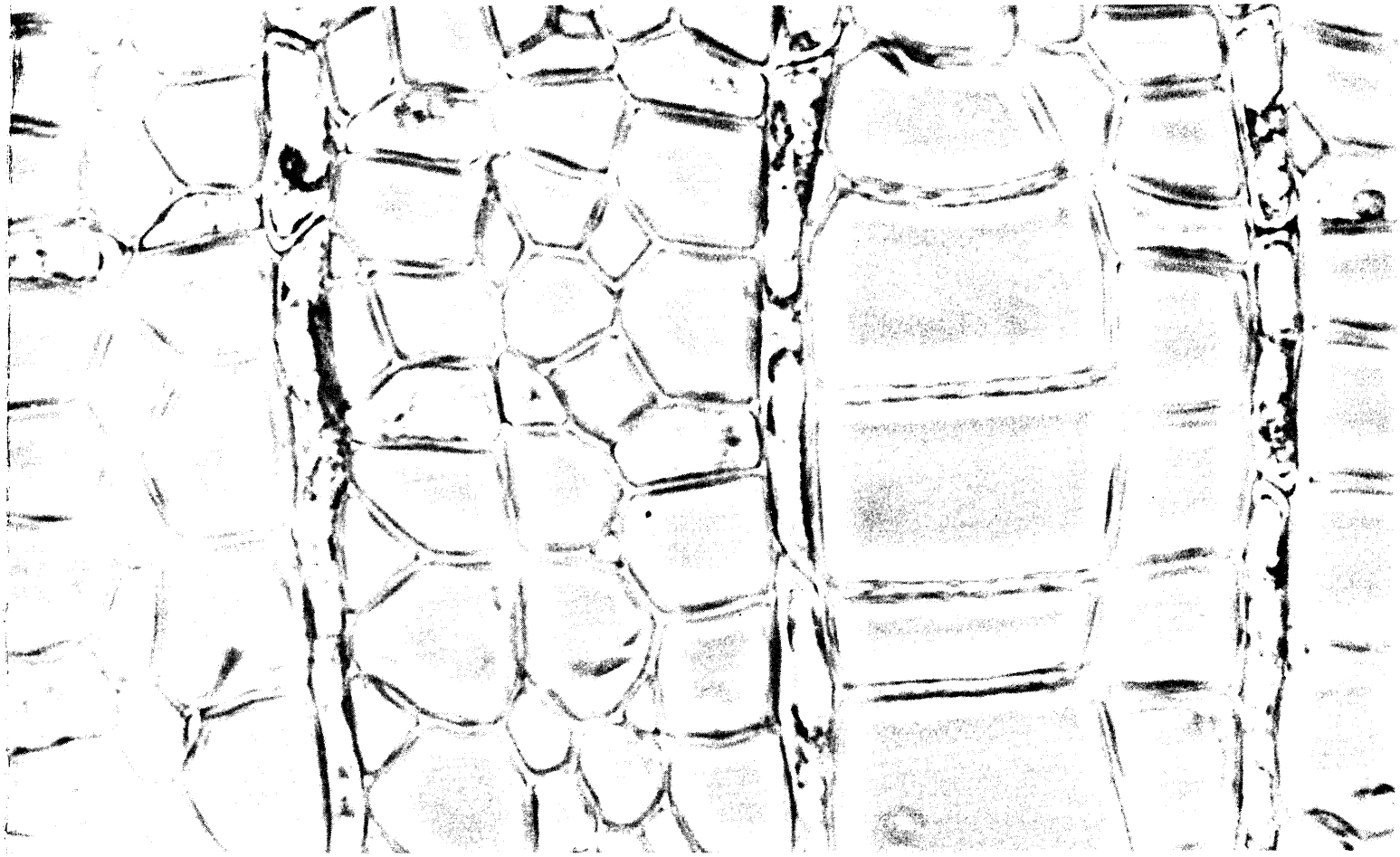
COMPARATIVE WOOD ANATOMY OF SOME SHRUBS NATIVE TO THE NORTHERN ROCKY MOUNTAINS

ARLENE DALE



RESEARCH PAPER INT-45, 1968
Intermountain Forest and Range
Experiment Station
Ogden, Utah

THE AUTHOR

MRS. ARLENE DALE has been a research technician in the Department of Botany, University of Montana, Missoula, since 1964. Most of her work deals with histological studies of fungi--primarily the needlecast of conifers --and of plants damaged by air pollutants.

This paper is based on content of the thesis submitted by the author as partial fulfillment of the requirements for the Master of Arts degree in Botany at the University of Montana. This project was supported jointly by the University of Montana and the U.S. Forest Service, Intermountain Forest and Range Experiment Station.

U.S. Forest Service
Research Paper INT-45
1968

COMPARATIVE WOOD ANATOMY OF SOME SHRUBS NATIVE TO THE NORTHERN ROCKY MOUNTAINS

ARLENE DALE

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401
Joseph F. Pechanec, Director

CONTENTS

COMPARATIVE WOOD ANATOMY OF SOME SHRUBS NATIVE TO THE NORTHERN ROCKY MOUNTAINS

Arlene Dale

INTRODUCTION

Presented here is a key for identification of shrubby plants native to the Northern Rocky Mountain area. This key supplements those already in existence that are based on plant organs, such as flowers, leaves, fruits, and other macroscopic characters. In contrast, the characters upon which this key is based are those of the wood, or technically, the xylem. Such a key would be valuable to substantiate identifications made by means of the ordinary keys and to aid in the identifications of plants when flowers, leaves, and fruits are not available.

Fifty-five species, representing 35 genera (see page 3), have been incorporated in this key. Xylem characters determined the arrangement of the species. Where certain characters were held in common by all genera of a family, these species parallel their usual taxonomic arrangement. Depending on characters present, identification is to a species, a genus, or a group of genera. Further study will make possible more detailed identification.

A review of the literature concerning wood anatomy indicates a change in emphasis has occurred within the past 20 years--from a heavy reliance on quantitative data in distinguishing among woods to the use of qualitative characters. This change has been caused by increased understanding of the extent and causes of variations within a species. No longer is it assumed that a single specimen accurately represents a species. To determine the range of variability of all 55 species was beyond the scope of this study; the diversity of characters within each species will be discovered only as this key is used. In this key, cell patterns--created by the ordered activity of the cambium--are employed extensively.

METHODS AND MATERIALS

FIELD COLLECTIONS

Specimens were collected for over 60 species of shrubs from sites in western Montana and northern Idaho.[1] Several of these species were rejected from consideration because they were represented by only one specimen; others were rejected because the specimens collected were only 1 year old. While some species were represented by as many as five specimens, the minimum number was two.

---

[1] Most of the collections and all of the identifications were made by Peter F. Stickney, Associate Plant Ecologist, U.S. Forest Service, Intermountain Forest and Range Experiment Station. Identifications were made by means of the following: Hitchcock, C. L., A. Cronquist, M. Ownbey, and J. W. Thompson. Vascular plants of the Pacific Northwest. Seattle: Univ. Wash. Press. Part 2: Salicaceae to Saxifragaceae, 1964; Part 3: Saxifragaceae to Ericaceae, 614 pp., 1961; Part 4: Ericaceae through Campanulaceae, 510 pp., 1959; Part 5: Compositae, 314 pp., 1955.

SPECIMEN PREPARATION

The paraffin-embedding method was employed in preparing the microscopic slides from the specimens. Small wedges were cut from the specimens, aspirated, dehydrated through a tertiary butyl alcohol series, and embedded in Paraplast.[2] After soaking in an alcohol-glycerine solution of Aerosol OT 100, the embedded specimens were sectioned in thicknesses of from six to 20 micra on a rotary microtome; for most of the material a thickness of eight to 10 micra was optimum. The paraffin ribbons were affixed to slides with Haupt's adhesive. After removal of the paraffin by xylene, the sections were run through an ethyl-alcohol series into water, stained by means of the Feulgen reaction, dehydrated in a second alcohol series, and counterstained with fast green. In the first alcohol series, a celloidon solution was interposed to improve adhesion of sections. The mounting medium was Harleco's Synthetic Resin. Cross, radial, and tangential sections were cut for each species.

PREPARATION OF KEY

The key was first outlined from photomicrographs of the sections and then checked with the slides and with published accounts of wood anatomy. Because in many cases the original photographs did not show the characters sought, the slides for each species had to be examined several times. Each character used to distinguish a species was checked in all specimens representing that species.

The characters used to distinguish among the species are not in all cases the same; vessel distribution, perforation plates, rays, and axial parenchyma are the characters most often utilized. Where information about wood anatomy for a species was available, it was consulted as a check against the specimens used in this study. These accounts, with few exceptions, confirmed the conclusions outlined.

DISCUSSION

The premise upon which this study was based is that species of shrubs are identifiable on the basis of characteristics of the xylem. However, evidence indicates that such distinction cannot be made. The results of this study confirm that in many genera the species produce xylem that is so similar as to be valueless for identification; e.g., the two species of Ceanothus included in this key. Consequently, wood traits alone may not be adequate to identify a shrub.

Before attempting to use this key, the reader should recognize that identification of shrubs by means of microscopic characteristics of the wood is difficult. Careful preparation of specimens and adequate laboratory facilities are necessary. Moreover, error may result from two sources. The first is that the unknown shrub may be one not included in this study. The second is that species variability has not been assessed. Identification of unknown shrubs by xylem should be attempted only when all other means have been exhausted.

---

[2] Use of trade names herein is for identification only, and does not imply endorsement by the U.S. Forest Service.

GENERA INCLUDED IN KEY BY FAMILY[3]

Taxaceae
- Taxus

Pinaceae
- Juniperus

Compositae
- Artemisia
- Chrysothamnus

Rosaceae
- Amelanchier
- Cercocarpus
- Crataegus
- Holodiscus
- Physocarpus
- Prunus
- Purshia
- Rosa
- Rubus
- Sorbus
- Spiraea

Saxifragaceae
- Philadelphus
- Ribes

Aceraceae
- Acer

Salicaceae
- Populus
- Salix

Betulaceae
- Alnus
- Betula

Cornaceae
- Cornus

Ericaceae
- Arctostaphylos
- Ledum
- Menziesia
- Vaccinium

Anacardiaceae
- Rhus

Rhamnaceae
- Ceanothus
- Rhamnus

Caprifoliaceae
- Lonicera
- Sambucus
- Symphoricarpos

Elaeagnaceae
- Shepherdia

Celastraceae
- Pachistima

---

[3] As classified in Lawrence, George H. M. Taxonomy of Vascular Plants. New York: The MacMillan Co. 1951.

KEY TO SOME SHRUB WOODS NATIVE TO THE NORTHERN ROCKY MOUNTAINS

1 Vessels present 3
1 Vessels not present 2
2 Tracheids with spiral thickenings . . . . . Taxus brevifolia (p. 8-9)
2 Tracheids without spiral thickenings . . . . . Juniperus spp. (p. 8-9)
3 Rays 3 to many cells in width, often massive, dispersed between uniseriate rays . . . 4
3 Rays 1 or 2 cells in width (rarely 3) 17
4 Vessels grouped in patterns forming radial or concentric bands or arcs 5
4 Vessels predominantly solitary or in pairs, except for initial vessels of growing season which may be contiguous 8
5 Vessel bands radial . . . . . Prunus spp. (p. 16-17, 18-19)
5 Vessel bands concentric or vessels forming arcs 6
6 Band of cork tissue initiating each growth ring . . Artemisia tridentata (p. 8-9)
6 Band of cork not present as above 7
7 Vessels in concentric bands, alternating with bands of tracheids and fibers . . . . . Chrysothamnus nauseosus (p. 10)
7 Vessels in slight arcs rather than in concentric bands . Chrysothamnus viscidiflorus (p. 10-11)
8 Perforation plates simple 9
8 Perforation plates scalariform 11
9 Growth ring distinct; vessels decreasing in size from early to late wood; vessels relatively numerous 10
9 Growth ring indistinct; vessels not changing in size or spacing from early to late wood; vessels relatively few and far apart . . . . . Holodiscus discolor (p. 14-15) or Rubus spp. (p. 22-23, 24-25)
10 Vessels markedly larger in early than in late wood . . . . . Rosa woodsii (p. 20-21)
10 Vessels not markedly larger in early than in late wood . . . . . Rosa gymnocarpa (p. 20-21)
11 Tracheids and fibers alternating in radial bands . . . Philadelphus lewisii (p. 26-27)
11 Tracheids not alternating with fibers as above 12
12 Vessels forming complete or short concentric bands within growth ring, usually 1 vessel in width 13
12 Vessels not forming such bands, instead being more in diagonal bands or diffuse 14
13 Bands complete; vessels of successive bands in any one growth ring are of similar size . . . . . Ribes aureum (p. 28-29)
13 Bands tending to be interrupted not forming complete bands; vessels of successive bands in any one growth not similar in size; the initial vessels usually are markedly larger than succeeding ones . . . . . Ribes cereum (p. 28-29)
14 Vessels mostly solitary with some small clusters; are randomly dispersed, with no clear pattern evident 15
14 Vessels arranged in diagonal bands or arcs with a few short, tangential bands . . 16
15 Growth ring initiated with a band of larger vessels; the vessels become progressively smaller through the growing season; vessels relatively few . . . . . Ribes lacustre (p. 32-33, 34-35)
15 Growth ring not initiated with a band of larger vessels although the vessels of the last-formed wood are noticeably smaller than the initial vessels, making the growth rings discernible . . . . . Ribes hudsonianum (p. 30-31)

16 Vessels forming a zigzag pattern, radially alined . Ribes viscosissimum (p. 34-35)
16 Vessels may be diagonally alined, in short tangential bands, and/or diffuse, with none of these found exclusively; there is not the regularity of alternating diagonal bands as in the above . . . . Ribes irriguum (p. 30-31, 34-35) or Ribes setosum (p. 32-33)

17 Vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood 18
17 Vessels solitary, in pairs, or in various aggregates, including sometimes radial vessel chains but not vessel multiples 24
18 Perforation plates simple 19
18 Perforation plates scalariform 22
19 Rays composed of procumbent cells only 20
19 Rays composed of both procumbent and upright cells 21
20 Vessels with spiral thickenings; rays mainly uniseriate but some 2 to 4 cells wide . . . . . Acer glabrum (p. 36-37)
20 Vessels without spiral thickenings; rays uniseriate only . . . . . Populus spp. (p. 38-39, 40-41)
21 Rays 1 cell in width . . . . . Salix scouleriana (p. 40-41)
21 Rays 2 to 4 cells in width . . . . . Sambucus spp. (p. 60-61, 62-63)
22 Rays uniseriate only. 23
22 Rays both 1 and 2 cells in width. . . . . Betula spp. (p. 44-45)
23 Axial parenchyma forming tangential bands at short intervals between rays. . . . . Alnus incana (p. 42-43)
23 Axial parenchyma sparse and diffuse . . . . . Alnus sinuata (p. 42-43, 46-47)
24 Vessel perforation plates scalariform 25
24 Vessel perforation plates simple 28
25 Vessels regular in size and spacing throughout growth ring. . . . . Cornus stolonifera (p. 46-47)
25 Vessels not regular in size or spacing as above 26
26 Rays 1 to several cells wide . . . . . Vaccinium spp. (p. 50-51, 52-53)
26 Rays uniseriate only. 27
27 Growth ring initiated by a single row of large, closely spaced vessels. . . . . Menziesia ferruginea (p. 50-51)
27 Growth ring not initiated as above; no clear line of large vessels. . . . . Ledum glandulosa (p. 48-49)
28 Annual ring initiated by a definite band of large vessels; other vessels are much smaller and sparse, giving a two-banded appearance to the growth ring 29
28 Annual ring not initiated by band of large vessels as above; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size . . 30
29 Axial parenchyma numerous, paratracheal, and diffuse, often encircling the larger vessels . . . . . Symphoricarpos albus (p. 62-63)
29 Axial parenchyma few, if in contact with a vessel, a single cell rather than an encircling band . . . . . Arctostaphylos uva-ursi (p. 48-49)
30 Axial parenchyma predominantly paratracheal 31
30 Axial parenchyma predominantly terminal or diffuse 32
31 Axial parenchyma distributed as 2 to several cells on the periphery of each vessel group; vessels solitary or in

clusters of a few cells in the early wood progressing to radial files which are grouped secondarily to form tangential bands in the late wood . . . . . Rhus glabra (p. 52-53)

31 Axial parenchyma distributed as an occasional single cell adjacent to a vessel; vessels diffuse, not grouped as above . . . . . Pachistima myrsinites (p. 64-65)

32 Axial parenchyma predominantly terminal 33

32 Axial parenchyma predominantly diffuse or absent 35

33 Vessels decreasing gradually in size from early to late wood; vessels smooth in outline, solitary, or in occasional pairs . . . . . Physocarpus malvaceus (p. 16-17)

33 Vessels not decreasing gradually in size as above; vessels angular in outline. 34

34 Vessels arranged in diagonal and/or radial lines . Rhamnus alnifolia (p. 56-57)

34 Vessels solitary or in occasional multiples of a few cells . . . . . Rhamnus purshiana (p. 56-57)

35 Vessels occurring in patterns of radially alined S curves in mature wood; tannins occurring in even the young ray parenchyma. . . . . Ceanothus spp. (p. 54-55)

35 Vessels not in patterns as described above; tannins, if present, occurring in ray parenchyma only in the more mature cells 36

36 Axial parenchyma numerous 37

36 Axial parenchyma absent or sparse 39

37 Vessel walls composed of five or six facets, giving the vessel a definitely angular appearance 38

37 Vessel walls, although composed of several facets, giving a smoother, more rounded outline than above. . . . . Amelanchier alnifolia (p. 12-13)

38 Vessels tending to form concentric bands within the growth ring; vessels relatively few and large . . . Shepherdia canadensis (p. 64-65)

38 Vessels diffuse in distribution with no particular alinement; vessels relatively small and numerous. Crataegus douglasii (p. 14-15)

39 Spring wood vessels large, numerous, and solitary (although closely spaced); vessels of late wood not greatly smaller than those of early wood, but much more widely spaced; vessels markedly angular, with concave facets . . . . . Sorbus scopulina (p. 24-25)

39 Spring wood vessels not as above; if vessel spacing is as above, then vessels are rounded, with convex facets; if vessel shape is as above, then spacing differs 40

40 Early wood with a few large vessels; vessel size decreases greatly from early to late wood, but spacing of vessels remains similar . . . . . Cercocarpus ledifolius (p. 12-13)

40 Early wood may have a few large vessels but, if so, then the vessel size and spacing differ from the above 41

41 Axial parenchyma absent . . . . . Spiraea betulifolia (p. 26-27)

41 Axial parenchyma present although few in number. 42

42 Vessels angular in outline 43

42 Vessels rounded in outline . . . . . Purshia tridentata (p. 18-19)

43 Ray cells squared in outline in cross section . . . . . Lonicera utahensis (p. 58-59)

43 Ray cells radially elongated in cross sections . . . . Lonicera involucrata (p. 58-59)

PHOTOMICROGRAPHS

AND

SYNOPSES OF CHARACTERS

USED IN KEY

ALL PHOTOMICROGRAPHS ARE OF CROSS

SECTIONS UNLESS OTHERWISE NOTED AS:

* radial

** tangential

PLATE I

Taxus brevifolia (1a and 1b*)

Vessels absent; tracheids with spiral thickenings.

Juniperus communis (2a) and

Juniperus scopulorum (3a)

Vessels absent; tracheids without spiral thickenings.

Artemisia tridentata (4a and 4b)

Vessels present, grouped in patterns forming concentric bands; rays three to many cells in width, often massive, dispersed between uniseriate rays; band of cork tissue initiating each growth ring.

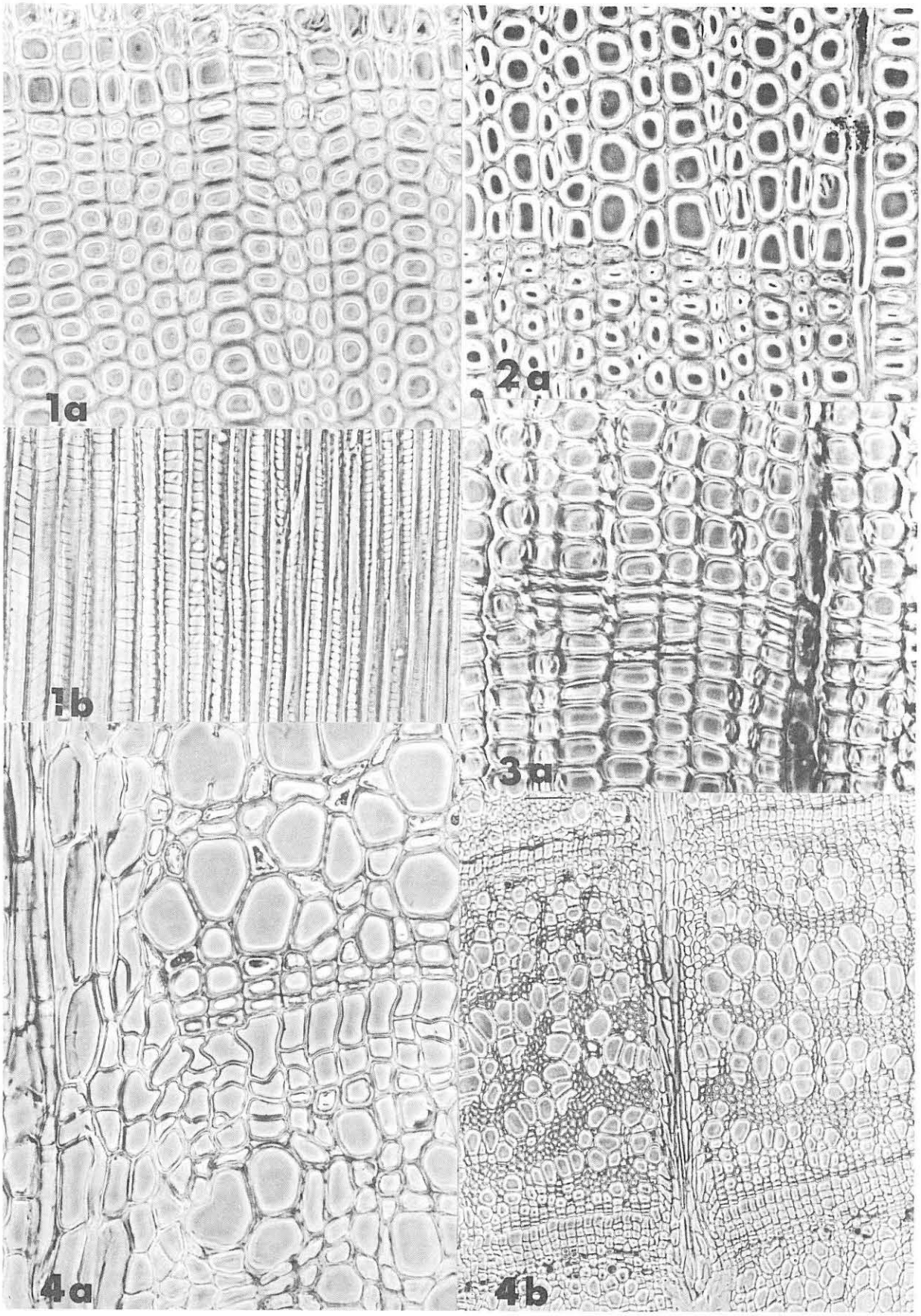

1a
2a
1b
3a
4a
4b

PLATE II

Chrysothamnus nauseosus (6a and 6b)

Vessels present, grouped in patterns forming concentric bands; rays three to many cells in width, often massive, dispersed between uniseriate rays.

Chrysothamnus viscidiflorus (5a and 5b)

Vessels present, grouped in patterns forming slight arcs; rays three to many cells in width, often massive, dispersed between uniseriate rays.

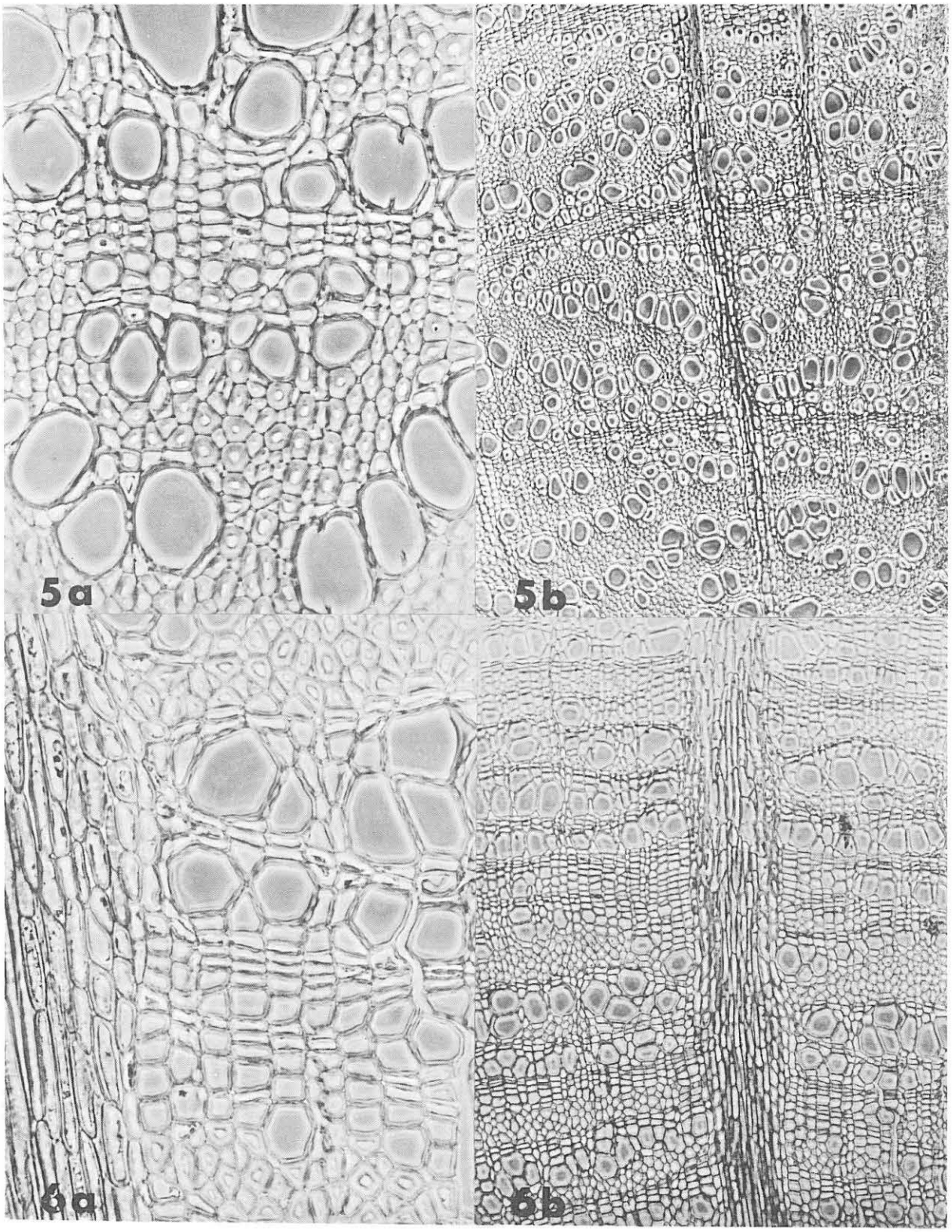

5a
5b
6a
6b

PLATE III

Amelanchier alnifolia (7a, 7b, and 7c*)

Vessels present, solitary or in pairs; annual ring not initiated by band of large vessels; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessel walls giving a smooth, rounded outline to vessel in cross section; vessel perforation plate simple; axial parenchyma numerous, diffuse; rays one to two cells in width (rarely three).

Cercocarpus ledifolius (8a and 8b)

Vessels present, solitary, in pairs or various aggregates; annual ring not initiated by a band of large vessels; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; early wood with a few large vessels; vessel size decreases greatly from early to late wood, but spacing of vessels remains similar; perforation plate simple; axial parenchyma absent or sparse and diffuse; rays one or two cells in width (rarely three).

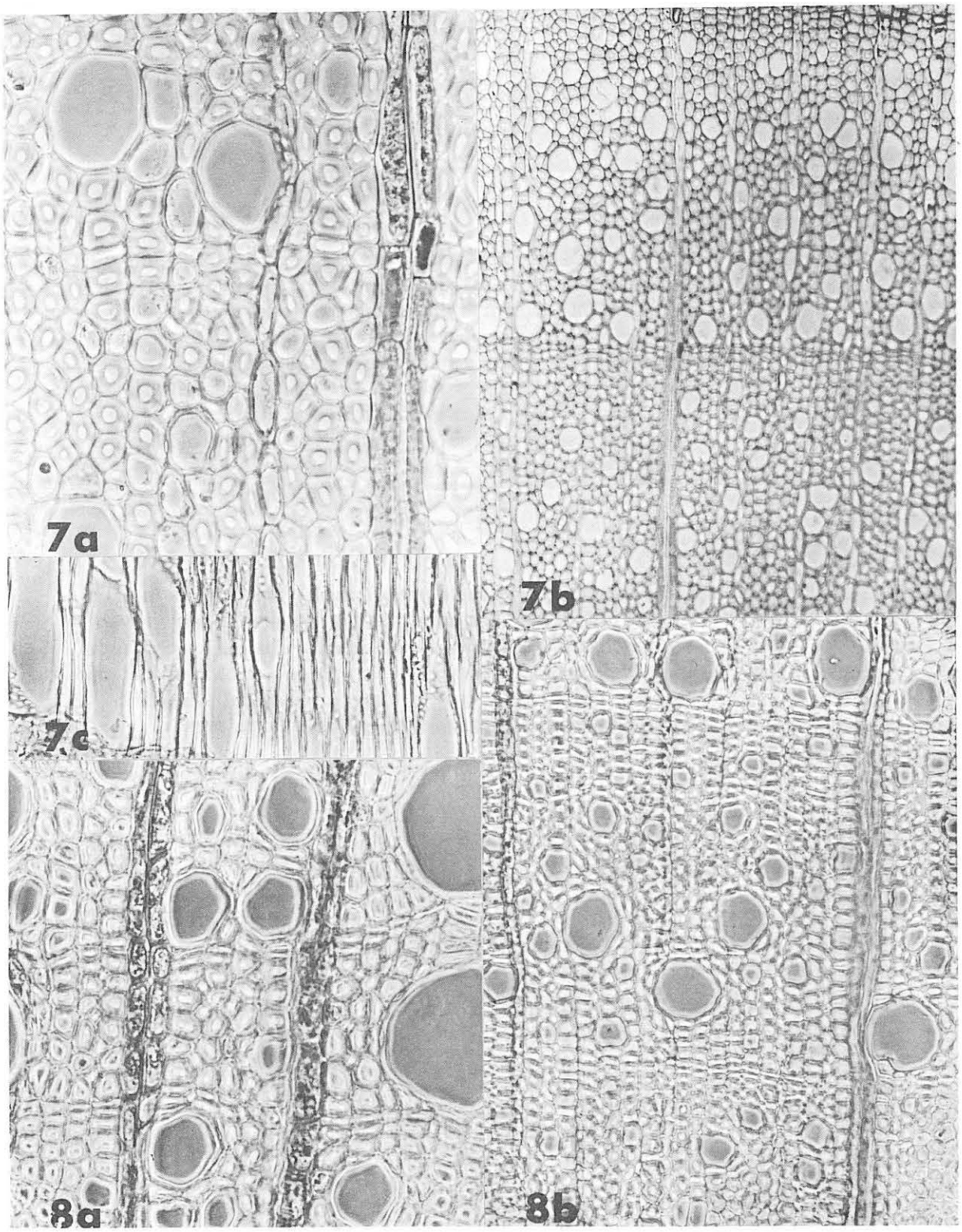

7a
7b
7c
8a
8b

PLATE IV

Crataegus douglasii (9a and 9b)

Vessels present, diffuse in distribution with no particular alinement; vessels relatively small and numerous; vessel walls composed of five or six facets, giving the vessel a definitely angular appearance; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels solitary or in pairs, or in various aggregates; vessel perforation plates simple; axial parenchyma absent or sparse, diffuse; rays one or two cells in width (rarely three).

Holodiscus discolor (10a and 10b)

Vessels present; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; growth ring indistinct; vessels not changing in size or spacing from early to late wood; vessels relatively few and far apart; perforation plates simple; rays three to many cells in width, often massive, dispersed between uniseriate rays.

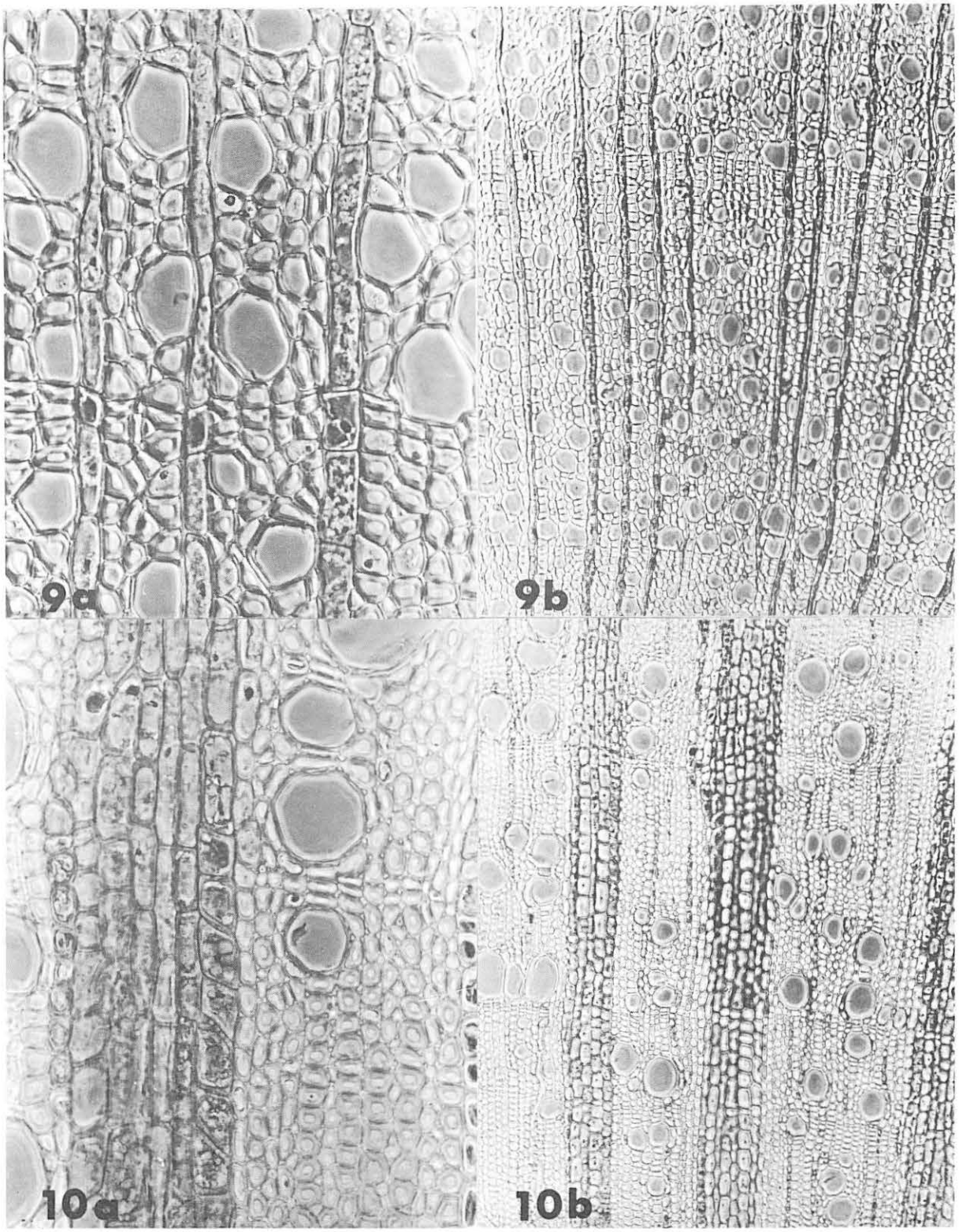

9a
9b
10a
10b

PLATE V

Physocarpus malvaceus (11a and 11b)

Vessels present; vessels decreasing gradually in size from early to late wood; vessels smooth in outline, solitary or in occasional pairs; vessel perforation plates simple; axial parenchyma predominantly diffuse or absent; rays one or two cells in width (rarely three).

Prunus emarginata (12a, 12b, and 12c*)

Vessels present; vessels grouped in radial bands; rays three to many cells in width, dispersed between uniseriate rays.

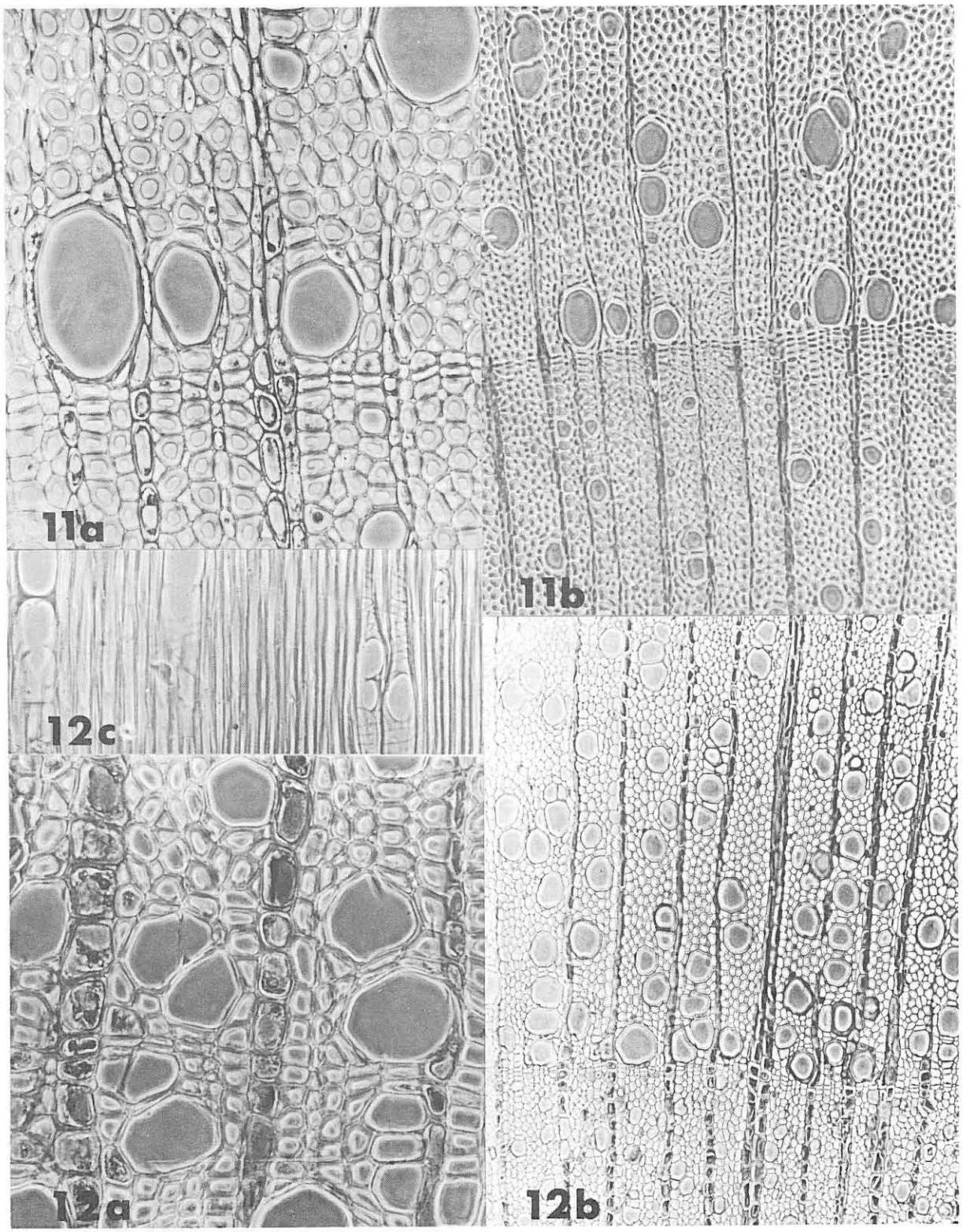

11a
11b
12c
12a
12b

PLATE VI

Prunus virginiana (13a and 13b)

(Same synopsis as for Prunus emarginata, page 16)

Purshia tridentata (14a and 14b)

Vessels present; vessels rounded in outline; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels solitary, in pairs, or in various aggregates; perforation plates simple; axial parenchyma present although few in number, diffuse; rays one or two cells in width (rarely three).

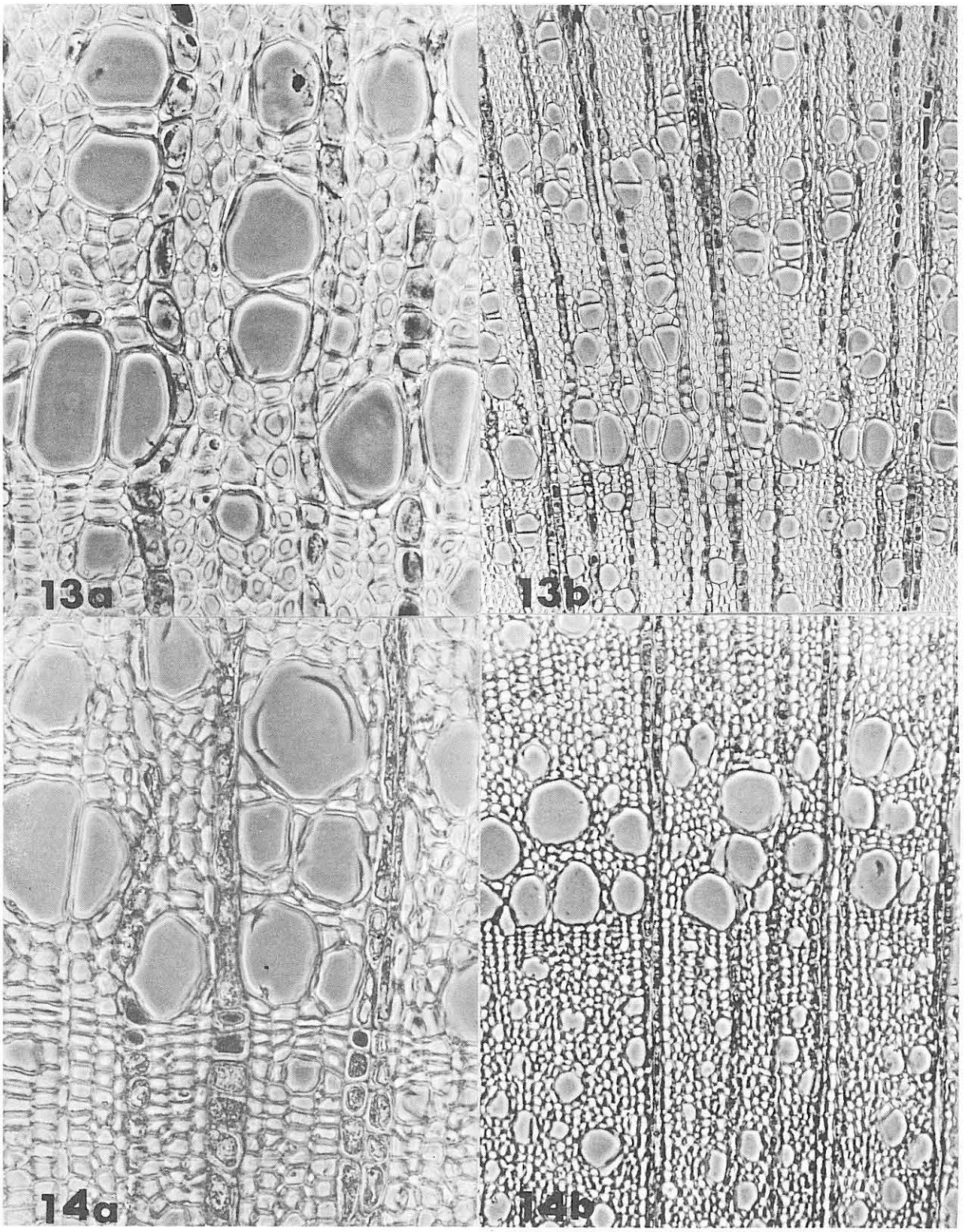

13a
13b
14a
14b

PLATE VII

Rosa gymnocarpa (15a and 15b)

Vessels present; vessels not markedly larger in early than in late wood; growth ring distinct; vessels decreasing in size from early to late wood; vessels relatively numerous; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; perforation plates simple; rays three to many cells in width, dispersed between uniseriate rays.

Rosa woodsii (16a and 16b)

Vessels present; vessels markedly larger in early than in late wood; growth ring distinct; vessels decreasing in size from early to late wood; vessels relatively numerous; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; perforation plates simple; rays three to many cells in width, dispersed between uniseriate rays.

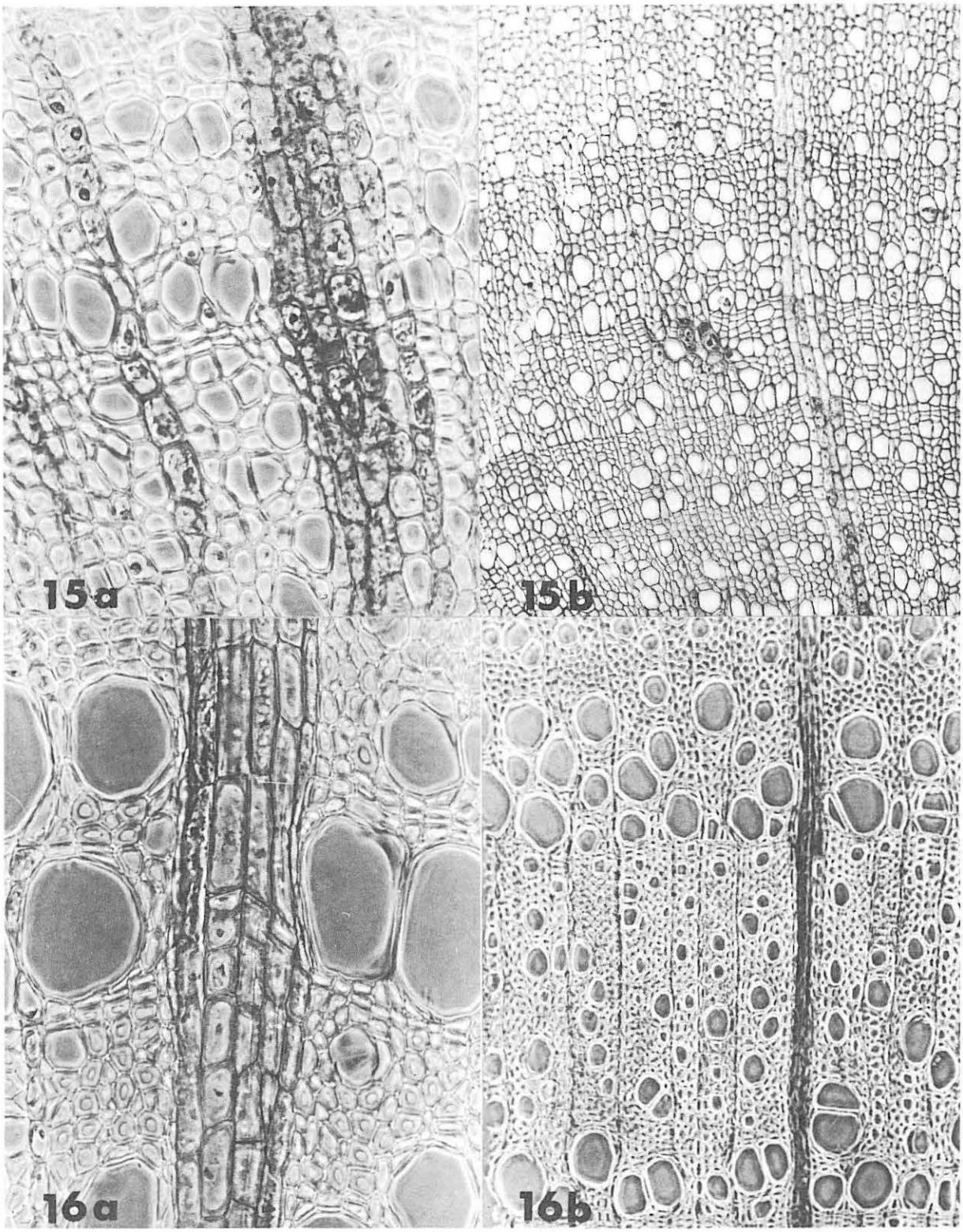

15a
15b
16a
16b

PLATE VIII

Rubus idaeus (17a, 17b, and 17c**) and

Rubus leucodermis (18a and 18b)

Vessels present; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; growth ring indistinct; vessels not changing in size or spacing from early to late wood; vessels relatively few and far apart; perforation plates simple; rays three to many cells in width, dispersed between uniseriate rays.

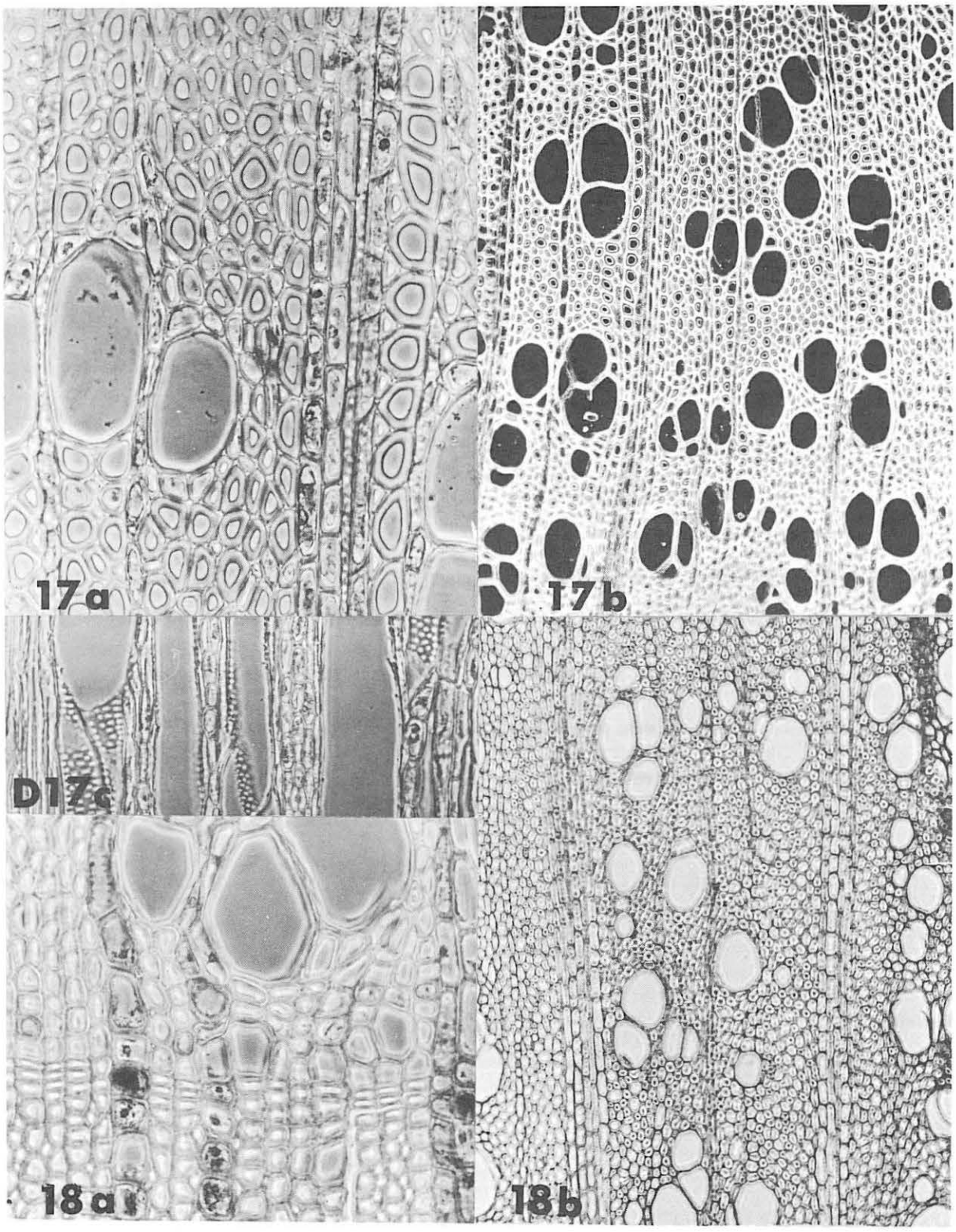

17a
17b
D17c
18a
18b

PLATE IX

Rubus parviflorus (19a and 19b)

(Same synopsis as for Rubus leucodermis, page 22)

Sorbus scopulina (20a and 20b)

Vessels present; spring wood vessels large, numerous and solitary (although closely spaced); vessels of late wood not much smaller than those of early wood, but much more widely spaced; vessels markedly angular, with concave facets; perforation plate simple; axial parenchyma absent or sparse and diffuse; rays one or two cells in width (rarely three).

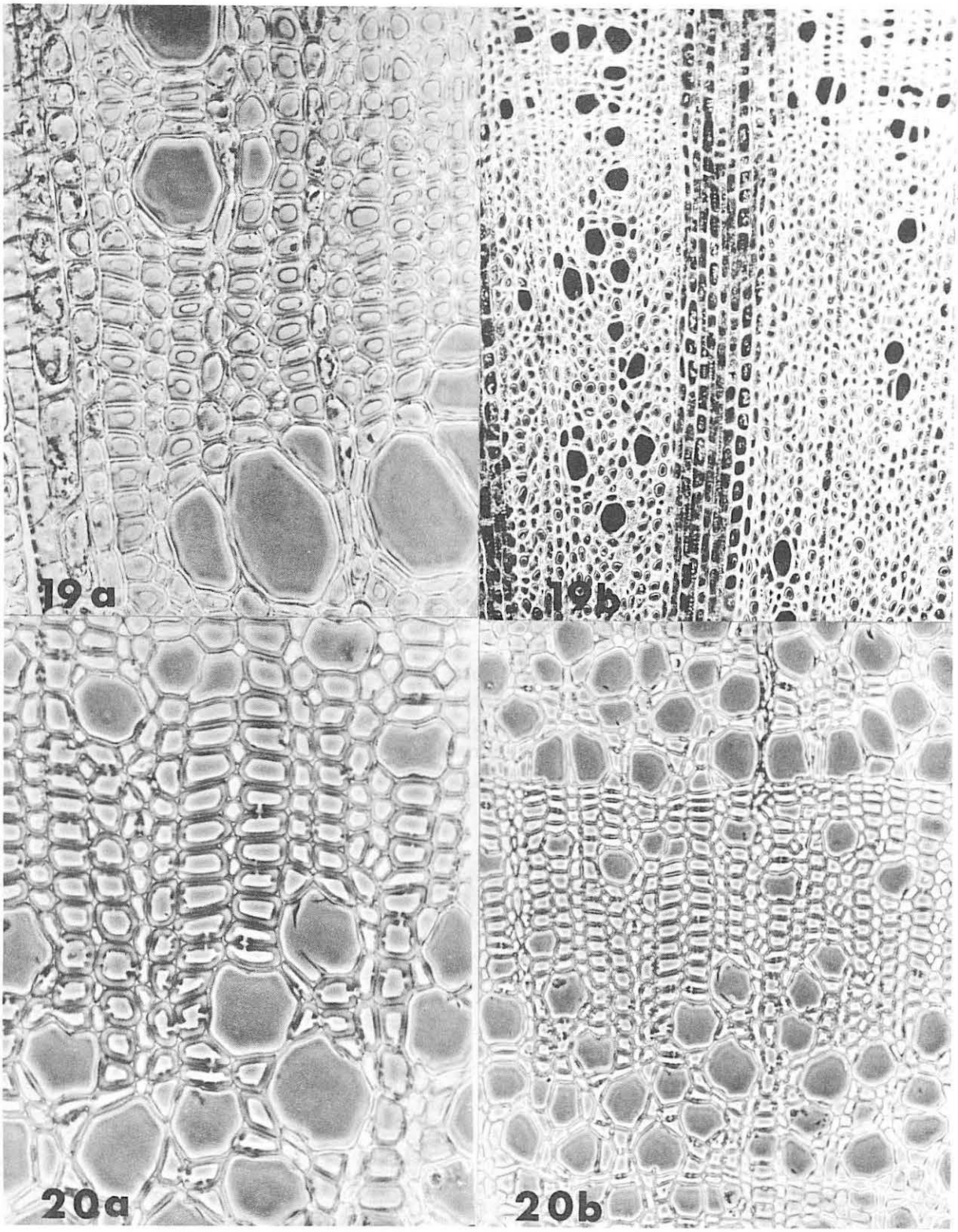

19a
19b
20a
20b

PLATE X

Spiraea betulifolia (21a and 21b)

Vessels present; vessels grade into smaller sizes as the growing season progresses; without an abrupt change in size; vessels solitary, in pairs, or in various aggregates; perforation plates simple; axial parenchyma absent; rays one or two cells in width (rarely three).

Philadelphus lewisii (22a and 22b)

Vessels present; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; perforation plates scalariform; rays three to many cells in width, often massive, dispersed between uniseriate rays; tracheids and fibers alternating in radial bands.

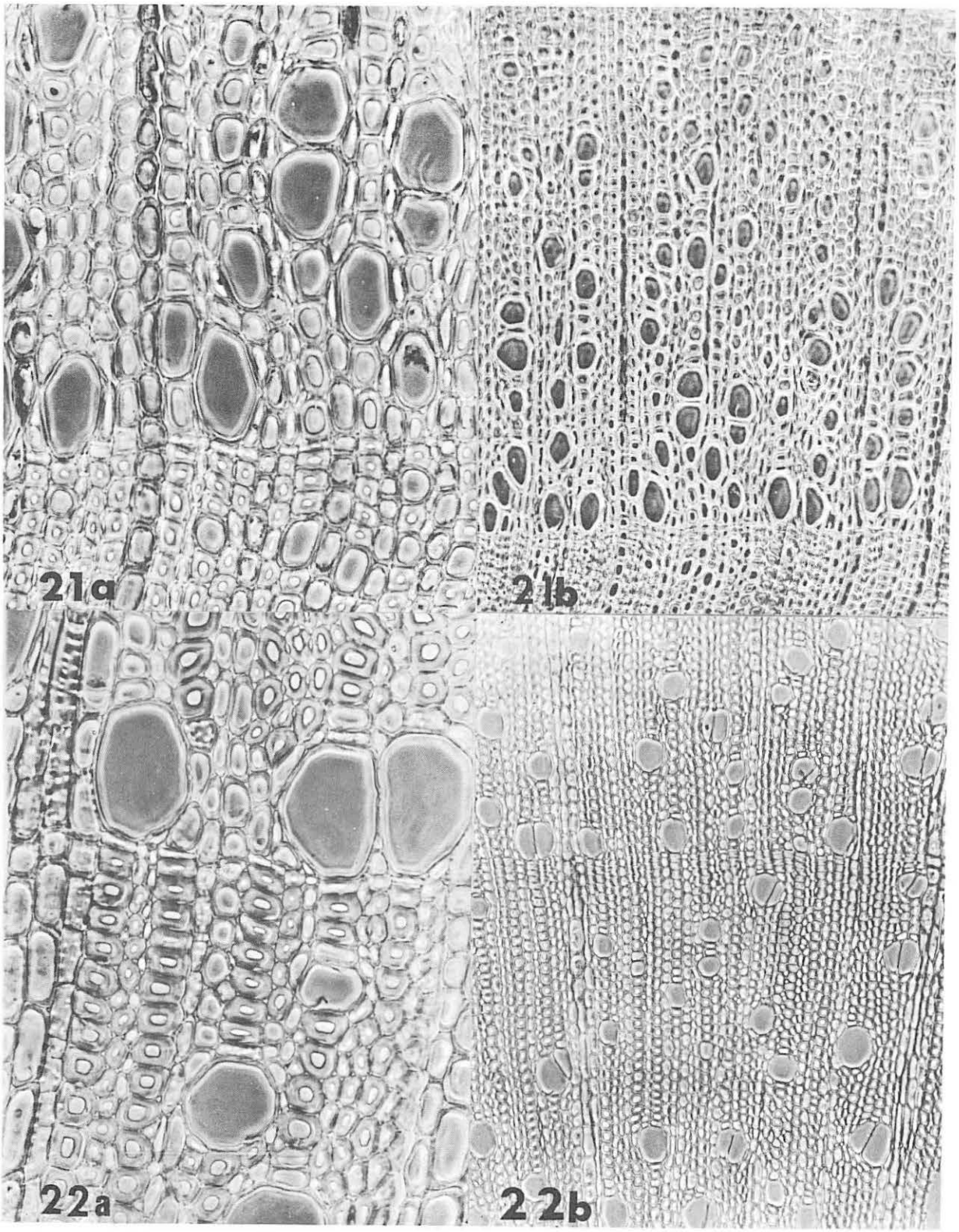

21a
21b
22a
22b

PLATE XI

Ribes aureum (23a and 23b)

Vessels present; vessels forming complete concentric bands within the growth ring, usually one vessel in width, vessels of successive bands in any one growth ring are of similar size; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; perforation plates scalariform; rays three to many cells in width, often massive, dispersed between uniseriate rays.

Ribes cereum (24a and 24b)

Vessels present; vessels forming interrupted concentric bands within the growth ring, usually 1 vessel in width; vessels of successive bands in any one growth ring not similar in size; the initial vessels are usually markedly larger than succeeding ones; vessels predominantly solitary or in pairs, except for initial vessels which may be contiguous; perforation plates scalariform; rays three to many cells in width; often massive, dispersed betwwen uniseriate rays.

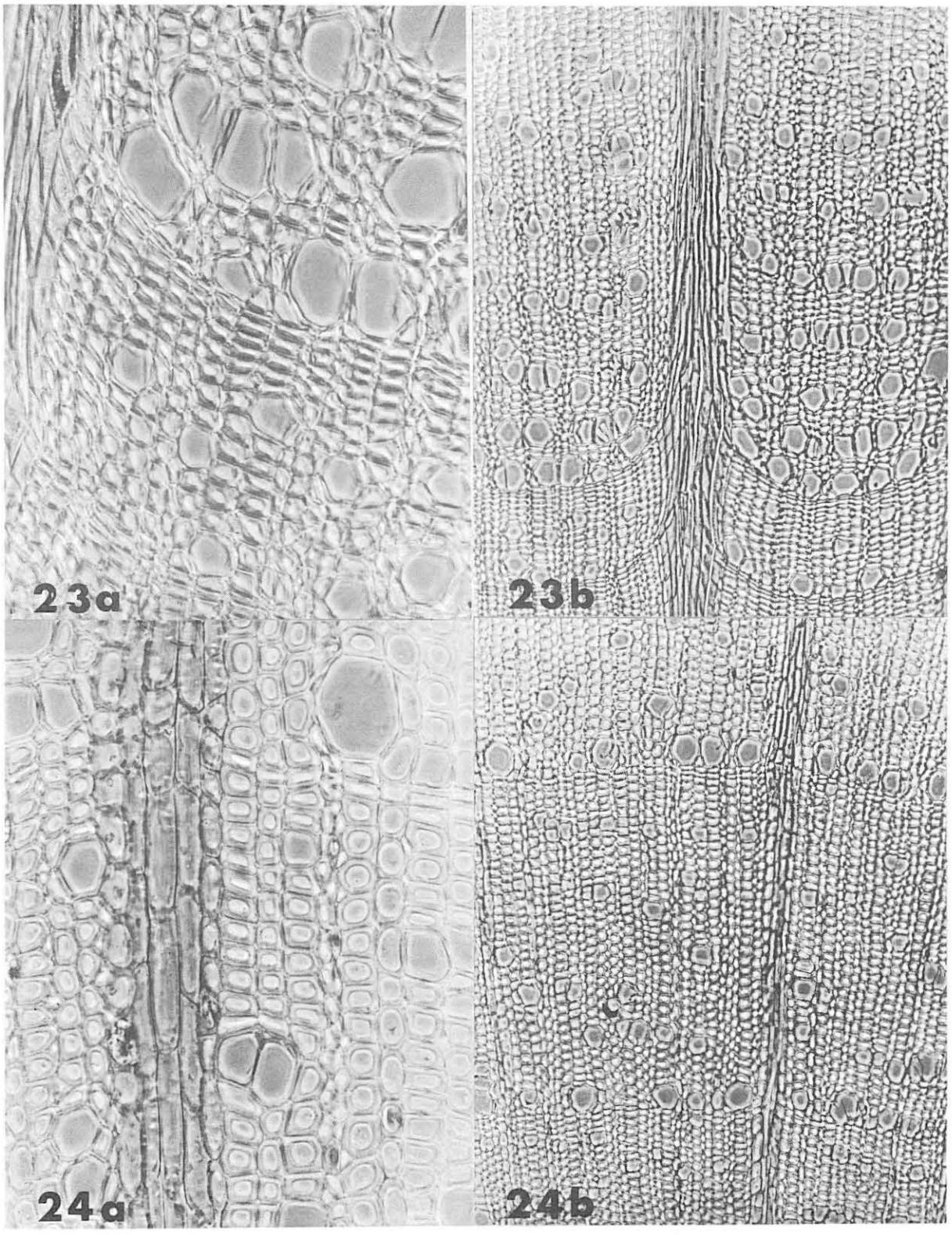

23a
23b
24a
24b

PLATE XII

Ribes hudsonianum (25a and 25b)

Vessels present; vessels mostly solitary with some small clusters of vessels; these vessels or clusters are randomly dispersed with no clear pattern evident; growth ring not initiated with a band of larger vessels although the vessels of the last-formed wood are noticeably smaller than the initial vessels, making the growth rings discernible; perforation plates scalariform; rays three to many cells in width, often massive, dispersed between uniseriate rays.

Ribes irriguum (26a and 26b)

Vessels present; vessels may be diagonally alined, in short tangential bands, and/or diffuse, with none of these found exclusively; perforation plate scalariform; rays three to many cells in width, often massive, dispersed between uniseriate rays.

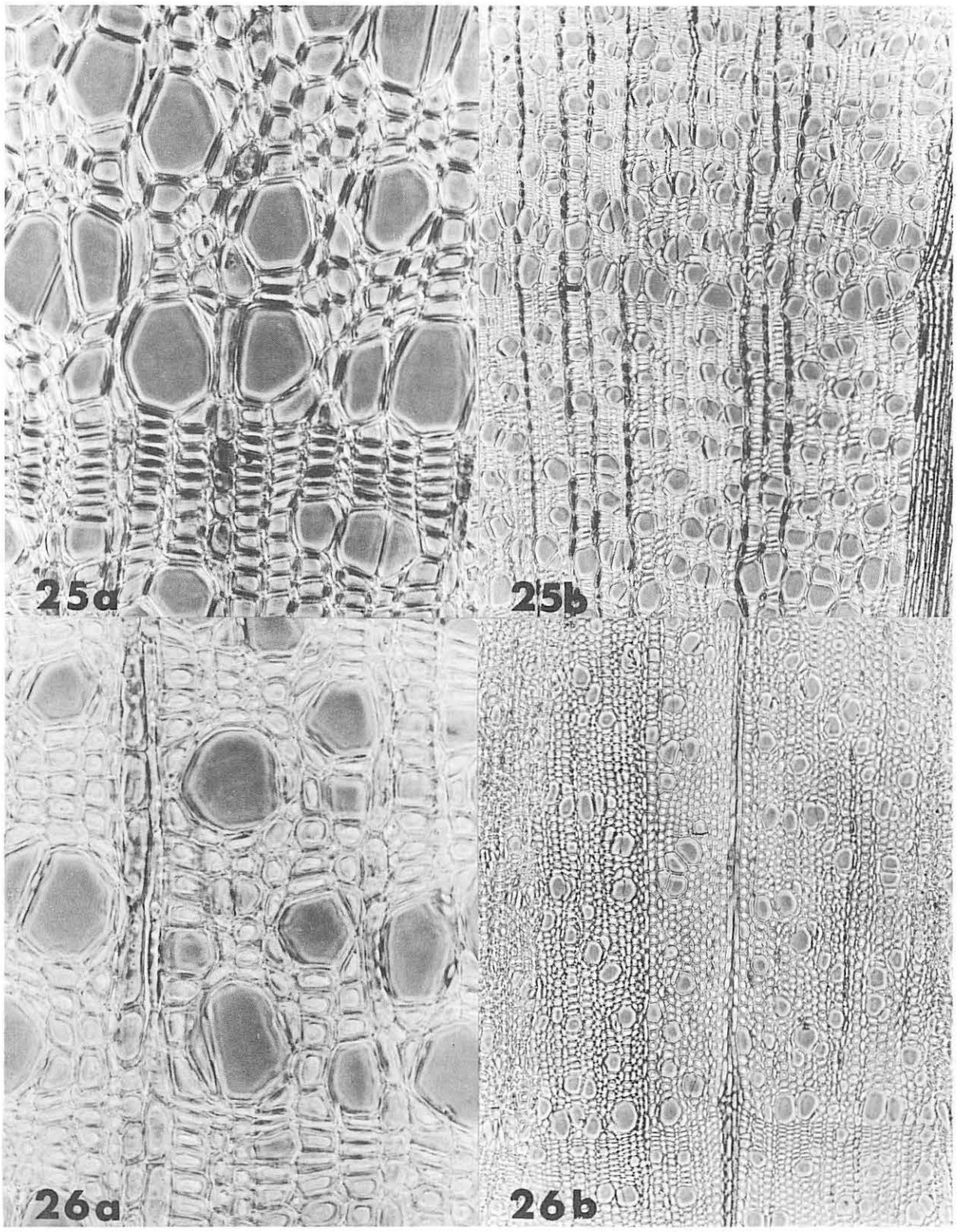

25a
25b
26a
26b

PLATE XIII

Ribes lacustre (27a and 27b)

Vessels present; growth ring initiated with a band of larger vessels; the vessels become progressively smaller through the growing season; vessels relatively few; vessels predominantly solitary, in pairs, or in various aggregates; perforation plate scalariform; rays three to many cells in width, often massive, dispersed between uniseriate rays.

Ribes setosum (28a and 28b)

(Same synopsis as for Ribes irriguum, page 30)

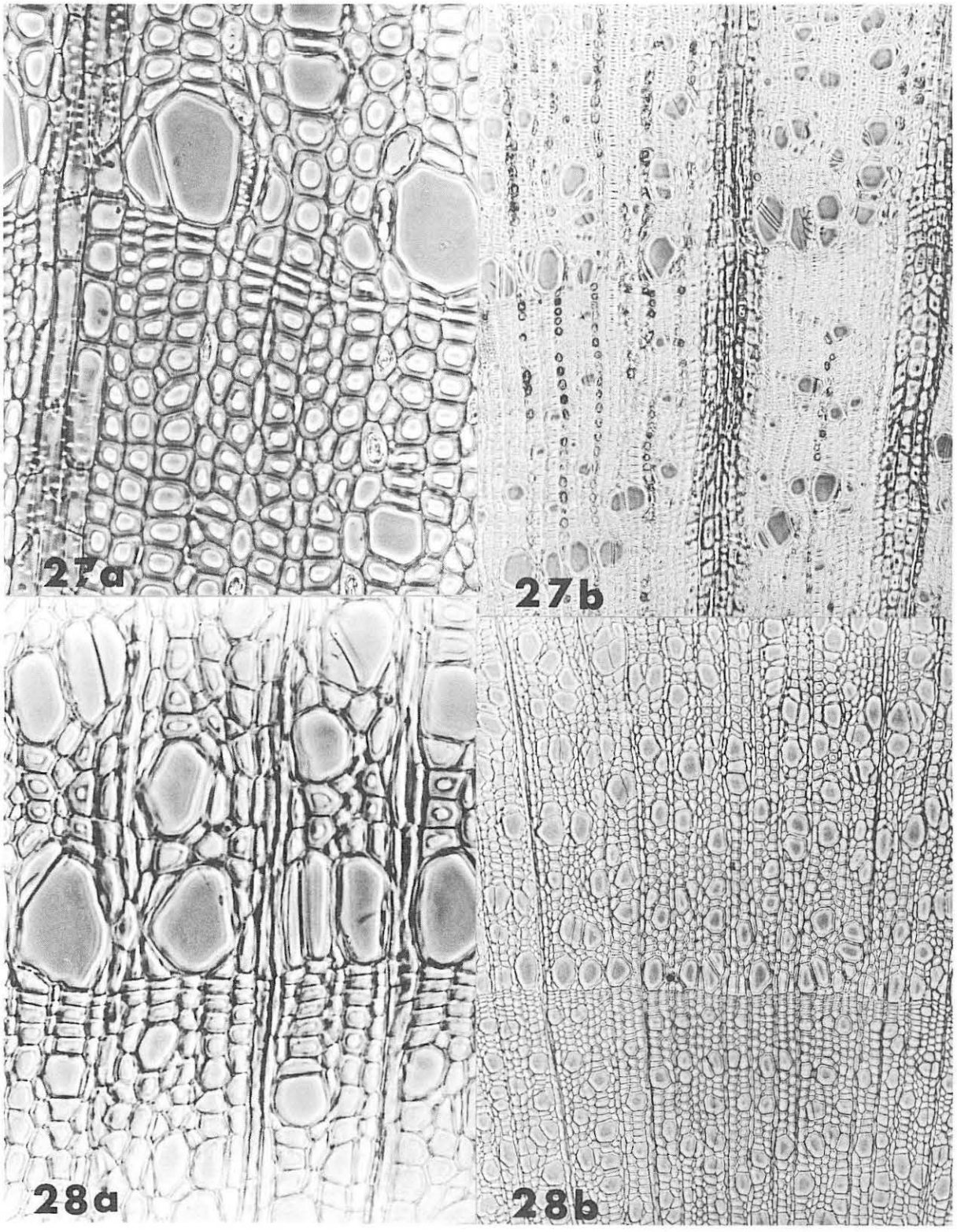

27a
27b
28a
28b

PLATE XIV

Ribes viscosissimum (29a and 29b)

Vessels present; vessels predominantly solitary, in pairs, or in various aggregates; vessels forming a zigzag pattern, radially alined; perforation plates scalariform; rays three to many cells in width, often massive, dispersed between uniseriate rays.

Ribes irriguum (26c*)

(See page 30)

Ribes lacustre (27c**)

(See page 32)

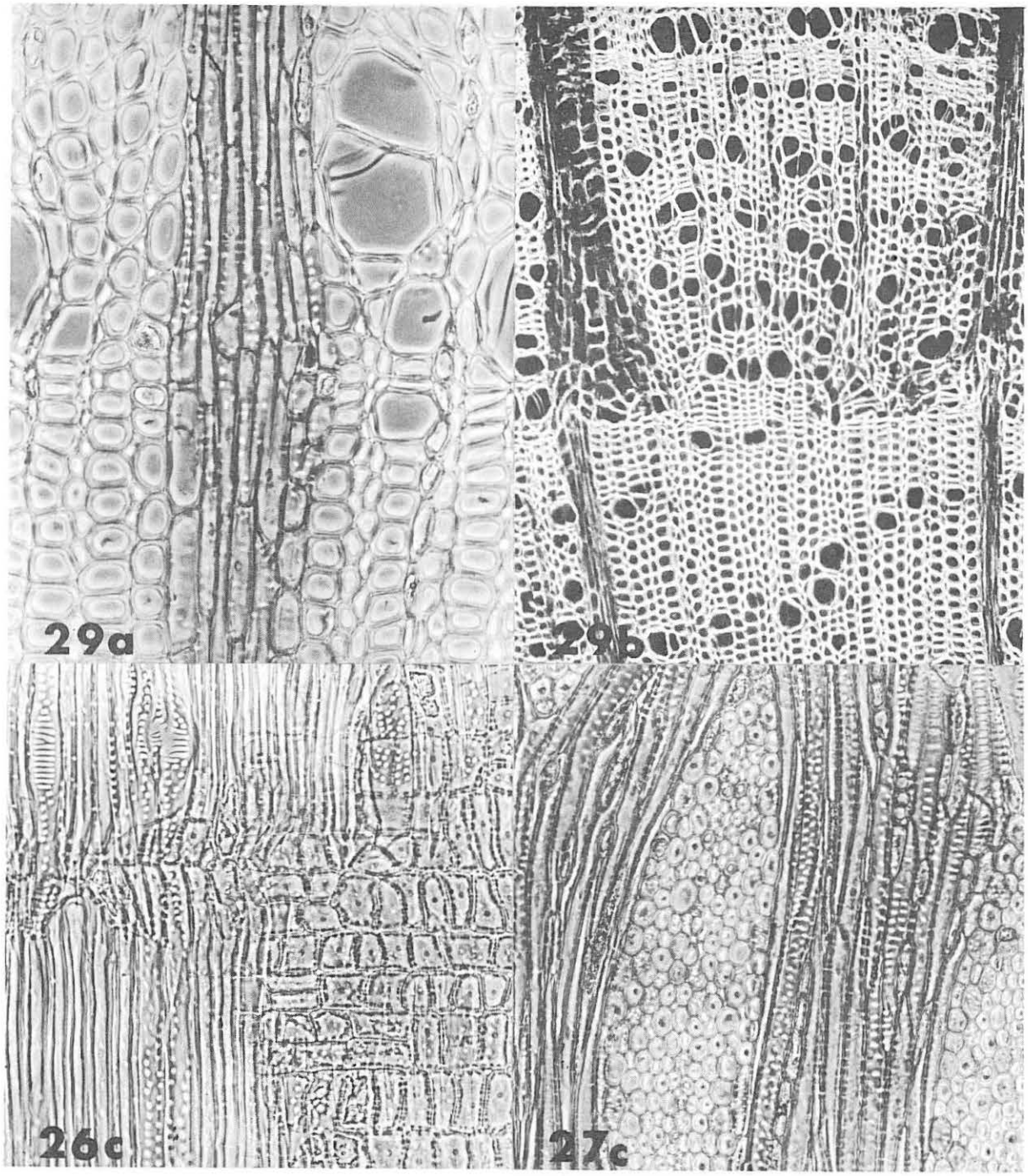

29a
29b
26c
27c

PLATE XV

Acer glabrum (30a, 30b, 30c**, and 30d*)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessels with spiral thickenings; perforation plates simple; rays composed of procumbent cells only; rays mainly uniseriate but some two to four cells wide.

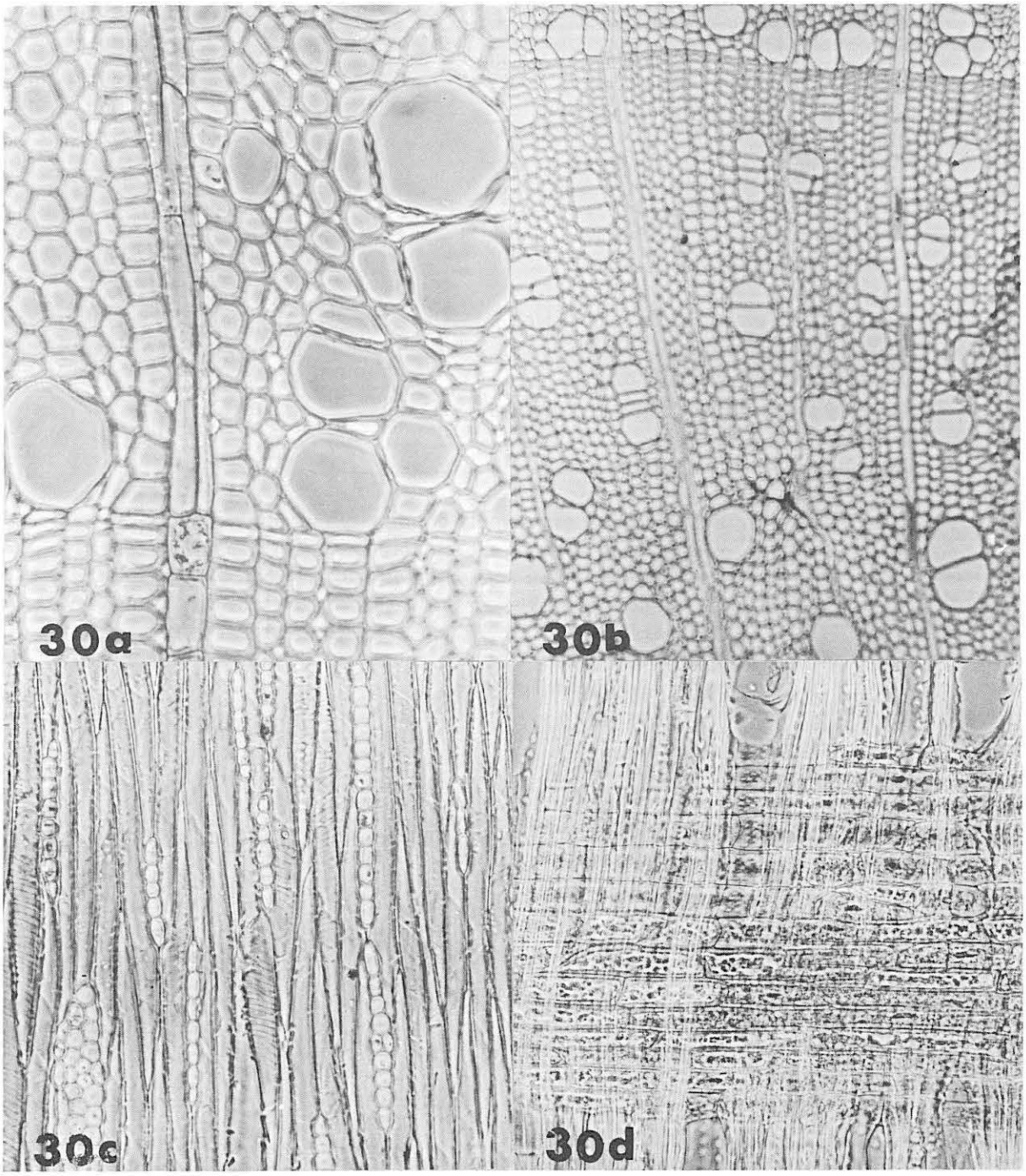

30a
30b
30c
30d

PLATE XVI

Populus tremuloides (31a and 31b) and

Populus trichocarpa (32a and 32b)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessels without spiral thickenings; perforation plates simple; rays composed of procumbent cells only; rays uniseriate only.

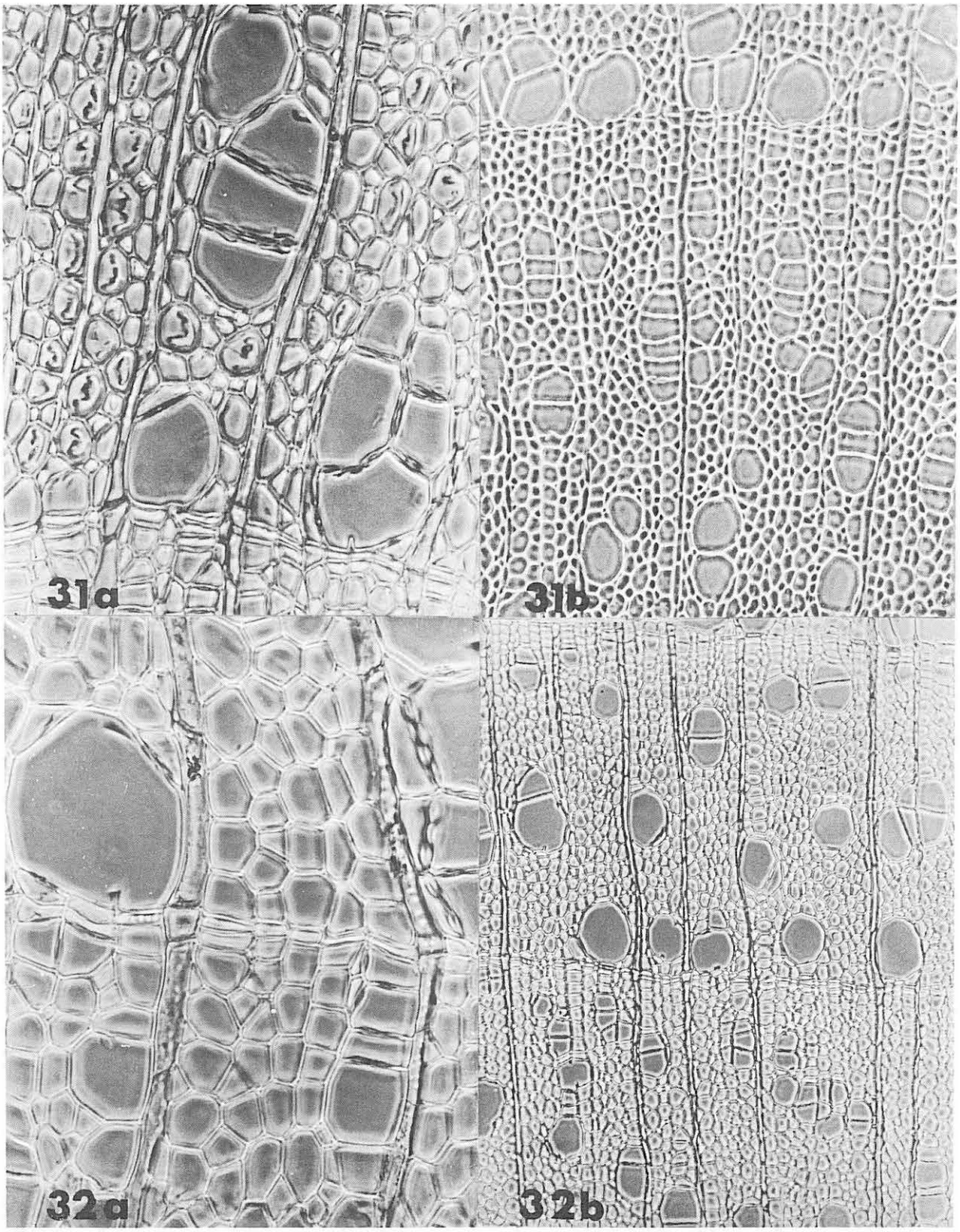

31a
31b
32a
32b

PLATE XVII

Salix scouleriana (33a, 33b, and 33c*)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessel perforation plates simple; rays composed of both procumbent and upright cells; rays uniseriate only.

Populus trichocarpa (32c*)

(See page 38)

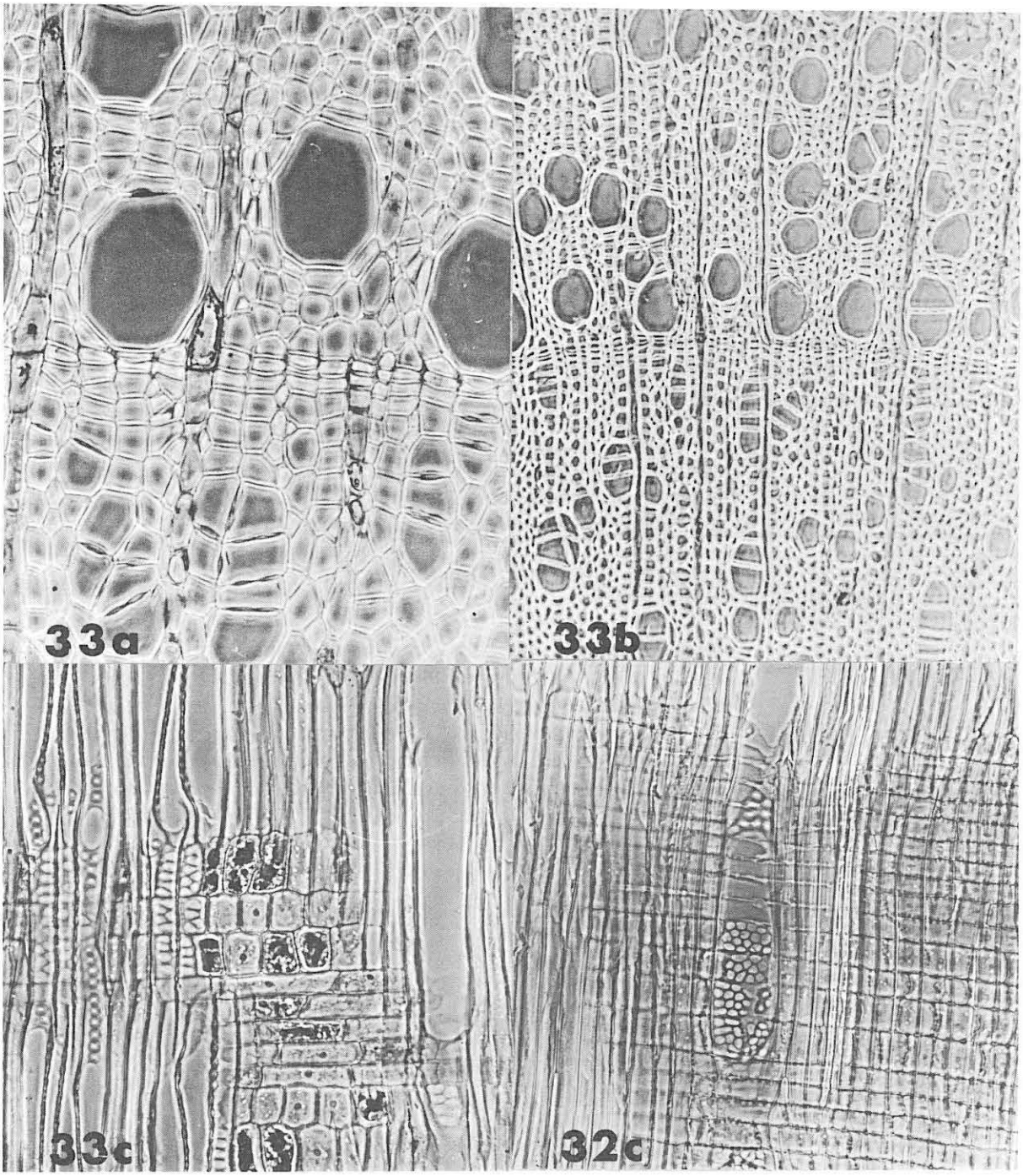

33a
33b
33c
32c

PLATE XVIII

Alnus incana (34a and 34b)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessel perforation plates scalariform; axial parenchyma forming tangential bands at short intervals between rays; rays uniseriate only.

Alnus sinuata (35a and 35b)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessel perforation plates scalariform; axial parenchyma sparse and diffuse; rays uniseriate only.

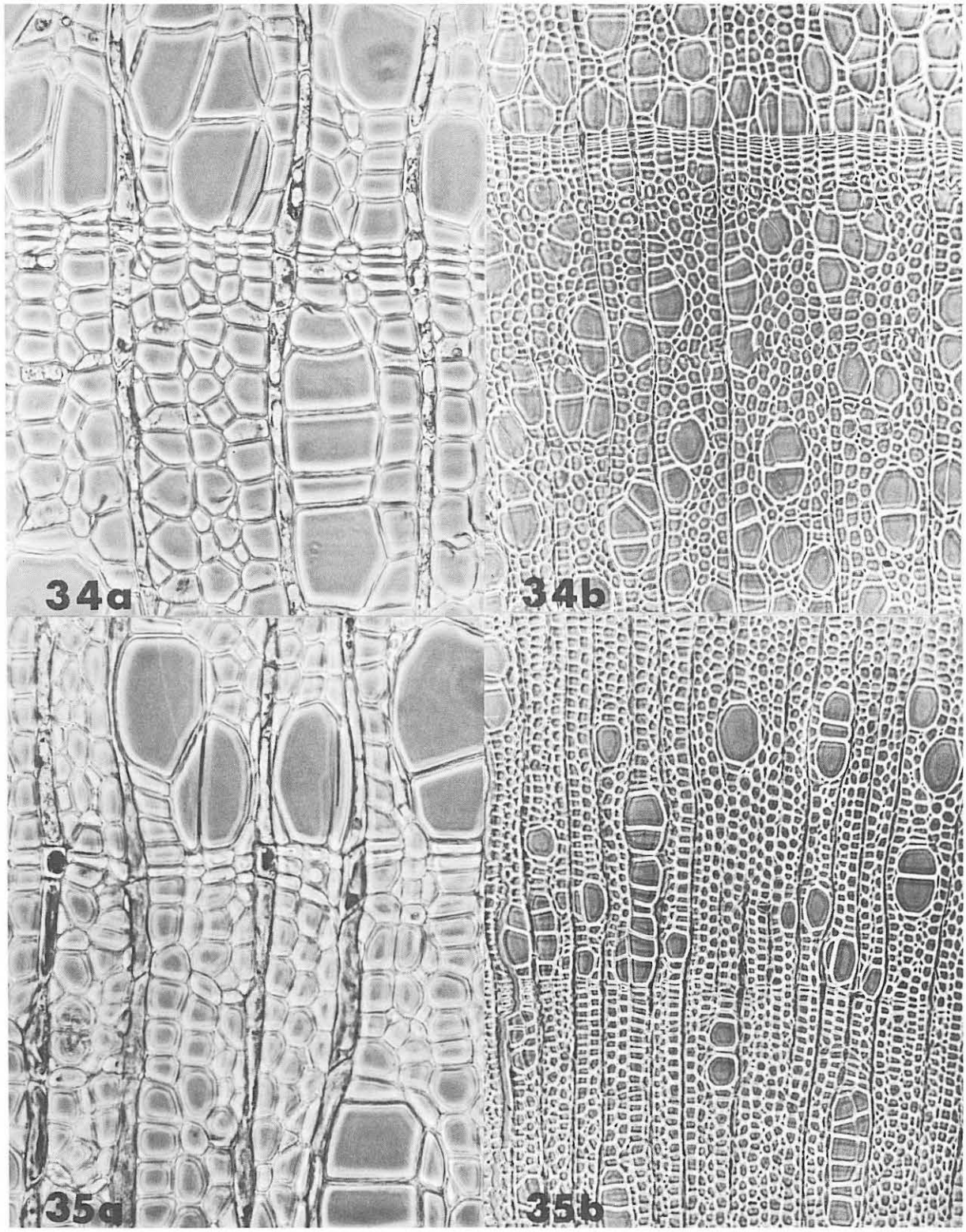

34a
34b
35a
35b

PLATE XIX

Betula glandulosa (36a and 36b) and

Betula occidentalis (37a and 37b)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessel perforation plates scalariform; rays both one and two cells in width.

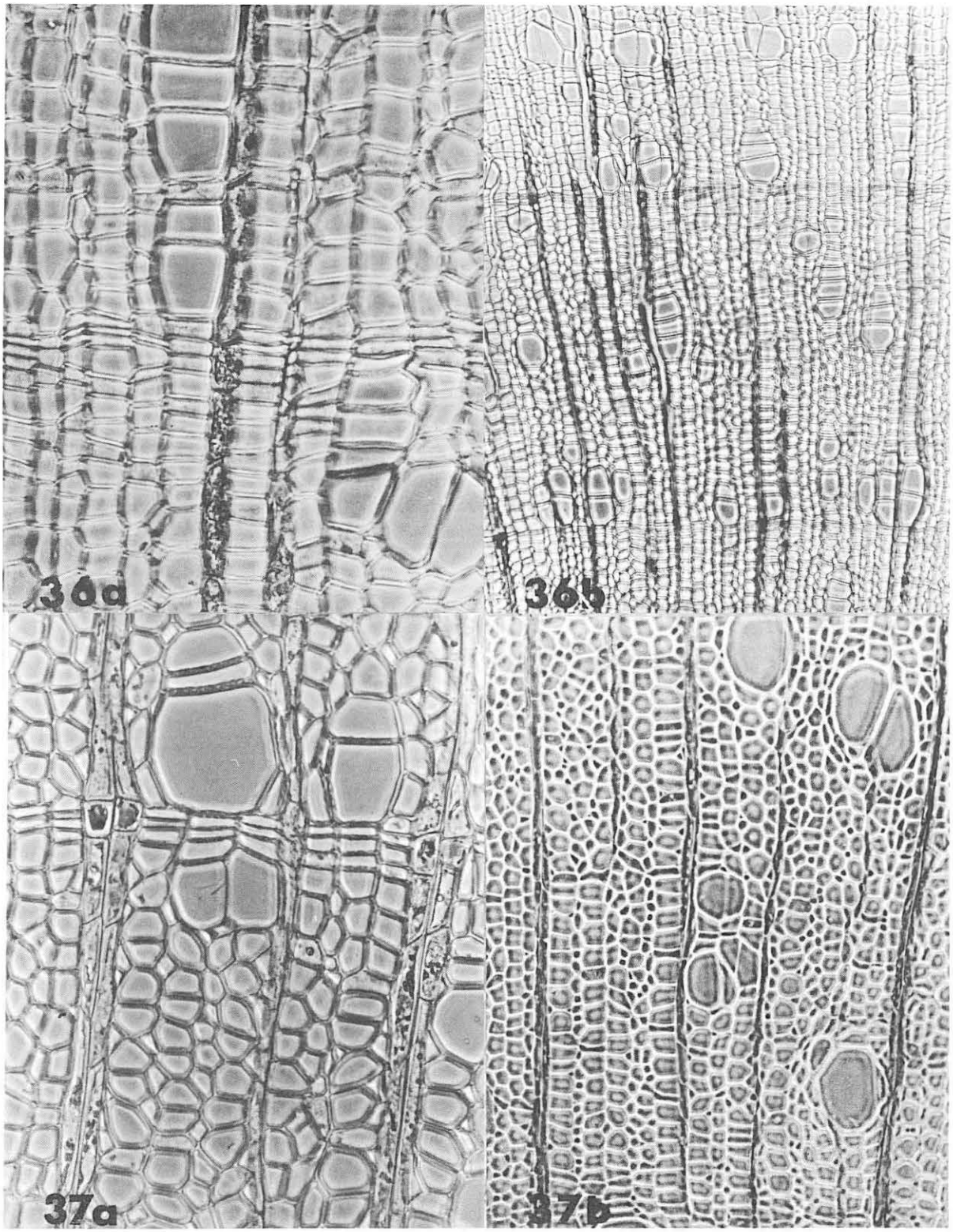

36a
36b
37a
37b

PLATE XX

Cornus stolonifera (38a, 38b, and 38c*)

Vessels present; vessels solitary or in pairs (appearing as a bisected vessel); vessels regular in size and spacing throughout growth ring; perforation plates scalariform; rays one or two cells in width (rarely three).

Alnus sinuata (35c*)

(See page 42)

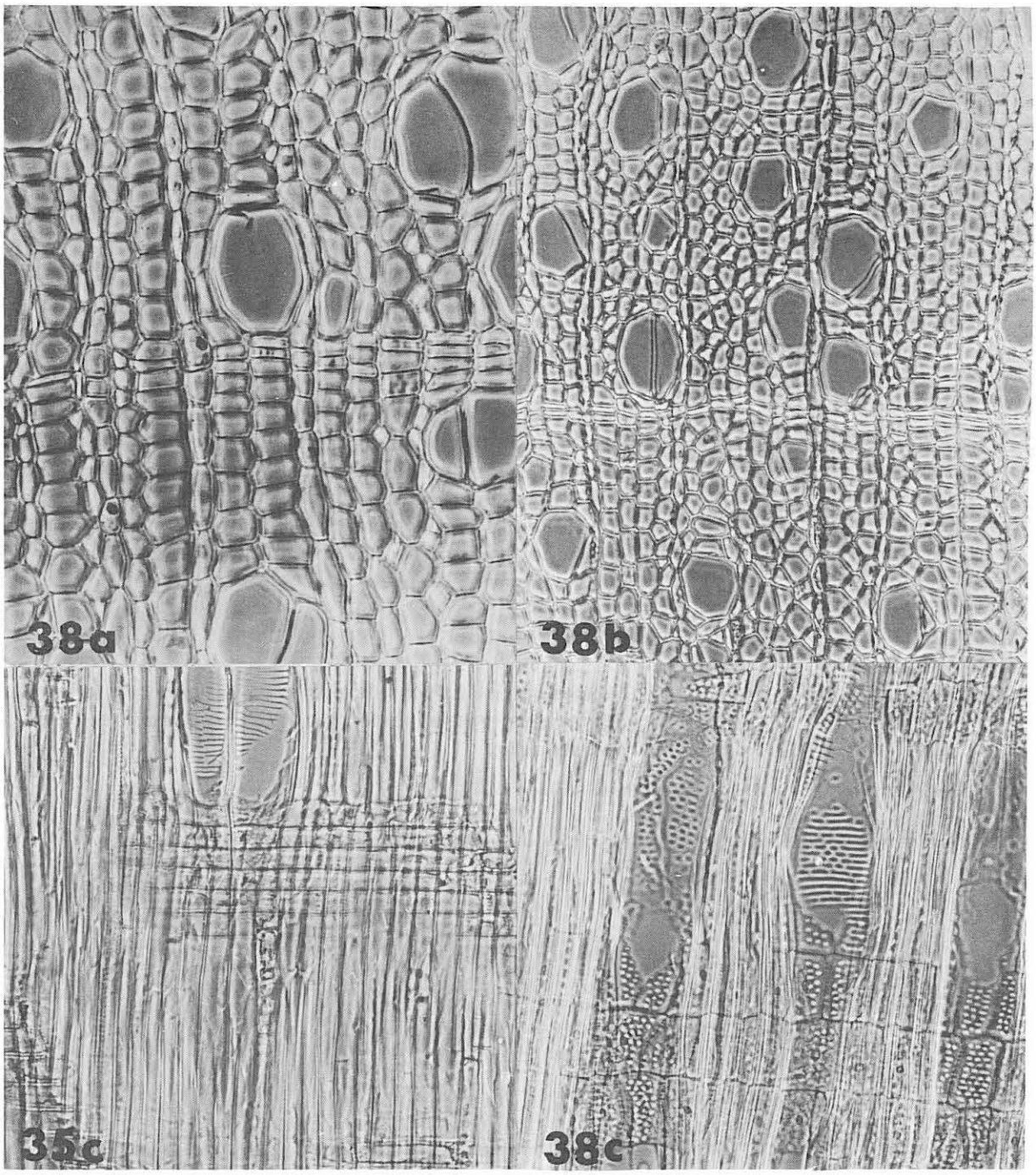

38a
38b
35c
38c

PLATE XXI

Arctostaphylos uva-ursi (39a, 39b, and 39c*)

Vessels present; vessels solitary, in pairs, or in various aggregates; annual ring initiated by a definite band of large vessels; other vessels are much smaller and sparse, giving a two-banded appearance to the growth ring; perforation plates simple; axial parenchyma few, if in contact with a vessel, a single cell rather than an encircling band; rays one or two cells wide (rarely three).

Ledum glandulosa (40a and 40b)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessel perforation plates scalariform; rays uniseriate only.

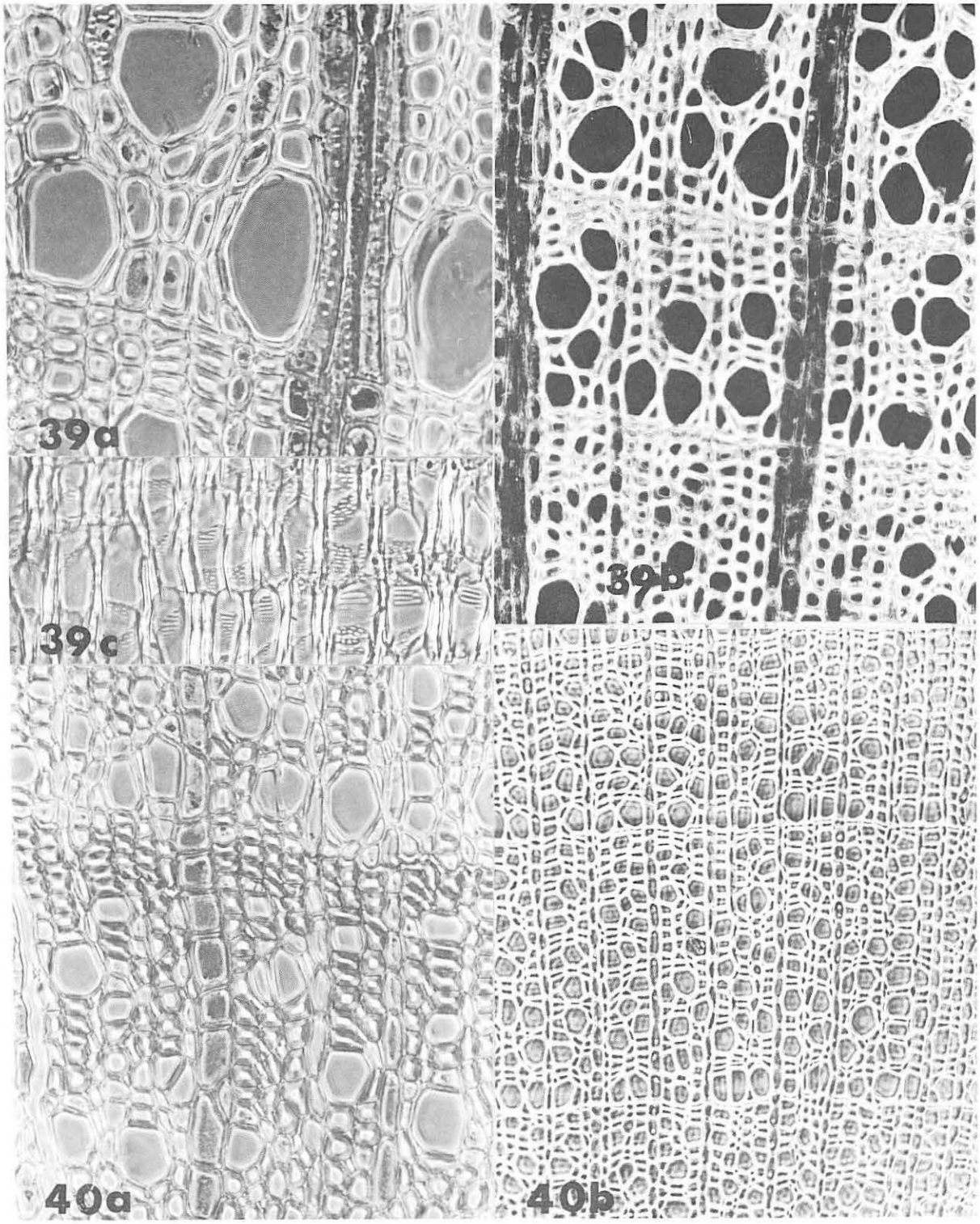

39a
39b
39c
40a
40b

PLATE XXII

Menziesia ferruginea (41a, 41b, and 41c*)

Vessels present; growth ring initiated by a single row of large, closely spaced vessels; vessels solitary, in pairs, or in various aggregates; perforation plate scalariform; rays uniseriate only.

Vaccinium membranaceum (42a and 42b)

Vessels present; vessels solitary, in pairs, or in various aggregates; perforation plate scalariform; rays one to several cells wide.

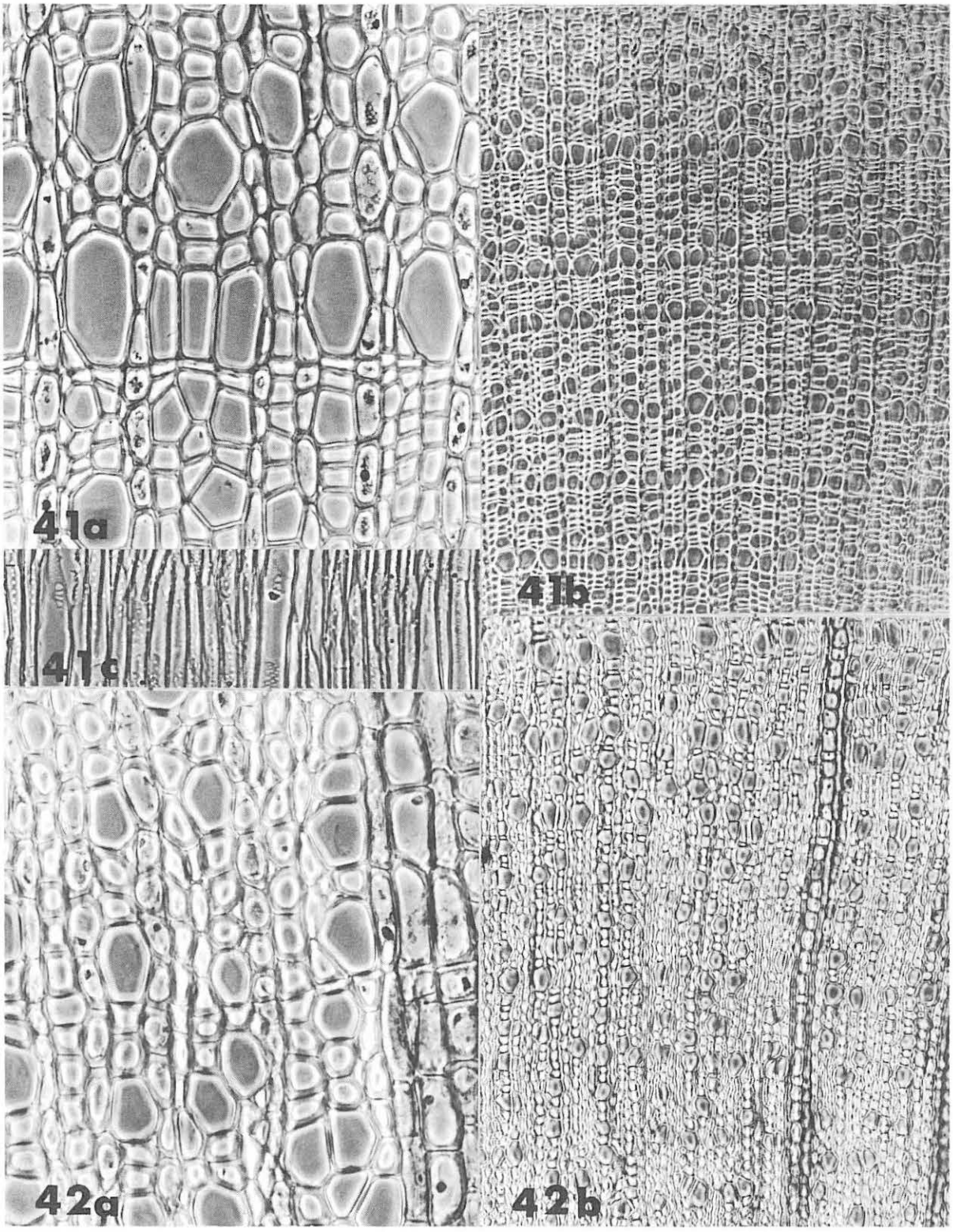

41a
41b
41c
42a
42b

PLATE XXIII

Vaccinium scoparium (43a, 43b, and 43c*)

(Same synopsis as for Vaccinium membranaceum, page 50)

Rhus glabra (44a and 44b)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels solitary or in clusters of a few cells in the early wood progressing to radial files which are grouped secondarily to form tangential bands in the late wood; perforation plate simple; axial parenchyma distributed as two to several cells on the periphery of each vessel group; rays one or two cells wide (rarely three).

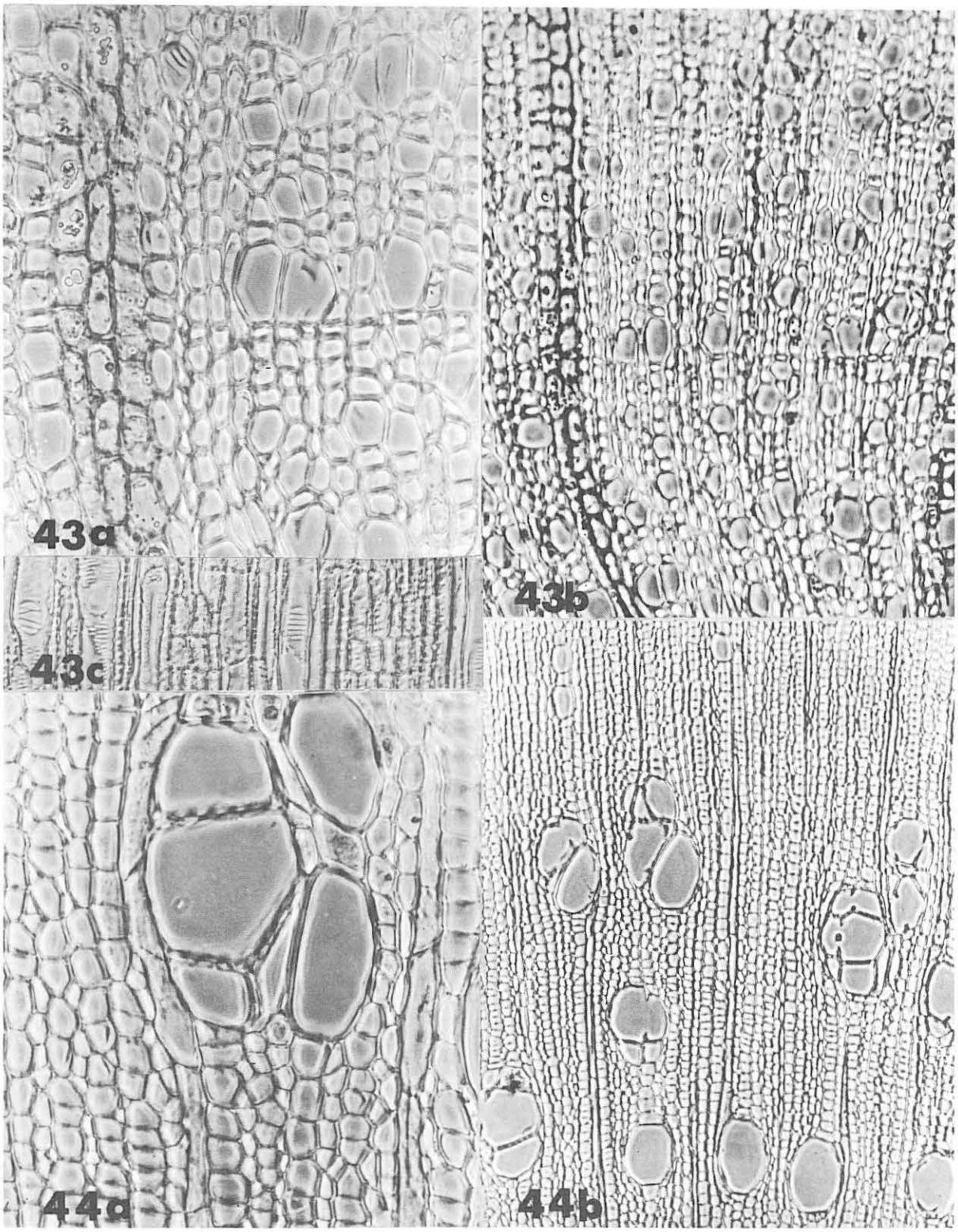
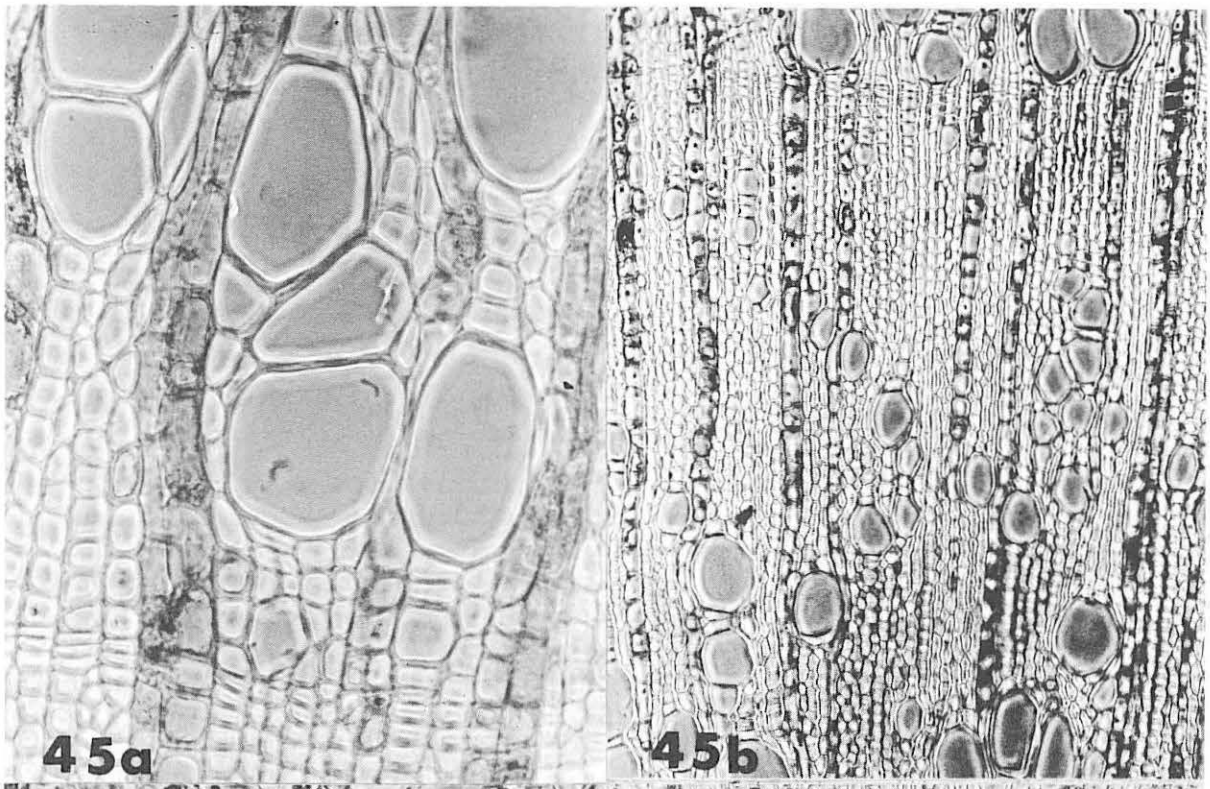

43a
43b
43c
44a
44b

PLATE XXIV

Ceanothus sanguineus (45a and 45b) and

Ceanothus velutinus (46a and 46b)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels occurring in patterns of radially alined S curves in mature wood; perforation plates simple; axial parenchyma predominantly diffuse; rays one or two cells in width (rarely three); tannins occurring in even the young ray cells.


45a
45b

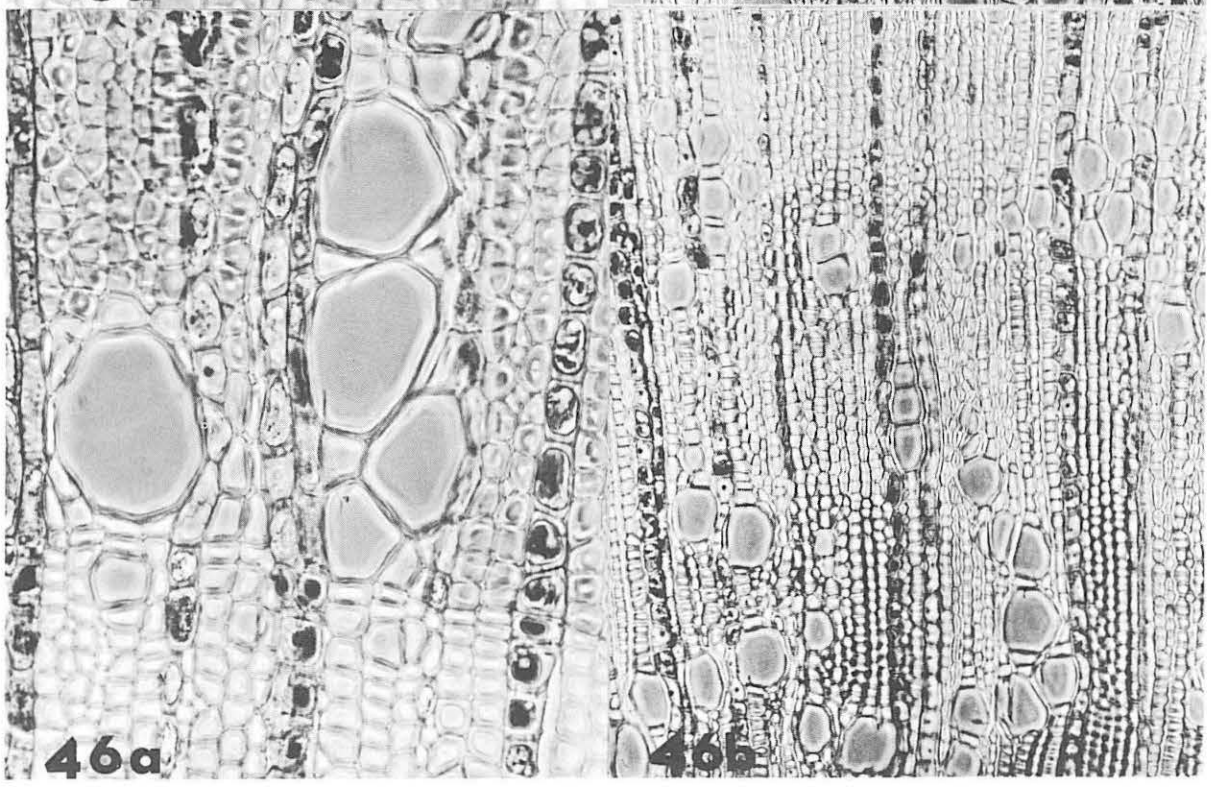

46a
46b

PLATE XXV

Rhamnus alnifolia (47a and 47b)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels arranged in diagonal and/or radial lines; vessels angular in outline; perforation plates simple; axial parenchyma predominantly terminal rays one or two cells in width (rarely three).

Rhamnus purshiana (48a, 48b, and 48c*)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels solitary or in occasional multiples of a few cells; vessels angular in outline; perforation plates simple; axial parenchyma predominantly terminal rays; one or two cells in width (rarely three).

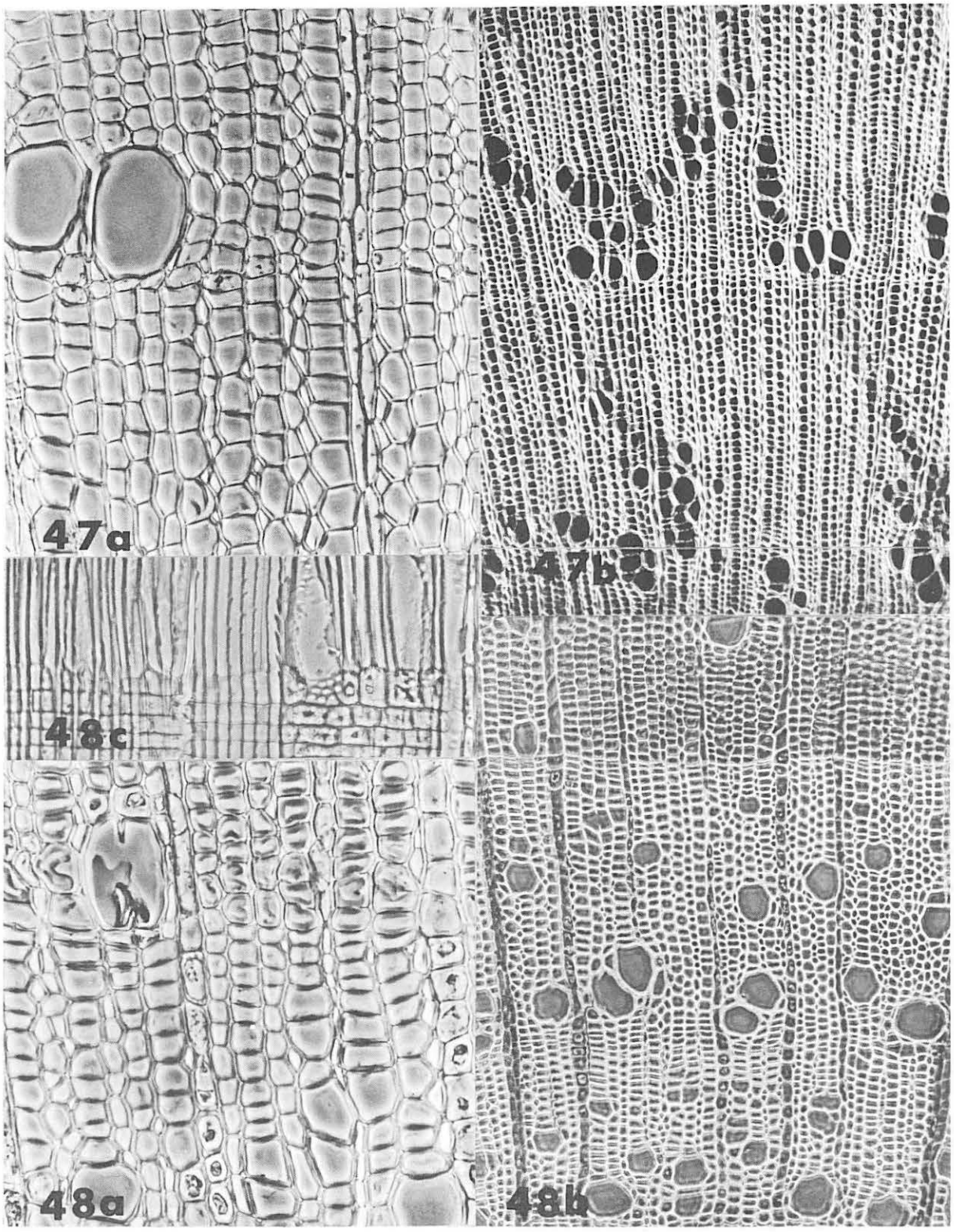

47a
47b
48c
48a
48b

PLATE XXVI

Lonicera involucrata (49a and 49b)

Vessels present; vessels angular in outline; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessel perforation plates simple; axial parenchyma present though sparse and diffuse; rays one or two cells in width (rarely three), ray cells radially elongated in cross sections.

Lonicera utahensis (50a, 50b, and 50c*)

Vessels present; vessels angular in outline; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessel perforation plates simple; axial parenchyma present though sparse and diffuse; rays one or two cells in width (rarely three); ray cells squared in outline in cross sections.

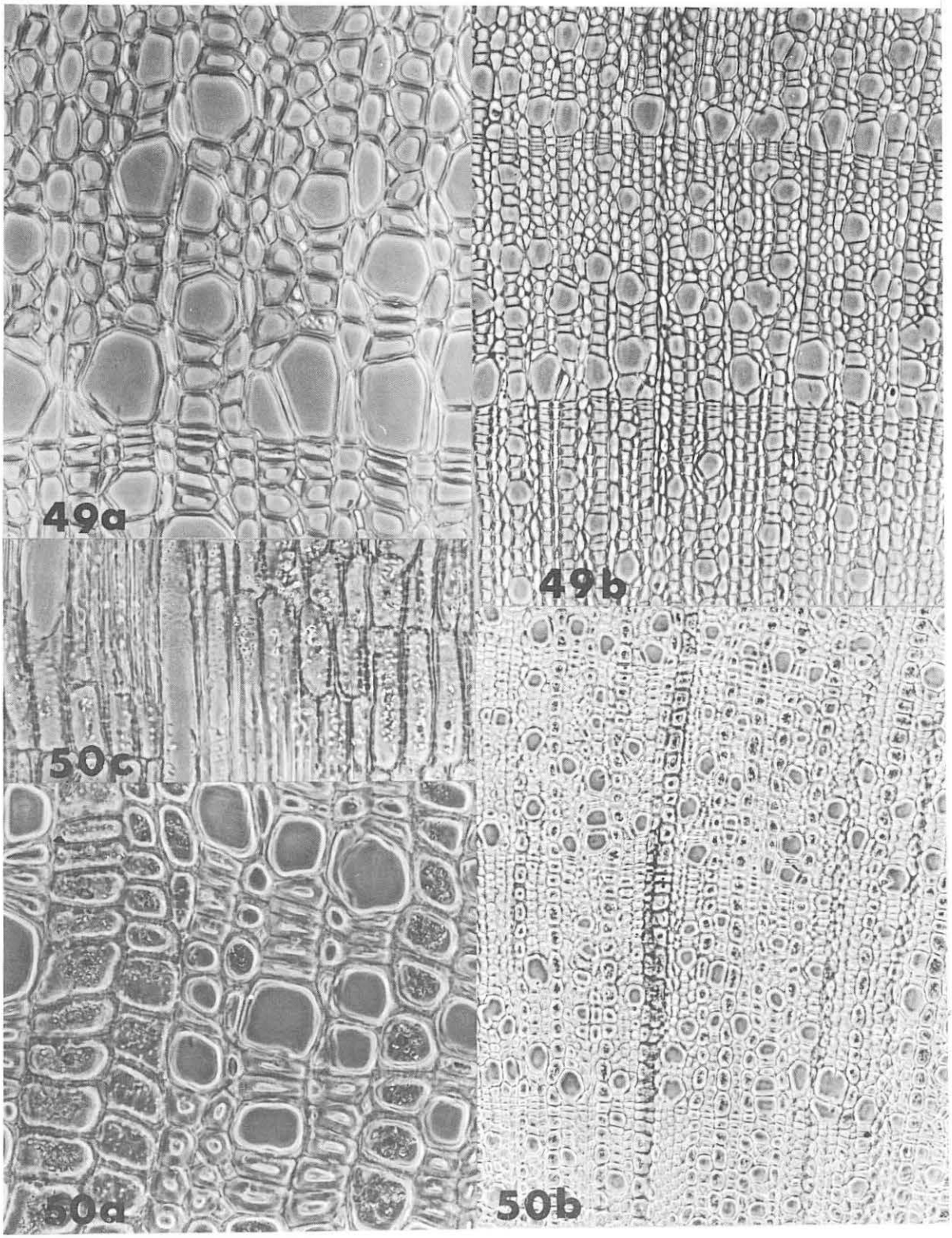

49a
49b
50c
50d
50b

PLATE XXVII

Sambucus cerulea (51a and 51b) and

Sambucus racemosa (52a and 52b)

Vessels present; vessels commonly in radial multiples; often spring wood vessels are closely spaced singles or in irregular clusters (some appearing as subdivisions of a single vessel), the vessels progressing toward formation of radial multiples from early to late wood; vessel perforation plates simple; rays composed of both procumbent and upright cells; rays two to four cells in width.

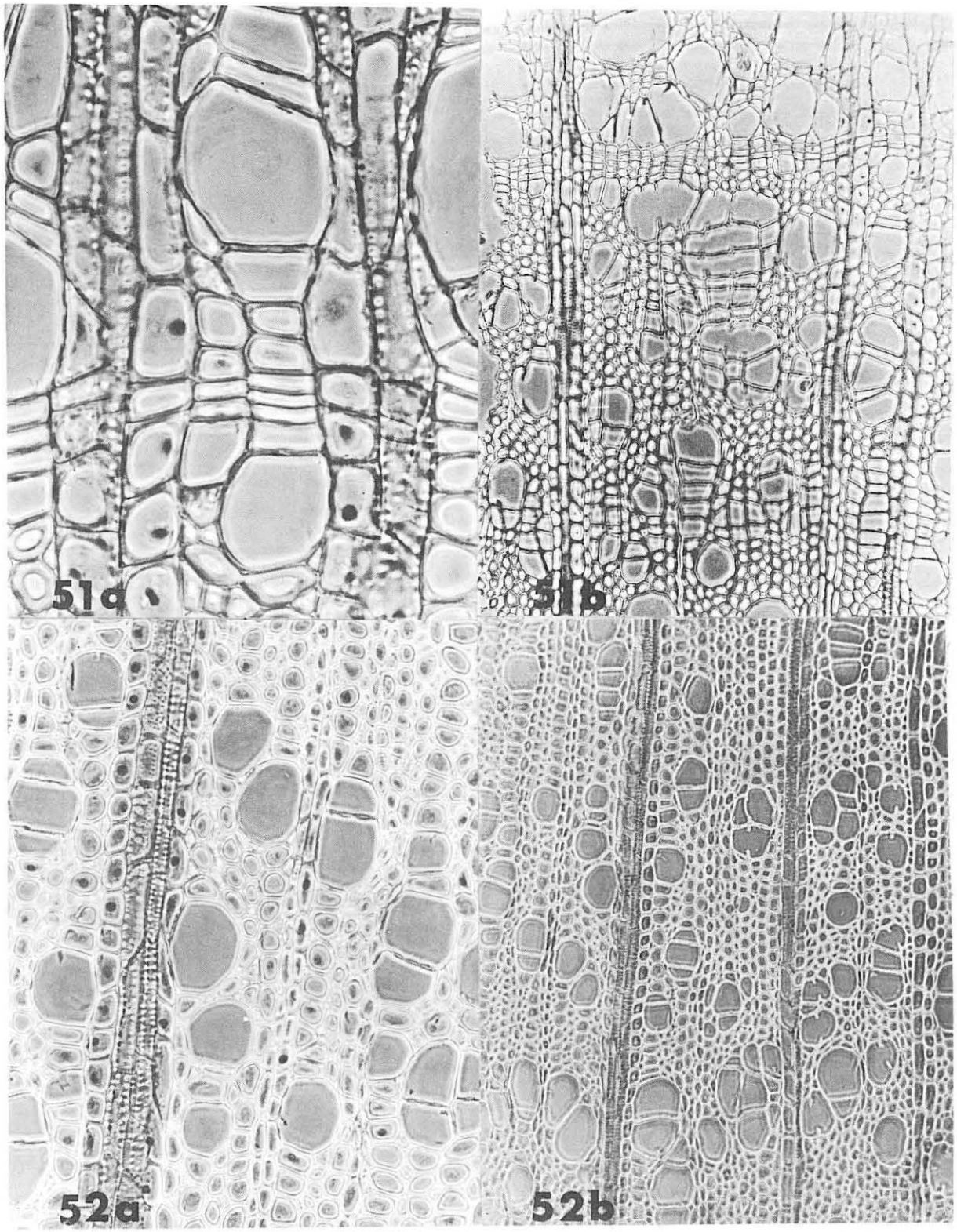

51a
51b
52a
52b

PLATE XXVIII

Sambucus racemosa (52c* and 52d**)

(See page 60)

Symphoricarpos albus (53a and 53b)

Vessels present; vessels solitary, in pairs, or in various aggregates; annual ring initiated by a definite band of large vessels; other vessels are much smaller and sparse, giving a two-banded appearance to the growth ring; perforation plates simple; axial parenchyma numerous, paratracheal and diffuse, often encircling the larger vessels, rays one or two cells wide (rarely three).

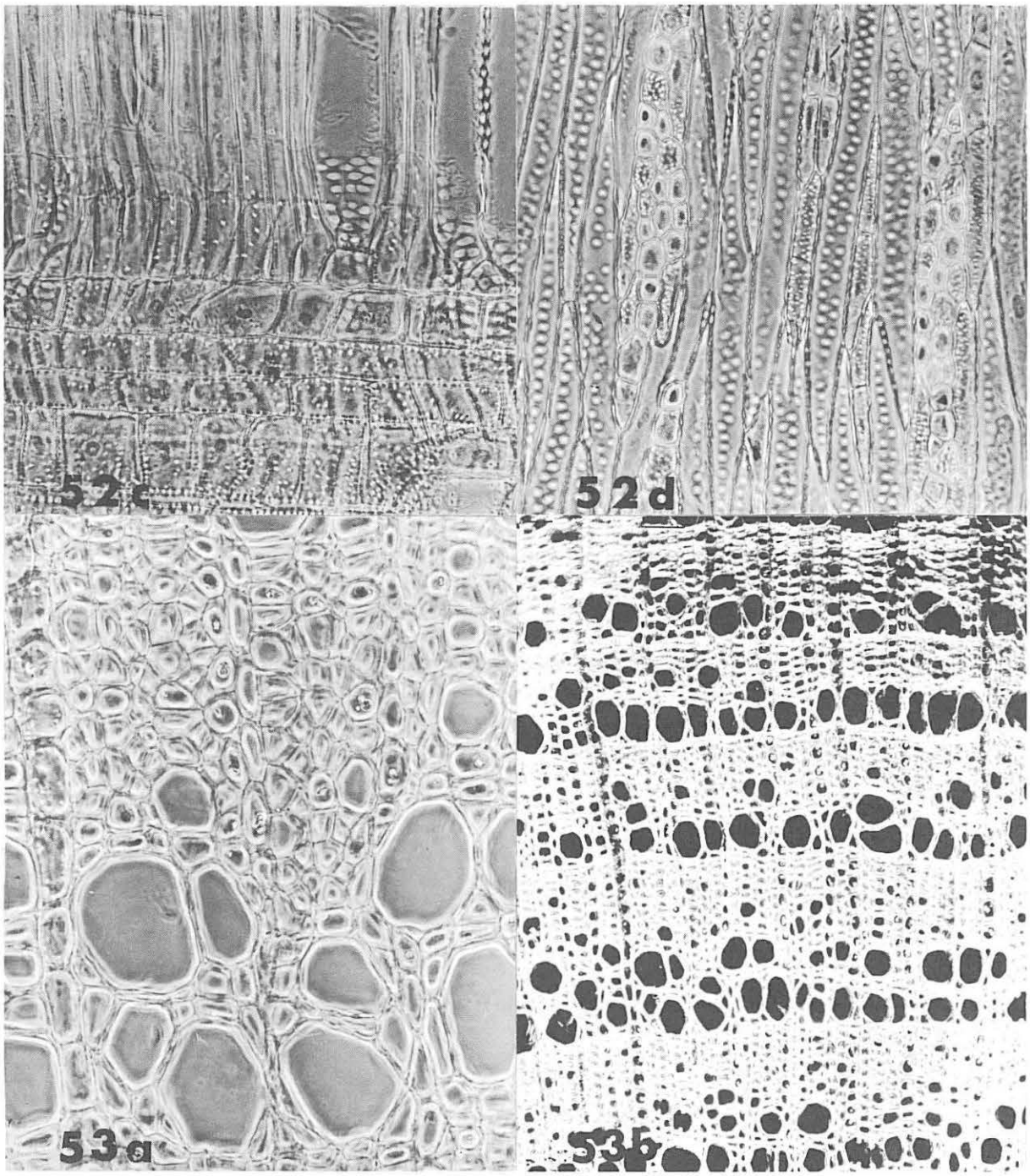

52c
52d
53a
53b

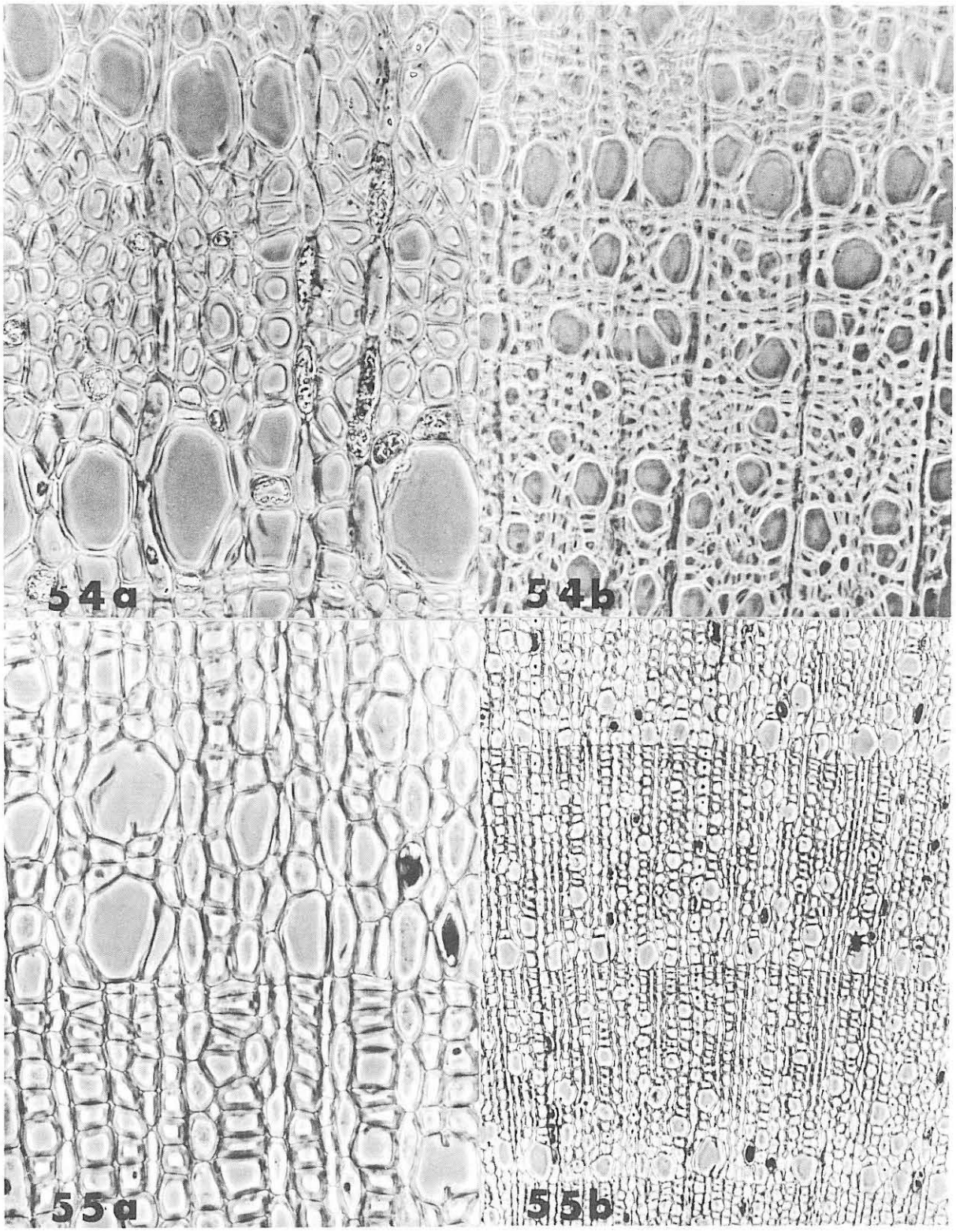
PLATE XXIX

Shepherdia canadensis (54a and 54b)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessels tend to form concentric bands within the growth ring; vessels relatively few and large; vessel walls composed of five or six facets, giving the vessel a definitely angular appearance; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessel perforation plates simple; axial parenchyma absent or sparse, diffuse; rays one or two cells in width (rarely three).

Pachistima myrsinites (55a and 55b)

Vessels present; vessels solitary, in pairs, or in various aggregates; vessels grade into smaller sizes as the growing season progresses without an abrupt change in size; vessels diffuse; perforation plate simple; axial parenchyma distributed as an occasional single cell adjacent to a vessel; rays one or two cells wide (rarely three).


54a
54b
55a
55b

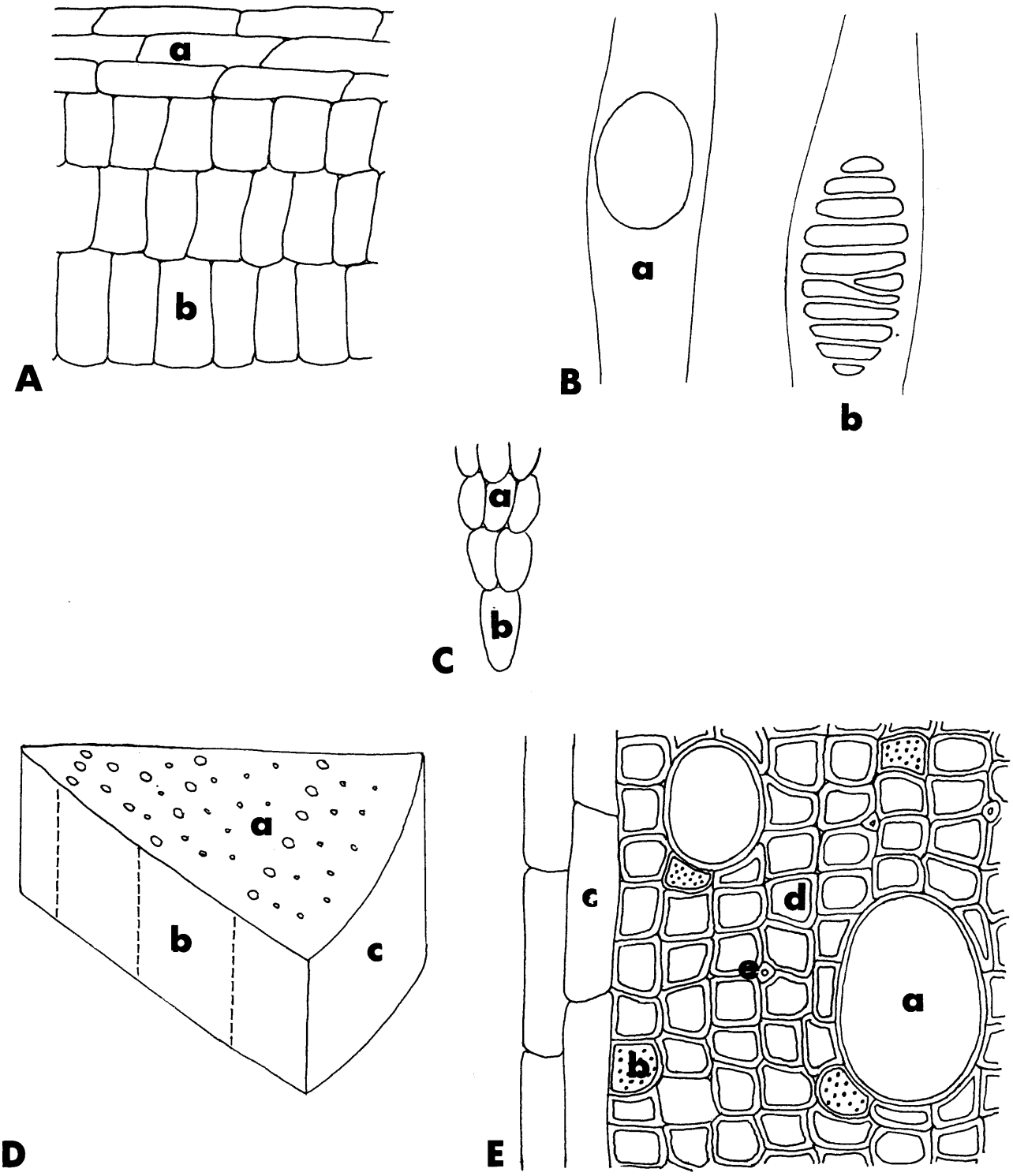


PLATE XXX. DIAGRAMS OF WOOD CHARACTERS. A, (a) procumbent ray cells in radial view; (b) upright ray cells in radial view. B, (a) simple perforation plate; (b) scalariform perforation plate. C, (a) procumbent ray cells in tangential view; (b) upright ray cells in tangential view. D, (a) cross or transverse view; (b) radial view; (c) tangential view. E, xylem elements as seen in cross view: (a) vessel; (b) axial parenchyma; (c) ray parenchyma; (d) tracheid; (e) fiber.

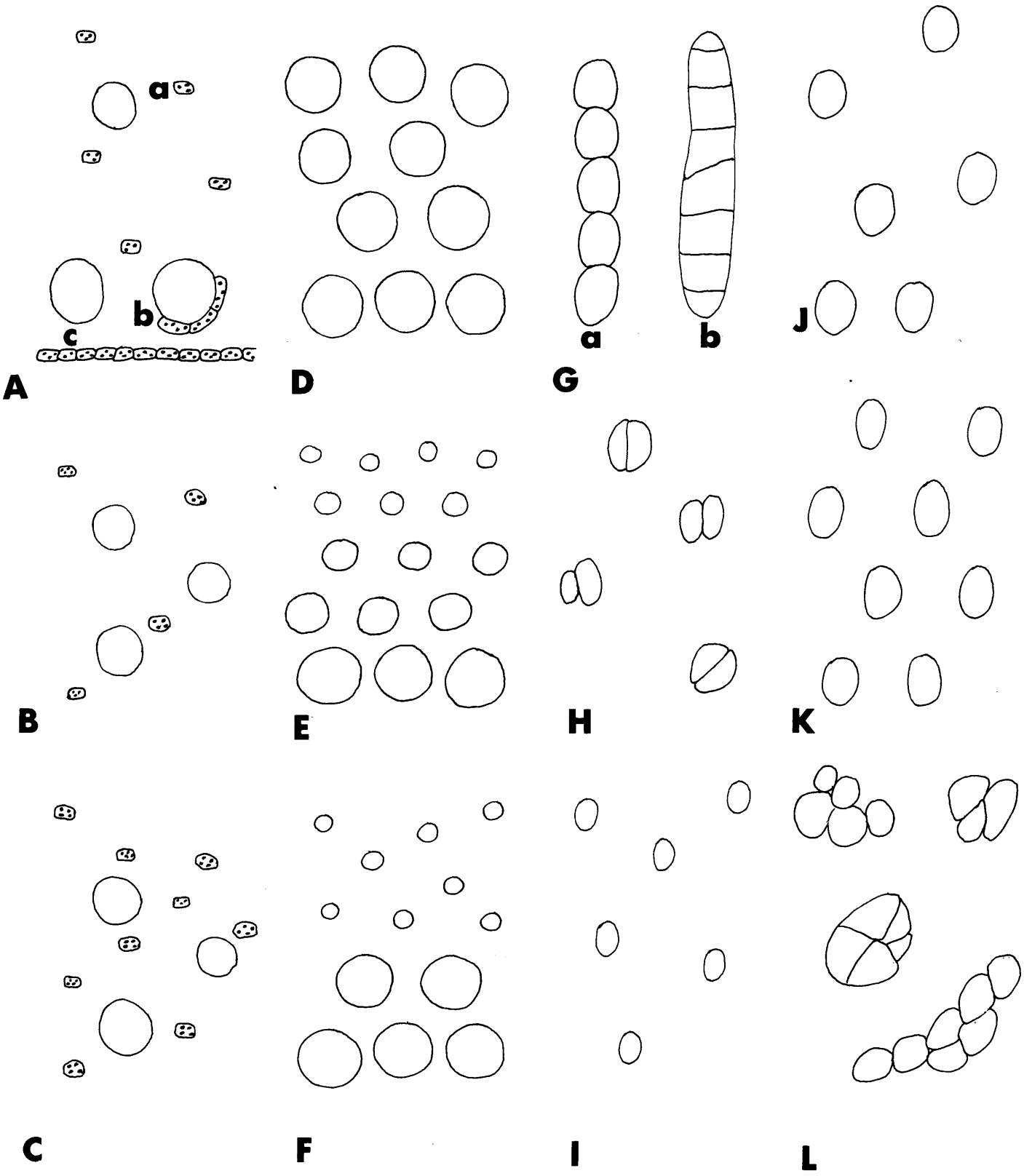


PLATE XXXI. DIAGRAMS OF WOOD CHARACTERS. A, axial parenchyma distribution: (a) diffuse; (b) paratracheal; (c) terminal. B, axial parenchyma few. C, axial parenchyma numerous. D, vessels not changing in size in growth ring. E, vessels changing gradually in size in growth ring. F, vessels changing abruptly in size in growth ring. G, radial vessel alinement: (a) radial chain; (b) radial multiple. H, types of vessel pairs. I, solitary vessels. J, spacing of vessels increases in growth ring. K, spacing of vessels remains similar in growth ring. L, types of vessel aggregates.

GLOSSARY[4]

Cell.--A chamber or compartment at some time containing a protoplast; cells form the structural units of plant tissues.

Fibre, Fiber (Am.).--A general term of convenience in wood anatomy for any long, narrow cell of wood or bast other than vessels and parenchyma. Note: Often further qualified as wood fibres or bast fibres; the former including both the tracheids of gymnosperms and the libriform wood fibres and fibre-tracheids of woody angiosperms. Also used loosely for wood elements in general.

Growth layer.--A layer of wood or bark produced apparently during one growing period; frequently, especially in woods of the temperate zones, divisible into early and late wood or bark (IAWA).

Parenchyma.--Tissue composed of cells that are typically brick-shaped or isodiametric and have simple pits; formed in wood from (a) fusiform cambial initials by later transverse divisions of the daughter cells (axial parenchyma), or (b) ray initials (ray or radial parenchyma). Syn. Soft tissue, Storage tissue. See also Parenchyma cell, fusiform. Note: Primarily concerned with the storage and distribution of food materials. Termed wood parenchyma or xylem parenchyma if occurring in the xylem, and phloem parenchyma if in the phloem.

Parenchyma, apotracheal.--Axial parenchyma typically independent of the pores or vessels. Note: This includes Terminal, Diffuse, and Banded apotracheal parenchyma.

Parenchyma, axial.--Parenchyma cells derived from fusiform cambial initials. Syn. Longitudinal parenchyma (deprec.), Vertical parenchyma (deprec.), cf. Parenchyma, ray.

Parenchyma, diffuse.--Single apotracheal parenchyma strands or cells distributed irregularly among fibres, as seen in cross section (IAWA modif.).

Parenchyma, paratracheal.--Axial parenchyma associated with the vessels or vascular tracheids (IAWA modif.). Note: This includes Scanty paratracheal, Vasicentric, Aliform and Confluent parenchyma.

Parenchyma, ray.--Parenchyma composing the rays wholly or in part. (IAWA modif.). Syn. Radial parenchyma.

Parenchyma, terminal.--Apotracheal parenchyma cells occurring either singly or forming a more or less continuous layer of variable width at the close of a season's growth. Note: Before a distinction was made between "terminal" and "initial" parenchyma, this term was used to include both forms and is still used in this sense as a term of convenience.

Perforation, simple.--A single and usually large and more or less rounded opening in the perforation plate, cf. Perforation, multiple (IAWA).

---

[4] Excerpts from Committee on Nomenclature, International Association of Wood Anatomists. International Glossary of Terms Used in Wood Anatomy. 1957.

Perforation, vessel.--An opening from one vessel member to another (IAWA).

Perforation plate.--A term of convenience for the area of the wall (originally imperforate) involved in the coalescence of two members of a vessel (IAWA).

Perforation plate, scalariform.--A plate with multiple perforations elongated and parallel. The remnants of the plate between the openings are called Bars (IAWA).

Pit.--A recess in the secondary wall of a cell, together with its external closing membrane; open internally to the lumen. Note: Essential components are the pit cavity and the pit membrane (IAWA modif.).

Pore.--A term of convenience for the cross section of a vessel or of a vascular tracheid (IAWA).

Pore, solitary.--A pore completely surrounded by other elements (IAWA).

Pore chain.--A series or line of adjacent solitary pores (IAWA).

Pore multiple.--A group of two or more pores crowded together and flattened along the lines of contact so as to appear as subdivisions of a single pore (IAWA). Note: The most common type is a Radial pore multiple, in which the pores are in radial files with flattened tangential walls between them. Another type is a Pore cluster, in which the grouping is irregular.

Protoplast.--The mass of protoplasm enclosed by a cell wall.

Ray.--A ribbonlike aggregate of cells formed by the cambium and extending radially in the xylem and phloem (IAWA modif.). Note: The terms Medullary ray and Pith ray are now restricted to the parenchyma connecting the primary cortex with the pith.

Ray, multiseriate.--A ray two or more cells wide as seen in tangential section.

Ray, uniseriate.--A ray one cell wide as seen in tangential section.

Ray cell, procumbent.--A ray cell with its longest axis radial (IAWA).

Ray cell, upright.--A ray cell with its longest dimension axial (IAWA modif.). Note: Such cells compose certain uniseriate rays and parts, typically the margins, of some multiseriate rays.

Ring, annual.--In wood and bark, a growth layer of 1 year as seen in cross section (IAWA modif.), cf. Ring, growth.

Ring, growth.--In wood and bark a growth layer as seen in cross section (IAWA modif.).

Spiral thickening.--Helical ridges on the inner face of, and part of, the secondary wall (IAWA). Note: Often erroneously called tertiary spirals to distinguish them from the spirals of primary xylem.

Storied (storeyed).--A term applied to the axial cells and rays in wood when these are arranged in horizontal series on tangential surfaces. Note: The term is applied to particular tissues, e.g., "storied parenchyma" or used in a general sense, as in "woods with storied structure." The presence of storied structure is the cause of the ripple marks visible with the unaided eye.

Tannins.--A heterogeneous group of phenol derivatives; they appear as yellow, red, or brown substances within the cell, commonly in the vacuoles, but also within the cytoplasm.[5]

Tracheid.--An imperforate wood cell with bordered pits to congeneric elements (IAWA modif.).

Vessel.--An axial series of cells that have coalesced to form an articulated tubelike structure of indeterminate length; the pits to congeneric elements are bordered (IAWA modif.). Syn. Trachea.

Vessel member or element.--One of the cellular components of a vessel (IAWA). Syn. Vessel segment (deprec.).

Wood.--The principal strengthening and water-conducting tissue of stems and roots. Characterized by the presence of tracheary elements. Syn. Xylem.

Wood, diffuse-porous.--Wood in which the pores are of fairly uniform or only gradually changing size and distribution throughout a growth ring (IAWA).

Wood, early.--The less dense, larger celled, first formed part of a growth ring (IAWA). Syn. Spring wood.

Wood, late.--The denser, smaller celled, later formed part of a growth ring (IAWA). Syn. Autumn wood (deprec.). cf. Summer wood.

Wood, ring-porous.--Wood in which the pores of the early wood are distinctly larger than those of the late wood and form a well-defined zone or ring, cf. Wood, diffuse-porous (BSI modif.).

Xylem.--See Wood.

---

[5] Description from Esau, Katherine. Plant anatomy, 2d ed. New York: John Wiley & Sons, Inc. 1965.

REFERENCES

1. Carlquist, S. 1958. "Wood anatomy of Heliantheae (Compositae)," Trop. Woods. 108: 1-30.

2. Chattaway, M. Margaret. 1932. "Proposed standards for numerical values used in describing woods," Trop. Woods. 29: 20-29.

3. Committee on Nomenclature, International Association of Wood Anatomists. 1957. "International glossary of terms used in wood anatomy," Trop. Woods. 107: 1-36.

4. Doorenbos, J. 1965. "Juvenile and adult phases in woody plants." In: Encyclopedia of Plant Physiology XV/1. New York: Springer-Verlag.

5. Esau, Katherine. 1965. Plant Anatomy, 2d ed. New York: John Wiley & Sons, Inc.

6. Hill, Ralph R. 1964. Key to identification of Rocky Mountain shrubs by characteristics of the wood and bark. Denver: R. R. Hill, 3535 Benton Street. 9 pp. (mimeo).

7. Hitchcock, A. S. 1925. Methods of Descriptive Systematic Botany. New York: John Wiley & Sons, Inc.

8. Ingle, H. D., and Dadswell, H. E. 1956. "The anatomy of the timbers of the southwest Pacific area. IV. Cunoniaceae, Davidsoniaceae, and Eucryphiaceae," Austral. J. Bot. 4: 125-151.

9. Jane, Frank W. 1956. The Structure of Wood. London: A. & C. Black. 427 pp., illus.

10. Larson, Philip R. 1964. "Some indirect effects of environment on wood formation," In: The Formation of Wood in Forest Trees. New York: Academic Press.

11. Lawrence, George H. M. 1951. Taxonomy of Vascular Plants. New York: The MacMillan Co.

12. Metcalfe, C. R., and Chalk, L. 1950. Anatomy of the dicotyledons. Oxford: Clarendon Press.

13. Panshin, Alexis John. 1964. Textbook of Wood Technology, 2d ed. New York: McGraw-Hill.

14. Record, S. J. 1934. Identification of the timbers of temperate North America. New York: John Wiley & Sons, Inc.

15. Record, S. J., and Chattaway, M. Margaret. 1939. "List of anatomical features used in classifying dicotyledonous woods," Trop. Woods. 57: 11-16.

16. Reinders-Gouwentak, Cornelia. 1965. "Physiology of the Cambium and other secondary meristems." In: Encyclopedia of Plant Physiology XV/1. New York: Springer-Verlag.

17. Tiemann, Harry D. 1951. Wood Technology; constitution, properties and uses. 3d ed. New York: Pitman Pub. Corp.

18. Whaley, W. G. 1965. "The interaction of genotype and environment in plant development." In: Encyclopedia of Plant Physiology XV/1. New York: Springer-Verlag.

SPECIES INDEX

Dale, Arlene.

1968. Comparative wood anatomy of some shrubs native to the Northern Rocky Mountains. U.S. Dep. Agr., Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah, 84401. 73 pp., illus. (U.S. Forest Serv. Res. Pap. INT-45)

This paper describes some xylem characteristics of the more important shrub species of the Northern Rockies and presents a key for identifying shrub-wood specimens by microscopic characters. The paper contains photomicrographs of 55 shrub woods.

Dale, Arlene.

1968. Comparative wood anatomy of some shrubs native to the Northern Rocky Mountains. U.S. Dep. Agr., Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah, 84401. 73 pp., illus. (U.S. Forest Serv. Res. Pap. INT-45)

This paper describes some xylem characteristics of the more important shrub species of the Northern Rockies and presents a key for identifying shrub-wood specimens by microscopic characters. The paper contains photomicrographs of 55 shrub woods.

Dale, Arlene.

1968. Comparative wood anatomy of some shrubs native to the Northern Rocky Mountains. U.S. Dep. Agr., Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah, 84401. 73 pp., illus. (U.S. Forest Serv. Res. Pap. INT-45)

This paper describes some xylem characteristics of the more important shrub species of the Northern Rockies and presents a key for identifying shrub-wood specimens by microscopic characters. The paper contains photomicrographs of 55 shrub woods.

Dale, Arlene.

1968. Comparative wood anatomy of some shrubs native to the Northern Rocky Mountains. U.S. Dep. Agr., Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah, 84401. 73 pp., illus. (U.S. Forest Serv. Res. Pap. INT-45)

This paper describes some xylem characteristics of the more important shrub species of the Northern Rockies and presents a key for identifying shrub-wood specimens by microscopic characters. The paper contains photomicrographs of 55 shrub woods.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Project headquarters are also at:

Boise, Idaho
Bozeman, Montana (in cooperation with Montana State University)
Logan, Utah (in cooperation with Utah State University)
Missoula, Montana (in cooperation with University of Montana)
Moscow, Idaho (in cooperation with the University of Idaho)
Provo, Utah (in cooperation with Brigham Young University)

FOREST SERVICE CREED

The Forest Service of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing nation.