WOOD 280
WOOD ANATOMY AND IDENTIFICATION
2016-17

LABORATORY MATERIAL

TABLE OF CONTENTS

Key for handlens identification of common Canadian wood species

1 Pores absent; general cell structure consisting of distinct radial rows of tracheids visible only with magnification **2**

Pores present; may be visible with or without aid of magnification **12**

2 Resin canals present, mostly confined to latewood **3**

Resin canals normally absent **7**

3 Resin ducts large, relatively distinct and numerous, visible to the naked eye as light or dark spots on cross-section, solitary or in small tangential groups of 2-3; on tangential surface of boards, resin canals visible as fine longitudinal lines or scratches **4**

Resin canals small, relatively inconspicuous, usually not numerous, sometimes absent in some rings, barely visible to the naked eye, solitary or in tangential groups of 2-3 ..... **5**

4 Transition from earlywood to latewood gradual; wood practically uniform, soft, light. ..... **Eastern white pine**, **Western white pine**

Transition from earlywood to latewood more or less abrupt; latewood conspicuous, darker and denser than earlywood. ..... **Lodgepole pine**, **Ponderosa pine, Southern pine**

5 Latewood not very conspicuous; transition from earlywood to latewood gradual; latewood usually occupying less than 1/3 ring width; wood comparatively soft and light; heartwood not coloured or little different from sapwood. ..... **White spruce** ..... **Black spruce**, **Engelmann spruce**

Latewood conspicuous; transition from earlywood to latewood abrupt; latewood usually occupying 1/3 or more of ring width; wood moderately hard and heavy; heartwood coloured **6**

6 Heartwood light reddish brown; sapwood whitish to yellowish or reddish-white; resin canals numerous, mostly in small tangential groups. ..... **Douglas-fir**

Heartwood tending to brown; sapwood whitish; wood surfaces feel oily; resin canals relatively few, mostly solitary or in small tangential groups. ..... **Western larch**, **Tamarak**

7 Wood without aromatic odour **8**

Wood with aromatic odour **9**

8 Transition from earlywood to latewood gradual; earlywood whitish to light brown in colour, latewood brownish. ..... **Subalpine fir**, **Amabilis fir**, **Balsam fir**, **Grand fir**

Transition from earlywood to latewood may be more or less abrupt; wood with a pale reddish-brown tinge. ..... **Western hemlock**, **Eastern hemlock**

9 Heartwood dark, sapwood whitish **10**

Heartwood relatively light coloured **11**

10 Wood moderately hard and heavy; heartwood reddish-brown to dull red; odour and taste mild, not spicy. ..... **Eastern red cedar**

Heartwood reddish brown; odour fragrant; taste faintly bitter; wood moderately soft and light. ..... **Western red cedar**

11 Heartwood yellowish or yellowish-brown; taste somewhat bitter; distinct dour. ..... **Yellow cedar**

Heartwood light brown; odour mild. ..... **Eastern white cedar**

12 Pores with sharp transition in size between earlywood and latewood; wood ring porous **13**

Pores uniform or with gradual transition in size between earlywood and latewood; wood diffuse porous or semi-ring porous **19**

13 Pores in latewood create radial, flame-like designs **14**

Latewood without radial, flame-like designs **15**

14 Small pores of latewood not distinct with hand lens; large pores of earlywood filled with tyloses in heartwood; broad rays commonly exceeding 25mm in height. ..... **White oak**

Pores of latewood distinct with hand lens; tyloses in large pores of earlywood usually absent or sparse; broad rays seldom exceeding 25mm in height. ..... **Red oak**

15 Latewood figured with long or short wavy tangential bands of pores **16**

Latewood not figured by wavy tangential bands of pores; pores in latewood few, solitary or in small multiples **18**

16 Pores in earlywood usually in a single row **17**

Pores in earlywood in more than one row. ..... **Slippery elm**

17 Pores in earlywood regularly spaced with few tyloses; transition to latewood abrupt. ..... **White elm**

Pores in earlywood variable in size, irregularly spaced, and mostly plugged with tyloses; transition to latewood more or less gradual. ..... **Rock elm**

18 Earlywood pores closely spaced, usually in several rows; tyloses present but not abundant; transition from earlywood to latewood abrupt. ..... **White ash**, **Black ash**

Earlywood pores not closely but irregularly spaced, usually in a single row; light coloured tissue (parenchyma) in numerous fine tangential lines plainly visible with a hand lens in latewood; transition from earlywood to latewood gradual. ..... **Hickory**

19 Pores easily visible on all surfaces without hand lens and on longitudinal surfaces appearing as minute grooves or scratches; pores not uniformly distributed throughout growth ring **20**

Pores invisible or barely distinguishable without aid of lens; pores more or less uniformly distributed throughout growth ring **21**

20 Heartwood light chocolate brown or purplish brown; wood hard and heavy with characteristic odour on freshly cut surface. ..... **Black walnut**

Heartwood light chestnut brown; wood soft and light without characteristic odour. ..... **Butternut**

21 Ray of variable width; some twice (or more) the width of largest pores **22**

Broad rays absent; all rays narrow **24**

22 Rays predominantly broad, appearing as closely packed broken lines on tangential surface. ..... **Sycamore**

Broad rays few relative to fine rays. **23**

23 Broad rays distinct and lustrous; appear on radial surfaces as brownish flecks, usually not over a few mms in depth but rarely 6 mm in depth or over; growth ring ends with a distinctly darker zone of latewood. ..... **Beech**

Broad rays dull and relatively indistinct; frequently over 6 mm in depth; growth ring does not end with a distinct zone of latewood. ..... **Red alder**

24 Rays indistinct to naked eye **25**

Rays distinct to naked eye **26**

25 Rays indistinct with hand lens. ..... **Aspen**, **Cottonwood**

Rays distinct with hands lens **27**

26 Pores not crowded, distributed fairly uniformly throughout growth ring. ..... **Maple**

Pores numerous, usually crowded, particularly in earlywood that is initiated by a relatively inconspicuous single more or less continuous band of pores. ..... **Black cherry**

27 Pores relatively few, not crowded; wood hard to moderately hard **28**

Pores numerous, crowded; wood soft, easily dented with thumbnail, growth ring delineated by narrow, light-coloured line. ..... **Basswood**

28 Pores clearly wider than widest rays. ..... **Birch**

Width of pores equal to or smaller than width of widest rays. ..... **Maple**

WOOD 280

Identification of Hardwoods by Gross and Handlens Features

It is most important that you develop some mental images of commercially important hardwood timbers, and there is, perhaps, no better way of fixing these impressions than by systematic identification. You will be directed to carefully examine the transverse, radial, and tangential surfaces of many species, and make decisions concerning what you see. You will be expected to identify the following species or genera using any of the keys provided or one that you develop yourself. The following list indicates the degree to which you will be expected to separate various genera, species groups and species (page numbers refer to the Panshin and deZeeuw textbook).

	Identification	**Remarks**
1.	Red oaks, *Quercus* spp.	The red oak **group** of species typified by *Quercus rubra*
2.	White oaks, *Quercus* spp.	The white oak **group** of species typified by *Quercus alba*
3.	Elm, *Ulmus* spp.	The elm genus, typified by *Ulmus americana*, *Ulmus rubra* and hard elms.
4.	Ash, *Fraxinus* spp.	The ash genus, typified by *Fraxinus americana*, and *Fraxinus nigra*.
5.	Hickory, *Carya* spp.	The hickory genus, comprising both the true and pecan hickories.
6.	Salicaceae family	Comprising the cottonwoods, *Populus* spp. (p. 543); the aspens, *Populus* spp. (p. 546); and black willow, *Salix nigra* (p. 547).
7.	Yellow-poplar or tulip-tree, *Liriodendron tulipifera*	
8.	Red alder, *Alnus rubra*	
9.	Black walnut, *Juglans nigra*	
10.	Sycamore, *Platanus occidentalis*	
11.	American beech, *Fagus grandifolia*	

12. Maple, *Acer* spp.	Comprising the hard and soft maples and big leaf maple *Acer macrophyllum*
13. Birch, *Betula* spp.	A large genus, of which yellow birch, *Betula alleghaniensis* and white birch, *Betula papyrifera* are the most common.
14. Basswood, *Tilia* spp.	Comprising *Tilia americana* and *Tilia heterophylla*
15. Black cherry, *Prunus serotina*	
16. Genuine mahogany, *Swietenia* spp.	A genus of the family Meliaceae; also called American or Honduras mahogany; grows in West Indies, Central America and northern South America.
17. Philippine mahogany, *Shorea, Parashorea*, or *Pentacme* spp.	A wood from the family Dipterocarpaceae, which may come from a number of species of the three genera listed. Also called "lauan" and "meranti" in the timber trade. Grows in Malaysia, Indonesia, Philippines, and Indian sub-continent.
18. Teak, *Tectona grandis*	A member of the Verbenaceae family. Native to Thailand, Burma and Bangladesh, but planted widely throughout the tropics.

You will not always be required to identify individual **species**, because although the trees may be distinguished by different leaf, flower and fruit characteristics, the wood of closely related species often is indistinguishable. It is important to realize the limitations of wood identifications, and not to attempt separations on gross characteristics that can only be done with the microscope, if at all.

Identification of woods 7, 16, 17, and 18 cannot be done with the key, which covers only Canadian species.

WOOD 280

Hardwood Identification Summary

Red oak **White oak**	oak-type rays - fewer, larger latewood pores, fewer tyloses - plentiful, smaller latewood pores, more tyloses
Elm	latewood pores in wavy tangential lines
Ash	linking of latewood pores by white parenchyma large earlywood pores, rays constant size
Hickory	very hard, semi-ring porous, parenchyma in tangential bands
Aspen **Cottonwood**	small pores, fine rays, soft, annual ring - darkish
Basswood	very white, low ray volume, annual ring - white line
Red alder	large aggregate rays, pinkish colour, soft
Tulip tree	greenish colour, clearly visible rays sharp light band at beginning of growth ring
Black cherry	bright rays, first row of pores closely packed black streaks, not very coarse
Birch	rays generally not distinct to naked eye average pore diameter > largest ray width
Maple	prominent rays plus smaller one present, largest ray width > average pore diameter
Beech	prominent rays fewer and further apart than sycamore finer rays also present
Sycamore	prominent rays close together, wide ray ends and ray flecks white band at beginning of growth ring
Black walnut	semi-ring porous, short bands of white parenchyma distinctive dark brown colour
Teak	semi-ring porous, waxy feel, white parenchyma in earlywood
Genuine mahogany	distinct terminal parenchyma, ripple marks
Red lauan	coarse wood, tangential lines of white gums ducts, indistinct rays

WOOD 280

Identification of Softwoods by Gross and Handlens Features

You will be expected to identify the following species or genera using the key provided. The key attempts separation of some genera and species that is not realistic. You will be expected only to identify to the groupings listed below.

	Identification	**Remarks**
1.	White/Ponderosa pine: *Pinus strobus* *Pinus monticola* *Pinus ponderosa*	Although the key attempts to separate the white pines from ponderosa, this cannot be done with any degree of confidence or consistency, because they both are quite soft, with large resin canals and limited late-wood. While ponderosa pine usually has a more abrupt early-wood-latewood transition within an annual ring, this feature is not objective enough to permit separation from the white pines.
2.	Hard Pines: Lodgepole pine, *Pinus contorta* Jack pine, *Pinus banksiana* Red pine, *Pinus resinosa* Southern pine, several species of *Pinus* Ponderosa pine, *Pinus ponderosa*	This group of species has more latewood than white/ponderosa, with an abrupt earlywood-latewood transition. Its resin canals are abundant but smaller than (1), except in the southern pines. Dimpling on the split tangential surface is quite evident to the naked eye in lodgepole/jack pine, and can usually be used to separate these species. Dimpling is also less pronounced and frequent in some samples of ponderosa pine and Sitka spruce. Ponderosa pine is a special problem in identification, and hence is included in this group of hard pines, as well as (1) above.
3.	Spruce, *Picea* spp.	Sitka spruce is often different from other species, based on the darker pink or flesh-coloured cast of sitka spruce, and its occasional dimpled grain. However, these features are not always well developed, so you are not held for any finer separation beyond generic identification to spruce.
4.	Douglas-fir/larch/tamarack: *Pseudotsuga menziesii* *Larix occidentalis* *Larix laricina*	Although fresh-cut Douglas-fir has a rather distinctive odour and reddish coloured heartwood compared to the odorless and brownish larches, the distinction is more difficult or less reliable on older pieces, so the text key separation for the two genera is not required.

5.	Hemlock/(true) Fir: *Tsuga* spp. *Abies* spp.	These genera are the first of the non-resin canal woods. They are also devoid of any particular colour or odour, rendering them quite non- descript for identification. Some fresh-cut species of *Abies*, particularly *Abies lasiocarpa,* often have a distinctive, somewhat putrid odour due to extractives and/or bacterial infection. The key separation of these genera is not reliable.
6.	Western red cedar, *Thuja plicata* Eastern white cedar *Thuja occidentalis*	The key attempts to separate these two species of the genus *Thuja*, on the basis of colour. However, western red cedar shows great variation in colour, ranging from straw-yellow to chocolate-brown, thereby making positive separation difficult. Often Western red cedar has a sweeter fragrance than eastern white cedar, which has a pungent, rubbery smell.
7.	Yellow-cedar (yellow cypress, Alaska cedar) *Chamaecyparis nootkatensis*	Harder and firmer than *Thuja* spp. This wood has a very distinctive odour.
8.	Eastern red cedar *Juniperus virginiana*	Usually flecked with included sapwood. This wood has a very distinctive odour.
9.	Redwood *Sequoia sempervirens*	Not in key. More uniformly red, harder, and odourless as compared to w. red cedar.
10.	Baldcypress, *Taxodium distichum*	Not in key. Often with mildly unpleasant pleasant odour, greasy feel, and with contiguous annual rings very different in width and percentage of latewood.

WOOD 280

Softwood Identification Summary

White pine	gradual ew/lw transition large resin canals soft, light
Hard pines	abrupt ew/lw transition resin canals smaller than white pine dimpled tangential surface (sometimes) heavier, harder than white pine
Spruce	resin canals as white dots resin canals sometimes in groups of 2-3 gradual ew/lw transition less-developed latewood
Douglas fir **Larch** **Tamarack**	heavy, hard resin canals small and scattered large amount of latewood abrupt ew/lw transition
Western red cedar **Eastern white cedar**	crumbles when cut, little latewood, light WRC - distinct sweet odour EWC - rubbery odour - wide variety in colour
Yellow cedar	distinct odour yellow colour few blemishes little ew/lw variation
Juniper	purple colour, distinct smell hard, heavy sometimes included sapwood (white marks)
Hemlock **True fir**	no normal resin canals gradual ew/lw transition sometimes black streaks on longitudinal surface
Redwood	abrupt ew/lw transition no resin canals darker than WRC
Bald Cypress	large variation in ring widths slightly waxy feel non-fragrant odour

WOOD 280 Microscopic Wood Identification - Laboratory

Introduction

Rather than systematically observing a wide range of microscopic wood anatomy features in many different species these laboratories focus on some of the wood identifications that have in the past proven to be the more difficult using the hand lens alone. The labs will demonstrate how you can be much more positive with identifications using microscopic features and how to distinguish between some of the species with which you might previously have had trouble separating. These species separations are also among those that might have some practical application in your work experiences.

Your task

Listed on the next page are pairs of species (or species groups) that are sometimes confused in the macroscopic identifications.

For each of the pairs you should:

- Review the features visible with a hand lens that are used to identify the species.
- If any of these features have been difficult for you to see with the hand lens, try looking for the same features on the prepared microscope slides. Make sure that you select the appropriate section on the slide to investigate. Sometimes it can be useful to examine the microscope slides using the hand lens first before using the microscope.

For each of the species, there are listed some microscopic features that can be used to differentiate between them (some of these features may be the same as those used for the macroscopic separation but some are not visible with a hand lens alone and the light microscope must be used). Additional information for each species can be found on page 14 (hardwoods) and page 15 (softwoods) of this laboratory handout.

Laboratory report

- Please observe using the microscope the slides of each of the wood species concerned.
- Make some labeled diagrams to demonstrate that you understand what these features are, how they appear when viewed under the light microscope and how they can be used to distinguish between the two species.

These diagrams will either be (a) hand sketches that you draw based on what you see down the microscope or (b) digital images taken using the computer image capture system that will be demonstrated to you in class.

Please bring a USB drive on which to save your image files.

You should hand in your work and it will be graded. Each of these labs (one each for hardwoods and softwoods) will count the same as one of the identification quizzes towards your final lab grade. You will not be graded on your artistic ability but the diagrams should be clear enough to demonstrate that you have observed the features and that you understand what they are.

Labels should be clearly written and point to the exact feature being described. The electronic images can have labels added using a range of different software packages (e.g., MS Powerpoint, Photoshop). Brief comments should demonstrate your understanding of the differences observed.

You can work in groups during the laboratory periods but you must hand in your own, individual laboratory report.

Hardwoods

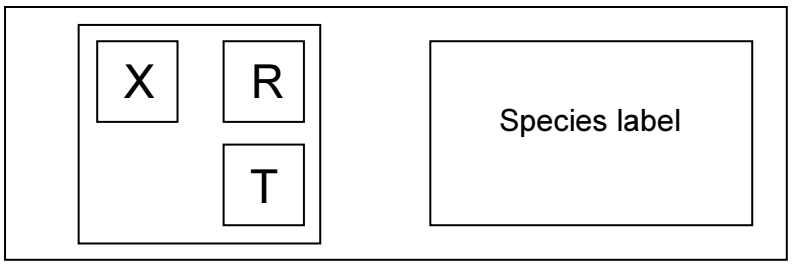
Maple vs. Birch **[X, R, T]**	Confirm the differences in the width of the rays (T, X), the nature of the perforation plates (R), and the presence of spiral thickening in maple and its absence in birch (R, T)
Aspen vs. Basswood **[X, T]**	Confirm the difference in the width of the rays (T, X), and the spacings between the rays (X).

Softwoods

Spruce-Pine-Fir (SPF) **[R, T]**	Confirm the presence of fusiform rays (containing horizontal resin canals) in spruce and pine and their absence in true fir (T). Observe the differences in cross-field pits (R), and any other features of the ray crossings (R) between the three woods.
Hemlock vs. True fir **[R]**	Confirm the presence of ray tracheids in hemlock and their absence in true fir (R). Observe the difference in cross-field pits (R).
Douglas-fir **[R or T]**	Confirm the presence of spiral thickening (R, T)

X = Transverse section (cross section, end grain)
T = Tangential longitudinal section (flat grain)
R = Radial longitudinal section (edge grain)

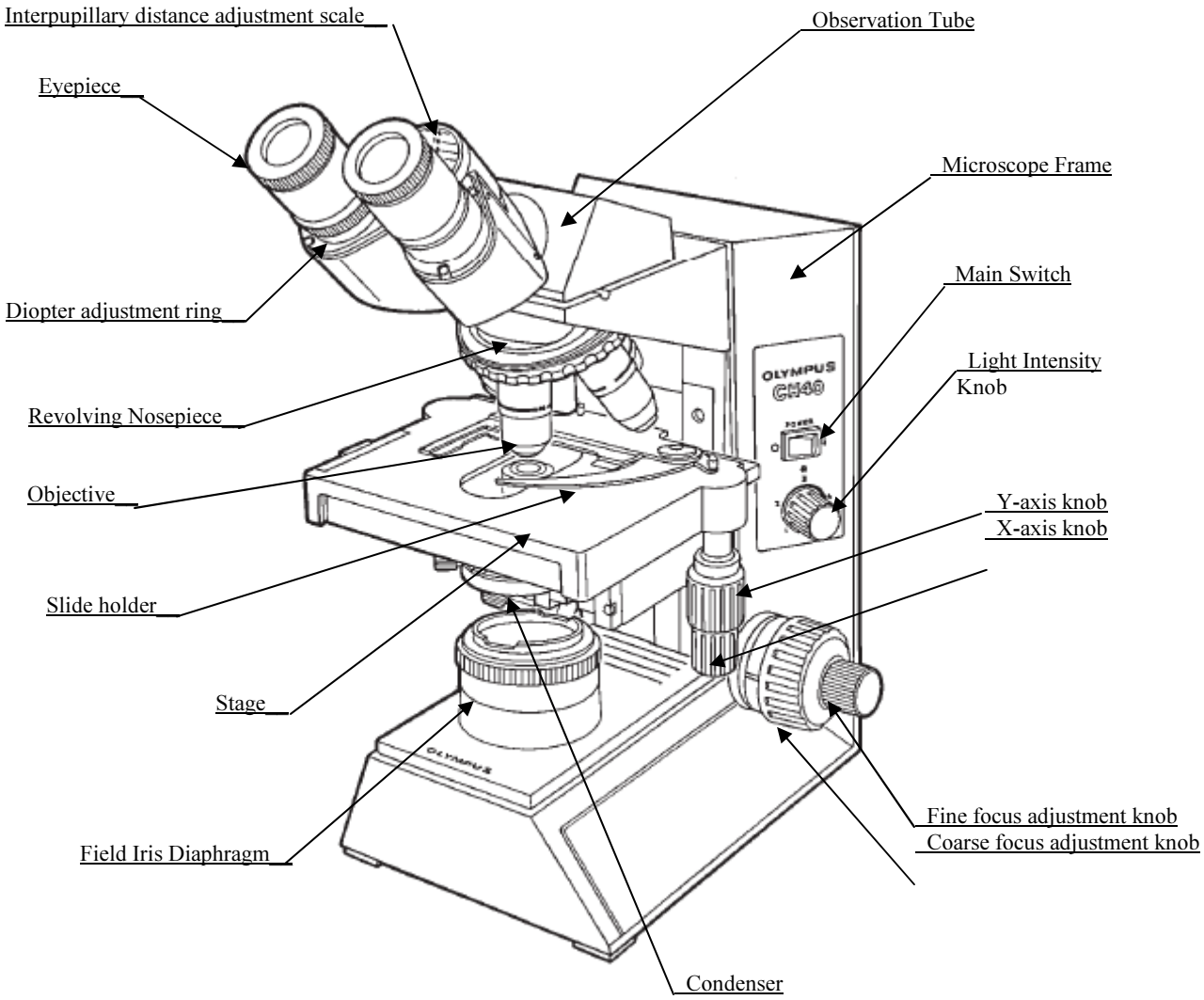
The sections are normally arranged on the prepared microscope slides as shown in the figure below.

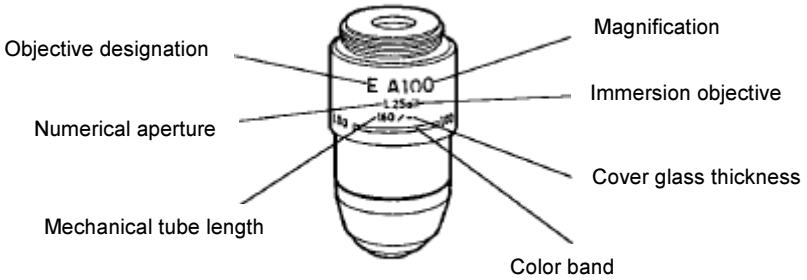


Note: Any student who brings a printed note to the start of the first lab covering this material to indicate that they have read these instructions will receive a 10% bonus mark on one of these assignments (just a short note is fine, not a rewrite of the content).

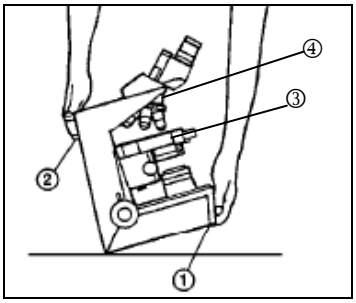
Olympus CH30 Microscope

I. Nomenclature





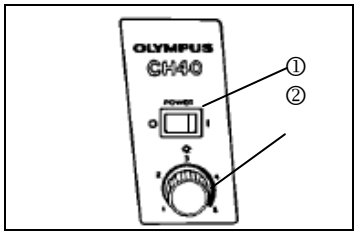
II. Moving Microscope



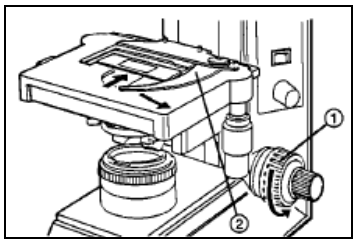
Carry with one hand UNDER the base ① and the other hand holding at the recessed handle on the rear of the arm ②

- NEVER hold the microscope by the stage ③ or binocular section ④
- DO NOT slide the microscope on the surface of the bench.

III. Using Microscope



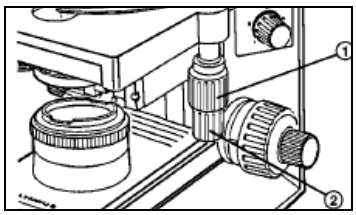
1. Switch the main switch ① to I (ON) and adjust the brightness with the light intensity knob ②



2. Lower the stage by turning the coarse adjustment knob ① counterclockwise in the direction of the arrow.

   Open the spring-loaded curved finger ② on the specimen holder and slide the slide into the holder from the front

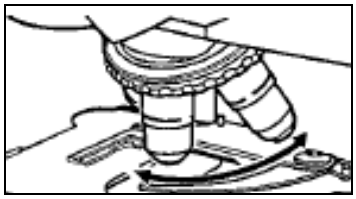
   Place the slide in as far as it will go, gently release the curved finger ②.



3. Turn the X-axis knob ① and Y-axis knob ② to move the slide into the light path.

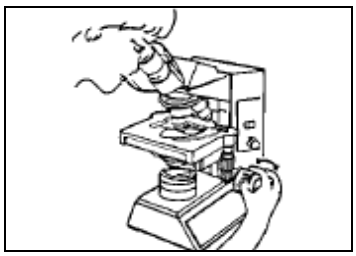
   NEVER move the slide by holding the specimen holder or stage directly.

   DO NOT apply excessive force when turning the axis knobs.

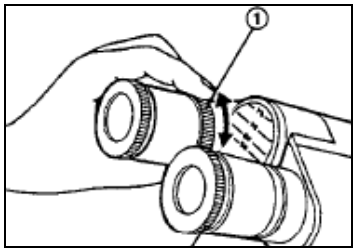


4. Turn the revolving nosepiece to engage the 10X objective.

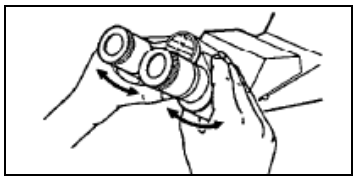
   Make sure the nosepiece stops with an audible ‘click’.



5. Look through the right eyepiece with your right eye, turn the coarse adjustment and fine adjustment knobs to bring slide into focus.

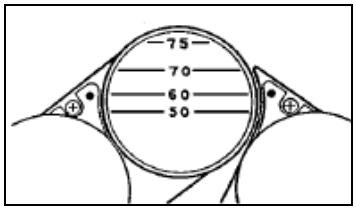


6. Look through the left eyepiece with your left eye, turn the diopter adjustment ring ① to focus the specimen.

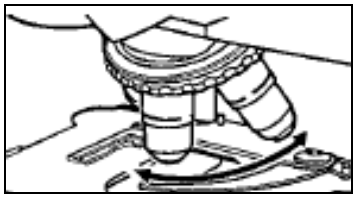


7. Adjust the interpupillary distance of the eyepiece.

   While looking through the eyepieces, adjust the binocular vision until the left and right fields of view coincide completely.



8. Adjust so that the two index dots • are horizontal.



9. Engage the objective for observation and adjust the light intensity to the desired level, readjust the focus.

IV. Microscope Controls

Condenser

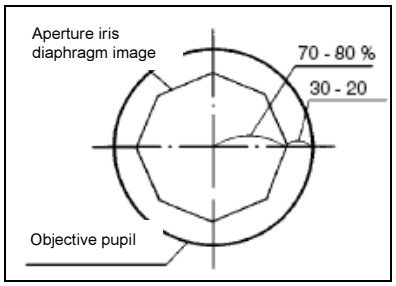


Figure 1

Aperture Iris Diaphragm

The aperture iris diaphragm determines the numerical aperture of the illumination system.

Matching the numerical aperture ① of the illumination system with that of the objective provides better image resolution and contrast and also increases the field of depth.

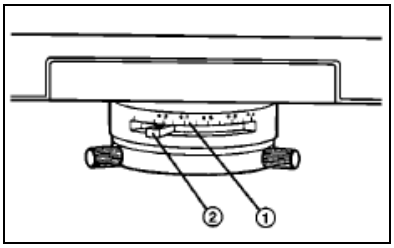


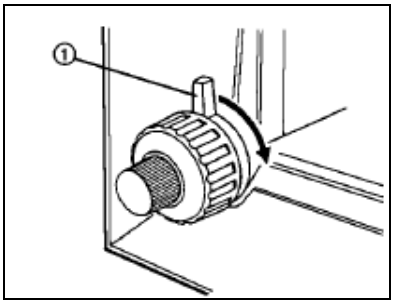
Figure 2

Since the contrast of microscope specimens is ordinarily low, setting the condenser aperture iris diaphragm to 70-80% of the N.A. of the objective in use is usually recommended.

When necessary, adjust the ratio by removing the eyepiece and looking into the eyepiece sleeve while adjusting the aperture iris diaphragm lever ② until the image to bring the field iris diaphragm image into focus shown in Figure 1.

If the aperture is opened wider (to the left), more light comes through but the image often appears to lack definition and seems washed out. If the aperture is more closed (to the right) the image often appears too dark and any imperfections in the slide are magnified. Sometimes the best image is obtained by closing the aperture to provide the desired contrast and then increasing the bulb's intensity to provide the desired brightness.

Focus Adjustment Knob



Pre-focusing Lever

The pre-focusing lever ensures that the objective does not come in contact with the slide and simplifies focusing. After focusing on the specimen with the coarse adjustment knob, turn this lever ① clockwise in the direction of the arrow to set a lower limit on coarse adjustment movement.

Focusing with the fine adjustment knob is not affected by this pre-focusing lever.

When not required, leave the pre-focusing lever UNLOCKED.

Individual hardwood species microscopic characteristics

Acer sp. (maple)

Vessel distribution	diffuse porous
Perforation plates	simple
Vessel pitting	alternate
Spiral thickening	present
Parenchyma	sparse
Rays	homocellular,
	hard maple
	wider rays 3-8 seriate
	narrow rays 1-3 seriate (mainly 1)
	soft maple
	homocellular, 1-5 seriate
	intermediate width rays present

Betula sp. (birch)

Vessel distribution	diffuse porous
Perforation plates	scalariform
Vessel pitting	alternate
Spiral thickening	absent
Parenchyma	apotracheal diffuse
	paratracheal aggregate
	marginal (sometimes)
Rays	homocellular, 1-5 seriate

Populus sp. (aspen , cottonwood)

Vessel distribution	diffuse porous
Perforation plates	simple
Vessel pitting	alternate
Spiral thickening	absent
Parenchyma	marginal
Rays	homocellular, uniseriate

Tilia americana (basswood)

Vessel distribution	diffuse porous
Perforation plates	simple
Vessel pitting	alternate
Spiral thickening	present
Parenchyma	abundant, marginal and apotracheal banded
Rays	wider rays 1-6 seriate
	essentially homocellular
	narrower rays, uniseriate
	much lower than broad rays
	cells uniform in size and higher
	than those in broad rays

Individual softwood species microscopic characteristics

Pinus sp. (hard pine)

Growth rings	abrupt transition
Normal resin canals	present (thin-walled epithelium)
Tracheids	up to 55 mm (av. 35-45)
Bordered pits	1 row, occasionally 2
Longitudinal parenchyma	wanting
Ray parenchyma	thin-walled (1-15+ high)
Cross-field pits	pinoid (2-4)
Ray tracheids	present, dentate

Picea sp. (spruce)

Growth rings	gradual transition
Normal resin canals	present (thick-walled epithelium)
Tracheids	up to 35 mm (av. 25-30)
Bordered pits	1 row (rarely 2)
Longitudinal parenchyma	wanting
Ray parenchyma	end walls nodular with indentures (1-20+ high)
Cross-field pits	piceoid (2-4)
Ray tracheids	present, smooth

Tsuga sp. (hemlock)

Growth rings	gradual transition
Normal resin canals	absent
Tracheids	up to 45 mm (av. 28-40)
Bordered pits	1-2 (mostly 1)
Longitudinal parenchyma	marginal and very sparse or wanting
Ray parenchyma	end walls nodular with indentures (1-16 high)
Cross-field pits	piceoid to cupressoid (3-4)
Ray tracheids	present, smooth

Abies sp. (true fir)

Growth rings	gradual transition
Normal resin canals	absent
Tracheids	up to 50 mm (av. 30-40)
Bordered pits	1 row (very rarely paired)
Longitudinal parenchyma	very sparse, marginal or wanting
Ray parenchyma	end walls nodular (1-30 high)
Cross-field pits	taxodioid (2-3)
Ray tracheids	very rarely
Miscellaneous	crystalliferous ray parenchyma

Pseudotsuga menzesii (Douglas-fir)

Growth rings	abrupt transition
Normal resin canals	present (thick-walled epithelium)
Tracheids	up to 55 mm (av. 35-45)
Bordered pits	1 row (occasionally 2)
Longitudinal parenchyma	marginal and very sparse or wanting
Ray parenchyma	end walls nodular with indentures (1-25+ high)
Cross-field pits	piceoid (4)
Ray tracheids	present, smooth
Miscellaneous	spiral thickening abundant

Summary of hardwood micro-anatomy

Species	Vessel distribution	Perforation plates	Intervessel pitting	Spiral thickening	Rays	Longitudinal Parenchyma
Red oak (*Quercus rubra*)	Ring	Simple	Alternate	Absent	Oak-type, homocellular Uniseriate, homocellular	abundant; paratracheal; apotracheal diffuse apotracheal banded
White oak (*Quercus alba*)	Ring	Simple	Alternate	Absent	Oak-type, homocellular Uniseriate, homocellular	abundant; paratracheal; apotracheal diffuse apotracheal banded
Elm (*Ulmus*)	Ring	Simple	Alternate	Absent	Homocellular 1-7 wide (mostly 3-5)	paratracheal scanty to vasicentric; apotracheal diffuse
Ash (*Fraxinus*)	Ring	Simple	Alternate	Absent	Homocellular 1-3 wide	paratracheal vasicentric, aliform to confluent
Hickory (*Carya*)	Semi-ring	Simple	Alternate	Absent	Homocellular to heterocellular 1-5 wide	apotracheal diffuse and aggregate banded 1-4 cells wide
Walnut, Butternut (*Juglans*)	Semi-ring	Simple	Alternate	Absent	Homocellular to heterocellular 1-5 wide	paratracheal scanty to vasicentric apotracheal diffuse to banded,
Sycamore (*Platanus*)	Diffuse	Simple and scalariform	Alternate	Absent	Homocellular 1-14 wide	paratracheal scanty apotracheal diffuse
Beech (*Fagus*)	Diffuse	Simple	Opposite to linear	Absent	Homocellular or with marginal upright cells, 15-25 and 1-5 wide	abundant apotracheal diffuse to banded

Summary of hardwood micro-anatomy

Species	Vessel distribution	Perforation plates	Intervessel pitting	Spiral thickening	Rays	Longitudinal Parenchyma
Hard maple (*Acer* sp.)	Diffuse	Simple	Alternate	Present	Homocellular wider rays 3-8 wide narrower rays mainly 1 wide	sparse
Soft maple (*Acer* sp.)	Diffuse	Simple	Alternate	Present	Homocellular 1-5 wide	sparse
Birch (*Betula*)	Diffuse	Scalariform	Alternate	Absent	Homocellular 1-5 wide	paratracheal aggregate marginal (sometimes) apotracheal diffuse
Aspen, Cottonwood (*Populus*)	Diffuse	Simple	Alternate	Absent	Homocellular 1 wide	marginal
Willow (*Salix*)	Diffuse	Simple	Alternate	Absent	Heterocellular 1 wide	marginal
Basswood (*Tilia*)	Diffuse	Simple	Alternate	Present	Heterocellular 1 wide	abundant; marginal apotracheal banded
Tulip tree (*Liriodendron*)	Diffuse	Scalariform	Opposite	Absent	Homocellular to heterocellular 1-5 wide (mainly 3-5)	marginal 1-5 cells wide
Red alder (*Alnus rubra*)	Diffuse	Scalariform (10+)	Alternate	Absent	Homocellular uniseriate and aggregate	paratracheal scanty apotracheal diffuse
Cherry (*Prunus*)	Diffuse	Simple	Alternate	Present	Homocellular to heterocellular 1-6 wide (mainly 3-4)	very sparse

Summary of softwood micro-anatomy

Species	EW/LW transition	Resin canals	Ray tracheids	Cross-field pitting	Longitudinal parenchyma	Comments
Soft pine (*Pinus*)	Gradual	Present	Smooth	Fenestriform	Wanting	Thin walled epithelial parenchyma
Hard pine (*Pinus*)	Abrupt	Present	Dentate	Pinoid	Wanting	Thin walled epithelial parenchyma
Spruce (*Picea*)	Gradual	Present	Smooth	Piceoid	Wanting	Thick walled epithelial parenchyma
Douglas-fir (*Pseudotsuga*)	Abrupt	Present	Smooth	Piceoid	Marginal and wanting	Spiral thickening present throughout growth ring
Larch (*Larix*)	Abrupt	Present	Smooth	Piceoid	Marginal and wanting	Spiral thickening present in a few latewood cells
Hemlock (*Tsuga*)	Gradual	Absent	Smooth	Cupressoid	Marginal and wanting	Bordered pits sometimes in pairs
True fir (*Abies*)	Gradual	Absent	Absent	Taxodioid	Very sparse	Crystalliferous ray parenchyma
Western red cedar Eastern white cedar (*Thuja*)	Abrupt but narrow latewood	Absent	Smooth, on the margins of some rays	Taxodioid	Banded, very variable in distribution	
Yellow cedar (*Chamaecyparis*)	Gradual	Absent	Smooth, often comprising all of low rays	Cupressoid	Sparse to abundant, diffuse	
Juniper (*Juniperus*)	Abrupt but narrow latewood	Absent	Absent	Cupressoid	Diffuse, 2-3 contiguous and banded	
Redwood (*Sequoia*)	Abrupt but fairly narrow latewood	Absent	Absent	Taxodioid	Diffuse to aggregate-diffuse	Some biseriate rays Bordered pits often in pairs
Baldcypress (*Taxodium*)	Very variable	Absent	Absent	Taxodioid	Diffuse to aggregate-diffuse	