

Fritz H. Schweingruber  
Hugo Berger

# **Anatomic Atlas of Gras-Stems**

**Poacea Flower Stalks of the Alps**

impressum

# Content

<b>1 Introduction</b> .....	7
<b>2 Basics</b> .....	8
2.1 Material and herbarium vouchers .....	8
2.2 Anatomical preparation techniques .....	9
2.3 Ecological classification .....	9
<b>3 Definition of anatomical features</b> .....	10
3.1 Definition of the features .....	10
<b>4 Monographic presentation</b> .....	23
4.1 Structure of the monographic presentation .....	23
4.2 Characterisation of 301 species .....	24
<b>5 Results</b> .....	324
<b>6 Frequency in relation to ecological factors</b> .....	325
6.1 Relation to vegetation zones .....	235
6.2 Relation to humidity .....	327
6.3 Relation to culm length .....	329
<b>7 Differences between genera</b> .....	331
<b>8 Conclusion</b> .....	331
<b>9 Acknowledgements</b> .....	332
<b>10 References</b> .....	332
<b>11 Index</b> .....	333

# 1. Introduction

Flower stalks are the most obvious parts of grasses. They are part of the photosynthetic system and guarantee generative reproduction by exposing flowers to various permanent and extreme environment factors. Therefore they must be green, stiff and flexible. The response to these three characteristics is reflected in the anatomy of culms. Various culm sizes and forms however let assume that internal adaptations modify the general structure.

These basics of culm and leaf anatomical structures have been recognized and described more than 200 years ago (De Candolle 1813, Möbius 1937). Leaf structures were since the beginning in focus of detailed studies because they are taxonomically more significant than that of culms. (Metcalfe 1960, Conert 1998). Metcalfe 1960 created with his gigantic work an anatomical base for anatomical descriptions and characterized hundreds of species in detail. His ultimate goal was to underline and enlarge taxonomic classification with anatomical characteristics.

He was aware that the anatomy varies along culms and that ecological conditions can modify the structure. Based on his studies and own experiences with grasses from the Himalaya (Dolezal et al. 2017) we decided to enlarge his taxonomic approach with ecological questions and formulated the following concept.

- Presentation of anatomical structures of a large number of species within the family of Poaceae in the region of the Alps from sea level to the nival zone.
- Evaluation and presentation of major characteristic anatomical features.
- Relating all microscopic features to plant size, altitude and hydrological conditions and taxonomic origin

The study is based on cross sections of culms. Each section of 300 Poaceae specimen from natural sites are located in internodes above leaf sheathes, approximately in the middle part of the total length of culms. Analyzed are all genera but only one specimen of each species, which occur in the alpine region (Aeschimann et al. 2004). The material includes species of all vegetation zones from 100 to 3000 m a.s.l. of all possible habitats from wet to arid, from calcifuge to acid and from nutrient rich to poor and salty sites. Respected are endemic and introduced species. Since anatomical variation is minimized by the constant internal location of the section within the culm, the whole set of analyzed material is comparable. Double staining gives additional information about the distribution of lignified and unligified parts.

With this sampling and preparation strategy we are able to describe general culm characteristics and modifications related to ecology and taxonomy.

Since Conert 1998 and Hubbard 1985 described morphological traits in details we present only a few general characteristics of each species described. Temperature and precipitations indicator values, defined by (Aeschmimann et al. 2005,) are the base for anatomical comparisons.

We know, that the analysis of one specimen of each species gives an overlook but does not allow final conclusions.

The Poaceae atlas is part of a stem anatomical project of northern hemispheric seed plants (Schweingruber 1990, Schweingruber et al 2011 and 13, Dolezal et al 2017).

## 2. Basics

### 2.1 Material for sections and herbarium vouchers

The present study is based exclusively on material form of the Zürcher Herbarien. The plants as well as the labels and the position of the section of each analyzed plant are documented on [www.herbarien.uzh.ch](http://www.herbarien.uzh.ch) ((Reto))

Each species is characterized by a few general morphological and ecological characteristics (Conert 1995 and Hubbard1985).

The analyzed material contains 80 genera with 300 of 370 occurring species in the alpine region (Aeschimann et al. 2005). The missing specimens are absent in the herbaria or were not suitable for microscopic analysis. A digital databank allows finding any taxonomic, morphologic, geographic, ecological or anatomical characteristic of each slide.

Each species is characterized by a few general morphological and ecological characteristics (Conert 1995 and Hubbard1985).

The analyzed material contains 80 genera with 301 of 370 occurring species in the alpine region (Aeschimann et al. 2005). The missing specimens are absent in the herbaria or were not suitable for microscopic analysis. A digital databank allows finding any taxonomic, morphologic, geographic, ecological or anatomical characteristic of each slide.

### 2.2 Anatomical preparation techniques

Comparability of microstructures is a major goal of this atlas. Therefore all micro-photographs are based on recently prepared new microscopic slides. The technique is described in detail by Gaertner and Schweingruber 2013. After moistening the material with water for a few hours, most cross-sections have been made with razor blades under stereomicroscopic control. Very dense culms have been sectioned with a sliding microtome, type Reichert. All sections are stained for a few minutes with a one to one mixture of Safranin/Astrablue. Staining and dehydration with ethanol 96%, absolute ethanol and xylene occurs directly on the glass. Permanent slides are embedded in Canada Balsam. Photographs have been made in transmitting, normal light with an Olympus BX51 microscope. Sections are documented by magnifications 100 and 400 times.

### 2.3 Ecological classification

Most important for grasses is the length of the culm. It is influenced by mechanical forces, altitude, vegetation zones and the humidity of the sites (Aeschimann et al 2005). Vegetation zones are the dominating ecological factors. These factors have been classified as follows:

Length of the culm	0-15 cm 15-40 cm > 40 cm
Vegetation zones	alpine alpine/subalpine subalpine/mountain mountain/low altitude (colline) low altitude (colline)
Humidity of the site	very dry/dry dry/rather moist rather moist/moist moist wet

### 3. Definition of anatomical features

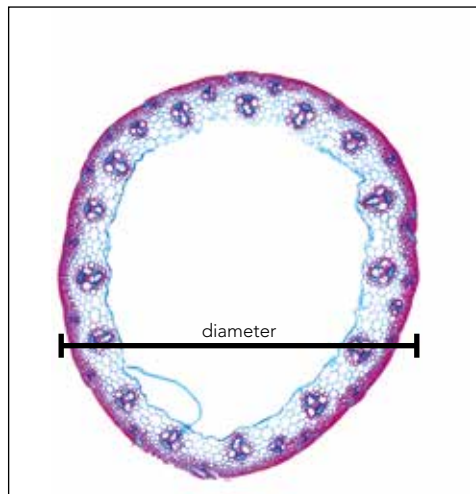
Anatomical key traits have primarily been defined by Metcalfe 1960. The present material however allowed a more specific classification and a standardization of features.

The anatomical key relies on the main structure of culms. The majority of culms are tubular. The periphery consists of an epidermis with stomata and a sub-epidermal part of unligified chlorenchyma (parenchyma containing chloroplasts) a layer of lignified sclerenchyma and a thin-walled parenchyma. Collateral closed vascular bundles are embedded in the parenchymatic and fibrous part. The key contains 15 anatomical characteristics which are defined by 44 different anatomical features. That is the base for statistical analyses. To describe these different anatomic features we used a standardized wording.

The feature numbers correspond with those of a key in preparation for all Monocots of the temperate zones.

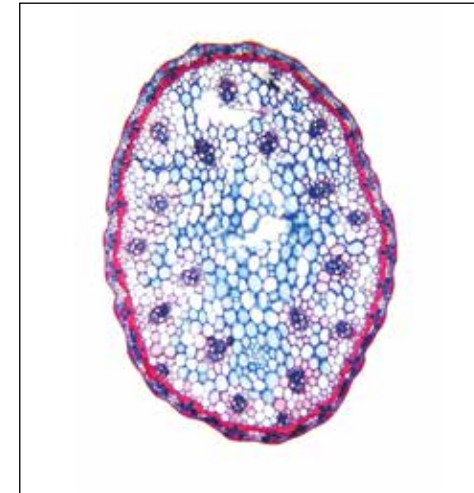
#### 3.1 Definition of the features

##### Culm-diameter

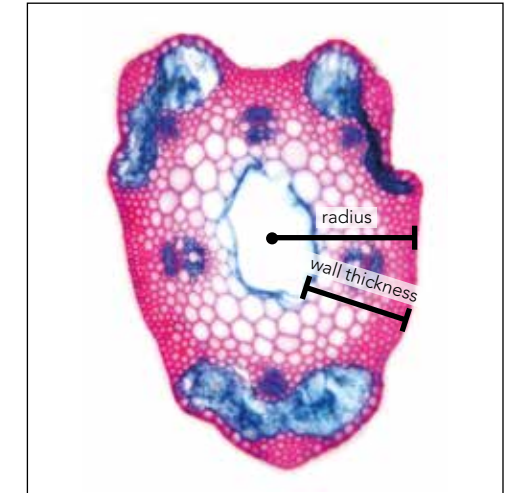


- 4a Culm-diameter < 0.5 mm
- 4b Culm-diameter 0.5-1 mm
- 5 Culm-diameter 1-2 mm
- 6 Culm-diameter 2-5 mm
- 7 Culm-diameter 5-10 mm
- 8 Culm-diameter 10-100 mm

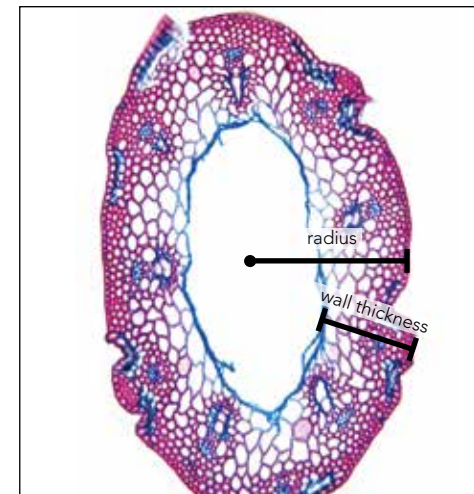
##### Culm-radius in relation to culm-wall



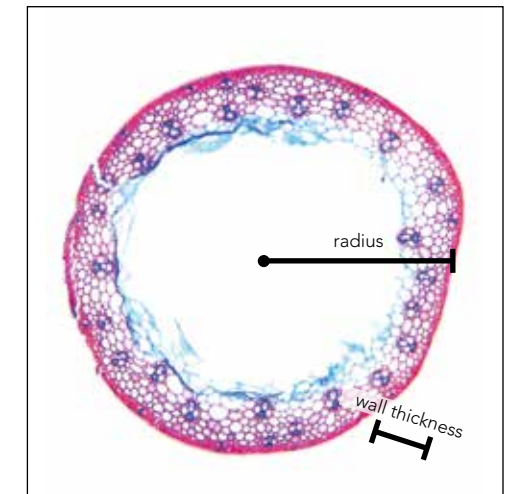
9a Center full, radius of culm in relation to wall thickness 1:1



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

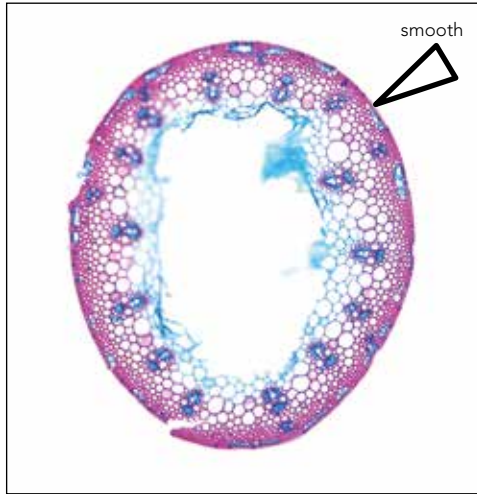


9c Wall large, radius of culm in relation to wall thickness approximately 1: 0.5

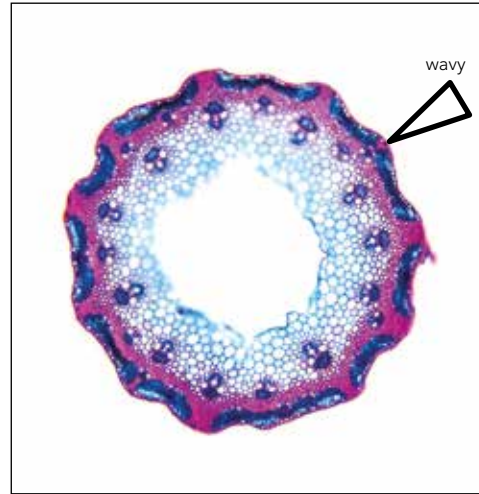


9d Wall thin, radius of culm in relation to wall thickness approximately 1: 0.25 or < 0.25

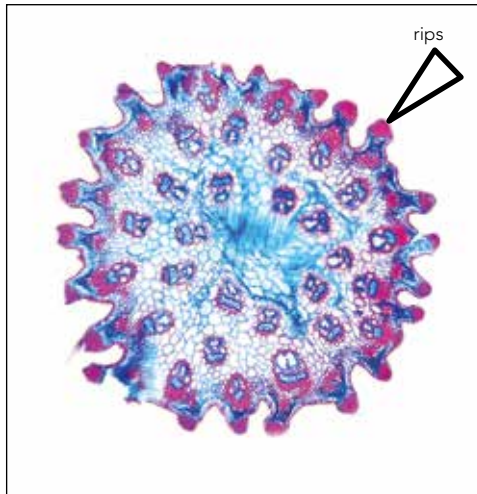
**Form of outline**



**10** Outline circular with a smooth surface

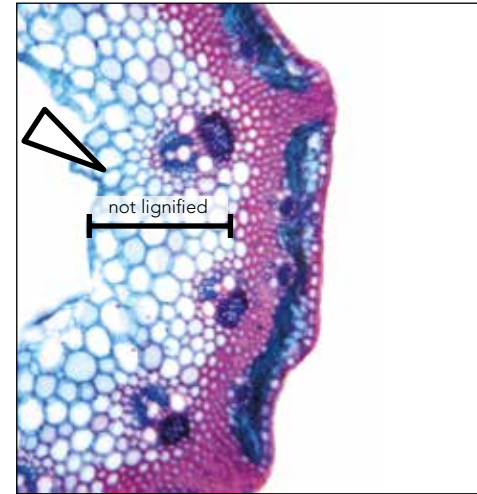


**11** Outline circular wavy

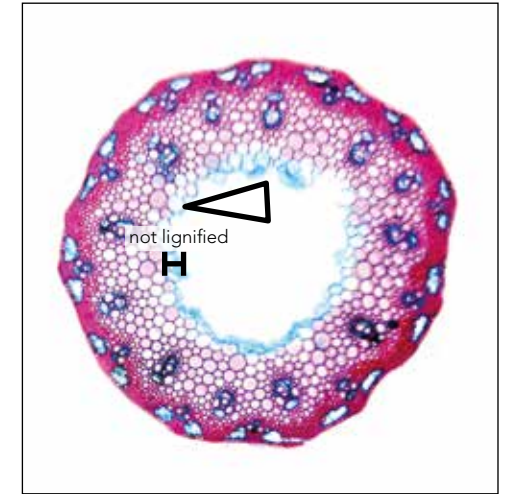


**12** Outline circular, with ribs

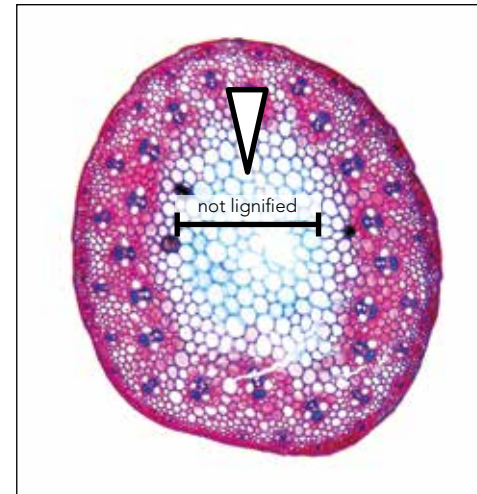
**Construction of culm center**



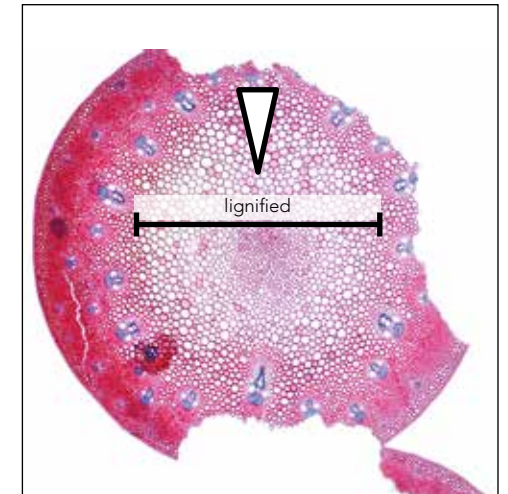
**19a** Culm-center hollow and surrounded by many large thin-walled, not lignified cells



**19b** Culm-center hollow and surrounded by a few thin-walled, not lignified cells



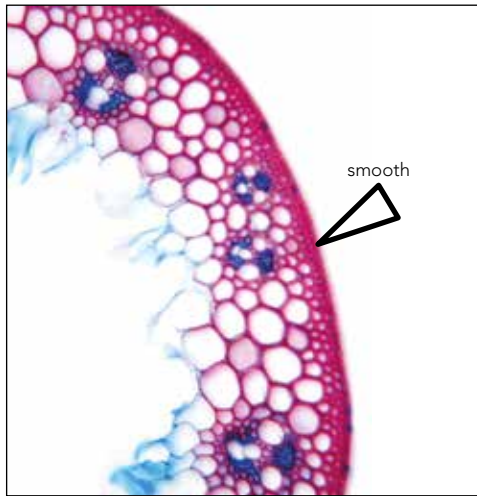
**20a** Culm-center full, containing unligified cells



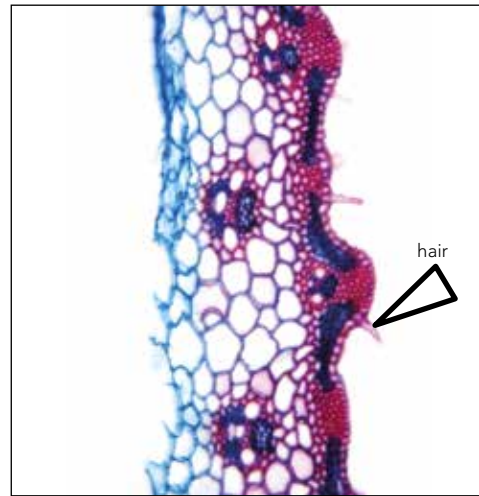
**19b** Culm-center full, containing lignified cells



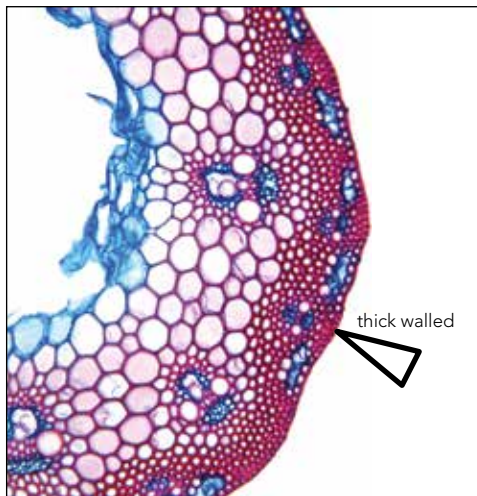
## Epidermis



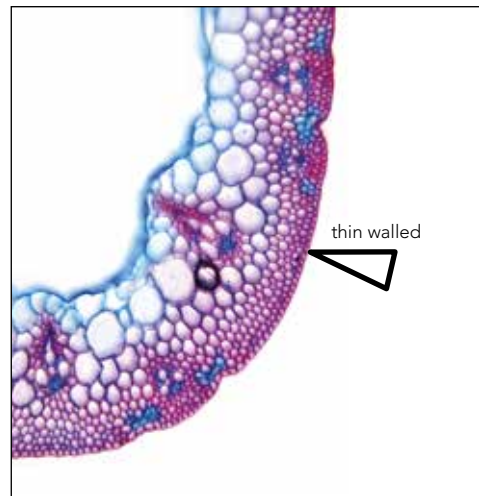
**30** Epidermis smooth



**32** Epidermis with hairs

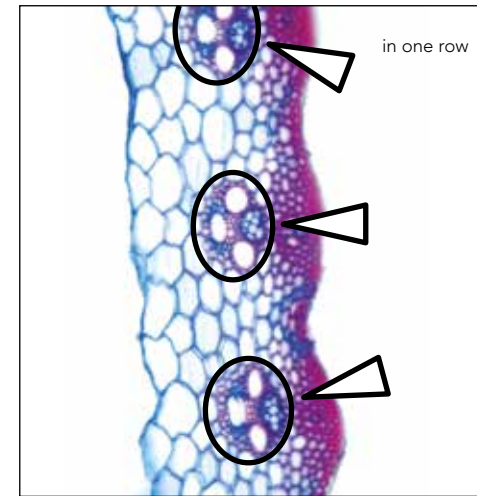


**36b** Epidermis-cells thick-walled all around

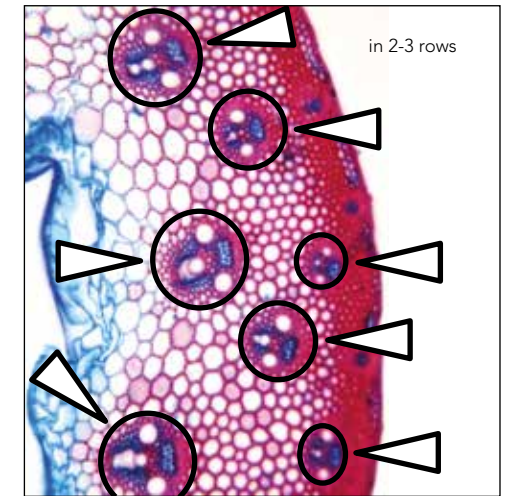


**36c** Epidermis-cells thin-walled all around

## Arrangement of large vascular bundles in uniform stems



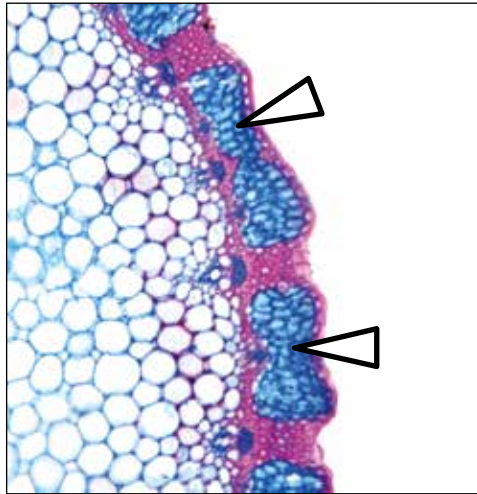
**41** Large vascular bundles arranged in one peripheral row



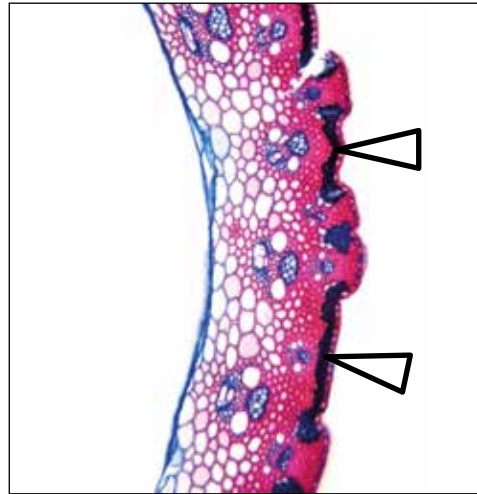
**41a** Large vascular bundles arranged in 2-3 peripheral rows



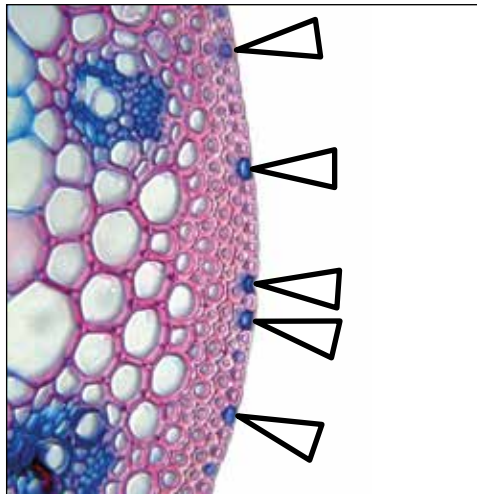
## Chlorenchyma



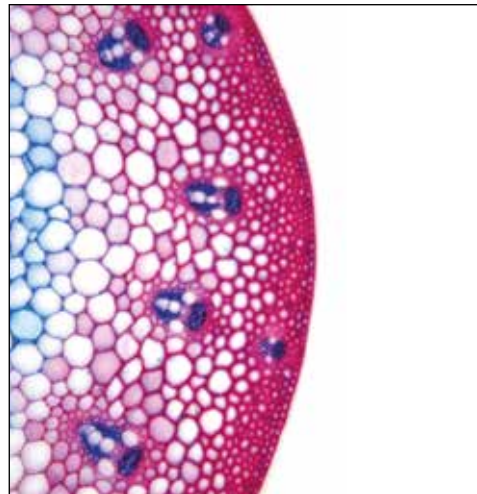
**48a** Chlorenchyma in round, oval, square or rectangular groups



**48b** Chlorenchyma in tangentially enlarged groups

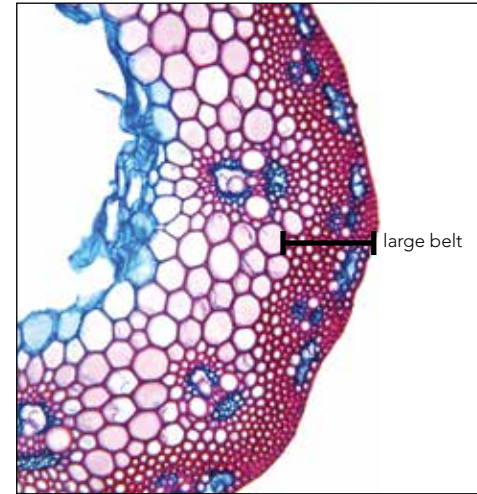


**49a** Chlorenchyma very small in 1-3 lined up cells

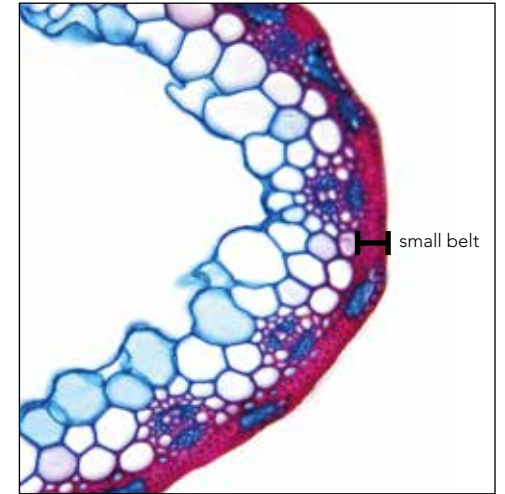


**49** Chlorenchyma absent

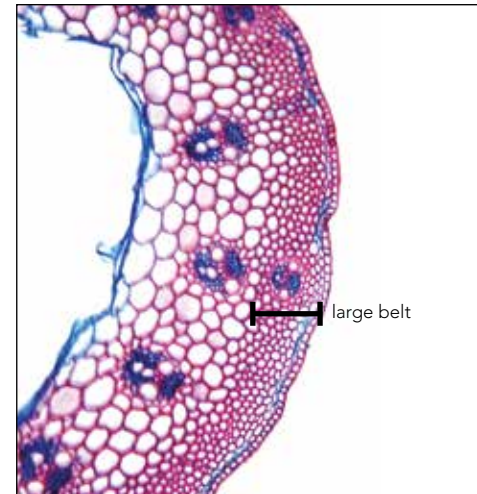
## Peripheral sclerenchyma belt



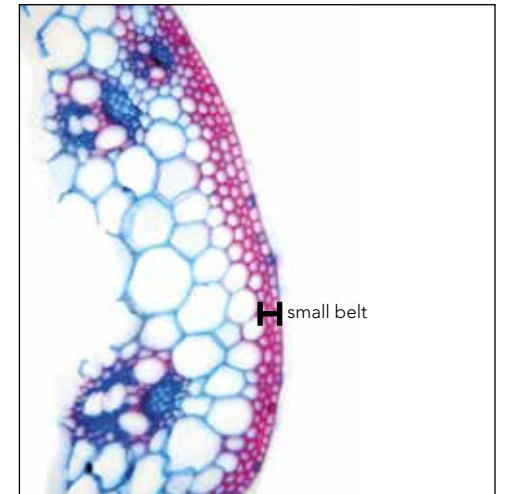
**52a** Sclerenchyma in a large, peripheral continuous belt (>3 cells), cells thick-walled



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

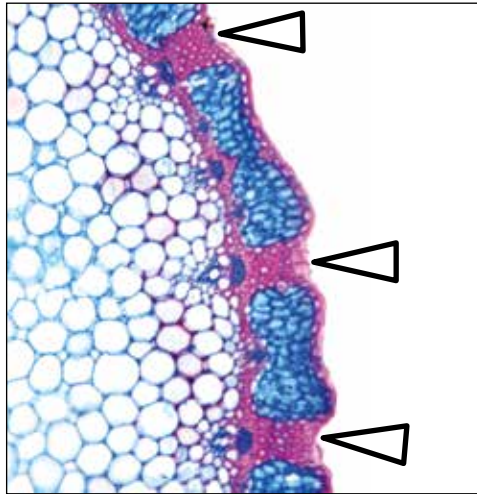


**52c** Sclerenchyma in a large, peripheral continuous belt (>3 cells), cells medium thick-walled

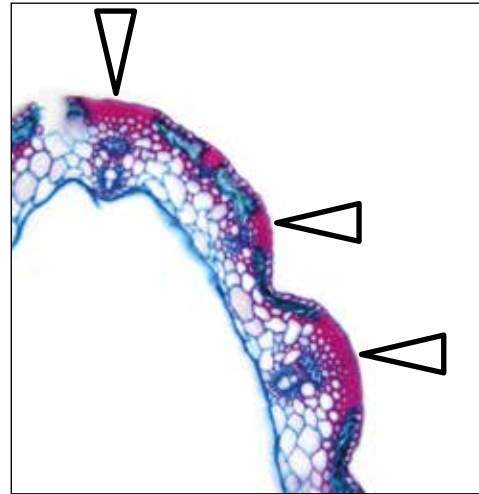


**52d** Sclerenchyma in a small, peripheral continuous belt (<4 cells), cells medium thick-walled

### Scelenchyma girders

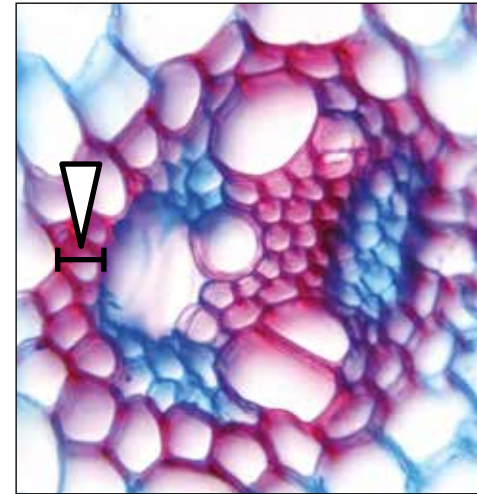


**55a** Girders square, rectangular or conic

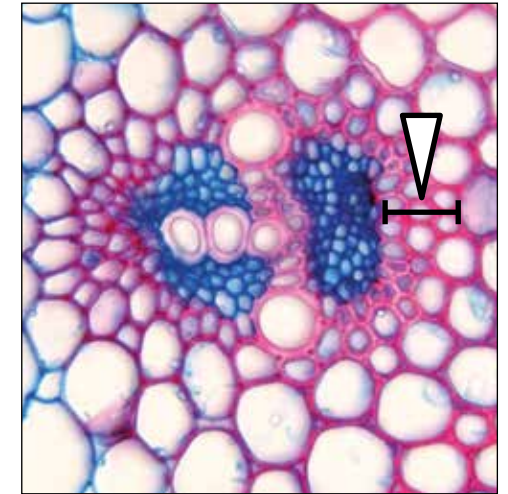


**55d** Girders tangentially enlarged

### Sclerenchymatic sheath around vascular bundles

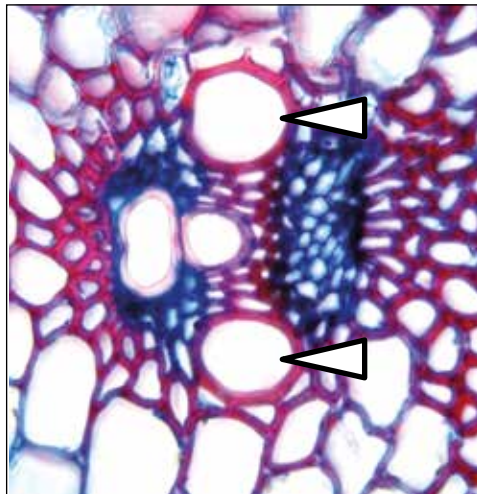


**82** Small sclerenchymatic sheath with 1-2 cells around vascular bundles

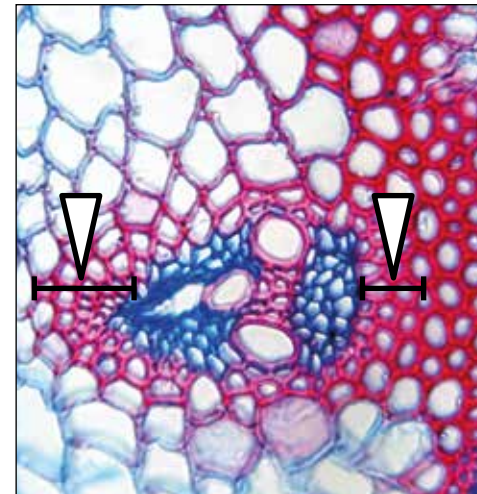


**83** Sclerenchymatic sheath around vascular bundles large, 3 to x cells

### Vessel arrangement



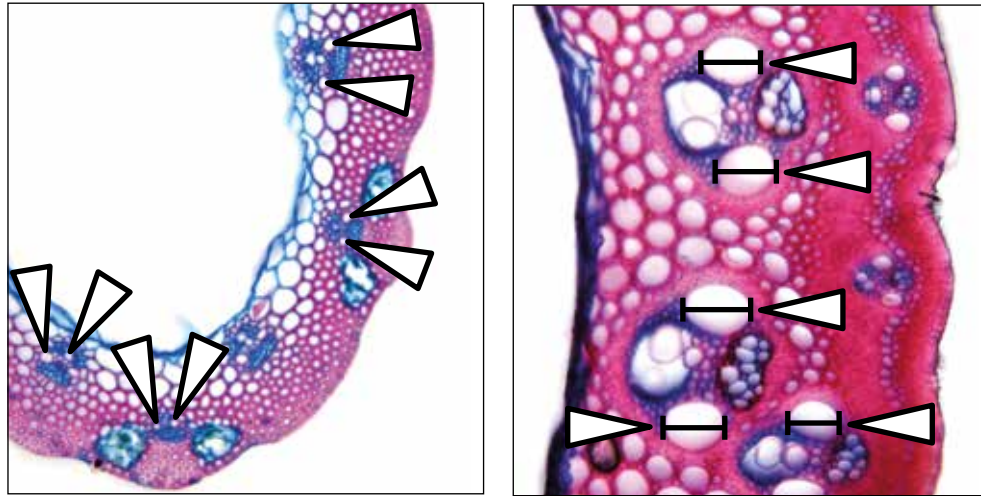
**90a** Largest vessels in vascular bundles in lateral position



**84** Sclerenchymatic sheath bilateral, large at both radial ends of vascular bundles

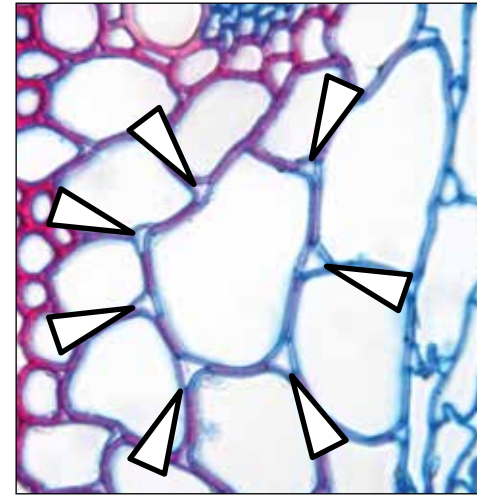


### Vessel size



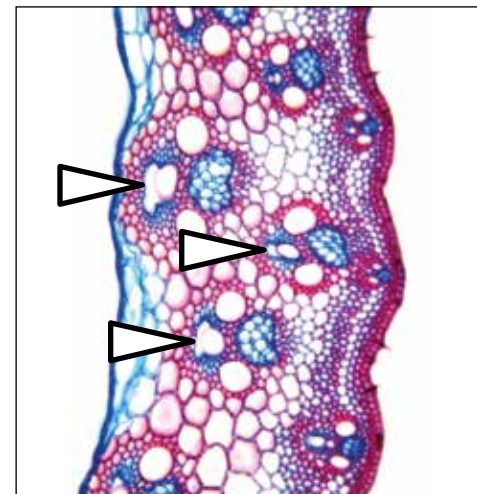
- 95 Largest vessel in the bundle small, < 20  $\mu\text{m}$
- 96 Largest vessel in the bundle 20-50  $\mu\text{m}$
- 97 Largest vessel in the bundle 50-100  $\mu\text{m}$
- 98 Largest vessel in the bundle > 100  $\mu\text{m}$

### Cavities (intercellulars) between parenchyma cells in uniform culms



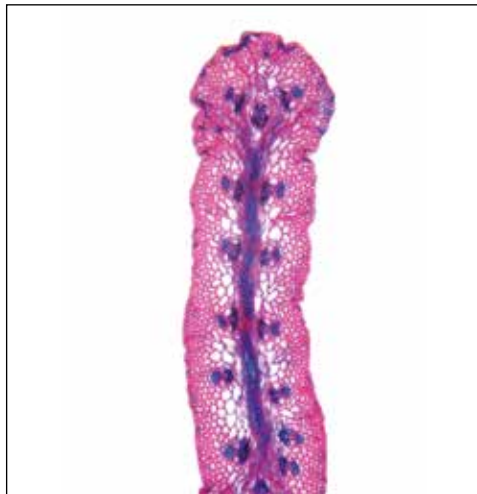
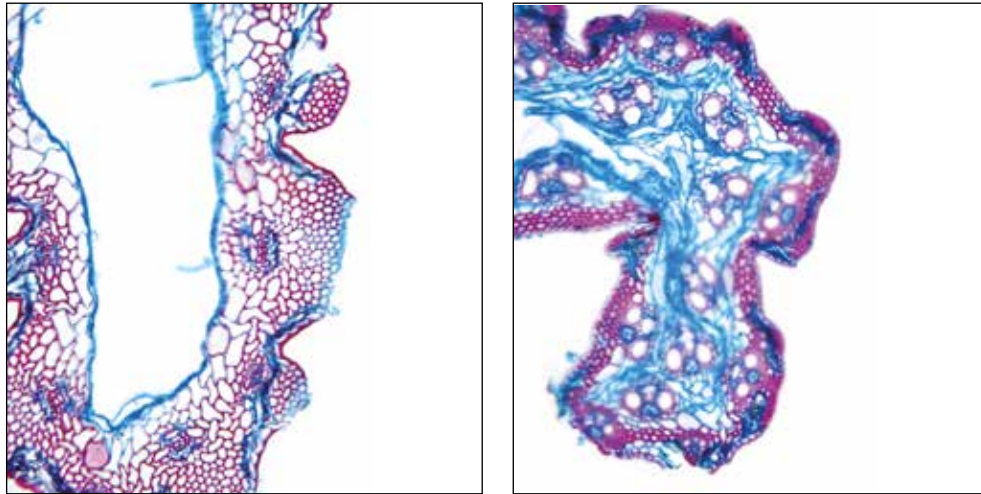
- 101a Cavities (intercellulars) between parenchyma-cells present, small, often triangular

### Cavities in vascular bundles



- 110a Distinct cavities (intercellulars) in the protoxylem area of vascular bundles

## Artifacts



**130** Artifacts on material from herbaria, e.g. compressed and deformed culms or exaggerated distinct ribs

## 4. Monographic presentation

### 4.1 Structure of the monographic presentation

**Genera**      **Species**      **Author**      **Family**

↓                    ↓                    ↓                    ↓

**Brachypodium retusum** (Pers.) P. Beauv.      **Poaceae**

Syn. *Brachypodium ramosum* ← **Synonym**

**General morphological description of the species**

↓

Perennial, 20-50 cm tall, erect culm, dry habitats in dry habitats at lower altitude.

Magnification 100 times

Magnification 400 times

Analyzed specimen: Between Porto and Partinella, Corsica. France. Length of culm 50 cm.

↑

**Information about the analysed specimen, e.g. locality, ecology, etc.**

Culm-diameter 0.5-1 mm, wall thin, radius of culm in relation to wall thickness approximately 1: 0.25 or < 0.25. Outline circular with a smooth surface. Culm-center hollow and surrounded by a few thin-walled, not lignified cells. Epidermis-cells thick-walled all around. Large vascular bundles arranged in 2-3 peripheral rows. Chlorenchyma in round, oval, square or rectangular groups. Sclerenchyma in a large, peripheral continuous belt (> 3 cells). Cells thick-walled. Girders square, rectangular or conic. Small sclerenchymatic sheath with 1-2 cells around vascular bundles. Largest vessels in vascular bundles in lateral position. Largest vessel in the bundle small, < 20µm. Cavities (intercellular) between parenchyma-cells present, small, often triangular. Distict cavities (intercellular) in the protoxylem area of vascular bundles.

↑

**Anatomical description of the species, composed of the definitions of the the Poaceae-Features**

ZT-00078019

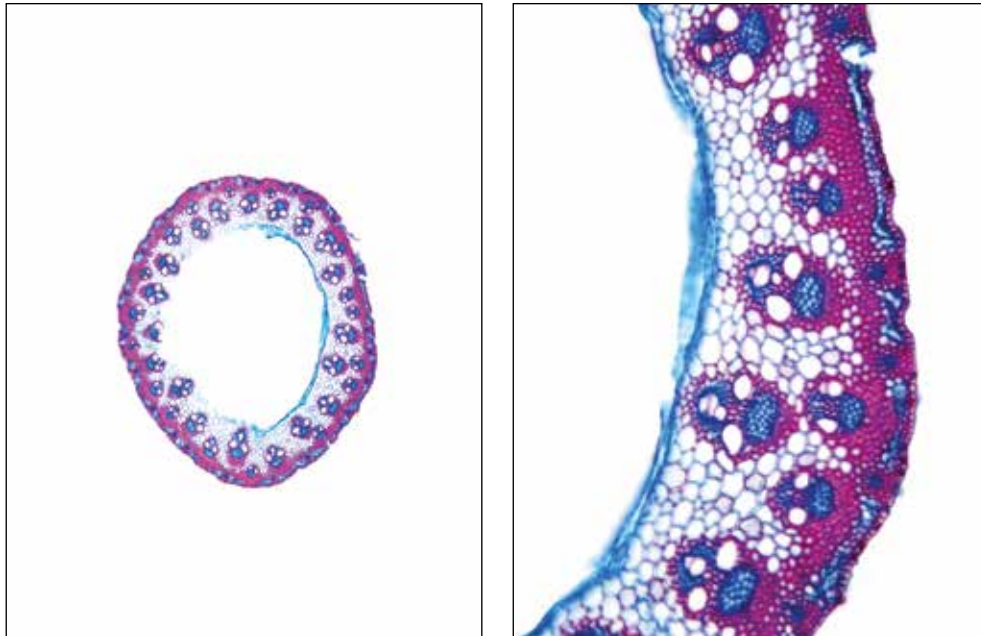
Barcode: Open the website [www.herbarien.uzh.ch](http://www.herbarien.uzh.ch) and with the corresponding barcode you will find a picture of the herbarium-voucher

## 4.2 Characterisation of 300 species

***Achnathenum calamagrostis*** Bertol.  
Syn. *Stipa calamagrostis*

**Poaceae**

25-60 cm tall, erect, densely caespitose, dry habitat at lower altitude.



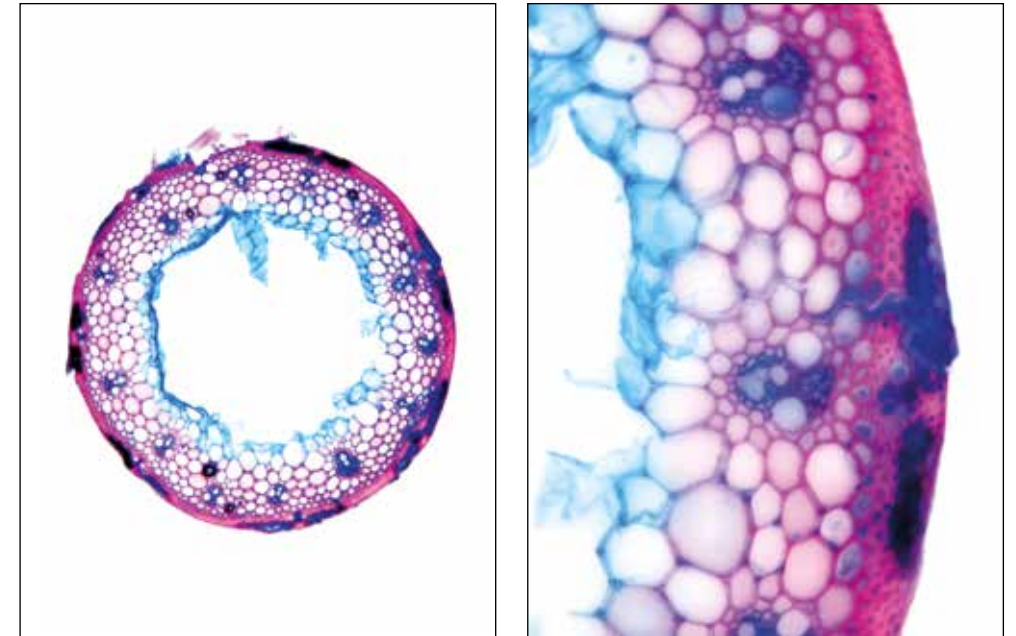
Analyzed specimen: Lauterbrunnen, Trümelbach, Canton of Bern, 900 m a.s.l. Switzerland. Lime stone scree. Length of culm 80 cm.

Culm-diameter 1-2 mm, center full, radius of culm in relation to wall thickness 1:1. Outline circular with a smooth surface. Culm-center hollow and surrounded by many large thin-walled, not lignified cells. Epidermis-cells thick-walled all around. Large vascular bundles arranged in 2-3 peripheral rows. Chlorenchyma in tangentially enlarged groups. Sclerenchyma in a small, peripheral continuous belt (< 4 cells). Cells thick-walled. Sclerenchymatic sheath around vascular bundles large, 3 to x cells. Largest vessels in vascular bundles in lateral position. Largest vessel in the bundle 2-50  $\mu\text{m}$ . Distict cavities (intercellulars) in the protoxylem area of vascular bundles.

***Aegilops cylindrica*** Host

**Poaceae**

Annual, 20-45 cm tall, erect culms, caespitose, dry habitats at lower altitude.



Analyzed specimen: Botanical Garden Bern, 550 m a.s.l., Switzerland. Length of culm 40 cm.

Culm-diameter 1-2 mm, wall large, radius of culm in relation to wall thickness 1: 0.5. Outline circular with a smooth surface. Culm-center hollow and surrounded by a few thin-walled, not lignified cells. Epidermis-cells thick-walled all around. Large vascular bundles arranged in one peripheral row. Chlorenchyma in tangentially enlarged groups. Sclerenchyma in a small, peripheral continuous belt (< 4 cells). Cells thick-walled. Girders tangentially enlarged. Small sclerenchymatic sheath with 1-2 cells around vascular bundles. Largest vessels in vascular bundles in lateral position. Largest vessel in the bundle 20-50  $\mu\text{m}$ .