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382 PHOTOMICROGRAPHS OF 91

# PAPER MAKING FIBERS

BY CHARLES H. CARPENTER
AND LAWRENCE LENEY

STATE UNIVERSITY OF NEW YORK
COLLEGE OF FORESTRY AT SYRACUSE


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382 PHOTOMICROGRAPHS OF 91

# PAPERMAKING FIBERS

By CHARLES H. CARPENTER and LAWRENCE LENEY

*The authors are wood technologists. Mr. Carpenter is consultant to the New York and Pennsylvania Co., Lock Haven, Pa. Mr. Leney is Instructor, State University of New York, College of Forestry at Syracuse.*

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1952

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## PREFACE TO REVISED EDITION

Technicians having to identify the cellular constituents of pulp and paper must know the form, size, and diagnostic markings of the various cells which may be present in the mixture. This information is obtained from illustrations or by comparison with known material. In the past the information has been furnished largely by line drawings supplemented by descriptions. Line drawings at best are not fully satisfactory. Exactness of representation is difficult to achieve, even though the artist is unusually skillful.

Because of advances in technique, photomicrography has become an important tool in fiber identification. Excellent photomicrographs can be made to record the wealth of detail required for accurate identification of unknown material.

Preparation of satisfactory photomicrographs of the cell types requires a specialist in this field of photography and consumes much time. Consequently such pictures are few.

To assist pulp and paper technicians in identifying cellular constituents, the New York State College of Forestry published *Atlas of Papermaking Fibers* in 1932. This appeared as Technical Publication No. 35 under the authorship of Charles H. Carpenter. It consisted of 56 plates depicting the cellular elements of wood and herbaceous plants of interest to the papermaker. The publication, now out of print, apparently met a need in the industry because demand for it has been constant.

This publication is a revision of the original publication and has been enlarged to include additional fiber types. The format has been changed, particularly in regard to plate descriptions, in an effort to improve utility of the subject matter. The fibrous elements of 86 plant species are illustrated: 35 coniferous woods, 35 hardwoods, and 16 cell types of herbaceous plants of interest to the papermaker. The remaining plates are devoted to wool, silk, asbestos, rayon, and nylon.

The fibrous plant materials used in making the mounts required for the photomicrographs were authentic, both in the original edition and in this revision. Each mount was critically examined. The cells or cell aggregates exhibiting the diagnostic characteristics considered most reliable in identification were selected for illustration. One or more of the photographs were then mounted in a plate. When a plate contains



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more than one type of cell, the different cells are designated by number. A legend on the facing page accompanies each plate.

That the new publication has limitations must be recognized. Space does not permit illustration of all variations in structure occurring within a species. Because of this, some illustrations may be regarded as atypical in spite of the care exercised in their selection. Descriptive information could be made more extensive but to do so might delay publication indefinitely. However, a more comprehensive work than this has been tentatively planned, to include keys for identification and lengthy descriptions. Meanwhile, constructive suggestions on the present work are solicited.* These will be carefully considered in preparing future revisions.

Thanks are extended to those who have contributed to preparation of this edition. We particularly appreciate the suggestions by members of the Department of Wood Technology at State University of New York, College of Forestry at Syracuse.

CHARLES H. CARPENTER

LAWRENCE LENEY

April 1952

* Address correspondence concerning this publication to Department of Wood Technology, State University College of Forestry, Syracuse 10, N. Y.



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# PAPERMAKING FIBERS



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## SUGAR PINE

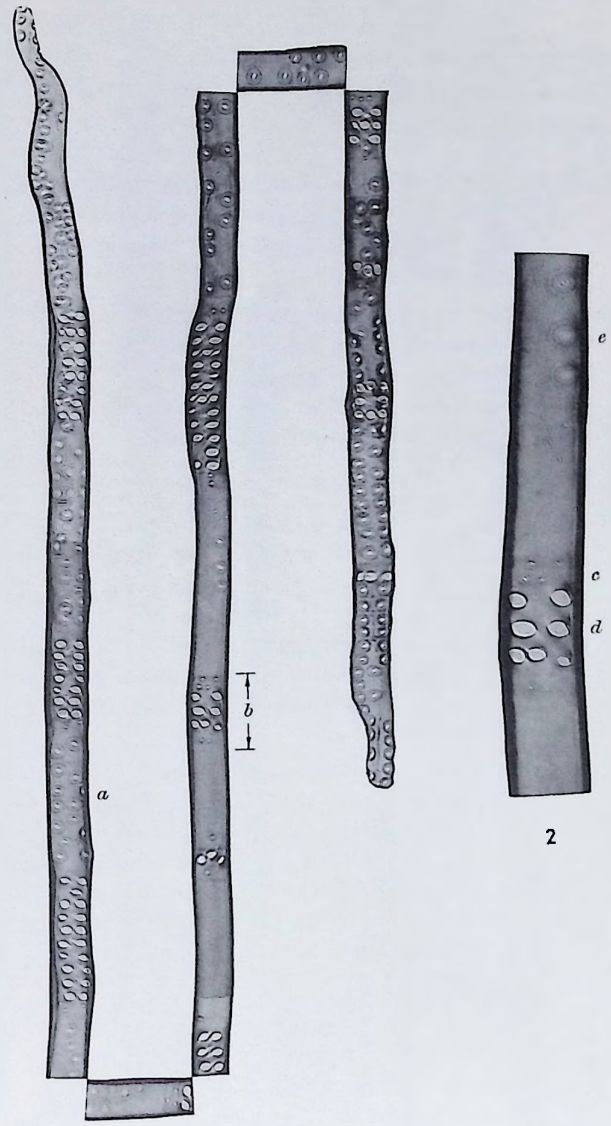
***Pinus lambertiana* Dougl.**

**1.** Springwood longitudinal tracheid, ×90, radial view
- **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
- **b.** Ray-contact area

**2.** Portion of a longitudinal tracheid, ×180
- **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
- **d.** Ray-parenchyma pits: large, window-like pits of pit pairs leading to ray parenchyma
- **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid











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## WESTERN WHITE PINE, IDAHO WHITE PINE

***Pinus monticola* Dougl.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, window-like pits of pit pairs leading to ray parenchyma

## EASTERN WHITE PINE

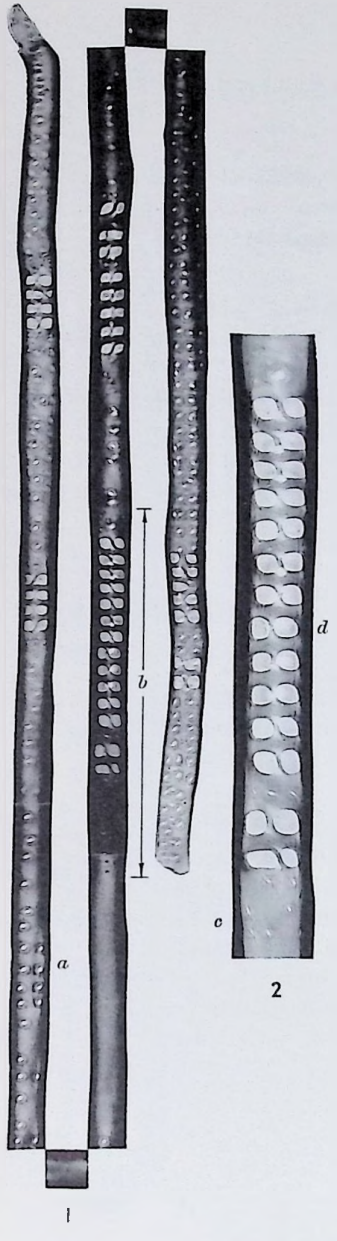
***Pinus strobus* L.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, window-like pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

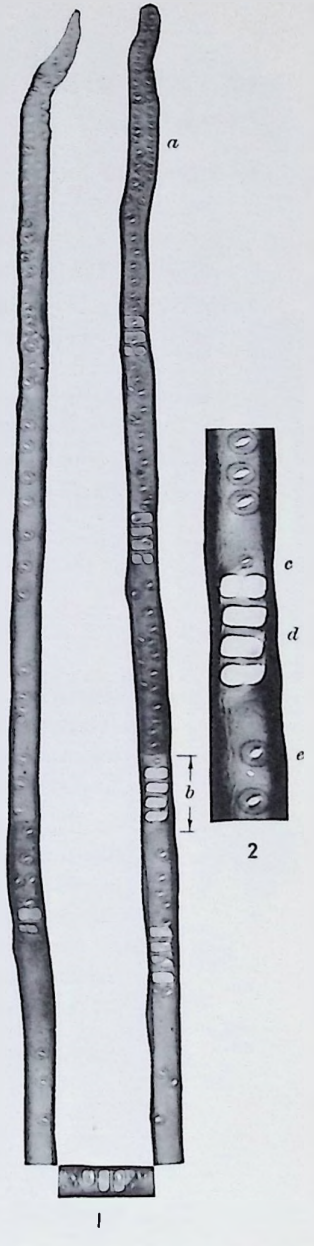




WESTERN WHITE PINE




EASTERN WHITE PINE







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## SCOTCH PINE, SCOTS PINE

***Pinus sylvestris* L.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, window-like pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

## RED PINE, NORWAY PINE

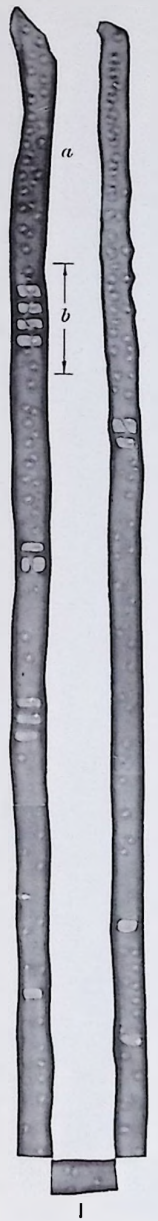
***Pinus resinosa* Ait.**

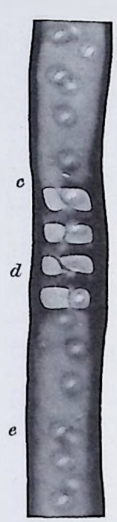
1. Springwood longitudinal tracheid, ×90, radial view
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   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, window-like pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid





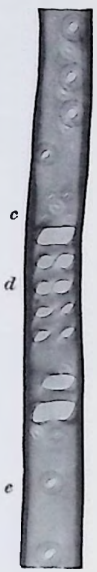
SCOTCH PINE




RED PINE







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## MONTEREY PINE

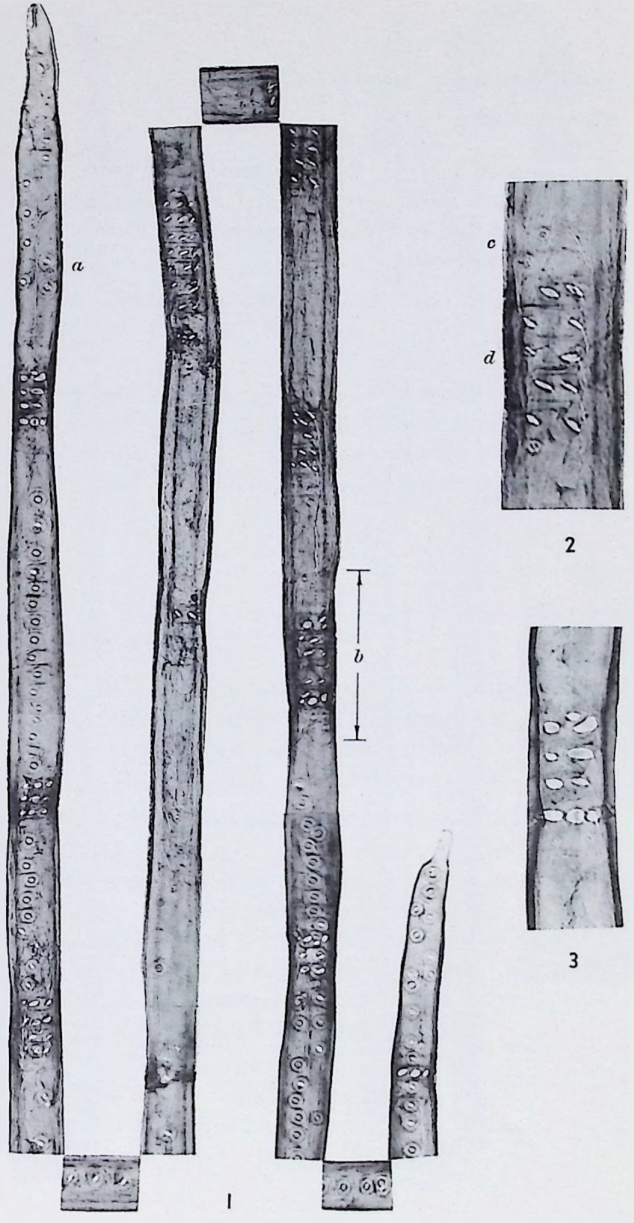
***Pinus radiata* D. Don, *Pinus insignis* Dougl.**

**1.** Springwood longitudinal tracheid, ×90, radial view
- **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
- **b.** Ray-contact area

**2.** Portion of a longitudinal tracheid, ×180
- **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
- **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma

**3.** Portion of a longitudinal tracheid, ×180, showing pit variation









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## SHORTLEAF PINE

***Pinus echinata* Mill.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portions of two longitudinal tracheids, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

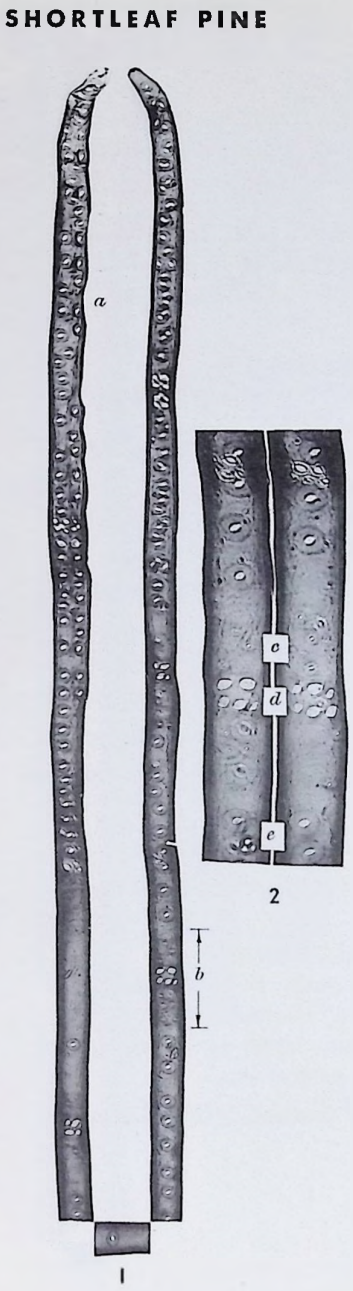
## LOBLOLLY PINE

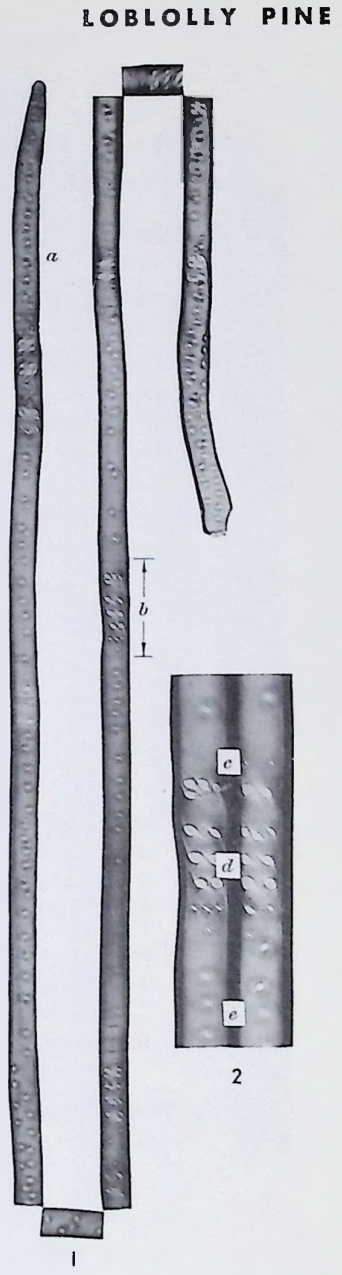
***Pinus taeda* L.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portions of two contiguous longitudinal tracheids, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid











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## LONGLEAF PINE

***Pinus palustris* Mill.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180, showing pit variation

## SLASH PINE

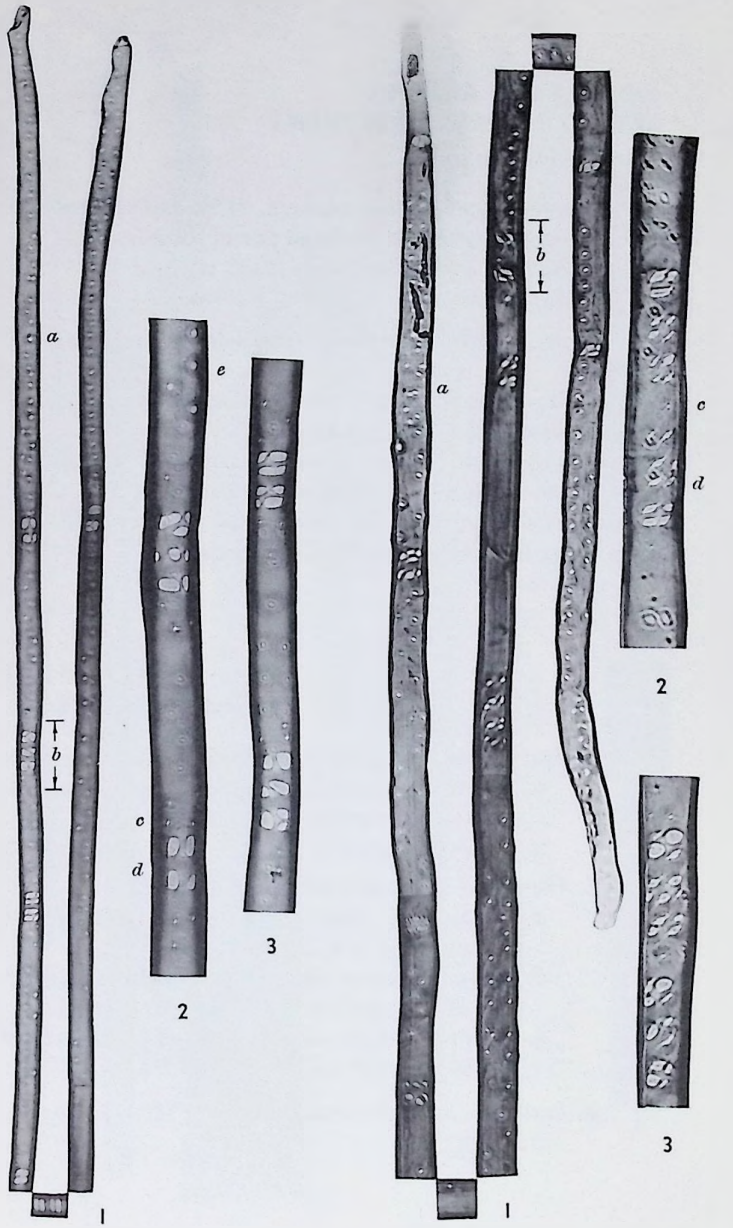
***Pinus caribaea* Morelet**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits leading to ray parenchyma
3. Portion of a longitudinal tracheid, ×180, showing pit variation



LONGLEAF PINE

SLASH PINE







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## PONDEROSA PINE, WESTERN YELLOW PINE

***Pinus ponderosa* Laws**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portions of two contiguous longitudinal tracheids, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

## JACK PINE

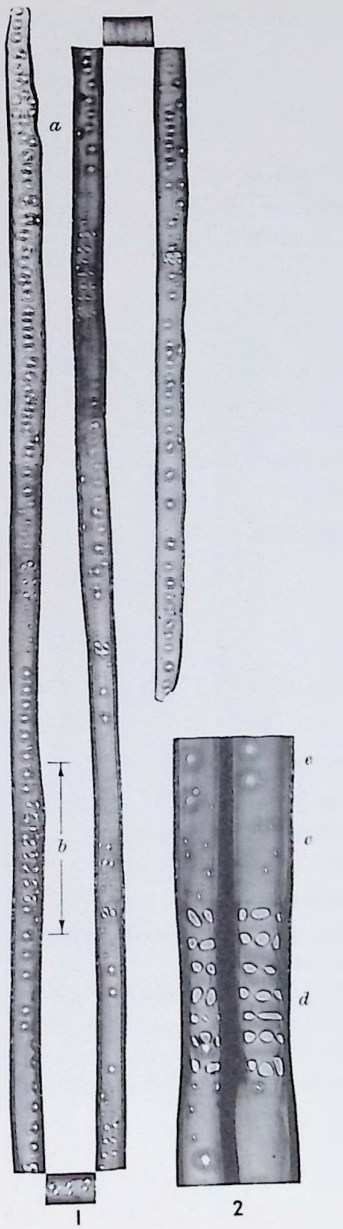
***Pinus banksiana* Lamb.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180, showing pit variation

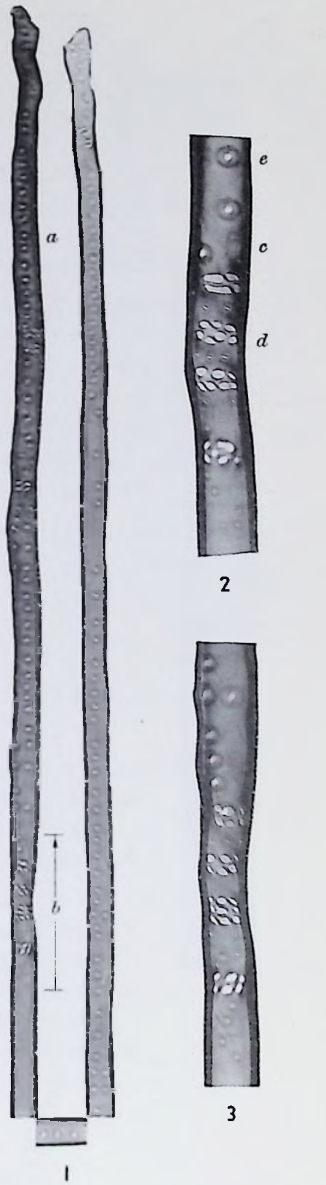




PONDEROSA PINE




JACK PINE







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## PITCH PINE

***Pinus rigida* Mill.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: large, varishaped pinoid pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180. showing pit variation

## WESTERN LARCH

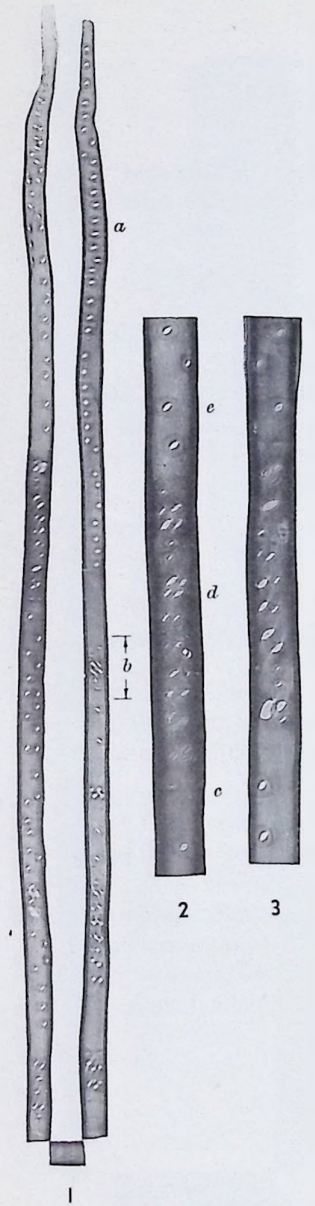
***Larix occidentalis* Nutt.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

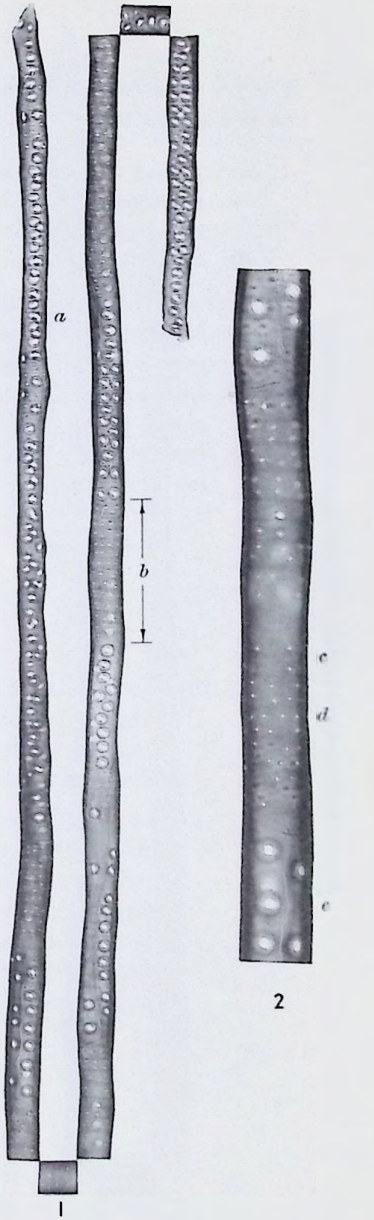




PITCH PINE




WESTERN LARCH






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## EUROPEAN LARCH

***Larix decidua* Mill.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

## EASTERN LARCH, TAMARACK

***Larix laricina* (DuRoi) K. Koch**

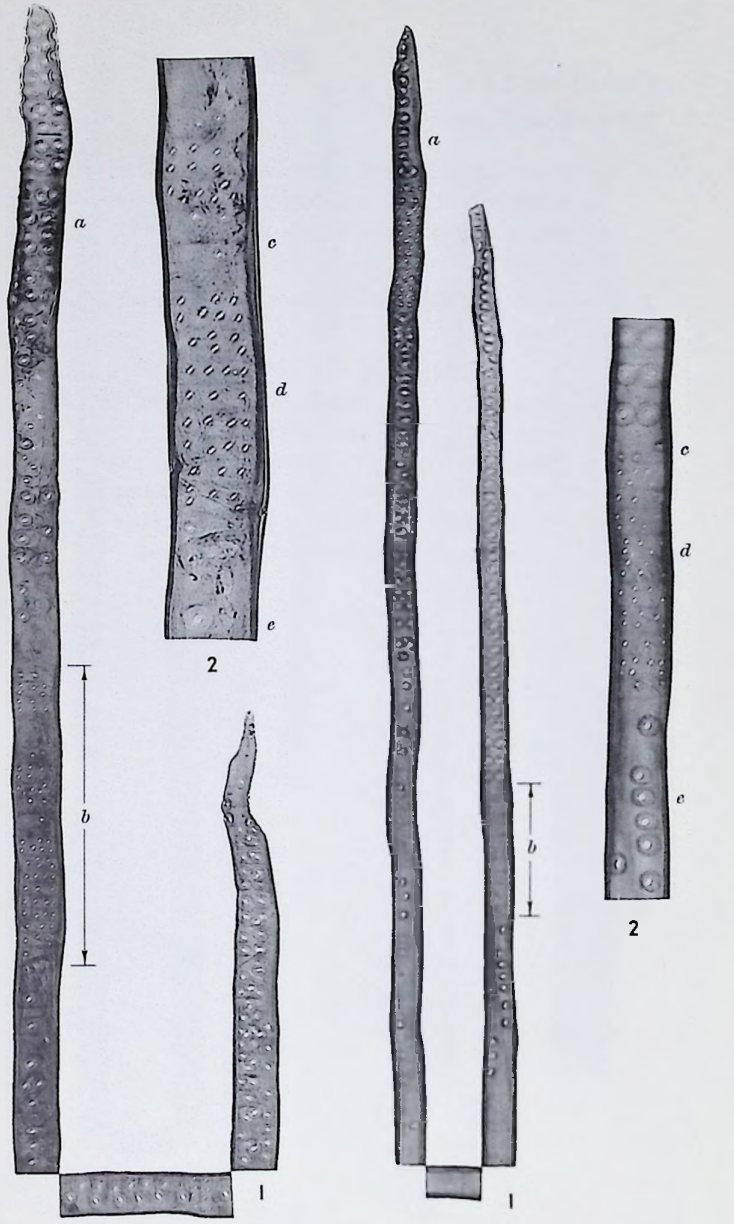
1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid





EUROPEAN LARCH

EASTERN LARCH








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## RED SPRUCE

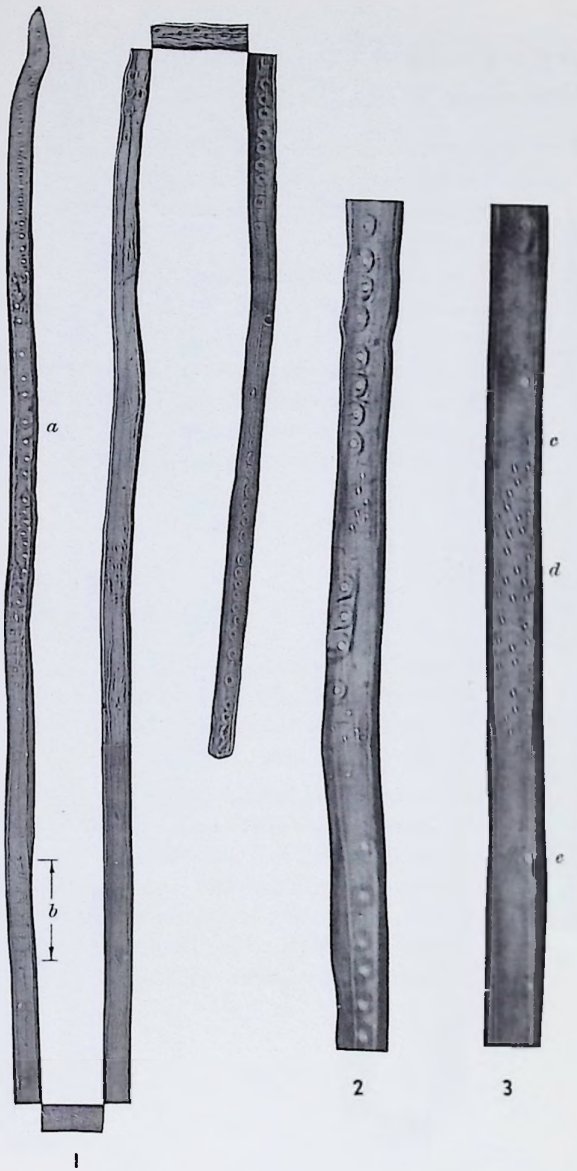
***Picea rubens* Sarg.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180, showing pit variation
3. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid












*91 Paper Making Fibers (1952)*
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## WHITE SPRUCE

***Picea glauca* (Moench.) Voss.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

## BLACK SPRUCE

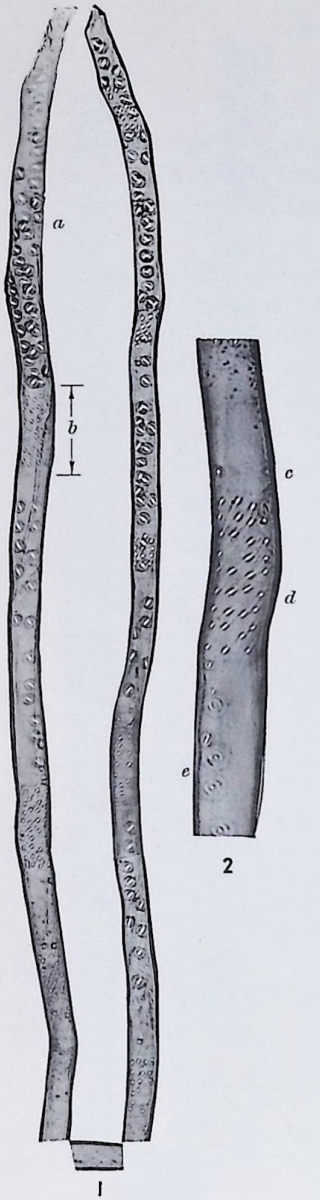
***Picea mariana* (Mill.) B.S.P.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

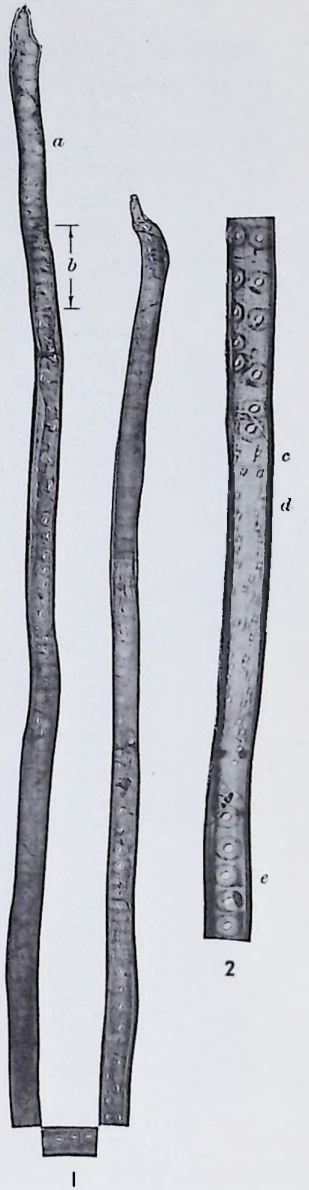




WHITE SPRUCE




BLACK SPRUCE







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## SITKA SPRUCE

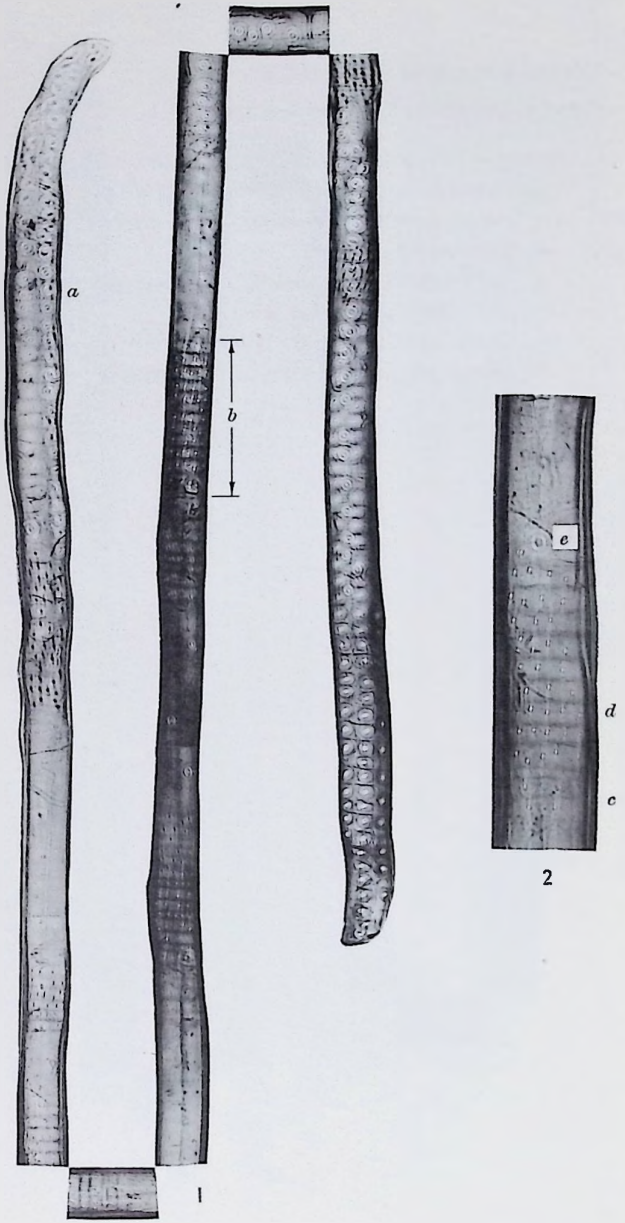
***Picea sitchensis* (Bong.) Carr.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pit of a pit pair leading to a contiguous longitudinal tracheid













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## ENGELMANN SPRUCE

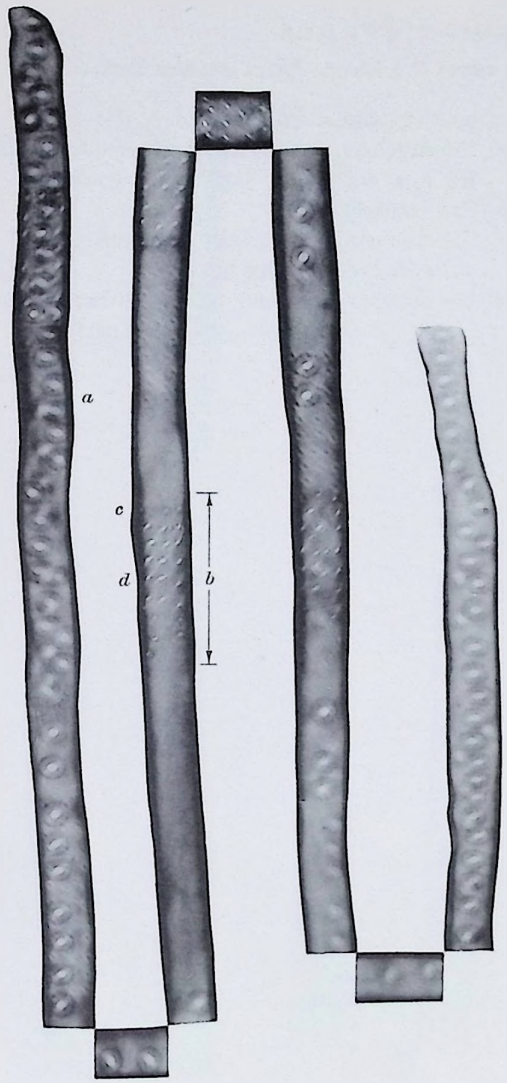
***Picea engelmanni* Parry ex Engelm.**

Springwood longitudinal tracheid, ×180, radial view

- **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
- **b.** Ray-contact area
- **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
- **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma











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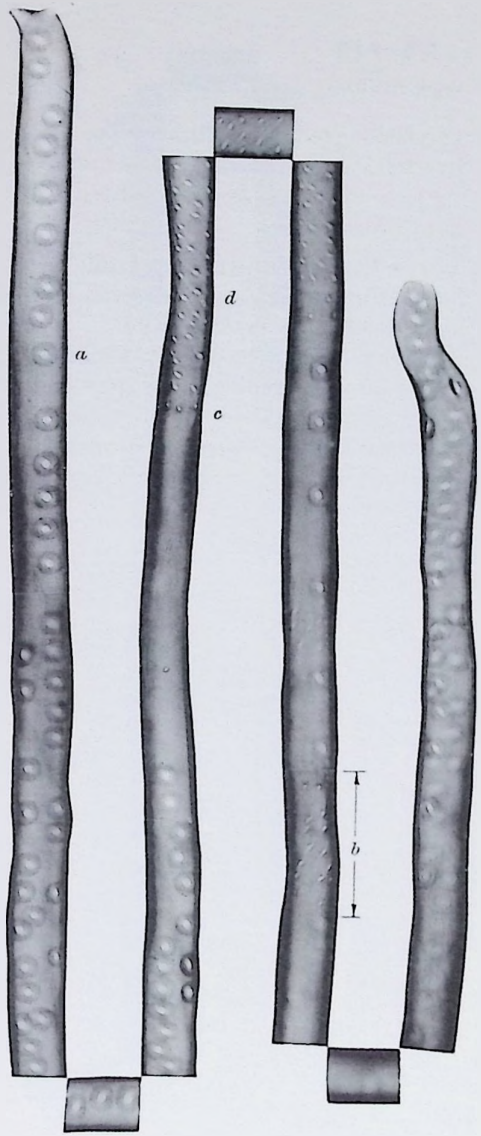
## NORWAY SPRUCE

***Picea abies* (L.) Karst., *Picea excelsa* Link.**

Springwood longitudinal tracheid, ×180, radial view

- **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
- **b.** Ray-contact area
- **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
- **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma












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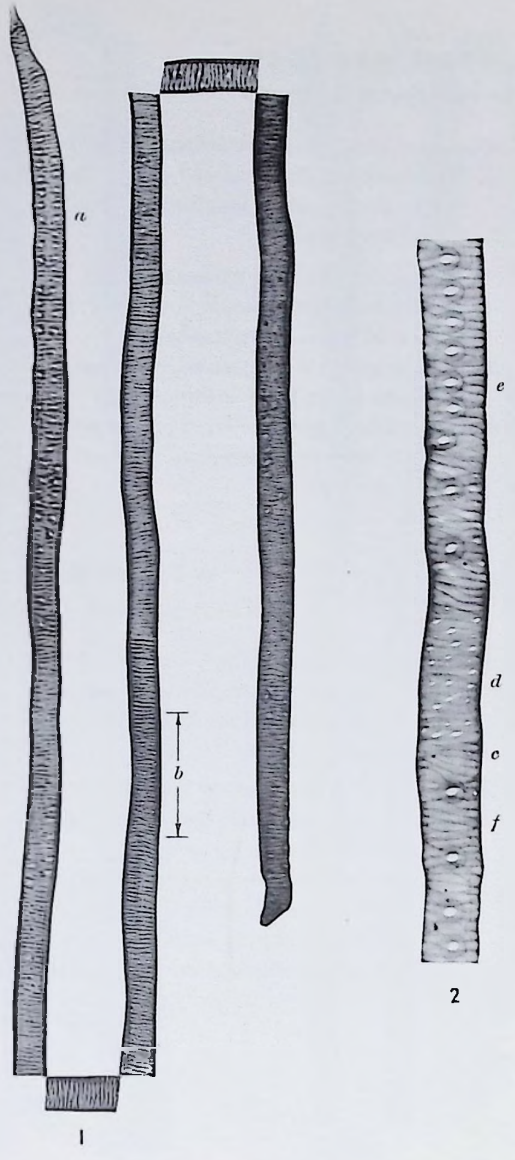
## DOUGLAS-FIR

***Pseudotsuga taxifolia* (Poir.) Britt.**

**1.** Springwood longitudinal tracheid, ×90, radial view
- **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
- **b.** Ray-contact area

**2.** Portion of a longitudinal tracheid, ×180
- **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
- **d.** Ray-parenchyma pits: small, slitlike piciform pits of pit pairs leading to ray parenchyma
- **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
- **f.** Spiral thickening: localized thickening of the secondary wall








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## EASTERN HEMLOCK

***Tsuga canadensis* (L.) Carr.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pits: small, bordered pits of pit pairs leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

## WESTERN HEMLOCK

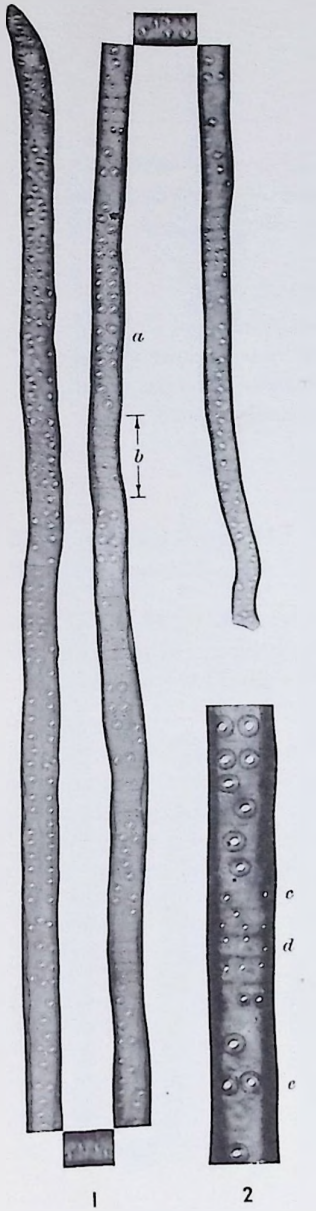
***Tsuga heterophylla* (Rafn.) Sarg.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-tracheid pit: small, bordered pit of a pit pair leading to a ray tracheid
   - **d.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **e.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

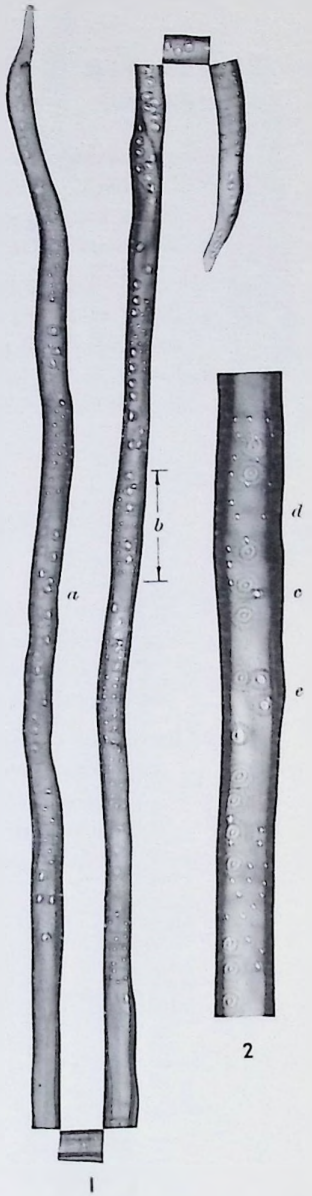




EASTERN HEMLOCK




WESTERN HEMLOCK







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## SILVER FIR

***Abies alba* Mill.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

## BALSAM FIR, EASTERN FIR

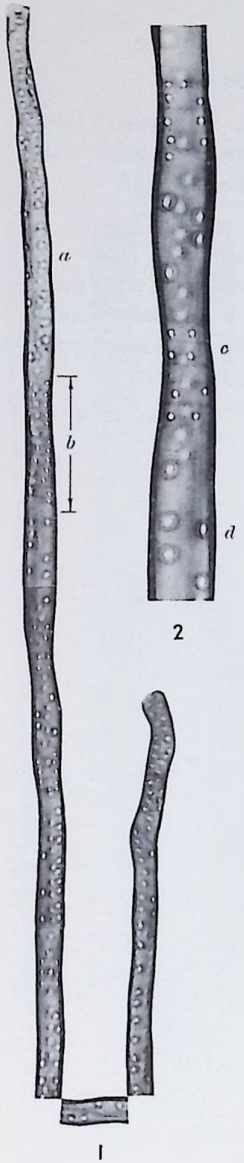
***Abies balsamea* (L.) Mill.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

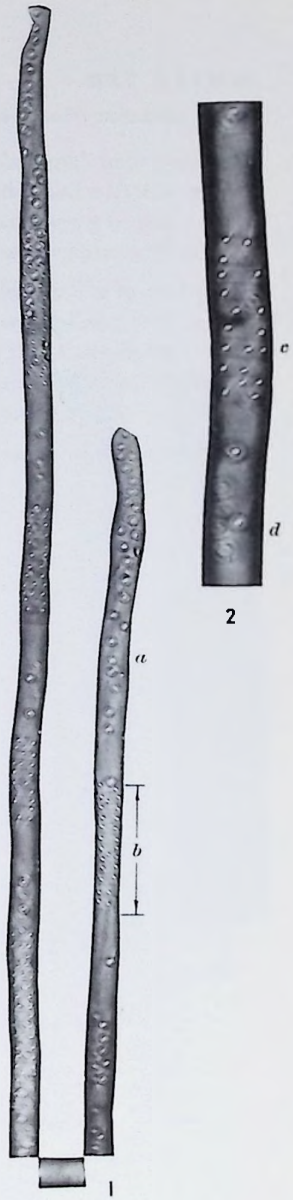




SILVER FIR




BALSAM FIR







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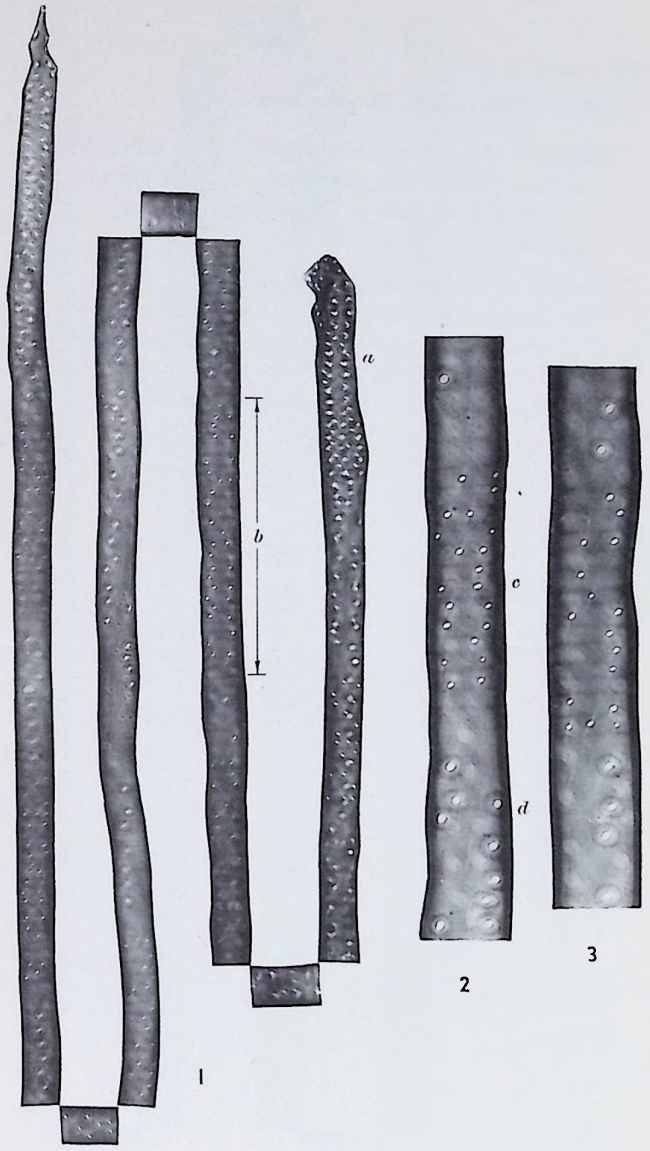
## WHITE FIR

***Abies concolor* (Gord. and Glend.) Hoopes**

1. Springwood longitudinal tracheid, ×90, radial view
   - a. Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - b. Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - c. Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - d. Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180, showing pit variation











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## REDWOOD

***Sequoia sempervirens* (D. Don) Endl.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid














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## BALD-CYPRESS

***Taxodium distichum* (L.) Rich.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid

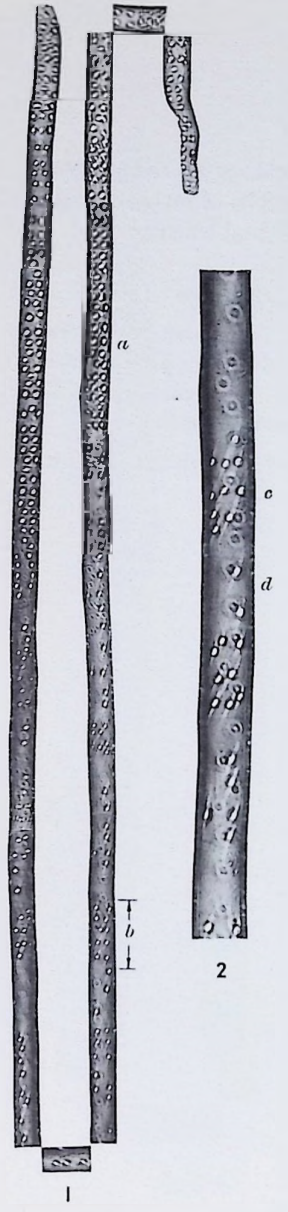
## INCENSE-CEDAR

***Libocedrus decurrens* Torr.**

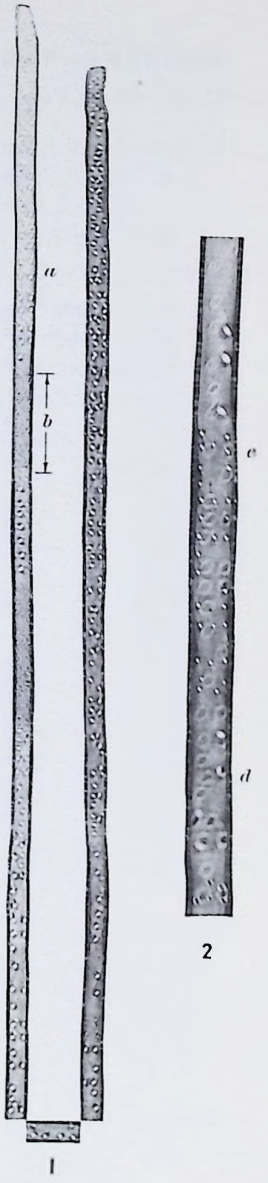
1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid



BALD-CYPRESS




INCENSE-CEDAR







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## WESTERN RED-CEDAR

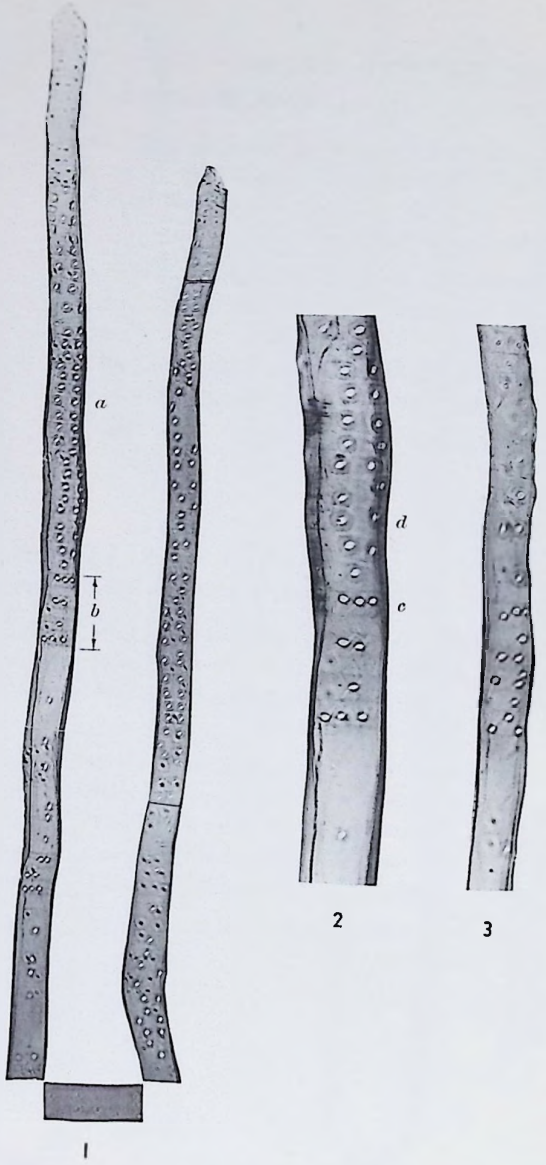
***Thuja plicata* Donn**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180, showing pit variation













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## PORT ORFORD-CEDAR

***Chamaecyparis lawsoniana* (A. Murr.) Parl.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180

## ALASKA YELLOW-CEDAR

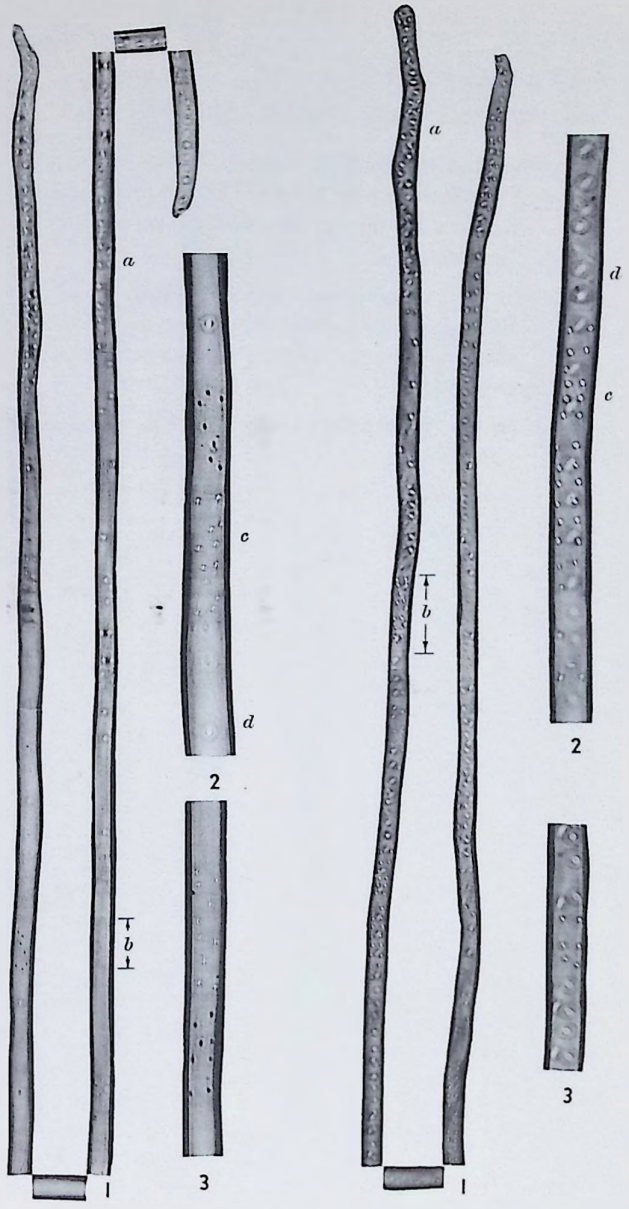
***Chamaecyparis nootkatensis* (D. Don) Spach**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: small, elliptical, uniformly sized pits of pit pairs leading to ray parenchyma
   - **d.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
3. Portion of a longitudinal tracheid, ×180, showing pit variation





PORT ORFORD-CEDAR ALASKA YELLOW-CEDAR







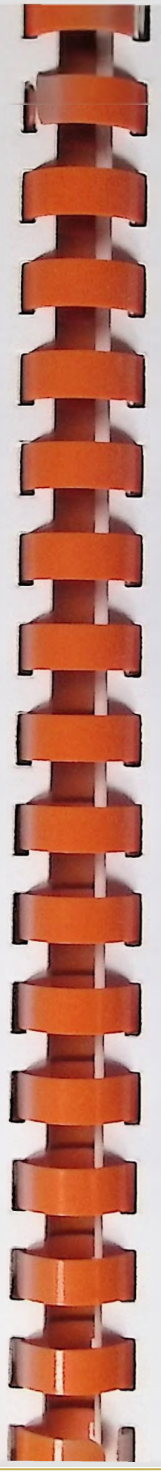
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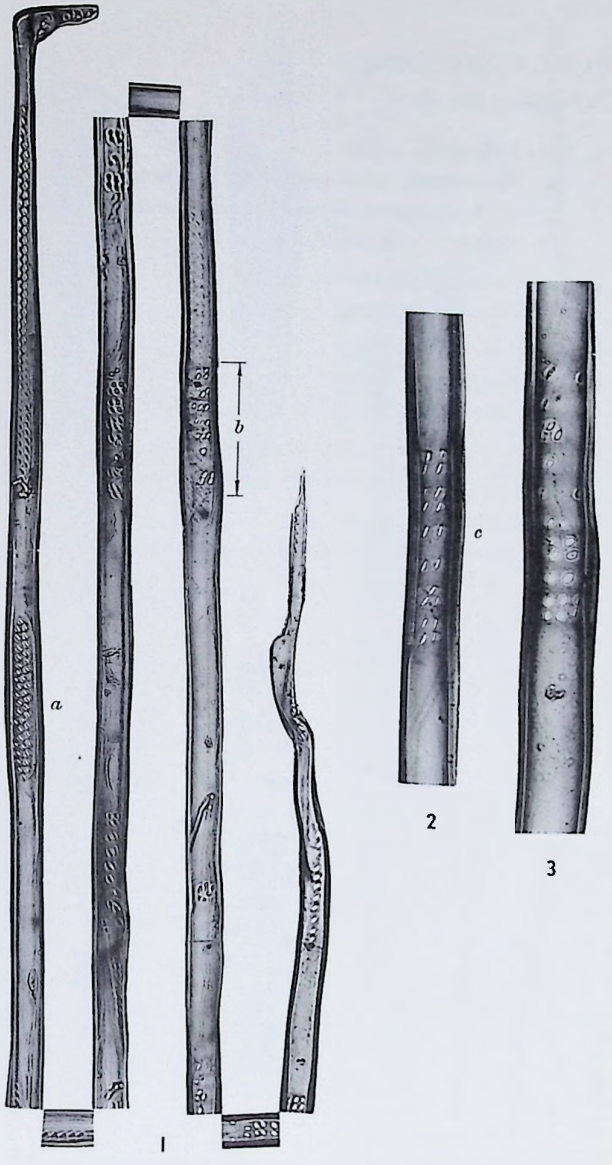
## PARANA-PINE

***Araucaria angustifolia* (Bert.) O. Ktze.**

1. Springwood longitudinal tracheid, ×90, radial view
   - **a.** Intertracheid pits: bordered pits of pit pairs leading to a contiguous longitudinal tracheid
   - **b.** Ray-contact area
2. Portion of a longitudinal tracheid, ×180
   - **c.** Ray-parenchyma pits: large, varishaped (often slitlike) pits of pit pairs leading to ray parenchyma
3. Portion of a longitudinal tracheid, ×180, showing pit variation













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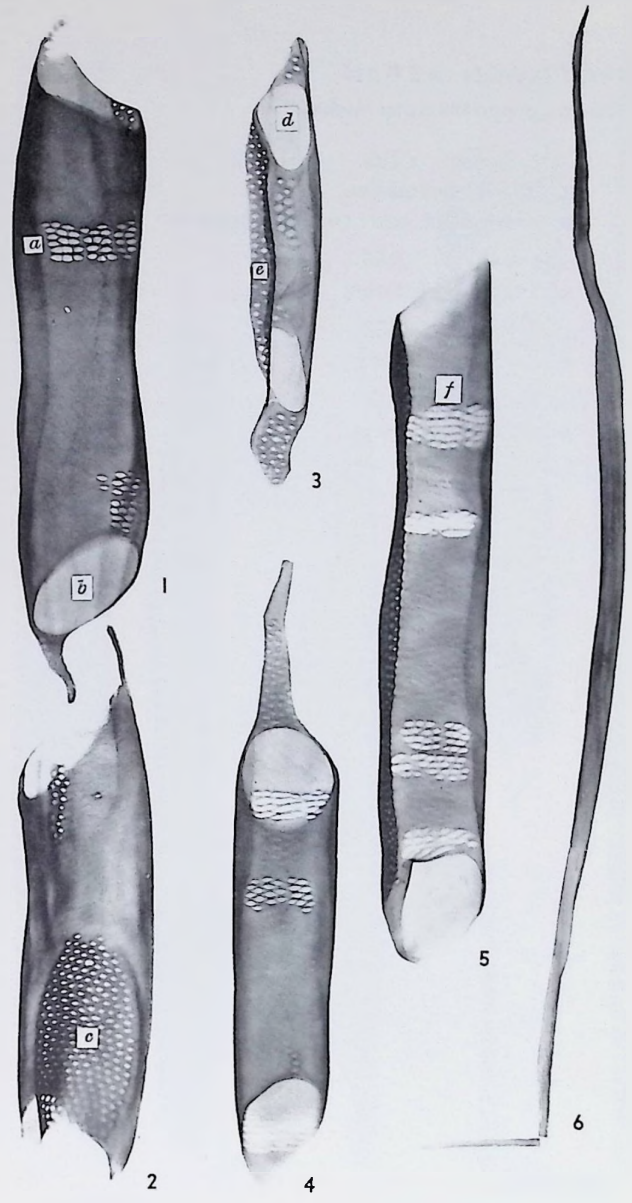
## BLACK WILLOW

***Salix nigra* Marsh.**

1. Vessel element, ×180
   - **a.** Ray-contact area consisting of three longitudinally elongated ray-cell contact areas
   - **b.** Simple perforation
2. Vessel element, ×180
   - **c.** Intervessel pitting
3. Vessel element, ×180
   - **d.** Simple perforation
   - **e.** Intervessel pitting
4. Vessel element, ×180, showing intervessel pitting (caudate tip) and three ray-contact areas
5. Vessel element, ×180
   - **f.** Ray-contact area: four areas are visible at different levels
6. Fiber, ×180











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## BIGTOOTH ASPEN

***Populus grandidentata* Michx.**

**1.** Vessel element, ×180
- **a.** Simple perforation
- **b.** Ray-contact area: two such areas are visible

**2.** Vessel element, ×180
- **c.** Simple perforation

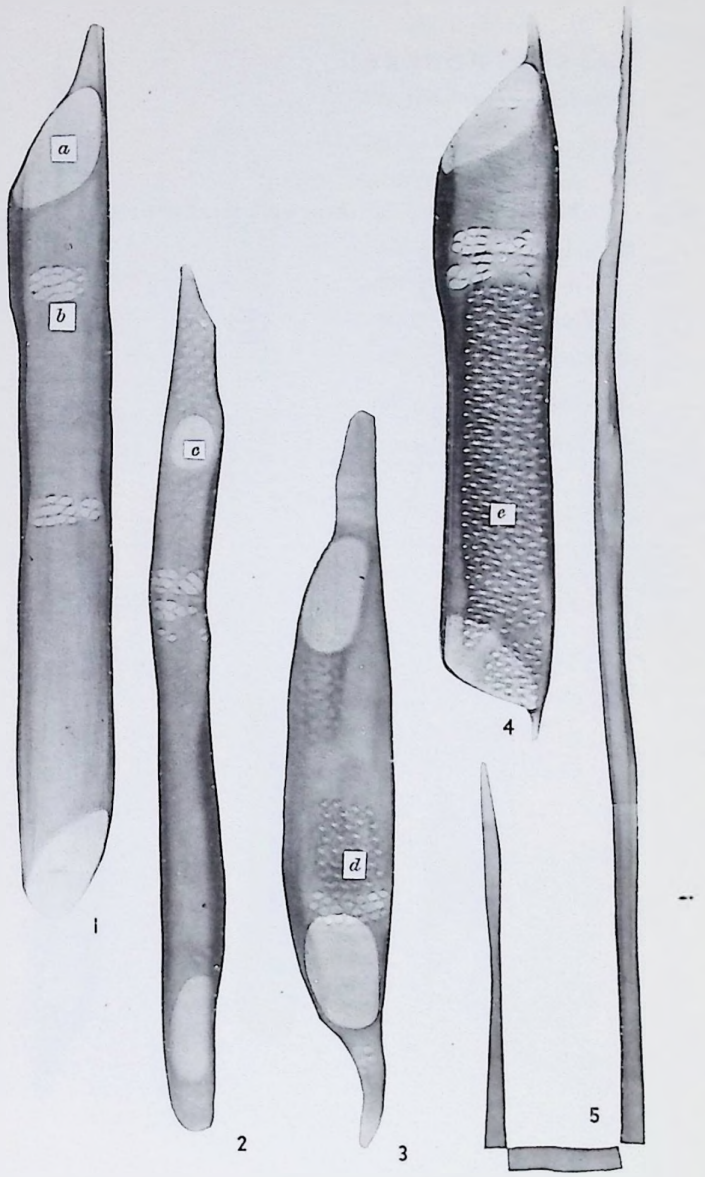
**3.** Vessel element, ×180
- **d.** Intervessel pitting

**4.** Vessel element, ×180
- **e.** Intervessel pitting

**5.** Fiber, ×180











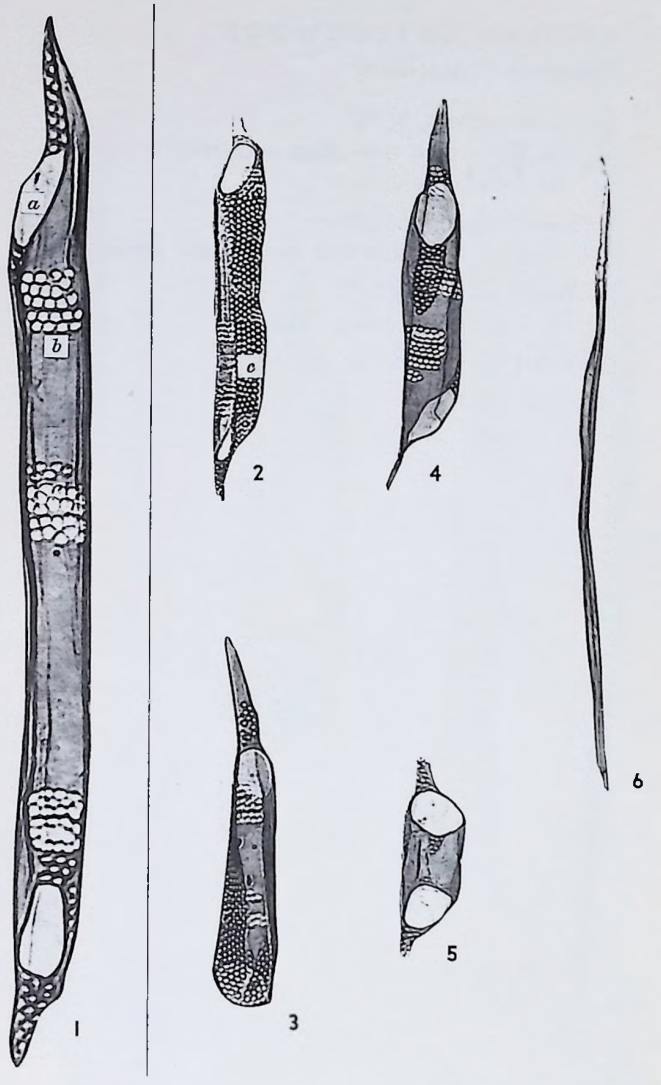
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## BALSAM POPLAR

***Populus tacamahaca* Mill.**

1. Vessel element, ×180
   - **a.** Simple perforation
   - **b.** Ray-contact area: three such areas are visible
2. Vessel element, ×90
   - **c.** Intervessel pitting
3. Vessel element, ×90
4. Vessel element, ×90
5. Vessel element, ×90
6. Fiber, ×90












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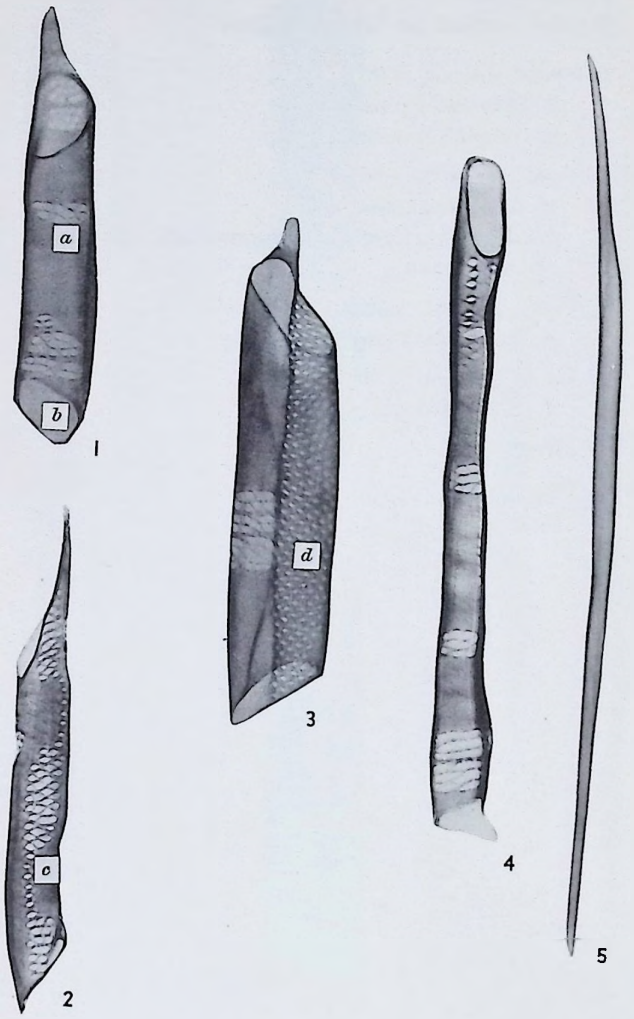
## EASTERN COTTONWOOD

***Populus deltoides* Bartr.**

1. Vessel element, ×180
   - a. Ray-contact area: three such areas are visible
   - b. Simple perforation
2. Vessel element, ×180
   - c. Area of contact with longitudinal parenchyma
3. Vessel element, ×180
   - d. Intervessel pitting
4. Vessel element, ×180
5. Fiber, ×180











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## BLACK COTTONWOOD

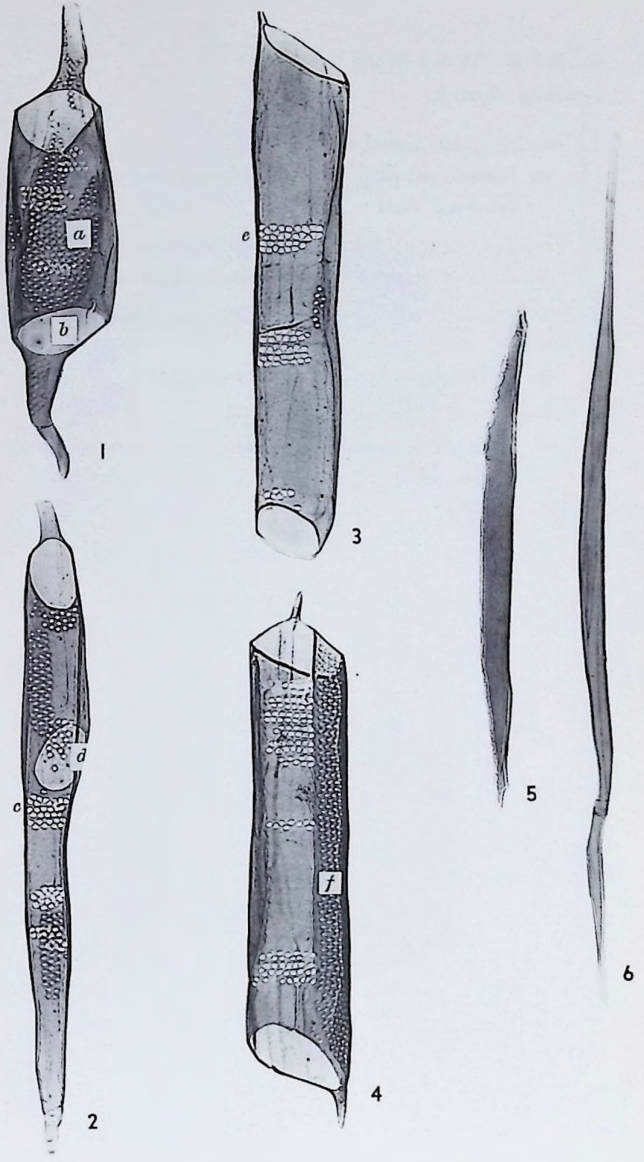
***Populus trichocarpa* Torr. and Gray**

1. Vessel element, ×90
   - **a.** Intervessel pitting
   - **b.** Simple perforation
2. Vessel element, ×90
   - **c.** Ray-contact area
   - **d.** Simple perforation: intervessel pits visible in background
3. Vessel element, ×90
   - **e.** Ray-contact area
4. Vessel element, ×90
   - **f.** Intervessel pitting
5. Fiber, ×90
6. Fiber, ×90













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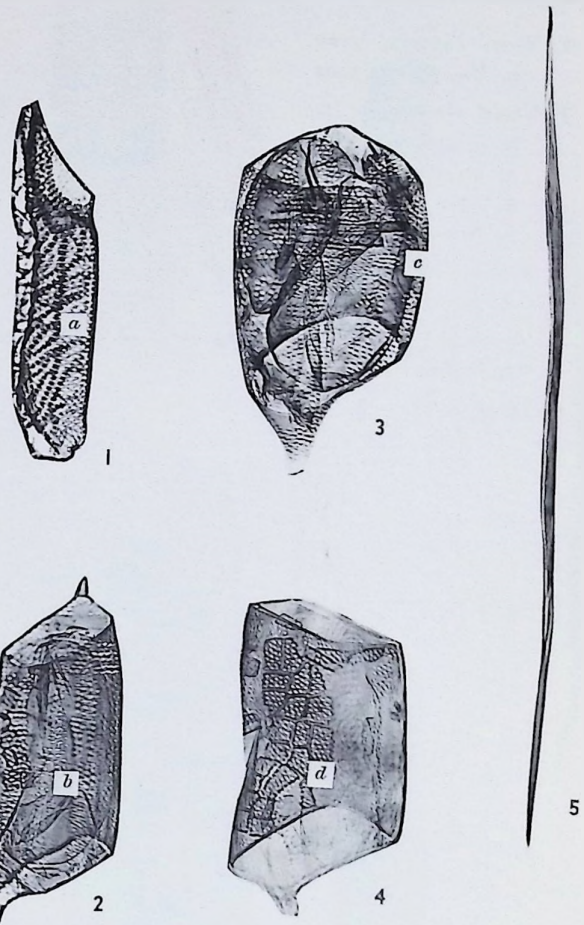
## BLACK WALNUT

***Juglans nigra* L.**

1. Summerwood vessel element, ×90
   - **a.** Intervessel pitting: vessel element is reticulate on the back wall
2. Vessel element, ×90, containing a balloon-like tylosis
   - **b.** Area of contact with longitudinal parenchyma
3. Springwood vessel element, ×90: two tyloses are visible
   - **c.** Ray-contact area in the foreground
4. Springwood vessel element, ×90
   - **d.** Cells of longitudinal parenchyma in contact, as in the wood
5. Fiber, ×90











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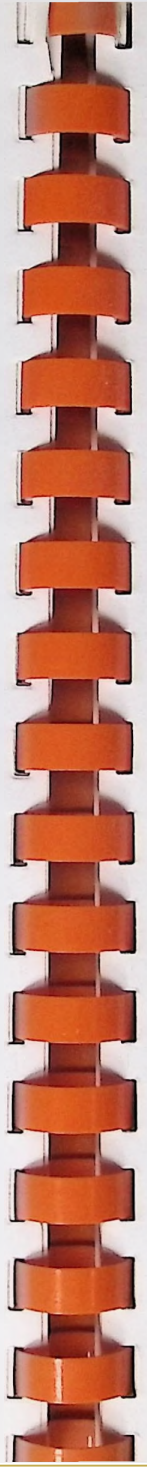
## BUTTERNUT

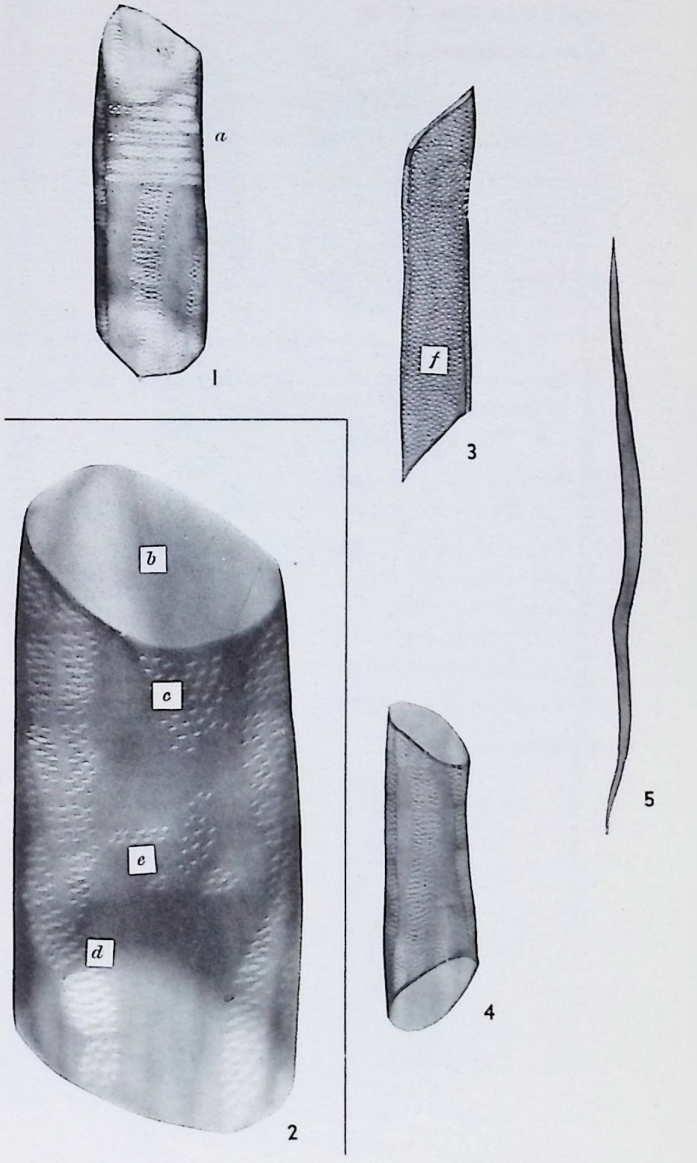
***Juglans cinerea* L.**

1. Vessel element, ×90
   - **a.** Ray-contact area
2. Vessel element, ×180
   - **b.** Simple perforation
   - **c.** Intervessel pitting
   - **d.** Area of contact with longitudinal parenchyma
   - **e.** Ray-contact area
3. Vessel element, ×90, tangential view
   - **f.** Intervessel pitting
4. Vessel element, ×90, showing areas of contact with longitudinal parenchyma
5. Fiber, ×90













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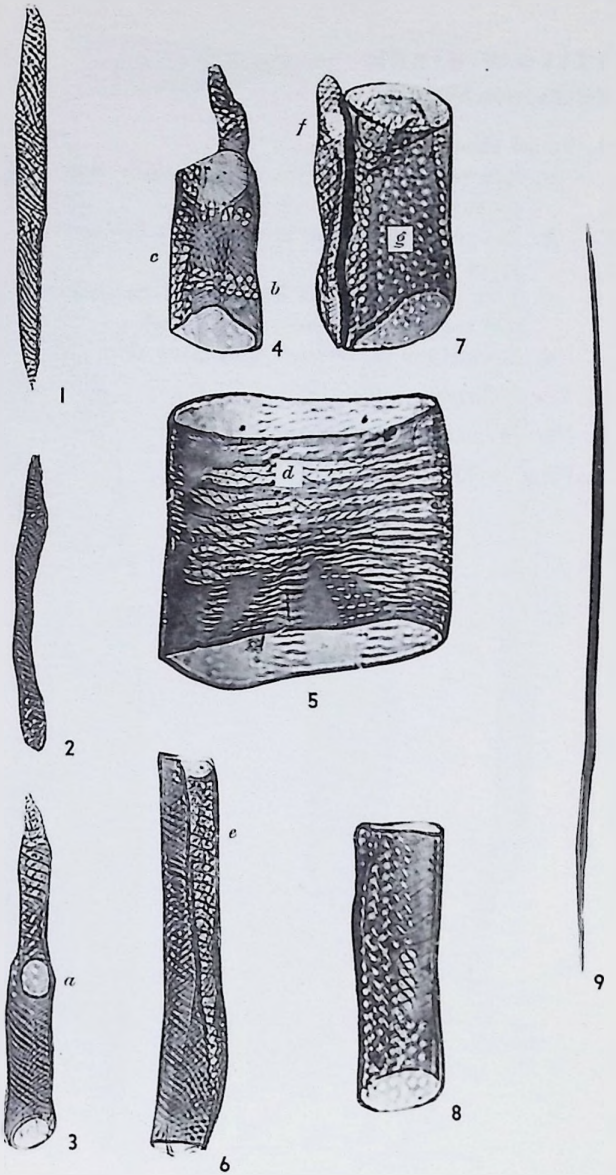
## AMERICAN ELM

***Ulmus americana* L.**

1. Vascular tracheid, ×180, with spiral thickening
2. Vascular tracheid, ×180, with spiral thickening
3. Summerwood vessel element, ×180, with spiral thickening
   - **a.** Simple perforation
4. Vessel element, ×180
   - **b.** Ray-contact area
   - **c.** Area of contact with longitudinal parenchyma
5. Springwood vessel element, ×180. Spiral thickening is not evident
   - **d.** Ray-contact area
6. Summerwood vessel element, ×180
   - **e.** Pronounced spiral thickening in pitted area
7. Vessel element, ×180, (right) in contact with a narrow vessel element which resembles a vascular tracheid
   - **f.** Simple perforation
   - **g.** Intervessel pitting
8. Vessel element, ×180
9. Short fiber, ×180











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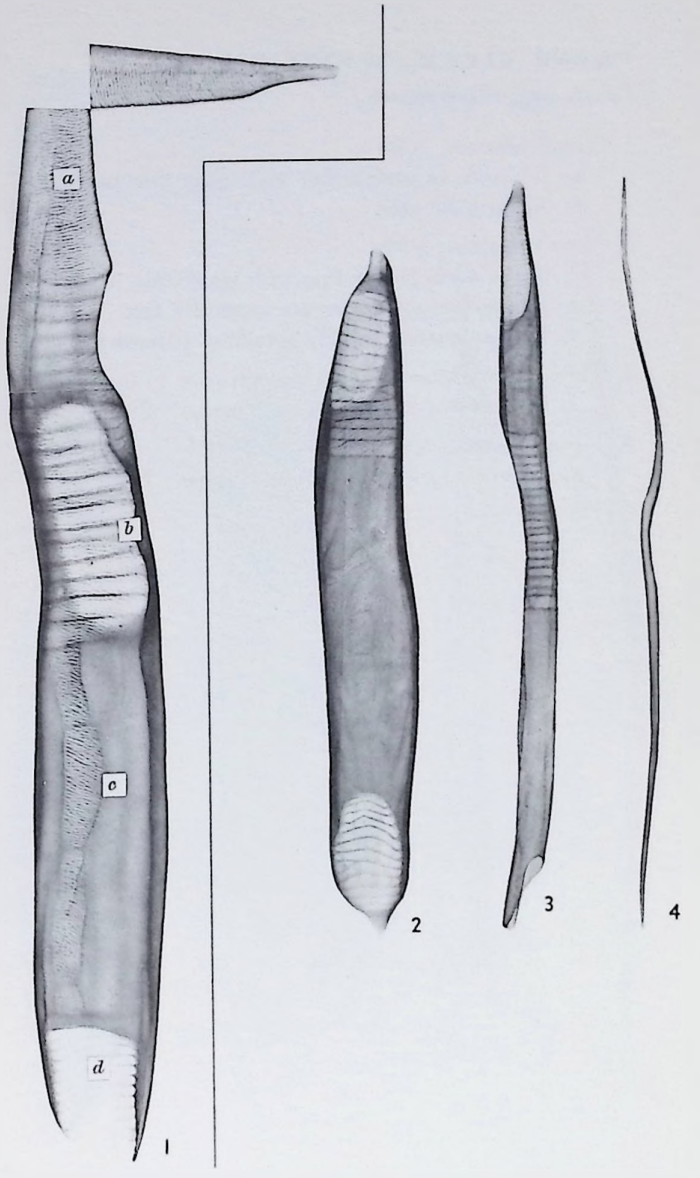
## YELLOW BIRCH

***Betula lutea* Michx. f.**

1. Vessel element, ×180
   - a. Intervessel pitting: pits are extremely fine and confluent
   - b. Ray-contact area: pits are extremely fine and confluent
   - c. Area of contact with longitudinal parenchyma: pits are extremely fine and confluent
   - d. Scalariform perforation with many thin bars
2. Vessel element, ×90
3. Narrow vessel element, ×90
4. Fiber, ×90









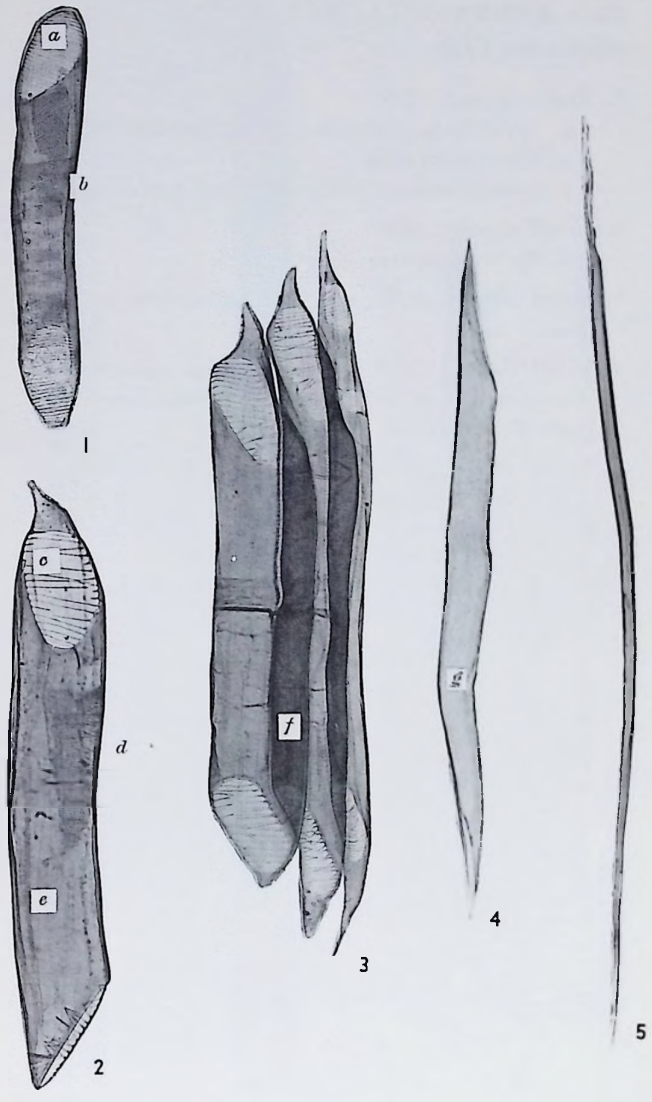

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## PAPER BIRCH, WHITE BIRCH

***Betula papyrifera* Marsh.**

1. Vessel element, ×90
   - **a.** Scalariform perforation with many thin bars
   - **b.** Ray-contact area
2. Vessel element, ×90
   - **c.** Scalariform perforation with many thin bars
   - **d.** Ray-contact area: pits are extremely fine
   - **e.** Area of contact with longitudinal parenchyma
3. Three vessel elements, ×90, in contact, as in the wood
   - **f.** Intervessel pitting: pits are extremely fine
4. Vessel element, ×90
   - **g.** Intervessel pitting: pits are extremely fine
5. Fiber, ×90












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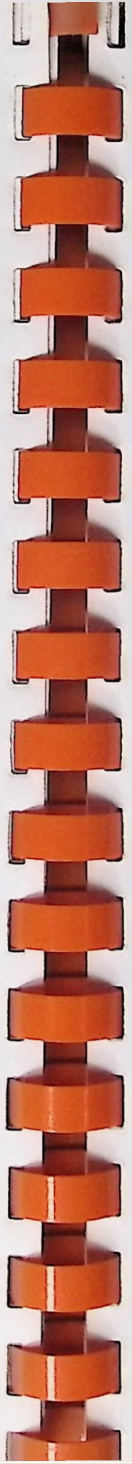
## RED ALDER

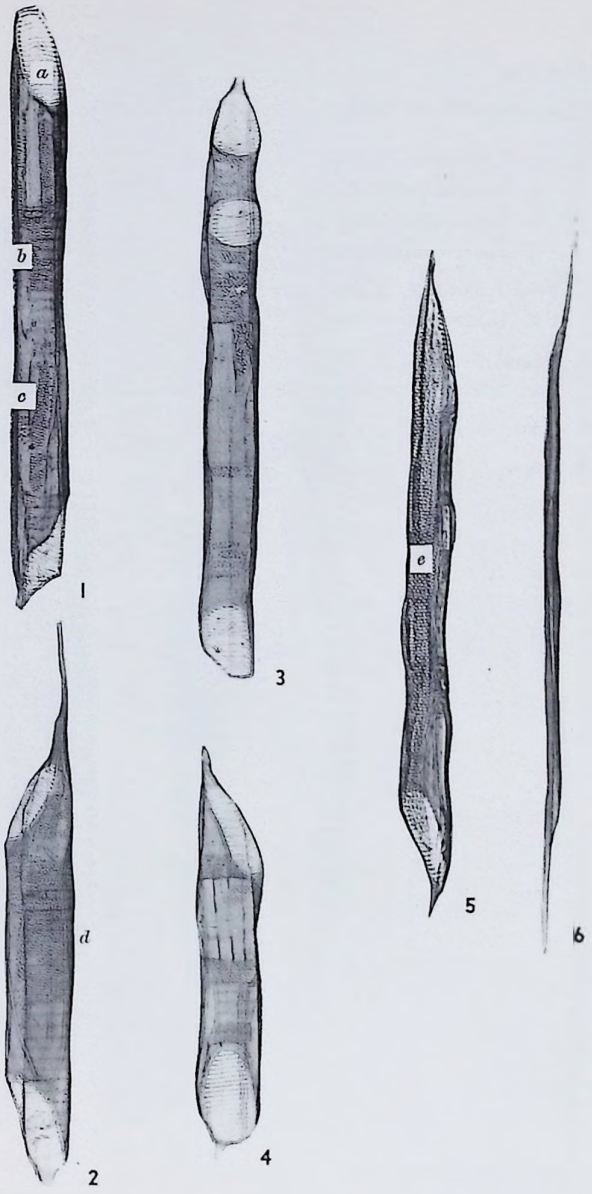
***Alnus rubra* Bong.**

1. Vessel element, ×90
   - **a.** Scalariform perforation with many thin bars
   - **b.** Ray-contact area
   - **c.** Area of contact with longitudinal parenchyma
2. Vessel element, ×90
   - **d.** Ray-contact area
3. Vessel element, ×90, with three scalariform perforations
4. Vessel element, ×90, with scalariform perforations, ray-contact areas, and area of contact with longitudinal parenchyma
5. Vessel element, ×90
   - **e.** Intervessel pitting
6. Fiber, ×90













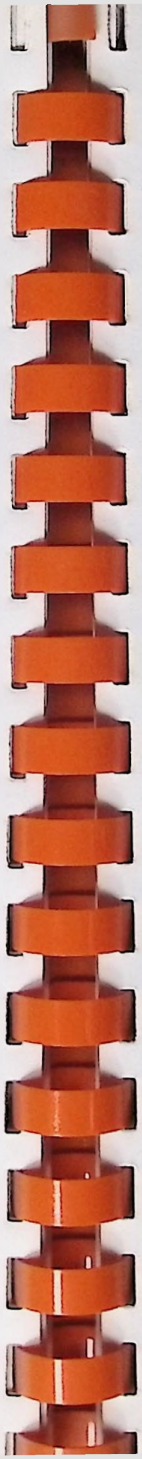
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## BEECH

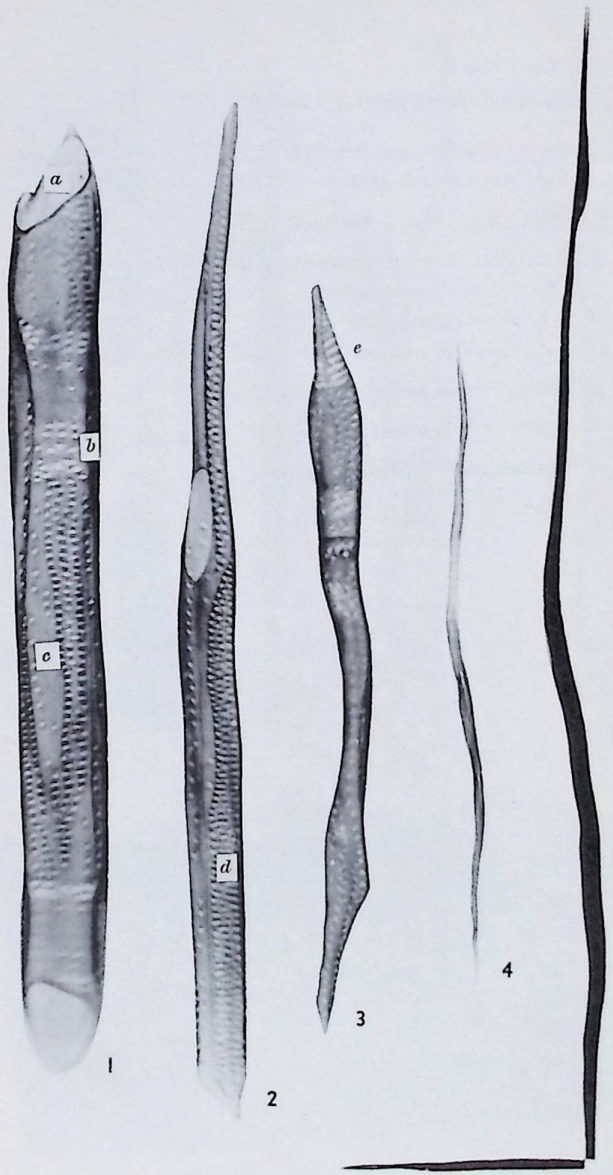
***Fagus grandifolia* Ehrh.**

1. Vessel element, ×180
   - **a.** Simple perforation
   - **b.** Ray-contact area
   - **c.** Fiber-contact areas
2. Vessel element, ×180
   - **d.** Intervessel pitting
3. Vessel element, ×180
   - **e.** Scalariform perforation with a few thick bars
4. Fiber, ×180
5. Fiber, ×180













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## CHESTNUT

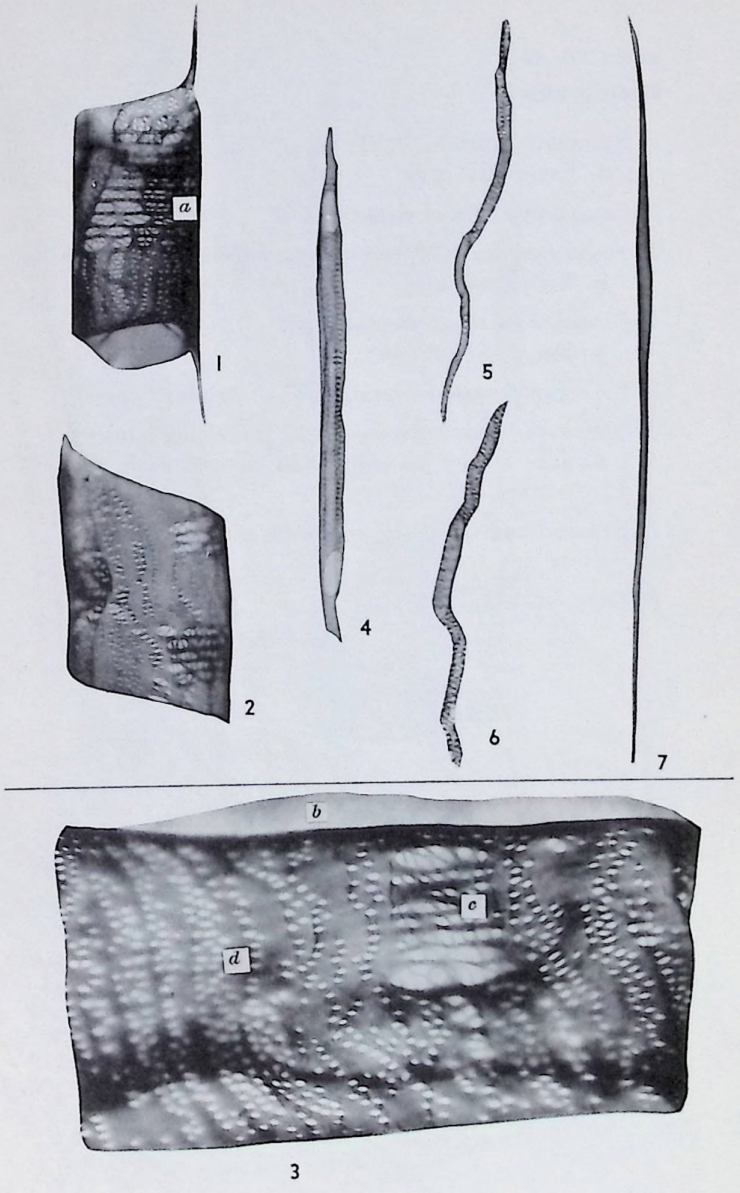
***Castanea dentata* (Marsh.) Borkh.**

1. Springwood vessel element, ×90
   - **a.** Ray-contact area
2. Springwood vessel element, ×90
3. Springwood vessel element, ×180
   - **b.** Simple perforation
   - **c.** Ray-contact area
   - **d.** Areas of contact with vasicentric tracheids
4. Summerwood vessel element, ×90
5. Vasicentric tracheid, ×90
6. Vasicentric tracheid, ×90
7. Fiber, ×90













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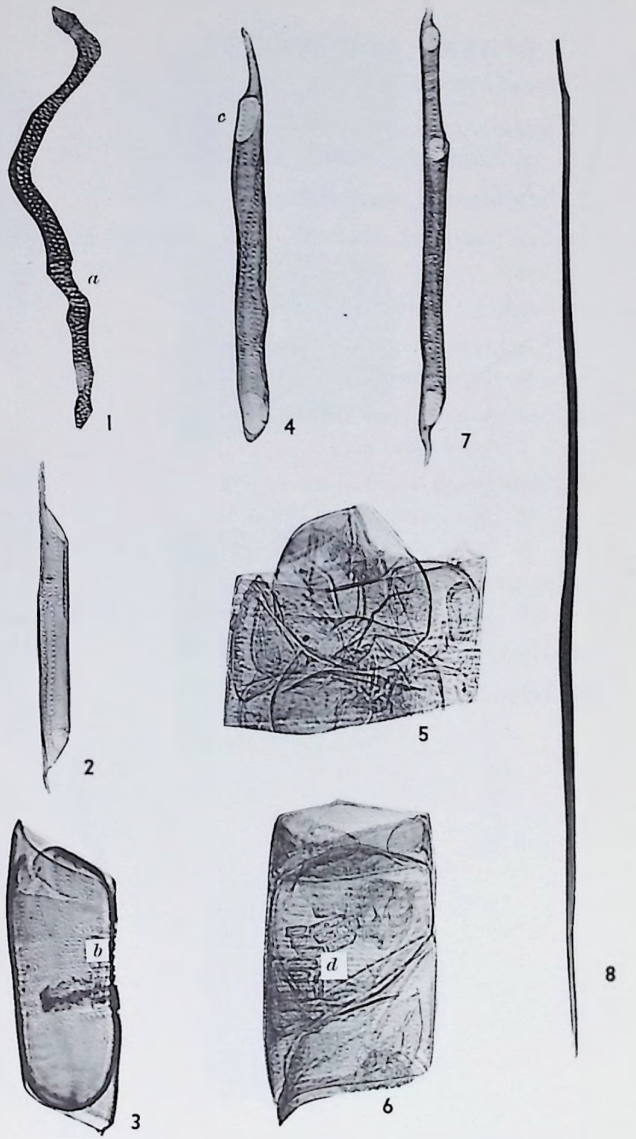
## WHITE OAK

***Quercus alba* L.**

1. Vasicentric tracheid, ×90
   - **a.** Ray-contact area
2. Summerwood vessel element, ×90
3. Vessel element, ×90, containing a balloon-like tylosis
   - **b.** Ray-contact area
4. Summerwood vessel element, ×90
   - **c.** Simple perforation
5. Springwood vessel element, ×90, containing tyloses
6. Springwood vessel element, ×90, containing tyloses
   - **d.** Cells of ray parenchyma in contact, as in the wood
7. Summerwood vessel element, ×90, with three simple perforations
8. Fiber, ×90











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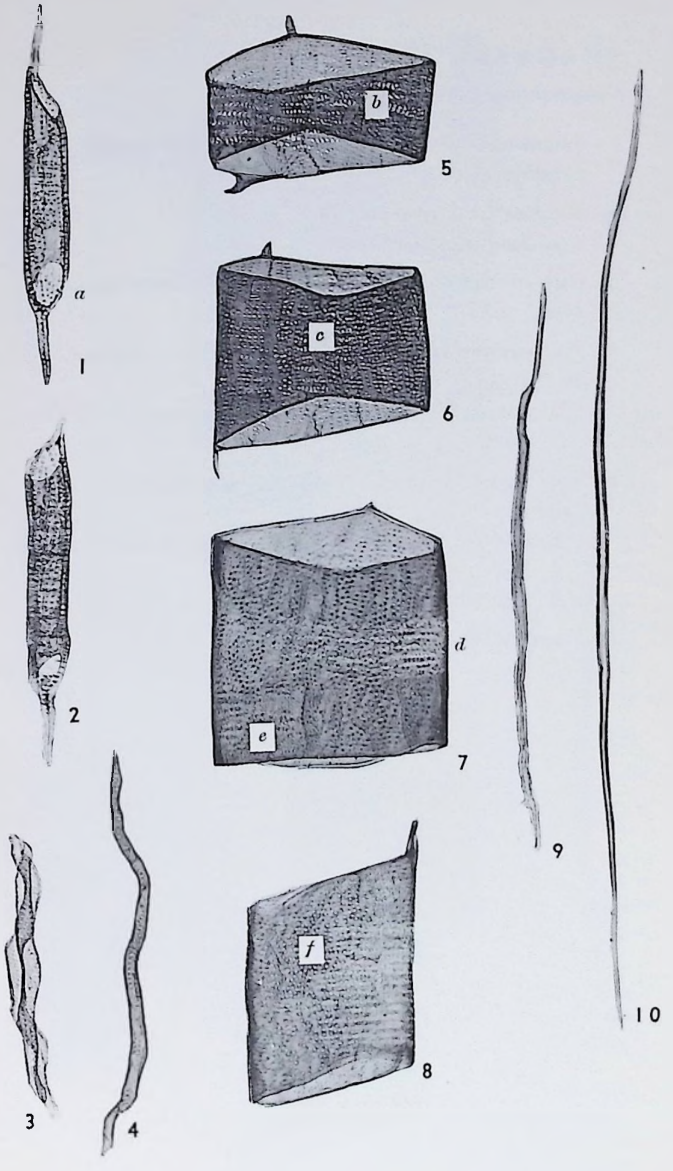
## NORTHERN RED OAK

***Quercus borealis* Michx. f.**

1. Summerwood vessel element, ×90
   - a. Simple perforation
2. Summerwood vessel element, ×90
3. Two vasicentric tracheids, ×90, entwined, as in the wood
4. Solitary vasicentric tracheid, ×90
5. Springwood vessel element, ×90
   - b. Ray-contact area
6. Springwood vessel element, ×90
   - c. Ray-contact area
7. Springwood vessel element, ×90
   - d. Ray-contact area
   - e. Areas of contact with vasicentric tracheids
8. Springwood vessel element, ×90
   - f. Areas of contact with vasicentric tracheids
9. Fiber, ×90
10. Fiber, ×90











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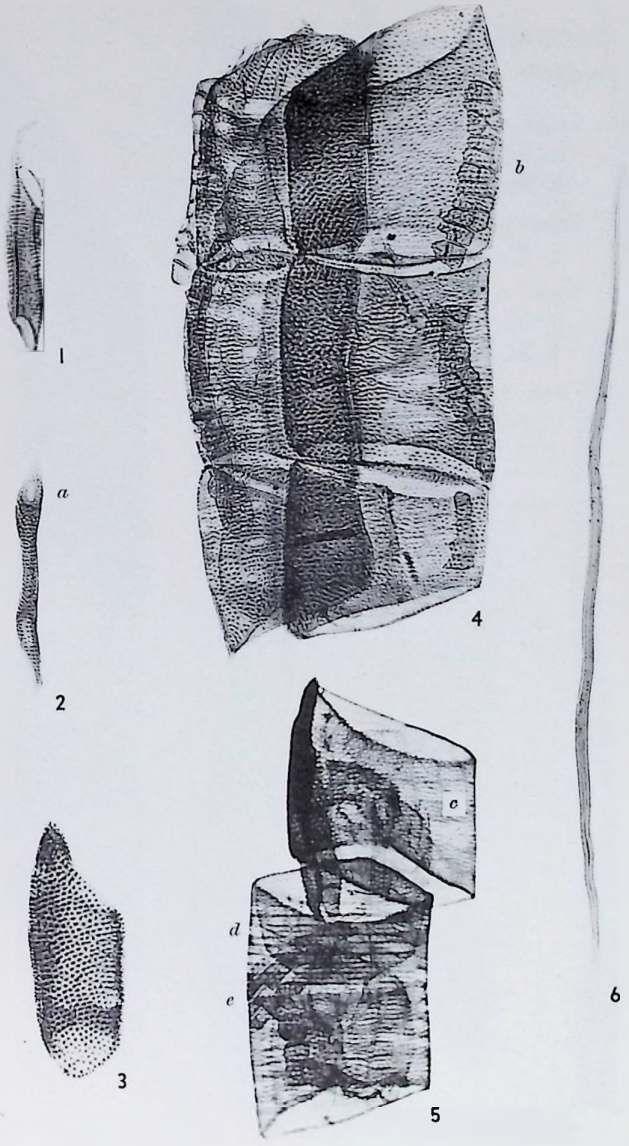
## SHAGBARK HICKORY

***Carya ovata* (Mill.) K. Koch**

1. Summerwood vessel element, ×90, with simple perforation at each end
2. Summerwood vessel element, ×90
   a. Simple perforation
3. Late springwood vessel element, ×90, showing intervessel pitting
4. Six springwood vessel elements, ×90, in contact, as in the wood
   b. Longitudinal parenchyma in contact, as in the wood
5. Two vessel elements, ×90, partially separated, containing tyloses
   c. Area of contact with longitudinal parenchyma
   d. Ray-contact area
   e. Displaced ray cells
6. Fiber, ×90









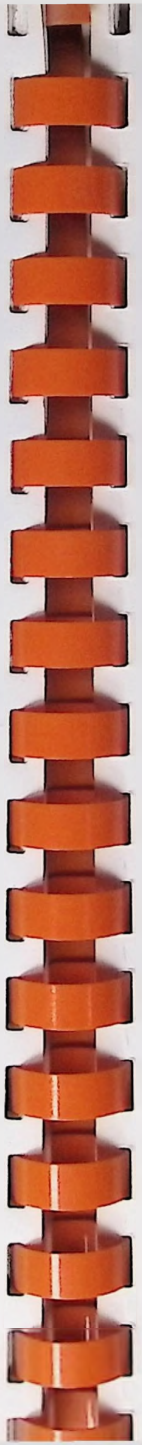


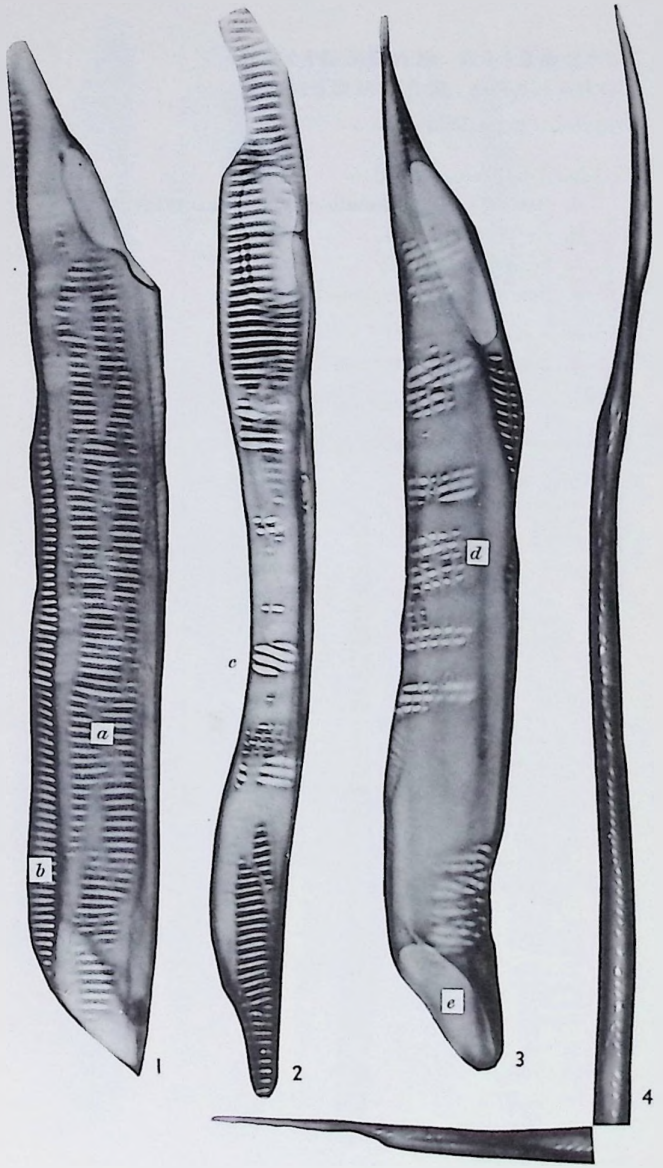
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## CUCUMBER-TREE

***Magnolia acuminata* L.**

1. Vessel element, ×180
   - **a.** Scalariform intervessel pitting
   - **b.** Scalariform intervessel pitting
2. Vessel element, ×180
   - **c.** Ray-contact area
3. Vessel element, ×180
   - **d.** Ray-contact area
   - **e.** Simple perforation
4. Fiber, ×180









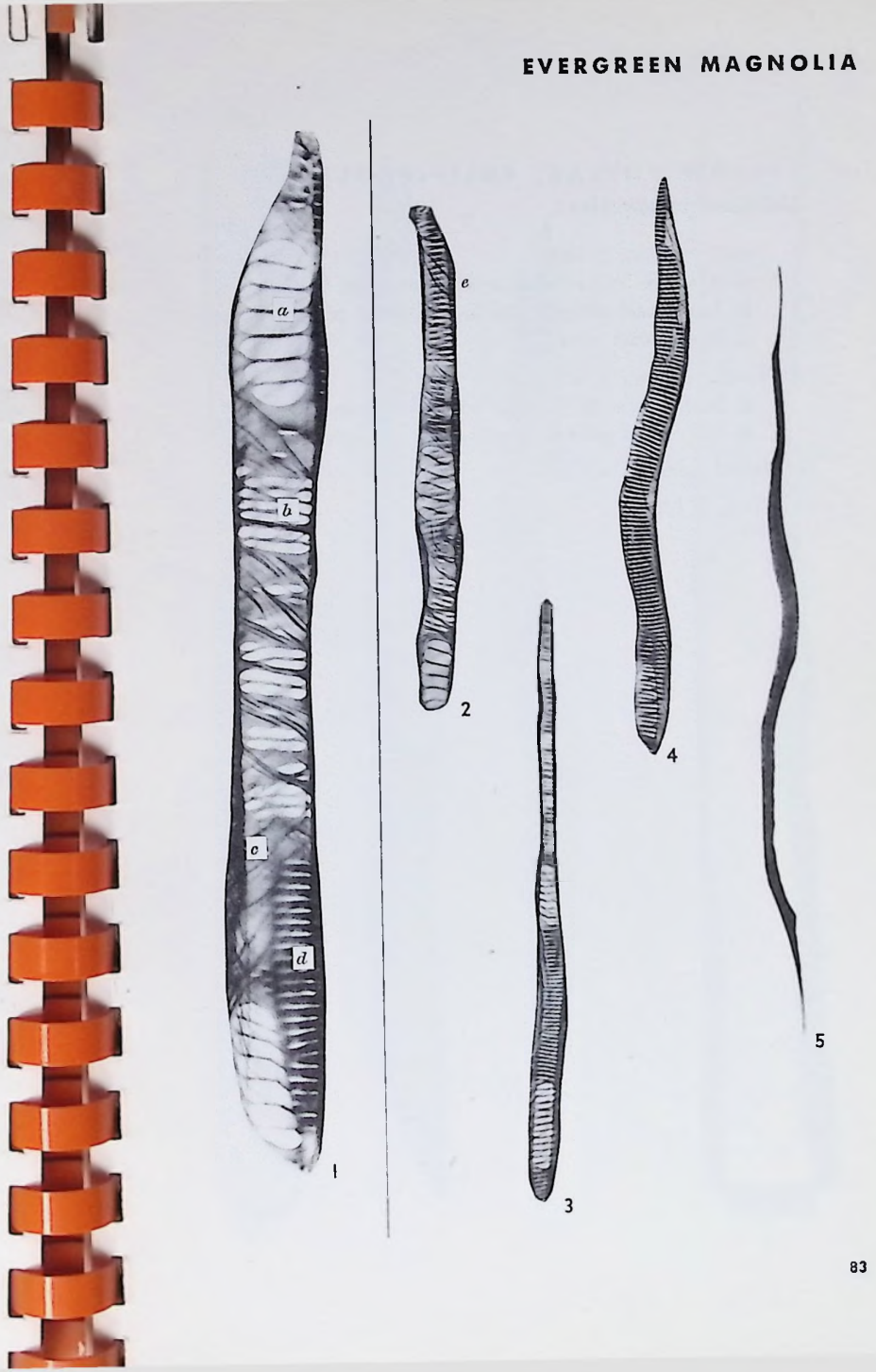



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## EVERGREEN MAGNOLIA, SOUTHERN MAGNOLIA

***Magnolia grandiflora* L.**

1. Vessel element, ×180
   - **a.** Scalariform perforation with a few thick bars
   - **b.** Ray-contact area
   - **c.** Spiral thickening
   - **d.** Scalariform intervessel pitting
2. Vessel element, ×90
   - **e.** Scalariform intervessel pitting
3. Narrow vessel element, ×90
4. Narrow vessel element, ×90
5. Fiber, ×90










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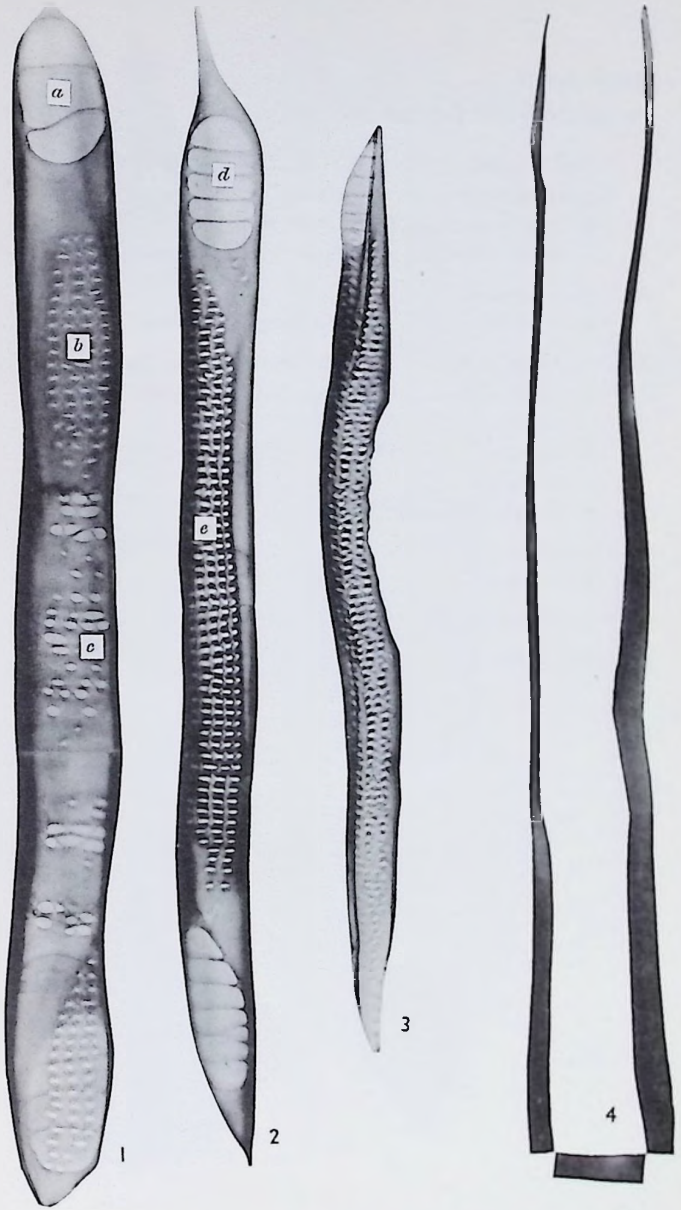
## YELLOW-POPLAR, TULIP-POPLAR

***Liriodendron tulipifera* L.**

1. Vessel element, ×180
   - **a.** Scalariform perforation with two stout bars
   - **b.** Intervessel pitting: pits in transverse rows
   - **c.** Ray-contact area
2. Vessel element, ×180
   - **d.** Scalariform perforation with four stout bars
   - **e.** Intervessel pitting: pits in transverse rows
3. Vessel element, ×180
4. Fiber, ×180











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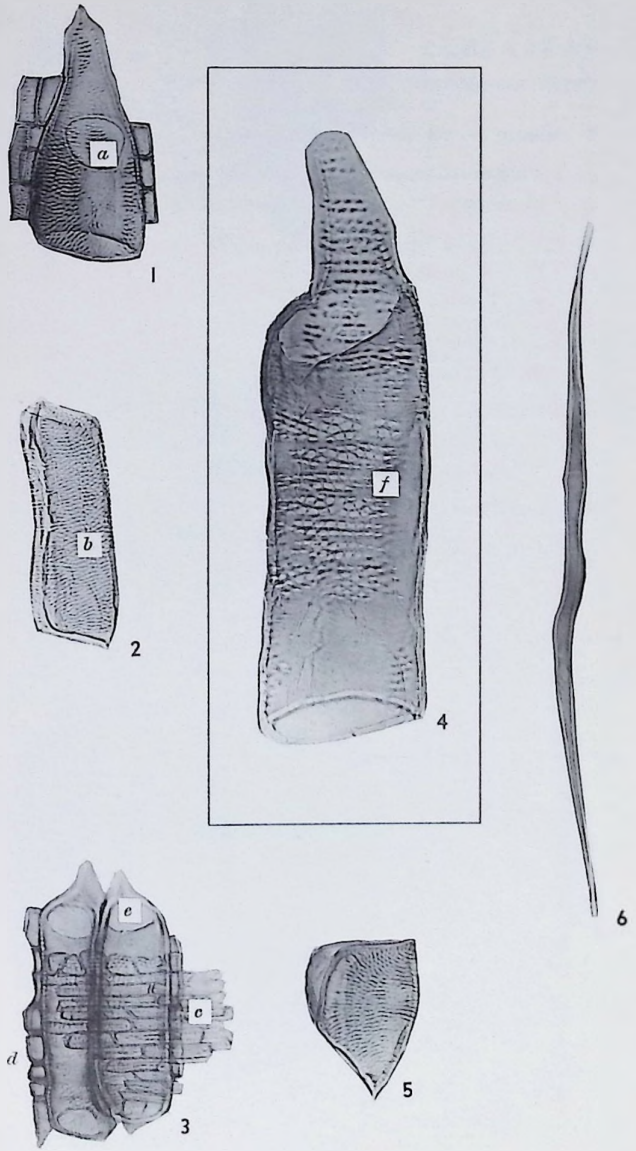
## RED-BAY

***Persea borbonia* (L.) Spreng.**

1. Vessel element, ×90, with cells of longitudinal parenchyma in contact, as in the wood
   - **a.** Simple perforation in rear wall, visible through the intervessel-pitted front wall
2. Vessel element, ×90
   - **b.** Intervessel pitting: pit apertures confluent
3. Two vessel elements, ×90, in contact, as in the wood
   - **c.** Cells of ray parenchyma in contact, as in the wood
   - **d.** Cells of longitudinal parenchyma in contact, as in the wood
   - **e.** Simple perforation
4. Vessel element, ×180
   - **f.** Ray-contact area
5. Short vessel element, ×90
6. Fiber, ×90











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## SASSAFRAS

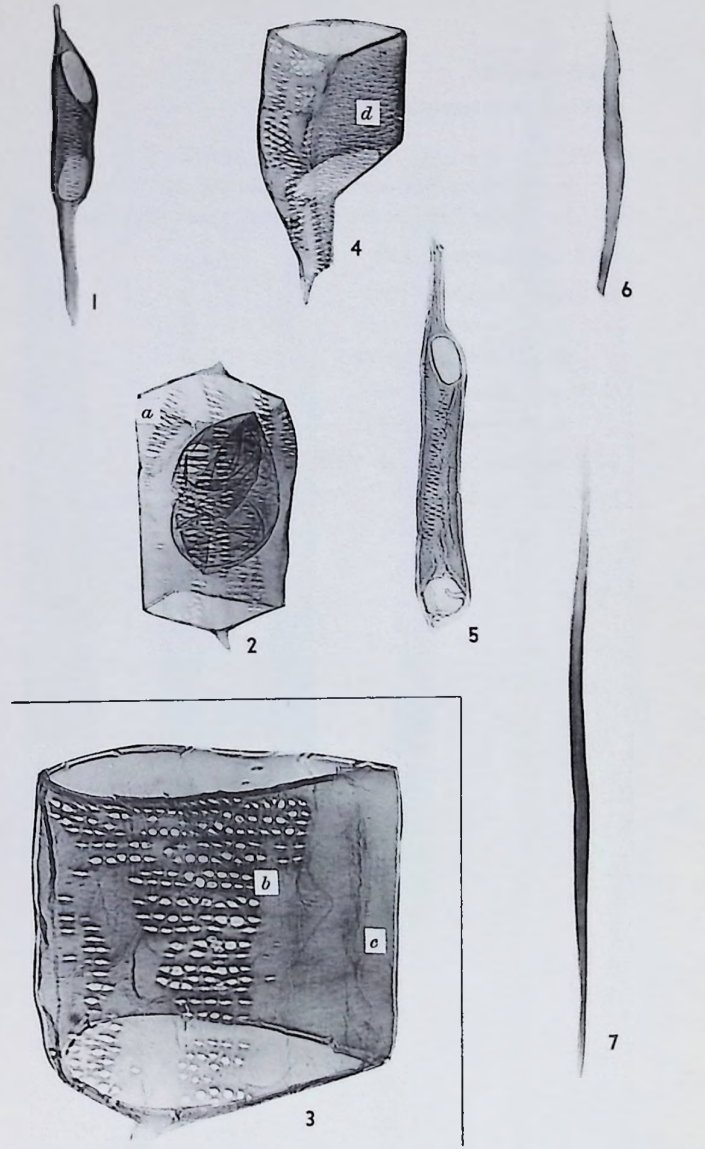
***Sassafras albidum* (Nutt.) Nees**

1. Summerwood vessel element, ×90
2. Springwood vessel element, ×90, containing a tylosis
   - **a.** Areas of contact with longitudinal parenchyma
3. Springwood vessel element, ×180
   - **b.** Ray-contact area
   - **c.** Fiber-contact area
4. Vessel element, ×90
   - **d.** Intervessel pitting
5. Summerwood vessel element, ×90

   *Note: Summerwood vessel elements occasionally have scalariform perforations*
6. Short fiber, ×90
7. Fiber, ×90











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## RED-GUM

***Liquidambar styraciflua* L.**

**1.** Portion of a long vessel element, ×180
- **a.** Spiral thickening confined to the tip
- **b.** Scalariform perforation with many thin bars

**2.** Vessel element, ×90

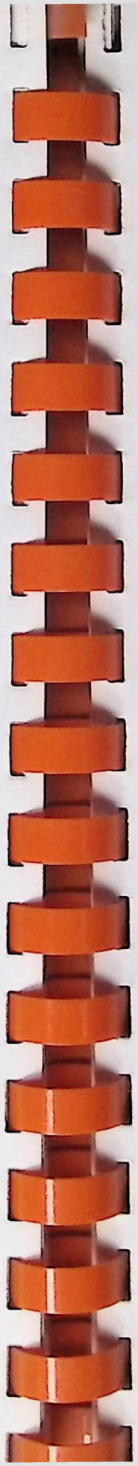
**3.** Vessel element, ×90
- **c.** Ray-contact area
- **d.** Fiber-contact area

**4.** Vessel element, ×90
- **e.** Ray-contact area

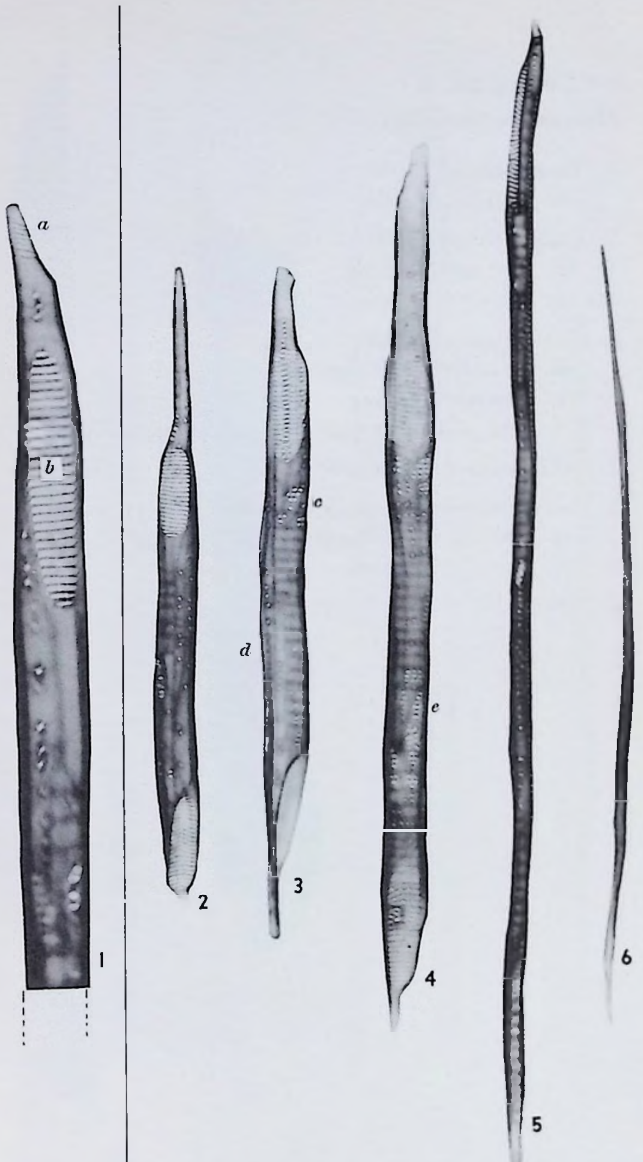
**5.** Long vessel element, ×90

**6.** Fiber, ×90













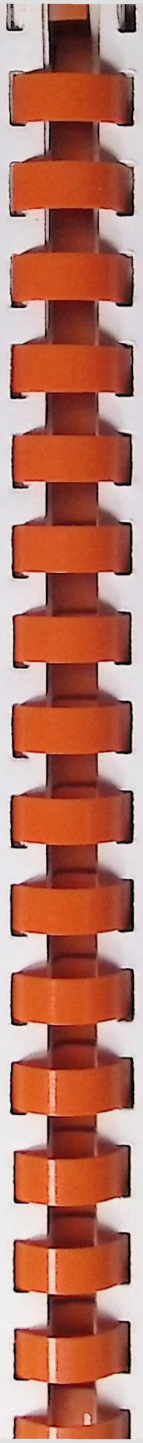
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## SYCAMORE

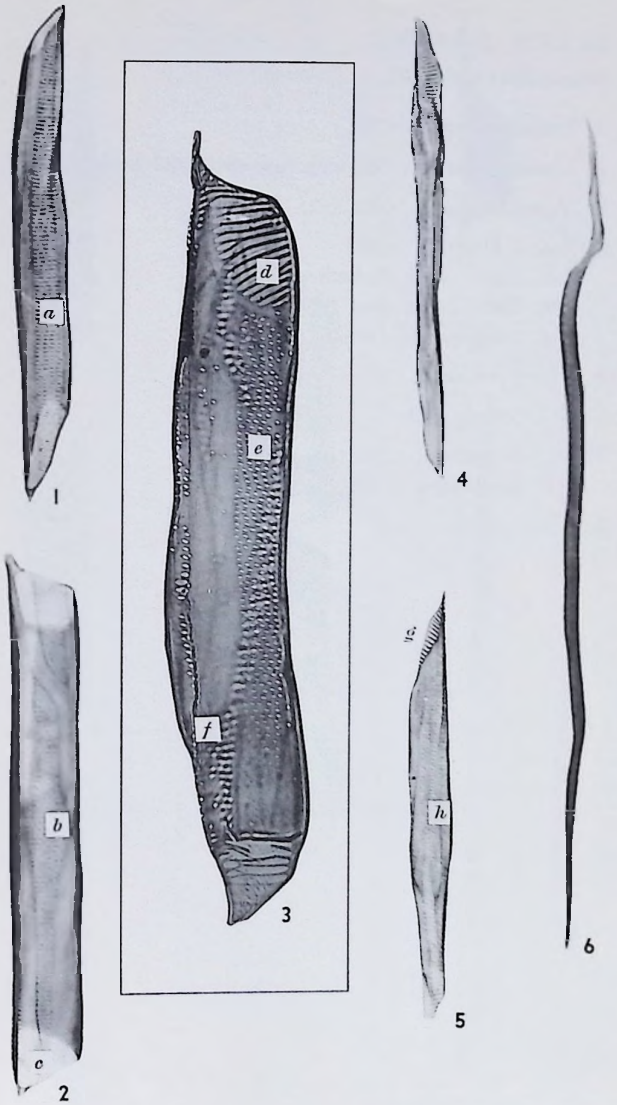
***Platanus occidentalis* L.**

1. Vessel element, ×90
   - **a.** Intervessel pitting
2. Vessel element, ×90
   - **b.** Intervessel pitting
   - **c.** Simple perforation
3. Vessel element, ×180
   - **d.** Scalariform perforation
   - **e.** Intervessel pitting
   - **f.** Area of contact with longitudinal parenchyma
4. Narrow vessel element, ×90
5. Narrow vessel element, ×90
   - **g.** Scalariform perforation with thin bars
   - **h.** Fiber-contact areas
6. Fiber, ×90













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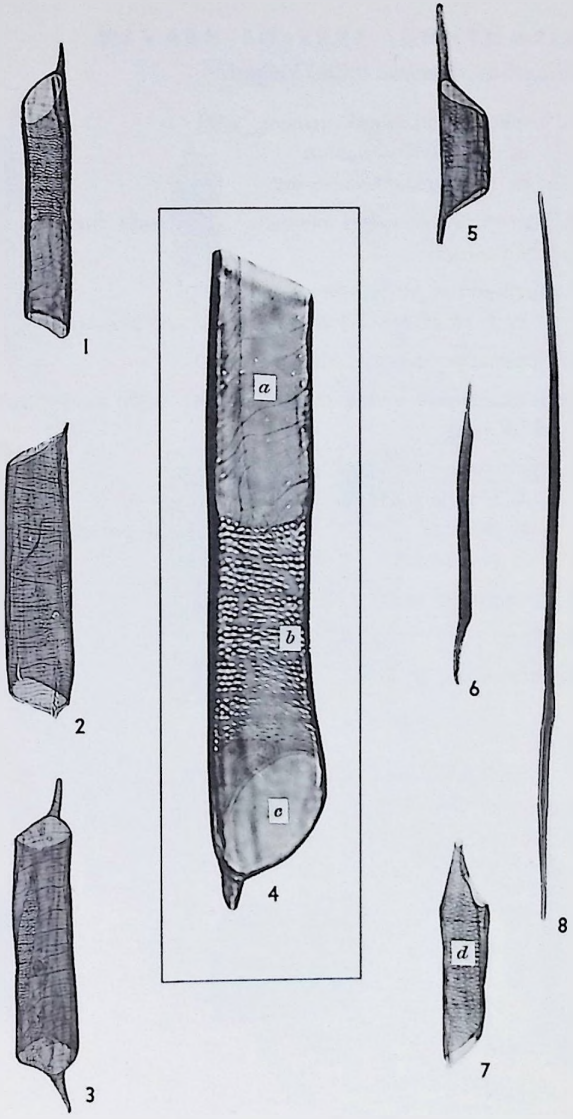
## BLACK CHERRY

***Prunus serotina* Ehrh.**

1. Vessel element, ×90
2. Vessel element, ×90, with fine spiral thickening
3. Vessel element, ×90
4. Vessel element, ×180
   - a. Fine spiral thickening
   - b. Ray-contact area
   - c. Simple perforation
5. Vessel element, ×90
6. Short fiber, ×90
7. Vessel element, ×90
   - d. Intervessel pitting
8. Fiber, ×90











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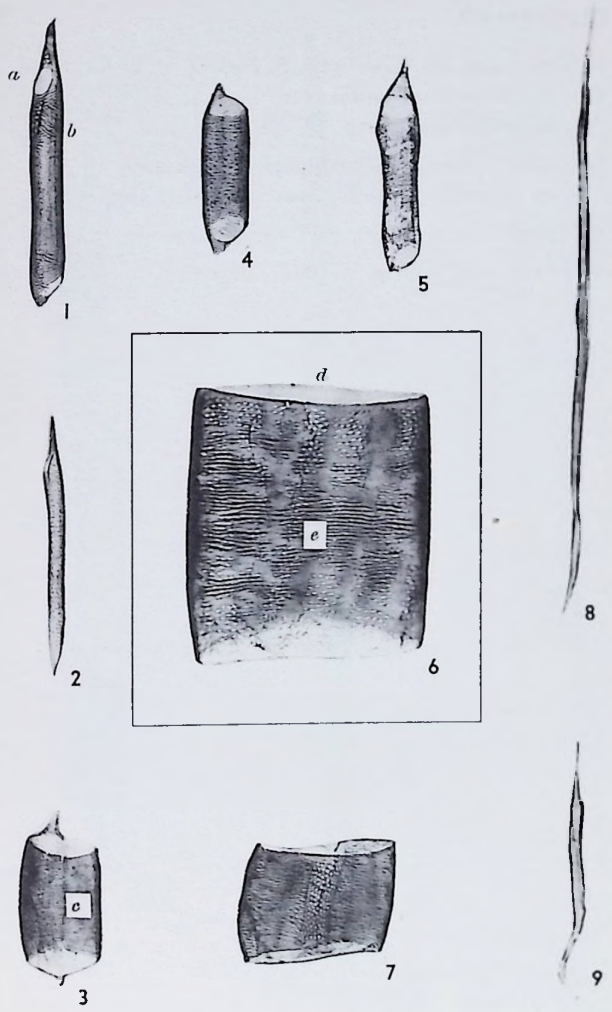
## AILANTHUS, TREE-OF-HEAVEN

***Ailanthus altissima* (Mill.) Swingle**

1. Summerwood vessel element, ×90
   - **a.** Simple perforation
   - **b.** Fine spiral thickening
2. Summerwood vessel element, ×90, with fine spiral thickening
3. Springwood vessel element, ×90
   - **c.** Area of contact with longitudinal parenchyma
4. Summerwood vessel element, ×90
5. Summerwood vessel element, ×90, with fine spiral thickening
6. Springwood vessel element, ×180
   - **d.** Simple perforation
   - **e.** Area of contact with longitudinal parenchyma: pit apertures confluent
7. Springwood vessel element, ×90
8. Fiber, ×90
9. Short fiber, ×90











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## HOLLY

***Ilex opaca* Ait.**

**1.** Two vessel elements, ×90, in contact, as in the wood
- **a.** Scalariform perforation
- **b.** Spiral thickening

**2.** Vessel element, ×90, with spiral thickening
- **c.** Scalariform perforation with many thin bars

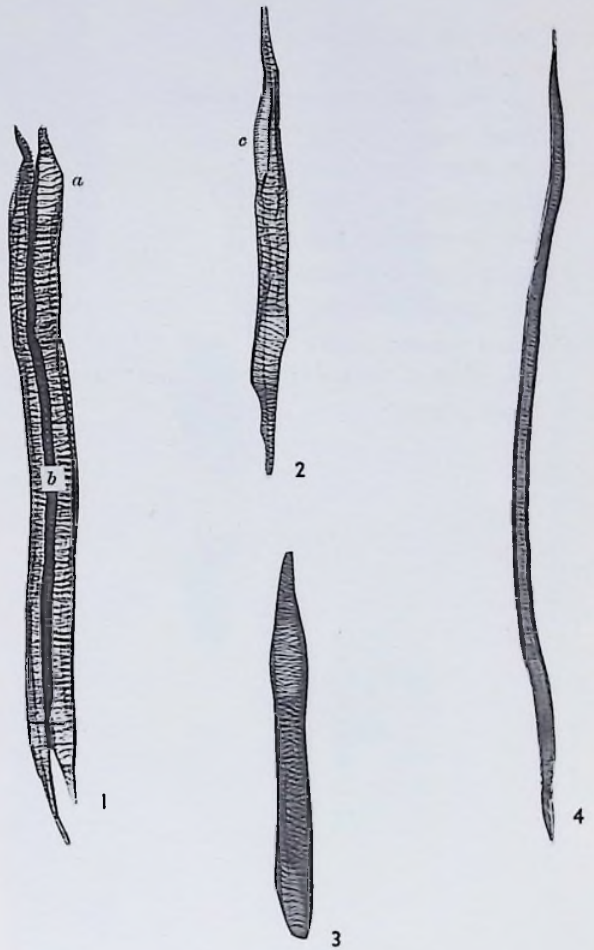
**3.** Vessel element, ×90, with spiral thickening

**4.** Fiber, ×90, with spiral thickening













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## SUGAR MAPLE

***Acer saccharum* Marsh.**

**1.** Vessel element, ×180
- **a.** Ray-contact area
- **b.** Fine spiral thickening on wall

**2.** Vessel element, ×180
- **c.** Simple perforation

**3.** Vessel element, ×180
- **d.** Intervessel pitting

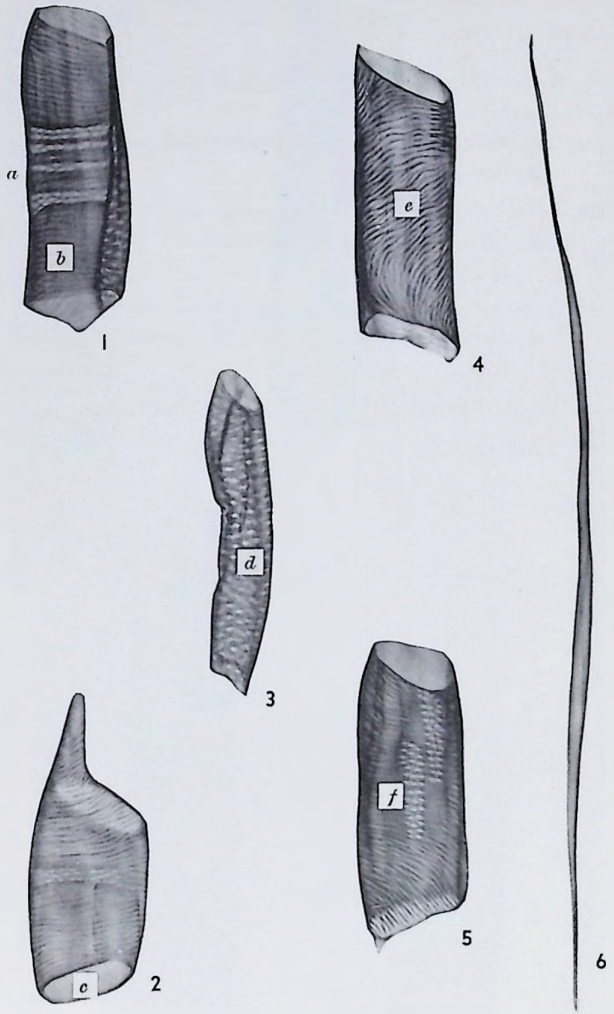
**4.** Vessel element, ×180
- **e.** Spiral thickening

**5.** Vessel element, ×180
- **f.** Areas of contact with longitudinal parenchyma

**6.** Fiber, ×180











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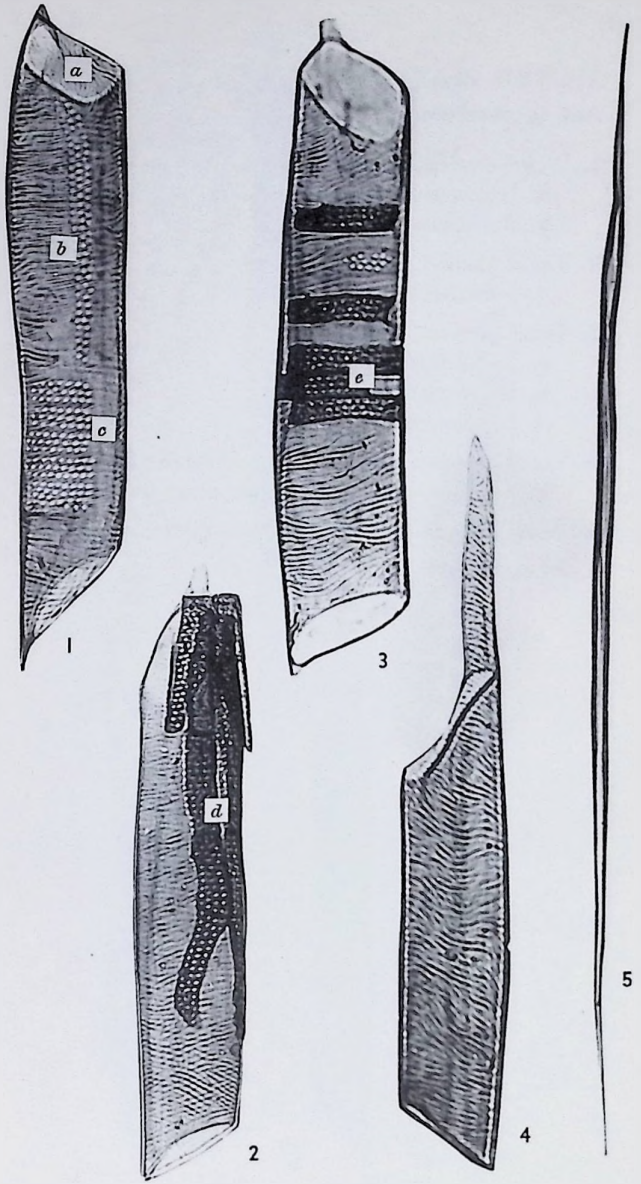
## RED MAPLE

***Acer rubrum* L.**

1. Vessel element, ×180, with spiral thickening
   - **a.** Simple perforation
   - **b.** Area of contact with longitudinal parenchyma
   - **c.** Ray-contact area
2. Vessel element, ×180, with spiral thickening
   - **d.** Cells of longitudinal parenchyma in contact, as in the wood
3. Vessel element, ×180, with spiral thickening
   - **e.** Cells of ray parenchyma in contact, as in the wood
4. Vessel element, ×180, with spiral thickening
5. Fiber, ×180










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## SILVER MAPLE

***Acer saccharinum* L.**

**1.** Vessel element, ×180
- **a.** Intervessel pitting
- **b.** Ray-contact area

**2.** Vessel element, ×180
- **c.** Intervessel pitting

**3.** Vessel element, ×180
- **d.** Spiral thickening
- **e.** Ray-contact area
- **f.** Simple perforation

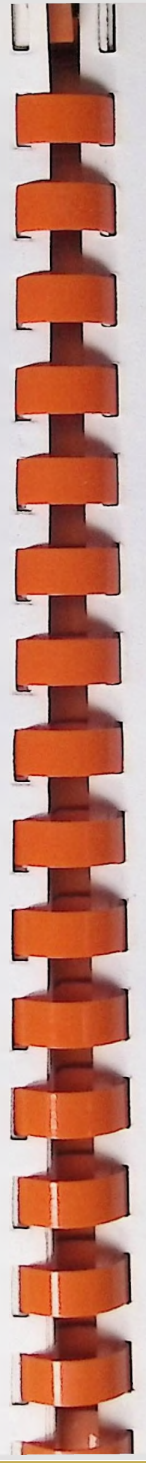
**4.** Vessel element, ×180, with spiral thickening
- **g.** Areas of contact with longitudinal parenchyma

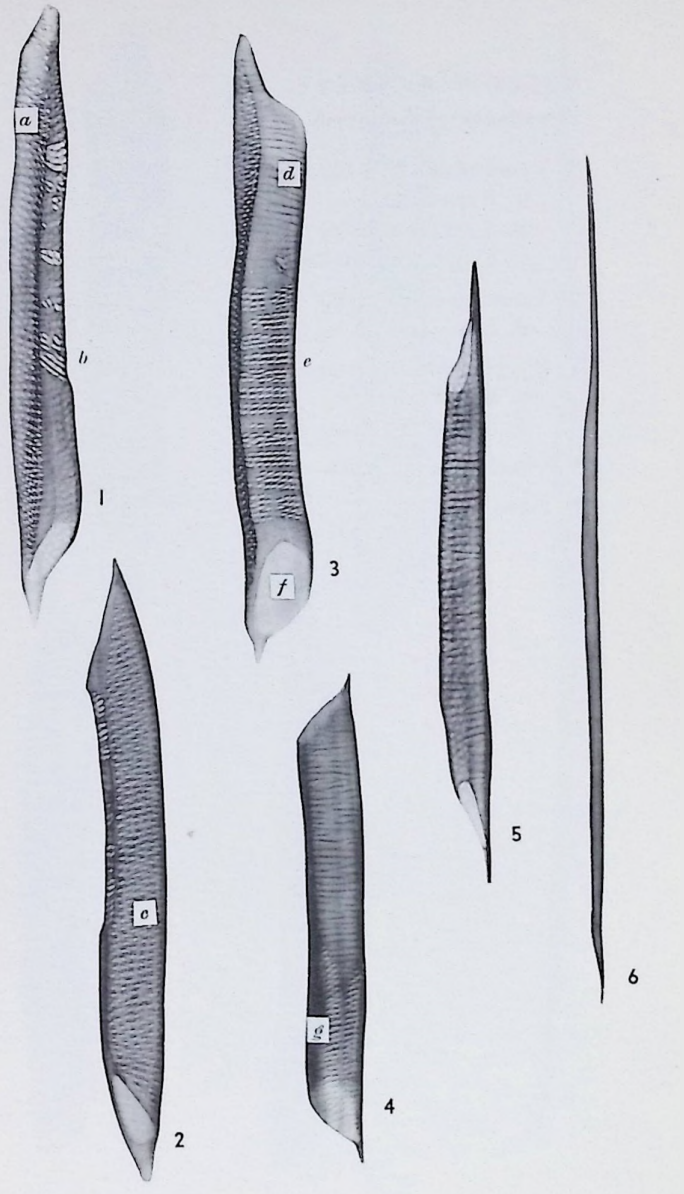
**5.** Vessel element, ×180, with spiral thickening

**6.** Fiber, ×180













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## YELLOW BUCKEYE

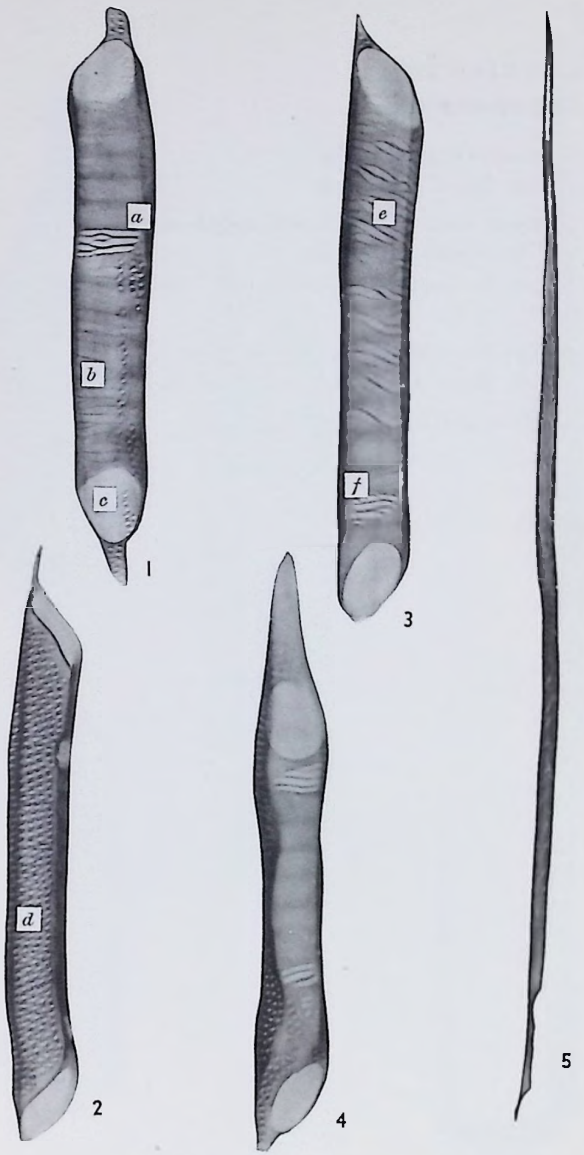
***Aesculus octandra* Marsh.**

1. Vessel element, ×180
   - a. Ray-contact area
   - b. Spiral thickening
   - c. Simple perforation
2. Vessel element, ×180
   - d. Intervessel pitting
3. Vessel element, ×180
   - e. Spiral thickening
   - f. Ray-contact area
4. Vessel element, ×180
5. Fiber, ×180













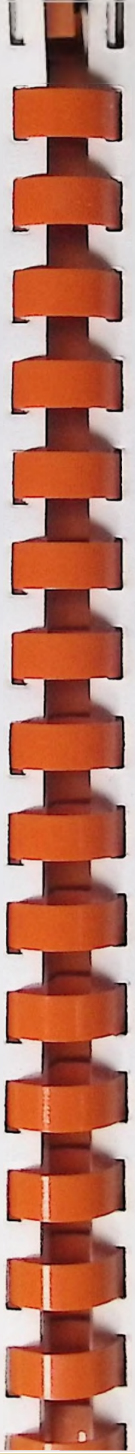
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## BASSWOOD

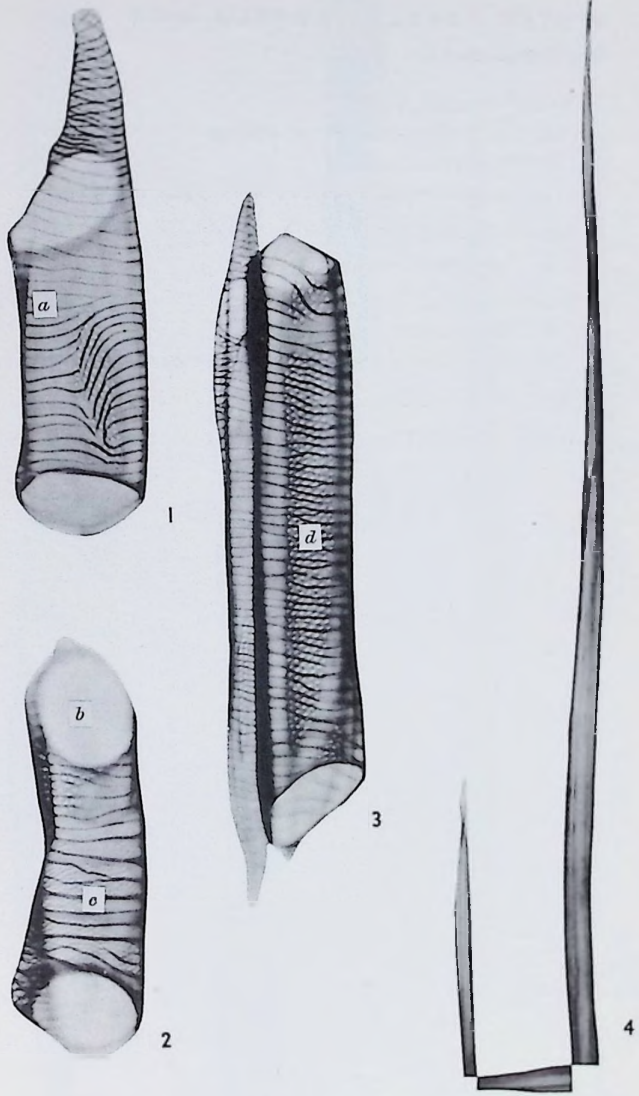
***Tilia americana* L.**

1. Vessel element, ×180
   - **a.** Spiral thickening
2. Vessel element, ×180, with spiral thickening
   - **b.** Simple perforation
   - **c.** Ray-contact area, with spiral thickening on rear wall
3. Two vessel elements, ×180, in contact, as in the wood
   - **d.** Intervessel pitting and spiral thickening
4. Fiber, ×180












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## BLACK-GUM, BLACK TUPELO

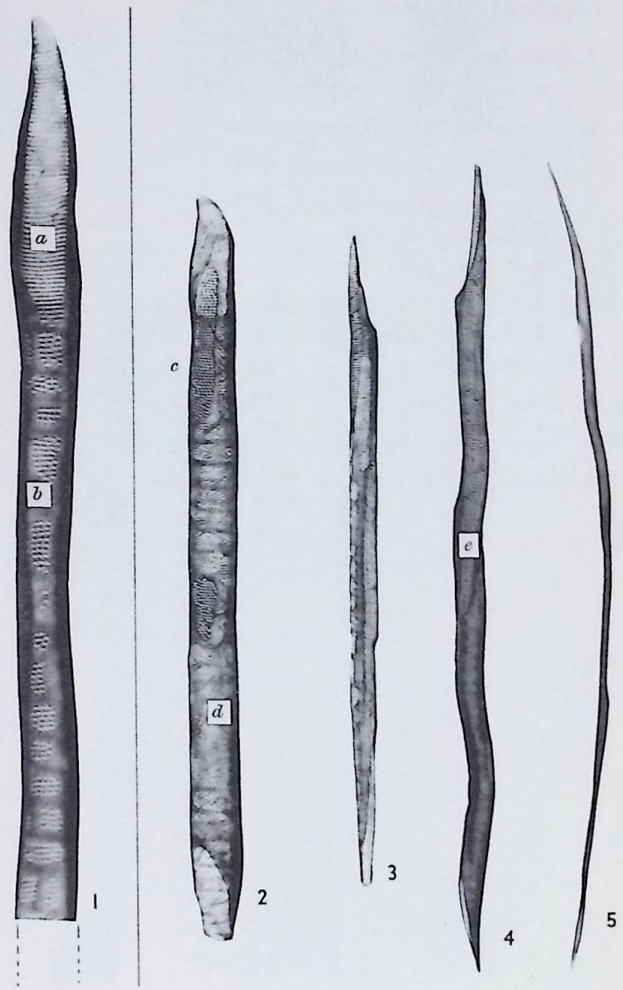
***Nyssa sylvatica* Marsh.**

1. Portion of a long vessel element, ×180
   - **a.** Scalariform perforation with many fine bars
   - **b.** Ray-contact area
2. Vessel element, ×90
   - **c.** Intervessel pitting: fine pits in transverse rows
   - **d.** Fiber-contact area
3. Narrow vessel element, ×90
4. Narrow vessel element, ×90
   - **e.** Intervessel pitting: fine pits in transverse rows
5. Fiber, ×90













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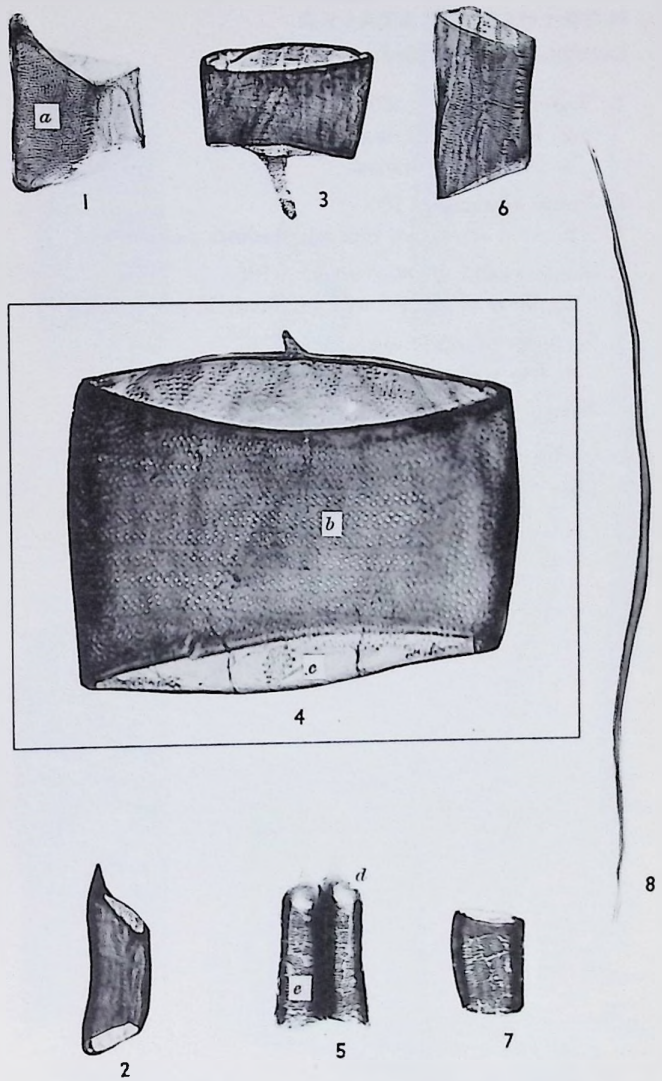
## WHITE ASH

***Fraxinus americana* L.**

1. Springwood vessel element, ×90
   - **a.** Intervessel pitting
2. Summerwood vessel element, ×90
3. Springwood vessel element, ×90
4. Springwood vessel element, ×180
   - **b.** Ray-contact area
   - **c.** Simple perforation
5. Two vessel elements, ×90, in contact, as in the wood
   - **d.** Simple perforation
   - **e.** Area of contact with longitudinal parenchyma
6. Vessel element, ×90
7. Summerwood vessel element, ×90
8. Fiber, ×90











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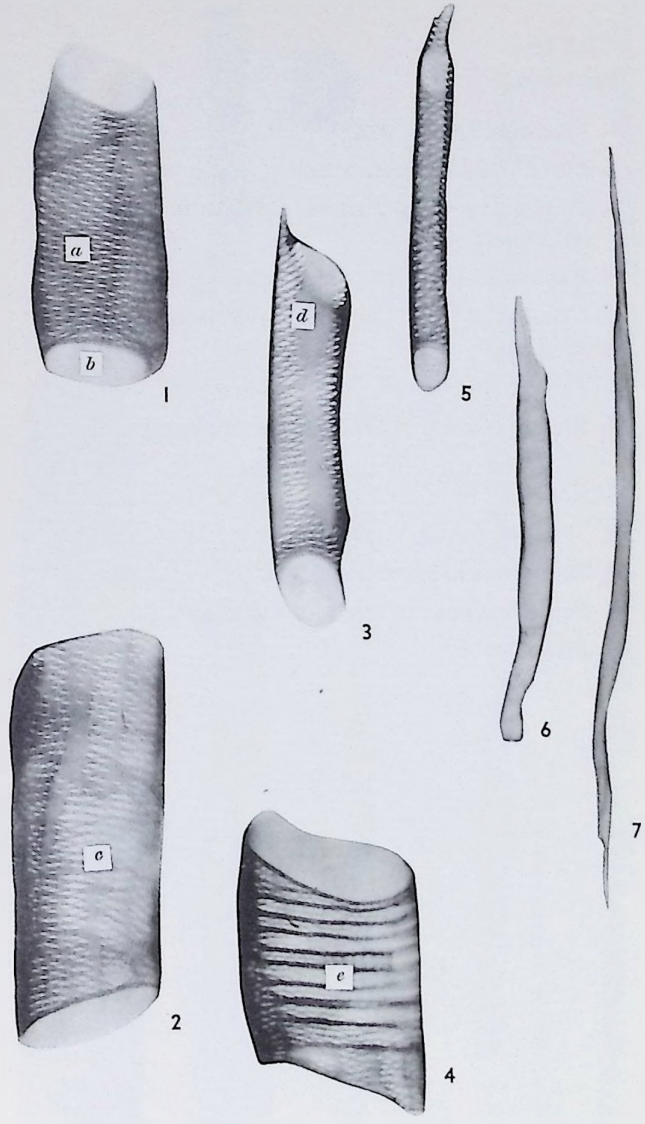
## NORTHERN CATALPA

***Catalpa speciosa* Ward.**

1. Vessel element, ×180
   - **a.** Intervessel pitting
   - **b.** Simple perforation
2. Vessel element, ×180
   - **c.** Area of contact with longitudinal parenchyma
3. Summerwood vessel element, ×180
   - **d.** Areas of contact with longitudinal parenchyma
4. Springwood vessel element, ×180
   - **e.** Ray-contact area
5. Narrow, summerwood vessel element, ×180
6. Short, wide-lumened fiber, ×180
7. Fiber, ×180











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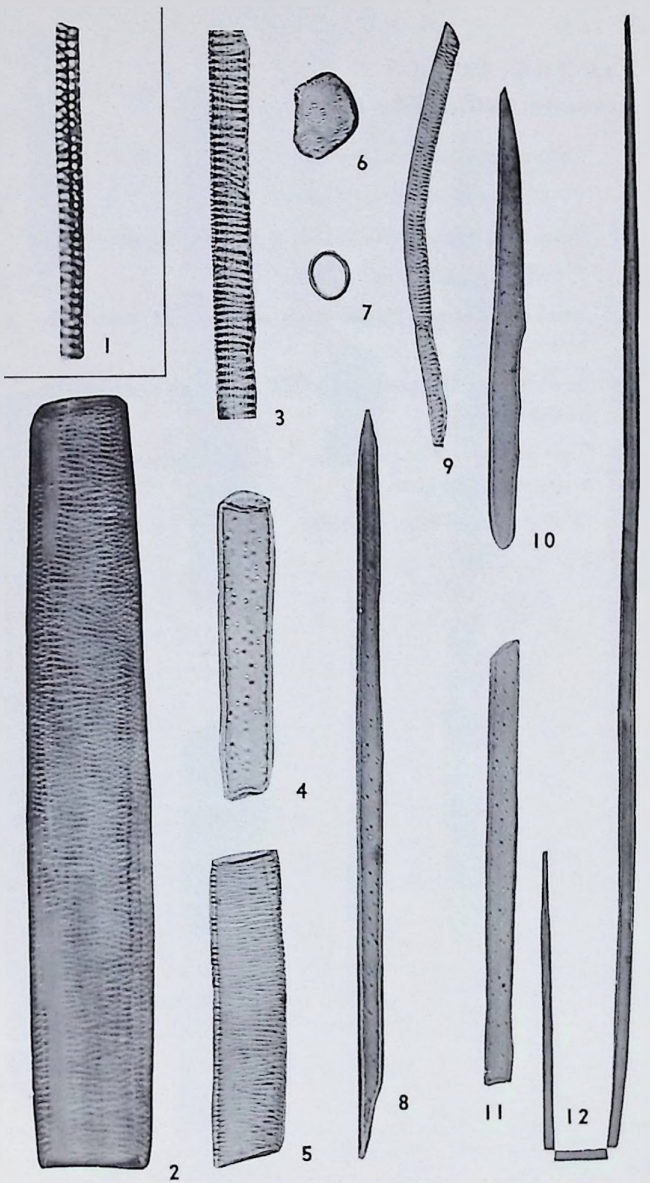
## CORN

**Zea mays L.**

1. Tracheid-like cell, ×270
2. Pitted vessel element, ×180
3. Portion of a vessel element, ×180, with annular thickenings
4. Parenchymatous cell, ×180, with simple pits
5. Vessel element, ×180, with scalariform-reticulate thickenings
6. Parenchymatous cell, ×180, from ground tissue
7. Ring-thickening, ×180, from an annular vessel element
8. Fiber, ×180
9. Tracheid, ×180
10. Short, wide-lumened fiber, ×180
11. Parenchymatous cell, ×180, with simple pits
12. Fiber, ×180







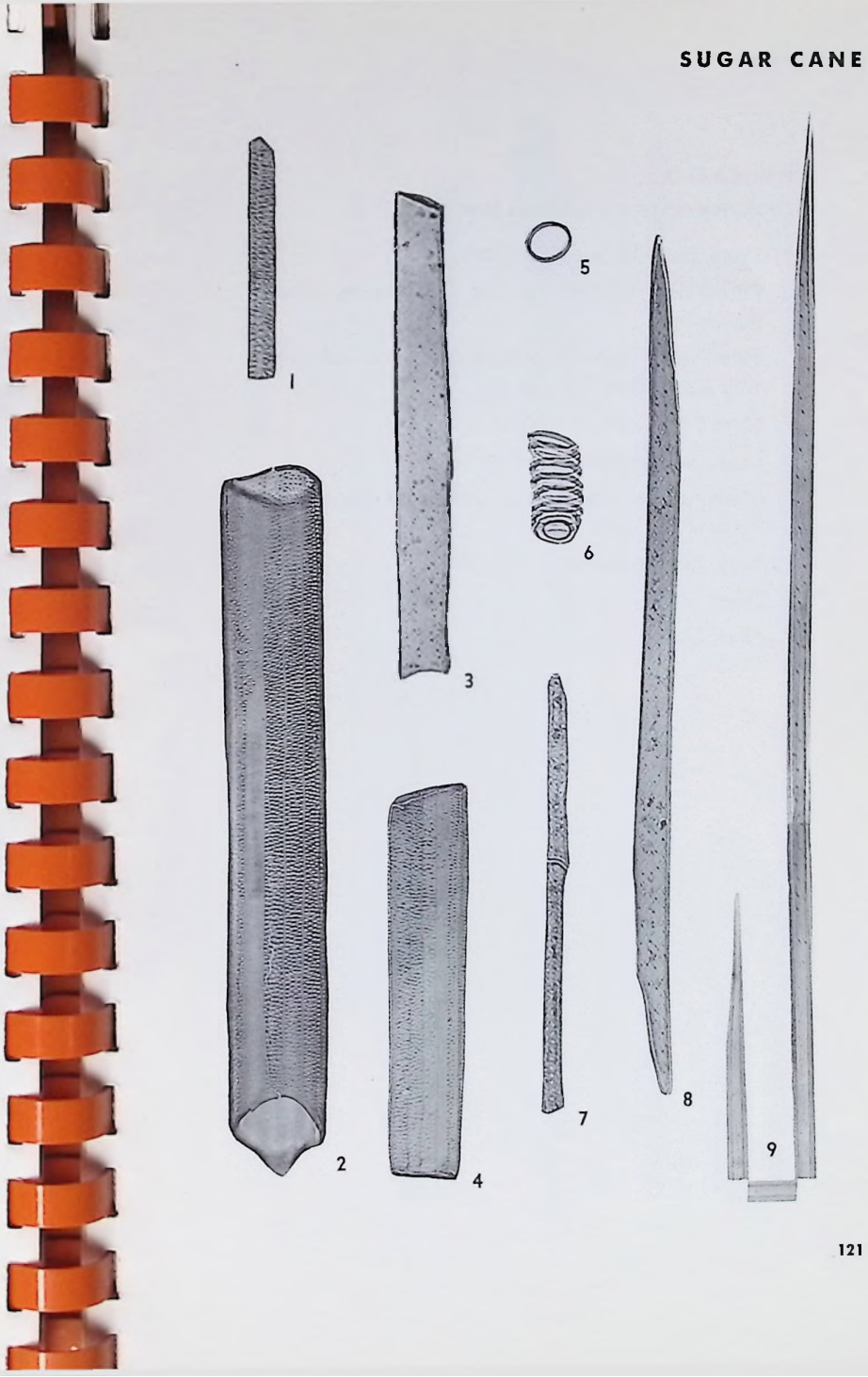
## SUGAR CANE

***Saccharum officinarum* L.**

1. Parenchymatous cell, ×180
2. Pitted vessel element, ×180
3. Parenchymatous cell, ×180, with minute, simple pits
4. Pitted vessel element, ×180
5. Ring-thickening, ×180, from an annular vessel element
6. Several ring-thickenings, ×180, from an annular vessel element
7. Two parenchymatous cells, ×180, in contact lengthwise, as in the tissue
8. Wide-lumened fiber, ×180
9. Fiber, ×180










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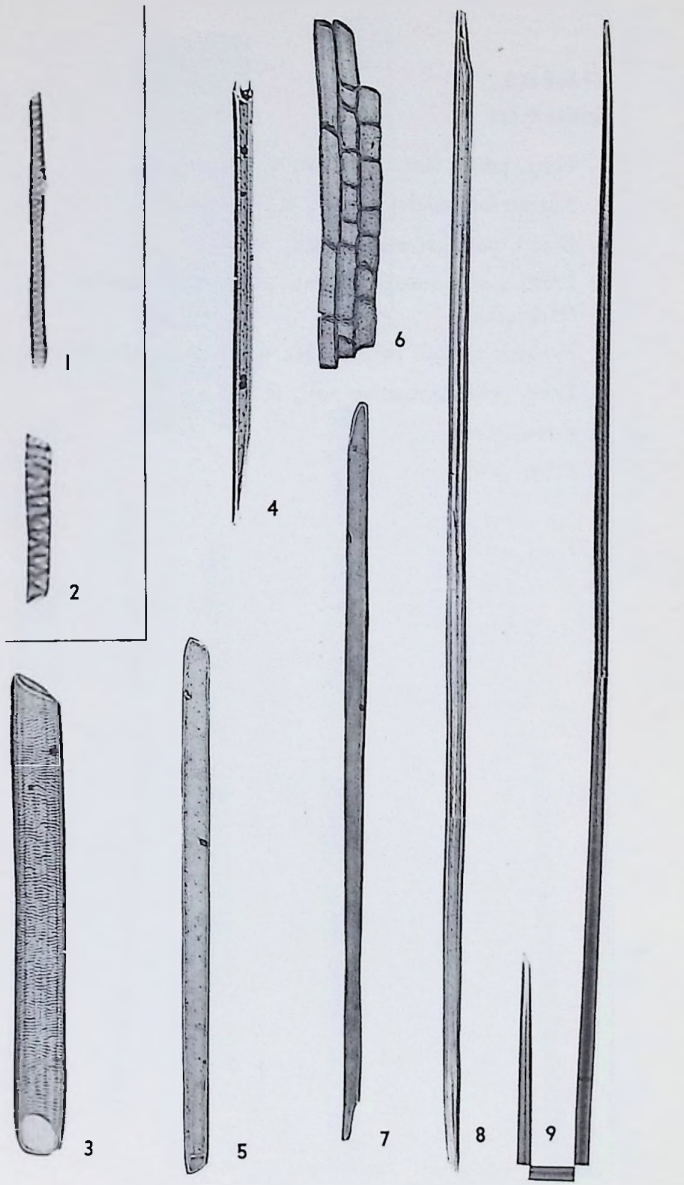
## BAMBOO

***Cephalostachyum pergracile* Munro**

1. Short, tracheid-like cell, ×270
2. Pitted, short, tracheid-like cell, ×270, with spiral thickening
3. Pitted vessel element, ×90, showing areas of contact with longitudinal parenchyma
4. Short fiber, ×90, notched at upper end
5. Long, parenchymatous cell, ×90
6. Cluster of parenchymatous cells, ×90, from ground tissue of the culm
7. Long, parenchymatous cell, ×90
8. Fiber, ×90
9. Fiber, ×90










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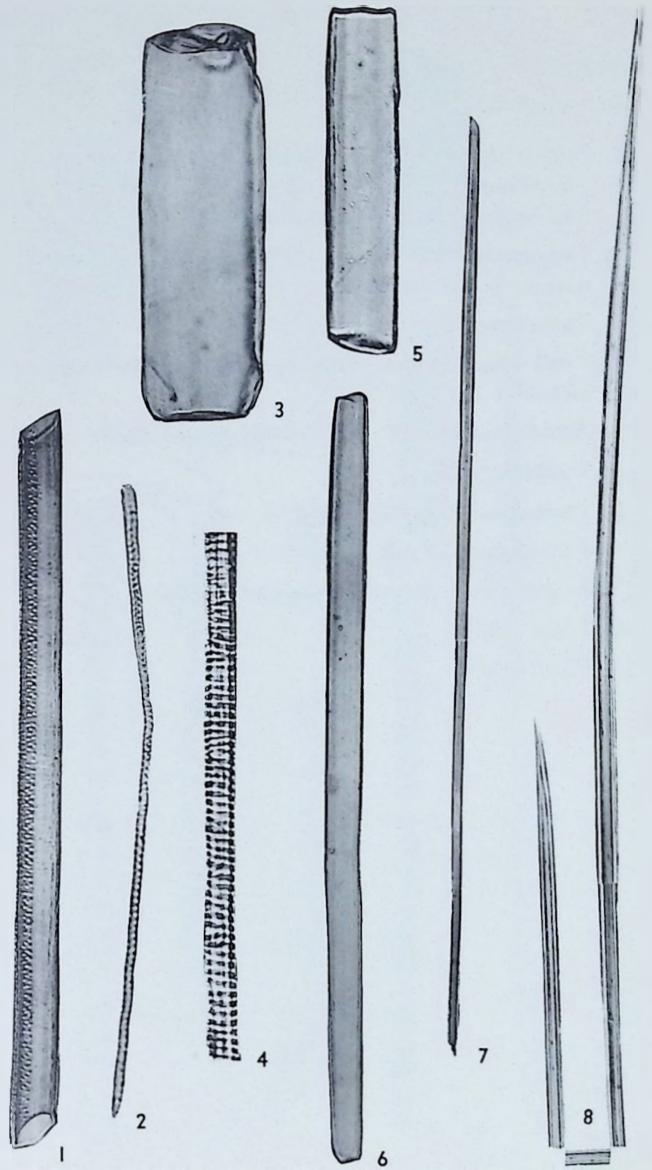
## WHEAT

***Triticum* sp.**

1. Long, pitted vessel element, ×180
2. Narrow-lumened tracheid, ×180
3. Broad, parenchymatous cell, ×180
4. Portion of a vessel element, ×180, with annular thickenings
5. Parenchymatous cell, ×180, with sparse, simple pits
6. Long, parenchymatous cell, ×180
7. Fiber, ×180
8. Fiber, ×180











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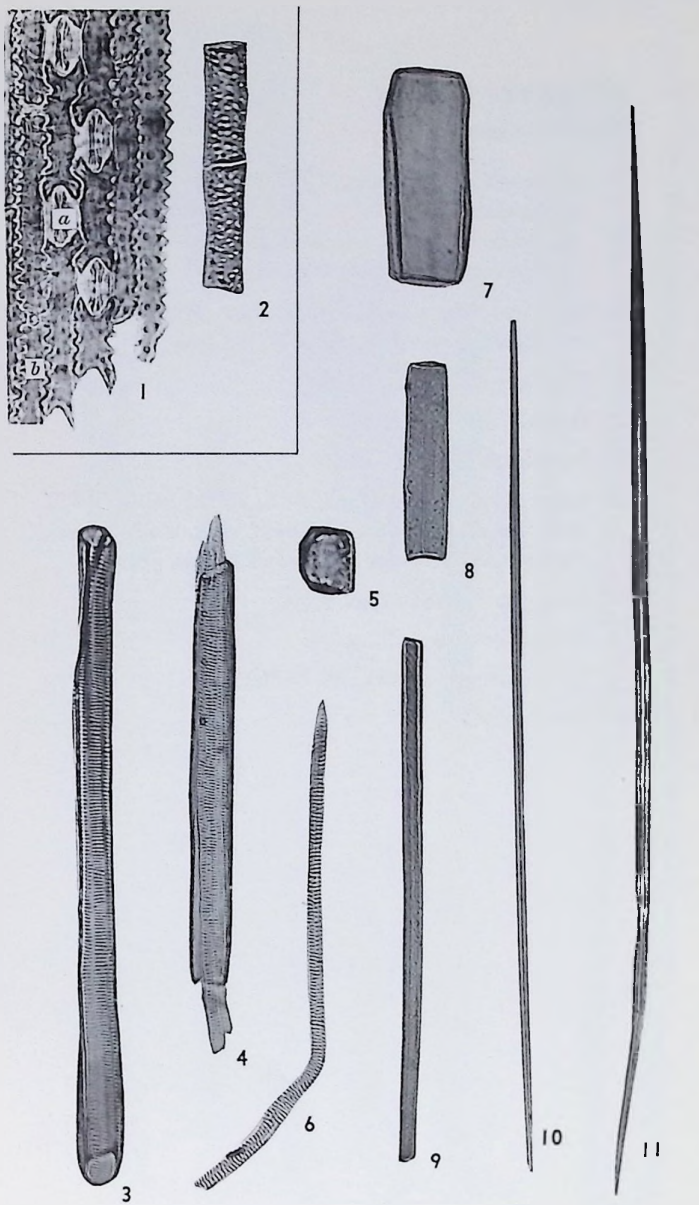
## RICE

***Oryza sativa* L.**

1. Portion of leaf epidermis, ×360, surface view
   - a. Stomate
   - b. Epidermal cell with scalloped wall
2. Two parenchymatous cells, ×360, in contact lengthwise, as in the tissue
3. Pitted vessel element, ×180
4. Pitted vessel element, ×180, with two tracheids in contact, as in the tissue
5. Parenchymatous cell, ×180, from ground tissue
6. Tracheid, ×180
7. Parenchymatous cell, ×180
8. Parenchymatous cell, ×180
9. Long, narrow, parenchymatous cell, ×180
10. Fiber, ×180
11. Fiber, ×180











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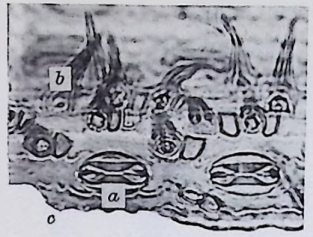
## ESPARTO GRASS

***Stipa tenacissima* L.**

1. Portion of leaf epidermis, ×360, surface view
   - a. Stomate
   - b. Epidermal hairs seated on surface
   - c. Epidermal cell with scalloped wall
2. Epidermal hair, ×360, lateral view, with epidermal cell attached, as in the tissue of the leaf
3. Pitted vessel element, ×360
4. Tracheid-like cell, ×360
5. Narrow tracheid, ×360
6. Series of irregular-shaped, thick-walled cells, ×360, with intercellular spaces, lateral view. Cells of this type are present in the mixture of fibrous elements
7. Short, tracheid-like cell, ×360
8. Parenchymatous cell, ×360
9. Wide-lumened, fibrous cell, ×360
10. Fiber, ×360








1



2



3



4



5



6



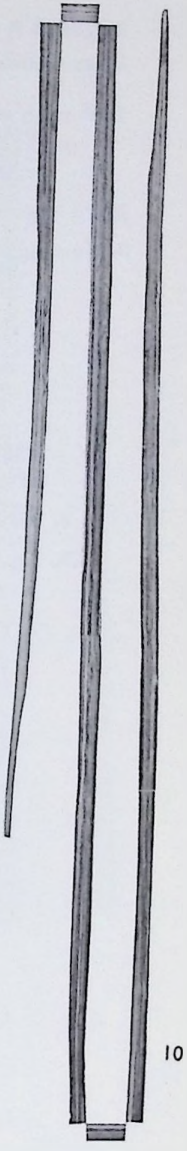
7



8



9



10




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## WATER TUPELO, TUPELO-GUM

***Nyssa aquatica* L.**

**1.** Vessel element, ×180
- **a.** Scalariform intervessel pitting
- **b.** Ray-contact area
- **c.** Scalariform perforation with many fine bars

**2.** Vessel element, ×90
- **d.** Ray-contact area

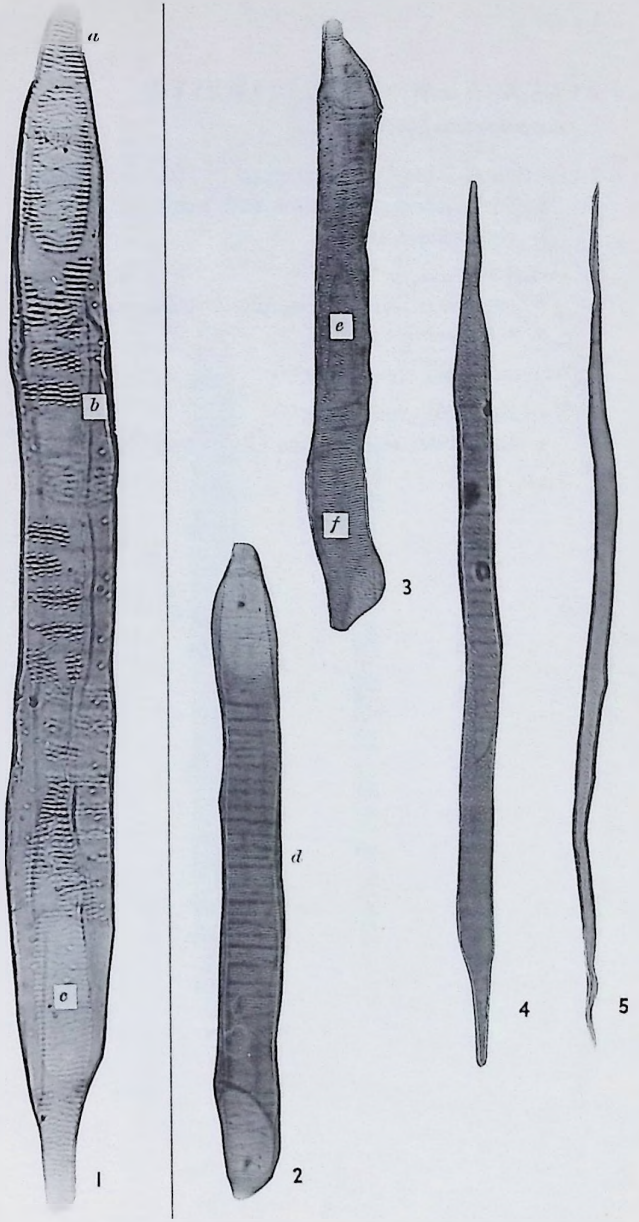
**3.** Vessel element, ×90
- **e.** Fiber-contact area
- **f.** Intervessel pitting: fine pits in transverse rows

**4.** Wide-lumened fiber, ×90

**5.** Narrow-lumened fiber, ×90










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## MANILA HEMP

***Musa textilis* Née**

1. Portion of a leaf fiber, ×180
   a. Pits of pit pairs leading to a contiguous longitudinal fiber
2. Portion of a leaf fiber, ×180
3. Terminal portion of a leaf fiber, ×180

## JUTE

***Corchorus* sp.**

1. Portion of a bast fiber, ×180, showing variable width of cell lumen
2. Portion of a bast fiber, ×180
3. Terminal portion of a bast fiber, ×180











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## HEMP

***Cannabis sativa* L.**

1. Portion of a thick-walled bast fiber, ×270, with narrow lumen showing as a dark line
2. Portion of a thick-walled bast fiber, ×270
   - **a.** Failures in cell wall which develop during processing
3. Portion of a thick-walled bast fiber, ×270
   - **b.** Failures in cell wall which develop during processing

## SISAL, HENNEQUEN

***Agave* sp.**

1. Terminal portion of a leaf fiber, ×270
2. Portion of a leaf fiber, ×270
3. Portion of a leaf fiber, ×270
   - **a.** Pits of pit pairs leading to a contiguous longitudinal fiber














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## PAPER-MULBERRY

***Broussonetia papyrifera* Vent.**

1. Central, broadened portion of a bast fiber, ×270, with outer lamella of wall showing as light-colored boundary layer
2. Portion near the end of a long bast fiber, ×270

## PINEAPPLE

***Ananas* sp.**

1. Portion of a leaf fiber, ×360
2. Portion of a leaf fiber, ×360










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## RAMIE, CHINA GRASS

***Boehmeria nivea* (L.) Gaud.**

1. Portion of a bast fiber, ×180
   - **a.** Nodelike failures in cell wall due to processing
   - **b.** Air bubble in lumen
2. Terminal portion of a bast fiber, ×180
3. Terminal portion of a bast fiber, ×180
   - **c.** Rounded tip

## FLAX

***Linum usitatissimum* L.**

1. Portion of a bast fiber, ×180, with a fairly wide lumen
2. Portion of a bast fiber, ×180, with a narrow lumen
   - **a.** Nodelike failures in cell wall due to processing














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## COTTON

***Gossypium* sp.**

1. Portion of a twisted seed hair, ×180
2. Portion of a twisted seed hair, ×180
3. Portion of a twisted seed hair, ×180

## KAPOK

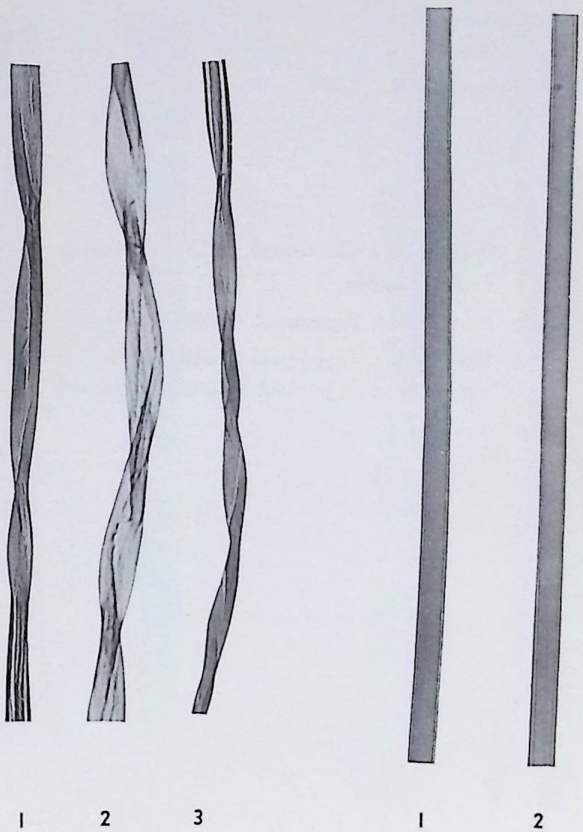
***Ceiba pentandra* Gaertn.**

1. Portion of a thin-walled, wide-lumened seed hair, ×180
2. Portion of a thin-walled, wide-lumened seed hair, ×180



COTTON

KAPOK







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## WOOL

1. Portion of a hair, ×180
   - **a.** Ridges which have appearance of imbricated scales
   - **b.** Medulla
2. Portion of a hair, ×180

## SILK

1. Portion of a silk thread, ×180, consisting of several double strands
2. Portion of a degummed strand, ×180
3. Portion of a degummed strand, ×180
   - **a.** Indication of double nature of strand













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## ASBESTOS

Sample of a commercial asbestos paper, ×180

**a.** Aggregate consisting of thin, filamentous crystals











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## RAYON

1. Portion of a fiber, ×360
2. Portion of a fiber, ×360

## NYLON

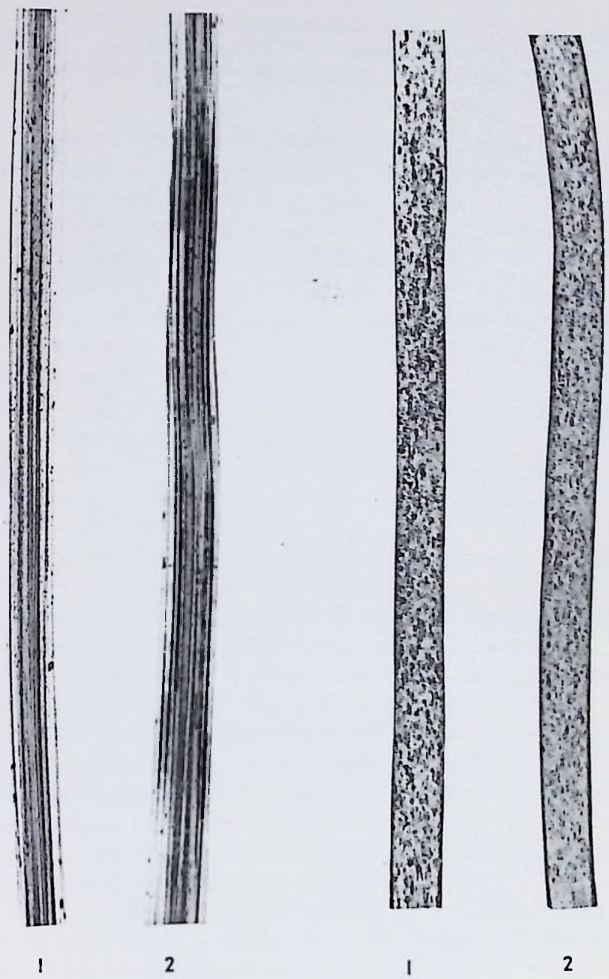
*(Containing a delustrant)*

1. Portion of a fiber, ×360
2. Portion of a fiber, ×360



RAYON

NYLON







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## GLOSSARY

For a detailed treatment of the anatomical features of the commercial woods of the United States, see *Textbook of Wood Technology*, Volume I, by H. P. Brown, A. J. Panshin, and C. C. Forsaith, McGraw-Hill Book Company, New York, N. Y. 1949.

**annular vessel:** a vessel with annular thickenings on the inner surface of its otherwise relatively thin wall; the rings may be close-spaced or at wide and frequently at irregular intervals.

**bast fiber:** a fiber from the phloem portion of the vascular tissue of a plant, as distinguished from its xylary portion.

**bordered pit:** a pit with an overhanging margin, *i.e.*, a pit in which the cavity becomes abruptly constricted during the thickening of the secondary wall.

**element:** a specific cell type.

**epidermal cell:** a cell from the epidermis of a plant; the epidermis is the tegumentary (covering) tissue of the plant.

**fiber:** a general term for a narrow elongated cell with tapering ends; different types are recognized according to wall thickness, width of lumen, and nature of the pitting.

**ground tissue:** the thin-walled parenchyma between the vascular bundles in a monocotyledonous stem.

**intertracheid pits:** pits of pit pairs in the wall of a tracheid leading to a contiguous tracheid before the wood was pulped.

**intervessel pits:** pits of pit pairs in the wall of a vessel leading to a contiguous vessel before the wood was pulped.

**longitudinal:** directed or extending lengthwise, as along the long axis of a plant stem or parallel to the grain of wood.

**longitudinal parenchyma:** strands of parenchymatous cells extending along the grain in wood.

**lumen:** the cavity of a cell enclosed by its wall; viewed laterally, it is canal-shaped when the cell is elongated.

**parenchyma:** collective noun designating relatively short cells with simple pits; they are usually quite thin-walled and often remain alive for a considerable time.

**perforation:** the opening (or openings) between two vessel segments.

**pit:** a recess in the secondary wall of a cell spanned at its outer end by a closing membrane (pit membrane); pits result through failure of the secondary wall to form at these points.



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**ray:** a ribbon-like band of tissue extending radially in the vascular tissue of a tree so oriented that the face of the ribbon is exposed in a radial section.

**ray-cell contact area:** the pitted area on the wall of a longitudinal element where a ray cell was originally in contact with it.

**ray-contact area:** the pitted area on the wall of a longitudinal element where a ray was originally in contact with it.

**ray parenchyma:** collective term for ray parenchymatous cells with simple pits, and with living contents as long as they are in the sapwood of a tree.

**ray tracheid:** a ray cell with bordered pits and devoid of living contents at maturation (see ray parenchyma).

**reticulate:** netlike; said of a cell wall with either openings or variations in wall thickness which have a netlike pattern.

**scalariform:** ladder-like; said of linear pits arranged transversely in parallel, and of perforations with transverse parallel bars.

**scalariform perforation:** a perforation spanned by two to many transverse bars in a ladder-like arrangement.

**scalariform pitting:** said of linear pits arranged scalariformly (see scalariform).

**simple perforation:** a round or oval perforation without cross bars.

**spiral thickening:** spiralled ridgelike thickening of the inner wall of a cell

**springwood:** the wood formed during the early part of a growing season; the inner, usually less dense portion of an annual increment; also called earlywood

**springwood tracheid:** a tracheid in the springwood of softwoods; it has a larger radial diameter, a thinner wall, and wider lumen than a summerwood tracheid (see summerwood tracheid).

**springwood vessel segment:** a vessel segment in the springwood of a ring porous hardwood; it is appreciably wider than a summerwood vessel segment (see summerwood vessel segment).

**stomate:** the opening and the adjacent specialized guard cells in the epidermis of a plant (see epidermal cell).

**summerwood:** the wood formed during the latter part of a growing season; the outer, usually denser portion of an annual increment; also called latewood.

**summerwood tracheid:** a tracheid in the summerwood of softwoods; it has a smaller radial diameter, thicker wall, and narrower lumen than a springwood tracheid (see springwood tracheid).





**summerwood vessel segment:** a vessel segment in the summerwood of a ring porous hardwood; it is appreciably narrower than a springwood vessel segment (see springwood vessel segment).

**tracheid:** a narrow elongated cell with tapering ends and numerous bordered pits.

**tylosis** (plural — **tyloses**): a balloon-like or saclike structure sometimes present as an inclusion in a vessel segment.

**vasicentric tracheid:** a relatively short, crooked fibrous cell with many bordered pits.

**vessel segment:** one of the perforated units of a vessel; a vessel consists of a longitudinal series of such units.




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