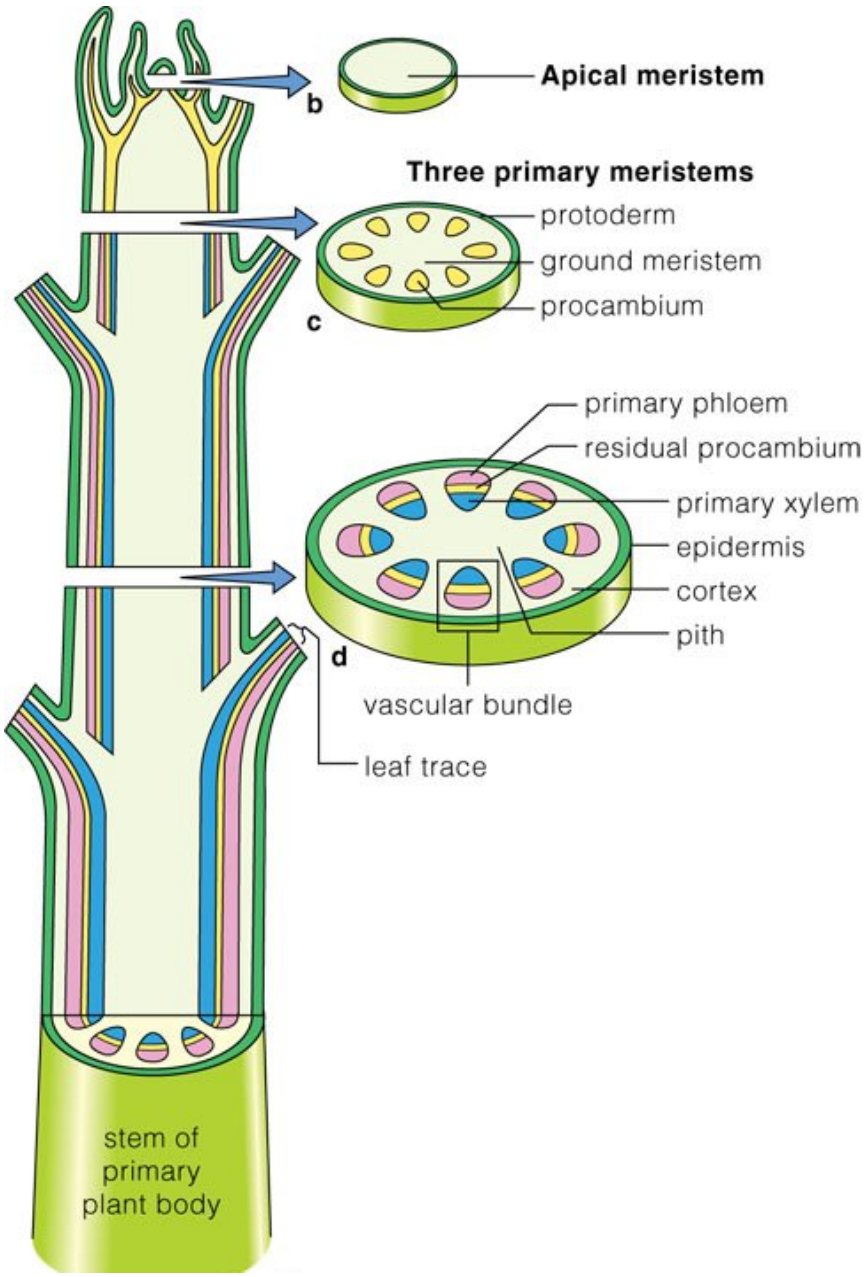
Corn (*Zea mays*) mature stem cross-section showing single vascular bundle, Brightfield (LM ×400)

Vascular bundle (asterid)



Wild Sunflower (*Helianthus* sp.) with nearly mature vascular bundle (LM ×35)

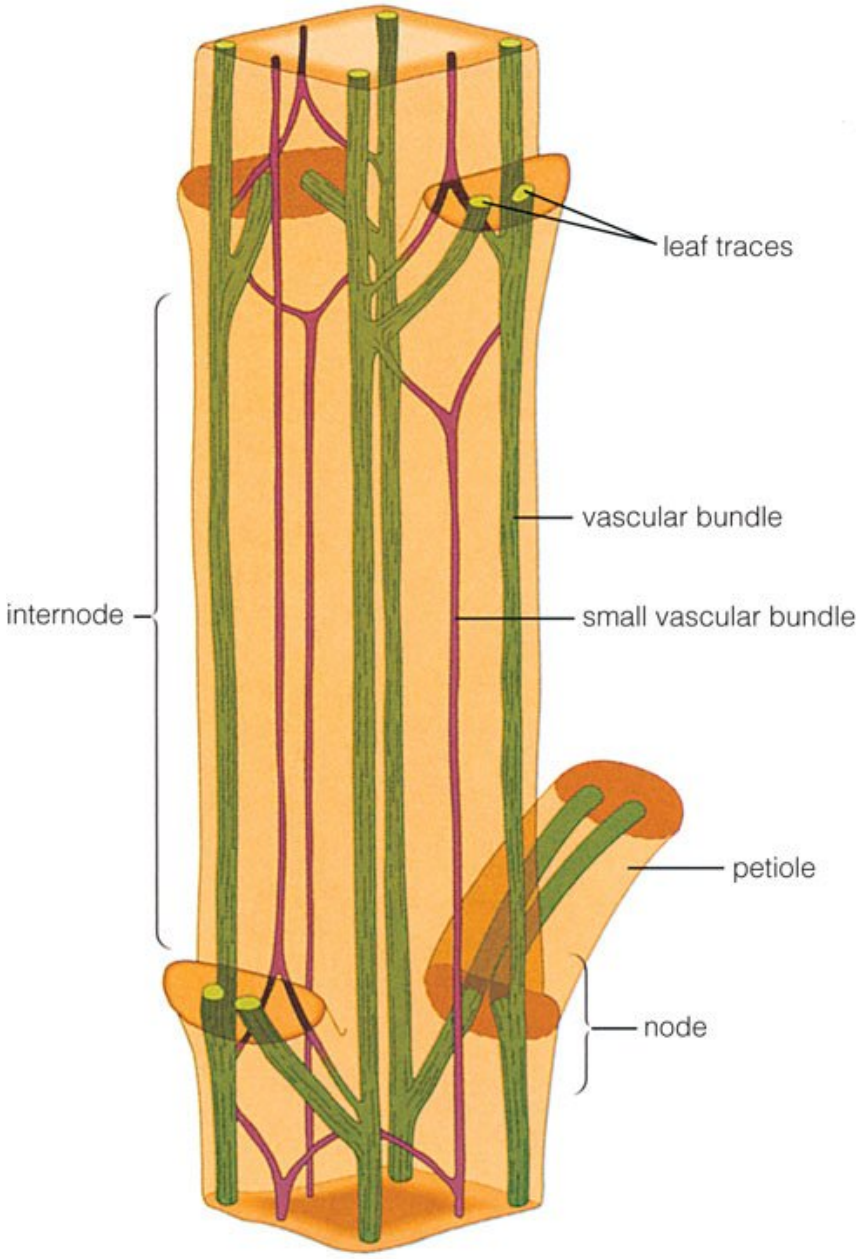
Origin of vascular bundles



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



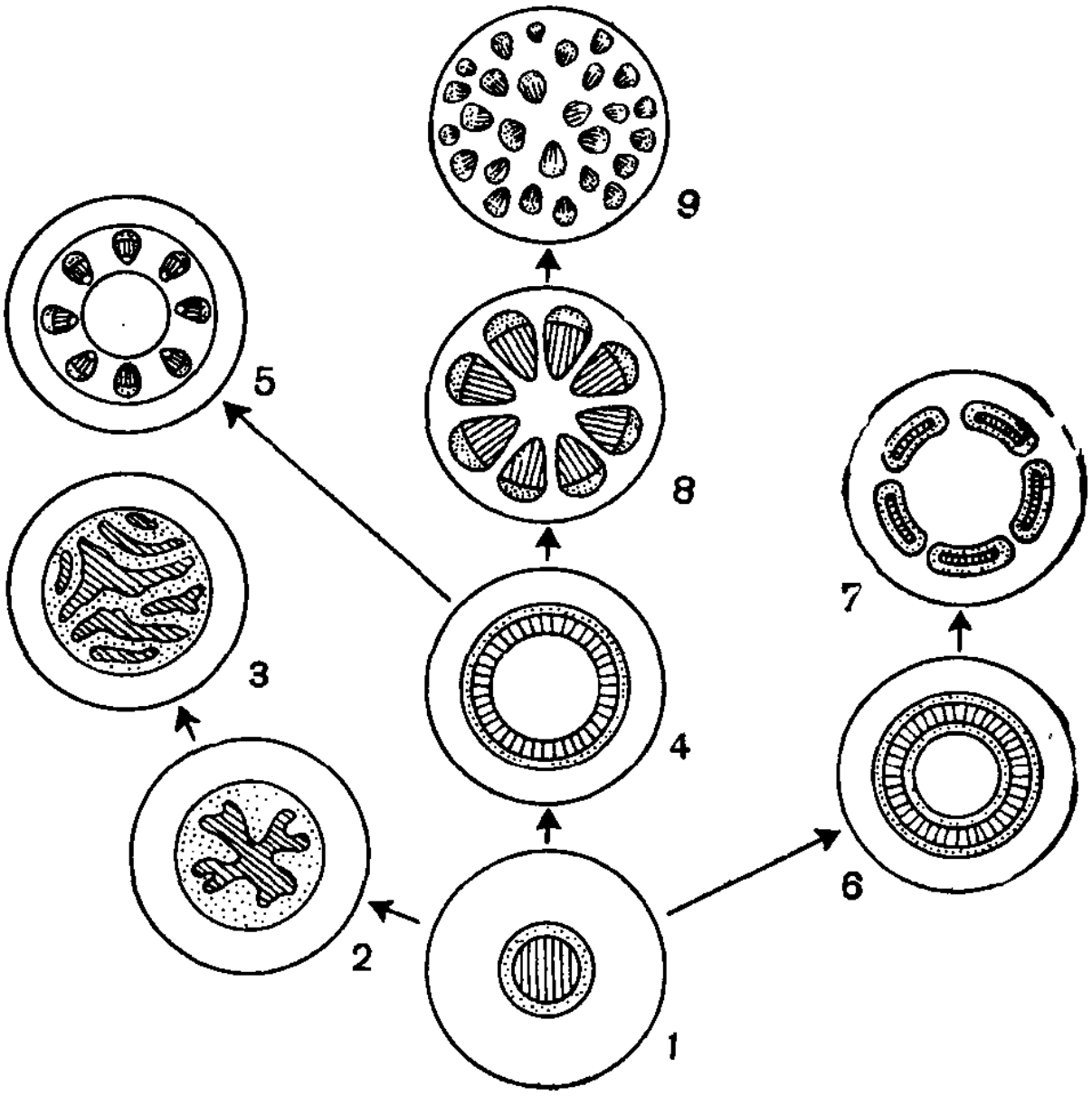
Monocot stem

Corn (*Zea mays*) stem (LM ×4)

Steles

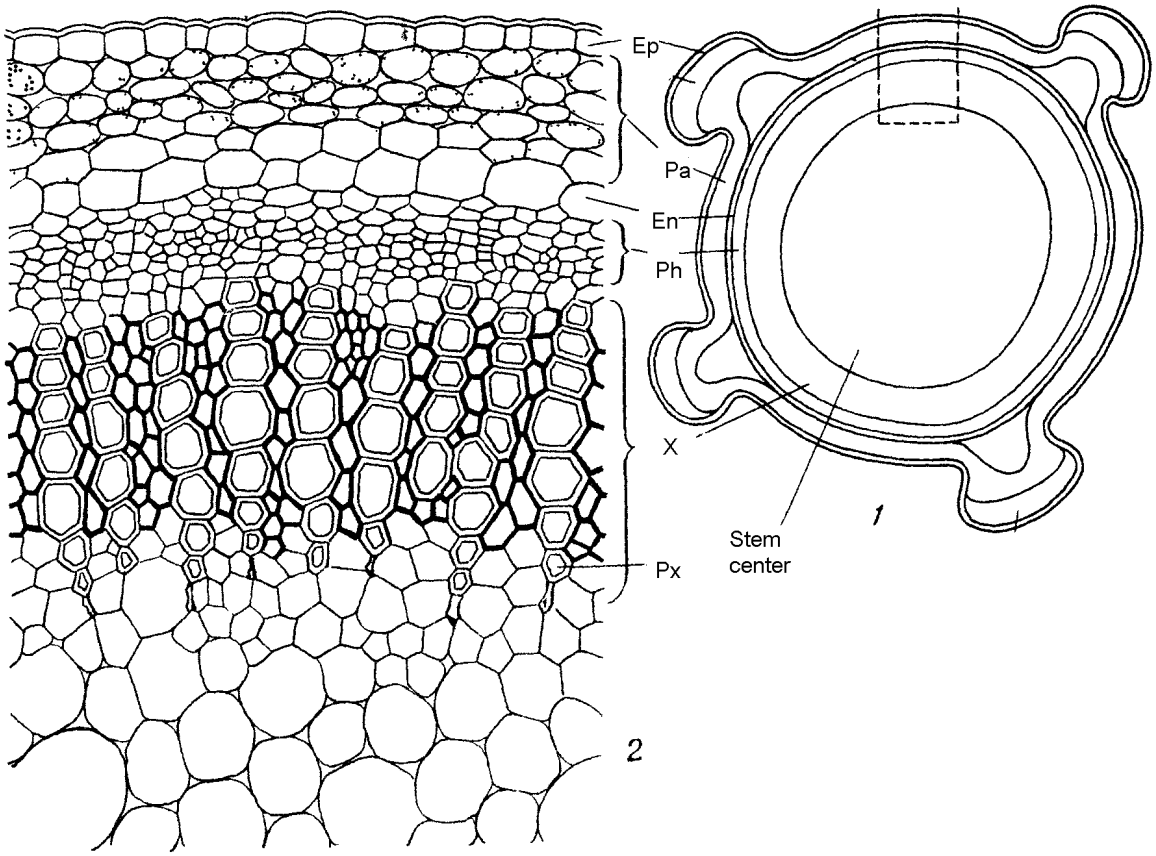
- **Stele** is an overall configuration of primary vascular system of plant stem
- The most important kinds of steles are: **protostele**, **solenostele**, **eustele** and **ataktostele***

Diversity of steles



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

Vascular cylinder: alternative to ring of bundles



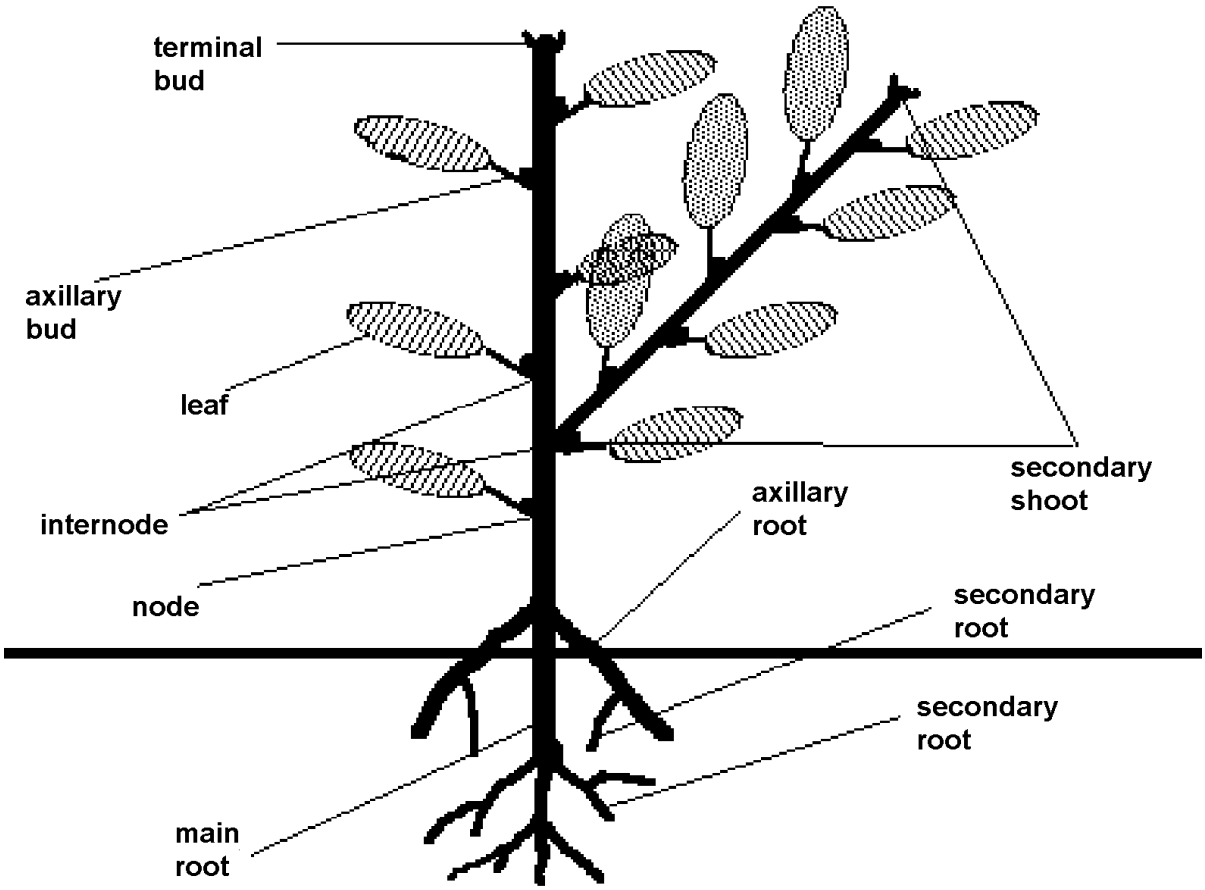
Sometimes, vascular bundles are so dense that they form almost a cylinder. We may call this vascular cylinder "solenostele" (#4 on the scheme of steles)

20.2 Components of shoot

Components of vegetative shoot system

1. Main and secondary shoots
2. Terminal and axillary (lateral) buds
3. Nodes and internodes
4. Leaves

Components of shoot

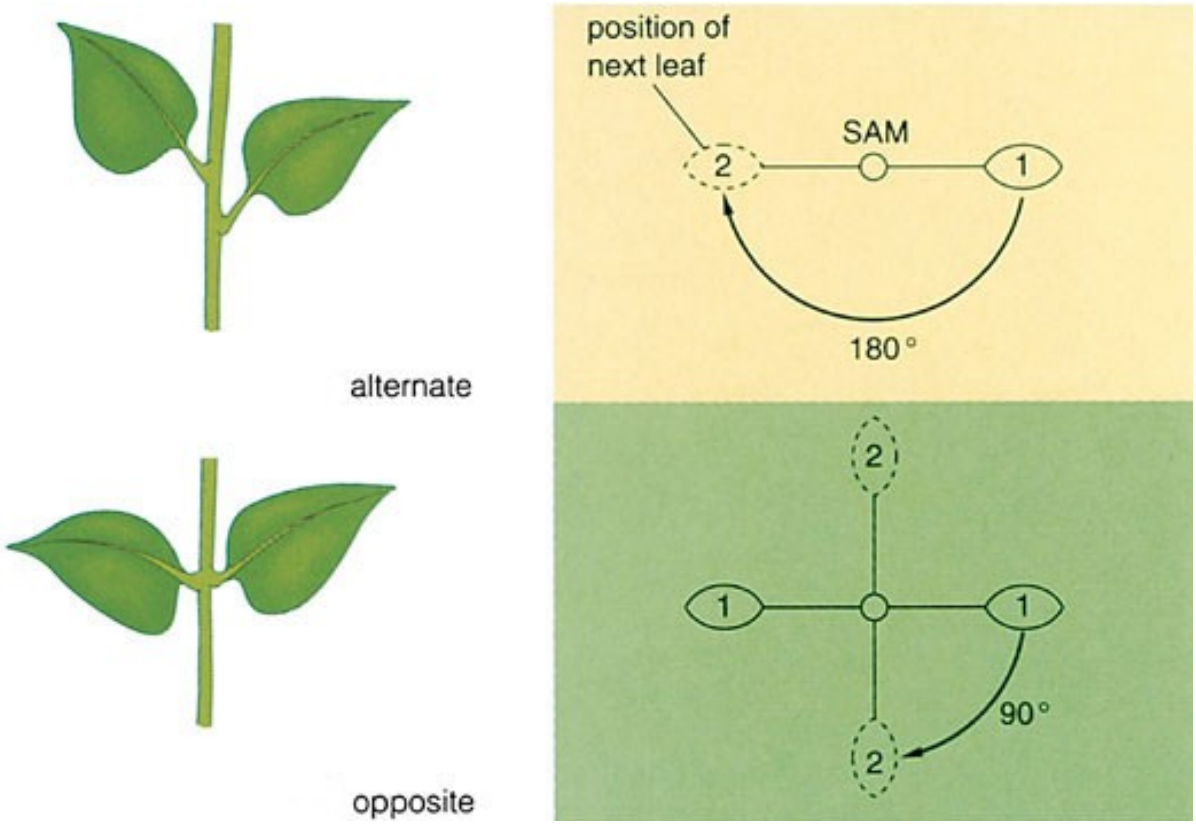


20.3 Phyllotaxis

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



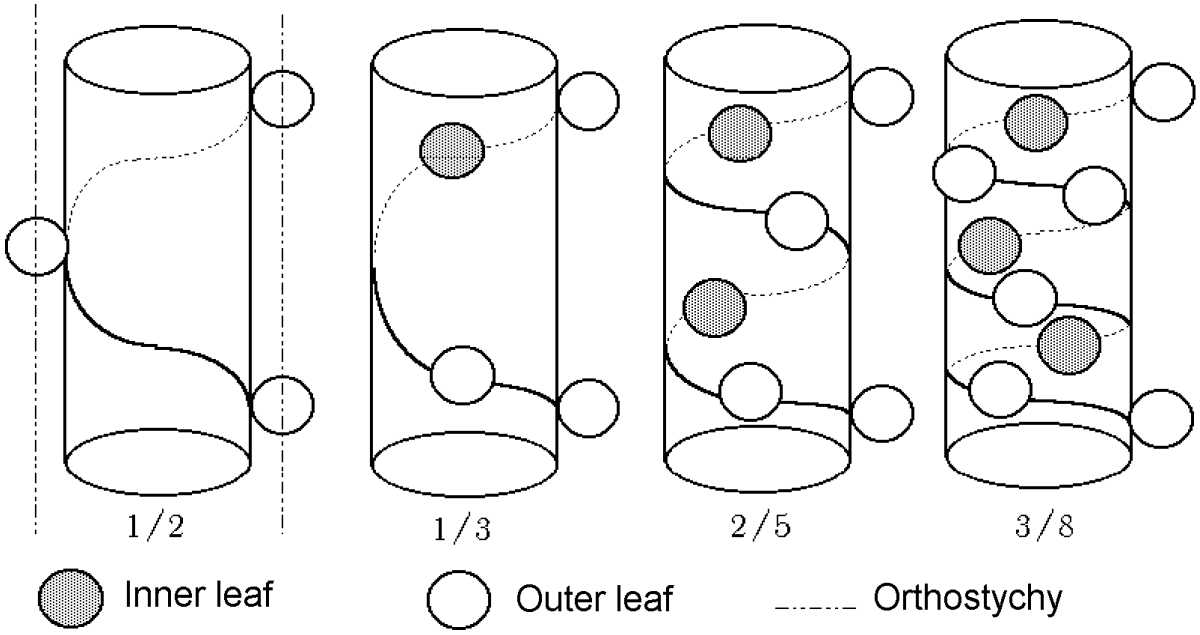
Spiral phyllotaxis: Fibonacci rule

- 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)

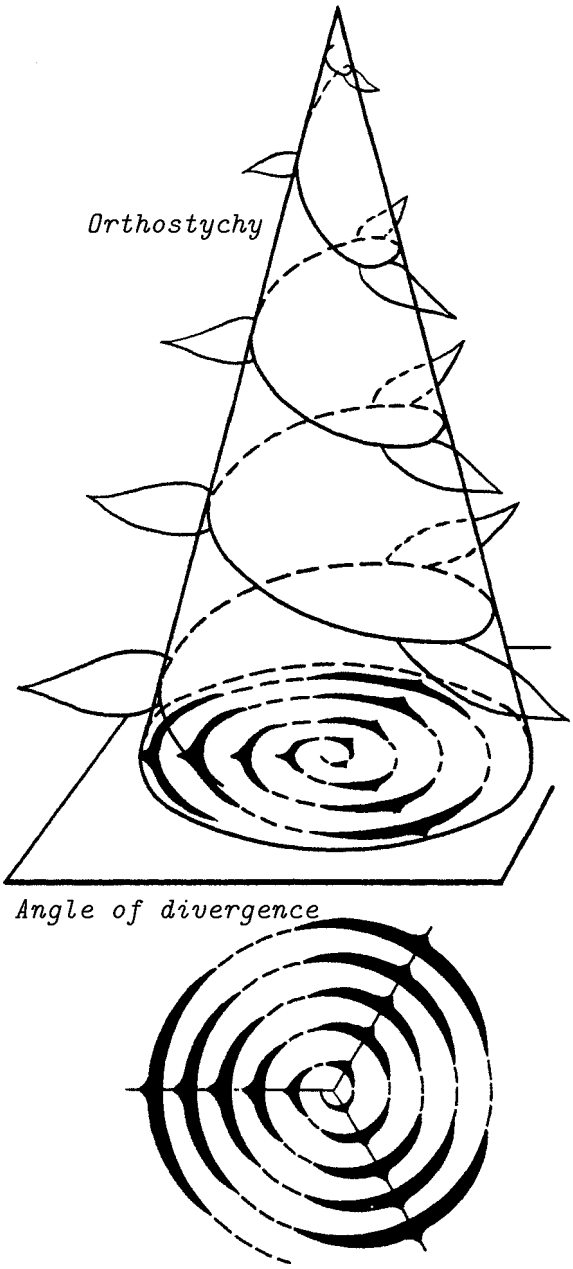
Spiral phyllotaxis: how to make a formula

- 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)

What is ataktostele?

Summary

- SAM produces **protoderm** and **ground meristem**, ground meristem differentiates into **cortex** and **pith**
- Procambium forms **vascular bundles** or vascular cylinder
- Outer layers of procambium transform into primary phloem, inner layers — into primary xylem
- Monocot stem usually has dispersed vascular bundles (**ataktostele**)

- Spiral arrangement of leaves follows **Fibonacci** rule

For Further Reading

References

[1] A. Shipunov. *Introduction to Botany* [Electronic resource]. 2010—onwards. Mode of access: `http://ashipunov.info/shipunov/school/biol_154`

[2] Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy. *Plant Biology*. 2nd edition. Thomson Brooks/Cole, 2006. *Chapter 5*.

21 Example questions for the exam

Start time _____ *End time* _____

22 Short answers

1. Why insectivorous plants use their leaves (not roots, not stems) for catching insects? (*3 points for every reliable explanation*)

2. Describe one leaf from this branch (*unlimited amount of points, every reliable element of description = 1 point*)

General characters:

1st level repetitive characters:

2nd level repetitive characters:

Terminal characters:

23 Multiple choice

Every question in this section costs either 1 or 0. Please **mark** the appropriate answer on the **scantron**.

1. Which of the following is always the primary tissue?
   (a) Epidermis
   (b) Phloem
   (c) Periderm
2. Epidermis:
   (a) Presents in roots and leaves
   (b) Takes water from soil
   (c) Develops from cambium
   (d) Is a complex tissue
3. Poikilohydric plants:
   (a) Trying to save water
   (b) Trying to get rid of water
   (c) Do not depend on soil water
4. Three basic plant organ systems
   (a) Shoot system, flower system, vascular tissues
   (b) Root system, vegetative shoot system, generative shoot system
   (c) Root system, shoot system, FU
5. In the cross section of a stem, the parenchyma is typically found:
   (a) In the center
   (b) In the middle
   (c) On the surface
6. Which of the following is NOT a characteristic of the leaves of hygrophyte plants?
   (a) Thin cuticle
   (b) Thick leaves
   (c) Few stomata