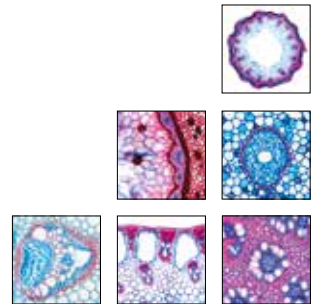


Microscopic features of monocotyledonous plants

**Features of culms, flower stalks,
stems and rhizomes**

Vol. IV



**Fritz H. Schweingruber
Hugo Berger**

Coverphoto
Eriophorum scheuchzeri

Species on the cover
Top: *Agropyron cristatum*
Middle (left to right): *Luzula alpina-pilosa*, *Potamogeton pectinatus*
Base (left to right): *Carex acutiformis*, *Carex pseudocyperus*, *Carex appropinquata*

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1. Introduction

The list of monocotyledonous culms, flower stalks, rhizomes and stem-features is a result of the studies published in three volumes:

- Vol. I Anatomy of grass culms (Schweingruber and Berger 2017)
- Vol. II Anatomy of culms and rhizomes of sedges (Schweingruber and Berger 2018)
- Vol. III Anatomy of culms and flower stalks of monocotyledonous plants (Schweingruber and Berger 2018)

Here we present the first time a list of features which is applicable on the whole spectrum of monocotyledonous plants in temperate zones of the northern hemisphere. The definition of features is primarily based on double stained microscopic slides from recently collected material. The origin of some feature-characterization originates from monographs of Schenk 1886 and Evans 2003, Seago et al. 2005 and Jung et al. 2008 all of them concentrated on aerenchymatic tissues.

The anatomy of monocotyledonous shoots was subject of many taxonomic studies primarily from Metcalfe 1960 and 1971, Conert 1968, Cutler 1969, Grosser 1971, Schulze-Motel 1980, Stern 2014 and Thomlinson 1961. The species are described in monographs of Poaceae, Cyperaceae, Juncaceae (Juncus and Luzula) and Helobia (Alismatales, Hydrocharitales, Scheuchzeriales, Potamogetonales), Orchidaceae, Bambusae and Palmae.

A few anatomic-ecological studies concentrate on water plants in eastern North America (Ogden 1974) and Central Europe (Schweingruber et al. in preparation) on alpine plants in Ladakh, Himalaya (Dolezal et al. 2018) and on Halophytes (Grigore et al. 2014). Previous studies are cited in all mentioned monographs.

The present study is part of an anatomical project about all stem anatomical traits of angiosperms (Schweingruber et al., 2011 and 2013, Crivellaro and Schweingruber 2015)

The goal of the study is the photographic presentation and characterization of principal features which occur in monocotyledonous plants of the temperate zone of the northern hemisphere.

Three major groups are presented: Culms of Poaceae, Juncaceae and Typhaceae, culms and rhizomes of Cyperaceae and flower stalks for the other families. Parts of plants are mainly characterized by some functional traits as outline, the epidermis, the culm center, the arrangement of vascular bundles, the chlorenchyma, the peripheral belt of sclerenchyma, aerenchyma, crystals and dark stained substances.

The numbering of features is rather erratic because we did not know the whole spectrum when we began the study. We decided to keep the numbering in vol. IV. Therefore all feature numbers of vol. I to IV have the same significance. Totaly 102 culm and 54 rhizome features are described.

2. Material

Cross-sections of all Poaceae species are based on material from the United Herbaria Z and ZT of the University and ETH Zürich. Since thin-walled anatomical structures collapse during drying processes we had to section primarily fresh material from all other families, which has been collected in nature or botanical gardens.

The feature list is based on the anatomical evaluation of 580 species.

Included is material from the temperate and Mediterranean zone along altitudinal gradients from the lowland to the alpine zone in Western Europe. Respected are terrestrial species from very dry and moist sites (helophytes) and water plants (hydrophytes). For detailed species-related information about growth form, plant size, site conditions and localities see remarks on top each species characterization in vol. I-III.

3. Preparation

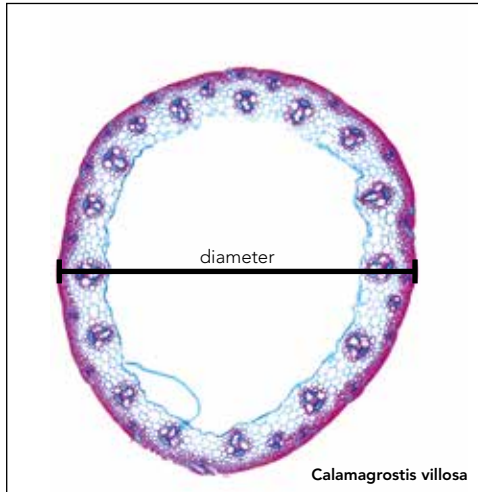
Culms were sectioned in the upper half of the culm outside of leaf sheets or flower stalks and well-preserved parts of rhizomes. Cross-sections of large plants are made from the periphery of stems (Draceaena, Bambusae).

After collection significant parts of the plant were labeled and stored in ethanol 40%. The detailed technique is described by Gaertner and Schweingruber 2013. All sections are stained with a one to one mixture of Safranin/Astrablue for a few minutes. Staining and dehydration with ethanol 96% and xylene occurred directly on the glass. Sections are embedded in Canada Balsam. Photographs have been made in transmitting light with an Olympus BX51 microscope.

Sections are documented by 100 and 400 times (objective 10, 40, eyepiece 10). Slides are stored at the address of the first author.

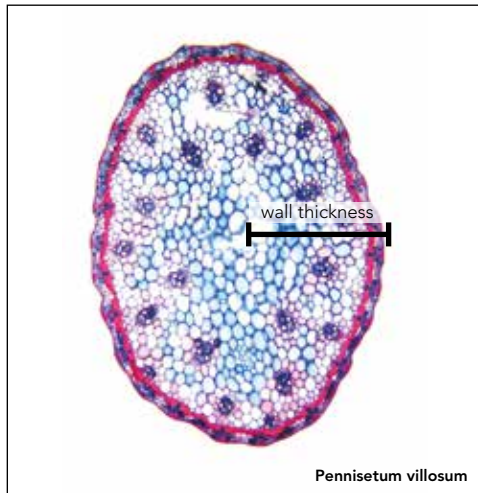
4. Features of culms, flower stalks and stems

Culm-diameter

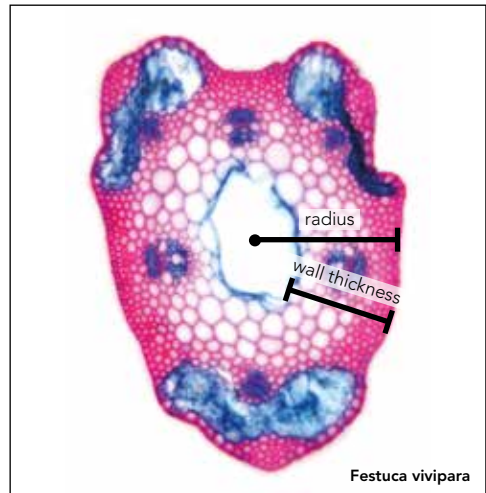


- 4a** Culm-diameter < 0.5 mm
- 4b** Culm-diameter 0.5-1 mm
- 5** Culm-diameter 1-2 mm
- 6** Culm-diameter 2-5 mm
- 7** Culm-diameter 5-10 mm
- 8** Culm-diameter > 10 mm

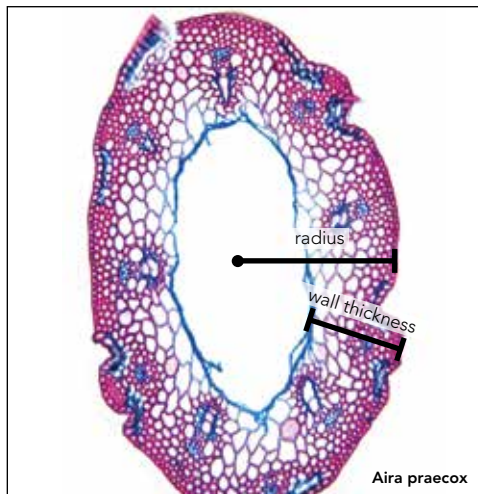
Culm-radius in relation to culm-wall



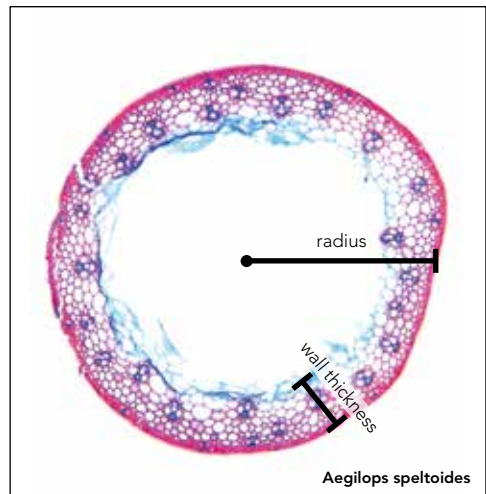
9a Center full, radius of culm or flower stalk in relation to wall thickness 1:1.



9b Wall very large, radius of culm or flower stalk in relation to wall thickness approximately 1:0.75.

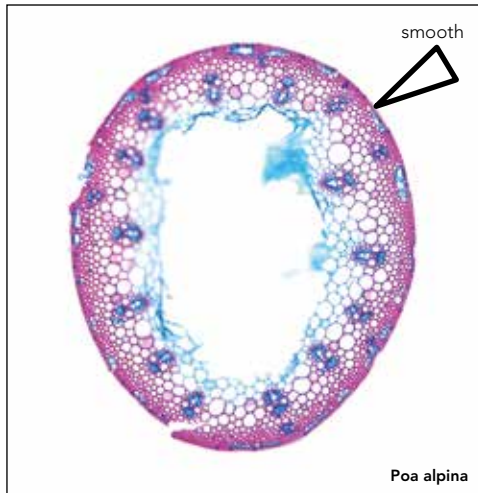


9c Wall large, radius of culm or flower stalk in relation to wall thickness approximately 1:0.5.

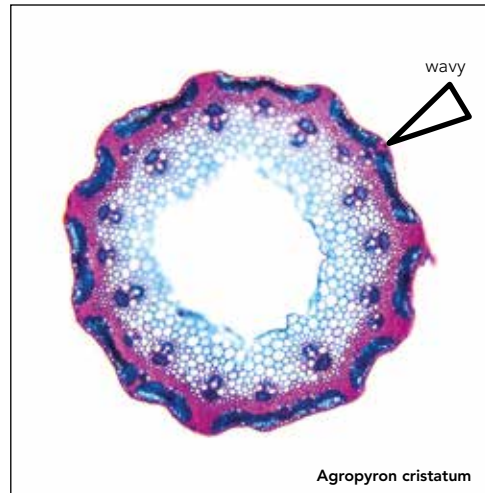


9d Wall thin, radius of culm or flower stalk in relation to wall thickness approximately 1:0.25 or < 0.25.

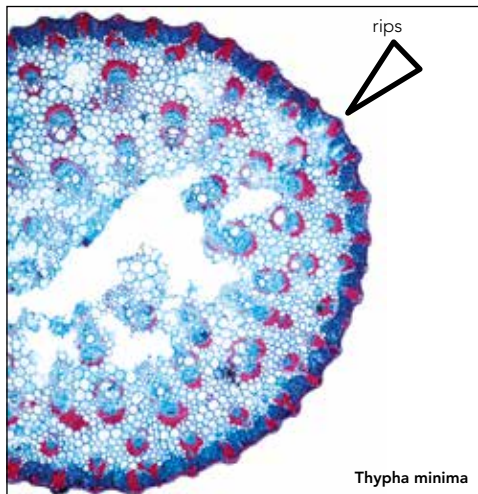
Form of outline



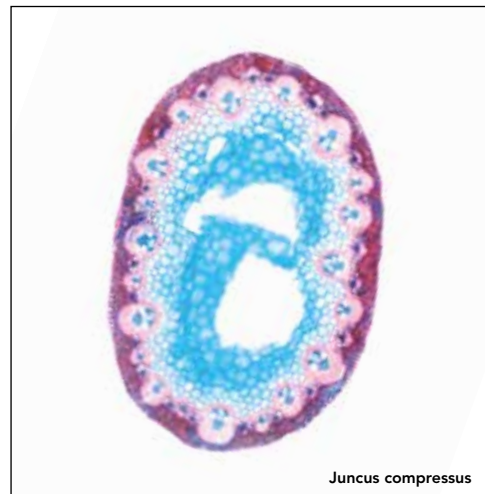
10 Outline circular with a smooth surface.



11 Outline circular wavy.

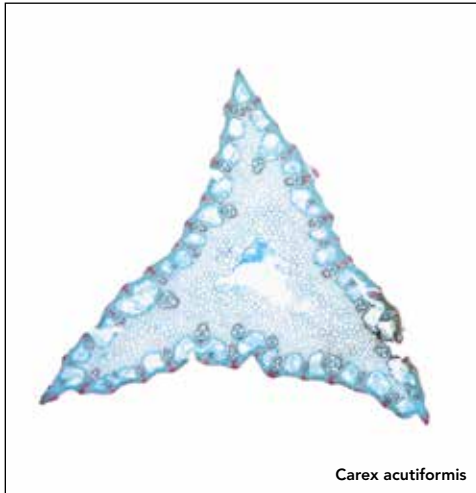


12 Outline circular, with ribs.

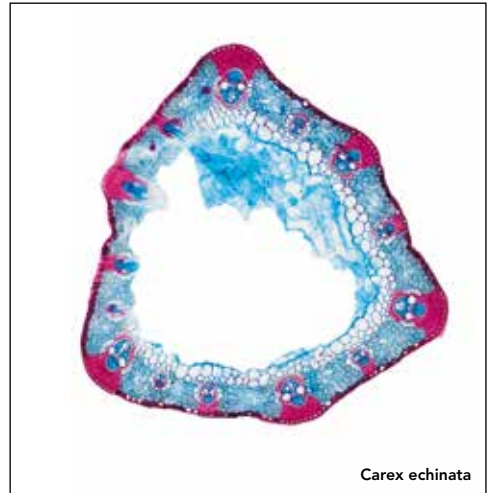


13 Outline oval.

Form of outline



14 Outline triangular, acutely.

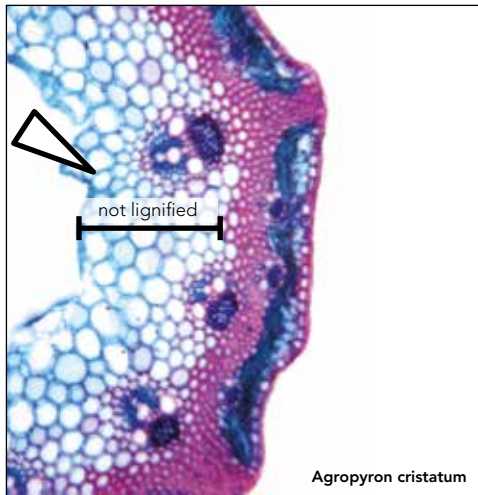


15 Outline triangular, obtusely.

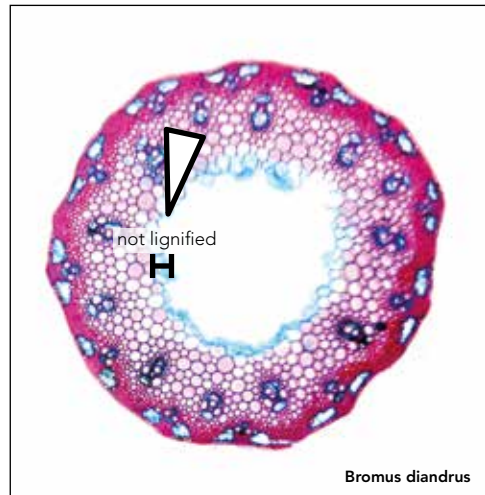


16 Outline of other form.

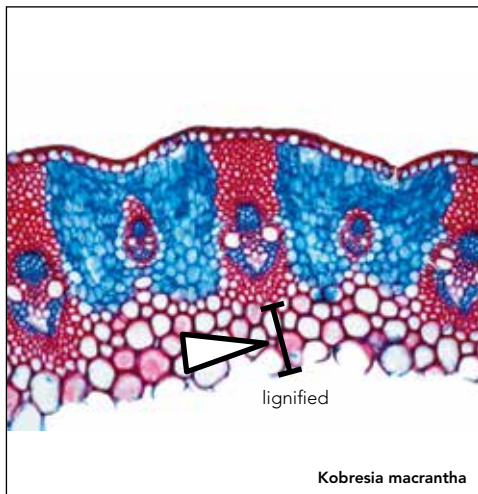
Construction of culm center



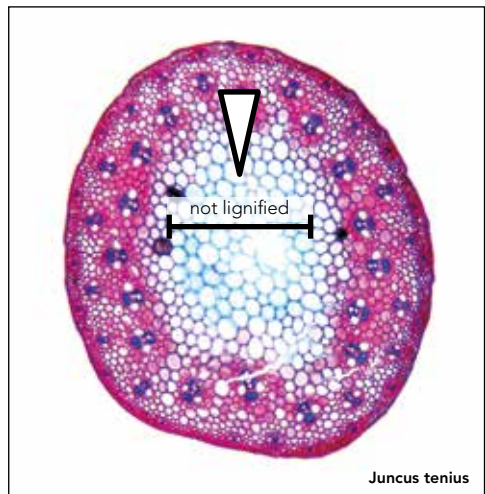
19a Center hollow and surrounded by many large thin-walled, not lignified cells.



19b Center hollow and surrounded by a few thin-walled, not lignified cells.

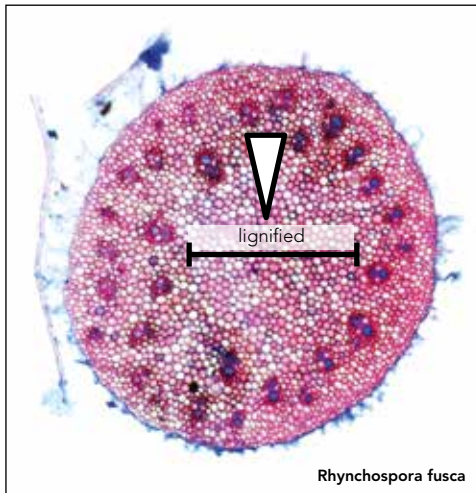


19c Center hollow, surrounded by thin-walled lignified cells.

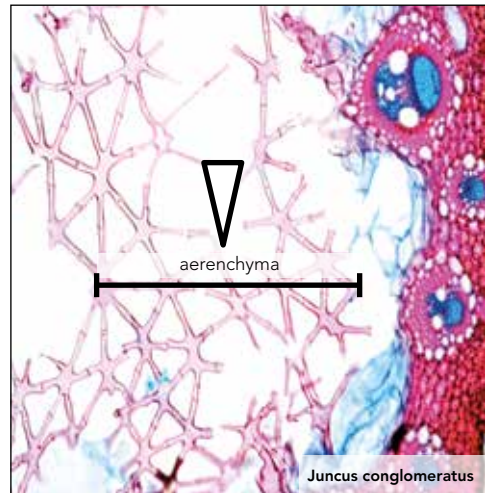


20a Center full, containing unligified cells.

Construction of culm center

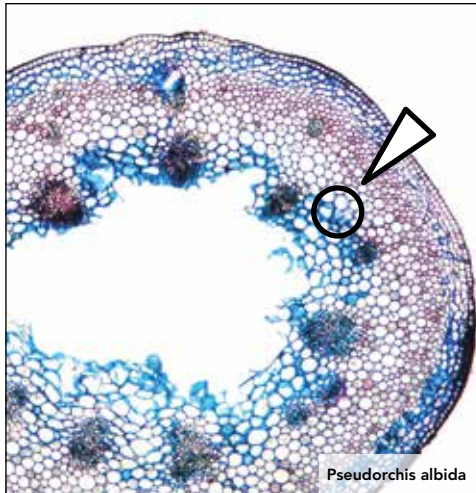


20b Center full, containing lignified cells.

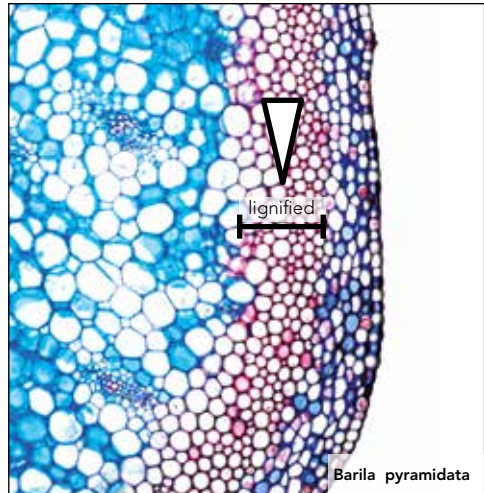


21 Center with net-like aerenchyma (Stellate).

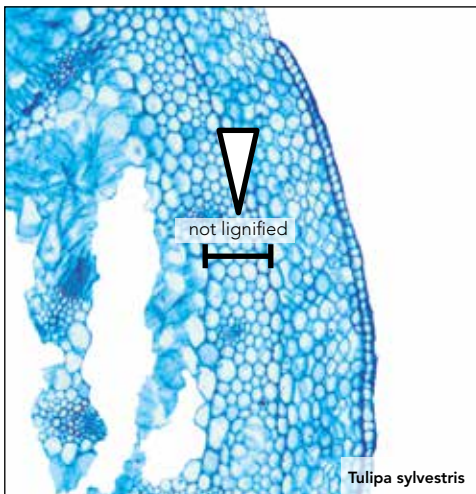
Separation within the culm, flower stalk or stem



25 Without cortex/central cylinder separation. Endodermis absent.



26a Culm without endodermis but with a sheath of lignified cells around the center.

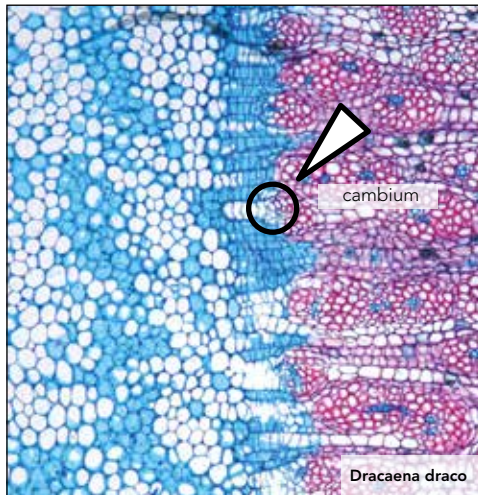


26b Culm without endodermis but with a sheath of unligified cells around the center.



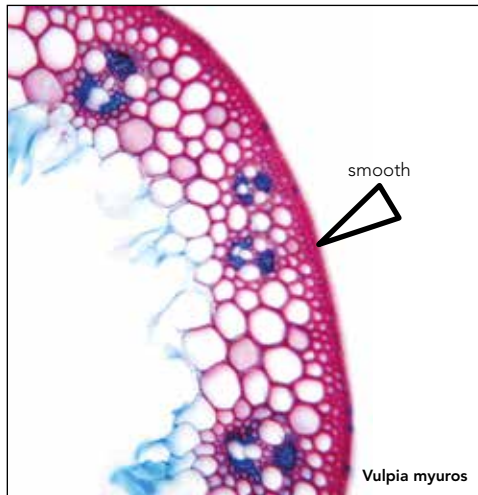
27 With cortex/central cylinder separation. Endodermis present.

Separation within the culm, flower stalk or stem

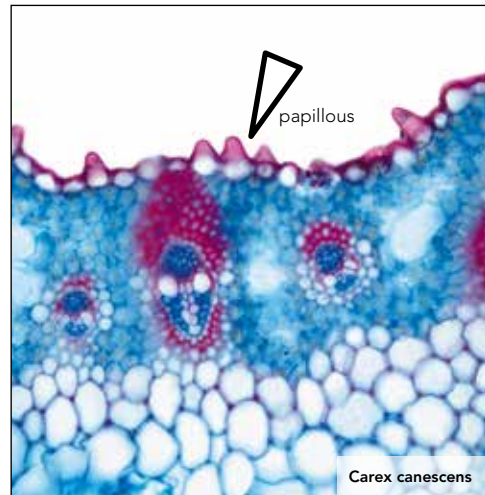


28 With secondary growth.

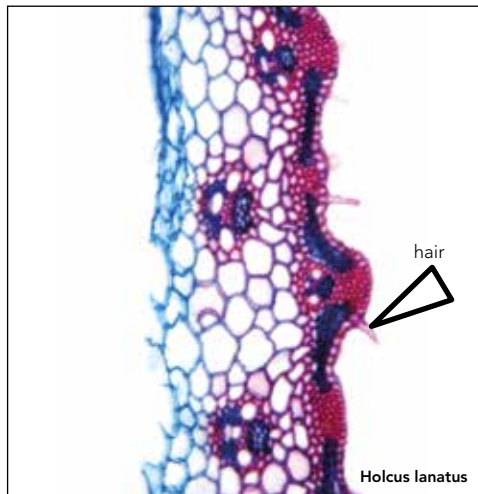
Epidermis



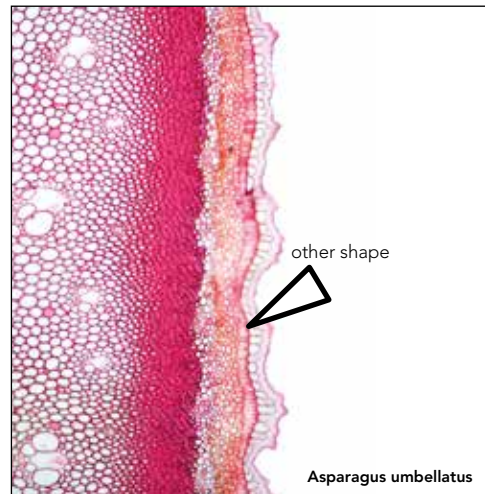
30 Epidermis smooth.



31 Epidermis with papillae (bulliform).

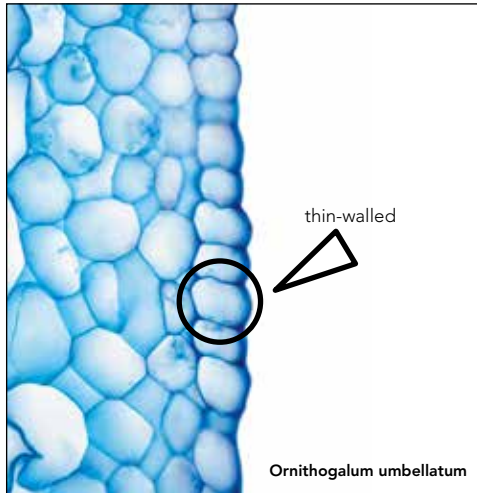


32 Epidermis with hairs.

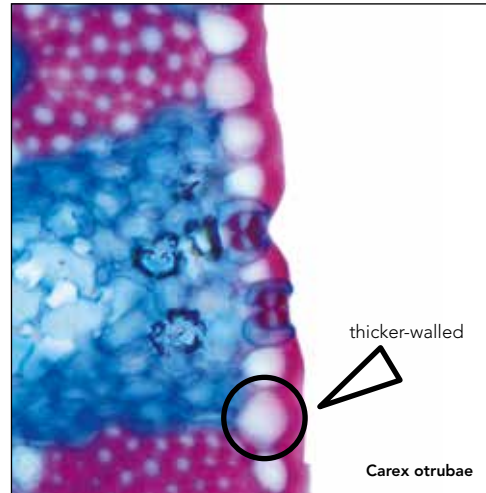


33 Epidermis with other shape.

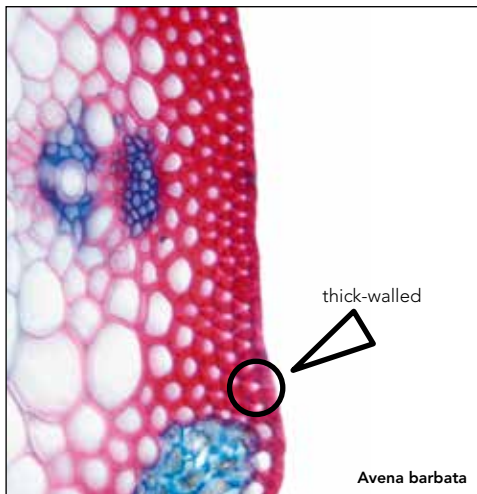
Epidermis



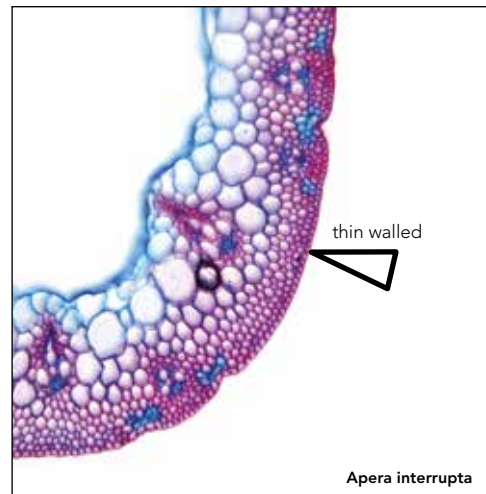
34 Epidermis cells thin-walled all around.



35 Epidermis cells inside thin-, peripheral thicker-walled (lignified).



36b Epidermis cells thick-walled all around.



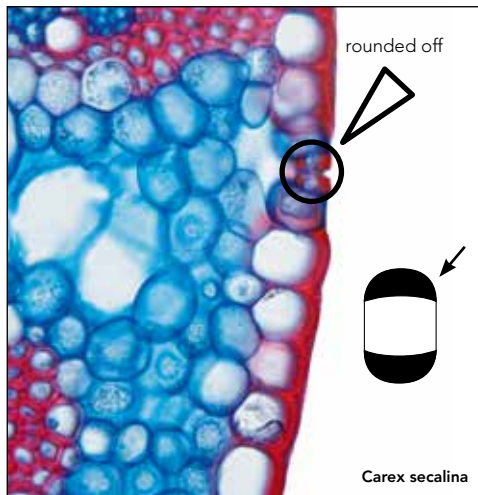
36c Epidermis-cells thin-walled all around. Corresponds with feature 34.

Cuticula

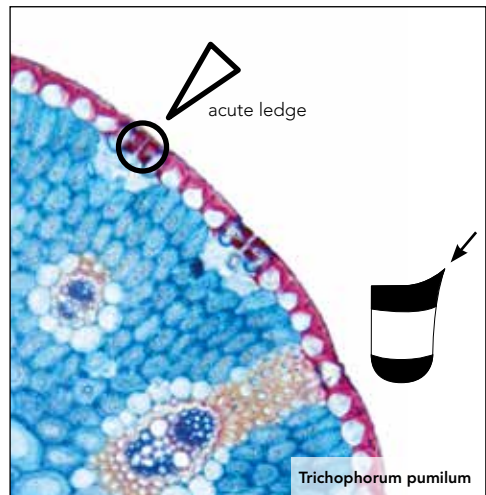


36d Cuticula very thick.

Construction of stomata

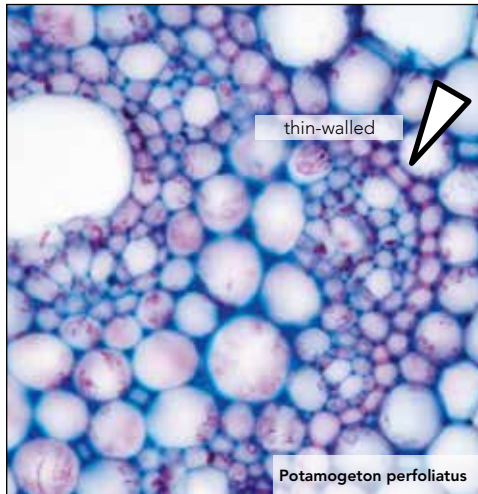


36g Guard cells externally rounded off. Difficult to recognize.

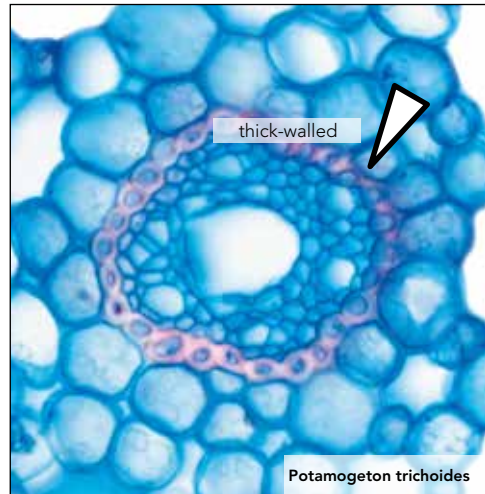


36h Guard cells with and externally acute ledge. Difficult to recognize (see also feature 101h).

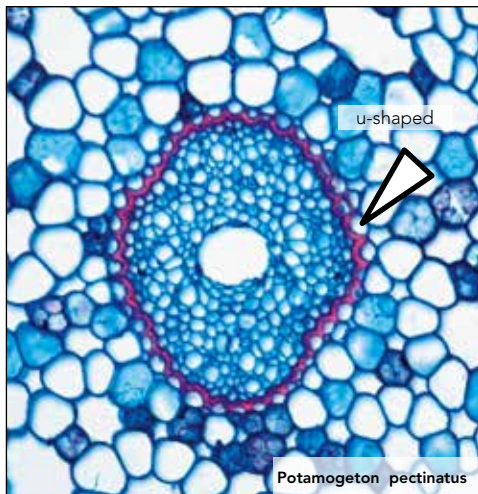
Endodermis



37 Endodermis thin-walled.

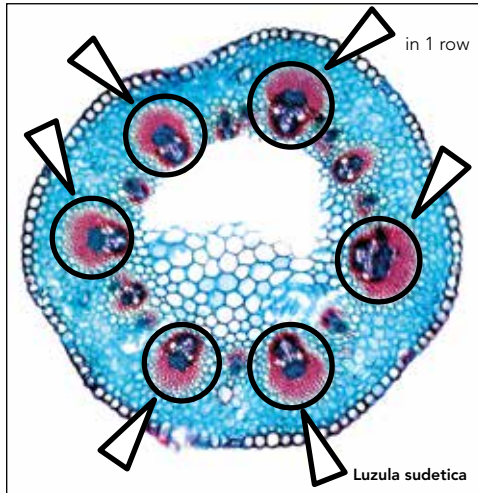


38 Endodermis thick-walled all around.

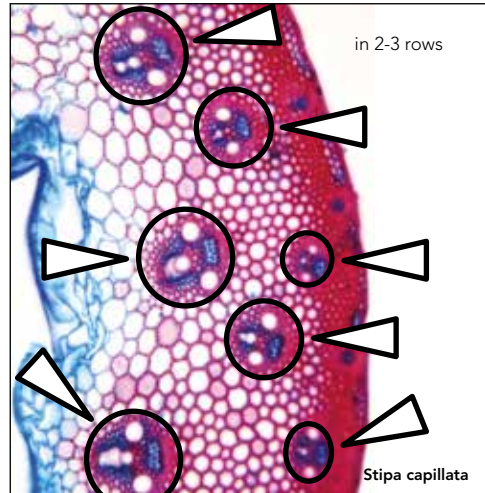


39a Endodermis u-shaped and thick-walled.

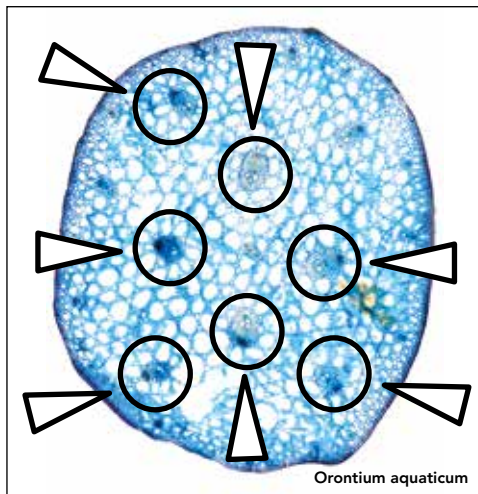
Arrangement of large vascular bundles



41 Vascular bundles arranged in one peripheral row.

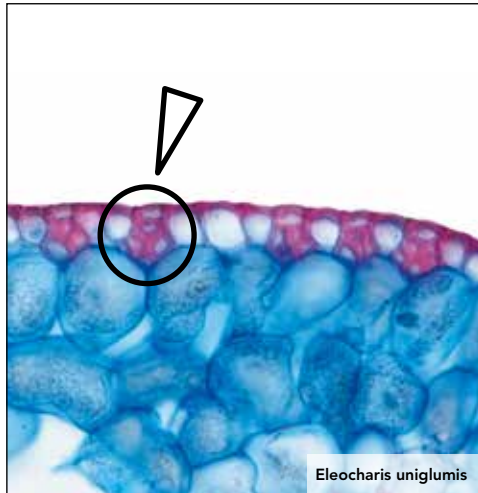


41a Vascular bundles arranged in 2-3 peripheral rows.

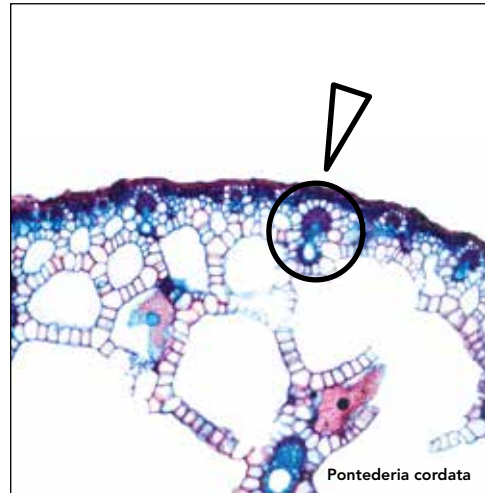


42 Large vascular bundles distributed in the whole culm.

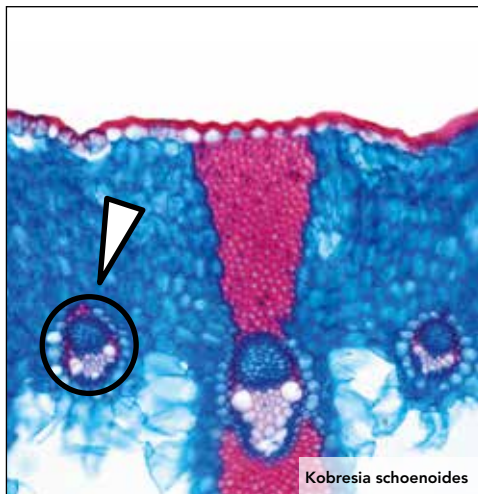
Arrangement of small or rudimentary vascular bundles



43 Small or rudimentary vascular bundles (reduced to fibres) in the hypodermis or epidermis.

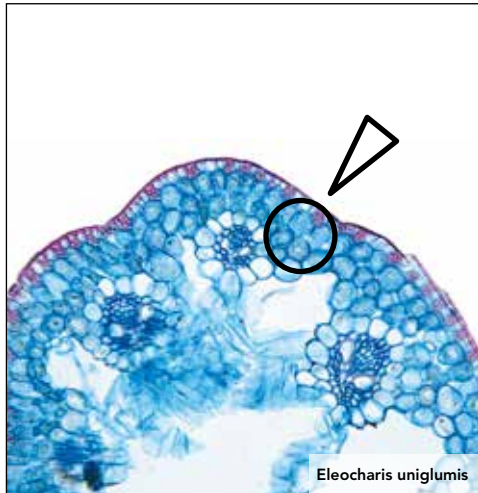


44a Small or rudimentary vascular bundles, mainly at the periphery.

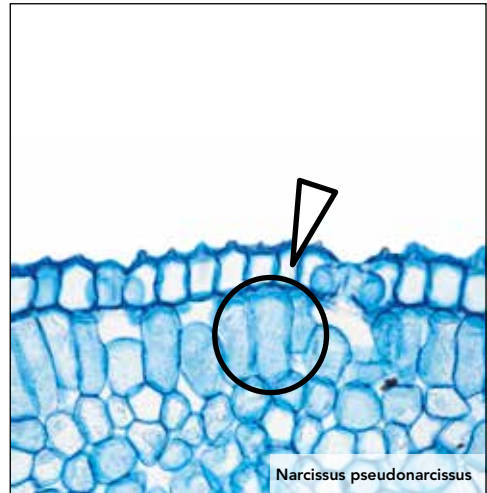


44b Small or rudimentary vascular bundles within in the chlorenchyma.

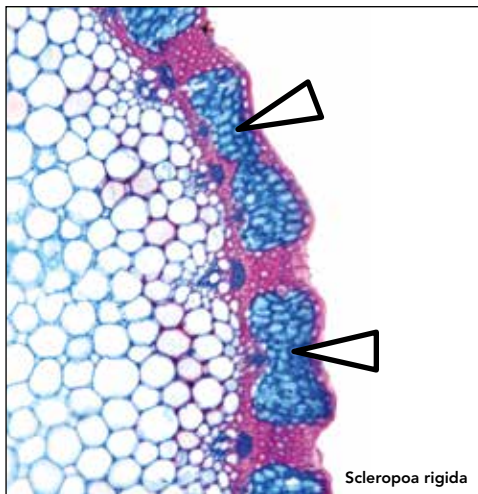
Chlorenchyma



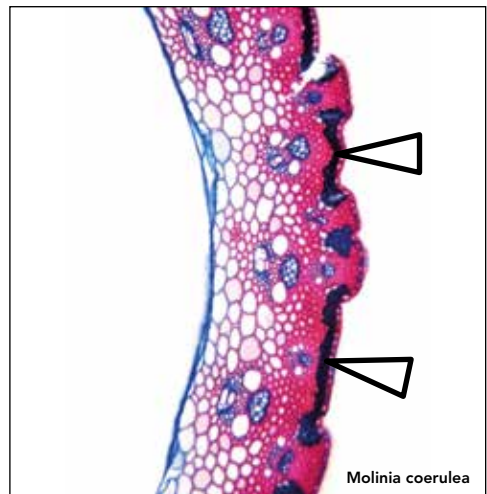
46 Chlorenchyma present, continuous peripheral belt with unignified, round cells (like a large cortex).



47 Chlorenchyma present, in form of unignified thin-walled palisade-like cells.

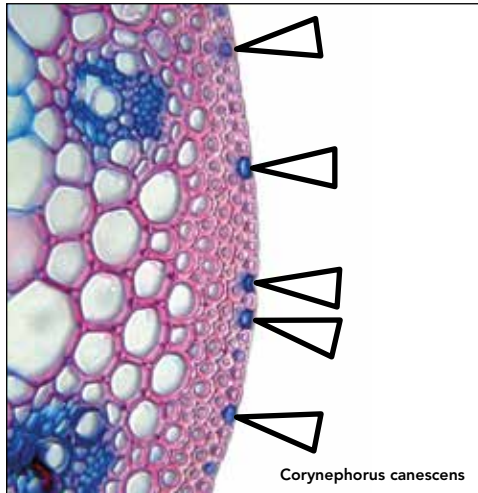


48a Chlorenchyma in round, oval, square or rectangular groups.

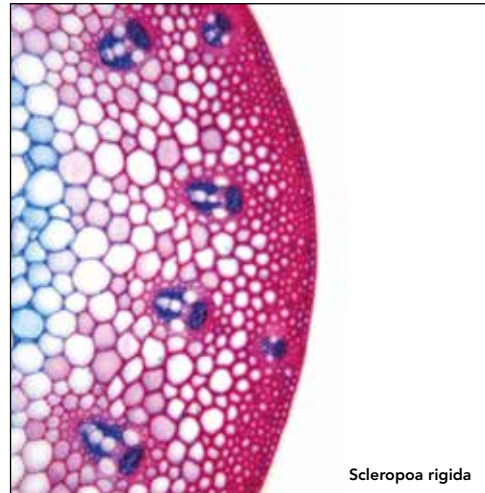


48b Chlorenchyma in tangentially enlarged groups.

Chlorenchyma

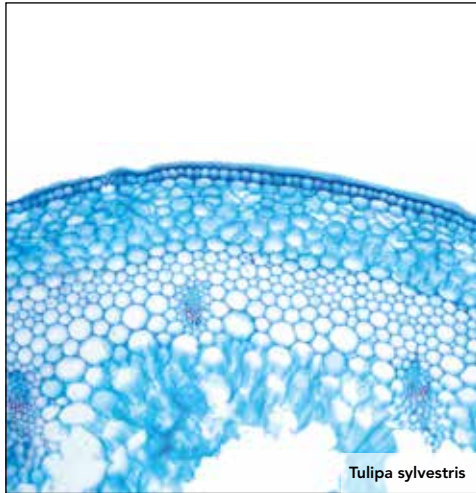


49a Chlorenchyma very small in 1-3 lined up cells.

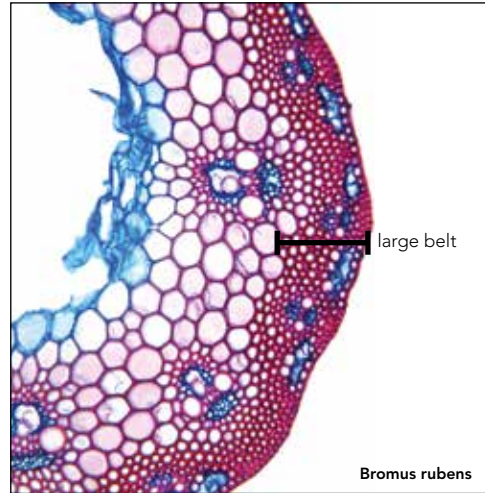


49b Chlorenchyma absent.

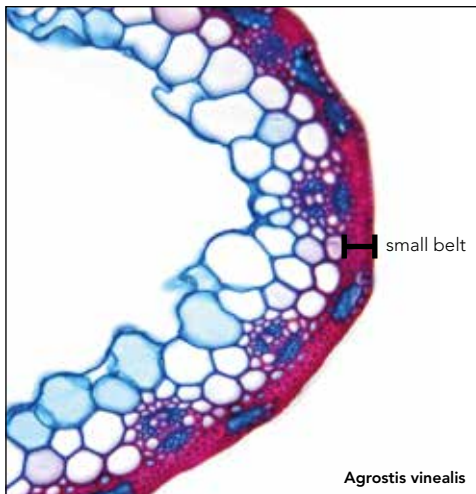
Peripheral sclerenchyma belt



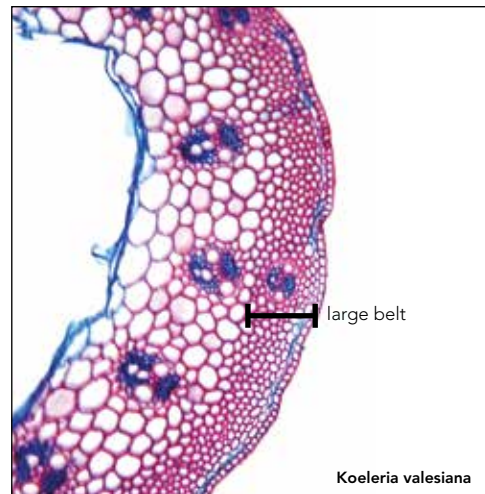
51 Sclerenchyma belt absent but sometimes with a belt of un lignified cells.



52a Sclerenchyma belt in a large, peripheral continuous belt (>3 cells), cells thick-walled.

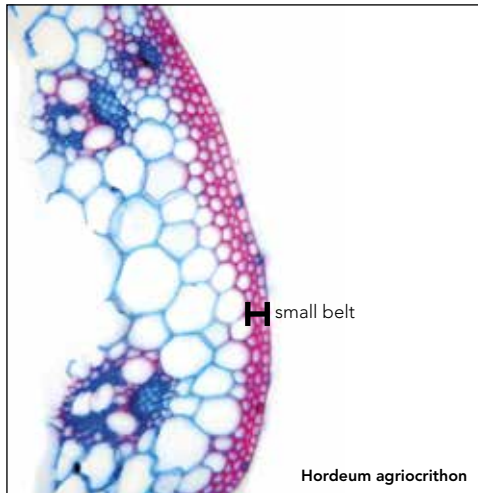


52b Sclerenchyma in a small, peripheral continuous belt, (< 4 cells), cells thick-walled.

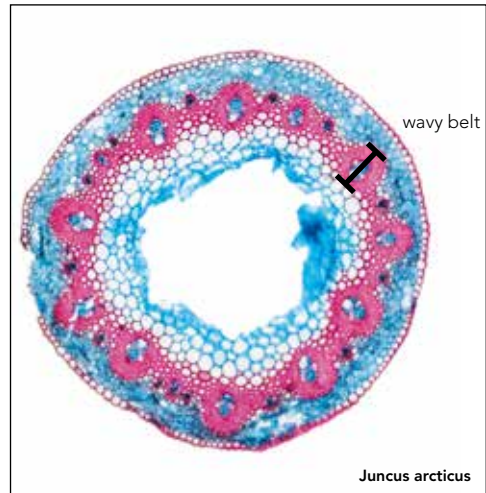


52c Sclerenchyma in a large, peripheral continuous belt (> 3 cells). Cells medium thick-walled.

Peripheral sclerenchyma belt

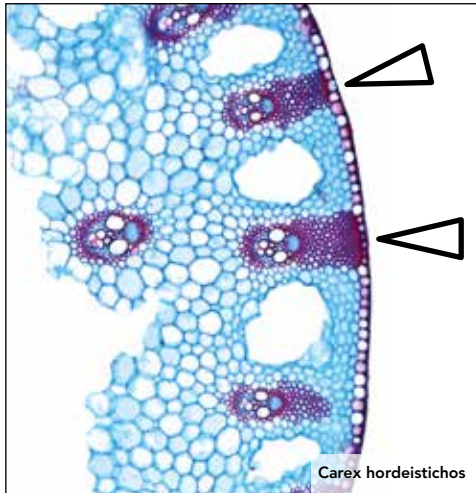


52d Sclerenchyma in a small, peripheral continuous belt (< 4 cells). Cells medium thick-walled.

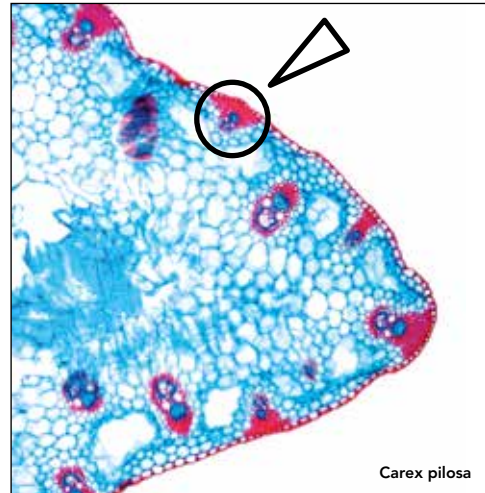


53b Sclerenchyma belt in a wavy continuous belt centripetal of the chlorenchyma.

Groups of sclerenchyma at the periphery of culms (girders)



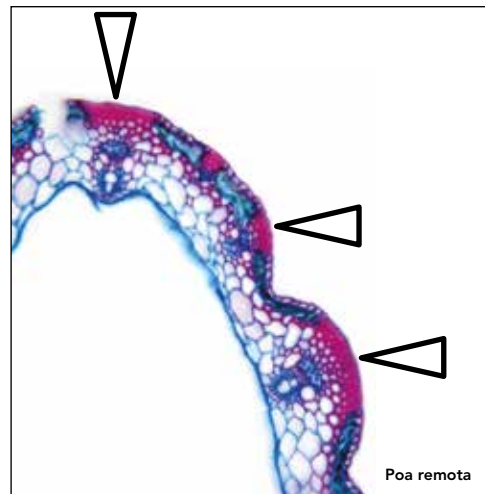
55a Groups of sclerenchyma (girders) square or rectangular.



55b Groups of sclerenchyma (girders) conic.

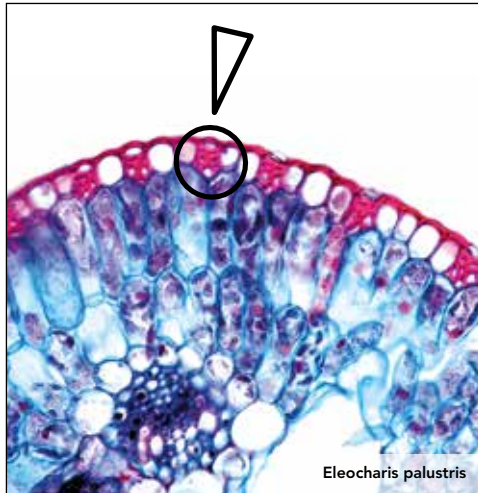


55c Groups of sclerenchyma (girders) at the periphery round. Sometimes not lignified.



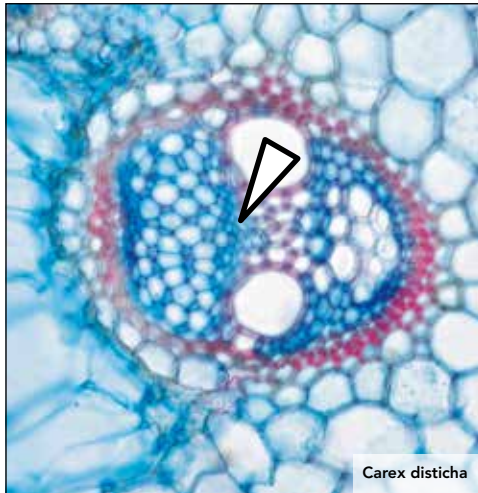
55d Groups of sclerenchyma (girders) tangentially enlarged.

Groups of sclerenchyma at the periphery of culms (girders)

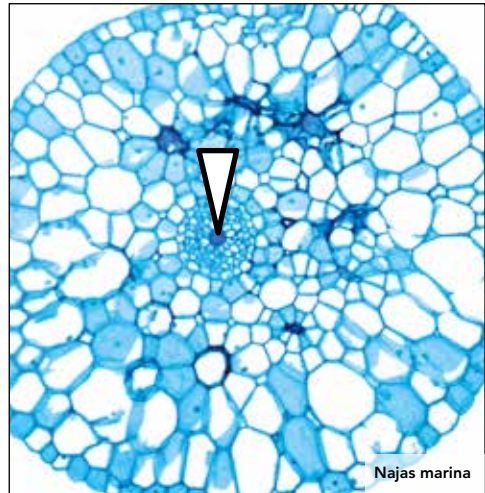


- 55f** Groups of sclerenchyma (girders) small within the epidermis (see also feature 43).

Types of vascular bundles

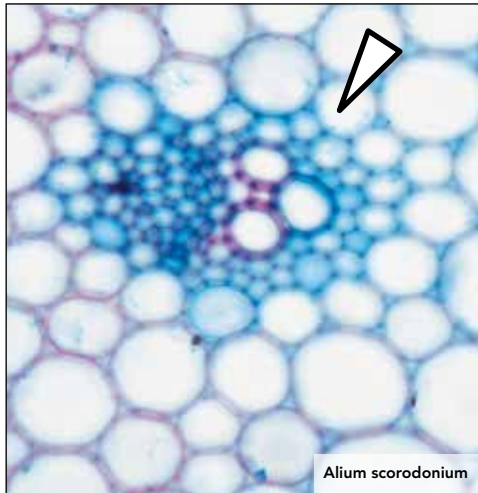


78 Vascular bundles collateral closed (absent cambium).

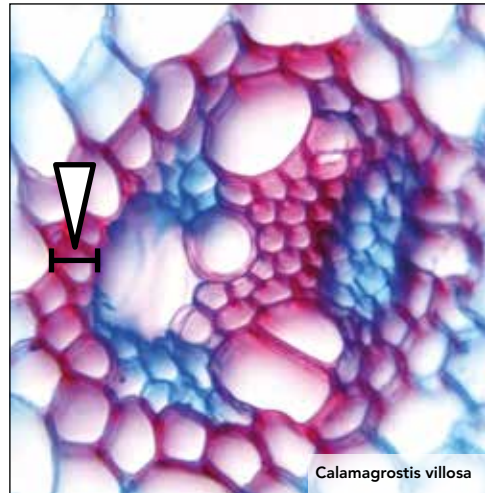


78a One vascular bundle in the center (stele).

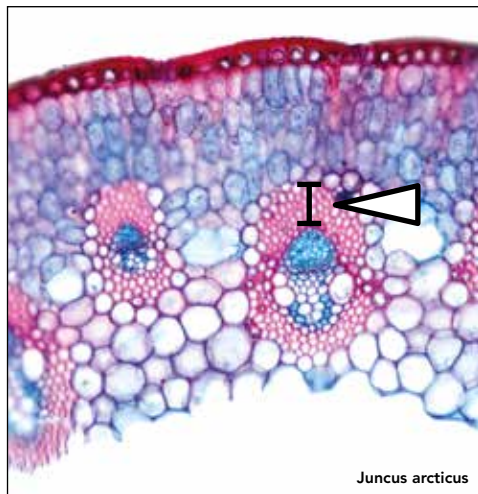
Sclerenchymatic sheath around vascular bundles



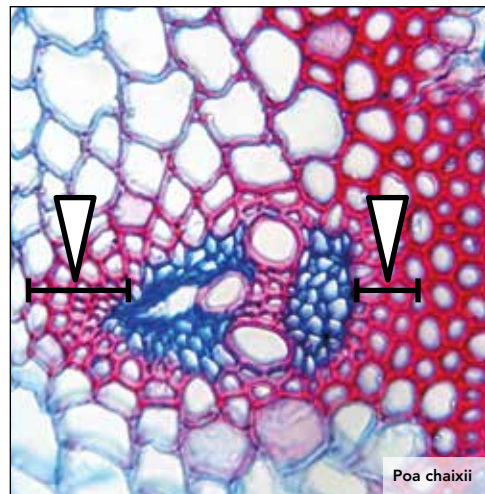
81 Sheath around vascular bundles absent or not lignified.



82 Small sclerenchymatic sheath around vascular bundles with 1-2 cells.

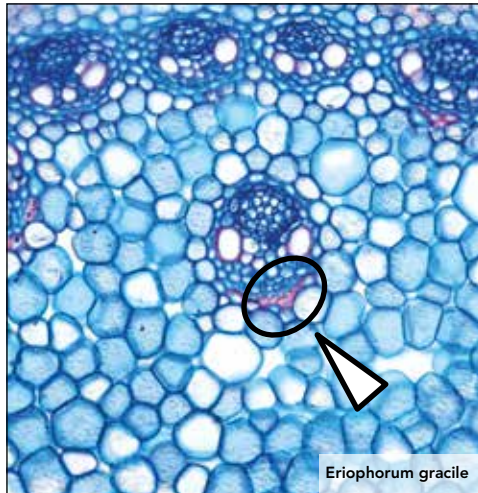


83 Sheath around vascular bundles circular large, 3 to x cells

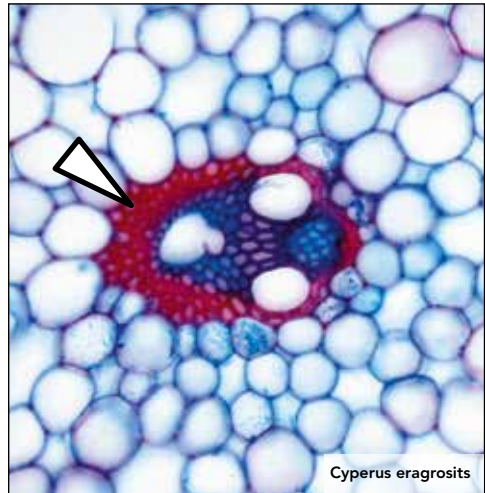


84 Sclerenchymatic sheath around vascular bundles bilateral, large at both radial ends.

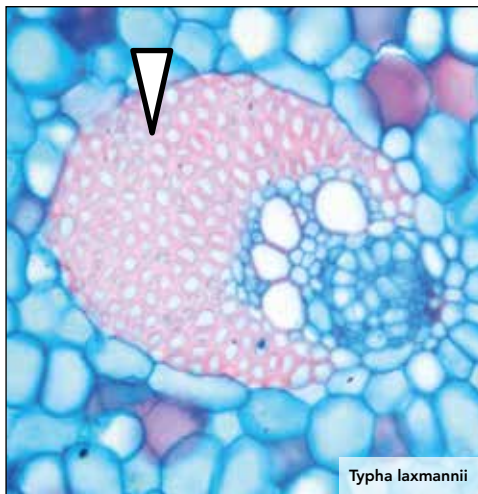
Sclerenchymatic sheath around vascular bundles



85a Sclerenchymatic sheath around vascular bundles one-sided small, 1-2 cells.



85b Sclerenchymatic sheath around vascular bundles one-sided large 2-4 cells, centripetal.



86 Sclerenchymatic sheath around vascular bundles one-sided large. Drop-like at the centripetal side.