Plant Systematics Laboratory Manual

Dr. Michael G. Simpson
San Diego State University

Plant Systematics Lab Manual

Table of Contents

Plant Systematics Laboratory #1
PLANT SYSTEMATICS: AN OVERVIEW

OBJECTIVES FOR THIS LABORATORY:

1. Review the major groups of plants.
2. Review the major concepts and terms of phylogenetic systematics.
3. Understand the basics of taxonomy by performing exercises in its components.

PLANT SYSTEMATICS

What is a plant?

Observe and label the examples of each of the major plant groups on display: liverworts, hornworts, mosses, lycophytes, psilophytes, equisetophytes, ferns, conifers, cycads, Ginkgo, Gnetales, and angiosperms (monocots and eudicots). Have your instructor check your labels.

Begin to think about the differences between these plant groups, such as the characters are used to separate them, and how they are related to one another. Why are all of these organisms called plants? Are any left out that have traditionally been called "plants?"

What is systematics?

Review the primary objective of systematics. As a class the following terms: **cladogram, lineage/clade, common ancestor, divergence, speciation, apomorphy, monophyletic, paraphyletic/polyphyletics**.

For the above plant groups, ***draw*** *what you think is a phylogenetic tree* (cladogram). Can you name some of the apomorphies that link these major groups together?

PLANT TAXONOMY

Taxonomy can be defined as the science dealing with the description, identification, nomenclature, and classification of life. The following are exercises to practice using these interrelated components.

Description

Description is **assigning features or attributes to an entity.** An important concept in taxonomic description is that of the **character** (a feature) and **character states** (two or more forms of a character).

Obtain a shoot (stem + leaves) from each of several species. Study these specimens. Then, working in a small group, come up with characters and corresponding character states, using Table 1.1. You may refer to the book for technical terms, but work quickly. The object here is to master the concept of character and character state; the actual technical terminology will be mastered later.

After you work on this for about 15 minutes, a member of each group should stand up and *i)* ***state and define*** *one character; and ii)* ***explain*** *the character states for the taxa examined*. Then, another group can ***explain*** *a second character and character states*. The object here is for the whole class to discuss and perhaps agree on the characters and character states.

OPTIONAL: Obtain a flower from a given plant species. Look at it with the naked eye or under a dissecting microscope. Next, describe the flower in writing to the best of your ability (using Table 1.2), spending no more than about 10 minutes. ***Discuss*** the types of words you used in this description? At a later time, your descriptions will be compared with those written after you have had training in descriptive morphological terminology. ***Hand in*** *the flower description to your instructor.*

Table 1.1 Description Exercise

No.	Scientific name	Character #1:	Character #2:	Character #3:	Character #4:	Character #5:
1.						
2.						
3.						
4.						
5.						
6.						

Table 1.2 Flower Description Exercise

Plant species: _____

Identification

Identification is **associating an unknown entity with a known entity**. There are several ways to identify a plant: specimen comparison, image comparison, taxonomic keys, and expert determination. The following will give you an introduction to these methods.

a. One tool used in identification is a **taxonomic key**. Working in a group, construct an indented and numbered dichotomous taxonomic key to the species that you studied above (from shoots), using the characters from Table 1.1. Begin by sorting the specimens into two groups and devising a character that distinguishes the two groups, with each group having a different character state of the character. This character and its states become the basis for the first **couplet** (composed of two **leads**) of the key. Next, divide each of these groups two subgroups, continuing this until you are left with one sample. In writing the key, be sure to list the organ or part first, then the character state. Do not list characters. For example, say "Leaves opposite, pinnately compound," not "Leaf arrangement opposite, leaf type pinnately compound." As you write the key, try to list more than one character state in some of the leads. Write onto Table 1.3.

After the key is written, select someone from your group to ***write*** *one couplet* on the board. The next group puts in a second couplet, etc., until the key is written. The whole class should agree on the best, final key.

b. Working together as a class, construct an indented and numbered dichotomous key to all of the students in the class. In writing the key, be sure to list the character first, then the character state. Divide the class into two, logical groups, and then each of these into two, etc. Think of characters and character states that describe the physical features of these people. To make it more interesting, only use characteristics visible only from the "neck up". What are some potential problems with some of the characters, e.g., in terms of variation? In what ways can class members be classified?

c. Review and examine taxonomic keys on-line, both dichotomous and polythetic. How does a polythetic (multi-entry) key differ from a dichotomous one? What are the advantages of the former?

Table 1.3 Identification Exercise: Key to Plant Species

Nomenclature

a. Syllabize and accent each of the names from the earlier exercise. Record onto Table 1.4. Practice pronouncing the names.

a. Use references to ***record*** *the* *etymology* (derivation and meaning) of these scientific names onto Table 1.4.

c. Working with a few other people, memorize the scientific names of the plant species identified. Ask your instructor about the correct or preferred pronunciation of each name. Use one or more of three methods to remember names: i) learn the etymology of the genus and specific epithet names and mentally connect that meaning with the plant; ii) use a mnemonic device, involving a vivid image, to associate the plant itself with a word that sounds like the scientific name of the species; and iii) practice, use repetition until the name becomes familiar. ***Recite*** *each of the names* when shown a sample of the plant.

Classification

a. Working together as a class, use available references to look up the common name, family, and native distribution of each of the plant species identified above. Place this information on the chalkboard or computer projector until all are completed. Then copy the information onto Table 1.4.

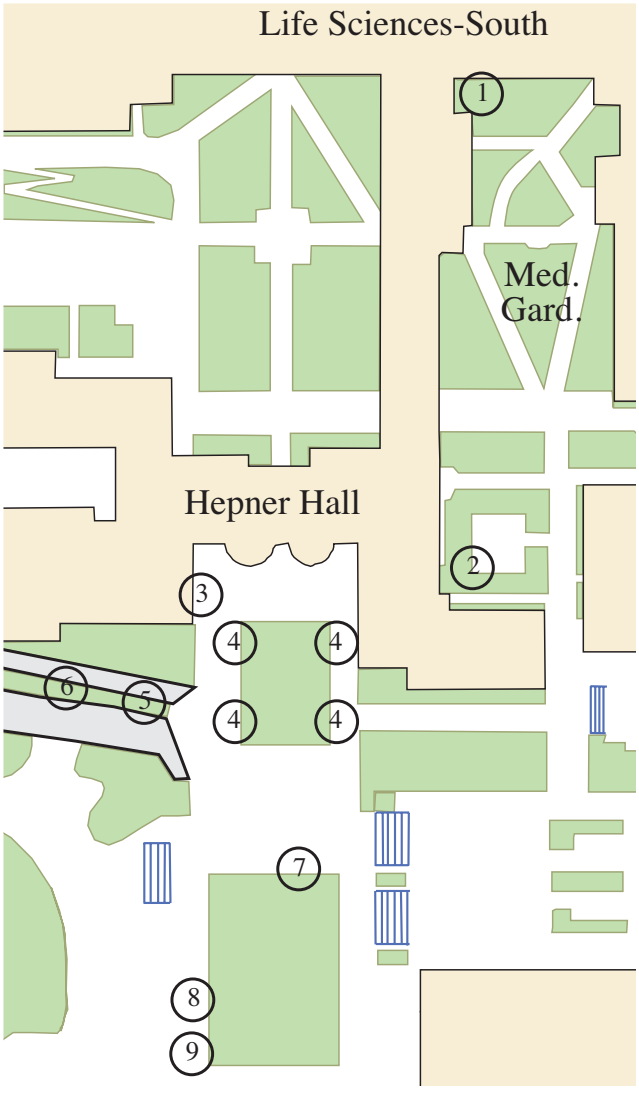
Note: Check out some Web pages, e.g., *International Plant Names Index* <http://www.ipni.org>, *Angiosperm Phylogeny Website* <http://www.mobot.org/MOBOT/research/APweb/>, or (for California plants) *The Jepson Online Interchange* <http://ucjeps.berkeley.edu/interchange.html>.

Table 1.4 Identification of Selected Taxa

No.	Scientific name Syllabize/Accent	Etymology (genus and spec. eptithet)	Family	Distribution
1.				
2.				
3.				
4.				
5.				
6.				

KEY TO TEN SELECTED TREES AT SAN DIEGO STATE UNIVERSITY

1. Trunk unbranched (at least above base); leaves more than two feet long, acrocaulis (arising near apex of trunks)
   2. Trunk single; leaves pinnately compound, leaflets in more than one plane . . . . . *Syagrus romanzoffiana*
   2’ Trunks multiple from rhizomatous base; leaves simple with large blade, blade often torn . . . . . *Strelitzia nicolai*
1’ Trunk with numerous lateral branches; leaves simple or compound, <3 feet long
   3. Leaves simple
      4. Leaves opposite, gen. < 10 cm long, narrowly oblanceolate, silvery-white below . . . . . *Olea europaea*
      4’ Leaves alternate, > 10 cm long, elliptic, green or brown-red hairy below . . . . . *Magnolia grandiflora*
   3’ Leaves compound (with two or more discrete leaflets)
      5. Leaves ternately compound, with 3 leaflets . . . . . *Erythrina caffra*
      5’ Leaves pinnately or bipinnately compound, with more than 3 leaflets
         6. Leaves pinnately compound (leaflets along one main axis, the rachis)
            7. Leaves usually whorled (usu. three per node), leaflets scabrous (rough, like sandpaper) . . . . . *Kigelia africana*
            7’ Leaves alternate (one per node), leaflets smooth, not scabrous
               8’ Leaves paripinnate (without a terminal leaflet); leaflets widely elliptic, entire (without teeth) . . *Ceratonia siliqua*
               8’ Leaves imparipinnate (with a terminal leaflet); leaflets elliptic, often with small teeth . . *Schinus terebinthifolius*
         6’ Leaves bipinnately compound (leaflets along secondary axes, rachillae) . . . . . *Jacaranda mimosifolia*



Plant Systematics Laboratory #2
PHYLOGENETIC SYSTEMATICS

OBJECTIVES

1. To understand and review the concepts and methodology of phylogenetic reconstruction.
2. To learn how to use a computer algorithm (MacClade) for visualizing cladograms and character evolution.
3. To explore interactive Web sites for investigating plant interrelationships.

PHYLOGENY RECONSTRUCTION EXERCISE

Study Figure 2.1, which illustrates eight species (A-H) of a hypothetical group of plants. This figure also shows a presumed extinct ancestor ("Anc"), which contains all ancestral characteristics. Your job is to infer relationships of the eight species of this taxon.

a) Working with a partner, name and record as many characters with associated character states as possible. Arrange these in a "Character x Taxon" data matrix, with "Taxa" in a column (at left) and "Characters" in a row at the top (Table 2.1). Name and record the character states of each character for each taxon.

b) For each character, circle those character states that are derived. Those shared by two or more taxa are synapomorphies, apomorphies that can be used to link together all taxa that possess them.

c) Draw the cladogram for the hypothetical organisms in the space at Table 2.2. Circle all monophyletic groups.

e) Use the data of Figure 2.2 to add to the data matrix. Do these new data confirm your original hypothesis of relationship? Refine the cladogram and redraw it in Table 2.3

d) From the refined cladogram devise an indented classification scheme at Table 2.4, both dichotomous and annotated. Make up new names for monophyletic groups as needed. Experiment with placing these new monophyletic groups into ranks, assuming that the ingroup (species A-H) represent a subfamily of plants.. What are the advantages and disadvantages of having ranks?

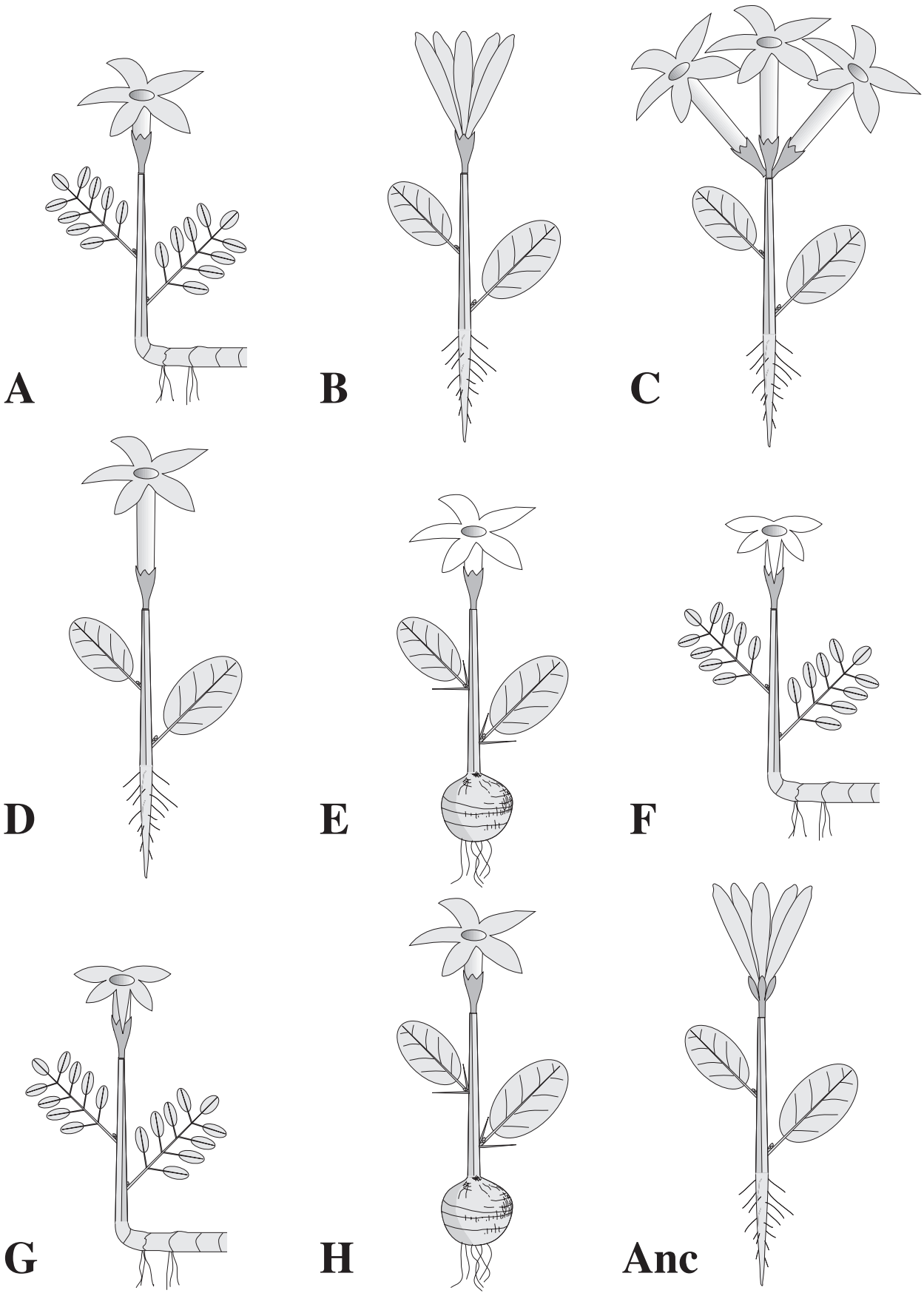


Figure 2.1 Hypothetical plants.

Table 2.1 Character X taxon matrix for hypothetical plant exercise (Figure 2.1) and most parsimonious cladogram (draw below).

	CHARACTERS										
TAXA ↓											
A											
B											
C											
D											
E											
F											
G											
H											
Anc											

Table 2.2 Most parsimonious cladogram (below), from data matrix of Table 2.1. Indicate all character state changes.

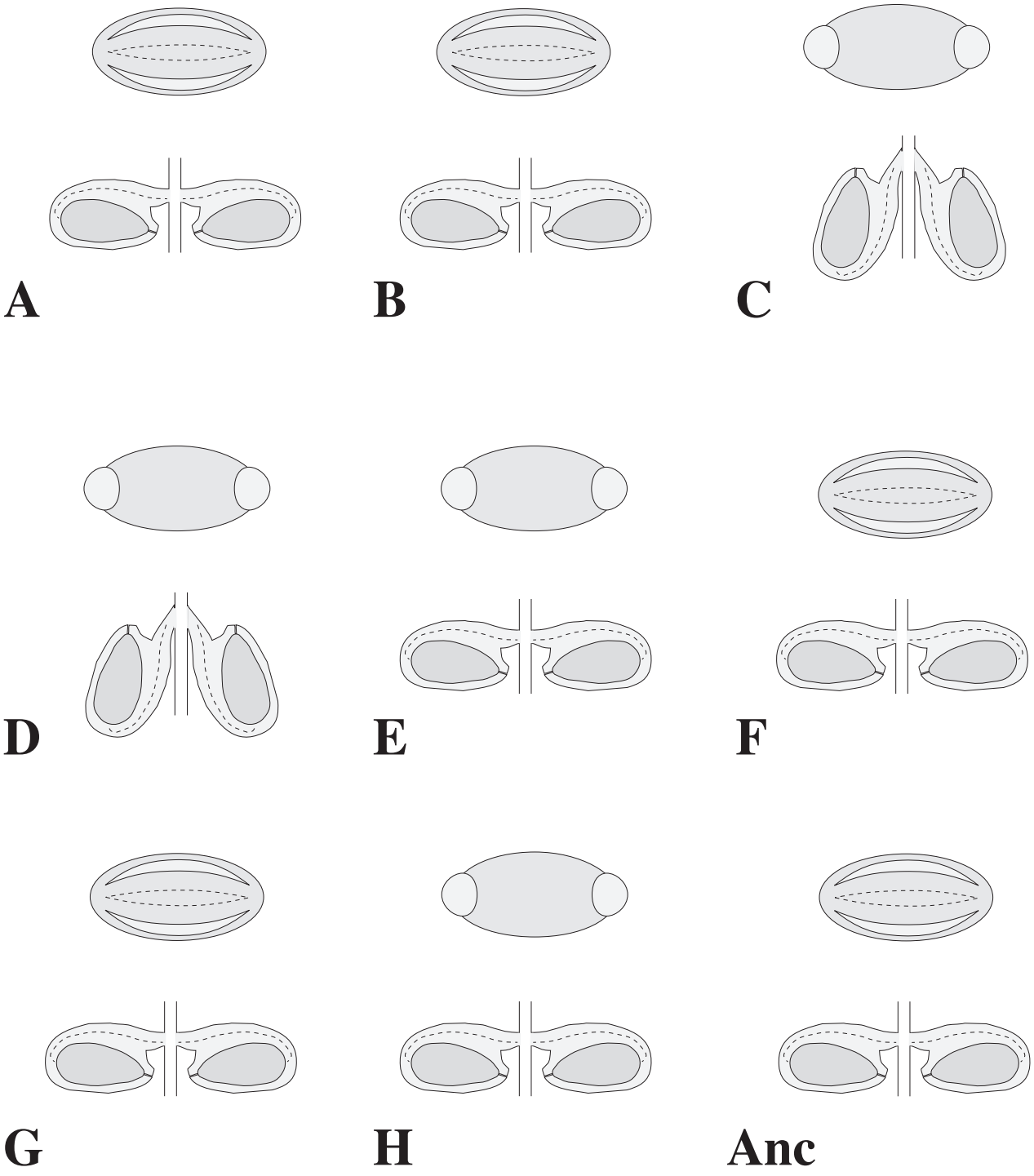


Figure 2.2 Added characters for hypothetical plants: pollen morphology (above) and ovule mrophology (below).

Table 2.3 Refined most parsimonious cladogram (below), from data matrix of Table 2.1, with pollen and ovule characters (Figure 2.2) added to original set. Indicate all character state changes.

Table 2.4 Classification scheme for taxa of Figure 2.1. A. Annotated. B. Dichotomous.

A.

B.

USE OF COMPUTER ALGORITHM FOR VISUALIZING CLADOGRAMS & CHARACTERS

1. Computer phylogeny applications. If a computers are available, you may wish to explore one of the commonly used phylogeny software applications. The program we will be using for visualizing cladograms is: MacClade (Maddison and Maddison, 2000), written for computers using the Macintosh operating system. Other programs are available for Windows OS (e.g., Winclada; Nixon, 1999). These programs allow the user to input data, including taxa names and their characters and character states. They allow visualization of both the phylogenetic relationships of taxa and character state changes.

With the help of your instructor, enter a data file using MacClade, or some other phylogeny application for a given taxonomic group. You may use the data matrix in Table 2.4, illustrating relationships of the families of the Zingiberales.

See Appendix 2.1 for information on the use of MacClade. Engage the function that displays characters; visualize several of these, noting the distribution of their states. You may also "swap branches" on the cladogram, exploring alternative evolutionary hypotheses and noting the change in tree length. Try to find the most "optimal" (most parsimonious) tree by swapping branches and getting the shortest tree.

If time allows, choose a volunteer to re-draw the cladogram from MacClade onto the chalkboard. List each apomorphy illustrated on MacClade by placing the derived character state (apomorphy) beside a hatch-mark on the cladogram. Circle and tentatively name all monophyletic groups.

Review as a class the following terms: cladogram, lineage/clade, common ancestor, speciation, apomorphy, synapomorphy, autapomorphy, monophyletic, paraphyletic.

Table 2.5. Example data set of the families of the Zingiberales (from *Plant Systematics*, 2010, p. 51)

	Lf. Arr.	Seed Aril	Polyarc Root	Inner Med. Stamen	Raphides	Silica crystals
Cannaceae	distichous	+	+	+	-	+
Costaceae	monistichous	+	+	+	-	+
Heliconiaceae	distichous	+	+	+	+	-
Lowiaceae	distichous	+	-	-	+	-
Marantaceae	distichous	+	+	+	-	+
Musaceae	spiral	-	-	-	+	-
Strelitziaceae	distichous	+	+	-	+	-
Zingiberaceae	distichous	+	+	+	-	+

	Stamen number	Staminode petaloid	Perisperm	Out. Tepals fused	Anther type
Cannaceae	1	+	+	-	monothecal
Costaceae	1	+	+	+	bithecal
Heliconiaceae	5	-	-	-	bithecal
Lowiaceae	5	-	-	-	bithecal
Marantaceae	1	+	+	-	monothecal
Musaceae	5	-	-	-	bithecal
Strelitziaceae	5	-	-	-	bithecal
Zingiberaceae	1	+	+	+	bithecal

WEB SITES ON PLANT PHYLOGENY AND CLASSIFICATION

Log onto the **Angiosperm Phylogeny Website** <http://www.mobot.org/MOBOT/Research/APweb>, **Tree of Life** <http://tolweb.org/tree>, or **TreeBase** <http://www.treebase.org/treebase/index.html>. These web pages contains up to date information on the relationships of various organismal groups. Note that cladograms, characters, images, and apomorphies may be illustrated in an interactive format. Also note that some phylogenetic relationships and classification schemes may differ, indicating that workers in the field may disagree and that systematic studies have not yet unambiguously resolved all the details of phylogenetic relationships.

Appendix 2.1 Use of MacClade, version 4.05 (D. R. Maddison and W. P. Maddison, 2002)
A computer program for phylogeny and character visualization

Commands Commonly Used:

NOTE: You must hold down the command key while typing the next letter

Command	Command Name	Menu	Function
D	**Trace Character**	**Trace**	View optimized tracing of character evolution
E	**Data Editor**	**Windows**	View and edit data matrix
I	**Character List**	**Characters**	View character coding information
K	**Trace All Changes**	**Trace**	View apomorphic changes at each lineage
N	**New File**	**File**	Creates a new data file
O	**Open File**	**File**	Open a file to display data matrix or tree(s)
R	**Show MPRs Mode**	**Trace**	Visualization of alternative char state changes
S	**Save File**	**File**	Save a file to memory; including all changes
T	**Tree Window**	**Windows**	View tree
W	**Close File**	**File**	Close a file, necessary before opening a file
Y	**Tree List**	**Trees**	Select alternative trees

Getting Started:

Open MacClade by double clicking on the **MacClade** "cladogram" icon.

Open a data file; e.g., select the **MacClade Examples** folder, then select **Vertebrates** by double clicking or by highlighting and then clicking **Open**. To open future data files, type Command **O** or select **Open File** from the **File** menu. To close, type Command **W** or select **Close File** from the **File** menu.

Data matrix:

A spreadsheet with the character/taxon matrix will appear. If a tree appears instead, type Command **E** (or select **Data Editor** from the **Windows** menu). Briefly study this matrix. You may "scroll" through characters and taxa by clicking and holding on the arrows at the bottom or to the right. Note that taxa appear in the left column, character numbers and names in the top row, and character state names within the matrix. Selecting **Transposed Matrix** from the **Display** menu inverts the taxa/characters rows and columns. Moving the "ruler" in the upper left corner changes column width. You may change the character state names to symbols (the character codes) by selecting **Data Matrix Styles ® Plain** from the **Display** menu. Try making these changes.

Tree Visualization:

Type Command **T** (or select **Tree Window** from the **Windows** menu) and a tree will appear. If the tree appears too small or too large for your computer, select **Expand Window** or **Reduce Window** from the **Display** menu. (You may select from a list of trees by clicking Command **Y** or selecting **Tree List** from the **Tree** menu.) If you wish the tree represented as 90^{o} (instead of 45^{o}) intersecting lines, select **Tree Shape & Size** from the **Display** menu and click into the second icon. With the latter type of tree visualization, you may also specify that the branches be centered from the same menu.

Note the treelength, which for the "Bad Guess" cladogram of the Vertebrate data set is 35 character state changes. Also note the listing of number of taxa (10) and characters (13). If CI is not already visible on the data box in the lower right, select **Consistency Index** from the ∑ menu.

Character/Character State Visualization:

Perhaps the most valuable feature of MacClade is the character tracing function, allowing for the

clear visualization of character state distributions for each character. Type Command **D** (or select **Trace Character** from the **Trace** menu). Try typing Command **D** a few times; it operates as a toggle switch. Note the character box that appears in the lower right corner and the optimized character state are displayed on the cladogram. Click the right arrow on the character box, noting how you may proceed through the character list in sequence.

Practice rearranging branches by placing the arrow anywhere on a clade, holding down the mouse button, "dragging" to another clade, and then releasing the mouse button. Note that you may rearrange branches with the character tracing function (Command **D**) turned on. The new character state distribution will appear for this new topology. Try moving clades around to fit the relationships you think correct. Do this by going through the characters one at a time and grouping taxa based on apomorphies. For example, choose character #1, "amnion". The character state distributions for absence/presence of an amnion are superimposed on individual clades. Drag the clades that possess an amnion into one group. Continue this for all other characters in the data set. Note that equivocal state optimizations appear as horizontal lines on given clades. Attempt to minimize the treelength (i.e., attain the most parsimonious tree) by noting the change in treelength in the tree data box. Note that CI changes inversely with treelength; thus, to find the most parsimonious tree, minimize treelength and maximize CI. (Hint: The most parsimonious tree is 19 steps long.)

After creating the most parsimonious "Vertebrate" cladogram, go through the character list once again. Choose the character #1 again, "amnion." The presence of an amnion appears as an apomorphy for a monophyletic group, the "Amniotes," containing turtles, mammals, snakes, lizards, crocodiles, and birds. Select character #2, "appendages." Note three different clade shadings (or colors) for the three character states. These are coded as "ordered." The presence of "legs only" is a synapomorphy for a monophyletic group, the "Tetrapods," containing salamanders, frogs, turtles, mammals, snakes, lizards, crocodiles, and birds; "legs only" became modified to "legs+wings" in the bird lineage. Note also the "uncertain" shading for the box above the "mammal" clade, indicating that the character state for mammals was coded as polymorphic (because only some mammals, i.e., bats, have wings). Select character #3, "body covering," and note the tracings for five states, plus one for "equivocal," the latter indicating that there is no single most parsimonious state assignment for the clade immediately below the "Tetrapods." In other words, the occurrence of neither "smooth" nor "epidermal scales" body covering can be supported for the internode just above the "lungfish" clade. Note, in the next character, #4, "thermoregulation," the convergent evolution of homeothermy in mammals and birds. Continue through the data set to get a feel for this feature of MacClade. Its value is in allowing easy visualization of character state changes and of alternative, equally parsimonious optimizations.

Type Command **K** (or select **Trace All Changes** from the **Trace** menu). This allows you to show the total number of changes on each branch, where unambiguous (unequivocal) changes occur on the cladogram. By clicking on one of these clades, a listing of the specific changes occurring can be seen. To turn off this function, type Command **K** again. By selecting **Trace Labeling** from the **Display** menu you have several options for display of state changes on the cladogram. Experiment with these.

As you trace character evolution using Command **D** (**Trace Character** from the **Trace** menu), you may discover "equivocal" areas (shaded with horizontal bars) on the cladogram. These represent nodes (HTUs, ancestors) that have alternative, equally parsimonious character states. To find out exactly how many equally parsimonious optimizations there are for a given equivocal lineages and exactly which character states are possible, type Command **R** (or select **Show MPRs Mode** from the **Trace** menu). Using this function, you will see the shading/character states change at the equivocal node(s). Continue toggling (Command **R**) and you will go through all possible reconstructions. A count of the number of equally parsimonious reconstructions can be obtained by choosing **Number of MPRs** from the **Trace** menu. Character 3, for example, has three equally parsimonious optimizations. (By choosing **Expand**

Clade from the **Tools** menu, you can click on the node of interest and obtain precisely the number of reconstructions under the assumption that the outgroup node is ancestral.)

For certain characters, a given cladogram topology may show an "equivocal" condition (shaded as horizontal bars) at a given internode that can be explained as either of two equally parsimonious character optimizations: **DELTRAN** (**DEL**ay **TRAN**sformations) or **ACCTRAN** (**ACC**elerate **TRAN**sformations). DELTRAN delays changes away from the root node, which in effect promotes convergent character evolution; ACCTRAN accelerates changes toward the root node, which maximized reversals. DELTRAN and ACCTRAN options may be visualized with MacClade as follows. First, select the character of interest on the tree with the Trace Character (Command **D**) option on. Then select **Resolving Options** from the **Trace** menu. Click either **DELTRAN** or **ACCTRAN** and then click **OK** (or type the Return key). Note the change in character optimization on the tree. Not all equivocal optimizations are resolved using DELTRAN or ACCTRAN.

Character Status:

Type Command **I** (or select **Character List** from the **Characters** menu). Note the display of characters, listing: a) character number; b) character name; c) whether included (box with a check) or excluded from the analysis (box with an "X"); d) character type (unordered, ordered, irreversible, stratigraphic, Dollo, or user-defined); e) character weight; f) number of character states; g) optimized number of character steps (for the current tree); and h) character CI. You may alter the first four variables by clicking on and highlighting a given row and then clicking the small arrow beside the column headings. To remove the Character Status box, click the upper left red spot (or Command **W**). Note that the default character type is unordered; thus, if you wish any to be ordered, irreversible, statigraphic, Dollo, or user defined, you must specify it.

Tools:

From the **Windows** menu select **Tool Palette** and note the Tool box that appears, with several functions, different in Edit mode (Command E) versus Tree mode (Command T). In Tree & Display (Command D) mode, these are (from left to right, top to bottom):

1) Search Above	Performs a search upward pass and selects that cladogram topology which is most parsimonious based on that upward pass.
2) Reroot Tree	Allows tree to be rerooted at any point.
3) Make Ancestral	Allows you to make a terminal OTU a direct ancestor at the immediate node below.
4) Exclude Clade	Allows exclusion of any particular clade; may be reversed by selecting **Include-Exclude Taxa** from the **Tree** menu.
5) Move Branch	This is the default setting, allowing you to move clades into different topologies.
6) Polytomy Exchange	Allows branch rearrangements within a polytomy.
7) Rotate Branches	Rotates branches at the node immediately above the clade selected.
8) Rotate to Lean Right	Rearranges branches such that they are "ladderized"
9) Collapse Clade	Arranges every clade above a given branch into a polytomy.
10) Collapse Branch	Collapses a given clade, such that the immediate branches above form a polytomy with that/those below.
11) Test Correlation	[Click in and read.]
12) (Unused)	
13) List States	Will list the character state at a given clade.
14) (Unused)	

15) Fix States — Allows fixing the state of a given character at a given clade. Works by clicking into the desired state at the character state box and then clicking into the desired clade.
16) (Unused)
17) Select in List Window — Allows clicking on a given clade and viewing the matrix for taxa characteristics.
18) Set Evolve Segments
19) Expand Clade — Allows visualization and expansion of only part of the cladogram, that immediately above the lineage selected; reversed by clicking the most basal clade.
20) Move Tree — Moves tree on the screen.

Practice using the **Rotate Branches** command, a useful exercise for beginning students. Note that by flipping branches, the general appearance of the cladogram may change drastically, but the topology (and cladistic relationships) are unchanged. You may "ladderize" the cladogram (or a portion thereof) by selecting **Rotate to Lean Right** from the Tools menu.

Try the **Expand Clade** command. This may also be implemented by simply double-clicking with the **Move Branch** arrow on a clade internode. To reverse, double click on the basal-most internode.

Another useful exercise is to use the **Reroot Tree** command. This will not alter the topology of the unrooted tree, but it will definitely alter relationships in the rooted tree. The **Make Ancestral** command will collapse a terminal taxon to a hypothetical direct ancestor on the clade.

Polytomies (in which three or more clades arise from the same point) may be represented in the tree as follows. First, rearrange the branches such that those clades that will form a polytomy at a given node are placed into a monophyletic group of dichotomizing branches. Next, select **Collapse Clade** from the **Tools** menu and click into the root clade of this monophyletic group. Finally, select **Collapse Branch** from the **Tools** menu and click into the same root clade to remove it and create the polytomy.

MacClade is very limited with regard to finding most parsimonious trees. Thus, a powerful computer algorithm, such as PAUP, is needed to find all most parsimonious trees for even a modest data set. However, for relatively small data sets the **Search Above** command may be attempted.

Taking the Vertebrate data set as an example, begin by selecting the Bad Guess cladogram (trees seen using Command **Y**). Note that "rayfinned fish" is at the most basal or outgroup position. Select the **Search Above** command from the **Tools** menu and click at the internode just above the common ancestor of "rayfinned fish" and the other taxa. Note the decrease in Tree Length and increase in CI. Is this tree equivalent to the tree that you obtained by manually swapping branches?

Another useful feature is that of arbitrarily changing the state of a given clade; i.e., the cladogram topology will remain unchanged but the most parsimonious character distribution will be altered. Select **Fix States** from the **Tools** menu. A paintbrush-like icon will appear. Move this icon (using the mouse) to the character box at the lower right. Click into the desired character state (shaded box) for a given character, then click into that clade for which you wish to change to the given state. The shading for that clade will change to that selected. To remove your character tracing alteration, select the **Unfix all** command from the **Trace** menu.

Formating New Data Files:

Enter a data set into MacClade. First, close any opened file by typing Command **W** or selecting **Close File** from the **File** menu. Next, type Command **N**, or select **New file** from the **File** menu. MacClade utilizes a very handy user-friendly spreadsheet format, allowing you to easily enter and manipulate your data.

Type in the following: 1) Taxa (in left-hand column by default, which you may expand or contract

as needed by moving the mouse below until arrows appear, holding down the mouse button, and then moving up or down); 2) Characters, top row, which you may expand by selecting (from the **Display** menu) **Data Matrix Styles**, then **Wide with State Names**; 3) Character states (internal data matrix; should be entered initially as whole, non-negative numbers, from 0 onward). Polymorphic character states (in which more than one state apply) may be listed by typing all character states with either a space or a "/" between them. Taxa or characters may be moved to different rows or columns, respectively, by clicking at the far left or top and dragging the row or column to a new location.

After entering the raw data, name your characters and character states by selecting **State Names & Symbols** from the **Characters** menu.

After entering all the data, you may visualize the state names (instead of numbers) by selecting **Data Matrix Styles**, then **Wide with State Names** from the **Display** menu.

MacClade allows you to assign "user defined characters," which allow for custom designing with regard to the number of state changes between character states of a multistate character. To define a user defined character, enter the data matrix (Command **E**), then click into the top region of the character you wish assigned. (The entire column will become highlighted.) Next, from the **Characters** menu, select **Edit Type**. A listing of character codings will appear at the top (unordered, ordered, irreversible, etc.). If not already visualized, select "**unordered**" (the default). To define a new user defined character click **New**, name the user defined character; and then click **Create**. The new name will then appear in the character listing. Finally, alter the original "unordered matrix" as you desire by clicking into a cell, typing the desired number of state changes, and clicking **Enter**. When finished, click **OK** (or type the **Return** key). This user defined character may be used for other characters of the data matrix (Command **E**) by typing Command **I**, clicking into a character (highlighting the entire row), then clicking the character **Type** and selecting a particular character coding. Type Command **I** or select **Character Status** from the **Display** menu to visualize the status of your characters.

When you are finished, select "Close file" from the File menu. You will be asked whether or not to save the tree or to save the (revised) data file. If you wish, save your newly entered file. (Alternatively, you may type Command **S** or select **Save File** from the **File** menu.) If using a shared computer, create and name your own folder or save the file on a memory stick.

Interfacing with PAUP:

It is suggested that you create all your data files using MacClade because of the ease of using the data editor. The data matrix can then be opened directly using the program PAUP* (Swofford, 2003), which you will use to find the most parsimonious trees. Use the **Save File As** option in PAUP to save the trees under a given file name. You may then go back to MacClade to examine the tree(s) that were generated with PAUP, noting character transformations. This iterative approach, using MacClade to enter data, PAUP to generate trees, and then MacClade to examine trees and perhaps to re-code the data, maximizes the value of the two programs.

Plant Systematics Laboratory #3
EVOLUTION AND DIVERSITY OF GREEN AND LAND PLANTS

OBJECTIVES FOR THIS LABORATORY

1. Be able to recognize and name apomorphies for monophyletic taxa.
2. Understand the function and adaptive significance of these apomorphies.
3. Be able to identify and name the major plant groups and their features.

GREEN PLANTS (CHLOROBIONTA)

Chloroplasts & cell wall

Pull off a young leaf of the aquatic plant flowering *Elodea* (Hydrocharitaceae) and prepare a "wet mount" by placing in a drop of water on a microscope slide and covering with a cover glass. Observe under a compound microscope. Observe the cells, each having a **1^{o} cell wall** that is composed largely of **cellulose**. The cellulosic wall in *Elodea* is thin and appears as a thin whitish line viewed with the light microscope.) Note also the green **chloroplasts**, which are pushed to the periphery of the cell by a large central **vacuole** (the membrane of which is usually invisible). The green color is caused by selective absorbance/ reflectance of the major photosynthetic pigments, **chlorophyll a + b**. The chloroplasts may be moving in a circular motion, a phenomenon called cytoplasmic streaming or cyclosis. Observe the electron micrographs of chloroplasts, noting the **thylakoids** (chlorophyll-containing membranes) that are stacked into units called **grana**. (A cellulosic cell wall and chloroplasts containing chlorophyll b, grana, and starch are major apomorphies for all green plants.) ***Draw and label*** *a cell, showing the cell wall and chloroplasts.*

Oogamy and Antheridia

Observe the available material of the genus *Chara* or *Nitella* of the Charales, among the closest relatives of the land plants. Note the plant habit from preserved material. These are small (up to 30 cm tall), erect, fresh water aquatics. Observe the *Chara* whole mount prepared slides of sexual organs. Observe the spherical, sperm-producing **antheridia**, which are surrounded by a sterile "jacket" layer of cells. Also note the **egg** cell, which in *Chara* is enclosed within a structure called an **oogonium** (surrounded by noticeable helically-oriented cells). This type of sexual reproduction, in which one gamete (the egg) has become larger and non-motile is called **oogamy**. The antheridium, oogamy, and retention of the egg cell (e. g., in an oogonium) on the plant body represent major apomorphies for some Chlorobionta, among them the Charales and the land plants. ***Draw*** *an oogonium (showing the egg and outer helical cells) and an antheridium, showing the sterile jacket layer and internal sperm cells.*

Observe the demonstration *of* the fossil oogonia of Charales, some dating from as far back as the Devonian (345-395 million years ago).

SOME GENERAL ADAPTATIONS OF THE LAND PLANTS

The non-vascular land plants, including mosses, liverworts, and hornworts, share a number of derived features (apomorphies) with the vascular land plants. All of these represent major adaptations to life on land.

Cuticle. Observe the available prepared microscope slides of leaf cross-sections (e. g., *Cycas revoluta*, a seed plant, which has a particularly thick cuticle). The cuticle appears as a translucent, homogeneous layer covering the outer epidermal cells. What is it composed of? What is its function? ***Draw, labeling*** *the cell, cell wall, and cuticle.*

Antheridium. Observe the microscope slide of the available moss (e.g. *Mnium*) or liverwort (e.g. *Marchantia*) antheridium. ***Draw and label*** *an* ***antheridium****, with enclosed* ***sperm cells****.*

Archegonia. Observe the microscope slide of the available moss or liverwort archegonium. Note the egg cell and nucleus, ventral canal cell, neck, and neck canal cells. ***Draw and label*** *an* ***archegonium****, including neck, neck canal cells, ventral canal cell and egg.*

NON-VASCULAR LAND PLANTS ("BRYOPHYTES")

Liverworts (Hepaticae)

Observe the live or preserved material of a thalloid liverwort, such as *Marchantia*. Virtually all of the material you see here is haploid (n) **gametophyte**, which in the non-vascular land plants is the dominant, long-lived life cycle phase. In *Marchantia* the gametophyte is a flat mass of tissue or thallus. On the upper surface look for "gemmae cups," which contain "gemmae." These structures function in vegetative (asexual) reproduction; when a droplet of water falls into the gemmae cup, the gemmae spores may be dispersed some distance away, growing into a genetic clone of the parent. Pores in the upper surface allow for gas exchange. These pores are not true stomata, as they have no regulating guard cells. Also look for antheridiophores and archegoniophores, if present. What do these structures produce? ***Draw*** *a thalloid liverwort gametophyte, including (if available) gemmae cups and antheridiophores or archegoniophores.*

Observe the material of a leafy liverwort. Note the very different appearance of the gametophyte, which consists of a terete axis bearing three rows of leaves (generally two above or dorsal and one below or ventral); these leaves evolved independently from, and are thus not homologous with, those of vascular plants. ***Draw*** *a leafy liverwort gametophyte in upper (dorsal) and lower (ventral) views, showing the three ranks of leaves.*

Observe the prepared slide of a liverwort sporophyte, e. g., *Marchantia*. Note that the sporophyte is attached to (and nutritionally dependent on) the gametophyte. Also note the numerous spores (each a haploid product of meiosis) and surrounding elaters, specialized structures that hygroscopically aid in spore release. ***Prepare*** *an outline drawing of the sporophyte and a close-up drawing of some of the spores and elaters.*

Stomates

Stomates are derived features for all land plants, with the exception of the Liverworts. It is as yet unclear if stomates evolved once or independently two or more times. Make a wet mount in a drop of water of an epidermal peel of the lower epidermis of available material (e. g., *Coleus*, *Commelina*, *Graptopetalum*, or *Zebrina*). Observe the **stomates** (= stomata), containing two **guard cells** which control the size of the pore (**stoma**). Stomata are the only epidermal cells with chloroplasts. ***Draw and label*** *a stomate, noting the two* ***guard cells*** *and* ***stoma****.*

Mosses (Musci)

The true Mosses are a group of non-vascular land plants that have evolved a diversity of morphological forms. Observe various moss **gametophytes**, the haploid, green, leafy part of the life cycle. ***Draw and label*** *a moss gametophyte.*

Moss Sporophyte. All land plants have a specialized life cycle phase: the diploid (2n) **sporophyte**. A young sporophyte attached to the gametophyte is called an **embryo**, hence the alternate name **Embryophyta** for the land plants. In the non-vascular land plants ("Bryophytes"), the sporophyte is relatively small, short-lived, and generally non-photosynthetic, being nutritionally dependent on the gametophyte. Observe sporophytes of mosses. These appear as brownish, short to elongate structures that are attached to the leafy, green gametophyte. Sporophytes grow from the fertilized egg (zygote) within the archegonium. The sporophyte terminates in an expanded **sporangium** (also called a **"capsule"** in "Bryophytes"), a specialized organ where meiosis occurs, producing **spores**. Most moss sporangia have teeth-like structures, called **peristome teeth**, that are hygroscopic, opening and closing depending on atmospheric moisture, effecting spore dispersal in the process. ***Draw and label*** *a moss sporophyte, showing the* ***seta*** *(stalk),* ***capsule*** *(sporangium),* ***operculum*** *(cap),* ***peristome teeth****, and* ***spores****.* [Optional: observe the capsule longitudinal-section.]

Sphagnum **PEAT MOSS**. Observe this moss, which grows in wet bogs and chemically modifies its environment by making the surrounding water acidic. If available, make a wet mount of live *Sphagnum* leaves and observe with the compound microscope. The leaves of *Sphagnum* are unusual in having two cell types: **chlorophyllous cells** that form a network around large, clear **hyaline cells**, the latter having characteristic pores and helical thickenings. The pores of the hyaline cells give *Sphagnum* remarkable properties of water absorption and retention, making it quite valuable horticulturally in potting mixtures. Observe the sample of peat. **Peat** is fossilized and partially decomposed *Sphagnum*, and is mined for use in potting mixtures and as an important fuel source in parts of the world.

Draw and label *a portion of a Sphagnum leaf, showing the chlorophyllous cells and hyaline cells, the latter with pores and helical thickenings:*

Observe the prepared slide of germinating moss spores, which develop into a filamentous **protonema**. The protonema represents a ancestral vestige, resembling a filamentous green "alga." It soon grows into a parenchymatous gametophyte. The spores of mosses and basal vascular plants have a thick outer layer called a **perine layer**, which may constitute an apomorphy for mosses and vascular plants. Also, note the 3-lined structure on the spore wall, called a trilete mark, that is the scar from the junction of the 4 spores after meiosis. ***Draw and label*** *a* ***spore****, showing the trilete mark, a filamentous* ***protonema****, and a young* ***gametophyte****, if present.*

Hornworts (Anthocerotae)

Observe the live, preserved, or whole mounts of a hornwort, e.g., *Anthoceros*. Note that the gametophytes of hornworts are thalloid, very similar to those of the thalloid liverworts. ***Draw*** *a hornwort, showing the* ***thalloid gametophyte*** *and the* ***cylindrical sporophyte*** *with a stout* ***foot*** *embedded in the gametophyte and surrounding gametophytic* ***collar****.*

If available, study the longitudinal-section of a hornwort sporophyte. ***Draw and label*** *the* ***spores****, central* ***columella****, and* ***pseudoelaters****, the latter functioning in spore dispersal.*

Plant Systematics Laboratory #4
EVOLUTION AND DIVERSITY OF VASCULAR PLANTS

OBJECTIVES

1. To be able to recognize and name (on sight) all taxa listed below in **bold type**.
2. To be able to recognize and name (on sight) major organs or structural components of these taxa, including knowing all terms listed in **bold type**.
3. To be able to recognize and know the function of the major apomorphies described.

VASCULAR PLANT APOMORPHIES

Vascular Tissue

1. Observe the demonstration slides of **xylem tracheary elements** (**tracheids** or **vessels**). Note that each cell is a miniature tube. *Draw and label.*
2. Observe the demonstration slide of **phloem sieve elements** (**sieve cells** or **sieve tube elements**). Note, in sieve tube elements, the **sieve plates** with aggregates of callose-lined **pores**. *Draw and label.*
3. Observe the demonstration slide of **fibers**. Note that each of the long, tapering cells has a thick, lignified cell wall. *Draw and label.*
4. If available, observe the demonstration slide of **sclereids**. Note the pits in the lignified, secondary cell wall. *Draw and label.*

Shoot and Stem Structure

1. Shoot: Study the prepared slide of a shoot longitudinal section, e.g. *Coleus* stem tip. Note **apical meristem**, **leaf primordia**, and **bud primordia**. Also note the young **vasculature**. *Check off each of these terms from your textbook.*
2. Stem anatomy: Observe the stem cross-section of *Lycopodium*, (clubmoss), *Helianthus* (sunflower), or some other vascular plant. Note the **epidermis**, **cortex**, **pith**, and **vasculature tissue**, consisting of **xylem** and **phloem**. Also note **fibers**, typically outer to the phloem tissue. *Check off each of these terms from your textbook.*

Sporophytic Leaf Structure

1. Leaf Structural Anatomy: Observe the prepared slide leaf cross-section of *Ligustrum*. Note **upper epidermis**, **palisade mesophyll**, **spongy mesophyll**, **lower epidermis** (with **stomata**), and **vascular bundle** (vein), with **xylem** and **phloem**. The vascular bundle contains phloem below and xylem above (when the slide is correctly oriented). *Check off each of these terms from your textbook.*

Root Structure and Function

1. Root morphology: Observe the roots growing from the available material, e. g., *Eichhornia crassipes*, water-hyacinth, or *Raphanus sativus*, radish. Note **root hairs** and **rootcap**.
2. Root development: Look at the prepared slide of a root longitudinal section (e. g., *Ranunculus* or *Elodea* root tip). Note the **root cap** and **apical meristem**, where a high rate of mitosis occurs. Observe that cells elongate as they mature, until at a later stage cells completely differentiate (mature). *Check off each of these terms from your textbook.*
3. Root anatomy: Observe a representative root cross-section of a dicot (e. g., *Ranunculus* older root mature metaxylem). Note the **epidermis**, **cortex** (filled with starch grains), **endodermis**, **xylem**, and **phloem**. What is the function of each? *Check off each of these terms from your textbook.*

DIVERSITY OF NON-SEED VASCULAR PLANTS

The vascular plants differ from "Bryophytes" in having a dominant, photosynthetic, long-lived sporophyte generation. The gametophyte is relatively small and short-lived. Thus, the obvious component of each of the vascular plants below is a diploid sporophyte.

RHYNIOPHYTES

Rhynia. If available, observe the fossilized remains of this plant, one of the earlier vascular plants. These fossil stems are embedded in a rock type called chert, "Rhynie Chert," collected in Aberdeenshire, Scotland. Peruse the references showing photographs and drawings of other representative Rhyniophytes.

LYCOPODIOPHYTA - LYCOPOPHYTES

Lycopodium Club-Moss. Note the general morphology of *Lycopodium*, commonly known as CLUB-MOSS. It is not, of course, a true moss; how does it differ? Vegetatively, there are numerous spirally arranged leaves, **microphylls**, covering the photosynthetic stem. *Lycopodium* has true **roots**, present in all vascular plants except the Psilophytes. Note the yellowish **sporangia** on top of the small leaves. These produce numerous **spores** (which develop into what?). In some species the sporangia are aggregated into a terminal **strobilus** (cone), consisting of an axis of **sporophylls** bearing **sporangia**. *Lycopodium* spores were once used as flash powder in photography.

Draw and label a *Lycopodium* shoot, showing the strobilus. **Optional:** Make an outline drawing of a strobilus longitudinal section, showing the sporophylls and sporangia.

_____***Selaginella*** Spike-Moss, Moss-Fern. *Selaginella bigelovii* BIGELOW'S MOSSFERN. Note the moss-like appearance of this plant, which is actually a vascular plant, native to our region. Stems are rhizomatous to decumbent. The leaves, which are **microphylls**, are very tiny, spirally arranged, and isomorphic, of one size and shape.

Selaginella apoda. This species differs in being prostrate and in having dimorphic leaves in four rows: two with small, dorsal leaves and two with larger, ventral leaves. Observe the leaf morphology. *Draw and label a close-up, showing the four rows of dimorphic microphylls.*

Selaginella sporangia. Observe the longitudinal-section of Selaginella, showing microsporangia, with microspores, and megasporangia, with megaspores. Note the vast difference in spore size. What is the evolution of two spore types termed?

Isoetes Quillwort, Merlin's Grass. This genus of lycopods occur in wet areas, e. g., vernal pools in our region. In most species the stem is short and erect, bearing numerous long, thin leaves, which are **microphylls**. Sporangia are located at the leaf base (upper surface) of some leaves. **Draw and label** the whole plant.

Fossil Lycopods. Note the fossil specimens of ***Lepidodendron*** [=*Stigmaria*]. These plants were large trees (some taller than 100 feet tall), living approximately 200-300 million years ago. *Lepidodendron* stems are recognizable in having the remains of diamond-shaped leaf scars covering the surface. Other representative fossil lycopods may include casts, compressions, or coal-ball peels of *Sigillaria* (stems), *Lepidostrobus* (cones), and *Lepidophlois*. Fossil lycopods are of economic importance in being a major contributor to present day coal and oil deposits. *Learn to recognize Lepidodendron:*

EUPHYLLOPHYTA - EUPHYLLOPHYTES
MONILOPHYTA - MONILOPHYTES
EQUISETOPSIDA - HORSETAILS

***Equisetum* - Equisetaceae**. Observe the herbarium sheets and live material of *Equisetum*, the only extant genus of this group. The Equisetophytes are recognized by 1) the longitudinal ridges on the outer photosynthetic stem; 2) the articulate (jointed), septate nodes; and 3) the whorls of leaves (**microphylls**) present at these nodes.

Species of *Equisetum* lacking many lateral branches are called "scouring rushes," after their use in colonial times as a souring brush to, e. g., clean pots and pans. This use is possible because of the presence of considerable silica in the cell walls of the stems. Species of *Equisetum* with numerous lateral branches (arising from the nodes) are called "Horsetails."

Equisetum hyemale Scouring Rush. Note the rhizomatous underground stem, which often develops into an extensive clonal colony (sometimes encompassing several acres). Also note the whorled leaves (**microphylls**), forming an encircling sheath by virtue of being laterally fused. Terminal **strobili** (cones) may be visible on stems.

Equisetum arvense Horsetail. Note that this species differs from the above in having dimorphic stems. The sterile, photosynthetic stems have numerous lateral branches arising at the nodes. The branches actually pierce the base of the sheath-like leaves and give the plant its characteristic "horsetail" appearance. **Strobili** (cones) are borne at the tips of non-photosynthetic stems which lack the lateral branches. *Draw and label a close-up of the ridged stem, whorled leaves, and (if present) lateral branches.*

***Equisetum* strobilus.** Observe the strobilus (cone) of *Equisetum*. This unique structure consists of a central axis bearing units called **sporganiophores**. Each sporangiophore is a peltate (umbrella-shaped) structure with a stalk, outer shield (somewhat hexagonal in shape), and several inwardly-curved, longitudinally-dehiscent **sporangia**. Observe a sporganiophore with sporangia. Open up a sporangium under the dissecting microscope to expose the **spores**. As they dry, note their amazing movement, caused by hygroscopic elaters attached to the spores that effect spore dispersal. Make a wet-mount of the spores and view with the compound microscope. *Draw and label the strobilus, sporangiophore, and spore.*

Fossil Equisetophytes. During the Carboniferous period and beyond, Equisetophytes were much more common than today and contributed significantly to the biomass of plants. ***Calamites*** was a tree Equisetophyte common during this

time. It is a major component of coal deposits. Observe the fossil *Calamites*, which is recognizable from the longitudinal striations present on this impression of the stem. Other fossil Equisetophytes may include casts, compressions, or coal-ball peels of *Calamodendron* and *Arthropitys*. *Learn to recognize Calamites.*

PSILOTOPSIDA

Ophioglossales - Ophioglossoid Ferns

Observe the specimens of *Ophioglossum* and *Botrychium* spp. in the family Ophioglossaceae. What is distinctive about their leaf anatomy? What type of gametophyte and sporangium to they have?

Psilotales - Whisk Ferns

Psilotum nudum Whisk Broom (Psilotaceae). Observe and draw a stem and **microphyll** of *Psilotum*. What is the underground portion of the plant? The vascular plants differ from liverworts, hornworts, and mosses in having a dominant, photosynthetic, long-lived sporophyte generation. The gametophyte is relatively small and short-lived. Thus, the material you see is diploid sporophyte.

Draw and label a plant of *Psilotum*, showing the **rhizomes** (underground stem), **dichotomously branched aerial stem**, and **microphylls**. Also, *draw and label* a *Psilotum* **synangium**, a fusion product of 3 sporangia, and its forked appendage. **Optional:** Make a wet-mount preparation of the spores and observe with a microscope.

MARATTIOPSIDA - MARATTIOID FERNS

Observe the examples of marattioid ferns, e.g., *Angiopteris, Danaea, Marattia*. Note that these look like typical "ferns," some being quite large. However, carefully observe the sporangia, located on the abaxial surface of some leaves. These are **eusporangia**, which develop from several cells and have a sporangial wall which is many cells thick. This is in contrast to the leptosporangia of the Polypodiopsia (below).

POLYPODIOPSIDA - LEPTOSPORANGIATE FERNS

Note the fern **sporophyte**, the most visible phase of the life cycle. Fern leaves (**fronds**) bear on their underside **sporangia**, often grouped together into **sori** (singlular, **sorus**). Observe the **fiddleheads** or **croziers** (young coiled fern leaves or fronds), exhibiting **circinate vernation**. These are collected and used as a vegetable (tastes similar to asparagus), particularly popular in parts of China.

Salviniales-Aquatic/Heterosporous Ferns

These are true leptosporangiate ferns but are unusual both in being aquatic and **heterosporous** (producing both male and female spores, which develop into separate male and female gametophytes). *Learn to recognize:*

_____***Marsilea*** sp. water clover **Marsileaceae**
_____***Pilularia*** sp., pillwort **Marsileaceae**
_____***Salvinia*** sp. water spangles **Salviniaceae**
_____***Azolla*** sp. mosquito fern **Salviniaceae** [Azollaceae]

If available, observe the endosporic female gametophytes of *Marsilea*, with gelatinous acrolamellae, in which you may find embedded sperm cells.

Cyatheales

Cyatheaceae Scaly Tree Fern family

Cyathea cooperi Australian Tree Fern Cyatheaceae

Note the very large, bi- to tripinnately compound fronds arising from an erect trunk.

Polypodiales

Aspleniaceae Spleenwort family

Asplenium nidus Bird's Nest Fern Polypodiaceae

Note simple fronds and linear sori and indusia, the latter diagnostic for this family.

Polypodiaceae Polypody family

Polypodium aureum Hare's Foot Fern Polypodiaceae

This illustrates a **pinnatifid** (=pinnately divided) frond division. Note the round **sori**, which are **exindusiate**, characteristic of this family.

Platycerium bifurcatum Staghorn Fern Polypodiaceae Australia, New Guinea

This is an epiphytic fern with dimorphic fronds. Sterile fronds overlap the base and function to trap decaying vegetation.

Fertile fronds are erect and pinnately lobed, with **acrostichoid** (not aggregated in sori).

Pteridaceae Pteroid Fern family

Adiantum sp. Maidenhair Fern

Note the generally tripinnately compound fronds. The venation of each pinnule is dichotomous. *Adiantum* has what is called a **false indusium**, a flap of tissue covering the sori originating from the leaf blade margin.

Pteris sp.

Note the marginal sporangia, with a **false indusium**.

Plant Systematics Laboratory #5
EVOLUTION AND DIVERSITY OF WOODY AND SEED PLANTS

OBJECTIVES

1. To be able to recognize and name (on sight) the major apomorphies of the groups described and evaluate their adaptive significance.
2. To be able to recognize and name (on sight) all taxa listed below in **bold type**.
3. To be able to recognize and name (on sight) the major organs or structural components of these taxa, including knowing all terms listed in **bold type**.

LIGNOPHYTA (WOODY PLANT) APOMORPHIES

Eustele

Observe the cross-section of a young stem (before wood formation) of a seed plant. Note the **eustele**, a single ring of vascular bundles, each bundle consisting of an inner group of xylem tracherary elements and an outer group of phloem sieve elements.

Observe a **eustele**, identifying and labeling **vascular bundles**, **xylem**, **phloem**, **cortex**, **pith**, and **epidermis**. Note, at higher magnification, one of the vascular bundles, illustrating a few **tracheary elements** of the xylem, **sieve elements** of the phloem, and **fibers** (if present). *Check off these terms from the illustrations in your book.*

Wood

Study the slide of a young woody stem cross-section. Note the incipient **vascular cambium**, consisting of specialized cells that divide and form **secondary tissue**. *Check off the terms from the illustrations in your book:* **primary xylem**, **primary phloem**, **vascular bundle**, **vascular cambium**, **cortex**, and **pith**.

Study the slide of an older woody stem cross-section. Observe the **vascular cambium**, which has deposited layers of **secondary phloem** to the outside and **secondary xylem** (**wood**) to the inside. Note the annual rings of wood, each layer corresponding to one year's growth, and the **rays** which traverse the secondary tissue. Also note the formation of a **periderm**, from the **cork cambium** at the stem periphery. *Check off the terms from the illustrations in your book:* **secondary xylem**, **secondary phloem**, **vascular cambium**, **cortex**, **pith**, and **periderm**.

Observe the demonstration slide of a close-up of the junction between one annual ring and the next. The rings are caused by the fact that the tracheary elements at the beginning of a growth season are larger and thinner walled, constituting the **spring wood**; those at the end of the season are smaller and thicker walled, constituting the **summer wood**. *Draw* a few cells of each annual ring (at their junction) and label which is the **spring wood** and which **summer wood**.

Observe the wood samples on demonstration. Note the **rays**, **tracheary elements** (tracheids or vessels), and **annual rings**. What is the adaptive significance of wood? Note also the difference in thickness of the annual rings. What might these differences reflect? How can scientists use this data? What is this science called?

DIVERSITY OF NON-SEED WOODY PLANTS

Observe the available material or illustrations of the fossil plant ***Archeopteris*** (not to be confused with the very famous, ancient reptilian bird, *Archeopteryx*), a non-seed Lignophyte. *Archeopteris* was a large tree, with wood like a conifer but leaves like a fern. Sporangia born on fertile branch systems produced spores.

SPERMATOPHYTA (SEED PLANT) APOMORPHIES

The Seed

Observe an **ovule** (immature seed, prior to fertilization and embryo development) from the available material. Prepare a longitudinal section of an ovule or observe the demonstration material. Note the outer **seed coat** and the inner tissue of the **female gametophyte**.

Observe the prepared slides of ovules with a dissecting and compound microscope. Note the outer seed coat, if present. Observe the **megasporangium** (nucellus), having a distal **pollination chamber**. Look closely here for **male gametophytes**: pollen grains with pollen tubes. Note the massive tissue of the **female gametophyte**. Look for the **archegonia** at the distal end of the female gametophyte. *Draw and label* the prepared slide of a seed, noting the above components.

Observe the parts of a seed, from a Cycad, *Ginkgo*, or Conifer. What different functions does the seed have in all these taxa?

If available, dissect a "pine nut" (Pignolia), which is the edible seed of a species of pine (*Pinus pinea*) minus the outer seed coat. Carefully split open (with fingernails or razor blade) the outer, whitish **female gametophyte** tissue to reveal the

central, longitudinally-oriented embryo. With care, you can remove or expose the **embryo** intact. Observe the **radical** (attached to long, stringy suspensor cells), **cotyledons** (3-18 in Pine), and **epicotyl** (observed by removing some cotyledons). *Draw and label* the dissected Pine seed, noting the above components.

Observe the prepared slide of a seed longitudinal section, noting the female gametophyte and embryo parts described above. *Draw.*

DIVERSITY OF SEED PLANTS

Fossil "Seed ferns"

Observe the available material of the fossil seed ferns. "Seed ferns" are a paraphyletic (non-natural) group of fossil plants that had fern-like foliage, yet bore seeds. ***Medullosa*** is one example of a seed fern; note the fossil stems. As in many fossil plants, different organs of *Medullosa* are placed in separate "form genera." For example, the fern-like leaves of *Medullosa* are in the form genera *Alethopteris* and *Neuropteris*. *Dolerotheca* (having huge pollen grains) refers to the pollen-bearing organs of *Medullosa*. Also note the fossil seed *Pachytesta*; both longitudinal and cross-sections are on display.

Cycads (Cycadales)

Cycads are a relatively ancient group of plants, now fairly restricted in distribution. None are native to our area, although many, especially *Cycas circinalis*, are planted horticulturally. Observe the potted specimens of cycads on display. Note the generally short, erect stem, **lacking axillary branching** (a possible apomorphy for the group). Stems bear spirally arranged, coriaceous (leathery), pinnately compound leaves (bipinnately compound in the tropical Australian *Bowenia*). Note that immature leaves have **circinate vernation**.

Note the available reproductive material. All cycads are dioecious, either male or female. Each **male cone (strobilus)** has a central axis bearing **microsporophylls**, which bear **microsporangia** on the abaxial surface. The microsporangia form **microspores**, which develop into **pollen grains**. *Draw and label* a male cycad cone plus a close-up of a microsporophyll with microsporangia.

Note **female cones (strobili)** with **megasporophylls**, each bearing two **seeds**. The genus Cycas itself is the only cycad that lacks cones, having large megasporophylls bearing several seeds. *Draw and label* a female cycad cone and/or *Cycas* megasporophyll plus a close-up of a megasporophyll with attached ovules or seeds. (If suitable material is available, try to observe motile (flagellate) sperm within cycad seeds.)

Cycas (e. Africa to Japan & Australia) ***C. revoluta*** **Sago-Palm** commonly planted as outdoor ornamental; this species and others are a source of sago from pith (probably carcinogenic), used for flour & bread in India; *C. media*, seeds boiled, eaten by Australian Aborigines

Dioon (Mexico & Central America) *D. spinulosa*; *D. edule* (Mexico) has edible seeds

Encephalartos (trop. to s. Africa) Cultivated ornamental; stems a source of sago (starchy food)

Macrozamia (Australia) Cultivated ornamental; seeds edible (e. g., Queensland Nut)

Zamia (trop. & warm Americas) Cultivated ornamental; starch sources (toxic until boiled)

Microcycas (Cuba) Monotypic (*M. calocoma*), endemic to Cuba, almost extinct; mis-named, as it tallest cycad, approaching palms in height (see photograph).

Ginkgo (Ginkgoales)

Observe the live and/or herbarium material of ***Gingko biloba***. *Ginkgo* is native only to certain remote regions of China but has now been planted worldwide as a popular street tree. Note the **short shoots** (in addition to long shoots) and the distinctive obtriangular, apically 2-lobed leaves with dichotomous venation. *Ginkgo*, like the Cycads, is dioecious and has motile (flagellate) sperm that arise from the pollen grain after pollination.

Draw, label, and learn to recognize a *Ginkgo* leaf and short shoot.

Conifers (Coniferales)

Pinaceae PINE FAMILY. Observe a pine branch. Note that the leaves of the main branch, the **long shoot**, are small, brownish, and often non-photosynthetic scale leaves. In the axil of each scale leaf occurs a modified lateral branch, known as a **short shoot** or **fascicle**. Each short-shoot or fascicle consists of stem tissue, one or more needle-shaped leaves, and persistent bud scales. Remember that the fascicle is a shoot system and will arise from an bud in the axil of a scale leaf. *Draw and label* a pine fascicle.

Note the **male cones** of a pine, consisting of **microsporophylls** bearing **microsporangia** (little yellow sacs where pollen grains are produced). ***Draw and label*** a male cone and a close-up of a microsporophyll with microsporangia. If available, observe the male cone longitudinal-section and ***draw*** the same structures.

Make a wet-mount of some pollen grains of pine and observe with a compound microscope. ***Draw and label*** a single pollen grains, noting the saccate morphology (appearing as a "mickey mouse" shape). What is the possible function of the saccate pollen grain morphology?

Female cones are determinate shoots consisting of a stem axis which bears **ovuliferous scales**, each ovuliferous scale subtended by a **bract**. The bracts are generally small but can get large, e.g., in *Pseudotsuga* (DOUGLAS-FIR). Each ovuliferous scale bears **two ovules** (which, of course, develop into **two seeds**) on its adaxial surface. Ovuliferous scales evolved from much more elaborate lateral branch systems, which became fused and flattened; this fertile shoot system constitutes a synapomorphy with the Ginkgoales. Pine seeds are often winged. When the female cones are closed, the outer exposed surface of the ovuliferous scale is called an **apophysis**; a raised portion of the apophysis is known as an **umbo**. The umbo often ends in a prickle. Note **first year cones**, **second year cones**, and mature cones that have released the seeds already.

Observe the prepared slide of a pine female cone, noting **ovule**, **ovuliferous scale**, and **bract**. ***Draw and label***.

Pinaceae. Pine family. *Draw and label* parts of one female cone of a representative members:

Pinus spp. Pines. Note the representative species of pines, including ***P. canariensis***, *P. coulteri*, *P. jeffreyi*, *P. monophylla*, and *P. torreyana*. Note the species differences in the number, shape, and size of the leaves of the fascicle and differences in female cone morphology.

Abies sp. Fir. Note the petiolate to subsessile, linear leaves of the Fir tree. The cones of Fir are erect.

Picea sp. Spruce. Note the petiolate, linear leaves, which leave behind a characteristic peg-like leaf-scar.

Pseudotsuga sp. Douglas-Fir. Note the petiolate, linear leaves. The female cones are pendant (hang down) and have elongate, trifid bracts.

Cupressaceae Cypress family (including Taxodiaceae). Members of this family have characteristic small, triangular (awl-shaped) leaves, which are often (though not always) decussate and closely appressed to the stem.

Calocedrus decurrens [*Libocedrus decurrens*] Incense-Cedar. A large tree of high altitude, coniferous forests (e.g., Cuyamaca, Laguna Mts. of S.D. Co.). Note that the minute, decussate leaves are decurrent along the highly branched and flattened stems.

Chamaecyparis thyoides White Cedar, eastern U.S.

Cupressus forbesii Tecate-Cypress Note the minute leaves and highly branched shoots of this somewhat rare species. The female cones are spherical with tightly closed ovuliferous scales bearing a raised umbo.

Cupressus sempervirens var. *stricta* Italian-Cypress This commonly cultivated tree is tall and very narrow.

Juniperus californica California Juniper. The junipers differ from the cypresses in having succulent, "berry-like" female cones, caused by a thickening and fusion of the ovuliferous scales.

Metasequoia glyptostroboides **Dawn Redwood**

Sequoia sempervirens **Redwood**

Sequoiadendron giganteum **Giant Sequoia**

Taxodium distichum **Bald-Cypress**

Taxodium mucronatum **Montezuma-Cypress**

Thuja occidentalis Eastern White Cedar, *T. plicata* Western Cedar. This genus can be recognized in part by the flattened branch systems.

Araucariaceae. Members of this family are found in parts of South America, Australia, Oceania, and s.e. Asia.

Araucaria bidwillii Bunya-Bunya, n. e. Australia

Araucaria heterophylla Norfolk Island-Pine, Norfolk I., Australia

Podocarpaceae. Members of this family have very reduced female cones, appearing as a single seed.

Agathis sp.

Podocarpus gracilior East African Fern Pine (tropical Africa)

Podocarpus macrophyllus Japanese Yew Pine (Japan)

Gnetales

Ephedra sp. MORMON-TEA. *Ephedra* can be recognized by the photosynthetic, striate (longitudinally ridged) stems and the very reduced scale-like leaves, only 2 or 3 per node. (NOTE: Don't confuse with *Equisetum*; study the differences.) Male or female cones may be found in the axils of the leaves. *Draw and learn to recognize.*

Welwitschia *mirabilis* WELWITSCHIA. Observe the live or preserved material (if available) and photographs of this weird plant native to deserts of Namibia (southwestern Africa). An underground caudex bears only two leaves, these becoming quite long and lacerated in old individuals. Male and female cones are born on axes arising from the apex of the caudex. *Draw and learn to recognize.*

Gnetum. This plant is a tropical vine with opposite, simple leaves, looking all the world like an angiosperm but, of course, lacking true flowers. Observe photographs.

Plant Systematics Laboratory #6
EVOLUTION OF FLOWERING PLANTS

OBJECTIVES

1. To be able to recognize and name (on sight) the major apomorphies of the angiosperms and evaluate their adaptive significance.
2. To be able to recognize and name (on sight) the major organs or structural components of these taxa, including knowing all terms listed in **bold type**.

FLOWERING PLANT APOMORPHIES

Flower

Dissect a flower from the material available. Note the basic floral parts: a **perianth**, composed of a **calyx** of one or more **sepals** and a **corolla** or one or more **petals**; an **androecium**, composed of one or more **stamens**, each with an **anther** and **filament**, the latter of which may be absent; and a **gynoecium** composed of one or more **pistils**, each with an **ovary**, one or more **styles** (which may be absent) and one or more **stigmas**. ***Draw*** the whole flower and label the parts.

Observe the demonstration slide of early flower development in longitudinal-section. Note the resemblance between the determinate flower shoot and a vegetative shoot.

Observe the demonstration slide of a flower in cross-section. **Draw**, noting the **perianth**, **stamens** (with pollen inside), **ovary**, **carpels**, and **ovules**.

Anther

Remove a single anther from flowers of different stages (before and after pollen release) and observe under high magnification. Note the two anther halves, each half called a **theca** (plural, **thecae**). Section a very young anther or observe the microscope slides and note the two microsporangia per theca. **Draw and label**. At dehiscence these microsporangia fuse into a single anther locule.

Reduced Male Gametophyte

Observe an Angiosperm pollen grain from either a prepared slide or a wet mount (stained with acetocarmine or toluidine blue). Note the **tube cell nucleus** and **generative cell** (which later divides into two **sperm cells**). *Draw and label.*

Observe the prepared slides of Angiosperm pollen germination. Note the pollen tube, **generative cell**, and **tube nucleus**. In some, the generative cell may have divided to form the two **sperm cells**? *Draw and label.*

Carpel

If material is available, observe the **gynoecium** of a species that is **apocarpous** (carpels unfused) and of a species that is **syncarpous** (carpels fused).

Draw and label the **pistils** of the apocarpous species (if available), showing **ovary**, **style**, and **stigma**.

Observe the prepared slide of a flower longitudinal-section. Note the basic parts of the flower. In the ovary, observe **locule**(s), **ovules**, and **placentae**. ***Draw and label*** the latter.

If available, observe stages of fruit development. Note how an ovary can drastically change shape and increase in size as it matures into a fruit. ***Draw.*** What is the adaptive significance of a fruit?

Reduced Female Gametophyte

Observe under the dissecting scope the ovary cross sections of *Lilium* or *Fritillaria*. Make an **outline drawing**, showing **ovary wall**, **locules**, and **ovules**. Note the two linear rows of ovules per carpel.

Observe *Lilium* or *Fritillaria*ovules with a "compound" microscope. Observe a single ovule in mid-sagittal view, showing the **funiculus**, **inner integument**, **outer integument**, **micropyle**, and **megasporangium** (**nucellus**). Observe a mature female gametophyte of *Lilium* or *Fritillaria*, noting the three **antipodal cells**, two **polar nuclei**, and 3 cells of the "egg apparatus" (**egg** and **2 synergids**). ***Draw and label.***

If time permits, observe earlier developmental stages of *Lilium* or *Fritillaria*ovule development.

Endosperm

Observe the demonstration of a prepared slide of an angiosperm seed (e. g., *Capsella bursa-pastoris* Shephard's Purse, Brassicaceae). Observe the **endosperm** encasing the **embryo**, both surrounded by a **seed coat**. Note the parts of the embryo: **radical**, **hypocotyl**, **epicotyl**, **cotyledons**. How many cotyledons are there? ***Draw and label.***

Plant Systematics Laboratory #7
DIVERSITY AND CLASSIFICATION OF FLOWERING PLANTS: AMBORELLALES, NYMPHAEALES, AUSTROBAILEYALES, MAGNOLIIDS, CERATOPHYLLALES, AND MONOCOTS

The main objective is to learn to identify a given plant to plant family. Recognizing the family of an unknown angiosperm can be quite helpful in ultimately identifying it using a taxonomic key or specimen comparison. Another objective is to learn to use descriptive morphological terminology. A final objective is to learn the names of one or more exemplars of a given plant family.

The following include character sheets to be used for observing the characteristics of specific families of flowering plants. For each family, determine the character states of the characters listed and fill out the floral formula. Make a drawing of at least one plant family exemplar.

Learn to recognize and know scientific name of EXEMPLARS in **bold**. For EXEMPALRS marked "*", be able to recognize scientific name, and know common name, family, and plant use/part used.

NYMPHAEALES

Nymphaeaceae—Water-Lily family (*Nymphe*, a water nymph). 6 genera / 60 species.

If possible, study the rootstock (underground/underwater stem) of a water-lily. Take a single flower and pull off a single part, working from the outer perianth parts to the innermost stamens. Lay these out and observe the transition between perianth and stamens. ***Draw*** or photograph outer, middle, and inner perianth parts and outer, middle, and inner stamens.

Make a flower longitudinal section. ***Draw*** and observe the ovary position.

Make an ovary cross section. ***Draw*** the placentation.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Nymphaea sp.	Water-Lily	Nymphaeaceae	cult. orn.

MAGNOLIIDS

LAURALES

Lauraceae—Laurel family (L. *laurus*, laurel or bay). 45 genera / 2200 species.

Crush a leaf and smell the aromatic oils. If feasible, make a leaf cross-section and note the oil glands.

Observe the perianth cycly. Pull off 1-2 stamens from the base and ***draw*** carefully. Note any basal nectaries. Note and ***draw*** the anther dehiscence. Are any staminodes present?

Draw the pistil. Try to make a longitudinal section of the ovary and note the placentation. ***Draw***.

If fruits are available, carefully make section to note the fruit type. Is there an enlarged receptacular region? ***Draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

*Laurus nobilis**	Laurel, Bay	Lauraceae	Mediterranean region	herb flavoring
Umbellularia californica	Calif. Laurel, Bay	Lauraceae	nw U.S., California	herb flavoring

MAGNOLIALES

Annonaceae—Custard-Apple family (*Anona*, a Haitian name). 112 genera / 2150 species.

Carefully note and ***draw*** the leaf arrangement.

From a flower sample, note the perianth cycly and merosity.

Make a flower longitudinal section. Remove one or more stamens (***draw***) and note the carpels and placentation (***draw***).

If available, section a seed and note the ruminate endosperm (***draw***).

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

*Annona cherimola**	Cherimoya, Custard-Apple	Annonaceae	Andes, Peru & Ecuador	fruit tree

Magnoliaceae—Magnolia family (after Pierre *Magnol* of Monpelier, 1638–1715). 7 genera/200 species.

Note the stipulate leaves; the stipules encircle the stem, leaving an encircling stipule scar (***draw***).

Pull off one perianth part, from outside to inside, and compare. ***Draw***. What is the perianth arrangement?

Note the distinctive elongate receptacular axis. Note the spiral arrangement of stamens and pistils. Pull off a stamen and ***draw***. Pull off a carpel, section sagittally (dividing it into two mirror image halves). Note the placentation; ***draw***.

If fruits are available, note the fruit type and the seeds, with sarcotesta.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Magnolia grandiflora	Flowering Magnolia	Magnoliacae	s.e. United States	cult. orn.
Michelia doltsopa		Magnoliacae		cult. orn.

PIPERALES

Aristolochiaceae - Birthwort family (Gr. aristos, best + lochia, childbirth, from resemblance of a species of *Aristolochia* to the correct fetal position). 7 genera / 410 species.

Note the plant habit. Draw a leaf, showing its attachment and arrangement.

Draw one of the weird flowers. Note that the great bulk of the perianth is interpreted as a calyx.

Make a longitudinal section of a flower and ***draw***, showing the androecium and gynoecium.

Draw a close-up of the gynostemium, a fusion product of androecium and gynoecium.

Make a longitudinal and cross section of an ovary (appearing like a pedicel. What is the ovary position? placentation type?

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Aristolochia *gigantea*	Birthwort, Dutchman's Pipe	Cultivated ornamental
Aristolochia grandiflorum	Birthwort, Dutchman's Pipe	Cultivated ornamental

Piperaceae—Pepper family (*piper*, Indian name for pepper). 14 genera/1940 species.

Note the stem habit. Make a stem cross-section and note the "stelar" type.

Make a cross section of the inflorescence and note the fleshy axis. What is the inflorescence type?

From several cross sections or side views of the inflorescence, note the flower structure. Can you identify what a flower is? Remove and ***draw*** each flower part. Are the flowers bisexual or unisexual? The If available, section a fruit and note the fruit type. ***Draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Peperomia	Peperomia		Culivated ornamental
**Piper methysticum*	Kava		Source of kava kava, tea/mild euphoric
**Piper nigrum*	Black Pepper	India	Source of black and white pepper

MONOCOTS

MONOCOT APOMORPHIES

Atactostele

Observe the prepared slide of a monocot stem (e. g., *Zea mays*, CORN, Poaceae). Note the **atactostele**, consisting of scattered vascular bundles, lacking a vascular cambium. Make an **outline drawing** of the atactostele. ***Draw*** and ***label*** (below) a close-up of a single vascular bundle, illustrating cells of the xylem **tracheary elements** (**vessels**), phloem **sieve elements** (**sieve tube members**), and **fibers** (phloem bundle fibers).

Parallel or penni-parallel leaf venation

Observe the examples of monocot leaves, having parallel or penni-parallel venation. ***Draw*** and ***label*** (below) a close-up of the smallest veins, showing the **transverse veins** connecting two or more major parallel veins. Compare the monocot with a typical non-Monocot Angiospermous leaf, which has reticulate venation.

One Cotyledon

Observe the prepared slide of a typical monocot seed in section. Note the single cotyledon. ***Draw*** and ***label*** (below).

MONOCOTS

ALISMATALES

Alismataceae—Water-Plantain family (Alisma, a name used by Dioscorides for a plantain-leaved aquatic plant). 11 genera/ca. 80 species.

Draw a leaf, noting the leaf attachment.

Draw a whole flower in face view. What is the perianth cycly?

Note the gynoecium. What is the gynoecial fusion? Remove a stamen and carpel and ***draw*** close-up.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Sagittaria sp.	Arrowleaf	Cultivated ornamental

Araceae — Arum family (Arum, a name used by Theophrastus). 104 genera/ca. 3300 species.

Note the habit and leaf morphology of various examples of the Araceae. What is the inflorescence type? ***Draw***. Determine the flower sex and dissect and ***draw*** one or more flowers, noting all the parts.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Caladium sp.	Caladium		cultivated ornamental
*Colocasia esculenta**	Cocoyam, Taro	trop. Asia	Ornamental, food source in tropics
Dieffenbachia sp.	Dumb-cane	trop. America	Ornamental houseplant; poisonous
Monstera deliciosa	Monstera	trop. America	Ornamental (spathe white)
Philodendron selloum	Philodendron	trop. America	Cultivated ornamental
Xanthosoma sagittifolium	Yautia, Malanga	W. Indies, S. Am.	cult. orn.; rhizome food source
Zantedeschia aethiopica	Calla Lily	S. Africa	cultivated ornamental
Lemna sp.	Duckmeal		Ecologically important
Wolffia sp.	Watermeal		Ecologically important

ASPARAGALES

Apomorphy: Note exemplar seeds with black **phytomelan** in seed coats

Agavaceae—Agave family (after Agave, meaning "admired one"). Ca. 8 (-12+) genera/300+ species.

Note the plant habit and leaf morphology of typical members of the Agavaceae. Scrap a leaf lengthwise on both sides with a stout blade and note the fibrovascular bundles that remain. Study a flower and note the perianth cycly and ovary position, the latter variable in the family. Draw a flower and an ovary cross section, noting the placentation.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Agave sp.	Century Plant		cultivated ornamental
Yucca gloriosa	Spanish Dagger	U.S.: N. Car. - FL.	cultivated ornamental

Alliaceae—Onion family (Latin name for garlic). 13 genera/ca. 600 species.

Dig up the rootstock of members of this family and make a longitudinal section, noting the stem type. Note the characteristic "alliaceous" odor. ***Draw*** the inflorescence, which is characteristic of the family. Note the flower perianth cycly and ovary position. ***Draw*** a flower, stamen, and ovary, whole and in cross section.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

*Allium cepa**	Onion	Mediterranean region	bulb edible
*Allium sativum**	Garlic	Mediterranean region	bulb edible
Tulbaghia violacea	Society-Garlic		cultivated ornamental

MONOCOTS

ASPARAGALES (continued)

Amaryllidaceae—Amaryllis family (Latin name for a country girl). 59 genera / 850 species.

Compare members of this family with the Alliaceae, with which it is closely related. How are they similar in underground stem type, inflorescence type, and perianth cycly? How do they differ in odor and ovary position? Draw a flower, including an ovary cross section, noting the placentation.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Amaryllis sp.	Amaryllis		cultivated ornamental
Clivia miniata	S. African Lily	South Africa	cultivated ornamental
Hymenocallis sp.	Spider Lily		cultivated ornamental

Asphodelaceae—Asphodel or Aloe family. 15 genera / 780 species.

This family is characterized by the leaf texture. Cut a leaf and note the succulent storage tissue. If feasible, section and note the anatomical features. Observe the inflorescence type and flower morphology. ***Draw*** a flower, showing the perianth cycly, stamens, and ovary. Make a cross section to note the placentation. If available, study the fruits and seeds, the latter having characteristic arils. ***Draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Alöe spp.	Aloe	South Africa	cultivated ornamental
Bulbine spp.	Bulbine	South Africa	cultivated ornamental
Gasteria spp.	Gasteria	South Africa	cultivated ornamental
Haworthia spp.	Haworthia	South Africa	cultivated ornamental

ASPARAGALES

Iridaceae—Iris family (after Iris, mythical goddess of the rainbow). 70 genera/1750 species.

Note the underground stem type. Remove a leaf from the point of attachment to the stem. Note the sheathing base. Make a cross section of the leaf at this basal, sheathing region and two other sections 1/3 and 2/3 the distance from the base. ***Draw*** these sectional outlines. What is this leaf structural type called?

Note the inflorescence type of exemplars. How does it vary within the family?

Draw a single flower. How many stamens are there? What is the characteristic stamen position? If you are studying Iris or close relatives, what is distinctive about the styles/stigmas? Finally, what is the ovary position? Make an ovary cross section to note the placentation type. ***Draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Chasmanthe aethiopica	South Africa	cultivated ornamental	
Dietes spp.	African Iris	South Africa	cultivated ornamental
Iris spp.	Iris		cultivated ornamental
Sisyrhinchium spp.	Iris	California	native

ASPARAGALES

Orchidaceae—Orchid family (*orchis*, testicle, from the shape of the root tubers). 700–800 genera / ca. 20,000 species.

If available, note epiphytic members of the orchid family. What is the specialized root type? The flowers require special and detailed study. Note first that, with few exceptions, the flowers are resupinate, twisted 180˚. ***Draw*** a flower in face view. Note the perianth symmetry and cycly. What is the inner, anterior tepal called? Note the central column (gynostegium, gynostemium), a fusion product of androecium and gynoecium. Locate the specialized anther. ***Draw*** a pollinarium, pollinium, and viscidium. Can you locate an operculum? rostellum? Where is the stigma? Finally, observe the inferior ovary, often appearing as a pedicel. Make an ovary cross section and note the distinctive placentation. ***Draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Calodendrum sp.			cultivated ornamental
Dendrobium sp.			cultivated ornamental
Encyclia / *Epidendrum* sp.			cultivated ornamental
*Vanilla planifolia**	Vanilla	C., S. Am.	capsules used as flavoring

MONOCOTS: COMMELINIDS

ARECALES

Arecaceae (Palmae)—Palm family (from areca, Portuguese for the betel palm). ca. 190 genera / 2000 spp.

Observe several palm plants, noting the (typically) single trunk and acrocaulis leaves. Note the inflorescence position, whether infrafoliar, interfoliar, or suprafoliar. Also note leaf type and posture.

Note the inflorescence type and observe and ***draw*** a whole flower. Note perianth cycly, stamen number, and ovary position. From an ovary cross or longitudinal section, note and ***draw*** the placentation.

Section a fruit and note the fruit type. ***Draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Archontophoenix cunninghamiana	King Palm	Queensl., N.S.W., Austr.	cultivated ornamental
*Areca catechu**	Betel-Nut Palm	Trop. Asia (cultigen)	Stimulatory/med. seeds
*Calamus sp.**	Rattan Palm	Old World tropics	Stems-furniture, baskets
Caryota sp. (e.g., *C. mitis*)	Fishtail Palm	S. E. Asia	cultivated ornamental
Chamaedorea costaricana	Palm	Costa Rica	cultivated ornamental
Chamaerops humilis	Mediterr. Palm	Mediterranean region	cultivated ornamental
*Cocos nucifera**	Coconut Palm	Pan-tropical	Edible seed; husk (coir)
*Copernicia cerifera**	Carnauba Palm	n.e. Brazil	Leaves - wax
*Elaeis guineensis**	Oil Palm	W. Africa	Pericarp/seeds - oil
Phoenix canariensis	Canary Is. Palm	Canary Islands	cultivated ornamental
*Phoenix dactylifera**	Date Palm	w. Asia & n. Africa	Edible pericarp
Syagrus romanzoffiana	Queen Palm	c. Brazil to Argentina	cultivated ornamental
Washingtonia robusta	Mex. Fan Palm	Mexico in Son. & B.C.	cultivated ornamental

COMMELINALES

Haemodoraceae—Bloodwort family (Gr. *haimo*, blood, in reference to red pigmentation in roots and rootstocks of some members). 13 genera / 100 species.

Note the plant habit, underground stem type and leaf structural type. ***Draw*** the dendritic trichomes.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLAR:

Anigozanthos sp.	Kangaroo Paw	s.w. Australia	cultivated ornamental

Pontederiaceae– Pickerel-Weed family (for Buillo Pontedera, 1688-1757). 7 genera / 31 species.

Note the plant babit and plant habitat. All members of this family are aquatics. In Eichhornia crassipes (water-hyacinth), note the swollen, spongy petiole bases, functioning in floatation. Also note the adventitious roots with prominent root caps. If flowers are available, fill out a family sheet.

EXEMPLARS:

Eichhornia crassipes	Water-Hyacinth	S. Am.	cultivated ornamental; weed
Pontederia sp.	Pickerel-Weed		cultivated ornamental

ZINGIBERALES

Note the general characteristics (some of which are apomorphic) of this order: 1) leaves ***penni-parallel***; 2) ***supervolute ptyxis***, in which each half of the blade is rolled, one within the other; 3) ***diaphragmed air chambers*** in petioles; 4) ovary ***inferior***. The general floral formula is: **P** 3 + 3 **A** 1-6 **G** (3), inferior

Key to the eight families of the Zingiberales

Fertile stamens 5-6
- Lvs. spiral, flowers unisexual (plants monoecious) . . . . . **Musaceae**
- Lvs. distichous, flowers perfect
  - Lower median tepal of inner whorl a large labellum; style widened into three stigmatic lobes . . . . . **Lowiaceae**
  - Lower median tepal of inner whorl not larger than others; style not widened into three stigmatic lobes
    - Fruit a schizocarp; seeds 1 per carpel, exarillate . . . . . **Heliconiaceae**
    - Fruit a loculicidal capsule; seeds several per carpel, arillate . . . . . **Strelitziaceae**

Fertile stamen 1, staminodes 4, petaloid
- Anterior staminodes connate; fertile stamen not petaloid, fertile anther bithecal
  - Leaves distichous; labellum derived from connation of two inner staminodes . . . . . **Zingiberaceae**
  - Leaves spiral; labellum derived from connation of five petaloid staminodes . . . . . **Costaceae**

Anterior staminodes distinct; fertile stamen petaloid, fertile anther monothecal
Ovules several per carpel; seeds without aril . . . . . **Cannaceae**
Ovules one per carpel; seeds arillate . . . . . **Marantaceae**

ZINGIBERALES (continued)

Musaceae– Banana family (after Antonia Musa, physician to Emporer Augustus 63-14 BC). 3 genera (*Ensete*, *Musa*, and *Musella*) / ca. 40 species.

Note the plant habit, an herb with overlapping leaf sheaths that form a "pseudotrunk". What is the leaf arrangement? Note the penni-parallel venation and the diaphragmed air chambers in the petioles (***Draw***). If possible, dissect the leaves from an erect shoot and observe, at ground level, the apical meristem with leaf primordia.

Observe and dissect the female and male flowers. ***Draw*** each. What is the plant sex? What is the fruit type? ***Draw*** a floral diagram and fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Ensete ventricosum	Abyssinian banana	Ethiopia	cultivated ornamental
*Musa textilis**	Manila-Hemp, Abacá	Phillipines	fiber source
Musa acuminata	Banana		food source
Musa xparadisiaca	**Banana**	India	food source

Strelitziaceae - Bird-of-paradise family (after Charlotte of Mecklenburg-Strelitz, wife of King George III). 3 genera (*Phenakospermum*, *Ravenala*, *Strelitzia*) / 7 species.

Note the leaf morphology and its penni-parallel venation. How does the leaf arrangement differ from the Musaceae? With one inflorescence, make a cross-section of the flowers and note their zig-zag arrangement, forming a monochasial cyme. ***Draw***. Pull off a complete flower of another inflorescence and ***draw*** it. Note the three outer tepals and three inner tepals, in the latter of which the two anterior tepals are connate. Note the protruding stigma; gently pull this up to separate it from the androecium. What is the stamen number, fusion, and dehiscence? Make an ovary cross-section and ***draw***.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Ravenala madagascariensis	Traveler's-Palm	Madagascar	cultivated ornamental
Strelitzia nicolai	**Giant Bird-of-Paradise**	South Africa	cultivated ornamental
Strelitzia reginae	**Bird-of-Paradise**	South Africa	cultivated ornamental

Cannaceae— Canna-Lily family (Gr. canna, a reed). 1 genus (*Canna*) / 10-25 species.

Note the leaf arrangment. Find and carefully remove the outer tepals and inner tepals. Lay these in a row on the table, noting the difference in their morphology. Pull off the showy, petaloid staminodes and stamen, from outside to inside, and also lay out in the row of tepals. Carefully observe the single, fertile stamen. ***Draw*** a close-up of the anther. Note that it is monothecal. ***Draw*** the unusually shaped style. Finally, note the ovary position. Make an ovary cross-section and ***draw***. If fruits are available, draw these.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Canna edulis	Queensland Arrowroot	Australia	rhizome-easily digestible starch
Canna Xgeneralis	**Canna, Arrowroot**	S. Am.	cultivated ornamental

Zingiberaceae– Ginger family (from a pre-Gr. name, possibly from India). 50 genera / ca. 1,300 species.

Note the leaf venation and arrangment of an exemplar species. Pull off a complete flower and ***draw*** it in oblique view. Carefully note the outer tepals and inner tepals. What are the showy portions of the flower? Note the single stamen and its position. Note that the style traverses between the anther thecae. What is the ovary position? ***Draw*** a floral diagram.

Fill out a family sheet. (Note: Answer characters in **bold** first, then answer others as time permits.)

EXEMPLARS:

Alpinia speciosa	Shell-Ginger	e. Asia	cultivated ornamental
*Curcuma longa**	Turmeric	India?	rhizome-spice, in curry powder
*Elettaria cardamomum**	Cardamom	India	seeds used as spice
***Hedychium** flavescens*	Yellow-Ginger	India	cultivated ornamental
Hedychium flavum		India	cultivated ornamental
Hedychium gardnerianum	Kahili-Ginger	India	cultivated ornamental
*Zingiber officinale**	Common Ginger	trop. S.E. Asia	rhizome used as spice

POALES

Bromeliaceae - Bromeliad family (after Swedish medical doctor and botanist, O. Bromell, 1639-1705). 59 genera / 2,400 species.

Note the trichome cover of various bromeliad species. The trichomes function to absorb water from the atmosphere and water and mineral nutrients from runoff and also function in photoreflectance, perhaps in protecting the plant from UV radiation. Scrape off some trichomes from the surface of a leaf into a drop of water or 50% glycerol on a microscope slide and cover with a cover slip. Observe under a high powered compound microscope. ***Draw***, noting the details of the wall structure.

Note the general morphology of different types of bromeliads. Many bromeliads are epiphytic, some are "tank" species, in which the sheathing leaf bases form a catchment for rain water and detritus (and sometimes a home for animals). If available, examine closely the sympodial growth form of *Tillandsia usneoides*, Spanish-moss. Carefully ***draw*** a shoot, noting the sympodial units.

Dissect a flower and fill out a family sheet. Note the ovary position, which varies from superior to inferior. Notice if scales are present at the base of the perianth, and note the characteristic twisted style/stigma. Also note the fruit type (if available), usually a berry (sorosis in *Ananas comosus*) or a capsule, the latter with winged or plumose-crowned (comose) seeds.

EXEMPLARS: (Classification of subfamilies after Givnish et al. 2005)

Subfamily Bromelioideae [Some epiphytic, lvs. usu. spinose-serrate, G inferior, fr. berry, seeds w/o append.]

Aechmea (tank bromeliad)		
*Ananas comosus**	Pineapple	seedless cultigen, derived from native S. Am. sp.; fruit sorosis
Billbergia		lvs. flat; inflor. often pendant; fls. lax
Brocchinia		tank bromeliad that is possibly carnivorous
Bromelia		
Canistrum		infl. head-like; bracts spiral, colorful
Cryptanthus		lvs. undulate
Neoregelia		lvs. forming "tank;" infl. head-like, from center of rosette
Nidularium		lvs. forming "tank;" infl. head-like, from center of rosette

Subfamily Hechtioideae [Usu. terrestrial, G superior, fr. capsule, seeds winged]

Hechtia		lf. margin spinose-serrate

Subfamily Pitcairnioideae [Usu. terrestrial, G superior, fr. capsule, seeds winged]

Dyckia		lf. margin spinose-serrate
Pitcairnia		

Subfamily Puyoideae [Usu. terrestrial, G superior, fr. capsule, seeds winged]

Puya (e. g. *P. alpestris*)		large, coarse lf. rosettes

Subfamily Tillandsioideae [Epiphytic, lvs. usu. entire, G superior, fr. capsule, seeds comose]

Guzmania		lvs. flat; inflor. pedunculate; fl. bracts colorful, spiral
Tillandsia		lvs. var.; inflor. unit spicate; fls. distichous; bracts colorful
Tillandsia usneoides	**Spanish Moss**	s.e. U.S.; epiphytic
Vriesia		lvs. flat; inflor. unit spicate; fls. distichous; bracts colorful

Cyperaceae - Sedge family (Gr. for several species of the genus *Cyperus*). 104 genera / ca. 5,000 species.

If cauline leaves are present, note the closed, sheathing leaf bases and the tristichous leaf arrangement. Remove, observe, dissect, and ***draw*** a sedge spikelet, either in flower or fruit. Study the flower morphology, noting that the perianth, if present at all, consists of bristle-like tepals. Note the bracts (scales) arranged along an axis (rachilla), either in a spiral or distichous arrangement. Study and ***draw*** the fruit type for this family, an achene.

EXEMPLARS:

Cyperus involucratus	**Umbrella Plant**	W. Indies, S. Am.	cultivated ornamental
*Cyperus papyrus**	Papyrus	C. Africa, Nile Valley	cult. orn.; early "paper"

Juncaceae - Rush family (L. for binder, in reference to use in weaving and basketry). 7 genera/ca. 350 spp.

If material is available, study the flowers of a member of this family, noting the biseriate-homochlamydeous, scarious perianth, typically 6 stamens, and 3-carpellate, superior ovary. ***Draw***. Also study and ***draw*** the fruit, a capsule, and contrast this fruit type with that of the Cyperaceae.

EXEMPLAR:

Juncus sp._____	Rush	ecologically important

Poaceae (Gramineae) - Grass family (from Poa, Greek name for a grass). 668 genera / 9,500 species.

Note the leaves, which are distichous, with an open, sheathing leaf base and a ligule at the junction of sheath and blade. Remove, observe, dissect, and ***draw*** a grass spikelet, either in flower or fruit. Note its structure: typically 2 glumes at the base of an axis (rachilla), and one or more florets on a very short lateral branch. ***Draw*** a complete spikelet, then dissect open a floret, illustrating the lemma, palea, and reduced flower (lodicules, stamens, and pistil) or fruit within. Study and ***draw*** the fruit type for this family, a grain.

Arundo donax	Giant Reed	Europe	weed
*Avena sativa**	Oats	Mediterranean region	cereal grain
Cortaderia sp.	Pampas Grass	Argentina	cultivated ornamental
*Hordeum vulgare**	Barley	Mediterranean region	cereal grain
Muhlenbergia rigida	Deer Grass	California	ecologically important
*Oryza sativa**	Rice	s. e. Asia	cereal grain
Phyllostachys aurea	Golden Bamboo	China, Japan	cultivated ornamental
*Saccharum officinarum**	Sugar Cane	Asia or E. Indies(?)	sugar source
*Secale cereale**	Rye	Mediterranean region	cereal grain
*Triticum aestivum**	Wheat	Mediterranean region	cereal grain
*Zea mays**	Corn	Central, S. America	cereal grain

FAMILY CHARACTERISTICS: Example Sheet

FAMILY: Haemodoraceae
SPECIES SCIENTIFIC/COMMON NAME: *Anigozanthos flavidus*

Plant Habit	e.g., herb, shrub, tree, vine
Stem Type - Underground	e.g., rhizome, bulb, corm
Leaf Type	e.g., simple, pinnate, palmate, geminate-pinnate, ternate
Leaf Arrangement	e.g., spiral, opposite-decussate, distichous
Leaf Attachment	e.g., sessile, petiolate, amplexicaul, sheathing
Leaf/Leaflet Blade Shape	e.g., ovate, elliptic, lanceolate
Leaf/Leaflet Blade Base/Margin/Apex	e.g., cuneate / serrate / acuminate
Leaf/Leaflet Surface	e.g., glabrous, tomentose, pubescent
Stipule (+/-)	e.g., exstipulate, stipulate
Inflorescence Type	e.g., raceme, thryse, spike, panicle
Inflorescence Bract/Bractlet (+/-)	e.g., bracteate, involucrate
Flower Sex	e.g., unisexual, bisexual/perfect
Flower Bract/Bractlet (+/-)	e.g., fls. bracteate, ebracteate
Flower Symmetry	e.g., actinomorphic (radial), zygomorphic (bilateral)
Perianth Cycly	e.g., dichlamydeous, homochlamydeous
Perianth/Corolla Type	e.g., bilabiate, campanulate, urceolate
Calyx Fusion/Aestivation	e.g., synsepalous / valvate
Corolla Fusion/Aestivation	e.g., sympetalous / convolute
Hypanthium (+/-) / Shape	e.g., hypanthium tubular
Stamen Position	e.g., antisepalous, diplostemonous
Stamen Arrangement	e.g., didynamous, tetradynamous, whorled, spiral
Androecium Fusion	e.g., epipetalous, monadelphous
Staminode (+/-)/Shape	e.g., present / oblanceoloid, filiform
Anther Attachment	e.g., basifixed, dorsifixed-versatile
Anther Dehiscence/Direction	e.g., longitudinal, poricidal / introrse, extrorse
Gynoecial Fusion	e.g., syncarpous, apocarpous
Ovary Position	e.g., inferior, superior
Perianth/Androecial Position	e.g., hypogynous, perigynous, epigynous, epiperigynous
Carpel Number	e.g., 1, 2, 3, 4, 5, 10
Locule Number	e.g., 1, 2, 3, 4, 5, 10
Placentation	e.g., axile, parietal, basal
Ovule Number (per carpel)	e.g, 1, 2, ∞
Style Position / Stigma Shape	e.g., terminal, gynobasic / linear
Fruit Type	e.g., drupe, loculicidal capsule, achene, follicetum

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

Plant Systematics Laboratory #8
DIVERSITY AND CLASSIFICATION OF FLOWERING PLANTS: EUDICOTS

The main objective is to learn to identify a given plant to plant family. Recognizing the family of an unknown angiosperm can be quite helpful in ultimately identifying it using a taxonomic key or specimen comparison. Another objective is to learn to use descriptive morphological terminology. A final objective is to learn the names of one or more exemplars of a given plant family.

The following include character sheets to be used for observing the characteristics of specific families of flowering plants. For each family, determine the character states of the characters listed and fill out the floral formula. Make a drawing of at least one plant family exemplar.

Learn to recognize and know scientific name of EXEMPLARS in **bold**. For EXEMPALRS marked "*", be able to recognize scientific name, and know common name, family, and plant use/part used.

EUDICOT APOMORPHIES

Observe the demonstration slides of a typical non-Eudicot pollen grain. Note the single, furrow-shaped aperture, an aperture type termed **monosulcate**. ***Draw and label.***

Observe the demonstration slides of a typical Eudicot pollen grain. Note the three, furrow-shaped apertures, an aperture type termed **tricolpate**. ***Draw and label.***

PROTEALES

Platanaceae—Sycamore / Plane Tree family (Greek Platanus, broad leaf). 1 genus (*Platanus*) / 7 species.

Observe a vegetative and reproductive branch of *Platanus*. Note the distinctive encircling stipules (leaving an encircling stipule scar on the twigs), infrapetiolar buds, and palmately divided leaves. Note the inflorescence, consisting of globose head units, which bear either male or female flowers. What is the plant sex of family members? Also note the fruits, a multiple of achenes, with a bristly perianth.

EXEMPLAR:

Platanus racemosa	Western Sycamore	Platanaceae	W USA	cult. orn.

Proteaceae — Protea family (after Proteus, the sea god, for his versatility in changing form). 75 genera / 1350 species.

Observe members of this family. Note the typically coriaceous leaves and the flowers of great diversity of forms. The inflorescence is quite variable, sometimes with hundreds of flowers clustered in a head (e.g., *Protea*, *Leucospermum*) or raceme (e.g., *Banksia*). Carefully pull off a single flower and ***draw***. Note its structure: a perianth of 4 sepals, 4 antisepalous stamens (in some taxa at the tips of the sepals with sessile anthers), and a single pistil. Draw a stamen close-up. Make a longitudinal section of the ovary and note the placentation; ***draw***. Fill out a family sheet for an exemplar of this group.

EXEMPLARS:

Banksia sp.	Banksia	Proteaceae	Australia	cult. orn.
Protea sp.	Protea	Proteaceae	S. Africa	cult. orn.
*Macadamia ternifolia****	Macadamia	Proteaceae	Australia	edible seed

CARYOPHYLLAES

CORE CARYOPHYLLALES APOMORPHIES

If available, prepare or observe a demonstration slides of a typical campylotropous ovule, e.g., from a cactus. Note its structure and venation (see Chapter 12). ***Draw and label.*** What are two other apomorphies of the Core Caryophyllales?

HIGHER CARYOPHYLLALES APOMORPHY

Note the reddish coloration of various members of the so-called "Higher Caryophyllales", which include about 10 families. What causes this pigmentation and how is it different from other angiosperms?

Aizoaceae — Mesembryanthemum or Vygie family (meaning always alive"). 128 genera / 1850 species.

Note the leaf texture and arrangement of exemplars of the Aizoaceae. Section a leaf. Dissect a flower and note the uniseriate perianth and, in many taxa, staminodes that strongly resemble petals. What is the stamen merosity? the perianth/androecial position? the ovary position? the placentation? Fill out a family sheet for this group.

EXEMPLARS:

Aptenia cordifolia	Baby Sun-Rose	Aizoaceae	S. Africa
Carpobrotus edulis	Iceplant, Hottentot-Fig	Aizoaceae	S. Africa
Faucaria tigrina	Tiger's Jaw	Aizoaceae	S. Africa
Lithops sp.	Stone Plant	Aizoaceae	S. Africa
Trichodiadema sp.		Aizoaceae	S. Africa

Cactaceae — Cactus family (Greek for a spiny plant). 97 genera / 1400 species.

Note the distinctive vegetative form of various cacti, most of which lose their photosynthetic leaves early in development. Note the succulent stems, functioning to store water. Observe prickly pears, if available and note their stem type. What is the name for the distinctive, modified bud which bears leaf spines? Which group of cacti have glochidia? If available, observe glochidia under a dissecting microscope and note the distinctive retrorse barbs.

If flowers are available, dissect one and note the perianth, consisting of numerous parts grading from sepal-like to petal-like structures. What is the stamen merosity? perianth/androecial position? ovary position? placentation?

EXEMPLARS:

Opuntia spp.	Prickly-Pear, Cholla	Cactaceae	N., S. Am.
Pereskia grandifolia	Pereskia	Cactaceae	Brazil

Caryophyllaceae — Carnation family (meaning "clove-leaved"). 87 genera / 2300 species.

Polygonaceae — Buckwheat family (meaning "many knees," from swollen nodes found in some species). 46 genera / 1100 species.

Other CARYOPHYLLAES of economic importance:

*Beta vulgaris**	Beet	Amaranthaceae	Mediterranean
*Spinacia oleracea**	Spinach	Amaranthaceae	s.w. Asia
***Bougainvillea* sp.**	**Bougainvillea**	**Nyctaginaceae**	**S. Am.**
Plumbago capensis	**Plumbago**	**Plumbaginaceae**	**S. Africa**

SAXIFRAGALES

Crassulaceae — Stonecrop family (meaning "thick or succulent little plant"). 33 genera / ca. 1500 species.

Note the vegetative form of family exemplars. Section a leaf and note the distinctive texture. What is the photosynthetic pathway of members of this family?

If flowers are available, dissect one and note the perianth cycly, androecium cycly and position, and distinctive gynoecial fusion. Note the fruits, if available. Fill out a family sheet for this group.

EXEMPLARS:

Crassula argentea	Jade Plant	Crassulaceae	cult. orn.
Kalenchoë beharensis	Felt Plant	Crassulaceae	cult. orn.

ROSIDS

MYRTALES

Myrtaceae — Myrtle family (*myrtus*, Gr. name for myrtle). 120 genera / 3850 species.

What is the plant habit of family members? Observe the leaves under a dissecting microscope or hand lens and note the pellucid-glandular or punctate-glandular leaves. What is the function of these?

Dissect and study a flower, noting in particular the ovary position, perianth/androecial position, and stamen number. If *Eucalyptus* is available, note the distinctive perianth, a calyptra.

EXEMPLARS:

Callistemon citrinus	Bottlebrush	Myrtaceae	cult. orn.
Eucalyptus sideroxylon	Red Ironbark	Myrtaceae	cult. orn.
*Pimenta dioica**	Allspice	Myrtaceae	spice (from drupe)
*Psidium guajava**	Guava	Myrtaceae	fruit tree
*Syzygium aromaticum**	Cloves	Myrtaceae	spice (from fl. buds)

ROSIDS: EUROSIDS I

CUCURBITALES

Cucurbitaceae – Cucumber / Gourd family (L. for gourd). 120 genera / 775 species.

Note the plant habit, plant sex, and fruit type of a member of the Cucurbitaceae.

EXEMPLARS:

*Citrullus lanatus**	Watermelon	Cucurbitaceae	food crop
*Cucumis melo**	Melons	Cucurbitaceae	food crop
*Cucumis sativa**	Cucumber	Cucurbitaceae	food crop
*Cucurbita pepo**	Squash, Pumpkin	Cucurbitaceae	food crop
Luffa sp.*	Luffa	Cucurbitaceae	sponge

FABALES

Fabaceae – Bean/Pea family (after *faba*, Latin name for broad bean). 643 genera / 18,000 species.

Observe a ***legume***, the fruit type of all Fabaceae. What are the features of a legume? From what type of pistil is a legume derived?

For one or more of the following subfamilies, fill out a family sheet:

Caesalpinioideae. Note the flower symmetry, stamen fusion, and corolla aestivation.

Faboideae. Note the flower symmetry, stamen fusion, and corolla aestivation. What is the specialized type of perianth type of this subfamily?

Mimosoideae. Note the flower symmetry, stamen fusion, and stamen number. What is the showy part of the flower?

EXEMPLARS:

***Acacia** longifolia*	Wattle	Fabaceae	pan-tropical	cult. orn.
Acacia redolens	Wattle	Fabaceae		cult. orn.
*Arachis hypogaea**	Peanut	Fabaceae		edible seeds
Bauhinia variegata	Orchid Tree	Fabaceae	India, China	cult. orn.
Ceratonia siliqua	Carob, St. John's Bread	Fabaceae	e. Mediter.	cult., ed. fr.
Erythrina caffra	Coral Tree	Fabaceae	e. S. Africa	cult. orn.
Erythrina coralloides	Naked Coral Tree	Fabaceae	warm temp.,trop.	cult. orn.
*Glycine max**	Soybean	Fabaceae	n.e. China	edible seed
Medicago sativa	Alfalfa, Lucerne	Fabaceae		forage crop
*Phaseolus vulgaris**	Bean (incl. Pinto)	Fabaceae	C., S. Am.	edible seed
*Pisum sativum**	Pea	Fabaceae		edible seed

FAGALES

Fagaceae – Oak family (Latin for the beech tree). 8 genera / 700 species.

Observe the plant habit and leaf morphology of an oak in the genus *Quercus*. What is the plant sex? The inflorescence type?

EXEMPLARS:

Quercus suber	Cork Oak	Fagaceae	Mediterranean	source of cork

ROSIDS: EUROSIDS I (continued)

MALPIGHIALES

Euphorbiaceae – Spurge family (after Euphorbus, physician to the king of Mauritania, 1st century). ca. 300 genera / ca. 8,000 species.

Observe the vegetative form of some of the stem-succulent Euphorbia's (subfamily Euphorbioideae) from S. Africa. Note the often prominent stipular spines. Pierce the stem to see the distinctive latex. Obtain material of *Euphorbia* or *Chamaecyse* inflorescences, the cyathium. ***Draw*** this in face or oblique view and label the parts: bracts, glands (if present), male flowers, and female flowers. Make a longitudinal section of a cyathium and dissect out a single male flower, consisting of a single stamen. ***Draw***, noting the typical junction between pedicel and filament. Pull out a female flower and note the components. What is the carpel number? ***Draw***.

EXEMPLARS:

Aleurites fordii	Tung Oil Tree	central Asia	oil (drying)
Euphorbia grandicornis	Cow's-horn	S. Afr.	cult. orn.
Euphorbia milii	Crown-of-Thorns	Madagascar	cult. orn.
*Hevea brasiliensis**	Rubber Tree	S. Am.	source of natural rubber
*Manihot esculenta**	Bitter Cassava	trop. Brazil	food (from roots/cyanide!), tapioca
*Ricinus communis**	Castor Bean	e/ne Afr., ME	oil, poison (ricin, toxalbumin)

ROSALES

Rosaceae – Rose family (Latin for various roses). 95 genera / 2800 species.

Observe a member of the rose family and note the stipules at the base of the leaf, found in almost all members of the family. Make a longitudinal section of a flower and note the hypanthium. What is the perianth/androecial position, ovary position, and gynoecial fusion of family members vary? What are some fruit types of family members?

EXEMPLARS:

Eriobotrya japonica	Loquat	China, Japan	fruit edible
Fragaria X*ananassa**	Strawberry		fruit achenecetum
*Malus domestica**	Apple	Asia	fruit pome
Prunus X*domestica**	Plum	Asia	fruit drupe
*Prunus persica**	Peach	China	fruit drupe
*Pyrus communis**	Pear	Eur., w. Asia	fruit pome
Pyrus kawakami	Evergreen Pear	Taiwan	cult. orn.
Raphiolepis indica	Indian Hawthorn	S. China	cult. orn.
Rosa sp.	Rose		cult. orn.
*Rubus spp.**	Blackberry, Raspberry		fruit drupecetum

Moraceae – Mulberry family (Latin name for mulberry). ca. 40 genera / 1100 species

Make a sagittal longitudinal section of a fig (*Ficus* sp.) and note the inflorescence and/or fruit type. What is their structure? What are they called? What is the plant sex? The pollination mechanism?

EXEMPLARS:

*Ficus carica**	Fig (edible)	Moraceae	fruit crop
Ficus nitida	Indian Laurel Fig	Moraceae	cult. orn.
Ficus rubiginosa	Rusty Fig	Moraceae	cult. orn.
Morus sp.*	Mulberry	Moraceae	fruit crop

ROSIDS: EUROSIDS II

BRASSICALES

Brassicaceae (Cruciferae) – Mustard family (name used by Pliny for cabbagelike plants). 365 genera / 3250 species.

If available, note some economically important members of the Brassicaceae, e.g., some common vegetable plants such as brocolli, cauliflower, or mustard. What class of compounds causes the distinctive odor of these plants (an apomorphy for the order)?

Observe flowers of this distinctive family and note the calyx / corolla fusion and merosity. What is the perianth type? Count the size and number of stamens. What is the stamen arrangement? ***Draw***. Note the ovary and try making an ovary cross-section. Finally, note the fruit. How is it specialized? What are the names of the two fruit types of this family?

EXEMPLARS:

*Brassica campestris**	Turnip	Brassicaceae	Storage Root
Brassica oleracea v. *botrytis**	Brocolli	Brassicaceae	Immature flowers
Brassica oleracea v. *capitata**	Cabbage	Brassicaceae	Veg. shoot
Brassica oleracea v. *cauliflora**	Cauliflower	Brassicaceae	Immature flowers
Lobularia maritima	Sweet Alyssum	Brassicaceae	Europe
*Raphanus sativus**	Radish	Brassicaceae	Storage Root

MALVALES

Malvaceae – Mallow family (name used by Pliny, meaning "soft"). ca. 250 genera / 4230 species.

A good exemplar of this family is *Hibiscus*. Observe a flower and note the bracts subtending the calyx (what are they called?), the calyx aestivation, and the corolla aestivation. What is the stamen fusion? Make a flower longitudinal section to clearly see the ovary position, nectaries, and fusion of androecium and corolla. ***Draw***. What is the specialized anther type? ***Draw***. Note the style (through what does it traverse?), style branches, and stigmas. Finally, make an ovary cross-section to observe the ovule number and placentation. ***Draw***.

EXEMPLARS:

Chorchorus sp.*	Jute	fiber, from fibrovascular bundles
Chorisia speciosa	Floss-Silk Tree	cult. orn.
*Cola nitida**	Cola	flavoring plant
Gossypium sp.*	Cotton	fiber, from seed trichomes
Hibisus sp.	Hibiscus	cult. orn.
*Theobroma cacao**	Chocolate	flavoring plant, fr. roasted seeds

SAPINDALES

Anacardiaceae – Cashew family (Gr. for heart-shaped, after swollen, red pedicel in cashew fruit). 70 genera / 875 species.

EXEMPLARS:

*Anacardium occidentale**	Cashew	Anacardiaceae	trop. Am.
*Mangifera indica**	Mango	Anacardiaceae	Indomal.
*Pistacia vera**	Pistachio	Anacardiaceae	Iran-c. Asia
Schinus terebinthifolius	**Brazilian Pepper Tree**	**Anacardiaceae**	**Brazil**

Rutaceae – Rue / Citrus family (Latin for rue). 153 genera / 1800 species.

EXEMPLARS:

Citrus spp.*	Citrus (orange, lemon, grapefruit, etc.)	Rutaceae	Fruit crops
Ruta graveolens	Rue	Rutaceae	Herb

ASTERIDS

Dissect an ovule from a member of this group and note the unitegmic condition (see Lab 11, Embryology), an apomorphy for all or most of the Asterids. What other, chemical apomorphy is present? What is the typical corolla fusion of the Asterids.

ERICALES

Ericaceae – [including Empetraceae, Epacridaceae, Monotropaceae, Pyrolaceae] — Heath family (from Erica, a name used by Pliny, adapted from Theophrastus). 106 genera / ca. 3355 species.

Make a flower longitudinal section and ***draw***, noting the corolla fusion, stamen fusion, nectaries, and ovary position. ***Fill out a family sheet.***

Obtain fresh (or liquid preserved) material of a member of the Ericaceae exhibiting stages from young buds to mature flowers. Open the flower buds and ***draw*** a stamen from each of 2-4 stages, up to open flowers at anthesis. Note the 180˚ **inversion of the anthers**, an apomorphy for most of the group. Note the anther dehiscence type and direction and any anther appendages that might be present.

Dissect pollen grains from the anther of a member of the Ericaceae. Stain the grains with toludine blue or acetocarmine. If available, clear the grains in Hoyer's solution (see Lab 12, Palynology) and view with Phase contast or Nomarski (DIC) optics. Note that the four pollen grains resulting from meiosis remain attached (at the time or release) as a **tetragonal tetrad**, an apomorphy for all but basal members of the Ericaceae. Carefully draw a pollen tetrad, noting the boundaries of the pollen grains and the intersecting apertures.

EXEMPLARS:

Arbutus unedo	**Strawberry Tree**	**Ericaceae**	**Mediterranean**	**cult. orn.**
Rhododendron spp.*	Rhododendron, Azalea	Ericaceae		cult. orn.
Vaccinium spp.*	Blueberry	Ericaceae		food-berry
Xylococcus bicolor	Mission Manzanita	Ericaeae	California's	native

GENTIANALES

Apocynaceae [incl. Asclepiadaceae] — Dogbane/Milkweed family (Greek for "away from dog," in reference to some taxa used as dog poison). 411 genera / 4650 species.

Obtain flowers of an "Asclepiadoid", a milkweed, formerly classified in the Asclepiadaceae. Study the unusual flower morphology. Open a flower from the side to expose the gynoecium. Note and ***draw*** the two, distinct ovaries and styles, the latter leading to a common, enlarged stigma. From the side of the flower, note and ***draw*** the unusual anthers, which develop into pollinia. Take a dissecting needle and gently pull up on the "corpusculum", to which two arm-like "retinacula" and masses of connate pollen grains are attached. What is the name of the structure consisting of adnate androecium and gynoecium?

Obtain a flower of a more basal (non-milkweed) member of the Apocynaceae. Make a flower longitudinal section and note the ovary, style, and stigma, and any appendages that might be present. Do you see resemblances to the milkweed above?

EXEMPLARS:

Asclepias sp.	Milkweed	Apocynaceae		
Carissa grandiflora	Natal Plum	Apocynaceae	Natal, S. Africa	cult. orn.
Nerium oleander	Oleander	Apocynaceae	Mediterranean-Japan	cult. orn.
*Catharanthus roseus**	Madagascar Periwinkle	Apocynaceae	Madagascar	Source of alkaloids vincristine (leucocristine) & vinblastine (leucoblastine), used to treat childhood leukemia
*Rauvolfia serpentina**	Snakeroot	India	Source or reserpine, an important alkaloid used to treat hypertension (high blood pressure) and psychotic disorders	

LAMIALES

Bignoniaceae – Bignoniaceae — Bignonia family (after Abbé Jean-Paul Bignon, 1662–1743, court librarian at Paris, friend of Tournefort). 109 genera / 750 species.

Draw a flower of this family, especially noting the corolla fusion, corolla symmetry, and stamen arrangement. Observe and ***draw*** the seeds of a typical fruit and note their morphology.

Jacaranda mimosifolia	Jacaranda	Bignoniaceae	N. W. Argentina	cult. orn.

Kigelia pinnata	Sausage Tree	Bignoniaceae	Africa	cult. orn.
Spathodea campanulata	African Fountain Tree	Bignoniaceae	Tropical Africa	cult. orn.
Tecomaria capensis	Cape-Honeysuckle	Bignoniaceae	South Africa	cult. orn.

Lamiaceae – Lamiaceae (Labiatae) — Mint family (*lamium*, gullet, after the shape of the corolla tube or old Latin name used by Pliny). 251 genera / 6700 species.

Fill out a family sheet for an exemplar of the mint family. Note particularly the leaf arrangement, stem shape (often 4-sided), inflorescence type, and ovary shape/style position. Make a flower longitudinal section and ***draw***. Carefully remove the calyx and corolla of another flower and ***draw*** the 4-lobed ovary.

*Mentha piperita**	Peppermint	Lamiaceae	Europe	herb (leaf, oil)
*Mentha spicata**	Spearmint	Lamiaceae	Europe	herb (leaf, oil)
*Ocimum basilicum**	Basil	Lamiaceae	Trop. Asia, Afr.	herb (leaf)
*Origanum vulgare**	Oregano	Lamiaceae	Mediter. region	herb (leaf)
*Rosamarinus officinalis**	Rosemary	Lamiaceae	Mediterranean	herb(leaf)
*Salvia officinalis**	Sage	Lamiaceae	Mediter. region	herb (leaf)
*Thymus vulgaris**	Thyme	Lamiaceae	Mediter. region	herb (leaf)

SOLANALES

Solanaceae — Nightshade family (Latin for sleeping or comforter). 94 genera /2950 species.

Fill out a family sheet of a family member. Note the flower symmetry and corolla aestivation.

EXEMPLARS:

Atropa belladona	Belladona	Solanaceae	Alkaloid atropine (eye dilator)
Brugmansia sp.	Angel's Trumpet	Solanaceae	Cult. orn.
*Capsicum**	Pepper	Solanaceae	Food (berry), flavoring
Datura sp.	Jimson weed	Solanaceae	Hallucinogen, poisonous
*Lycopersicon esculentum**	Tomato	Solanaceae	Food (berry), flavoring
*Nicotiana tabacum**	Tobacco	Solanaceae	Fumatory (carcingenic)
Physalis philadelphica	Tomatillo	Solanaceae	Flavoring plant
*Solanum tuberosum**	Potato	Solanaceae	Food

APIALES

Apiaceae (Umbelliferae) — Carrot family (*apium*, used by Pliny for celerylike pl). 446 genera / 3540 spp.

Note the leaf attachment and inflorescence type of this family. ***Draw*** a single flower, noting the inferior ovary and stylopodium. ***Draw*** a fruit, a schizocarp of mericarps, noting the carpophore.

EXEMPLARS:

*Apium graveolens**	Celery	Apiaceae	Medit. region	Food (leaves), herb (fruits)
Conium maculatum	Poison Hemlock	Apiaceae	Medit. region	Poisonous plant
*Coriandrum sativum**	Coriander, Cilantro	Apiaceae	Medit. region	Herb (fruits), flav (leaves)
*Daucus carota**	Carrot	Apiaceae	Medit. region	Food (root), herb (fruits)
*Foeniculum vulgare**	Wild Fennel	Apiaceae	Medit. region	Herb (fruits)
*Petroselinum crispum**	Parsely	Apiaceae	Medit. region	Garnish (leaves)

Araliaceae — Ginseng family (possibly from French Canadian Aralie). 47 genera / 1325 species.

Note the leaf attachment and inflorescence type of this family. ***Draw*** a single flower, noting the inferior ovary. Make and ovary longitudinal section and note the placentation. ***Draw***. Make an ovary cross section and ***draw***, noting the carpel number. What is the fruit type? EXEMPLARS:

Fatsia japonica	Fatsia	Araliaceae	Cult. orn.
Hedera sp.	Ivy	Araliaceae	Cult. orn.
Panax sp.	Ginseng	Araliaceae	Medicinal uses/
Schefflera *actinophylla*	Schefflera	Araliaceae	Cult. orn.
Tetrapanax papyrifer	Chinese rice paper	Araliaceae	Paper

ASTERALES

Asteraceae (Compositae)—Sunflower family (after Aster, meaning star). 1528 genera / 22,750 species.

Note the typical inflorescence type of this family. Make a longitudinal section of a head and ***draw***, noting the compound receptacle, involucral bracts (phyllaries) and flowers. Carefully remove and ***draw*** a ray flower and disk flower. Note the ovary, calyx (modified as a pappus, which may be absent), and corolla. Carefully dissect the corolla from the side and ***draw*** the distinctive stamen fusion. Note and ***draw*** a fruit.

*Cynara scolymus****	Artichoke	Asteraceae	Medit.	Food (heads)
*Helianthus annuus****	Sunflower	Asteraceae	N. Am.	Seeds, oil
*Lactuca sativa****	Lettuce	Asteraceae		food (shoot)

FAMILY CHARACTERISTICS: Example Sheet

FAMILY: Haemodoraceae
SPECIES SCIENTIFIC/COMMON NAME: *Anigozanthos flavidus*

Plant Habit	e.g., herb, shrub, tree, vine
Stem Type - Underground	e.g., rhizome, bulb, corm
Leaf Type	e.g., simple, pinnate, palmate, geminate-pinnate, ternate
Leaf Arrangement	e.g., spiral, opposite-decussate, distichous
Leaf Attachment	e.g., sessile, petiolate, amplexicaul, sheathing
Leaf/Leaflet Blade Shape	e.g., ovate, elliptic, lanceolate
Leaf/Leaflet Blade Base/Margin/Apex	e.g., cuneate / serrate / acuminate
Leaf/Leaflet Surface	e.g., glabrous, tomentose, pubescent
Stipule (+/-)	e.g., exstipulate, stipulate
Inflorescence Type	e.g., raceme, thryse, spike, panicle
Inflorescence Bract/Bractlet (+/-)	e.g., bracteate, involucrate
Flower Sex	e.g., unisexual, bisexual/perfect
Flower Bract/Bractlet (+/-)	e.g., fls. bracteate, ebracteate
Flower Symmetry	e.g., actinomorphic (radial), zygomorphic (bilateral)
Perianth Cycly	e.g., dichlamydeous, homochlamydeous
Perianth/Corolla Type	e.g., bilabiate, campanulate, urceolate
Calyx Fusion/Aestivation	e.g., synsepalous / valvate
Corolla Fusion/Aestivation	e.g., sympetalous / convolute
Hypanthium (+/-) / Shape	e.g., hypanthium tubular
Stamen Position	e.g., antisepalous, diplostemonous
Stamen Arrangement	e.g., didynamous, tetradynamous, whorled, spiral
Androecium Fusion	e.g., epipetalous, monadelphous
Staminode (+/-)/Shape	e.g., present / oblanceoloid, filiform
Anther Attachment	e.g., basifixed, dorsifixed-versatile
Anther Dehiscence/Direction	e.g., longitudinal, poricidal / introrse, extrorse
Gynoecial Fusion	e.g., syncarpous, apocarpous
Ovary Position	e.g., inferior, superior
Perianth/Androecial Position	e.g., hypogynous, perigynous, epigynous, epiperigynous
Carpel Number	e.g., 1, 2, 3, 4, 5, 10
Locule Number	e.g., 1, 2, 3, 4, 5, 10
Placentation	e.g., axile, parietal, basal
Ovule Number (per carpel)	e.g, 1, 2, ∞
Style Position / Stigma Shape	e.g., terminal, gynobasic / linear
Fruit Type	e.g., drupe, loculicidal capsule, achene, follicetum

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K C A G** or **P A G**

FAMILY CHARACTERISTICS

Fill out the states for the following characters.

FAMILY: _____

SPECIES SCIENTIFIC/COMMON NAME: _____

Plant Habit	
Stem Type - Underground	
Leaf Type	
Leaf Arrangement	
Leaf Attachment	
Leaf/Leaflet Blade Shape	
Leaf/Leaflet Blade Base/Margin/Apex	
Leaf/Leaflet Surface	
Stipule (+/-)	
Inflorescence Type	
Inflorescence Bract/Bractlet (+/-)	
Flower Sex	
Flower Bract/Bractlet (+/-)	
Flower Symmetry	
Perianth Cycly	
Perianth/Corolla Type	
Calyx Fusion/Aestivation	
Corolla Fusion/Aestivation	
Hypanthium (+/-) / Shape	
Stamen Position	
Stamen Arrangement	
Androecium Fusion	
Staminode (+/-)/Shape	
Anther Attachment	
Anther Dehiscence/Direction	
Gynoecial Fusion	
Ovary Position	
Perianth/Androecial Position	
Carpel Number	
Locule Number	
Placentation	
Ovule Number (per carpel)	
Style Position / Stigma Shape	
Fruit Type	

FLORAL FORMULA: **K** **C** **A** **G** or **P** **A** **G**

Plant Taxonomy Laboratory #9
PLANT MORPHOLOGY

A. PLANT HABIT, PLANT HABITAT, ROOTS, STEMS, TWIGS

Objective: To be able to ***recognize*** and ***define*** the plant characters and character states exemplified below. Working in pairs, first determine the meaning/concept of a given character state. Then, learn the specific character state. Review at end. [You need not memorize specific examples on display.]

PLANT HABIT

What does plant habit refer to?

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
1)		
2)		
3)		
4)		

PLANT HABITAT

What does plant habitat refer to?

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
5)		
6)		
7)		

ROOT TYPE

What is the function of a root?

Observe and ***list*** the parts of a root.

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
8)		
9)		
10)		
11)		
12)		

STEM/SHOOT TYPE

What is the function of a stem? What is a shoot?

Define and ***list the parts of*** a shoot.

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
13)		
14)		
15)		
16)		
17)		
18)		
19)		
20)		
21)		
22)		
23)		
24)		
25)		

STEM HABIT

What does stem habit refer to?

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
26)		
27)		
28)		
29)		

TWIG MORPHOLOGY

Draw a representative twig and ***label*** the following: **leaf scar**, leaf **vascular bundle scars**, **stipule scars** (if present), **terminal bud**, **lateral (axillary) bud**, **node**, **internode**, **lenticels**.

For a single bud, carefully make a longitudinal section with a razor blade. Observe (under dissecting scope) the **bud scales** and young **leaf primordia**. ***Draw and label.***

BUD TYPE

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
30)		
31)		
32)		
33)		
34)		

STEM BRANCHING PATTERN

List one example and ***define*** each of the following character states. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
35)		
36)		
37)		

B. LEAF STRUCTURAL TYPE, LEAF ATTACHMENT, LEAF VENATION, LEAF TYPE

LEAF STRUCTURAL TYPE

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
9)		
10		
11		
12		

LEAF ATTACHMENT

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
13)		
14)		
15)		
16)		
17)		
18)		

LEAF VENATION

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
19)		
20)		
21)		
22)		
23)		
24)		

LEAF TYPE

List the character state and ***define (example optional)***. ***Draw*** or ***photograph*** as needed.

Character State	***Definition***	***Example (optional)***
25)		
26)		
27)		
28)		
29)		
30)		
31)		
32)		
33)		
34)		
35)		

NOTE: Be able to identify/define:

stipule

petiole

blade

rachis

rachilla

leaflet

petiolule

pulvinus.

C. SURFACE FEATURES

For each of the following surface types, ***define each character state*** and observe and list one example. **Draw** or **photograph** as needed.

VESTITURE

Character State	*Definition*	*Example (optional)*
arachnoid		
glabrous		
hirsute		
hispid		
scabrous		
sericeous		
sericeous		
villous		

TRICHOME TYPE

Character State	*Definition*	*Example (optional)*
Malpighian		
pilate-glandular		
stellate		

CONFIGURATION

Character State	*Definition*	*Example (optional)*
aculeate/prickly		
punctate		
rugose		

EXCRESCENCE

Character State	*Definition*	*Example (optional)*
glandular		
glaucous		
viscid		

B. VEGETATIVE MORPHOLOGY AND GENERAL TERMINOLOGY

VEGETATIVE MORPHOLOGY EXAMPLES: Answer the following.

Acacia longifolia/A. redolens Wattle Fabaceae

A) Leaf structural type:

B) Leaf shape:

C) Leaf base:

D) Leaf apex:

E) Leaf apical process:

Acmispon glaber Deer Weed Fabaceae

A) Leaf type:

B) Leaflet shape:

Adenóstoma fasciculàtum Chamise Rosaceae

A) Stem/shoot type:

B) Leaf arrangement:

C) Leaf shape:

D) Leaf apex:

Artemísia califórnica Coastal Sagebrush Asteraceae

A) Leaf division:

Arundo donax / Avena fatua Wild Oat Poaceae

A) Leaf arrangement:

B) Leaf venation:

C) Leaf attachment:

D) Lf str. type (inflor.):

Bauhinia variegata Orchid Tree Fabaceae

A) Leaf shape:

B) Leaf base:

C) Leaf division:

D) Leaf venation:

Calliandra hematocephala Powderpuff Fabaceae

A) Leaf type (specific):

B) Leaf arrangement:

C) Leaflet arrangement:

D) Leaflet venation:

E) Leaf parts at petiole base:

Encèlia californica California Encelia Asteraceae

A) Leaf base:

B) Leaf venation:

Eriogonum fasiculatum Ca. Buckwheat Polygonac.

A) Stem type (at leaves):

B) Leaf arrangement:

C) Leaf margin:

D) Leaf apical process:

Erythrina caffra Coral-Bean Fabaceae

A) Leaf type:

B) Leaf part (arrow):

C) Leaf part (arrow):

D) Leaf part (arrow):

Eucalyptus sideroxylon Eucalyptus Myrtaceae

A) Leaf type:

B) Leaf shape:

Foeniculum vulgare Fennel Apiaceae

A) Leaf division:

B) Leaf attachment:

Heterómeles arbutifòlia Toyon, Christmas Berry Rosac.

A) Leaf margin:

B) Leaf texture:

Juniperus sp. Juniper Cupressaceae

A) Leaf arrangement:

B) Leaf orientation:

A) Leaf shape:

Lupinus hirsutissimus Stinging Lupine Fabaceae

A) Leaf type:

B) Vestiture:

Malosma laurina Laurel-Sumac Anacardiaceae

A) Leaf texture:

B) Leaf posture (longitudinal):

Màrah macrocárpus Wild-Cucumber Cucurbitaceae

A) Plant habit:

B) Leaf type:

C) Leaf division:

D) Stem/Leaf structure (coiled):

Plátanus racemòsa California Sycamore Platanaceae

A) Leaf division:

B) Bud type:

C) Stipule scar type:

Pópulus fremóntii Western Cottonwood Salicaceae

A) Leaf shape:

B) Leaf base:

Prunus ilicifolia Holly-leaf Cherry Rosaceae

A) Leaf margin:

B) Leaf posture:

Rhus integrifòlia Lemonadeberry Anacardiaceae

A) Leaf texture:

B) Leaf margin:

Sagittaria latifolia Arrow Leaf Alismataceae

A) Leaf shape:

B) Leaf base:

Salix lasiolepis Arroyo Willow Salicaceae

A) Leaf epidermal excrescence (abax.):

Salvia mellifera Black Sage Lamiaceae

A) Leaf arrangement:

B) Leaf surface (configuration):

Schefflera sp. Araliaceae

A) Leaf type:

B) Leaf surface:

Schinus terebinthifolius Pepper Tree Anacardiaceae

A) Leaf type:

B) Leaf surface:

Stelitzia reginae Bird of Paradise Strelitziaceae

A) Leaf venation:

B) Leaf attachment:

C) Leaf blade shape:

Tropaeolum majus Nasturtium Tropaeolaceae

A) Leaf base:

B) Leaf blade shape:

Washingtonia robusta Fan Palm Arecaceae

A) Leaf posture:

B) Leaf division:

Leaf Texture:

A) Carpobrotus/Aloe leaf:

B) Protea: C) Allium (bulb scales):

Leaf Surface:

A) Nicotiana glauca leaf:

B) Banksia sp. leaf (abaxial): C) Kigelia africana leaf: D) Phacelia sp. stem/leaf:

VEGETATIVE MORPHOLOGY EXERCISE

Fill in the following for each species. For at least one, write a formal description, listing the organ or part (in **Bold**, below) followed by character state(s), the states separated by commas.

	SPECIES #1:	SPECIES #2:	SPECIES #3:
Plant Duration[1]			
Plant Habit / Height			
Stem Type[2]			
(**Aerial**) **Stem** Habit[2]			
Leaf (**Leaves**) Number / Length[3]			
Leaf Type			
Leaf Attachment			
Leaf stipule/stipel presence/absence			
Leaf Duration			
Leaf Position			
Leaf Arrangement			
Leaf Orientation[4]			
Leaf Posture			
Rachilla Number (if bi-compound)			
Leaflets Number (if compound)			
Leaf **Blade** / **Leaf outline** Shape[5]			
Leaflet Blade Shape (if compound)			
Leaflet Blade Attachment (if compd.)			
Leaf/Leaflet Blade Color / Length/Wid			
Leaf/Leaflet Blade Base			
Leaf/Leaflet Blade Margin			
Leaf/Leaflet Blade Apex /Apical Proc.			
Leaf/Leaflet Blade Division			
Leaf/Leaflet Blade Venation			
Leaf/Leaflet Blade Surface[6]			
Leaf/Leaflet Blade Texture			
Petiole/Petiolule Morph/Color/Size			
Stipule/Stipel Shape/Morph/Size			

[1]Omit if plant habit = shrub or tree; [2]Omit if not specialized; [3]Leaf Number (per plant) normally not listed unless unusual; may omit Length if listed for petiole & blade separately. [4]You may omit Orientation if variable or mostly horizontal. [5]Use Leaf **Blade** if leaf simple; **Leaf outline** if leaf compound. [6]Includes configuration, epidermal excrescence, and vestiture; distinguish adaxial and abaxial surfaces.

VEGETATIVE MORPHOLOGY EXERCISE

Fill in the following for each species. For at least one, write a formal description, listing the organ or part (in **Bold**, below) followed by character state(s), the states separated by commas.

	SPECIES #4:	SPECIES #5:	SPECIES #6:
Plant Duration[1]			
Plant Habit / Height			
Stem Type[2]			
(**Aerial**) **Stem** Habit[2]			
Leaf (**Leaves**) Number / Length[3]			
Leaf Type			
Leaf Attachment			
Leaf stipule/stipel presence/absence			
Leaf Duration			
Leaf Position			
Leaf Arrangement			
Leaf Orientation[4]			
Leaf Posture			
Rachilla Number (if bi-compound)			
Leaflets Number (if compound)			
Leaf **Blade** / **Leaf outline** Shape[5]			
Leaflet Blade Shape (if compound)			
Leaflet Blade Attachment (if compd.)			
Leaf/Leaflet Blade Color / Length/Wid			
Leaf/Leaflet Blade Base			
Leaf/Leaflet Blade Margin			
Leaf/Leaflet Blade Apex /Apical Proc.			
Leaf/Leaflet Blade Division			
Leaf/Leaflet Blade Venation			
Leaf/Leaflet Blade Surface[6]			
Leaf/Leaflet Blade Texture			
Petiole/Petiolule Morph/Color/Size			
Stipule/Stipel Shape/Morph/Size			

[1]Omit if plant habit = shrub or tree; [2]Omit if not specialized; [3]Leaf Number (per plant) normally not listed unless unusual; may omit Length if listed for petiole & blade separately. [4]You may omit Orientation if variable or mostly horizontal. [5]Use Leaf **Blade** if leaf simple; **Leaf outline** if leaf compound. [6]Includes configuration, epidermal excrescence, and vestiture; distinguish adaxial and abaxial surfaces.

D. FLOWER & INFLORESCENCE MORPHOLOGY

1) Basic Floral Parts and Dissection

Observe a flower from the outside and identify: **bract** (if present), **pedicel** (if present), and **perianth**. Note if the perianth consists of **tepals** or **tepal lobes** or is clearly delimited into **calyx** and **corolla**. If the latter (dichlamydeous), note the **sepals** or **calyx lobes** and the **petals** or **corolla lobes**. ***Draw***.

Now open up the flower by making a longitudinal section of the entire flower with a razor blade. Note the **stamens**, and whether **laminar** or **filamentous** (consisting of a **filament** and **anther**). ***Draw***.

Note the **gynoecium**, consisting of one or more **pistils**. Note the **ovary position**, whether superior, or inferior. Note if there is a **hypanthium**, a tube-like or cup-like structure (arising from the base to the top of the ovary), to which are attached the perianth and androecium. Determine the **perianth/androecial position**. ***Draw***.

Now, make an ovary cross-section. If the ovary is large enough, you can do this by holding the ovary vertically in one hand and slicing it with a razor blade held in the other hand. [You may instead hold the entire flower upside-down in one hand, such that you will be slicing through the perianth when making an ovary cross-section.] When slicing the ovary, gently cut across the ovary *while sliding the blade toward you*. (Be careful not to slice into a finger!) Make several, sequential slices with the razor blade. You may leave these on the blade or transfer to a microscope slide using a needle. Observe the sections with a dissecting microscope and note the **placentation**. ***Draw***.

2A) Floral Description

Dissect a flower and fill in the following character states for selected species. ***Write*** a description by listing each organ or part (in **Bold**, below) followed by character state(s) separated by commas. ***List*** the floral formula, ***draw*** appropriate floral parts, and ***illustrate*** with a floral diagram.

Characters	SP. #1:	SP. #2:
Inflorescence Position/Type		
Flower Sex		
Flower Symmetry		
Flower Attachment		
Bract(s)/Bractlet(s) (No.)/Size/Shape/Surface		
Receptacle Size/Shape		
Hypanthium (if present) Shape/Size		
Perianth Cycly / Aestivation		
Perianth (& Hypanthium) Type		
Calyx/Outer Tepal(s) Fusion		
Sepal(s)/Calyx **Lobes**/Outer Tepal(s) Merosity		
Corolla/Inner Tepal(s) Fusion		
Corolla/Inner Tepal(s) Color		
Petal(s)/Corolla **Lobe(s)**/Inner Tepal(s) Merosity		
Stamen(s) (Androecium) Cycly/Merosity		
Stamen Arrangement		
Stamen Position		
Stamen Insertion		
Stamen Fusion		
Staminode(s) (if present) No./Pos./Size/Shape		
Anther(s) Attachment		
Anther Dehiscence Type / Direction		
Gynoecium Fusion		
Ovary Position / Attachment (if not sessile)		
Perianth/Androecial Position		
Carpel(s) Number		
Locule(s) Number		
Placentation		
Ovule(s) Number (Per carpel)		
Style(s) Number (Per pistil)		
Style Position/Shape		
Stigma(s) Shape		
Nectary(s) Type/Position		

FLORAL FORMULAS: K C A G K C A G

or P A G P A G

2B) Floral Description

Dissect a flower and fill in the following character states for selected species. ***Write*** a description by listing each organ or part (in **Bold**, below) followed by character state(s) separated by commas. ***List*** the floral formula, ***draw*** appropriate floral parts, and ***illustrate*** with a floral diagram.

Characters	SP. #3:	SP. #4:
Inflorescence Position/Type		
Flower Sex		
Flower Symmetry		
Flower Attachment		
Bract(s)/Bractlet(s) (No.)/Size/Shape/Surface		
Receptacle Size/Shape		
Hypanthium (if present) Shape/Size		
Perianth Cycly / Aestivation		
Perianth (& Hypanthium) Type		
Calyx/Outer Tepal(s) Fusion		
Sepal(s)/Calyx **Lobes**/Outer Tepal(s) Merosity		
Corolla/Inner Tepal(s) Fusion		
Corolla/Inner Tepal(s) Color		
Petal(s)/Corolla **Lobe(s)**/Inner Tepal(s) Merosity		
Stamen(s) (Androecium) Cycly/Merosity		
Stamen Arrangement		
Stamen Position		
Stamen Insertion		
Stamen Fusion		
Staminode(s) (if present) No./Pos./Size/Shape		
Anther(s) Attachment		
Anther Dehiscence Type / Direction		
Gynoecium Fusion		
Ovary Position / Attachment (if not sessile)		
Perianth/Androecial Position		
Carpel(s) Number		
Locule(s) Number		
Placentation		
Ovule(s) Number (Per carpel)		
Style(s) Number (Per pistil)		
Style Position/Shape		
Stigma(s) Shape		
Nectary(s) Type/Position		

FLORAL FORMULAS: K C A G K C A G

or P A G P A G

2C) Floral Description

Dissect a flower and fill in the following character states for selected species. ***Write*** a description by listing each organ or part (in **Bold**, below) followed by character state(s) separated by commas. ***List*** the floral formula, ***draw*** appropriate floral parts, and ***illustrate*** with a floral diagram.

Characters	SP. #5:	SP. #6:
Inflorescence Position/Type		
Flower Sex		
Flower Symmetry		
Flower Attachment		
Bract(s)/Bractlet(s) (No.)/Size/Shape/Surface		
Receptacle Size/Shape		
Hypanthium (if present) Shape/Size		
Perianth Cycly / Aestivation		
Perianth (& Hypanthium) Type		
Calyx/Outer Tepal(s) Fusion		
Sepal(s)/Calyx **Lobes**/Outer Tepal(s) Merosity		
Corolla/Inner Tepal(s) Fusion		
Corolla/Inner Tepal(s) Color		
Petal(s)/Corolla **Lobe(s)**/Inner Tepal(s) Merosity		
Stamen(s) (Androecium) Cycly/Merosity		
Stamen Arrangement		
Stamen Position		
Stamen Insertion		
Stamen Fusion		
Staminode(s) (if present) No./Pos./Size/Shape		
Anther(s) Attachment		
Anther Dehiscence Type / Direction		
Gynoecium Fusion		
Ovary Position / Attachment (if not sessile)		
Perianth/Androecial Position		
Carpel(s) Number		
Locule(s) Number		
Placentation		
Ovule(s) Number (Per carpel)		
Style(s) Number (Per pistil)		
Style Position/Shape		
Stigma(s) Shape		
Nectary(s) Type/Position		

FLORAL FORMULAS: K C A G K C A G

or P A G P A G

2D) Detailed Floral Description Exercise

Dissect a flower and fill in the following character states for a given species. ***Write*** a description by listing each organ or part (in **Bold**, below) followed by character state(s) separated by commas. ***List*** the floral formula, ***draw*** appropriate floral parts, and ***illustrate*** with a floral diagram.

Characters	Species:
Inflorescence Position	
Inflorescence Development [1]/Type[2]	
Flower Sex	
Flower Size[3]	
Flower Arrangement[4]/Orientation	
Flower Symmetry[5]	
Flower Attachment	
Pedicel (if present) Size/Shape	
Bract(s)/Bractlet(s) (No.)/Size/Shape/Surface	
Receptacle Size/Shape[6]	
Hypanthium (if present) Shape/Size	
Perianth Cycly / Aestivation	
Perianth (& Hypanthium) Type[7]	
Calyx/Outer Tepal(s) Fusion	
Calyx/Outer Tepal(s) Size	
Calyx/Outer Tepal(s) Surface	
Sepal(s)/Calyx **Lobes**/Outer Tepal(s) Merosity	
Sepal(s)/Calyx Lobes/Outer Tepal(s) Shape	
Sepal(s)/Calyx Lobes/Outer Tepal(s) Size	
Corolla/Inner Tepal(s) Fusion	
Corolla/Inner Tepal(s) Cycly[8]	
Corolla/Inner Tepal(s) Color	
Corolla/Inner Tepal(s) Size	
Corolla/Inner Tepal(s) Surface	
Petal(s)/Corolla **Lobe(s)**/Inner Tepal(s) Merosity	
Petal(s)/Corolla Lobe(s)/Inner Tepal(s) Shape	
Petal(s)/Corolla Lobe(s)/Inner Tepal(s) Size	
Petal(s)/Corolla Lobe(s)/Inner Tepal(s) Orientation	
Stamen(s) (Androecium) Cycly/Merosity	
Stamen Type / Attachment	
Stamen Arrangement	
Stamen Position	
Stamen Insertion	
Stamen Fusion	
Staminode(s) (if present) No./Pos./Size/Shape	
Anther(s) Attachment	
Anther Dehiscence Type / Direction	
Gynoecium Fusion	
Ovary Position / Attachment (if not sessile)	
Perianth/Androecial Position	
Carpel(s) Number	
Locule(s) Number	
Placentation	
Ovule(s) Number (Per carpel)	
Style(s) Number (Per pistil)	
Style Position/Shape	
Stigma(s) Shape	
Nectary(s) Type/Position	

[1]Unecessary if development implied by inflorescence type; [2]List both secondary and primary (unit) inflorescence; e. g., "panicle of heads;" [3]Unecessary if sizes of individual flower parts given; [4]Often omitted unless unusual; [5]Describe symmetry of individual floral components; [6]Describe only if receptacle enlarged or unusual; [7]List here only if for whole perianth, not, e. g., for corolla alone; [8]List only if not uniseriate.

FLORAL FORMULA: K C A G or P A G

FLOWER & INFLORESCENCE MORPHOLOGY: EXAMPLES

Inflorescence Position	terminal; axillary
Inflorescence Development [1]/Type[2]	raceme of indeterminate umbels; head; panicle; thyrse
Flower Sex	bisexual/perfect; unisexual/imperfect (describe male/female)
Flower Size[3]	2.5 cm long; 9 mm broad
Flower Arrangement[4]/Orientation	opposite on rachis/divergent; inclined
Flower Symmetry[5]	actinomorphic (radial); zygomorphic (bilateral)
Flower Attachment	pedicellate; sessile; bracteate; ebracteate
Pedicel (if present) Size/Shape	2 cm long; terete
Bract(s)/Bractlet(s) (No.)/Size/Shape/Surface	bracts 3 mm long, ovate, hirsute; bractlets 2, 1mm, ovate
Receptacle Size/Shape[6]	3 mm long; hemispheric; discoid
Hypanthium (if present) Shape/Size	cup-shaped; flat; 4 mm long, 8 mm wide from edge to edge;
Perianth Cycly / Aestivation	biseriate; homochlamydeous / valvate; convolute
Perianth (& Hypanthium) Type[7] cruciate	campanulate; bilabiate; salverform; rotate; urceolate;
Calyx/Outer Tepal(s) Fusion	aposepalous; synsepalous basally; distinct; connate
Calyx/Outer Tepal(s) Size	1.4 cm long; 3 mm wide
Calyx/Outer Tepal(s) Surface	adaxially glabrous; abaxially pubescent; hirsute along veins
Sepal(s)/Calyx **Lobes**/Outer Tepal(s) Merosity	3, (or 3-merous, trimerous)
Sepal(s)/Calyx Lobes/Outer Tepal(s) Shape	lanceolate, attenuate (clawed), acute
Sepal(s)/Calyx Lobes/Outer Tepal(s) Size	4 mm long; 1.5 mm wide
Corolla/Inner Tepal(s) Fusion	apopetalous; sympetalous
Corolla/Inner Tepal(s) Cycly[8]	uniseriate; biseriate
Corolla/Inner Tepal(s) Color	yellowish; anterior lobe purple with red basal spots
Corolla/Inner Tepal(s) Size	35-55 mm long, 20 mm wide
Corolla/Inner Tepal(s) Surface	pubescent; hirsute; bearded at adaxial base
Petal(s)/Corolla **Lobe(s)**/Inner Tepal(s) Merosity	3; 4; 5 (or 5-merous, pentamerous)
Petal(s)/Corolla Lobe(s)/Inner Tepal(s) Shape	oblanceolate, acuminate
Petal(s)/Corolla Lobe(s)/Inner Tepal(s) Size	1.5 cm long; 3 mm wide
Petal(s)/Corolla Lobe(s)/Inner Tepal(s) Orientation	3 posterior petals/lobes divergent; 2 anterior recurved
Stamen(s) (Androecium) Cycly/Merosity	uniseriate, 8; biseriate and pentamerous (or 5 + 5)
Stamen Type / Attachment	filamentous; laminar / sessile
Stamen Arrangement	whorled; tetradynamous; didymous; didynamous
Stamen Position	antipetalous; antisepalous; diplostemous
Stamen Insertion	exserted; inserted
Stamen Fusion	epipetalous; monadelphous; syngenesious; diadelphous
Staminode(s) (if present) No./Pos./Size/Shape	One, posterior; 12 mm long; lanceoloid
Anther(s) Attachment	basifixed; subbasifixed; dorsifixed; versatile
Anther Dehiscence Type / Direction	longitudinal; poricidal / introrse; extrorse
Gynoecium Fusion	apocarpous; syncarpous; semicarpous; unicarpellous
Ovary Position / Attachment (if not sessile)	superior; inferior; half-inferior / stipitate (stylocarpepodic)
Perianth/Androecial Position	hypogynous; epigynous; perigynous; epiperigynous
Carpel(s) Number	1; 2; 3; 5; 10
Locule(s) Number	1; 2; 3; 4
Placentation	axile; parietal; marginal; free-central; basal; apical
Ovule(s) Number (Per carpel)	1; 2; 4; numerous (specify approx. number)
Style(s) Number (Per pistil)	1; 2; 3; 5
Style Position/Shape	terminal; subapical; gynobasic; lateral / terete, flattened
Stigma(s) Shape	capitate; clavate; decurrent; 3-lobed; plumose; terete
Nectary(s) Type/Position	septal; base of ovary; at base of spur

FLORAL FORMULAS: K=Calyx C=Corolla P=Perianth A=Androecium G=Gynoecium, superior or inferior ( )=fusion

INFLORESCENCE MORPHOLOGY (CALIFORNIA PLANTS)

Amorpha fruticosa Fabaceae**:**

A. Inflorescence type:

B. Inflorescence position:

Amsinkia menziesii var. intermedia Boraginac.**:**

A. Inflorescence type:

Avena fatua Poaceae**:**

A. Inflorescence type:

Bahiopsis laciniata S. D. Sunflower Asteraceae**:**

A. Inflorescence type:

B. Infl. parts:

Brodiaea kinkiensis Themidaceae**:**

A. Inflorescence type:

B. Structure (at "1"):

C. Structure:

Foeniculum vulgare Fennel Apiaceae**:**

A. Inflorescence type:

B. Structure:

C. Structure:

Lathyrus sulphureus Fabaceae**:**

A. Inflorescence type:

B. Inflorescence position:

C. Inflorescence structure:

D. Inflorescence structure:

E. Structure (flower part):

Marah macrocarpa Cucurbitaceae:

A. Plant sex:

B. Inflor. type (staminate):

C. Inflor. type (pistillate):

Mimulus aurantiacus Phrymaceae**:**

A. Inflorescence type:

B. Inflorescence position:

Mirabilis multiflora Nyctaginaceae:

A. Inflorescence type:

B. Infl. structure (subtending fls.)**:**

Penstemon spectabilis Plantaginaceae**:**

A. Infl. type:

Quercus kelloggii Fagaceae:

A. Inflorescence type:

B. Inflorescence sex:

Salvia mellifera Black Sage Lamiaceae**:**

A. Inflorescence type:

B. Flower symmetry:

C. Perianth structural type:

Sambucus nigra subsp. caerulea Adoxaceae**:**

A. Inflorescence type:

Saxifraga bryophora Saxifragaceae**:**

A. Inflorescence type:

FLOWER MORPHOLOGY (CULTIVATED PLANTS-Spring):

Alliaceae/Themidac. *Allium, Dichel. Tulbaghia*
- A) Perianth cycly:
- B) Perianth parts:
- C) Perianth fusion:
- D) Ovary position:

Apocynaceae *Carissa grandiflora*
- A) Perianth cycly:
- B) Perianth type:
- C) Leaf arrangement:
- D) Stem type (sharp):

Araceae
- A) Inflorescence type:
- B) Inflorescence bract:
- C) Flower sex:
- D) Plant sex:

Asteraceae
- A) Inflorescence type:
- B) Inflorescence bracts:
- C) Perianth types:

Balsaminaceae *Impatiens*
- A) Perianth type:

Begoniaceae *Begonia*
- A) Flower sex:
- B) Plant sex:
- C) No. perianth parts (male):
- D) No. perianth parts (female):
- E) Ovary position:

Boraginaceae *Echium*
- A) Inflorescence:
- B) Style position:
- C) Perianth type:

Brassicaceae *Brassica, Hirschfeldia, Lobularia*
- A) Perianth type:
- B) Stamen arrangement:

Convolvulaceae *Calystegia, Ipomoea*
- A) Perianth type:
- B) Perianth fusion:

Crassulaceae *Aeonium, Crassula, Dudleya*
- A) Stamen cycly:
- B) Stamen pos.:
- C) Gynoecial fusion type:

Cucurbitaceae *Marah*
- A. Inflorescence type (male):
- B. Flower sex:
- C. Plant sex:

Ericaceae *Arbutus, Xylococcus*
- A) Perianth type:
- B) Anther dehiscence:

Iridaceae *Chasmanthe, Iris*
- A) Inflorescence type:
- B) Ovary position:
- C) Perianth symmetry:

Lamiaceae *Salvia, Leonotis, Rosmarinus*
- A) Flower symmetry:
- B) Perianth type:
- C) Style position:

Lauraceae *Laurus, Umbellularia*
- A) Anther cycly:
- B) Anther dehiscence type:

Malvaceae *Hibiscus, Lavatera*
- A) Androecial fusion:
- B) Carpel number:
- C) Stigma shape:

Plumbaginaceae *Limonium, Plumbago*
- A) Perianth type:

Rhamnaceae *Ceanothus*
- A) Sepal posture:
- B) Petal posture:
- C) Stamen position:

Rosaceae *Prunus*, *Pyrus*
- A) Ovary position:
- B) Perianth/androecial pos.:
- C) Flower part:

Solanaceae *Nicotiana glauca*
- A) Perianth symmetry:
- B) Perianth type:
- C) Ovary position:

Solanaceae *Datura*
- A) Perianth symmetry:
- B) Perianth type:
- C) Stamen fusion:
- D) Ovary position:

FLOWER MORPHOLOGY (CULTIVATED PLANTS-Fall):

Agapanthaceae *Agapanthus*
- A) Inflorescence type:
- B) Perianth cycly:
- C) Ovary position:
- D) Perianth/androecial position:
- E) Flower symmetry:

Alliaceae *Tulbaghia*
- A) Perianth cycly:
- B) Perianth parts:
- C) Perianth fusion:
- D) Stamen fusion:
- E) Stamen insertion:

Apocynaceae *Carissa grandiflora*
- A) Perianth cycly:
- B) Perianth type:
- C) Leaf arrangement:
- D) Stem type (sharp):

Asteraceae
- A) Inflorescence type:
- B) Inflorescence bracts:
- C) Perianth types:

Balsaminaceae *Impatiens*
- A) Perianth type:

Begoniaceae *Begonia*
- A) Flower sex:
- B) Plant sex:
- C) No. perianth parts (male):
- D) No. perianth parts (female):
- E) Ovary position:

Brassicaceae *Lobularia maritima*
- A) Perianth type:
- B) Stamen arrangement:

Crassulaceae *Aeonium, Crassula*
- A) Stamen cycly:
- B) Stamen pos.:
- C) Gynoecial fusion type:

Ericaceae *Arbutus, Xylococcus*
- A) Perianth type:
- B) Anther dehiscence:

Haemodoraceae *Anigozanthos*
- A) Inflorescence type:
- B) Flower symmetry:
- C) Ovary position:
- D) Perianth trichome type:

Lamiaceae *Leonotis leonurus*
- A) Inflorescence type:
- B) Flower symmetry:
- C) Perianth type:
- D) Style position:
- E) Perianth (outer) vestiture:

Lauraceae *Laurus, Umbellularia*
- A) Anther cycly:
- B) Anther dehiscence type:

Lythraceae *Lagerstroemia indica* Crape Myrtle
- A) Perianth type:
- B) Perianth/androecial pos.:
- C) Corolla merosity:

Malvaceae *Hibiscus* or *Lavatera*
- A) Calyx aestivation:
- B) Corolla aestivation:
- C) Androecial fusion:
- D) Style no.:

Myrtaceae *Eucalyptus* sp.
- A) Perianth type:
- B) Ovary position:
- C) Perianth/androecial position:

Plantaginaceae *Linaria* or *Penstemon*
- A) Perianth symmetry:
- B) Perianth type:
- C) Stamen arrangement:

Plumbaginaceae *Limonium* or *Plumbago*
- A) Perianth type:
- B) Calyx trichomes:

Rosaceae *Raphiolepis*
- A) Ovary position:
- B) Perianth/androecial pos.:
- C) Flower part:

Solanaceae *Nicotiana* or *Brugmansia*
- A) Perianth symmetry:
- B) Perianth type:
- C) Ovary position:

E. FRUIT AND SEED MORPHOLOGY

Working with another person, ***complete the answers*** in this key to specific fruit types.

Fruit derived from a single flower
- Fruit derived from a single ovary (pistil) of 1 flower = **SIMPLE FRUIT**
  - Pericarp dry at maturity (i. e., at time of seed maturation and dispersal)
    - Fruit winged ..... **1)** _____
      [Note: Many fruit types below may be winged; these may be called a samara or, e.g., a "winged achene."]
    - Fruit not winged
      - Fruit dehiscent (splitting or opening in a regular manner)
        - Carpel 1
          - Fruit dehiscing along a single (ventral) line ..... **2)** _____
          - Fruit dehiscing along two lines ..... **3)** _____
        - Carpel 2 or more
          - Carpels 2; fruits dehiscent along 2 lines, w/ persistent central septum (replum) bearing seeds
            - Fruit about as long as broad ..... **4)** _____
            - Fruit 2X or more longer than broad ..... **5)** _____
          - Carpels 2 or more; fruits lacking a persistent central septum
            - Fruit splitting into 2 or more mericarps enclosing seed(s) at time of splitting ..... **6)** _____
              [Note: The mericarp may be identified as a specific unit fruit type; e. g., a "schizocarp of follicles."]
            - Fruit not splitting into mericarps
              - Fruit dehiscing by pores ..... **7)** _____ _____
              - Fruit dehiscing by lines
                - Lines of dehiscence transversely oriented ..... **8)** _____ _____
                - Lines of dehiscence vertically oriented
                  - Lines of dehiscence opposite locules ..... **9)** _____ _____
                  - Lines of dehiscence along septa ..... **10)** _____ _____
      - Fruit indehiscent
        - Seed coat fused completely to pericarp ..... **11)** _____
        - Seed coat not fused to pericarp
          - Pericarp moderately hard; seed attached to pericarp at one point
            - Pericarp inflated, bladder-like (i.e., pericarp large in relation to seed) ..... **12)** _____
            - Pericarp not inflated or bladder-like (i.e., pericarp ca. same size as seed) ..... **13)** _____
          - Pericarp very hard; seed attached to pericarp at one or more points ..... **14)** _____
  - Pericarp fleshy at maturity (i. e., at time of seed maturation and dispersal)
    - Endocarp hard and stoney ..... **15)** _____
    - Endocarp not hard and stoney
      - Ovary superior; endocarp with juice sacs (swollen liquid-filled trichomes) ..... **16)** _____
      - Ovary superior or inferior; juice sacs absent
        - Ovary inferior; exocarp leathery & placentation parietal or endocarp cartilaginous & plac. axile
          - Exocarp leathery and placentation parietal ..... **17)** _____
          - Endocarp cartilaginous and placentation axile ..... **18)** _____
        - Ovary superior or inferior; pericarp fleshy, but not a pepo nor a pome ..... **19)** _____
- Fruit derived from several ovaries (pistils) of 1 flower = **AGGREGATE FRUIT**. Some types:
  - Unit fruit fleshy at maturity**,** with a hard endocarp and fleshy mesocarp ..... **20)** _____
  - Unit fruit dry at maturity
    - Unit fruit indehiscent, 1-seeded ..... **21)** _____
    - Unit fruit dehiscent, with one line of dehiscence ..... **22)** _____

Fruit derived from more than 1 (usu. several) flowers = **MULTIPLE FRUIT**. Some types:
- Unit fruits fleshy, laterally fused, arising along a common central axis ..... **23)** _____
- Unit fruits not fused, born *inside* a fleshy compound receptacle with an apical pore ..... **24)** _____

FRUIT AND SEED EXAMPLES

Aceraceae *Acer macrophyllum* Big-Leaf Maple
- A) Fruit type:
- B) Dispersal mechanism:

Actinidiaceae *Actinidium chinensis* Kiwi
- A) Fruit type:
- B) Ovary position:
- C) Carpel number:

Agavaceae *Hesperoyucca whipplei* Chaparral Yucca
- A) Fruit type:
- B) Fruit dehiscence:
- C) Ovary position:
- D) Carpel number:
- E) Seed shape:

Anacardiaceae *Mangifera indica* Mango
- A) Fruit type:

Apiaceae *Foeniculum vulgare* Fennel
- A) Fruit type:
- B) Fruit unit:
- C) Structure between fruits:

Apocynaceae *Asclepias cordifolia* Milkweed
- A) Fruit type:
- B) Seed surface (vestiture):
- C) Dispersal mechanism:

Arecaceae *Cocos nucifera* Coconut
- A) Fruit type:
- B) Pericarp layers:
- C) Name white flesh, milky fluid:
- D) Dispersal mechanism:

Asteraceae *Helianthus annuus* Sunflower
- A) Fruit type:
- B) Fruit development:

Asteraceae *Xanthium* sp. Cocklebur
- A) Fruit type:
- B) Accessory part:
- C) Dispersal mechanism:

Brassicaceae *Arabis perennans*
- A) Fruit type:
- B) Name of central septum (partition):
- C) Carpel number:

Brassicaceae *Capsella bursa-pastoris* Shep's Pur.
- A) Fruit type:

Bromeliaceae *Ananas comosus* Pineapple
- A) Fruit type:
- B) Fruit development:
- C) Ovary position:

Caricaceae *Carica papaya* Papaya
- A) Fruit type:
- B) Placentation:

Cucurbitaceae *Cucumis/Cucurbita* Cucumber/squash
- A) Fruit type:
- B) Placentation:
- C) Ovary position:

Fabaceae *Acacia, Erythrina*. *Pisum*, *Senegalia*, etc..
- A) Fruit type:
- B) Number of lines of dehiscence:
- C) Carpel number:
- D Placentation:

Fabaceae *Arachis hypogaea* Peanut
- A) Fruit type:

Fagaceae *Quercus* sp. Oak
- A) Fruit type:
- B) Accessory structure, base of fruit:

Juglandaceae *Juglans regia* Walnut
- A) Fruit type:
- B) Accessory tissue:

Lamiaceae *Leonotis leonurus* Lion's Mane
A) Fruit type:
B) Style position:

Magnoliaceae *Magnolia grandiflora* Fl. Magnol.
A) Fruit development:
B) Fruit type:
C) Red, fleshy covering of seeds:

Moraceae *Ficus* sp. Fig
A) Fruit type:
B) Fruit part:

Musaceae *Musa paradisiaca* Banana
A) Fruit type:
B) Ovary position:
C) Carpel number:
D) Pericarp layers:

Myrtaceae *Eucalyptus* sp. Eucalyptus
Fruit type:

Papaveraceae *Papaver* sp. Poppy
A) Fruit type:

Platanaceae *Platanus racemosa* Calif. Sycamore
Fruit development:
Fruit type:

Poaceae *Zea mays* Corn
A) Fruit development:
B) Fruit type:

Rosaceae *Fragaria* X *ananassa* Strawberry
Fruit development:
Fruit type:
Accessory tissue:

Rosaceae *Malus pumila* Apple / *Pyrus* sp. Pear
A) Fruit type:
B) Placentation:
C) Ovary position:
D) Accessory tissue:
E) Dispersal mechanism:

Rosaceae *Prunus persica* Peach
A) Fruit texture:
B) Fruit type:
C) Pericarp layers:

Rosaceae *Rubus* sp. Blackberry/Raspberry
A) Fruit type:

Rutaceae *Citrus* sp. Orange, Grapefruit
A) Fruit type:
B) Locule number:
C) Placentation:
D) Pericarp layers:

Solanaceae *Nicotiana glauca* Tree Tobacco
A) Fruit type:
B) Carpel number:
C) Seed surface:

Solanaceae *Physalis* Tomatillo
A) Fruit type:
B) Accessory tissue:

Solanaceae *Solanum esculentum* Tomato
A) Fruit type:
B) Ovary position:
C) Placentation:

Vitaceae *Vitis* sp. Grape
A) Fruit type:
B) Ovary position:

SEED AND SEEDLING MORPHOLOGY

Bean (*Phaseolus vulgaris*): Observe **seed coat** and **embryo** (noting that endosperm is absent). The embryo consists of two large **cotyledons**, the **radicle** (embryonic root), the **hypocotyl** (between the cotyledons and radicle), and the **epicotyl** (embryonic shoot). Note the transformation of these structures from seed to seedling stage. The cotyledons are lifted above the ground on the hypocotyl (called "**epigeal**" germination) and eventually wither away. Is bean a dicot or monocot? **Draw and label** the seed.

Corn (*Zea mays*): Observe outermost **pericarp** (fruit wall), **seed coat**, **endosperm**, and **embryo**. The embryo consists of one **cotyledon**, a **radicle** (contained within the **coleorhiza**), and the **epicotyl** (contained within the **coleoptile**). Note the transformation of these structures from seed to seedling stage. The cotyledon and seed coat remain in the ground (called "**hypogeal**" germination). Is corn a dicot or monocot? **Draw and label** the seed.

If available, observe various seeds with different types of seed coats, including seeds that have: 1) **wings**; and 2) a **sarcotesta** (fleshy layer). Also, observe seeds that are **arillate**, i. e., with **arils**, which is an outer, fleshy layer additional to the seed coat proper.

FRUIT MORPHOLOGY

Foeniculum vulgare Fennel Apiaceae. Take a single unit fruit and examine under a dissecting scope. Note that these fruits split open at maturity. 1) ***Draw and label***. 2) What is the fruit type? 3) What is the name of each of the fruit halves? 4) What is the name of the stalk that attaches to each of these halves?

Fragaria sp. Strawberry Rosaceae. Take a single strawberry and observe the parts. Note the calyx below and, if you look carefully, persistent, withered stamens between the calyx and the fruit. Section the strawberry longitudinally to see the greatly expanded receptacle tissue. Observe the surface of the strawberry under a dissecting scope. 1) ***Draw and label*** a single pistil and note the style and stigma. Remove a few pistils and dissect, noting the single seed within. 2) What is the fruit type? 3) What is the name of the swollen, fleshy tissue (99% of the fruit volume)?

Lobularia maritima Sweet Alyssum Brassicaceae (or other member of the Brassicaceae). Remove the fruits and observe under a dissecting scope. Carefully make a cross-section with a razor blade to note the central replum (mature septum in fruit) and two locules. For mature fruits, note that the replum persists after the two valves detach. 1) ***Draw and label*** a fruit. 2) What is the fruit type? 3) What is the name of the persistent septum?

Plantago sp. Plantain Plantaginaceae. Look at the fruit under a dissecting scope and note the transverse line of dehiscence, characteristic of a circumscissile capsule. 1) ***Draw and label.*** 2) What is the fruit type?

Platanus sp. Sycamore Platanaceae. Observe the multiple fruits of this taxon. Pull off a single unit fruit and dissect, noting that it is one-seeded, dry and indehiscent. What is this unit fruit called? What is the multiple fruit called? 1) ***Draw and label.*** 2) What is the fruit type?

Rubus sp. Raspberry, Blackberry Rosaceae. Observe one of the unit fruits (derived from one pistil) under the dissecting scope. 1) ***Draw and label*** a unit fruit, noting the style and stigma. 2) What is the fruit type?

Salvia sp. or *Leonotus leonuris* Lamiaceae. Note the inflorescence type, a verticillaster. Pull off several calyces from the base and place under a dissecting scope. Carefully dissect these zygomorphic calyces to find 4 schizocarpic nutlets inside. The nutlets have probably fallen off; thus, an individual calyx may bear only a single nutlet. 1) ***Draw and label.*** 2) What is the fruit type? 3) What is the term of the unit of each fruit?

FRUIT & SEED MORPHOLOGY

	SPECIES #1:	SPECIES #2:
Fruit Origin/Development		
Fruit Texture		
Fruit Dehiscence (+/-;#;Pos.)		
Fruit Structural Type		
Fruit Color/Size		
Fruit Shape		
Fruit Surface		
Funiculus Size/Shape		
Seed Color/Size		
Seed Shape		
Seed Surface		
Seed Type (Nutritive Tissue)		
Aril (+/-), Size/Shape/Pos.		
Embryo Type (Size/Shape/Pos.)		
Cotyledon Position		
Radicle Position		
Seedling Type		

Draw and label the fruit, seed, and seed parts.

FRUIT AND SEED MORPHOLOGY: EXAMPLES

Fruit Origin/Development	simple; aggregate; multiple; accessory
Fruit Texture	dry; fleshy
Fruit Dehiscence (+/-;#;Pos.)	indehiscent; dehiscent: 2 longitudinal lines of deh.
Fruit Structural Type	septicidal capsule; drupe; follicetum; sorosis; hip
Fruit Color/Size	green; yellow / 2-3 cm long; 8-9 mm long, 2 mm wide
Fruit Shape	ovoid; ellipsoid; spherical; pyriform
Fruit Surface	farinaceous; glabrous; pubescent; tomentose; viscid
Funiculus Size/Shape	funiculus 1-2 mm long, narrow, curved
Seed Color/Size	dark brown; yellow / 1.1-1.7 mm long; 2.5 cm long
Seed Shape	discoid; ellipsoid; fusiform; lenticular
Seed Surface	comose; glabrous; scabrous; verrucose
Seed Type (Nutritive Tissue)	cotylespermous; endospermous
Aril (+/-), Size/Shape/Pos.	seeds arillate, aril small, basal
Embryo Type (Size/Shape/Pos.)	lateral; linear; rudimentary
Cotyledon Position	lateral
Radicle Position	basal
Seedling Type	epigeous; hypogeous

F. PLANT MORPHOLOGY TERMINOLOGY EXERCISE

Obtain a plant flora from a local region or of cultivated plants. For each character below, list one character state from a description in that flora, indicating the taxon name and page number.

GENERAL CHARACTERS

	Character state	***Taxon***	***Page no.***
COLOR / Color			
Color Pattern			
SIZE / Size			
NUMBER / Number			
Cycly			
Merosity			
TEXTURE / Texture			
FUSION			
General Fusion			
SHAPE			
Shape: Solid			
Shape: Plane			
Base			
Margin			
Apex: Shape			
Apex: Apical Process			
Division			
DISPOSITION			
Position			
Arrangement			
Orientation			
Transverse Posture			
Longitudinal Posture			
Twisting / Bending Posture			
VENATION / Venation			
SURFACE			
Configuration			
Epidermal Excrescence			
Vestiture			
Trichome Types			
Bristle Types			
SYMMETRY / Symmetry			

	Character state	***Taxon***	***Page no.***
TEMPORAL PHENOMENA			
Duration Maturation			
Periodicity			

PLANT STRUCTURE CHARACTERS: VEGETATIVE

	Character state	***Taxon***	***Page no.***
ROOTS			
Plant Parts Plant Habit			
Root Parts			
Root Type			
STEMS/SHOOTS			
Twig Structures Bud Types			
Stem parts: Bark			
Stem Branching Pattern			
Stem Habit			
Stem / Shoot Type			
LEAVES			
Leaf Parts Leaf Type			
Leaf Attachment			
Leaf Structural Type			

PLANT STRUCTURE CHARACTERS: REPRODUCTIVE

	Character state	***Taxon***	***Page no.***
INFLORESCENCES			
Inflorescence Parts Inflorescence Position			
Inflorescence Development			
Inflorescence Types			
FLOWERS			
Flower Parts Flower Sex			
Plant Sex			
Flower Attachment			
Floral Cycly Perianth Cycly			
Perianth Merosity			
Perianth Symmetry			
Aestivation			

	Character state	***Taxon***	***Page no.***
FLOWERS (continued)			
Perianth Fusion			
Perianth Parts			
Perianth (&Hypanthium) Type			
Stamen / Androecium Parts			
Stamen / Androecium Types			
Stamen Arrangement			
Stamen Position			
Stamen Cycly			
Stamen Attachment			
Stamen Insertion			
Stamen / Androecial Fusion			
Anther Parts			
Anther Attachment			
Anther Dehiscence Type			
Anther Dehiscence Direction			
Gynoecium/Carpel Parts			
Gynoecial Fusion			
Placentation			
Style Position			
Ovary Position			
Perianth/Androecial Position			
Ovule Parts			
Ovule Types			
Ovule Position			
FRUITS			
Fruit Parts Fruit Types			
SEEDS			
Seed Parts Seed (Endosperm) Types			

Plant Systematics Laboratory #10
PLANT ANATOMY AND PHYSIOLOGY

Cells and Organelles:

Chloroplasts: Place a small leaf of the aquatic plant *Elodea* in a drop of water on a slide and cover with a cover glass (known as a "wet mount"). Note an individual cell with 1^{o} cell wall, a large central vacuole (the membrane of which is usually invisible), and peripheral chloroplasts. Note the cytoplasmic streaming (cyclosis). ***Draw.***

Chromoplasts: Make a wet mount (unstained) of a small piece of a yellow flower petal. Observe under high (40x) magnification and draw the chromoplasts, containing variably shaped carotenoid deposits that impart color to the petal. ***Draw.***

Amyloplasts (starch grains): Tease a small piece of potato (*Solanum tuberosum*) both in a drop of water and in a drop of IKI and mount with a cover slip (or observe ground meristem of *Piper* stem xs). Observe the lamellate starch grains, often having a distinctive morphology for each species. The IKI solution stains starch blue to black in color. ***Draw.***

Crystals:

Observe calcium oxalate crystals in the form of druses (pith & cortex of *Aristolochia* 1-yr. stem) and needle-like raphides (ground meristem of *Cordyline* yg. stem l.s.). What is their function? ***Draw.***

Vacuoles:

Observe tissue from a purple-colored plant part. Note that the cells are completely filled with a vacuole, which contains either anthocyanins or betalains. ***Draw.***

CELL TYPES

Make a hand cross-section of celery (*Apium graveolens*) petiole. Stain with 0.05% toluidine blue. Note:

Parenchyma: From the celery cross-section observe the mostly transparent, live cells comprising most of the tissue of the petiole. Look for nuclei and (in outer tissues) chloroplasts. ***Draw.***

Collenchyma: From the celery cross-section observe the cells grouped near the periphery of the petiole having the white-glistening, unevenly-thickened cell wall. What compounds infuse the cell walls? What is the function of these cells? ***Draw.***

Sclerenchyma:

Fibers: From the celery cross-section observe note the fiber bundles occurring to the outer side of the vascular bundles. Note the thick, secondary cell walls of these fibers. What is their function? ***Draw.***

Observe the prepared slide of macerated fiber cells (*Yucca smalliana* peduncle-macerated). Note that they are thin, very elongate cells with tapering end walls and thick, secondary cell walls. ***Draw.***

Sclereids: Observe a preparation of cells from the flesh of pear (*Pyrus communis* fruit). Note the sclereids, which have a thick, secondary cell wall with numerous simple pits. Sclereids give the gritty taste to pears. ***Draw.***

Vessel elements: Look at the prepared slide of vessel elements (*Quercus alba* macerated wood). Note that they look like little hollow tubes, with perforation plates at each end. Observe the small pits (what is a pit?) on the side walls. Try to find vessel elements that are still attached end to end (to form a vessel). What is the function of these cells? ***Draw.***

Sieve tube members: Look at the prepared slides of sieve tube members (*Salix* stem XRT, phloem/xylem). Note that side walls contain groups of callose-lined pores (sieve areas) and end walls have bands of larger pores (sieve plates). Try to find sieve tube members that are attached end to end (forming a sieve tube). What is the function of these cells? ***Draw.***

Epidermis: Observe the cross-section of a Cycas leaf and note the epidermis, with a thick, outer cuticle region. With what is a cuticle impregnated? What is its function? ***Draw.***

Stomates: Make a wet mount of an epidermal peel of the lower epidermis of availabe material (e. g., *Coleus*, *Commelina*, or *Zebrina*. Observe the stomates (= stomata), containing two guard cells which control the opening (stoma). These are the only epidermal cells with chloroplasts. ***Draw.***

Laticifers: Observe the live material and the stem longitudinal sections of *Euphorbia* sp., a plant with a milky latex. Observe in the slide the laticifers, cells that function in secreting latex. What is the function of latex? ***Draw.***

Resin ducts: Observe the stem cross section only (appearing round on the slide) of *Pinus* stem X,R,T sect. Note the resin ducts interspersed in the wood. These ducts are lined with epithelial cells that secrete resin into the cavity of the duct. ***Draw.***

Laticifers: Observe *Euphorbia* stem ls (green box). Note, in this stem longitudinal section, the tube-shaped laticifers interspersed in the cortex. These are the specialized cells that secrete latex, economically important as the source of, e. g., rubber. ***Draw.***

Tannin cells: Observe the *Sambucus* stem c. s. Note the dark tannin cells interspersed in pith region.

Oil cells: Observe the *Citrus* fruit c.s. &/or a cross-section of a schizocarp of fennel. Oil cavities are prevalent at the periphery of the pericarp in both. ***Draw.***

PLANT ORGANS AND TISSUES

Root:

Root types: (observe)

Pistia stratiotes WATER LETTUCE or *Hydrocharis morsus-ranae* FROG BIT: Note rootcap, root hairs, and 1^{o} & 2^{o} roots

Orchid: Note aerial roots

Zea mays CORN: Note prop roots . What is their function?

Root growth: Look at the prepared slide of a root longitudinal section (e. g., *Ranunculus* or *Elodea* root tip). Note the root cap and apical meristem (region of cell division). Observe that cells elongate as they mature (region of cell elongation). Check off terms of **ROOT** handout.

Root mature structure: Look at the root cross-section of a eudicot (e. g., *Ranunculus* older root mat. metaxylem) [optionally, of a monocot, e.g., *Smilax* mature root]. Note epidermis, cortex (with starch grains), endodermis, pericycle, xylem, and phloem. In particular, note the suberized Casparian strips of the non-lignified endodermis. What is their function? In eudicots the xylem is structured as fluted ridges (appearing as "arms"); in monocots there are numerous xylem "arms" and a central, lignified pith region. Phloem strands alternate with xylem "arms" in both dicots and monocots. Check off terms of **ROOT** handout.

Shoot:

Look at the prepared slide of a shoot longitudinal section (*Coleus* stem tip). Note apical meristem, leaf primordia, bud primordia, and young vasculature. Check off terms of **SHOOT** handout.

Stem:

Make a hand-section or observe a prepared slide of a dicot stem, e. g., *Coleus* and stain with 0.05% toluidine blue (or use prepared slides of *Helianthus* mat. stem). First, note the tissue regions: epidermis, cortex, single ring of vascular bundles, and pith. The epidermis contains a thick, suberized cuticle. Just beneath the epidermis are 3-4 layers of collenchyma, characterized by having pectic-rich (appearing glistening white), unequally thickened cell walls. Note, from the l.s. that these are elongate cells, functioning in structural support. The bulk of the cortex is parenchyma cells, including the peripheral chloroplast-containing chlorenchyma. The vascular bundles contain xylem to the inside and phloem to the outside. The xylem is comprised of lignified tracheary elements (vessels and/or tracheids); phloem is made up of non-lignified sieve tube members and companion cells. Fibers are located in groups touching and to the outside of the phloem, in "bundle caps." Check off terms of **STEM** handout.

Make a hand cross-section or observe a prepared slide of a monocot stem, e. g., *Commelina* or *Zea*. Stain with IKI and note the starch grains present in the parenchyma cells. Note the numerous, scattered vascular bundles. Each bundle maintains the orientation of xylem and phloem. The vascular bundles tend to have a large lacuna (hole) where the xylem first differentiates ("protoxylem"). Check off terms of **STEM** handout.

Leaf:

Observe the prepared slide leaf cross-section of *Ligustrum*. Note upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis (with stomata), and vascular bundle (vein). The vascular bundle contains phloem below and xylem above (when the slide is correctly oriented). Check off terms of **LEAF** handout.

Wood anatomy:

Wood is technically 2^{o} xylem, derived from the vascular cambium.

Observe the demonstration of different cuts of wood:

Transverse (Cross) -- Identify annual rings, pores (vessels), rays.

Radial -- Note that annual rings are still visible and that rays appear as horizontal lines or bands.

Tangential -- Note that annual rings (because cuts are not perfectly even) appear as dark wavy loops and that rays appear as short vertical lines.Note the ring-porous wood of OAK

PINE (*Pinus* sp.) stem cross-section

Note 2^{o} xylem, 2^{o} phloem, annual rings, rays, tracheids, and resin canals. How old is this stem? ***Draw***.

PINE (*Pinus* sp.) wood XRT

Be able to distinguish between and identify the type of cut of the three types of sections. Identify 2^{o} xylem, annual rings, tracheids with circular bordered pits, rays, and resin canals in all three sections. (The resin canals are lined with epithelial cells that secrete resin into the cavity of the canal.) ***Draw***.

BASSWOOD (*Tilia* sp.) stem cross-section

Note 2^{o} xylem, 2^{o} phloem, annual rings, rays, vessels, fibers. How old is this stem? ***Draw***.

BASSWOOD (*Tilia* sp.) wood XRT

Be able to distinguish between and identify the type of cut of the three types of sections. Identify 2^{o} xylem, 2^{o} phloem, annual rings, rays, vessels, and fibers in all three sections. ***Draw***.

Dendrochronology:

Count the number of annual rings of the sectioned log on demonstration. Note that the wood to the outside is lighter sapwood, that toward the center is darker heartwood (because of deposition of tannins, resins, lignin, and/or gums). Note also that the width of annual rings varies. The wider the ring, the greater amount of growth during that year. Annual rings to the center of the stem tend to be wider, as growth is generally greater in the sapling stage. Annual rings will also be wider during favorable conditions (e.g., plentiful rainfall, sunlight, etc.). Thus, a history of climate can be deduced from the wood. From samples of wood of the southwestern U. S., this has been used in confirming sunspot cycles.

Paper:

Note specimens of PAPYRUS (*Cyperus papyrus*), an ancient source of paper. Flax (*Linum usitatissimum*) is also used to make paper, esp. cigarette papers and bank notes.

Today, 90% of all paper is derived from wood (2^{o} xylem) pulp. Take a very small piece of newspaper and make a wet-mount microscope slide, teasing the paper apart in a drop of water. ***Draw***. Note that paper is composed of a mat of "fibers," which can be true fiber cells, tracheids, or vessels (usually tracheids). If these are tracheids, can you see the circular bordered pits?

Cork:

Cork is derived from the outer bark of *Quercus suber*, the CORK OAK tree. Make a thin cross-section of a cork and prepare a wet-mount. Note the cubical cells, devoid of any living contents. (Robert Hooke first coined the term "cell" from observing cork tissue.) All that remains is the cell wall, which is heavily impregnated with suberin, a very water resistant compound. ***Draw***.

WOOD FORENSICS

The Case

A crime has been committed ... the vicious murder of Jack McCaw.

You are a famous, Nobel prize-winning botanist, an expert in wood and plant fibers. The police bring you samples to identify that may help to nab the criminal.

The First Sample

The first sample is a tiny fragment of wood, found in the skull of the murder victim. Determining the identity of this wood could be vital to identifying the murder weapon ... and the murderer!

From the sample of wood given to you (already XRT sectioned by your lab technician), determine the plant genus, using the key below. Then, verify your answer with named samples of the wood.

1. Wood porous, = with vessel elements (having perforation plates), lacking circular bordered pits
   2. Wood ring porous (having large vessels in spring wood, small ones in summer wood)
      3. Wood rays both multiseriate (with ∞ vertical columns of cells) and uniseriate (with 1 column of cells) . . . . . *Quercus* (oak)
      3' Wood rays mostly biseriate, = having 2 vertical columns of cells . . . . . *Fraxinus* (ash)
   2' Wood not ring porous; vessels in spring and summer wood of similar size . . . . . *Salix* (willow)

1' Wood non-porous, = lacking vessels, having only tracheids, with circular bordered pits
[Note: resin canals can falsely appear to be vessels but are not conductive.]
   4. Wood with numerous resin canals; rays mostly uniseriate, some multiseriate and associated with resin cells . . . . . *Pinus* (pine)
   4' Wood without resin canals; rays mostly 1-2-seriate . . . . . *Sequoia* (redwood)

From this information, infer the murderer, given this information:

A. Professor Plum possesses a cane, inherited from his father, made of solid oak.
B. Mister Green has a collection of baseball bats, made of ash.
C. Colonel Mustard has in his possession a club made of pine wood.
D. Misses Peacock has a hand-carved Indian relict, made of willow wood.
E. Miss Scarlet has a fine vase, made of beautiful redwood.

You testify in court, presenting the evidence. Who is implicated as the murderer?

ADDENDUM:

Material dissection and preparation:

A wealth of information can be gained by careful dissection and observation of plants. Look first at the outer form of the plant, noting the basic plant organs (root, stem, leaves, buds, flowers, fruits) and specific aspects of these organs. Gently pull apart the plant organs to better see their morphology. For flowers and fruits, use both your hands and naked eye and dissecting needles under a dissecting scope to examine the components.

Careful anatomical studies usually involves time consuming embedding and microtome sectioning. However, a simple technique of hand sectioning with a razor blade will allow you to see considerable detail of cell and

tissue anatomy. Stout material, such as an herbaceous stem, can be held upright in the left hand between thumb and index finger (assuming you are right-handed). More flimsy material, such as a leaf, can be sandwiched between two small pieces (cut only slightly larger than the material) of styrofoam; the end is moistened and both styrofoam and plant material are sectioned together. In either case, rest the side of the razor blade on your index finger and position your thumb a bit lower (so that if you do slip, you won't cut yourself). There are tricks of the trade to successful sections:

1) As you cut, move the razor blade toward you, as well as across the material; thus, the cut is somewhat diagonal.
2) Make an initial cut to level off (discarding this piece) and then make several thin slices, keeping the sections on the razor blade until they get too crowded; then, transfer the sections to water in a Syracuse dish or petri plate. Clean your razor blade and make a few more sections.
3) Select the thinnest sections, pull out with a brush, and place in a few drops of stain in another dish. After staining, rinse your sections very briefly in water and place in a drop of water or (for a semi-permanent mount) 50% glycerol. Cover with a cover slip, avoiding air bubbles and adding more fluid to the side if necessary.

Most important is to make those sections THIN!! Although you will want at least one complete section, other sections may be partial, as long as they are thin. Clean your razor blade afterward and you may reuse it.

For tough, fibrous or woody tissue place lie the material down on a plastic petri plate and make downward slices with your razor blade. This same technique can be used with softer, small plant material if it is sandwiched between two layers of Parafilm and the material sectioned in a "dicing" motion.

The following are some "vital" stains (i.e., used with live material):

Stain	Compound for which stain is specific	Color
Alcian blue	Pectins	Blue
Aniline blue	Callose	Blue (UV-fluoresces Yellow)
IKI	Starch	Blue to black
Phloroglucinol/HCl	Lignin	Red (NOTE: Takes sev. mins. to react)
Sudan III or Sudan IV	Oil droplets	Reddish
Toluidine blue	Metachromatic (will stain a variety of cell walls different shades of blue/green):	
	Lignified tracheary elements	Dark blue
	Sclerenchyma	Blue to blue-green
	Parenchyma	Light blue
	Collenchyma	Reddish-purple
	Sieve tubes and companion cells	Greenish
	Callose/Starch	Unstained

Drawings: Making careful drawings not only gives you a record of what you observe, it also helps you become a careful observer. When "forced" to draw it, you often see more than you otherwise would.
Make drawings with a #2 or #3 hard lead pencil. Draw the outlines of organs or tissues (e. g., of a root cross-section) at low magnification to record the overall structure. Then draw a portion of the whole (e. g., a "pie slice of the root section, showing some of the individual cells of a vascular bundle) to show details.

Plant Systematics Laboratory #11
PLANT EMBRYOLOGY

Equipment & supplies needed:

Compound microscope (preferably phase contrast or D.I.C.)
Syracuse dish
Dissecting needles
Fine forceps
Scalpel, w/ #11 blade
Microscope slides
Cover slips (squares or circles)
Kimwipes
Felt-tip pen, rapidograph, or diamond scribe (for marking slides)
Paper and pencil (2H)
Dropper bottles:
    Herr's Clearing Solution
Stock bottles:
    F.A.A. [5% formalin (commercial strength), 5% acetic acid (glacial), 63% ethanol]
    Ethanol - 70%
    Ethanol - 95%

Ovule Clearings:

Ovules must be individually removed from the ovary or a flower in order to observe histological and positional details. Flowering material may be dissected live or fixed beforehand in F.A.A. for 24-48 hours. (Replace F.A.A. with 70% ethanol after fixation.) Dissect in Syracuse dish while viewing under a dissecting scope, using needles, forceps, and scalpel. Place flower in a dish filled with 95% ethanol and detach the ovary. Carefully tear open the side of the ovary (from top or bottom) with forceps to expose the ovule(s); avoid damaging the ovule(s). Observe placentation, ovule type (if apparent), and ovule position; record information. Place the opened ovary on a small drop of ethanol on a microscope slide (**Don't let dry out!**). Detach the ovule(s) from the base of the funiculus with forceps or needle. (With patience and skill in dissecting, even the tiniest ovules can be successfully removed.)

Place two cover slips on either side of the ovule(s). Drain most of the ethanol (or allow to evaporate). Immediately, place 1-2 drops of Herr's Clearing fluid (Herr, 1971, 1982) directly on the ovule(s). Cover ovule with a third cover slip, which rests on the edges of the other two. This arrangement prevents the ovule from being squashed. Add more Herr's solution from the edge, as needed.

After ca. 5 minutes, place slide under brightfield, phase contrast, or D.I.C. microscope and observe. Note:

1) Placentation (axile, parietal, basal, apical, free-central, apical-axile, parietal-septate, laminar)
2) Ovule position (hypotropous, epitropous, pleurotropous; dorsal or ventral)
3) Ovule type (anatropous, orthotropous, or campylotropous & subtypes).
4) Number of integuments (unitegmic or bitegmic).
5) Number of cell layers per integument (1, 2, or more).
6) Micropyle type (amphistomal, exostomal, endostomal, or unistomal).
7) Vasculature traversing funiculus into nucellus.
8) Details of embryo sac (this usually requires careful and considerable observation).

Possible taxa to investigate:

Armeria maritima [Caryophyllales, Plumbaginaceae]:
Aptenia cordifolia [Caryophyllales, Aizoaceae]:
Centranthus ruber [Dipsacales, Valerianaceae]:
Eriogonum fasciculatum [Caryophyllales, Polygonaceae]:
Erythrina sp. [Fabales, Fabaceae]:
Euryops pectinata [Asterales, Asteraceae]:
Hedera helix [Apiales, Araliaceae]:

Malacothamnus fasciculatus [Malvales, Malvaceae]:
Pereskia grandiflora [Caryophyllales, Cactaceae]:
Phormium tenax [Asparagales, Phormiaceae]:
Salvia mellifera [Lamiales, Lamiaceae]:

Pollen Tube Growth

Carefully remove the style of a pollinated flower (e. g., a composite). Place the style in a couple of drops of aniline blue stain. Cover with a cover slip and slightly squash. Observe under the fluorescent microscope. Aniline blue is preferential for callose, which is deposited in the pollen tubes. Pollen tubes appear bright yellow under fluorescence microscopy. **Observe.**

Female Gametophyte (Embryo Sac) Development

Observe the mature female gametophyte of Phormium tenax and of the prepared slides of Lilium, noting the 3 antipodal cells, 2 polar nuclei, and 3 cells of the egg apparatus. If time permits, observe earlier developmental stages. **Draw.**

Embryo morphology:

Dissect out embryos or clear small seeds of a given species and observe under brightfield, phase contrast, or D.I.C. microscopy. **Draw.**

Taxa: Capsella bursa-pastoris Shephard's Purse or Lepidium sp. Peppergrass (both Brassicaceae)

Seed morphology:

Dicot:

Bean (Phaseolus vulgaris): Observe seed coat and embryo (noting that endosperm is absent). The embryo consists of two large cotyledons, the radicle (embryonic root), the hypocotyl (between the cotyledons and radicle, and the epicotyl (embryonic shoot). If available, note the transformation of these structures from seed to seedling stage. The cotyledons are lifted above the ground on the hypocotyl (called "epigeal" germination) and eventually wither away. **Draw the seed:**

Monocots:

Corn (Zea mays) grain: Observe outermost pericarp (fruit wall), seed coat, endosperm, and embryo. The embryo consists of one cotyledon, a radicle (contained within the coleorhiza), and the epicotyl (contained within the coleoptile). If available, note the transformation of these structures from seed to seedling stage. The cotyledon and seed coat remain in the ground (called "hypogeal" germination). **Draw the seed:**

Plant Systematics Laboratory #12
PALYNOLOGY

Equipment & supplies needed:

Compound microscope (brightfield, phase contrast, or D.I.C.)
Dissecting needles
Fine forceps (optional)
Microscope slides
Cover slips (22 X 22 squares & 18 circles)
Kimwipes
Paper and pencil (2H)
Felt-tip pen, rapidograph, or diamond scribe (for marking slides)
Dropper bottles:
- F.A.A. [5% formalin (commercial strength), 5% acetic acid (glacial), 63% ethanol]
- Ethanol - 70%
- Basic Fuchsin (in 50% glycerol)
- Glycerol - 50%
- Herr's Clearing Solution
- Acetocarmine
- IKI
- Sudan IV (or Sudan III)

Pollen grain observation: Pollen grains may be observed under brightfield microscopy by teasing apart anthers in a drop of Basic Fuchsin (in 50% glycerol) on a microscope slide. (Live or fixed material may be used.) After teasing out pollen grains, remove any large anther fragments, place a cover slip on the slide, and observe under the microscope. Basic fuchsin stains the outermost exine layer of the pollen grain, allowing for better visualization of structural detail. (IMPORTANT: Be sure to decrease the condenser aperture opening in order to obtain the best contrast.) Optional: You may also wish to mount pollen grains in 50% glycerol (without the basic fuchsin stain) or in Herr's clearing solution (preferably fixed briefly in F.A.A. or alcohol beforehand) and observe with a phase contrast or D.I.C. microscope. Note the following in your pollen grain samples:

1) Pollen unit (monad is most common; look for tetrads, polyads, or pollinia).
2) Pollen grain shape and size (need an ocular micrometer for the latter).
3) Wall sculpturing (e.g., verrucate, reticulate, echinate, psilate, rugulate).
4) Number, type, and arrangement of aperuture(s) (e.g., tricolpate, tricolporate, monoporate, monosulcate).
5) Pollen kit (yellowish or orange carotenoid-like material adhering to exine; functions in pollen dispersal).

Pollen grain nuclear number and storage product: The number of nuclei present in a pollen grain at the time of pollen release may be a valuable taxonomic character. Pollen grains are usually binucleate, containing one tube cell (consisting of a spherical nucleus with the bulk of the pollen grain acting as the cell) and one generative cell (usually crescent-shaped). In some taxa the mature pollen grains are trinucleate, vis-à-vis the precocious division of the generative cell into two sperm cells.

Dissect pollen grains of available material in a drop of acetocarmine solution, which stains DNA

(and therefore nuclei) a red color. Observe whether the grains are binucleate or trinucleate.

Pollen grains store either starch or oil as the energy reserve, a feature that may be taxonomic significant.

To detect starch, dissect pollen grains in a drop of IKI, add a cover slip, and observe. IKI stains starch grains a black to dark blue color. To detect oils, dissect pollen grains in a drop of either Sudan IV or Sudan III, which stains oil a deep red.

Pollen grain germination: Dissect pollen from available live material in a drop or two of growth medium. Do not allow to dry out! Cover with a cover slip. After 30 minutes to 3 hours, check under the microscope for pollen tube germination. Attempt to identify the tube nucleus and generative nucleus.

Place the stigma(s) and apical part of the style(s) in a drop of 1% Aniline blue. (Live or fixed material may be used.) Cover with a cover slip and observe under fluorescence microscope. Aniline is specific for callose, which fluoresces brightly. (Other components, such as the exine wall and stigma papilla may fluoresce as well, but not as brightly.) You may observe the course of the pollen tube through the style with this technique.

How is this technique valuable in studies of reproductive biology?

Pollen grain viability: Stain pollen with cotton blue in lactophenol. Live pollen stains dark blue; dead pollen stains light blue or clear. How is this technique valuable in studies of reproductive biology?

Possible taxa to investigate: (Draw)

Amaryllidaceae or Liliaceae: monosulcate
Asteraceae: echinate or spinulose, tricolporate
Cactaceae: pantoporate
Ericaceae: permanent tetrads
Malvaceae: echinate
Mimosoideae (Fabaceae): polyads (usu. in groups of 8)
Rosaceae: tricolpate or tricolporate

Plant Systematics Laboratory #13
PLANT REPRODUCTIVE BIOLOGY

1) Working in pairs, go outside or to the greenhouse and collect 5 flowers of different types to bring back. Speculate upon and be prepared to discuss the following:
   a) Mode of attraction for pollination
   b) Mode of reward for pollination
   c) Specific type of pollination mechanism

2) Observe visitation of a flower by an insect or bird. If possible, use a video camera to document this visitation. Can you note specific methods by which the animal obtains the reward and, in the process, pollinates the flower? Bring in an example of the flower and draw it (e.g., in longitudinal-section), in order to highlight this.

3) Examine specimens of two species of plants plus any putative hybrids between them.
   a) Study both vegetative and floral characters, from original observations or using a Manual of the area, and note which diagnostic features distinguish the two species.
   b) Decide upon which characters to measure in the specimens available.
   c) Record 10-25 measurements of each of the parameters chosen. Compare these by preparing graphs in order to recognize discontinuities (or lack thereof) of the three taxa.

4) Locate a population of a Composite (Asteraceae) species that has both disk and ray flowers. Observe insect visitors (potential pollinators) in each of two subsets of plants (or inflorescences): one undisturbed and another with all ray flowers removed. Count the number and type of visitors over a time period (e. g. 10-30 minutes) and record.

5) In the material available, observe ultraviolet light sensitive regions in the perianth by placing a flower into a jar saturated with ammonium vapors. Note that these regions of UV reflectance can be detected by bees.

6) If equipment and materials are available, observe UV fluorescence of pollen tube growth. This is a method of assessing whether or not pollen tubes are growing down a style, and can be used to determine self-compatibility.

7) As a longer-term project, do a caging/emasculating experiment, as explained in your textbook. What can you deduce about reproductive biology from this experiment?

8) Take notes on the movie "*Sexual Encounters of the Floral Kind*" and record plant names, pollinators, and pollination mechanisms.

OBSERVATION OF POLLINATION MECHANISM IN FLOWERING PLANTS

Species Name	**Hypothesis of likely pollinator based on:** 1) Tube +/-, length; 2) Flower color+/-; 3) Landing platform +/-; 4) Odor +/-, type ***LIST 4 FEATURES;*** ***HYPOTHESIZE POLLINATOR***	**Observation of pollen transport based on:** Position/orientation of anthers Position/orientation of stigma(s) ***LABEL DRAWING OF FLOWER,*** ***in LONGITUDINAL SECTION***	**Simulation testing transfer of pollen:** 1) Pollinator approach; 2) Deposition of pollen; 3) Transfer of pollen to stigma; 4) Effect of flower stage ***DEMONSTRATION WITH ORAL EXPLANATION***
1)			
2)			
3)			

Rubric

Rating	1	2	3	Score
Hypothesis of likely pollinator based on: Tube +/-, length Flower color+/- Landing platform +/- Odor +/-, type **ALL 3 SPECIES**	List provides evidence for only 1-2 of floral features	List provides evidence for 3 floral features	List provides evidence for all 4 floral features for all 3 species.	
Observation of pollen transport based on: Position/orientation of anthers Position/orientation of stigma(s) **ONLY 1 SPECIES**	Drawing shows position/orientation of anthers and stigmas not noted; parts not labeled.	Drawing shows position/orientation of anthers and stigmas not clearly drawn, and/or partially labeled.	Drawing shows position/orientation of anthers and stigmas clearly drawn and labeled.	
Simulation testing transfer of pollen: Pollinator approach Deposition of pollen Transfer of pollen to stigma Effect of flower stage **ONLY 1 SPECIES**	Demonstrates and explains only 1 of the steps of pollen transfer; does not account for effect of flower stage.	Demonstrates and explains only 2 of the steps of pollen transfer or does not fully account for effect of flower stage.	Demonstrates and explains how pollinator approaches flower, how pollen is deposited on animal, how pollen is transferred to stigma, and how flower stage effects transfer.	
Participation/ Teamwork	One person dominated, others were passive.	Most members participated fully.	All members participated fully.	
Total:				

Plant Systematics Laboratory #14
PLANT MOLECULAR SYSTEMATICS

1) **GENBANK**

Log onto GenBank <http://www.ncbi.nih.gov/Genbank> and perform a search on a species or genus for registered molecular data. For example, under "Entrez", search for the family name Haemodoraceae. Click the **Nucleotide: sequence database (GenBank)** link. (You should see about 50 entries; if not, repeat the search.) Scroll down all pages and list all types of genes for which sequences are cited. Is each of these a nuclear or chloroplast gene?

2) **MACCLADE**

Download an example molecular data set from the course web page <http://www.sci.sdsu.edu/plants/plsys530> and download the "MacClade Molecular Data Set" by holding down the Option key then clicking the link. Open MacClade (from the "dock" in Mac OSX) then open this file.

Observe the data matrix [from **Windows** menu, select **Data Editor** (or type **Command E**)] and view cells in color [from **Display** menu, select **Data Matrix Styles**, then **Plain Molecular**]. Scroll through the data matrix and note the characters and character states. What do these correspond to? Also note the missing data, indicated by a hash mark. Are there any large blocks of missing data? What might these correspond to?

Go to tree mode [from **Windows** menu, select **Tree Window** (or type **Command T**)]. Make sure the tool box shows an arrow tool, then drag the lineage terminating in *Kalenchoe* to the base of the tree to serve as the outgroup. From the toolbox select the **Search Above** tool (the first one) and click this icon at the base of the tree. After a time, the shortest tree will be calculated. Ladderize the tree by selecting the Rotate to Lean Right tool (row 2, column 3 of the toolbox) and click this icon at the base of the tree.

Note the monophyletic groups shown. Is your tree similar to others in the class? Is the genus *Dudleya* (indicated by "*D*.") monophyletic? What about the genus *Sedum*? Re-draw the tree (back).

3) **MOLECULAR DATA MATRIX**

From the following data matrix, determine the informative characters and character states. Check Figure 14.6 to check your results. What do the characters and character states mean?

```
                000000000000000000011111111111111111111111
                888888888999999999900000000001111111111122
                123456789012345678901234567890123456789012
Taxon 1         GCCTAGCCAAAGCTCTTCCAAGGTGACTCTCAGTTCAAGCT
Taxon 2         GCCTAGCCAAAGCTCTTCCAAGCTGACTCTCA------GCT
Taxon 3         GCCTAGCCTAAGCTCAACCAAGGTGTCTCTCAGTTCAAGCT
Taxon 4         GCCTAGCCTAAGCTCTTCCAAGGTGTCTCTCAGTTCAAGCT
Taxon 5         GCCTAGCCAAAGCTCTTCCAAGCTGACTCTCA------GCT
Taxon 6         CCCTAGCCAAAGCTCTTCCAAGCTGACTCTCAGTTCAAGCT
Taxon 7         CCCTAGCCAAAGCTCTTCCAAGCTGACTCTCAGTTCAAGCT
Taxon 8         GCCTAGCCTAAGCTCTTCCAAGCTGACTCTCAGTTCAAGCT
```

Informative Characters and Character States

```
Taxon 1
Taxon 2
Taxon 3
Taxon 4
Taxon 5
Taxon 6
Taxon 7
Taxon 8
```

4) **RESEARCH ARTICLE**

Peruse a research article in plant systematics using molecular data. Answer each of the following:

1) What are the objectives of the study?

2) Read over the Materials and Methods. What gene(s) were sequenced and what is the type of DNA?

3) How many analyses were performed and on what data sets? (I.e., how were the data *partitioned*?)

4) What was the total number of base pairs of sequence data used, and how many of these were phylogenetically informative for:

a) combined data set b) gene 1 c) gene 2

5) What is a bootstrap value and how are they determined? What is a decay index value? (see Ch2)

6) For the combined analysis tree, what is the: a) tree length?; b) CI? What do these terms mean? (Ch2)

7) Re-draw (back) the combined analysis tree, collapsing any nodes that have <70% bootstrap support.

Plant Systematics Laboratory #15
PLANT IDENTIFICATION

OBJECTIVES FOR THIS LABORATORY:

1. Review the basics of identification.
2. Practice identifying plant taxa using available dichotomous keys or polyclave keys.

Concepts of Identification

Examine the material available and review the possible ways that you could identify these plants. For each of these identification methods, discuss which would be most feasible or efficient, and under what conditions? Attempt to try each method.

Dichotomous Keys

Using a local flora, identify each of the available plants. First, examine the basic characteristics of the plant. Then, fill in the following data sheets before attempting to identify using keys. What are the general procedures for using a key? What are some possible pitfalls?

SPECIES #1:
Plant habit
Leaf shape
Leaf surface (abaxial)
Leaf venation
Leaf margin
Inflorescence type
Perianth structural type
Calyx fusion
Corolla fusion
Corolla symmetry
Corolla apex posture (in bud)
Androecial fusion type
Perianth/androecial position
Ovary position
Stigma shape
Carpel number
Locule number
Placentation
Ovule number/carpel
Floral formula

SPECIES: _____ FAMILY: _____

SPECIES #2:
Leaf arrangement
Inflorescence type
Perianth fusion type
Perianth cycly
Calyx fusion
Ovary position
Style number
Carpel number
Locule number
Ovule number
Placentation
Floral formula

SPECIES: _____ FAMILY: _____

SPECIES #3:

Leaf arrangement
Leaf surface (epidermal excrescence)
Inflorescence type
Inflorescence position
Calyx fusion
Calyx symmetry
Corolla fusion
Corolla parts
Corolla symmetry
Stamen fusion
Stamen arrangement
Ovary position
Stigma shape
Carpel number
Locule number
Placentation
Ovule number/carpel
Floral formula

SPECIES: _____ FAMILY: _____

SPECIES #4:

Plant habit
Stem surface
Stem structural type
Leaf arrangement
Leaf venation
Leaf margin
Inflorescence type
Flower orientation
Flower surface (outer)
Perianth/androecial position
Calyx fusion
Calyx symmetry
Corolla fusion
Corolla symmetry
Stamen position
Ovary position
Style number
Stigma number
Carpel number
Locule number
Placentation
Ovule number/carpel
Floral formula

SPECIES: _____ FAMILY: _____

POLYCLAVE KEYS

Using all or some the same plants as above, utilize a polyclave (multiple-entry) key, either using a computer program or (preferably) Web site. [See your instructor for Web addresses.] Write down the characters and the results you obtain below.

What are the advantages of a multiple-entry key? Are there any disadvantages?

Laboratory #16
PLANT NOMENCLATURE

Nomenclature Questions

1) Based on taxonomic judgement, a taxonomist decides to split the 60 species of the genus *Conostylis* into two genera, the new one to be called *Blancoa*. To which genus does each group of species belong?

2) A taxonomist decides to unite three genera: *Audibertia* B. Bentham (1876), *Ramona* E. Greene (1892), and *Salvia* L. (1753). What is the new genus to be called and why?

3) *Medicago polymorpha* L. var. *orbicularis* L. was raised to the rank of species by Bartal. (an abbreviation for Biagio Bartalini).
a) What must the new name be called (including author citation; use the abbreviated name)?

b) Does Bartal. have to retain the name *orbicularis* by the rules of the ICBN?

c) What is the term we use for the original name, *Medicago polymorpha* L. var. *orbicularis* L.? [Note that this can be answered two ways, to be complete.]

4) Suppose, from above, that another species named *Medicago orbicularis* Smith had already existed.
a) Is the name proposed above (3a) legitimate? Why or why not?

b) What would the name proposed above (3a) by Bartal. be termed?

c) What must Bartal. (or someone else) do now?

5) *Eriogonum polifolium* Benth. is changed in rank to a subspecies of *E. fasciculatum* Benth. by Torrey & A. Gray. What is the new name?

6) I. M. Johnston decides to treat *Cryptantha jonesii* A. Gray as a variety of *Cryptantha muricata* (Hooker & Arnold) Nelson & J. F. Macbride. Give the full names of the <u>two</u> resulting varieties, including full authorship.

7) What does the "&" mean in *Marsilea vestita* Hook. & Grev.?

8) What does "ex" mean in *Havetia flexilis* Spruce ex Plach. & Triana?

9) What does "in" mean in *Rhus laurina* Nutt. in Torr. & A. Gray?

10) Abbreviate *Malosma laurina* (Nutt. in Torrey & A. Gray) Nutt. ex Abrams.

NOMENCLATURE EXERCISES

Author abbreviations

List the full names and years of birth and death for the following author abbreviations, using the International Plant Names Index <**http://www.ipni.org**>.

A. Gray	L.
Benth.	Nutt.
DC.	Torrey

Nomenclatural Changes

Search the name *Hosackia strigosa* on the International Plant Names Index <**http://www.ipni.org**>.

1) Who is author (abbrev. & full name) and what is the publication (incl. year) from which this name is derived?

2) Do a search for *Lotus strigosus* and also list the full authorship and publication, incl. the year.

3) Finally, search for *Acmispon strigosus* and again list the full authorship and publication, incl. the year. What can you deduce from this information?

Synonyms

Search for *Cryptantha intermedia* on The Plant List <**http://www.theplantlist.org**> and record the number of synonyms. List one homotypic and one heterotypic, noting authorship and publications.

Type Specimens

Do a search for the California Academy of Sciences and find the botanical collection. Do a search for *Cryptantha mohavensis*. [Note: search for the type collection first; if necessary search in the general collection.]

1) Who originally collected this specimen, where, and when?

2) Observe the specimen image close-up. What was the original (basionym) name for this species, including authorship and publication (incl. year)?

3) Find the publication for the basionym on-line. Use the Biodiversity Heritage Library. What does this publication state?

4) What is the publication/year of the current name for this species, *Cryptantha mohavensis*? Write down the full authorship of this name. [Be sure to think about correctly citing the authorship.]

Valid Publication

Do a **Google Scholar** search for "Novon a new species-Pandanus." [Novon is the name of a journal.] Find a new species publication of this genus *Pandanus* in this journal. List/note the following:

1) Full species name, including authorship

2) Designation of rank

3) Designation of type (collector(s) and collection number)

4) Location of holotype and isotypes

5) Latin diagnosis

6) Description

7) Illustrations/photographs

International Code of Nomenclature for Algae, Fungi, and Plants
Peruse the ICN <http://www.iapt-taxon.org/nomen/main.php>. List/note the following:
1) DIVISION 1. PRINCIPLES

2) SECTION 3. Priority, Article 11

3) CHAPTER V. Valid publication of names, Article 32

BOTANICAL NAMES

For selected species, syllabize and accent the scientific names. Practice pronouncing these names according to the rules you have learned. What are alternative ways of pronouncing names?

Use available references and check the web site site **http://www.ipni.org** to determine the authorship and place/date of publication.

Taxon	Syllabize and accent name
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

Plant Systematics Laboratory #17
PLANT COLLECTING AND DOCUMENTATION

OBJECTIVES FOR THIS LABORATORY:

1. Review the basics of plant collecting.
2. Practice documenting information taken at the time of collecting.

Plant Collecting and Documentation

With a partner, review the proper procedure for collecting plants. Have your partner correct or add to what you recite.

Study the documentation information that should be recorded at the time of a plant collection. Next, with a partner, try to recite as much of this information as you can; have your partner correct or add to what you recite.

During class, go outside and collect both an herb (digging up the entire plants) and a woody shrub or tree. While outside, fill out (for one species only) as much as you can of the documentation sheet(s) on the next pages.

Store the two plants collected, as if you were going to keep them for some time before processing them.

Press the two plants collected above in an herbarium press and dry them in a plant drier.

Plant Mapping

Examine available topographic maps. Practice locating yourself on the map, using various landmarks.

Calculate the latitude and longitude of your location for inclusion in the documentation information.

Calculate the latitude and longitude of another specified location. Compare this with those obtained by the rest of the class.

LOCALITY #: **1**

FIELD SITE DATA

Date of collection:	Time (optional):
Country/State/Province/County/City:	
Specific Locality information:	
Latitude: _____º _____' _____" N / S	Longitude: _____º _____' _____" W / E
Source/Accuracy of Lat./Long.:	
Township & Range:	
Elevation (ft or m):	
Landmark information:	

PLANT DATA

Coll. No.:		Photo. doc.:
Collector (primary):		
Associated collector(s):		
Taxon:		
Ann./Bien./Per., Habit, Height, Branching:		
Fl./Fr., colors, other notes:		
Physical Habitat, Substrate:		
Slope, Aspect, Exposure:		
Community/Vegetation type:		
I.d. by:	Date:	I.d. source:
Accession Number:		

1

LOCALITY #:

FIELD SITE DATA

Date of collection:	Time (optional):
Country/State/Province/County/City:	
Specific Locality information:	
Latitude: _____º _____' _____" N / S	Longitude: _____º _____' _____" W / E
Source/Accuracy of Lat./Long.:	
Township & Range:	
Elevation (ft or m):	
Landmark information:	

PLANT DATA

Coll. No.:		Photo. doc.:
Collector (primary):		
Associated collector(s):		
Taxon:		
Ann./Bien./Per., Habit, Height, Branching:		
Fl./Fr., colors, other notes:		
Physical Habitat, Substrate:		
Slope, Aspect, Exposure:		
Community/Vegetation type:		
I.d. by:	Date:	I.d. source:
Accession Number:		

1

LOCALITY #:

FIELD SITE DATA

Date of collection:	Time (optional):
Country/State/Province/County/City:	
Specific Locality information:	
Latitude: _____º _____' _____" N / S	Longitude: _____º _____' _____" W / E
Source/Accuracy of Lat./Long.:	
Township & Range:	
Elevation (ft or m):	
Landmark information:	

PLANT DATA

Coll. No.:		Photo. doc.:
Collector (primary):		
Associated collector(s):		
Taxon:		
Ann./Bien./Per., Habit, Height, Branching:		
Fl./Fr., colors, other notes:		
Physical Habitat, Substrate:		
Slope, Aspect, Exposure:		
Community/Vegetation type:		
I.d. by:	Date:	I.d. source:
Accession Number:		

LOCALITY #: **1**

FIELD SITE DATA

Date of collection:	Time (optional):
Country/State/Province/County/City:	
Specific Locality information:	
Latitude: _____º _____' _____" N / S	Longitude: _____º _____' _____" W / E
Source/Accuracy of Lat./Long.:	
Township & Range:	
Elevation (ft or m):	
Landmark information:	

PLANT DATA

Coll. No.:		Photo. doc.:
Collector (primary):		
Associated collector(s):		
Taxon:		
Ann./Bien./Per., Habit, Height, Branching:		
Fl./Fr., colors, other notes:		
Physical Habitat, Substrate:		
Slope, Aspect, Exposure:		
Community/Vegetation type:		
I.d. by:	Date:	I.d. source:
Accession Number:		

1

LOCALITY #:

FIELD SITE DATA

Date of collection:	Time (optional):
Country/State/Province/County/City:	
Specific Locality information:	
Latitude: _____º _____' _____" N / S	Longitude: _____º _____' _____" W / E
Source/Accuracy of Lat./Long.:	
Township & Range:	
Elevation (ft or m):	
Landmark information:	

PLANT DATA

Coll. No.:		Photo. doc.:
Collector (primary):		
Associated collector(s):		
Taxon:		
Ann./Bien./Per., Habit, Height, Branching:		
Fl./Fr., colors, other notes:		
Physical Habitat, Substrate:		
Slope, Aspect, Exposure:		
Community/Vegetation type:		
I.d. by:	Date:	I.d. source:
Accession Number:		

1

LOCALITY #:

FIELD SITE DATA

Date of collection:	Time (optional):
Country/State/Province/County/City:	
Specific Locality information:	
Latitude: _____º _____' _____" N / S	Longitude: _____º _____' _____" W / E
Source/Accuracy of Lat./Long.:	
Township & Range:	
Elevation (ft or m):	
Landmark information:	

PLANT DATA

Coll. No.:		Photo. doc.:
Collector (primary):		
Associated collector(s):		
Taxon:		
Ann./Bien./Per., Habit, Height, Branching:		
Fl./Fr., colors, other notes:		
Physical Habitat, Substrate:		
Slope, Aspect, Exposure:		
Community/Vegetation type:		
I.d. by:	Date:	I.d. source:
Accession Number:		

How to use topographic maps

Topographic maps show topographic features of the landscape by means of **isoclines**, lines representing a single elevation above sea level. Isoclines show changes in elevation and help to visualize three dimensional features such as slopes, flats, canyons, cliffs, and peaks.

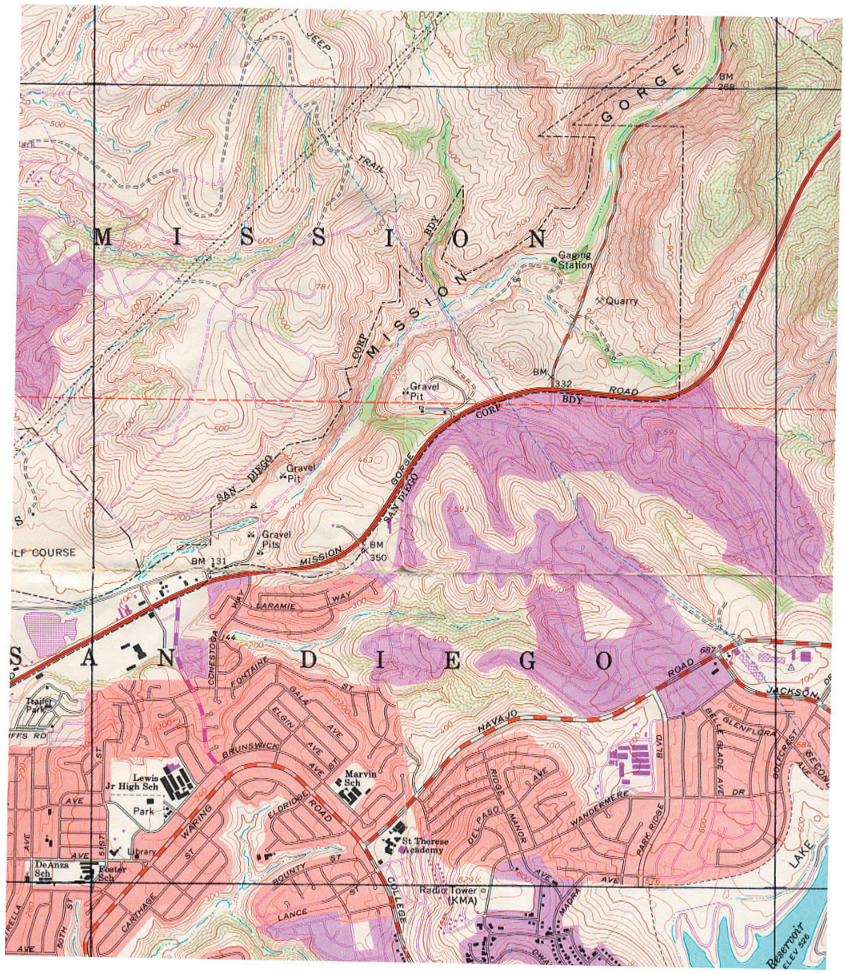
The difference in elevation between topographic isoclines is dependent on the scale of the map. A standard USGS (United States Geological Survey) 7.5 minute quad (quadrangle) topographic map has major (thicker-lined) isoclines separated by 100 feet and minor (thinner-lined) isoclines separated by 20 feet; thus, there are 4 minor isoclines between every two major ones (on a continuously increasing or decreasing slope).

Topographic maps also show things like trails, roads (dirt roads, paved streets, and highways), major power lines, buildings or other structures, rivers and other waterways, and general vegetation (e.g., woodland areas). Various coordinates are also indicated. Most commonly, and universally, used are standard longitude and latitude coordinates .

Longitude and latitude are based on imaginary circles drawn on the earth. Each of these circles is divided into 360˚ (“ ˚ “ = degrees). Each degree may be divided into 60 units termed **minutes** (represented by the ‘ symbol), and each minute divided into 60 smaller units termed **seconds** (represented by the “ symbol). Thus, there are 60 minutes in a degree and 60 x 60 = 3,600 seconds in a degree. [At the equator, each degree represents approximately 67 miles in length, each minute a little over 1 mile, and each second approximately 100 feet.] Degrees can be the sole representation of latitude and longitude. For example, 32˚ 16’ 58” converts to 32 + (16 / 60) + (58 / 3600) = 32.2669... degrees.

Lines of longitude are circles that pass through the true north and south poles. Longitude itself is measured from a single line of longitude that passes through Greenwich, England, which by convention represents 0˚ (zero degrees) longitude. Coordinates of longitude are measured east or west of this reference (termed the Greenwich Meridian or Prime Meridian) to a the other side of that same circle half-way around the world, which represents 180˚. Thus, when longitude is measured, it must be stated as either East or West of the prime meridian. For example, the longitude of a region in San Diego, California is 117˚ 07’ 32” W (stated as: 177 degrees, 7 seconds, 32 minutes west); a longitude in Cape Town, South Africa is 18˚ 24’ 48” E (stated as 18 degrees, 24 minutes, 48 seconds east). [Instead of stating “east” versus “west,” coordinates of longitudes may be distinguished as positive versus negative numbers, respectively. This is used, e.g., in computerized mapping programs.]

Lines of latitude include the equator itself plus circles that are parallel to the equator and between the equator and the poles. Thus, only the equator itself represents a circle whose plane passes through the earth’s center. As lines of latitude get progressively closer to the poles, the circles get smaller and smaller. Coordinates of latitude are measured from the equator, which represents 0˚ latitude, to either the north or south pole, each representing 90˚ latitude. Thus, latitude must be stated as either North or South of the equator. For example, the latitude of a region in San Diego, California is 32˚ 45’ 03” N (stated as: 32 degrees, 45 seconds, 3 minutes north); a latitude in Cape Town, South Africa is 33˚ 59’ 30” S (stated as 33 degrees, 59 minutes, 30 seconds south). [Coordinates of latitude, like those of longitude, may also be represented as positive versus negative numbers, latitude north being positive and latitude south being negative.]


M I S S I O N
GORGE
Gaging Station
Quarry
MISSION
CORP
BDY
TRAIL
JEEP
Gravel Pit
Gravel Pit
Gravel Pits
SAN DIEGO
GORGE
MISSION
ROAD
BM 332
BM 350
BM 131
BM 268
LF COURSE
S A N D I E G O
LARAMIE WAY
CONESTOGA
FONTAINE
GALA ST
ELGIN AVE
BRUNSWICK AVE
Lewis Jr High Sch
Park
Library
DeAnza Sch
Foster Sch
Marvin Sch
ELDRIDGE
WARING
CARTHAGE
BOUNTY
LANCE
COLLEGE
St Therese Academy
Radio Tower (KMA)
NAVAJO
ROAD
DEL PASO
MANOR
RIDGE
WANDERMERE
PARK RIDGE
BLVD
BELLE GLADE AVE
GLENFLORA
GOLFCREST
JACKSON
LAKE
Reservoir
Trailer Park
AVE
50TH
ST

Plant Community Classification, Identification, and Mapping

(contributed by Robert Lauri)

Plant communities are classified according to structure of canopy, or type, (tree, shrub, or herbaceous) and dominance of taxa. There are a number of common sub-classifications of plant communities within the California Floristic Province. These sub-classifications include, (forest, chaparral, riparian, and sage scrub, etc.), which are further divided into more specific classifications. These more specific classifications are referred to as series and are based on the dominant tree, shrub, or herb in that canopy. The name given to each series is often the common name of the dominant and co-dominant taxa coupled with the sub-classification type. Examples of these within the California Floristic Province are coast live oak woodland, chamise chaparral, white sage scrub, and white alder riparian.

Identifying plant communities can be a very difficult task, especially for the novice. It is common for plant communities to intergrade with one another and have no distinct boundaries. For this reason, it is common practice to identify and map plant communities is many stages. The first stage is to identify plant community canopy types in the field using visual inspection. Each plant community should then be rapidly mapped onto a USGS topography map, using an aerial photograph of the area to assist with the determination of tree versus shrub and herbaceous canopies. This first attempt at mapping the plant communities should be a rough estimate of the locations of each community, and then including identification of each community by visually assessing the dominance of the taxa. The next step in identification of the plant communities is to perform a more thorough evaluation of each by field inspecting them and recording habitat data using the California Native Plant Society (CNPS) Rapid Assessment method, **Figure 1**. This method allows the botanist to record the plant community and habitat data rapidly i.e. (location, latitude, longitude, history, soil type, dominance of each canopy type etc.) Once the rapid assessment has been completed the data can be compared with the initial field inspection data and revised accordingly. The revised identifications of the plant communities should be updated at this time to reflect the dominance and co-dominance of the taxa found during the rapid assessment. After the identifications have been revised, a final field inspection should be made to ensure that the mapping of the plant communities reflect the plant classification and identification revisions.

Plant community identification and mapping within government agencies and environmental consultants often ends with the rapid assessment method or similar methodology. However, I have found that the more in depth methods that include plant community transects (using belt and quadrangle) can provide more accurate and quantifiable taxa diversity and dominance data. Once the plant community habitats have been assessed, transects can be laid out in representative communities of each series. A minimum of ten transects should be run for each series with twelve data points collected for each belt transect, and four data points collected for each quadrant transect. All transect points are marked in the field with permanent rebar markers, or temporary construction nail markers. Two markers should be used for belt transects and one should be used for quadrant transects. The latitude, longitude, and elevation of the transect line can then be recorded using a GPS unit. Quadrant transects are taken by using a frame (wood or PVC) that is one meter square and split into four equal quadrants (**Figure 2**). This method is often used for dense herbaceous plant communities near ponds and streams. The transect frame is laid on the ground or over short vegetation, with the taxa then being identified and the coverage of each taxon recorded similar to the belt transects described below. There should be only one or two canopies identified using the quadrant method. For communities with three canopies, the belt transect is the preferred method. Belt transects should be between 50 and 100 meters long in order to collect the desired number of data points. Additional Belt transects may be necessary if twelve data points can not be made for the individual transect. For Belt transects, a 100-meter tape measure is used to span

the appropriate distance within the plant community between two points, (**Figure 3**). Approximately twelve, one meter squares should then chosen at random along the transect starting at the zero mark. The one-meter square can also be chosen by taking data points at 5-meter intervals. Once the data point has been chosen a meter stick, or a one-meter square frame can be used to temporarily delimit the area. The taxa that are contained within the data point can then be identified and listed on the data sheet (**Figure 4**), shortening the taxa name to six letters to reflect the full species name (the first three letters of the genus and specific epithet). After the taxa have been identified, the number of square centimeters of coverage of each taxon, bare soil, rock, and leaf litter should be estimated using the meter stick, and recorded. This should be accomplished by ensuring that the taxa considered are placed into a canopy layer that is considered 100 percent occupied. For the tree canopy there is either open sky, (zero percent canopy), or some percentage of tree cover. For the shrub canopy there are either no shrubs, or a percentage of shrub cover. For the herbaceous canopy there is either bare soil, rock, leaf litter, or some percentage of herbaceous cover. Once the data has been recorded for all the data points for that particular plant community, the data can be combined onto a master data sheet to quantify the dominant and co-dominant taxa for each series and plant community. Once all the data has been combined for each plant community, the community can then be reassessed to ensure the proper identification and classification has been made. This information should then be updated on the plant community map, along with the locations of the transects taken.

CALIFORNIA NATIVE PLANT SOCIETY - VEGETATION RAPID ASSESSMENT FIELD FORM
(Revised February 5, 2003)

For Office Use:	Final database #:	Final vegetation type name:	Alliance_____ Association_____

LOCATIONAL/ENVIRONMENTAL DESCRIPTION

Polygon/Stand #:	Air photo #:	Date:	Name(s) of surveyors:
_____	_____	_____	_____

GPS waypoint #: _____ GPS name: _____ GPS datum: (NAD 27) _____ Is GPS within stand? Yes / No

If No cite distance (note ft/m), bearing and view from point to stand center: _____ Error: ±_____ ft/m

UTM field reading: UTME ___ ___ ___ ___ ___ ___ UTMN ___ ___ ___ ___ ___ ___ ___ UTM zone: _____

Elevation: _____ ft/m Photograph #'s: _____

Topography: flat____ concave____ convex____ undulating____ | bottom____ lower____ mid____ upper____ top____

Geology: _____ Soil Texture: _____ % Large Rock_____ % Small Rock_____ % Bare/Fines_____

Slope exposure (circle one and/or enter actual °): NE_____ SE_____ SW_____ NW_____ Flat__ Variable__

Slope steepness (circle one and enter actual °): 0°__ 1-5° _____ 5-25°_____ > 25°_____ Upland or Wetland/Riparian (circle one)

Site history, stand age, and comments: _____

_____

_____

Type / level of disturbance (use codes): _____

VEGETATION DESCRIPTION

Field-assessed vegetation alliance name: _____

Field-assessed association name (optional): _____

Size of stand: <1 acre___ 1-5 acres___ >5 acres___ Adjacent alliances: _____ _____

_____ _____ _____ _____

Tree: T1 (<1" dbh), T2 (1-6" dbh), T3 (6-11" dbh), T4 (11-24" dbh), T5 (>24" dbh), T6 multi-layered (T3 or T4 layer under T5, >60% cover)
If Tree, list 1-3 dominant overstory spp.: _____

Shrub: S1 seedling (<3 yr. old), S2 young (<1% dead), S3 mature (1-25% dead), S4 decadent (>25% dead)

Herbaceous: H1 (<12" plant ht.), H2 (>12" ht.) Desert Palm/Joshua Tree: 1 (<1.5" base diameter), 2 (1.5-6" diam.), 3 (>6" diam.)

Desert Riparian Tree/Shrub: 1 (<2ft. stem ht.), 2 (2-10ft. ht.), 3 (10-20ft. ht.), 4 (>20ft. ht.)

% Overstory Conifer/Hardwood Tree cover: _____/_____ Shrub cover: _____ Herbaceous cover: _____ Total Veg cover:_____

Modal Conifer/Hardwood height: _____/_____ Tall Shrub/Low Shrub height: _____/_____ Herbaceous height: _____

Species (List up to 12 major species), Stratum, and Approximate % cover: (Jepson Manual nomenclature please)

Strata categories: T=tall, M=medium, L=low; % cover intervals for reference: <1%, 1-5%, >5-15%, >15-25%, >25-50%, >50-75%, >75%

Strata	Species	% cover		Strata	Species	% cover

Major non-native species (with % cover): _____

Unusual species: _____

PROBLEMS WITH INTERPRETATION

Confidence in identification: (L, M, H) _____ Explain _____

Other identification problems (describe): _____

Polygon is more than one type: (Yes, No) _____ (Note: type with greatest coverage in polygon should be entered in above section)

Other types: _____ _____ _____

Has the vegetation changed since air photo taken? (Yes, No) _____ If Yes, how? What has changed (write N/A if so)? _____

_____

Figure 1 California Native Plant Society Rapid Assessment Form

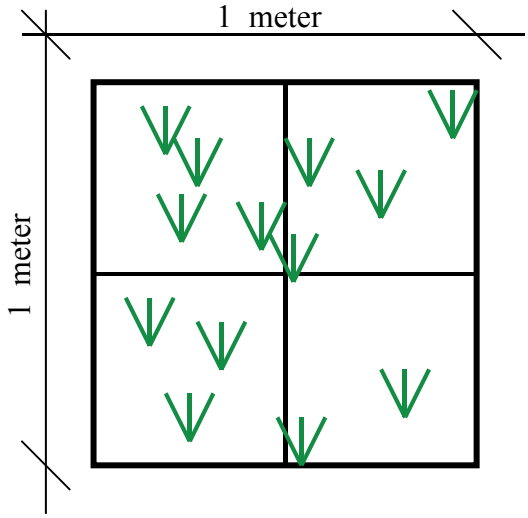


Figure 2 Quadrant Transect

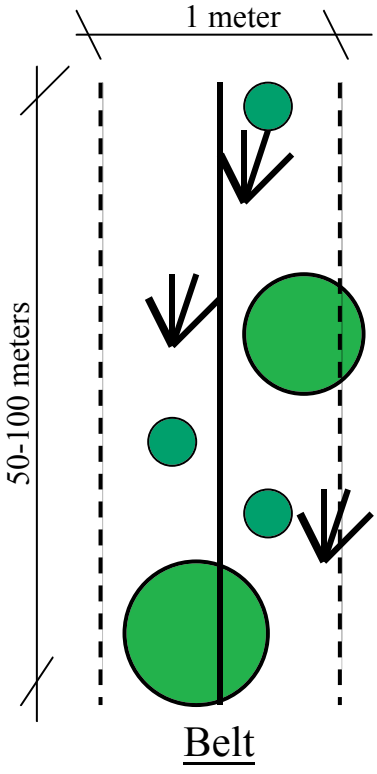


Figure3 Belt Transect

Taxon	0 m	5 m	10 m	15 m	20 m	25 m	30 m	35 m	40 m	45 m	50 m	55 m	60 m	65 m	70 m	75 m	80 m	85 m	90m	95m	100m	Tota
Open ground																						
Total taxa																						
Total chars.																						
Tree Layer																						
Shrub Layer																						
Ground Layer																						

Figure 4 Example Transect Data Sheet

Laboratory #18
HERBARIA AND DATA INFORMATION SYSTEMS

OBJECTIVES FOR THIS LABORATORY:

1. Review the basics of herbarium use and operation.
2. Practice removing and refiling herbarium specimens from the available collection.
3. Practice preparing herbarium labels.

HERBARIUM USE

The SDSU Herbarium

The San Diego State University Herbarium (with the internationally recognized acronym **SDSU**) contains a moderately large collection of plants (ca. 10,000), primarily of San Diego County and other regions of California, but including collections from the Southwestern United States and Mexico plus some cultivated plants. In addition, the herbarium has several reference books for identification as well as many notebooks containing plant collections of various habitats and regions.

The collection at **SDSU** is an important teaching resource and has many valuable specimens for research as well. For serious taxonomic work of plants of southern Californian and Mexico, however, one should study the more extensive collections at the San Diego Natural History Museum (**SD**) in San Diego and the Rancho Santa Ana Botanic Garden (**RSA**) in Clairemont. In addition, for California plants in general, one should study the specimens of the herbaria at University of California at Berkeley (**UC**, **JEPS**), University of California at Davis (**DAV**), and the California Acacdemy of Sciences (**CAS**).

In the **SDSU** Herbarium, specimens are filed alphabetically by family within major plant group categories: PSILOPSIDS, LYCOPODS, SPHENOPSIDS, & FERNS (**Cabinet #1**), CYCADS, GINKGO, CONIFERS, AND GNETALES (**Cabinet #2**), ANGIOSPERMOUS DICOTS (**Cabinets #3 - #14**), and ANGIOSPERMOUS MONOCOTS (**Cabinets #15 - #16**). If you do not know the family or the major category of that family, use the **Genus List** in the Herbarium to determine this information. In addition, families and genera are marked on a sheet attached to the inside of each cabinet door.

Within a family, specimens are filed alphabetically by genus, and within a genus they are filed alphabetically by species. Herbarium specimens are filed in genus folders **color-coded** according to general locality, as follows:

WHITE-MANILA	=	**SAN DIEGO COUNTY**
GREEN	=	**CALIFORNIA**
BROWN	=	**U. S. (other than California) & CANADA**
RED	=	**MEXICO, CENTRAL & SOUTH AMERICA**
BLUE	=	**CULTIVATED, NOT NATURALIZED**

A given genus may have anywhere from one to all five color-coded folders. If there are two or more color-coded folders, they should be placed in the order shown above (i. e., manila on top of green on top of brown, etc.).

You may use the **SDSU** herbarium by appointment or during general usage times. When using the herbarium, please be considerate of dissecting microscopes, tools, and references in the collection. Clean up after yourself; brush the table of debris (into a trash can) as needed.

Herbarium Use Exercise

You will often want to remove specimens from the collection for observation, e. g., to check the identity of your own plant or simply to study different taxa.

Obtain a list of plant species from your instructor. Locate and remove a specimen of the species

in one of the color-coded genus folders. Remove the entire genus folder from the cabinet. You may wish to slightly pull out the genus folders above or below the desired folder to mark the location. (However, always recheck the labels when filing!) Close the herbarium cabinet door immediately in order to inhibit insect transfer. Carefully transfer the genus folder to an open-space table for observation.

Be sure to handle the herbarium sheets (specimens) very carefully. Use common sense to treat them well. Always hold a specimen with two hands to avoid bending the sheet. Never place anything (e. g., books) on a specimen. Never turn a sheet upside down.

If you wish to scan through a genus folder, open the entire folder on a table with plenty of space. To sort through the specimens, you may remove the sheets on top of the desired specimen (either one at a time or in a group) to the left, and then expose or remove the specimen desired. If you wish, you may gently flip through the labels at the lower right to locate the specimen needed and then remove all of those on top.

Remove and study an herbarium specimen of one of the species to be located. Note the label and its information and the bar-coded accession number. From what general region was the specimen collected?

When finished, replace the specimen in correct alphabetical order within the original genus folder. If a genus folder was removed for a short period of time and not placed in proximity to plants or plant debris, it may be refiled immediately into the collection. **However, if there is a chance that insect contamination may have occurred, then freeze (-20 C) the entire genus folder before refiling.** Place the folder in the lowermost compartment of the freezer in the herbarium for 1-3 days before refiling. (Generally, an assistant curator will refile these genus folders).

If you are refiling a folder, be extremely careful to file it in the correct location, both by taxonomic category and locality (color-coding). Be sure to put the folders in the correct order of the color-coded system (above). Check list of families/genera on inside of door, which indicates location by column and compartment in the herbarium cabinet. Make any corrections, additions (in pencil only!) on this list as needed for future revision.

HERBARIUM LABEL PREPARATION

Making an Herbarium Label Using FileMaker Pro Database program (Mac version)

[Note: The "Command" key is the one just to the left of the spacebar with an apple/4-leaf clover icon.]

I. Getting Started:

1. Log onto http://herbdata.sdsu.edu and click one of the files. (Only 5 files can be open at any one time; if none work, try again later.) The username is "Admin". Leave password blank.

2. Records should already be entered that you can access, and the file should appear in Browse mode. If not, see 3-7. Otherwise, go the II. Entering Data (below).

3. Before beginning, from the **Record** menu, select **New Record** (or type Command-N).

4. To begin entering data, select the **Browse** mode from the **Mode** menu.
[FileMaker Pro has four four "**Modes**:" **Browse**, **Find**, **Layout** and **Preview**. The mode that loads automatically is the one last used for the document. You will generally be using only two modes: **Browse** and **Preview**. To change modes, click onto the **Mode** menu and you will see that directly below it is the listing for the four modes. Pull down to one of these to change the current mode. (The mode you are currently in will have a check next to it.)]

5. Available layouts are listed by clicking on the rectangle at the upper left of the open data window. Available layouts that we've created are: **Data Entry**, **Labels**, **Checklist**, etc. Click on the rectangle and select **Data Entry**. (The one currently engaged is checked in the menu; as with the modes, the layout that is loaded is that used last.)

6. In Data Entry layout, you will see a list of fields, e.g, **SDSU**, **Specimen Location**, **Collector: Lastname**, **Collector: Firstname**, etc. If records have already been entered you will see the entries. At the upper left of the window, you will see an image that looks like a three-ring notebook. Clicking on the pages takes you forward or backward through all the records entered. Pulling that "tab" at the right of the 3-ring notebook takes you quickly through the records.

7. If the **Data Entry Layout** window is blank, you may begin entering data. If not, create a new record for your data (if one is not already visible) by selecting **New Record** from the **Mode** menu.

II. Entering Data:

NOTE: whenever entering data, **do not add a blank space at the end of the data entry**. E.g, type "Smith" not "Smith ".

NOTE: leave the **SDSU** and **Specimen Location** fields blank. These are for filing purposes in the SDSU herbarium.

Note: you may use the tab key to go from one field to another.

1. Click to the right of the field heading, **Collector: Lastname**. Boxes will appear next to each field heading. This is where you type the information. (If you have collected the data properly in a field notebook, the fields will correspond to all or part of the field collection data.) In the **Collector: Lastname** box, type the last name of the prmary person who collected the plant. [Remeber: no blank space after this name.] Then move to the next field by either hitting the tab key or by clicking on to the next field "box".

2. **Collector: Firstname** field, type the full first name and middle initial of the primary collector.

3. **Teamcoll** field, type the name of the person or persons who helped collect the plant, if there were any. Type first name (or initial) first. **Example:** "John J. Jones" or "S. E. Gergus & D. H. Lawrence." [Don't make it too long, however.] Often, it's best to put my name - Michael G. Simpson - here, as I have a general collecting permit.

4. **Collection Date** field, type the date that the collection was made. Type **numerically** (not as text), with slashed ("/") separating numbers, as **month/day/year**. You need not put zeros in front of the month or day; type the year as four digits. **Example:** type 3/13/2003 for March 13, 2003.

5. **Collection Number** field, type the collection number that you assigned the specimen. **Example:** 3 or 28 or 138. Do not put any zero's before the number. [Note: If your collection number has prefixes or suffixes, e.g., 13III2000A, type these in the **Col. Number Prefix** and **Col. Number Suffix** fields. E.g., type 13III in **Col. Number Prefix**, 2000 in **Collection Number**, and A in **Col. Number Suffix**

NOTE: Pop-up menus will appear for many of the entries cited below. If you don't wish to use these pop-up entries, then click the field box again and begin typing. Be sure to confirm each of these entries. It is possible that some recent nomenclatural changes may not be listed in these menus.

6. **Country, State/Province,** and **County** boxes type the appropriate information. For country, type "U.S.A." For state, type "California." For county, follow the county name with "Co."; e.g., "San Diego Co."

7. **Family** field, type the family name of your specimen. Be sure to correctly spell it!

8. **Genus** field, type the genus name of your specimen. Do not italicize or underline this name, it will be done automatically for you when you print the label.

9. **Specific Epithet** field, type the specific epithet. As with the genus name, do not italicize or underline.

10. **Spec. Authorship** field, type the complete author of the species name, abbreviating where appropriate. **Example:** (L.) Nutt. for (Linnaeus) Nuttall. [Remember: if part of an authorship has parentheses, it will be followed by one or more authors not in parentheses.]

NOTE: If and only if your specimen is a variety or subspecies, type fields 11-13; otherwise go straight to 14 and do not collect $200.

11 **Infra. Type** field, type either var. or ssp. (for variety or subspecies, respectively.

12. **Infraspecific Name** field, type the subspecific or varietal epithet name. As with the genus and specific epithet fields, you do not italicize or underline.

13. In the **Infra Authorship** box type the author of the infraspecific (ssp. or var.) name.

14. **Latitude: Degrees, Minutes, Seconds** and the **Longitude: Degrees, Minutes, Seconds** fields, type the coordinates if you know them. Do not put the symbol for degrees, minutes or seconds, just the numbers. These symbols will be added when you print the label. Do not use decimal points for any of these! For seconds, round off to the nearest second.

15. **Lat Long Source Accur.** field, type the source and accuracy of the latitude/longitude coordinates. **Examples:** USGS 7.5' La Mesa quad, ±1" accuracy; GPS unit, ±1" accuracy. [Note: to get the "±" symbol, hold down both the option and shift key and type "="].

16. **Elevation in feet** field, type the elevation in feet at which the specimen was collected. Only type the number, do not put "ft." or "feet" after the number. As soon as you select on the **Elevation in meters** box you will see a number. It has already been calculated for you.

17. **Identity Determined By** field, put the name of the person who identified the specimen, even if it is the same as the collector.

18. **Det_Date** field, put the date that the specimen was identified, even if it is the same as the collection date. Use the same format that is explained for the collection date box.

19. **Det_Source & Type** field, put the reference that was used to identify the specimen. (Ignore and leave blank the **Print Date** box at the end.)

20. **Plant Description** field, type the data describing some of the important features of the plant that may not be readily apparent from an herbarium sheet. Describe (if appropriate) in order the plants **duration**, **habit**, **height**, **branching pattern**, **phenology**, **color**, or other features that you find important in identifying the specimen.

21. **Habitat Description** field, type a few sentences describing the site that the plant was collected from. Describe (if appropriate) in order the **physical habitat**, **substrate**, **slope**, **aspect** (direction of slope), **exposure**. Follow this by listing the **plant community (vegetation) type**.

22. **Locality** field, type a few sentences explaining where you collected the specimen. You should list any important landmarks that might be useful, distances from known roads, addresses, city, or any other information that would allow someone to use your locality information to find the site where you collected the specimen.

    Note: When you are ready to enter another record of a plant collected from the same region, often it is quicker to use this shortcut: First, start another record (Select **New Record** from **Records** menu), then, at every blank cell, press Command " to duplicate the entry from the previous entered record.

III. Printing a Label: (<u>Follow these instructions precisely!</u>)

1. To prepare a label, click on the rectangle at the upper left that changes the layout and select **Labels**. You will see your data (minus some of the row heading which are not normally put on an herbarium label) placed in the label format. This is not exactly what your label will look like so you will want to **Preview** it before printing.

2. From the **Mode** menu, select **Preview**. [If necessary, select **Page Setup** from the **File** menu and orient the page from portrait (vertical) to landscape (horizontal).] You will see the label as it will appear when it is printed. If more than one record has been placed in the file, you will see all the labels as they will appear when they are printed. Four labels fit on one page when printed. Make sure that nothing is in error. [Remember: Herbarium labels should be perfect, with no misspellings.] If there are errors, go back to the **Data Entry** layout and to the **Browse** Mode and change the information. [If only two, not four, labels appear (and you have more than two), select **Page Setup** from the **File** menu and reduce the label size until four labels appear on the page.]

3. If you are in Preview mode and all appears correct, you are ready to **Print** (**File** menu).

PRINT ONLY IF YOU ARE VIEWING THE <u>LABELS</u> IN <u>PREVIEW MODE</u>!!!!
(DO <u>NOT</u> PRINT IN DATA ENTRY OR BROWSE MODES!!!!)

4. To select only certain labels to print, you may do a search for those labels by any category. To individually select labels to print, do the following:

   a. In **Data Entry** and **Browse** mode, place today's (or any other single) date in the **Print Date** field at the lower left of the Data Entry Layout. Remember to type the date as, e.g., 3/3/2000.

   b. Type this same date (or copy & paste from the first record) to all other records you wish to print.

   c. <u>Search</u> for all records having this print date by selecting **Find** from the **Mode** menu, typing (or pasting) the date in the **Print Date** field, and clicking "Find." All records with that value will be selected. You may then print them as before.

d. Following a search, to display all of your records again, select **Select All** from the **Edit** menu.

ca. 5" wide

SAN DIEGO STATE UNIVERSITY HERBARIUM
USA
CALIFORNIA
San Diego Co.

Porophyllum gracile Benth.

Perennial subshrub, 30-40 cm tall, with several branches from base, densely branched above. In flower and fruit. Involucre purple. Corolla white to greenish yellow. Pappus bristles white to purplish. Leaves strongly pungent. Note: Flowers visited by checkerspot butterflies. Material preserved in Carnoy's fixative for chromosomal studies.

Near hiking trail, just east of Oak Canyon, ca. 1.5 miles north of trailhead at Hwy 83 and Ventura Rd., Pickwood State Reserve. Mountain slope. Rocky, sandy loam soil. Slope ca. 30 degrees, south facing, exposed. Open Eriogonum fasciculatum - mixed (Artemisia californica, Malosma laurina) scrub. 32˚50'28" N 117˚02'59" W (USGS 7.5' La Mesa quad, ±1" accuracy.) Elevation 1,100 ft. Ca. 4.7 miles northwest of Wilson Peak.

Cynthia D. Jones 702 24 April 1994
with John J. Smith

APPENDIX 1

PLANT DESCRIPTION

WRITING A PLANT DESCRIPTION

The following list of characters can serve as the basis for a detailed plant description. The basic form of the description is to list the plant organ (noted in **bold** in the character list below), followed by a listing of all character states that apply for that plant organ, with each character state separated by commas. Note that, for any particular species, not all characters will apply; these are simply omitted. Also note that some characters are listed with multiple character names, e.g., "**Sepal/Calyx lobes/Outer tepals**." This is designed as a guide, with the intention that only one of these three will be used, depending on whether the outer whorl of the perianth consists of distinct sepals (**Sepal** used), of fused sepals (**Calyx lobes** used), or of tepals (**Outer tepals** used).

There are different styles in writing a detailed plant description. Some use a telegraphic style, e.g., "Leaves simple, sessile, whorled, ovate, entire, glabrous." This style is common in floras, where space for text may be at a premium. Other descriptions use complete sentences, e.g., "Leaves are simple, sessile, whorled, ovate, entire, and glabrous." The use of "the" at the beginning of a sentence is optional, as in "The leaves are simple, sessile, whorled, ovate, entire, and glabrous."

Some general suggestions are as follows:

1. Be sure to *only* list the plant organs (and list only once), followed by the character states that apply to that plant organ. The major plant organs are sometimes placed in **bold** text to highlight them. *Do not* list the specific character names, unless a clarification is needed. Examples:
   Do write: "**Flowers** are bisexual, actinomorphic, pedicellate, 1.5–2.2 cm long (including pedicel) . . ." ["Flowers" refers to the plant organ; all other terms are character states.]
   Do not write: "**Flower sex** is bisexual, **symmetry** is actinomorphic, **attachment** is pedicellate, **length** is 1.5–2.2 cm …" ["Sex," "symmetry," "attachment," and "length" are characters and should not be listed.]
   However, *do* write: "**Leaf blades** are elliptic, serrate, rounded at base, obtuse at apex." ["Rounded" and "obtuse" could refer to either of the characters base or apex, so these characters should be listed for clarification.]
2. Description of the major organs may be written in the singular or plural form, but the latter should be used only if more than one such organ occurs in an individual. If only one organ occurs per individual, the singular should be used.
   Do write: "**Leaves** are trifoliolate, alternate, . . ." or "The **leaf** is trifoliolate, alternate, . . ." if there are multiple leaves.
   Do write: "The **inflorescence** is a solitary raceme, . . ." if there is a single raceme per individual.
3. Always use metric for plant or plant organ heights, lengths, and widths. Always abbreviate these: "mm" for millimeters, "cm" for centimeters, "dm" for decimeters, "m" for meters. Use mm and cm for smaller structures, dm or m for larger. Use the appropriate unit of measure to avoid values less than 1, if possible. (E.g., write "2–5 mm" instead of "0.2–0.5 cm".) Always place a "0" before a decimal point, as in "0.5 mm." Be clear about what you're describing. Examples:
   Do write: "**Flowers** are 0.5–1.3 mm long (excluding pedicel), 2–3 mm wide when fully opened."
   Do not write: "**Flowers** are .5–1.3 mm."
4. For characters that are variable, either list the range of variation (e.g., "**Leaves** oblaceolate to narrowly elliptic, crenate to dentate . . .") or list the most common morphology and in brackets list the exceptions (e.g., "**Leaves** trifoliolate [rarely pinnate with 5 leaflets]" or "**Leaves** 4–7 [2.5–10] cm long . . .").

COMPLETE MORPHOLOGICAL CHARACTER LIST

[Available as download from Website; Note: Not all characters apply to a given taxon; add characters for specialized structures.]

Species/Infraspecies Name (with authorship) [Common Name]: _____

Family: _____ **Native locality:** _____

Plant Habitat: _____

Plant Duration: _____
Plant Sex if not hermaphroditic: _____
Plant Habit: _____
Plant Height: _____
Root Type: _____
Root Origin (e.g., primary, adventitious): _____
Underground Stem Type if specialized: _____
Underground Stem Branching Pattern: _____
Underground Stem Size: _____
Aerial Stem Habit: _____
Aerial Stem Branching Pattern: _____
Bark Type: _____
Bark Lenticels presence/shape: _____
Twig Surface/Shape: _____
Twig Lenticel presence/shape: _____
Twig Shape/Cross-Sectional Outline: _____
Pith Type: _____
Pith Cross-Sectional Outline: _____
Fruit Scar presence/shape: _____
Leaf Scar Size/Shape: _____
Vascular Bundle Scar Number/Pattern: _____
Stipule Scar presence: _____
Stipule Scar Position/Shape if present: _____
Terminal Bud Scale Scars presence/absence: _____
Bud Type: _____
Bud Orientation: _____
Bud Shape/Size: _____
Bud Position: _____
Bud Scale Arrangement: _____
Bud Scale Surface/Texture: _____
Thorns if present: _____
Spines if present: _____
Prickles if present: _____
Spur Shoot if present: _____
Leaves/Leaf Number if unusual: _____
Leaf Type: _____
Leaf Length/Width: _____
Leaf Attachment: _____
Leaf stipule presence: _____
Leaf Duration: _____
Leaf Position if not cauline: _____
Leaf Arrangement: _____
Leaf Orientation if discrete: _____
Leaf Posture if discrete: _____

Petiole Shape: _____
Petiole Color: _____
Petiole Length: _____
Petiole Orientation: _____
Stipule Shape: _____
Stipule Surface adaxial: _____
Stipule Surface abaxial: _____
Stipule Length: _____

IF LEAVES SIMPLE:

Leaf Blade Color if unusual: _____
Leaf Blade Shape: _____
Leaf Blade Length: _____
Leaf Blade Width: _____
Leaf Blade Base: _____
Leaf Blade Margin: _____
Leaf Blade Apex: _____
Leaf Blade Apical Process: _____
Leaf Blade Division: _____
Leaf Blade Venation: _____
Leaf Blade Surface adaxial: _____
Leaf Blade Surface abaxial: _____
Leaf Blade Texture: _____

IF LEAVES COMPOUND:

Leaf Outline Shape: _____
Rachillae Number if decompound: _____
Leaflets Number if not very large: _____
Leaflet Arrangement: _____
Leaflet Blade Shape: _____
Leaflet Blade Attachment: _____
Leaflet Blade Color if unusual: _____
Leaflet Blade Length: _____
Leaflet Blade Width: _____
Leaflet Blade Base: _____
Leaflet Blade Margin: _____
Leaflet Blade Apex: _____
Leaflet Blade Apical Process: _____
Leaflet Blade Division: _____
Leaflet Blade Venation: _____
Leaflet Blade Surface adaxial: _____
Leaflet Blade Surface abaxial: _____
Leaflet Blade Texture: _____
Petiolule Shape: _____

Petiolule Color: _____
Petiolule Length: _____
Stipel presence: _____
Stipel Shape: _____
Stipel Surface adaxial: _____
Stipel Surface abaxial: _____
Stipel Length: _____

Inflorescence Position: _____
Inflorescence Bract presence: _____
Inflorescence Type: _____
Inflorescence Length: _____
Inflorescence Width: _____
Inflorescence Branch Orientation: _____
Inflorescence Sex: _____
Inflorescence Axis Surface: _____
Flower Sex: _____
Flower Bract presence: _____
Flower Length minus pedicel: _____
Flower Width minus pedicel: _____
Flower Arrangement: _____
Flower Orientation: _____
Flower Posture: _____
Flower Symmetry overall: _____
Flower Attachment: _____
Pedicel if present Length: _____
Pedicel if present Shape if unusual: _____
Bracts/Bractlets No (note inflorescence vs. flower): _____
Bracts Position: _____
Bracts Length: _____
Bracts Color if unusual: _____
Bracts Attachment: _____
Bracts Shape: _____
Bracts Base: _____
Bracts Margin: _____
Bracts Apex: _____
Bracts Apical Process: _____
Bracts Division: _____
Bracts Venation if unusual: _____
Bracts Texture if unusual: _____
Bracts Surface adaxial: _____
Bracts Surface abaxial: _____
Receptacle Size if unusual: _____
Receptacle Shape if evident: _____
Hypanthium presence: _____
Hypanthium Shape: _____
Hypanthium Length: _____
Hypanthium Width: _____
Perianth Cycly: _____
Perianth Arrangement if not whorled: _____

Perianth Type (if homochlamydeous): _____
Calyx/Outer Tepals Aestivation: _____
Calyx/Outer Tepals Fusion: _____
Calyx/Outer Tepals Symmetry: _____
Calyx/Outer Tepals Length: _____
Calyx/Outer Tepals Color if not green: _____
Calyx/Outer Tepals Surface adaxial: _____
Calyx/Outer Tepals Surface abaxial: _____
Calyx/Outer Tepals Venation if unusual: _____
Calyx/Outer Tepals Texture if unusual: _____
Sepal/Calyx Lobes/Outer Tepals Merosity: _____
Sepal/Calyx Lobes/O.T. Length: _____
Sepal/Calyx Lobes/O.T. Shape: _____
Sepal/Calyx Lobes/O.T. Base: _____
Sepal/Calyx Lobes/O.T. Margin: _____
Sepal/Calyx Lobes/O.T. Apex: _____
Sepal/Calyx Lobes/O.T. Apical Process: _____
Corolla Type (if dichlamydeous): _____
Corolla/Inner Tepals Aestivation: _____
Corolla/Inner Tepals Fusion: _____
Corolla/Inner Tepals Cycly if not uniseriate: _____
Corolla/Inner Tepals Color: _____
Corolla/Inner Tepals Symmetry: _____
Corolla/Inner Tepals Length: _____
Corolla/Inner Tepals Surface: _____
Corolla/Inner Tepals Venation if unusual: _____
Corolla/Inner Tepals Texture if unusual: _____
Petal/Corolla Lobes/Inner Tepals Merosity: _____
Petal/Corolla Lobe/I.T. Shape: _____
Petal/Corolla Lobe/I.T. Base: _____
Petal/Corolla Lobe/I.T. Margin: _____
Petal/Corolla Lobe/I.T. Apex: _____
Petal/Corolla Lobe/I.T. Length: _____
Petal/Corolla Lobe/I.T. Orientation: _____
Petal/Corolla Lobe/I.T. Posture: _____
Stamens (Androecium) Cycly: _____
Stamens (Androecium) Merosity: _____
Stamen Type: _____
Stamen Attachment: _____
Stamen Arrangement: _____
Stamen Position: _____
Stamen Insertion if applicable: _____
Stamen Fusion: _____
Staminodes if present No: _____
Staminodes if present Pos: _____
Staminodes if present Size: _____
Staminodes if present Shape: _____
Filament Shape/Color: _____
Filament Length: _____
Anthers Attachment: _____

Anther Type: _____
Anther Dehiscence Type: _____
Anther Dehiscence Direction: _____
Anther Color: _____
Anther Length: _____
Anther Shape: _____
Anther Thecae Arrangement: _____
Connective Morphology if unusual: _____
Pollen color: _____
Gynoecium Fusion: _____
Perianth Androecial Position: _____
Ovary Position: _____
Ovary Attachment if not sessile: _____
Ovary Color: _____
Ovary Length: _____
Ovary Shape: _____
Ovary Surface: _____
Styles Number per pistil: _____
Style Position: _____
Style Shape/Color: _____
Style Disposition/Length: _____
Stigmas Number: _____
Stigmas Position: _____
Stigmas Shape: _____
Stigmas Surface: _____
Nectaries presence/absence: _____
Nectary Type/Position: _____
Carpels Number: _____
Median Carpel Position relative to stem axis: _____
Locules Number: _____
Placentation: _____
Placenta Shape/Position if unusual: _____
Ovules Number per carpel: _____
Ovule Type: _____
Ovule Position: _____
Fruit Type: _____
Fruit Color: _____
Fruit Shape: _____
Fruit Length/Width: _____
Fruit Surface: _____

Seed Color: _____
Seed Shape: _____
Seed Length: _____
Seed Surface: _____
Funiculus Length: _____
Funiculus Shape: _____
Aril presence: _____
Aril Size: _____
Aril Shape: _____
Aril Position: _____
Seeds Nutritive Tissue: _____
Embryo Type Size/Shape/Position: _____
Cotyledon Position: _____
Radicle Position: _____
Seedling Type: _____

FLORAL FORMULA:

P _____ A _____ G
or K _____ C _____ A _____ G

Note: List number of parts after each symbol:
P = # perianth parts or tepals (outer + inner whorls)
or **K** = # sepals or calyx lobes **C** = # petals or corolla lobes
A = # stamens of androecium (outer + inner whorls)
G = # carpels of gynoecium (add ovary position)
( ) = fusion of parts [ ] = rare numbers of parts
Optional:
$\mathbf{K}_z$ = zygomorphic calyx; $\mathbf{C}_z$ = zygomorphic corolla; etc.

E. g., **K** (5) $\mathbf{C}_z$ (5) **A** 5 [4] **G** (2), inferior
= calyx synsepalous with 5 lobes
corolla zygomorphic, sympetalous with 5 lobes
stamens 5, rarely 4, distinct, in one whorl
gynoecium syncarpous, carpels 2, ovary inferior

E.g., **P** 3+3 **A** 3+3 **G** 3, superior
= perianth apotepalous with 3 outer and 3 inner tepals
stamens 6, distinct, in two whorls: 3 outer + 3 inner
gynoecium apocarpous, carpels (pistils) 3, ovaries superior

Appendix 2. Plant Morphology Review

ROOTS, STEMS, SHOOTS

Name the major plant organs.
What are the continuously actively dividing cell regions of a plant called and where are they located?
What is meant by plant habitat and what are the types of plant habitat?
What is meant by plant habit and what are the types of plant habit?
What is the function of roots?
What is a shoot?
What is a bud, where do buds typically develop, and what do they develop into?
Define node, internode.
What is stem habit and what are some types of stem habits?
What is the difference between monopodial and sympodial? To what character do these belong?

LEAVES

What is the difference between a bract and a scale?
From what is a phyllode derived?
Name three modifications of leaves found in carnivorous plants.

FLOWERS

Draw a typical flower and label all the parts, including collective terms.
Name the two basic types of flower sex.
Name the three basic types of plant sex. What is the corresponding type of flower sex for each?
What is the difference between protandrous and protogynous?
What are the two major types of perianth arrangement?
What is perianth cycly?
What is the difference between dichlamydeous and homochlamydeous?
What is a nectary and what are some types of nectaries?
What is the difference between a gynoecium, carpel, and pistil?
What are the 3 parts of a pistil? What is a locule?
How is carpel number determined?
Name the stalks/axes: pedicel, peduncle, petiole, petiolule, rachis, rachilla.

INFLORESCENCES

Name two types of inflorescence position.
What is the difference between determinate and indeterminate inflorescence development?
What is a dichasium?
How does a monochasium differ and what are two major types?

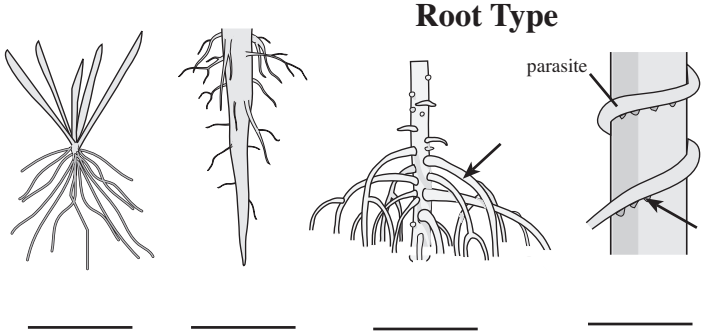
FRUITS & SEEDS

What are the differences between a simple, aggregate, and multiple fruit?
What is the difference between endospermous and exalbuminous?

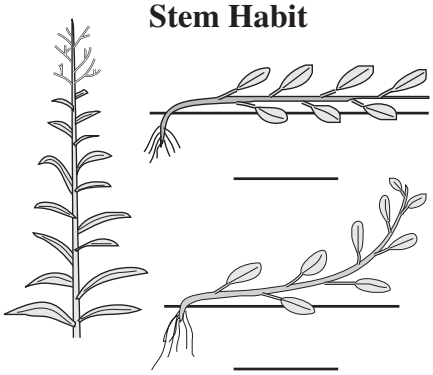
GENERAL TERMS

What is the difference between cycly and merosity? Give an example of each.
What is the difference between coriaceous and indurate? between scarious and succulent? What is the character for these?
What is the difference between connate and distinct? between adnate & free? between adherent & coherent? What is the character for these?
What is the difference between position. arrangement. and orientation?
What is the difference between transverse posture and longitudinal posture?
Surface refers to 3 features: configuration, epidermal excrescence, and vestiture. How do they differ?
What is the difference between glabrous, glaucous, and viscid?
What is the difference between annual, biennial, and perennial? For what character are these character states?
What is the difference between caducous and accrescent? For what character are these character states?

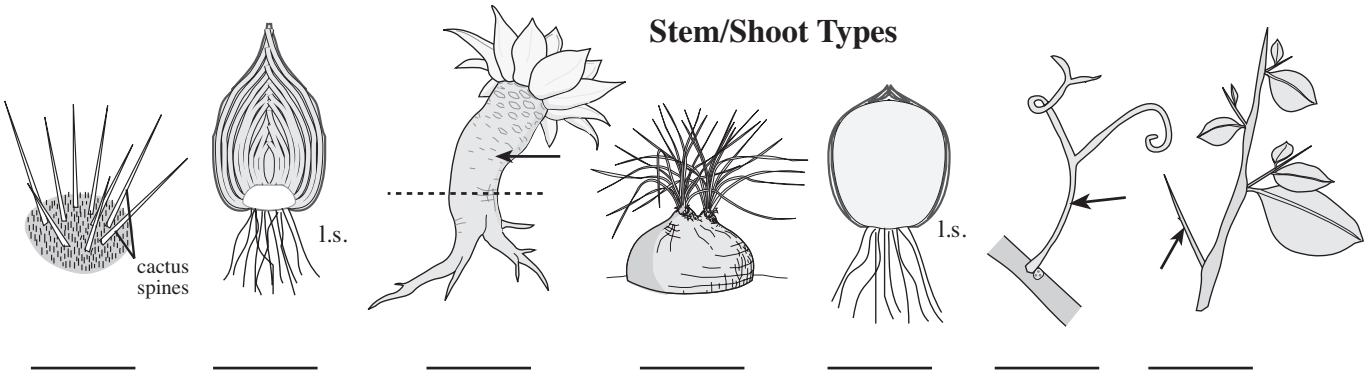
Root Type

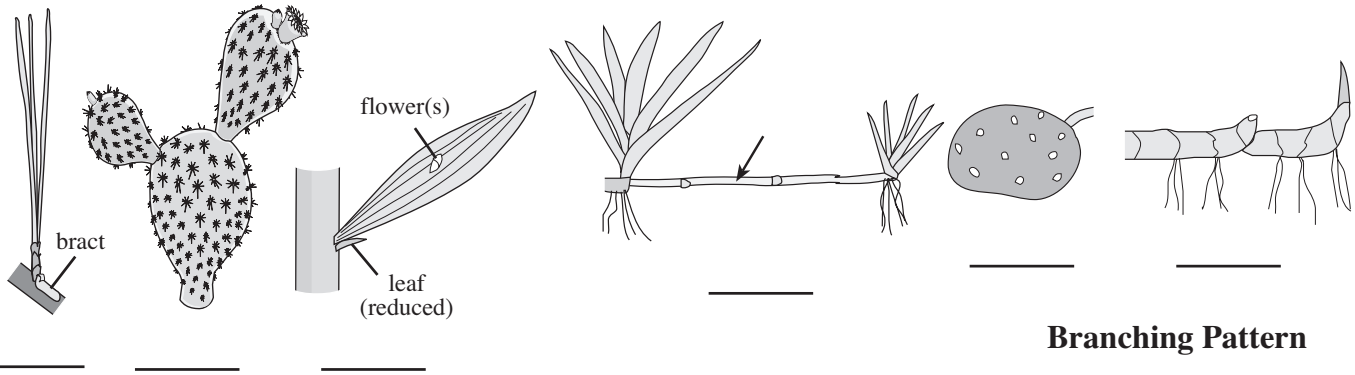


Stem Habit

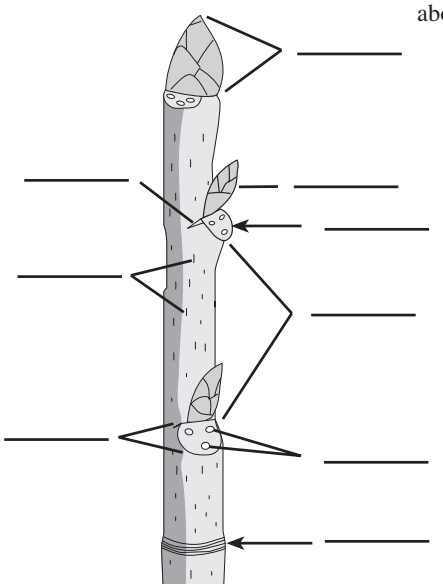


Stem/Shoot Types

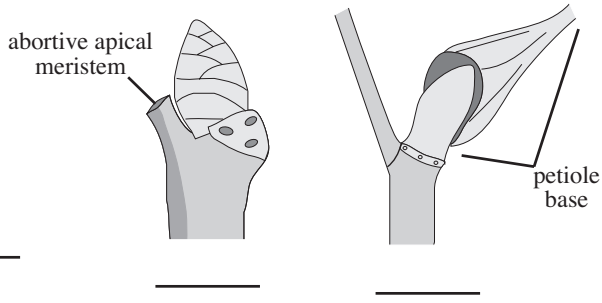


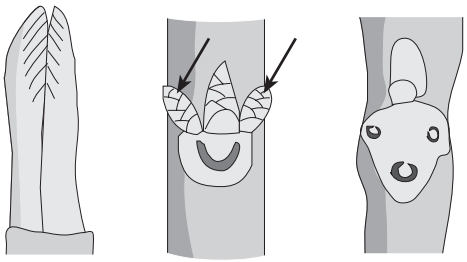


Twig Parts

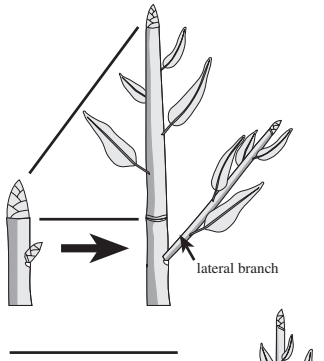


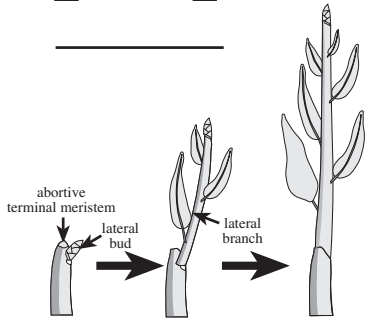
Bud Types / Parts



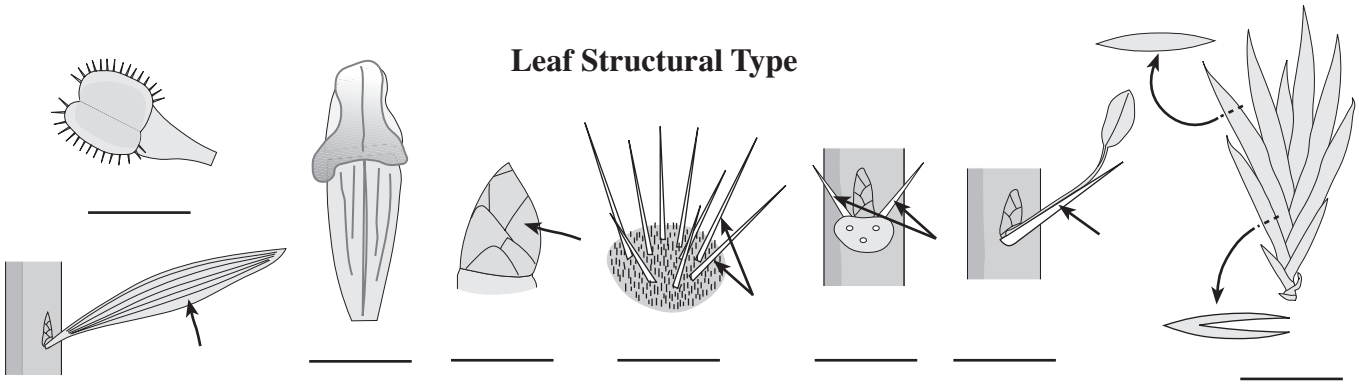


Branching Pattern

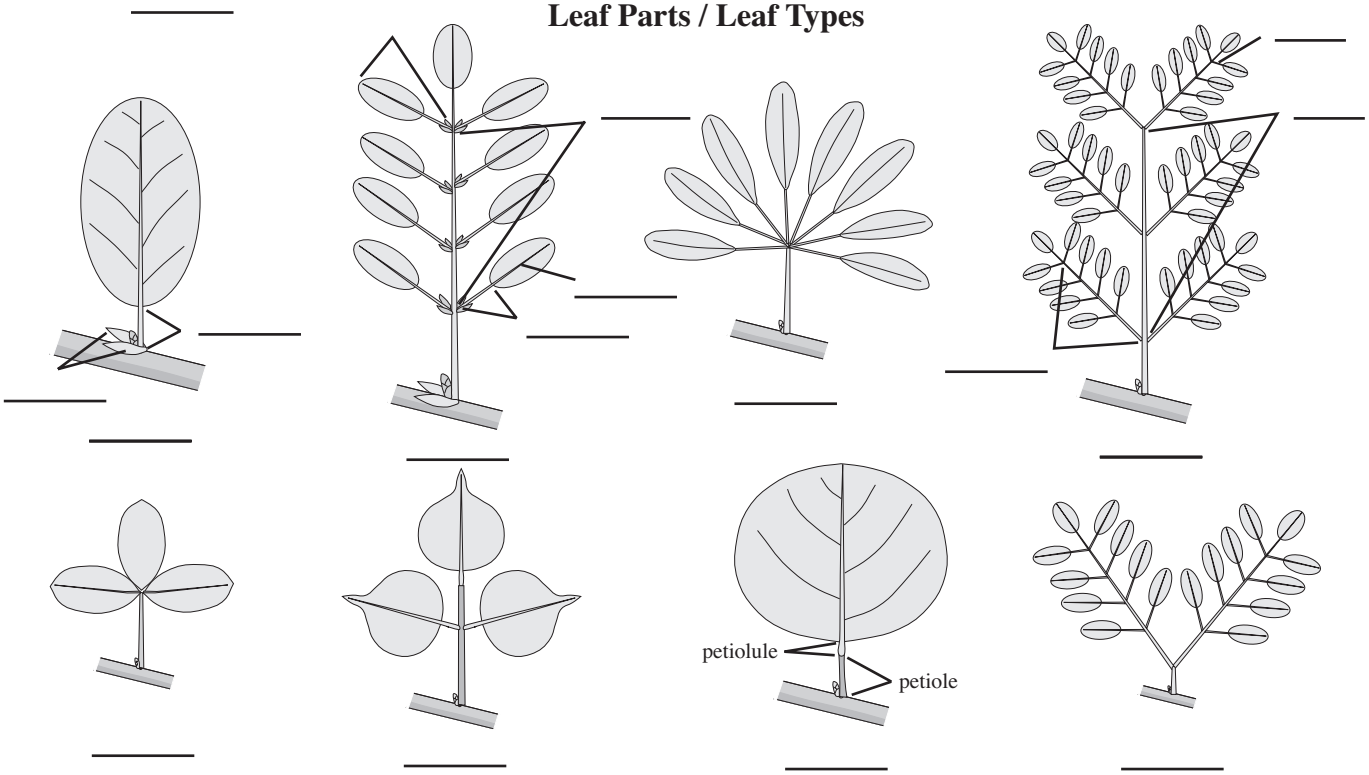




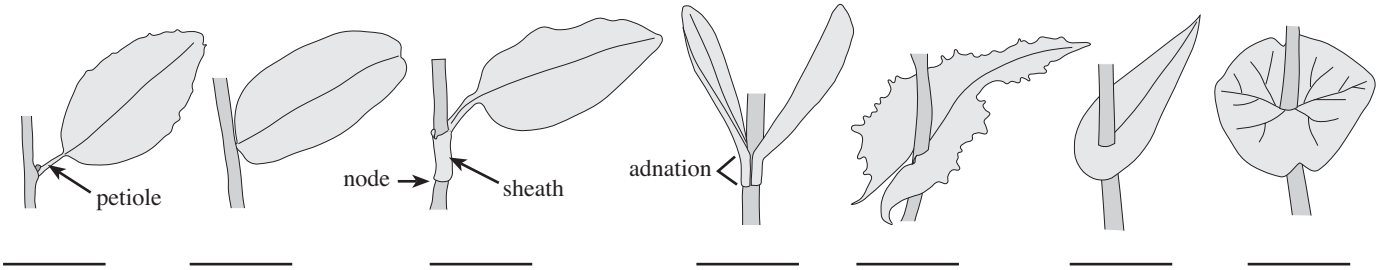
Leaf Structural Type



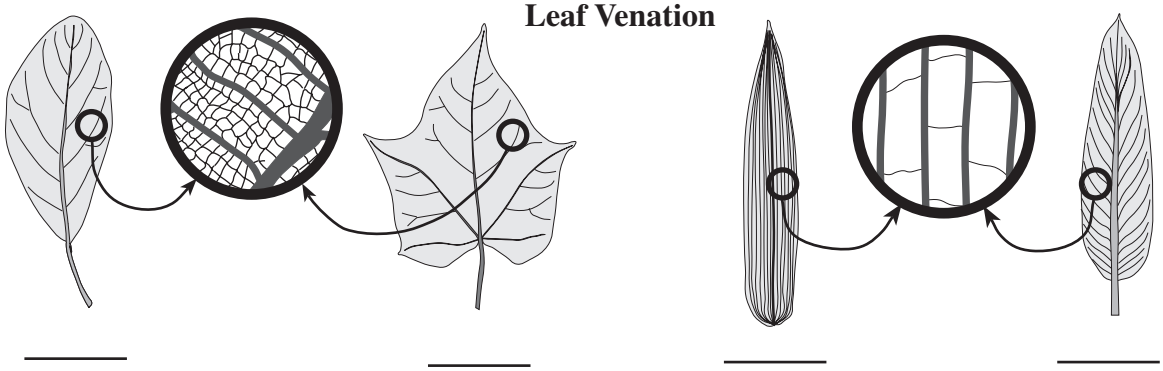
Leaf Parts / Leaf Types



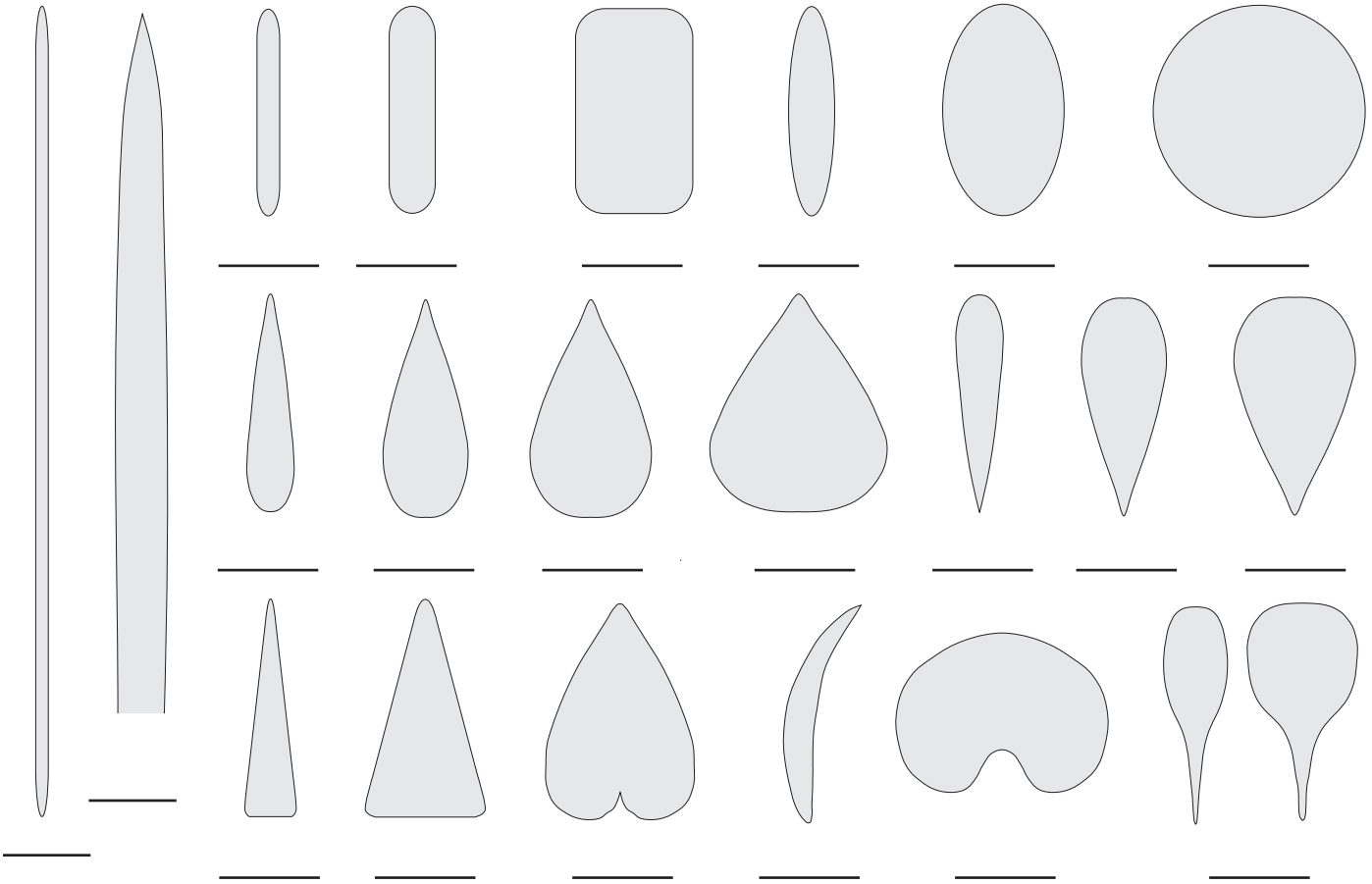
Leaf Attachment



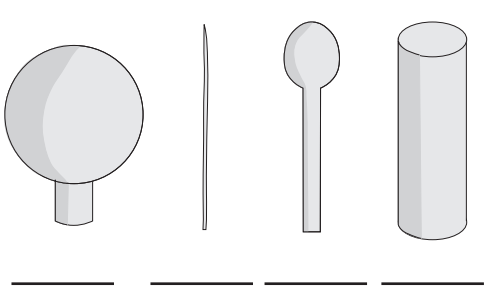
Leaf Venation



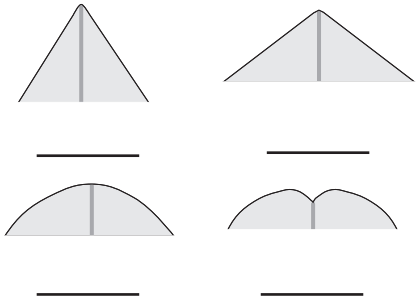
Shape: Plane



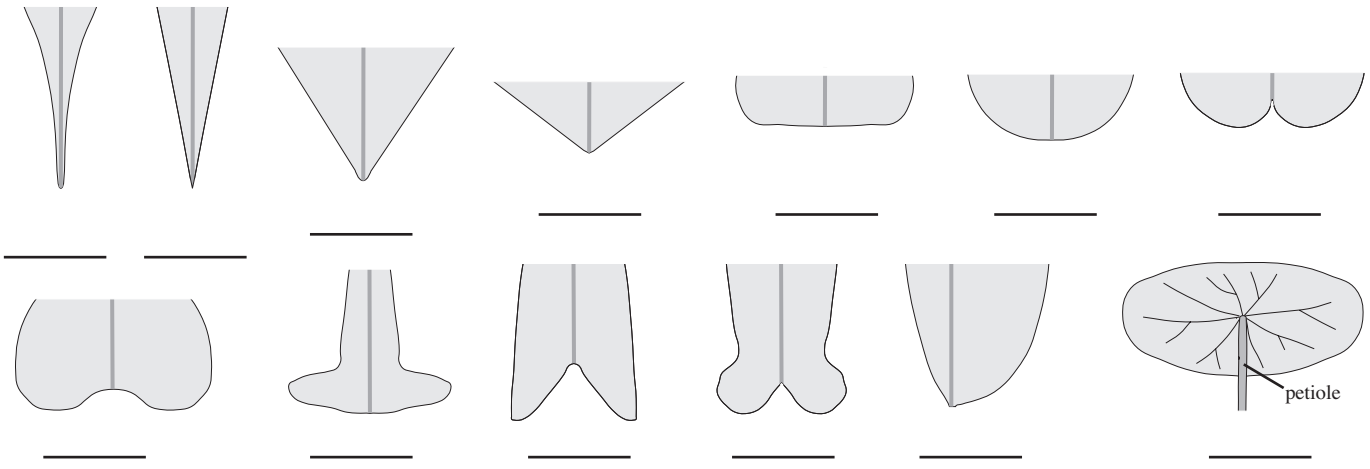
Shape: 3-D



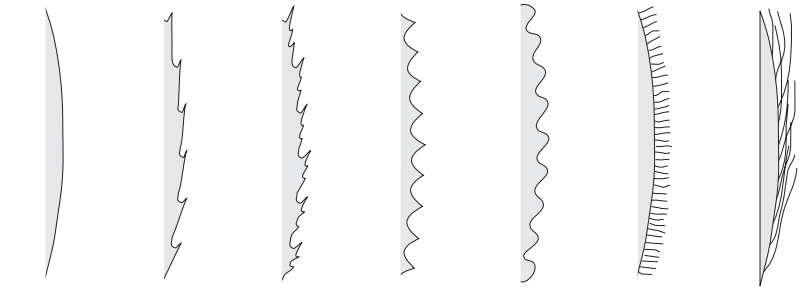
Apex Shape



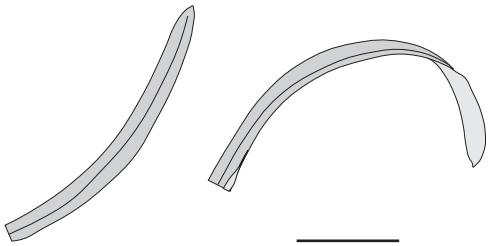
Base Shape



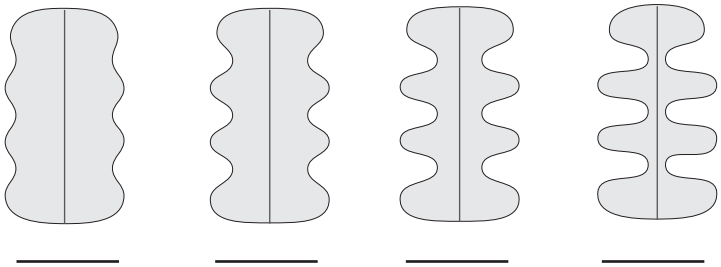
Margin



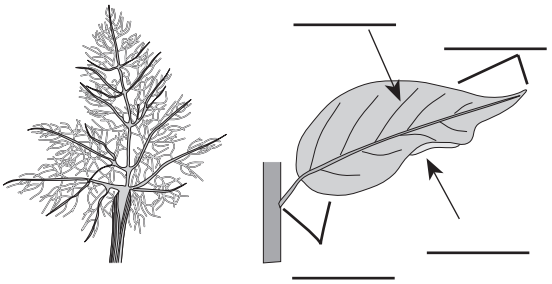
Posture: Transverse

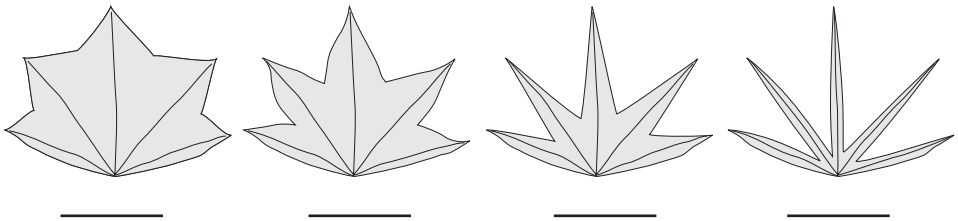


Division

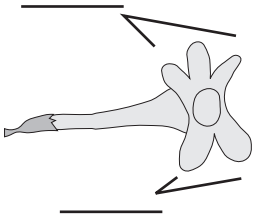


Position



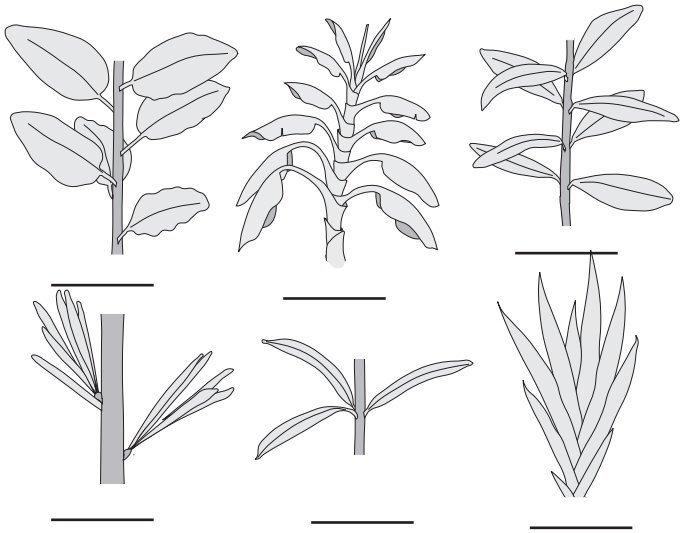


Position



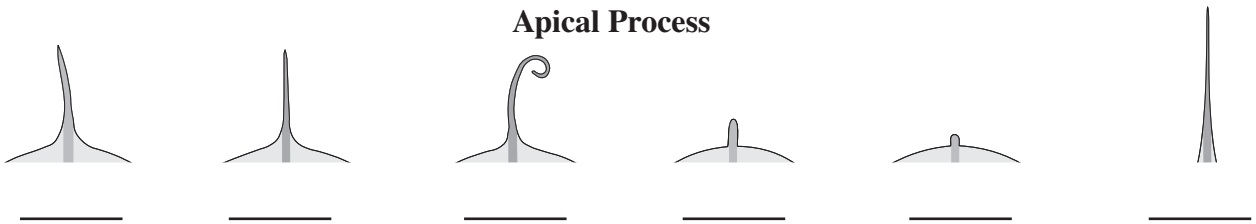
Posture: Longitudinal

Leaf Arrangement

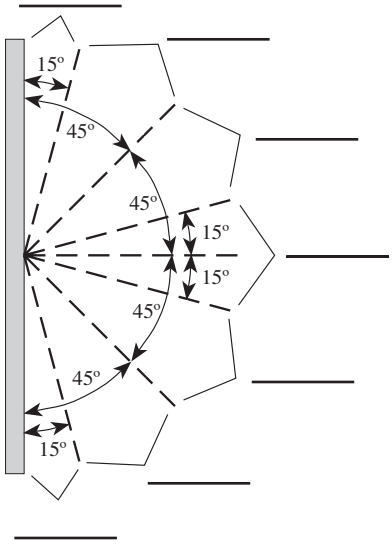


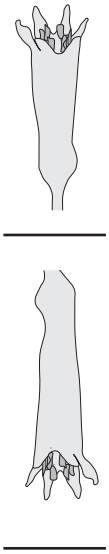
Leaf Position

Apical Process

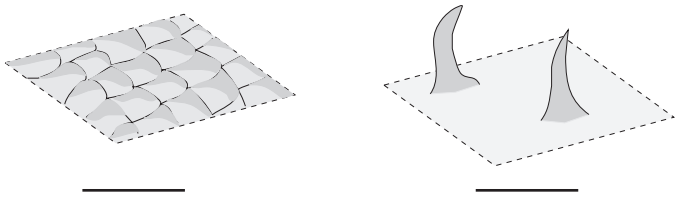


Orientation

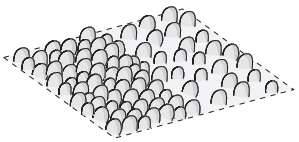




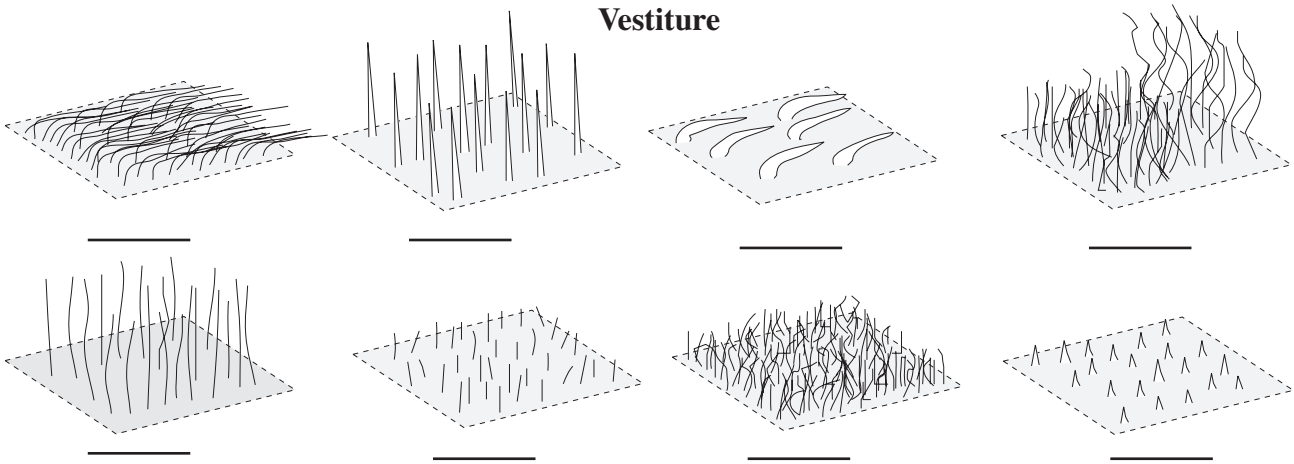
Configuration



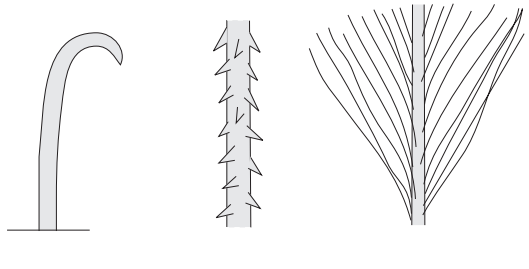
Epidermal Excrescence



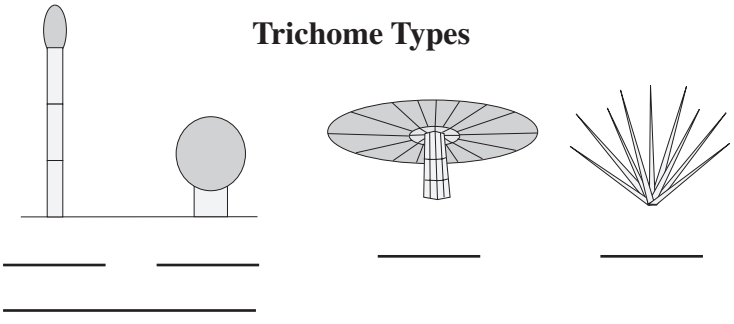
Vestiture



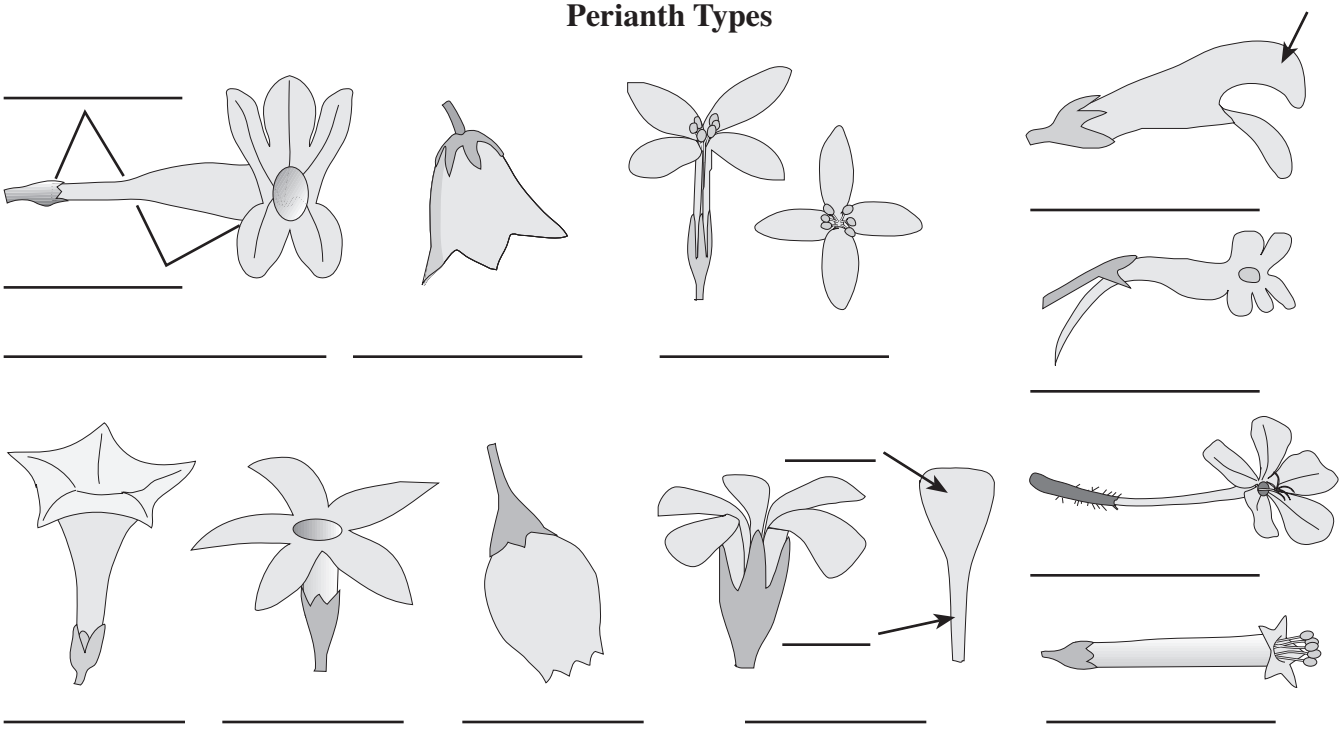
Bristle Types



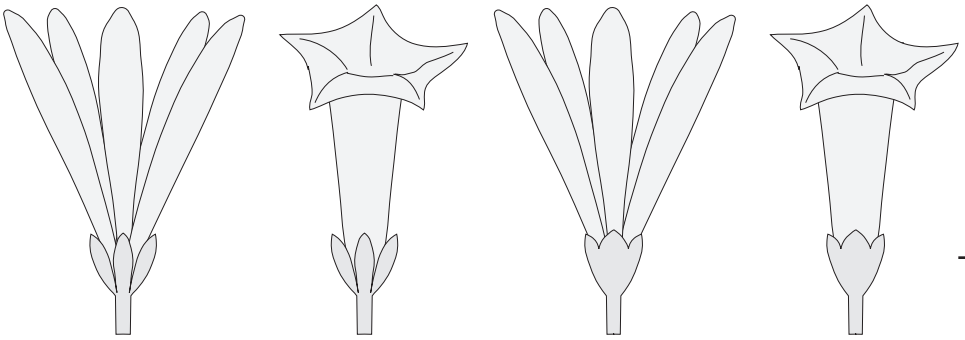
Trichome Types



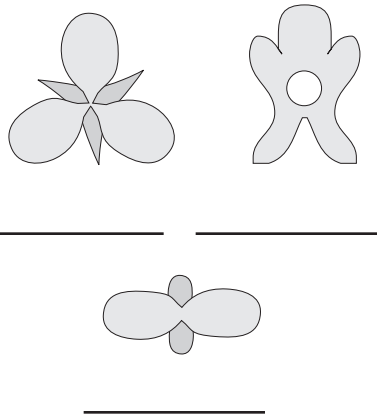
Perianth Types



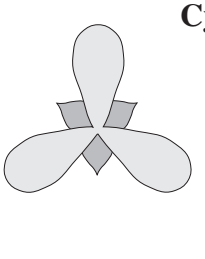
Calyx Fusion (top line)
Corolla Fusion (bottom line)



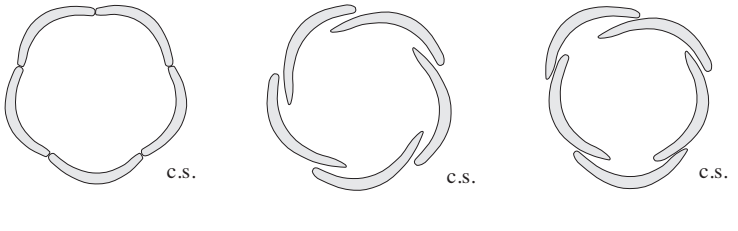
Symmetry



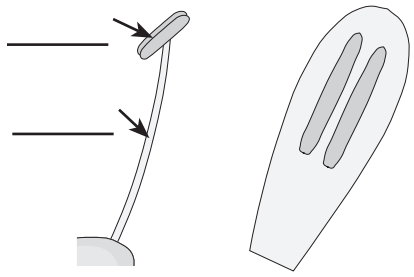
Cycly



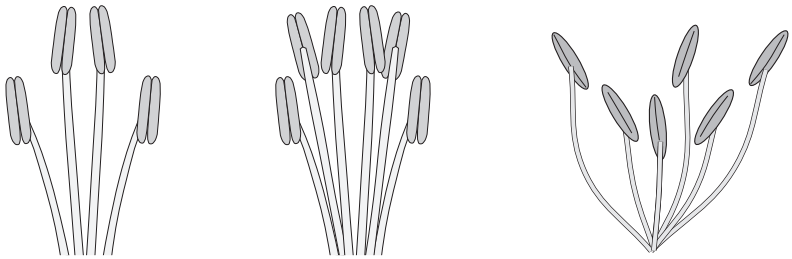
Aestivation



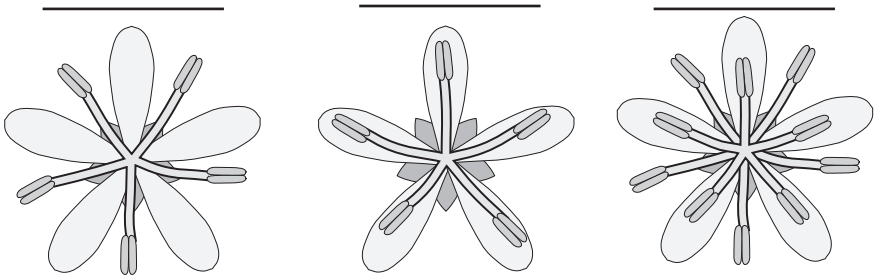
Stamen Types / Parts



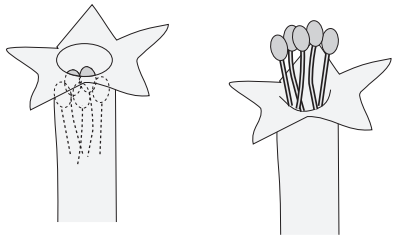
Stamen Arrangement



Stamen Cycly

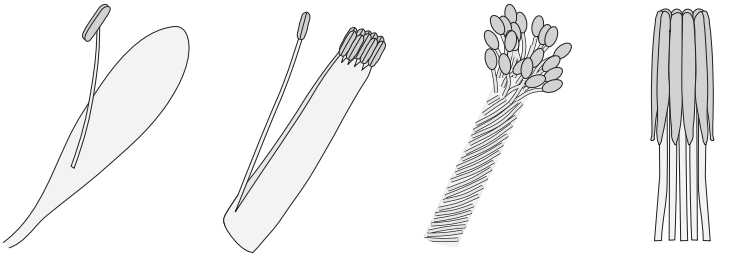


Stamen Insertion

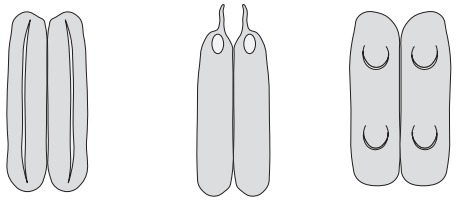


Stamen Position

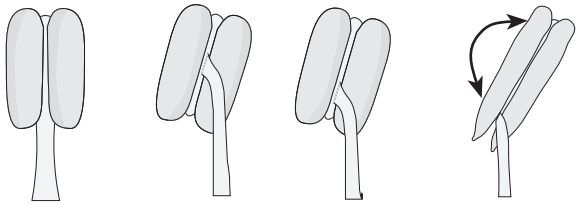
Androecial / Stamen Fusion



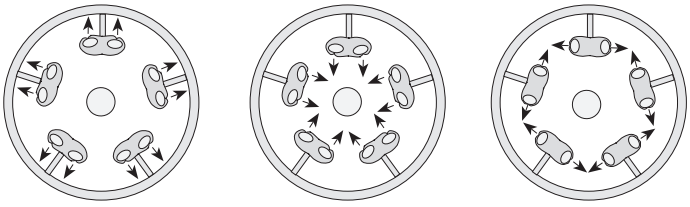
Anther Dehiscence Types



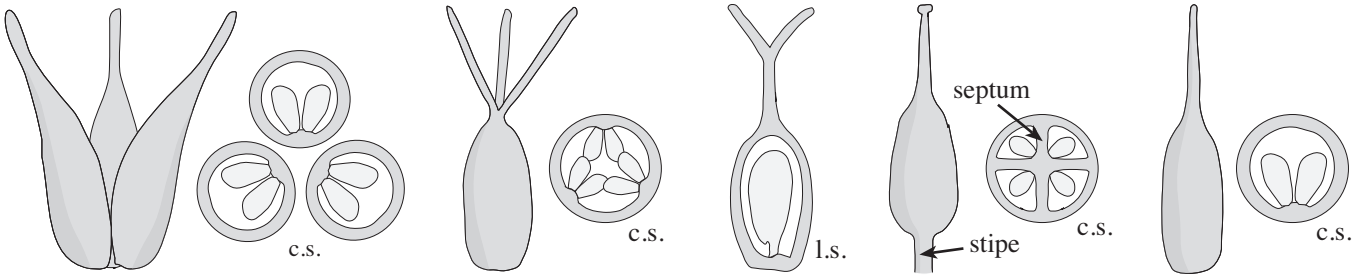
Anther Attachment



Anther Dehiscence Direction

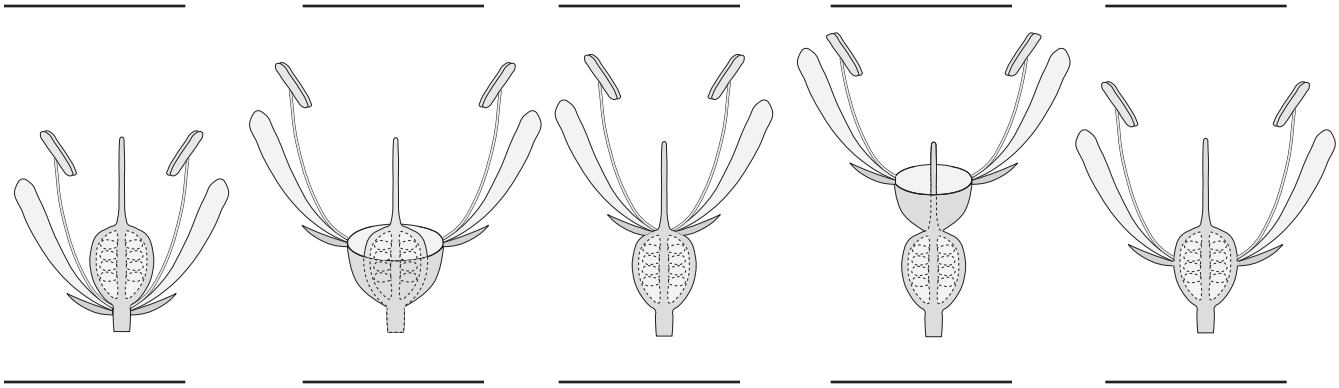


Gynoecial Fusion



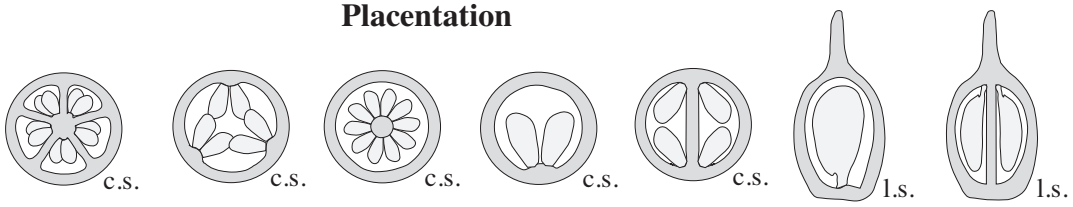
Carpel Number

Ovary Position

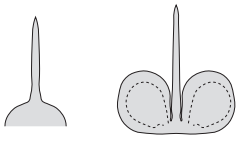


Perianth-Androecial Position

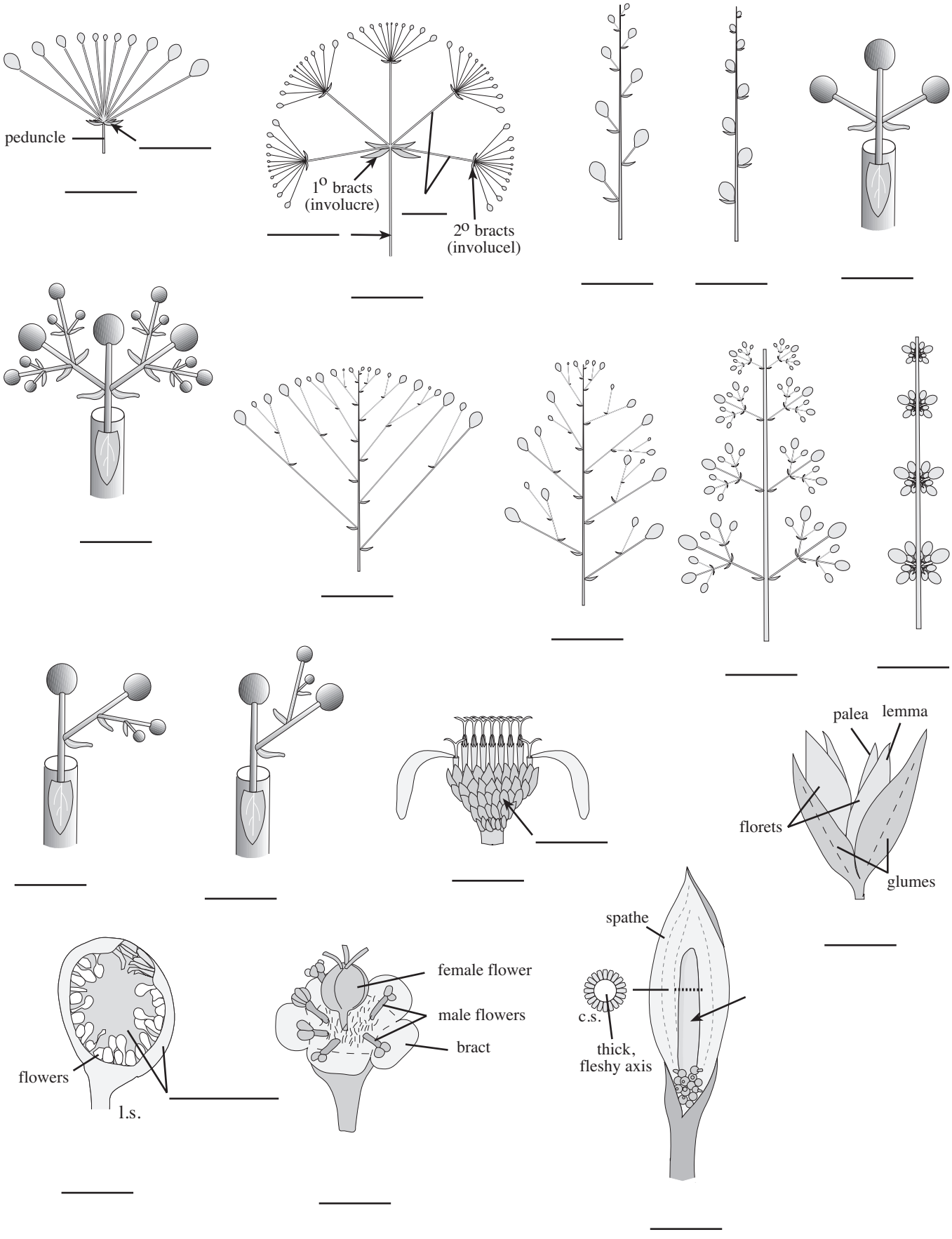
Placentation



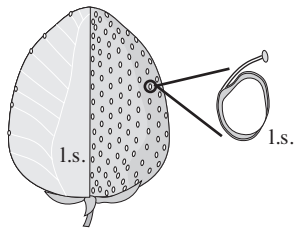
Style Position



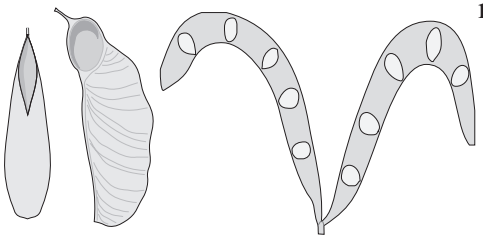
Inflorescence Types



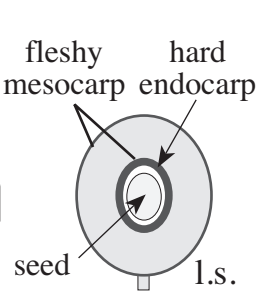
Fruit Types



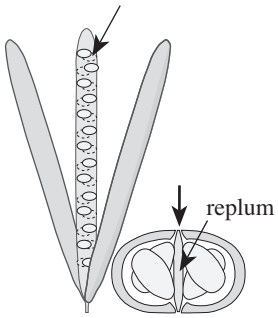
1. _____



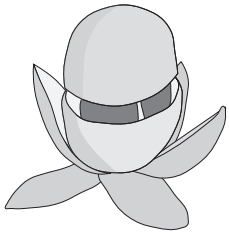
2. _____ **3.** _____



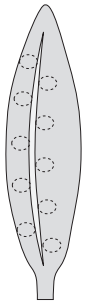
4. _____



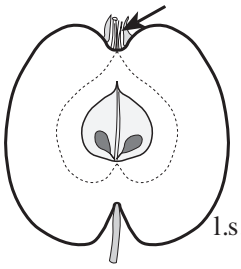
5. _____



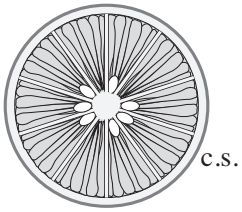
6. _____



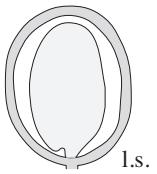
7. _____



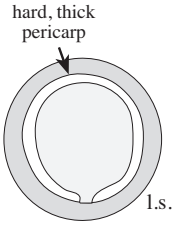
8. _____



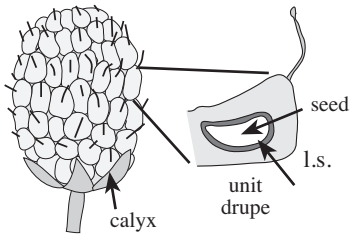
9. _____



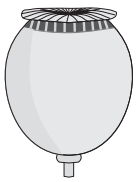
10. _____



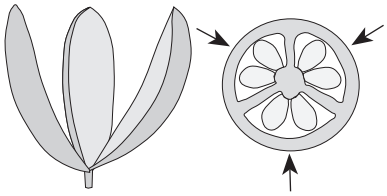
11. _____



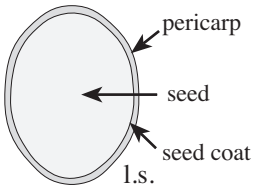
12. _____



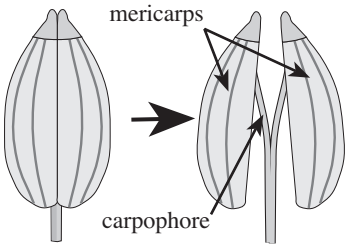
13. _____



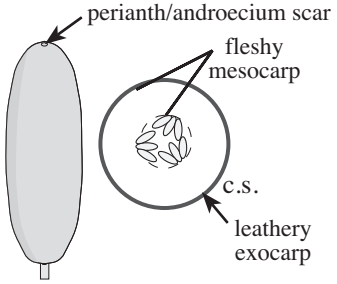
14. _____



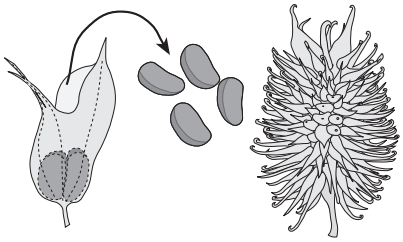
15. _____



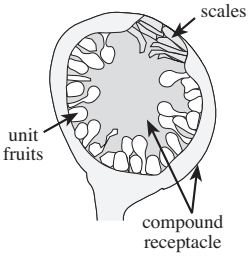
16. _____



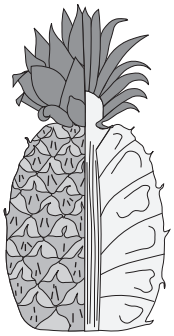
17. _____



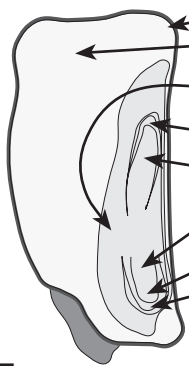
18. _____ **19.** _____

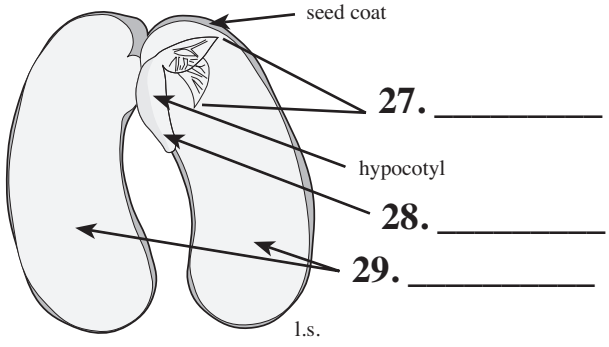


20. _____



21. _____





Seed Parts

CULTIVATED TREES OF SAN DIEGO STATE UNIVERSITY

Prepared by Michael Simpson, Gladys Baird, Linda Foster, and Scott McMillan, with contributions from Janice Curl, Ben Vine, Wende Wheeler, Jim Wilson, Theresa Wilkinson, and Nathan Authement

Department of Biology, San Diego State University, San Diego, CA 92182

(Revised July 2006; please send additions and revisions to Dr. Michael Simpson at the above address, or to: msimpson@sunstroke.sdsu.edu)

Taxa in alphabetical order of species name abbreviation

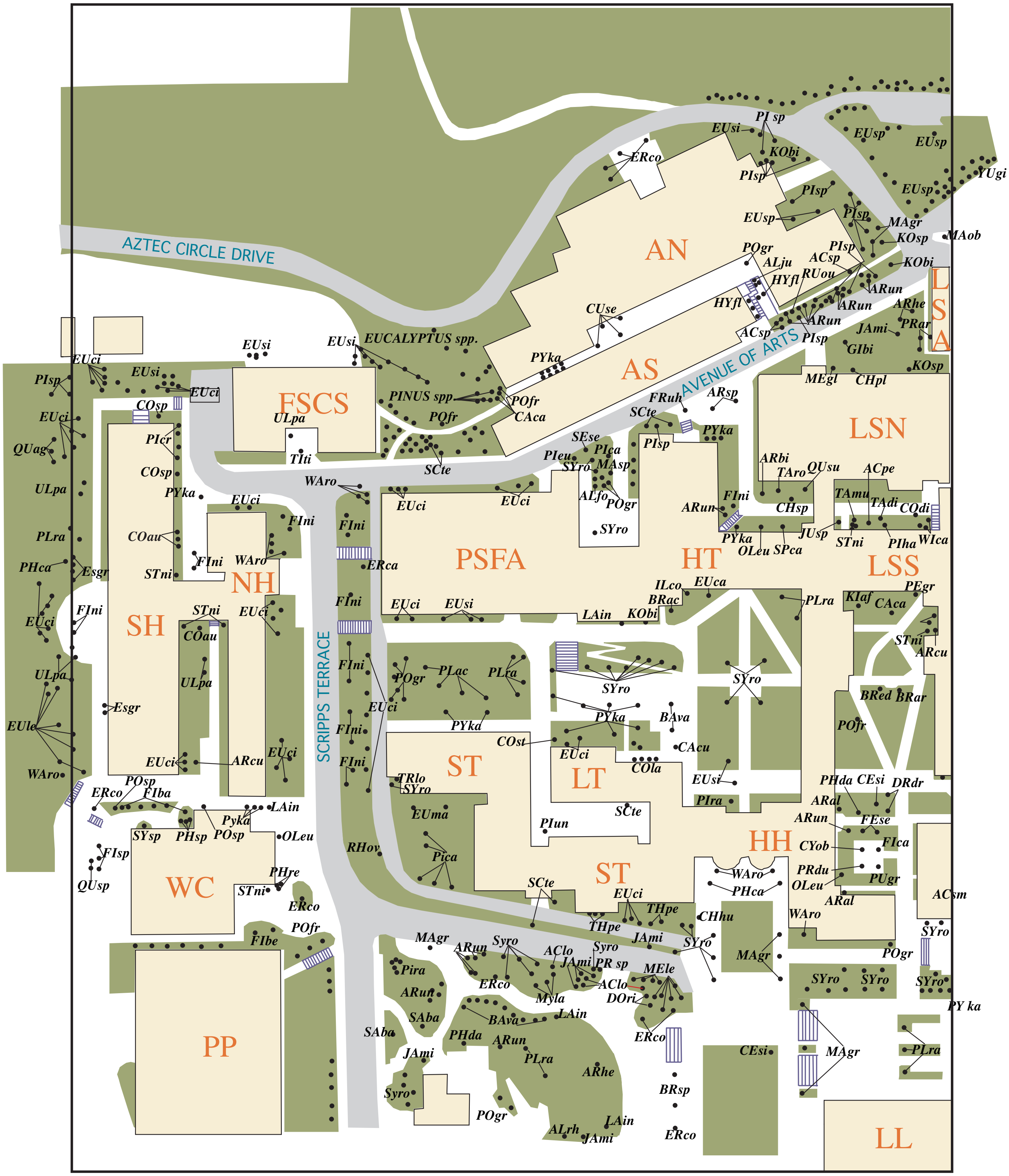
Abbr.	Scientific name [Synonyms]	Common name	Family	Native range
ACja	*Acer japonicum*	Japanese Maple	Aceraceae	Japan
AClo	*Acacia longifolia*	Sydney Golden Wattle	Fabaceae	e. Australia
ACpe	*Acacia pendula*	Weeping Acacia	Fabaceae	e. Australia
ACsm	*Acmena smithii*	Lilly-Pilly	Myrtaceae	Australia
ACsp	*Acacia* sp.		Fabaceae	
AGfl	*Agonis flexuosa*	Peppermint Tree	Myrtaceae	w. Australia
AGro	*Agathis robusta*	Queensland Kauri	Araucariaceae	n. e. Australia
ALar	*Alöe arborescens*	Candelabra A., Torch Pl.	Liliaceae	South Africa
ALfo	*Aleurites fordii*	Tung Oil Tree	Euphorbiaceae	central Asia
ALju	*Albizia julibrissin*	Mimosa Tree, Silk Tree	Fabaceae	Iran to Japan
ALrh	*Alnus rhombifolia*	White Alder	Betulaceae	w. North America
ARal	*Archontophoenix alexandrae*	Alexandra Palm, King P.	Arecaceae	n. e. Australia
ARar	*Araucaria araucana*	Monkey Puzzle	Araucariaceae	Chile
ARbi	*Araucaria bidwillii*	Bunya-Bunya	Araucariaceae	n. e. Australia
ARcun	*Araucaria cunninghamii*	Hoop-Pine	Araucariaceae	e. Australia
ARcu	*Archontophoenix cunninghamiana*	King Palm	Arecaceae	e. Australia
ARhe	*Araucaria heterophylla*	Norfolk Island-Pine	Araucariaceae	Norfolk I., Australia
ARun	*Arbutus unedo*	Strawberry-Tree	Ericaceae	s. Europe, Ireland
BAbl	*Bauhinia blakeana*	Hong Kong Orchid Tree	Fabaceae	Canton, China
BAva	*Bauhinia variegata*	Purple Orchid Tree	Fabaceae	India, China
BRac	*Brachychiton acerifolius*	Flame Tree	Sterculiaceae	e. Australia
BRar	*Brahea armata*	Mexican Blue Palm	Arecaceae	Baja Calif., Mexico
BRed	*Brahea edulis*	Guadelupe Island Palm	Arecaceae	Baja Calif., Mexico
BRdi	*Brachychiton discolor*	Scrub Bottle Tree	Sterculiaceae	cent.-n., e. Australia
BUca	*Butia capitata*	Pindo Palm, Jelly Palm	Arecaceae	Brazil, Urug., Argent.
CAca	*Carpephyllum cafrum*	S. African Plum	Sapindaceae	South Africa
CAci	*Callistemon citrinus*	Bottlebrush	Myrtaceae	s. e. Australia
CAcu	*Casuarina cunninghamiana*	River She-Oak	Casuarinaceae	e. Australia
CAmi	*Caryota mitis*	Fishtail Palm	Arecaceae	Myanmar-Java, Phil.
CAsp	*Caesalpinia spinosa*	Tara	Fabaceae	w. South America
CAvi	*Callistemon viminalis*	Weeping Bottlebrush	Myrtaceae	Australia: N.S.W.
CEde	*Cedrus deodara*	Deodar Cedar	Pinaceae	Himalayas
CEli	*Cedrus libani*	Cedar of Lebanon	Pinaceae	Asia Minor
CEsi	*Ceratonia siliqua*	Carob, St. John's Bread	Fabaceae	e. Mediterranean
CHhu	*Chamaerops humilis*	Mediterranean Fan Palm	Arecaceae	Mediterranean
CHpl	*Chiranthodendron pentadactylon*	Monkey Hand Tree	Malvaceae [Bombac.]	s. Mexico, Guatemala
CHsp	*Chorisia speciosa*	Floss-Silk Tree	Malvaceae [Bombac.]	Brazil, Argentina
CIca	*Cinnamomum camphora*	Camphor Tree	Lauraceae	China, Japan
COau	*Cordyline australis*	Palm-Lily	Agavaceae	New Zealand
COdi	*Cordia dichotoma*	Cordia	Boraginaceae	
COla	*Cocculus laurifolius*	Laurel-Leaf Snailseed	Menispermaceae	Himalayas
COlac	*Cotoneaster lacteus*	Cotoneaster	Rosaceae	w. China
COsp	*Cotoneaster* sp.	Cotoneaster	Rosaceae	
COst	*Cordyline stricta*	Australian Dracaena	Agavaceae	subtrop. Australia
CRag	*Crotolaria agatiflora*	Bird's Beak	Fabaceae	
CUan	*Cupaniopsis anacardioides*	Carrot Wood Tree	Sapindaceae	Australia

CUgu	*Cupressus guadalupensis forbesii*	Tecate Cypress	Cupressaceae	s. California
CUla	*Cunninghamia lanceolata*	China Fir	Taxodiaceae	China
CUma	*Cupressus macrocarpa*	Monterey Cypress	Cupressaceae	Monterey Co., CA.
CUse	*Cupressus sempervirens*	Italian Cypress	Cupressaceae	s. Europe, w. Asia
***CU*sp**	*Cupressus* sp.	Cypress	Cupressaceae	
CYob	*Cydonia oblonga*	Quince	Rosaceae	Mediterranean region
DOvi	*Dodonaea viscosa 'purpurea'*	Hopseed	Sapindaceae	Ariz,S.Am,OW trop.
DRdr	*Dracena draco*	Dragon Tree	Agavaceae	Canary Islands
ERca	*Erythrina caffra*	Coral Tree	Fabaceae	E. S. Africa
ERco	*Erythrina coralloides*	Naked Coral Tree	Fabaceae	Warm temp.&tropics
ERja	*Eriobotrya japonica*	Loquat	Rosaceae	China
ESex	*Escallonia* x*exoniensis*	Escallonia	Saxifragaceae	Cultivar
ESgr	*Escallonia grahamiana*[*E. illinita*]	Escallonia	Saxifragaceae	Chile
EUca	*Eucalyptus camaldulensis*	Red River Gum	Myrtaceae	Australia
EUci	*Eucalyptus citriodora*	Lemon Scented Gum	Myrtaceae	Queensland, Austral.
EUcl	*Eucalyptus cladocalyx*	Gum	Myrtaceae	Australia
EUco	*Eucalyptus cornuta*	Gum	Myrtaceae	Australia
EUfi	*Eucalyptus ficifolia*	Red Flowering Gum	Myrtaceae	West Australia
EUgl	*Eucalyptus globulus*	S. Blue Gum	Myrtaceae	Australia: NSW,W.A.
EUle	*Eucalyptus leucoxylon*	White Ironbark	Myrtaceae	Australia
EUma	*Eucalyptus maculata*	Spotted Gum	Myrtaceae	Australia
EUpo	*Eucalyptus polyanthemos*	Gum	Myrtaceae	Australia
EUpu	*Euphorbia pulcherrima*	Poinsettia	Euphorbiaceae	Mexico
EUri	*Eucalyptus risdonii* [*Angophora r.*]	Gum	Myrtaceae	Australia
EUsi	*Eucalyptus sideroxylon*	Red Ironbark	Myrtaceae	Australia
***EU*sp**	*Eucalyptus* sp.		Myrtaceae	Australia
EUti	*Euphorbia tirucalli*	Milkbush	Euphorbiaceae	Malabar, India
EUto	*Eucalyptus torquata*	Gum	Myrtaceae	Australia
EUvi	*Eucalyptus viminalis*	Manna Gum	Myrtaceae	Southern Australia
FEse	*Feijoa sellowiana*	Pineapple-Guava	Myrtaceae	S. South America
FIbe	*Ficus benjamina*	Weeping Fig	Moraceae	India
FIca	*Ficus carica*	Edible Fig	Moraceae	Mediterranean region
FIel	*Ficus elastica*	Rubber Tree	Moraceae	Nepal,Assam,Myan.
FIni	*Ficus nitida* [*F. microcarpa* v. *n.*]	Indian Laurel Fig	Moraceae	India
FIru	*Ficus rubiginosa*	Rusty Fig	Moraceae	Australia
***FI*sp**	*Ficus* sp.	Fig	Moraceae	
***FR*sp**	*Fraxinus* sp.	Ash	Oleaceae	
FRuh	*Fraxinus uhdei*	Shamel Ash	Oleaceae	Mexico
GIbi	*Ginkgo biloba*	Maidenhair Tree	Ginkgoaceae	E. China
HAca	*Harpephyllum caffrum*	Kaffir Plum	Anacardiaceae	S. Africa
HEar	*Heteromeles arbutifolia*	Toyon	Rosaceae	
HOfo	*Howea forsteriana*	Thatch Palm	Arecaceae	Lord Howe I. Austr.
HYfl	*Hymenosporum flavum*	Sweetshade	Pittosporaceae	Australia
ILco	*Ilex cornuta*	Chinese or Horned Holly	Aquifoliaceae	China
JAmi	*Jacaranda mimosifolia*	Jacaranda	Bignoniaceae	N. W. Argentina
***JU*sp**	*Juniperus* sp.	Juniper	Cupressaceae	
KIaf	*Kigelia africana* [*K. pinnata*]	Sausage Tree	Bignioniaceae	Africa
KObi	*Koelreuteria bipinnata*	Chinese Lantern Tree	Sapindaceae	China, Japan
KOel	*Koelreuteria elegans*	Chinese Lantern Tree	Sapindaceae	China, Japan

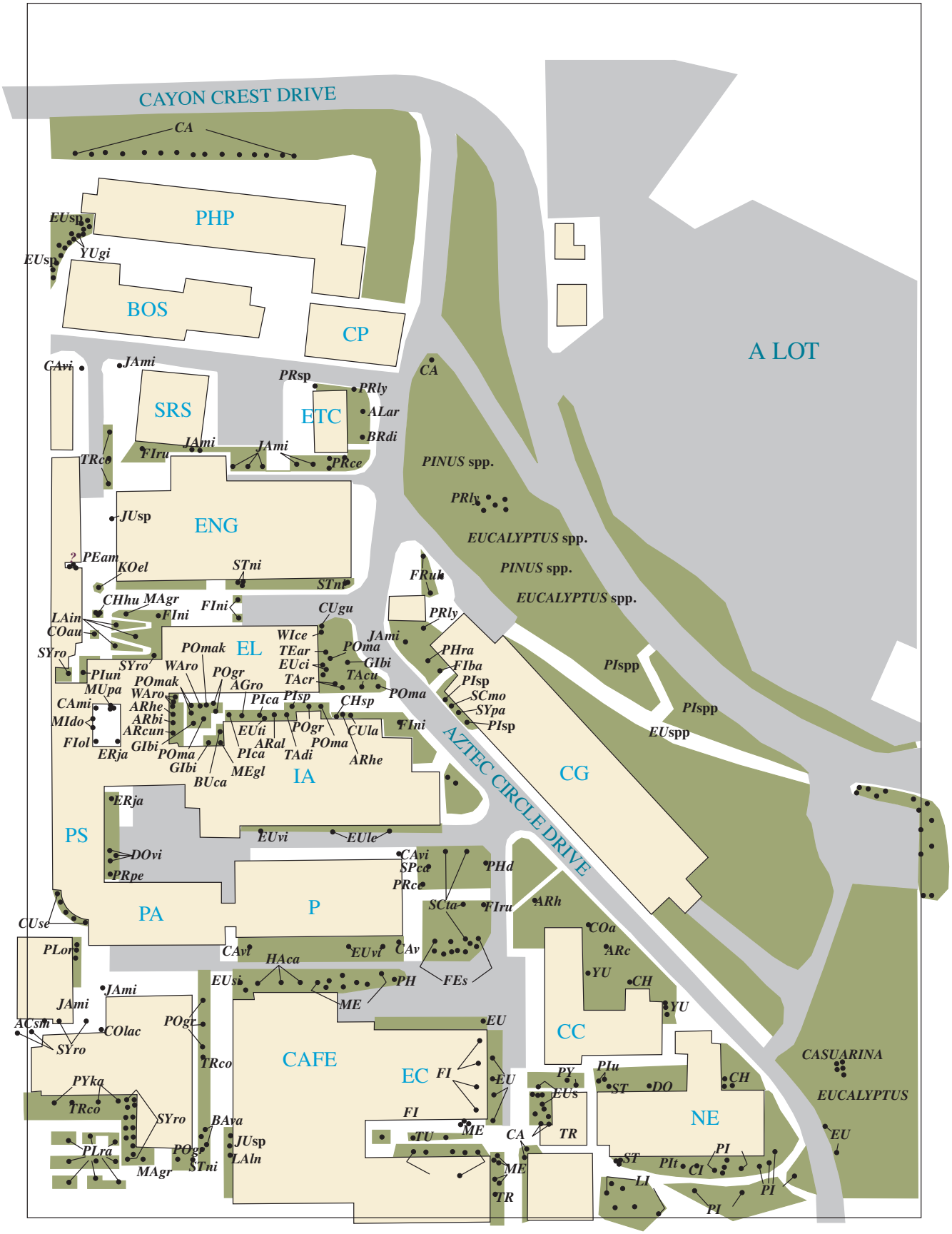
***KO*sp**	*Koelreuteria* sp.		Sapindaceae	
LAin	*Lagerstroemia indica*	Crape-Myrtle	Lythraceae	China
LEsc	*Leptospermum scoparium*	Manuka Tea Tree	Myrtaceae	N. Zealand; Austral.
LIst	*Liquidambar styraciflua*	Sweet Gum	Hamamelidaceae	SE US, Mexico
MAgr	*Magnolia grandiflora*	Southern Magnolia	Magnoliaceae	NC. to FL, TX
MAla	*Malosma laurina*	Laurel Sumac	Anacardiaceae	S. Calif. to Baja
MAob	*Markhamia obtusifolia*	Markhamia	Bignoniaceae	Trop. Africa
***MA*sp**	*Markhamia* sp.	Markhamia	Bignoniaceae	
MEex	*Metrosideros excelsus*	N. Zeal. Christmas Tree	Myrtaceae	New Zealand
MEgl	*Metasequoia glyptostroboides*	Dawn Redwood	Taxodiaceae	China
MEne	*Melaleuca nesophila*	Western Tea Myrtle	Myrtaceae	Australia
MEqu	*Melaleuca quinquenervia*	Cajeput Tree	Myrtaceae	Australia
MIdo	*Michelia doltsopa*		Magnoliaceae	Asia
MUpa	*Musa paradisiaca*	Banana	Musaceae	India
MYla	*Myoporum laetum*	Guitarwood	Myoporaceae	New Zealand
OLeu	*Olea europaea*	Olive	Oleaceae	Mediterranean region
PEam	*Persea americana*	Avocado	Lauraceae	Trop. Amer.
PHca	*Phoenix canariensis*	Canary Island Date Palm	Arecaceae	Canary Islands
PHda	*Phoenix dactylifera*	Date Palm	Arecaceae	W. Asia & N. Africa
PHre	*Phoenix reclinata*	Senegal Date Palm	Arecaceae	Tropical Africa
PHro	*Phoenix roebelinii*	Dwarf Date Palm	Arecaceae	Laos
PIca	*Pinus canariensis*	Canary Island Pine	Pinaceae	Canary Islands
PIcr	*Pittosporum crassifolium*	Karo	Pittosporaceae	New Zealand
PIeu	*Pittosporum eugenioides*		Pittosporaceae	Australia
PIha	*Pinus halepensis*	Aleppo Pine	Pinaceae	Mediterranean region
PIpi	*Pinus pinea*	Italian Stone Pine	Pinaceae	Mediterranean region
PIra	*Pinus radiata*	Monterey Pine	Pinaceae	S. California
***PI*sp**	*Pinus* sp.	Pine	Pinaceae	
PIte	*Pittosporum tenuifolium*		Pittosporaceae	
PIth	*Pinus thunbergii*	Japanese Black Pine	Pinaceae	Japan
PIto	*Pinus torreyana*	Torrey Pine	Pinaceae	S. California
PIun	*Pittosporum undulatum*	Victorian Box Tree	Pittosporaceae	Australia
PIvi	*Pittosporum viridiflorum*	Cape Pittosporum	Pittosporaceae	S. Africa
PLac	*Platanus acerifolia*	London Plane Tree	Platanaceae	North America
PLor	*Platycladus orientalis [Thuja o.]*	Oriental Arbor Vitae	Cupressaceae	N. China; Korea
PLra	*Platanus racemosa*	Western Sycamore	Platanaceae	Calif.; Baja Calif.
***PL*sp**	*Platanus* sp.	Sycamore	Platanaceae	
POfr	*Populus fremontii*	Fremont Cottonwood	Salicaceae	California; Arizona
POgr	*Podocarpus gracilior*	East African Fern Pine	Podocarpaceae	Tropical Africa
POma	*Podocarpus macrophyllus*	Japanese Yew Pine	Podocarpaceae	Japan
POmak	*Podocarpus macrophyllus* v. *maki*	Yew Pine	Podocarpaceae	Japan
PRar	*Prunus armenica*	Common Apricot	Rosaceae	China
PRce	*Prunus cerasifera atropurpurea*	Purple-Leaf Plum	Rosaceae	Cen. Asia to Balkans
PRdu	*Prunus dulcis*	Almond	Rosaceae	Mediterranean region
PRly	*Prunus lyonii*	Catalina Cherry	Rosaceae	Islands off S. Calif.
PRpe	*Prunus persica*	Peach	Rosaceae	Asia
***PR*sp**	*Prunus* sp.	Cherry	Rosaceae	
PUgr	*Punica granatum*	Pomegrante	Punicaceae	Mediterranean region
PYka	*Pyrus kawakami*	Evergreen Pear	Rosaceae	Taiwan

***QU*sp**	*Quercus* sp.	Oak	Fagaceae	
QUsu	*Quercus suber*	Cork Oak	Fagaceae	S. Europe, N. Africa
RHov	*Rhus ovata*	Sugarbush	Anacardiaceae	S. & Baja CA.,Ariz.
SAba	*Salix babylonica*	Weeping Willow	Salicaceae	
***SA*sp**	*Salix* sp.	Willow	Salicaceae	
SCac	*Schefflera actinophylla*	Umbrella Tree	Araliaceae	Queensland, Australia
SCmo	*Schinus molle*	Peruvian Pepper Tree	Anacardiaceae	Andes of Peru
SCte	*Schinus terebinthifolius*	Brazilian Pepper Tree	Anacardiaceae	Brazil
SEse	*Sequoia sempervirens*	Redwood	Taxodiaceae	S. Oregon - cen.CA.
SPca	*Spathodea campanulata*	African Fountain Tree	Bignoniaceae	Tropical Africa
STni	*Strelitzia nicolai*	Giant Bird of Paradise	Strelitziaceae	South Africa
SYja	*Syzygium jambos*	Rose Apple	Myrtaceae	
SYpa	*Syzygium paniculataum*	Eugenia, Brush Cherry	Myrtaceae	Australia
SYro	*Syagrus romanzoffiana*	Queen Palm	Arecaceae	Cen. Brazil - Argent.
***SY*sp**	*Syzygium* sp.		Myrtaceae	
TAap	*Tamarix aphylla*	Tamarisk	Tamaricaceae	
TAcr	*Taiwania cryptomeroides*		Taxodiaceae	Taiwan, Asia
TAcu	*Taxus cuspidata*	Japanese Yew	Taxaceae	Japan,Korea,Manch.
TAdi	*Taxodium distichum*	Bald Cypress	Taxodiaceae	Del. to Fla., La.
TAmu	*Taxodium mucronatum*	Montezuma Cypress	Taxodiaceae	Cen. Mex. to Pac.
TAro	*Tabebuia rosea*	Roble Blanco	Bignoniaceae	
TAsp	*Tabebuia sp.*	Trumpet Tree	Bigoniaceae	Trop. America
TEar	*Tetraclinis articulata*	Arar Tree	Cupressaceae	Malta, Spain, n. Afr.
THpe	*Thevetia peruviana*	Yellow Oleander	Apocynaceae	Tropical America
TIti	*Tipuana tipu*	Tipu Tree	Fabaceae	Southern Brazil
TRco	*Tristania conferta*	Brisbane Box	Myrtaceae	Australia
TRfo	*Trachycarpus fortunei*	Windmill Palm	Arecaceae	E. Asia
TUca	*Tupidanthus calyptratus*		Araliaceae	Tr. Asia: Ind.-Camb.
ULpa	*Ulmus parvifolia*	Chinese Elm Tree	Ulmaceae	China, Japan
WAro	*Washingtonia robusta*	Mexican Fan Palm	Arecaceae	Mexico: Son.& B.C.
WIca	*Wigandia caracasana*		Hydrophyllaceae	Tropical America
WIce	*Widdringtonia cedarbergensis*	African Cypress	Cupressaceae	S.W. Cape, S. Afr.
XYco	*Xylosma congestum*		Flacourtiaceae	China
YUgl	*Yucca gloriosa*	Spanish Dagger	Agavaceae	U.S.: N. Car. - FL.

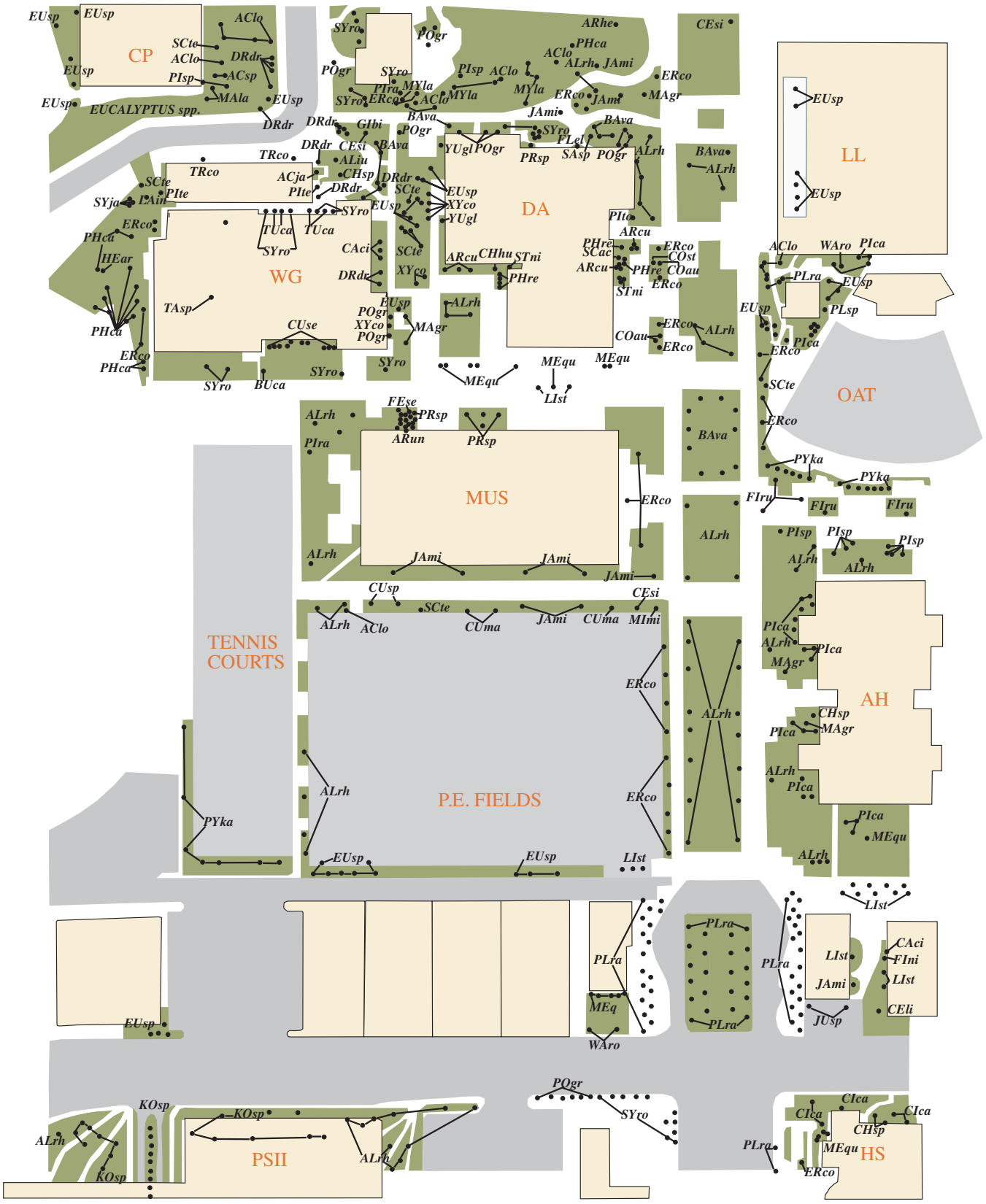
NORTHWEST SDSU CAMPUS



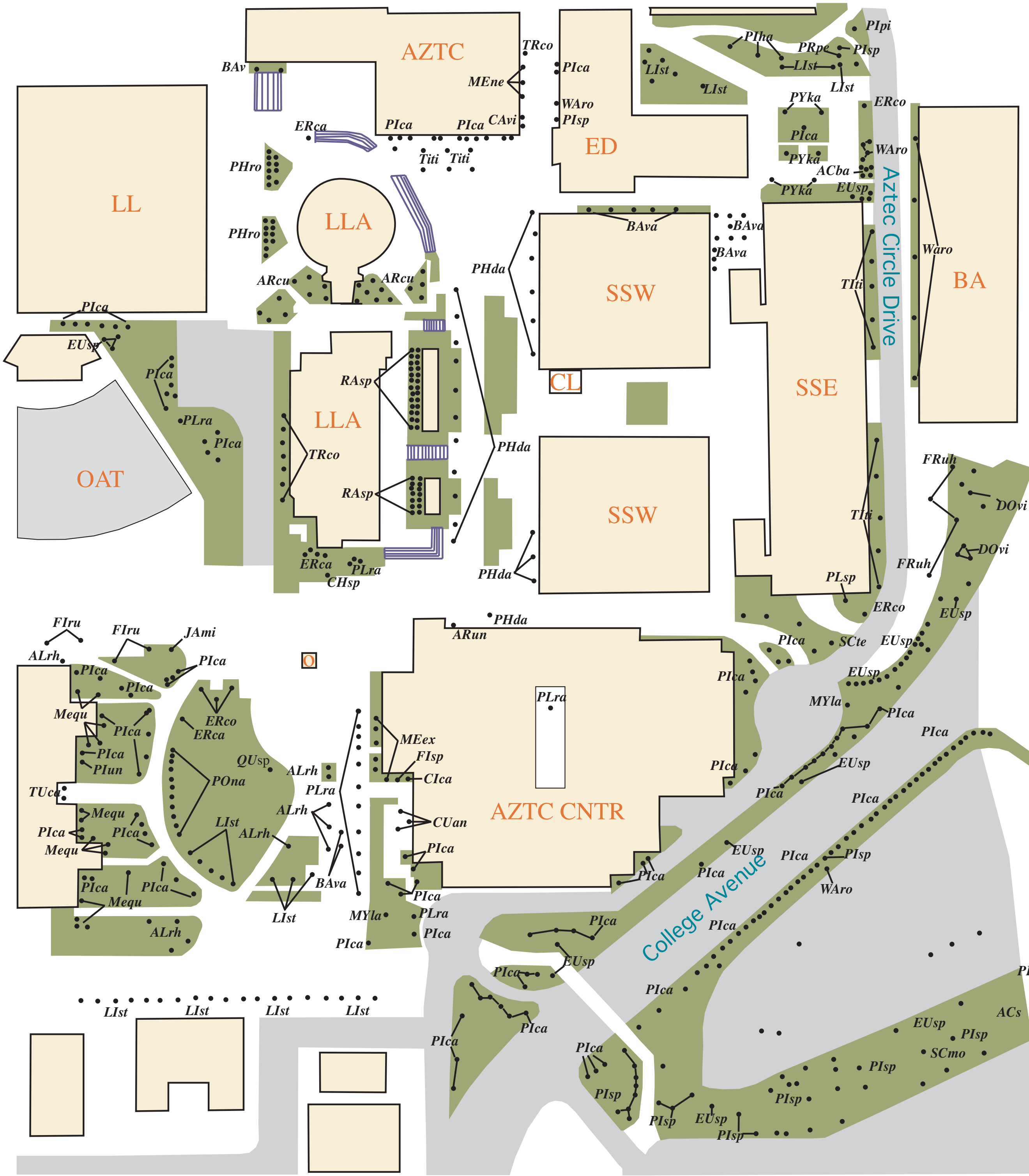
NORTHEAST SDSU CAMPUS



SOUTHWEST SDSU CAMPUS



SOUTHEAST SDSU CAMPUS



CULTIVATED SHRUBS AND HERBS OF SAN DIEGO STATE UNIVERSITY

Acacia longifolia		Fabaceae	Australia
Acacia redolens		Fabaceae	Australia
Agapanthus africanus	Lily-of-the-Nile	Liliaceae	Cape region, S. Afr.
Alocasia macrorhiza		Araceae	
Alyogyne huegelii [*Hibiscus huegelii*]	Blue Hibiscus	Malvaceae	S. & W. Australia
Aspidistra elatior	Cast-Iron Plant	Liliaceae	China
Asplenium daucifolium	Spleenwort	Polypodiaceae	Mauritius,Reunion I.
Beloperone brandegeana	Shrimp Plant	Acanthaceae	Mexico
Brahea edulis	Guadelupe Palm	Arecaceae	Guadelupe Is., Mex.
Caesalpinia		Fabaceae	
Calliandra haematocephala	Powderpuff	Fabaceae	Bolivia
Calodendrum capense	Cape Chestnut	Rutaceae	S. Africa
Camellia sasanqua	Camellia	Theaceae	China, Japan
Carissa grandiflora	Natal Plum	Apocynaceae	Natal, S. Africa
Ceanothus thyrsiflorus	Blue Brush	Rhamnaceae	N. CA.-S. Oregon
Chasmanthe aethiopica		Iridaceae	South Africa
Clivia miniata	Kaffir Lily	Amaryllidaceae	South Africa
Clytostoma callistegioides	Argentine Trumpet Vine	Bignoniaceae	S. Brazil, Argentina
Cordyline terminalis	Ti	Agavaceae	e. Asia
Cotoneaster lacteus		Rosaceae	W. China
Cotoneaster pannosa		Rosaceae	SW China
Crytomium falcatum	House Holly Fern	Polypodiaceae	Jap,China,S.Afr, Poly
Cycas revoluta	Sago Palm	Cycadaceae	Java
Doxantha unguis-cati	Cat's Claw	Bignoniaceae	W. Indies to Argentina
Dracaena fragrans	Corn Plant	Agavaceae	W. Africa: Upper Guinea
Dryopteris erythrosora	Japanese Shield Fern	Polypodiaceae	China,Japan
Duranta repens	Golden Dewdrop	Verbenaceae	W. Indies, Mex.-Brazil
Echium fastuosum	Pride of Madiera	Boraginaceae	Coastal Eur.; Canary I.
Equisetum hyemale		Equisetaceae	
Feijoa sellowiana	Pineapple Guava	Myrtaceae	South America
Furcraea sp.		Agavaceae	Brazil
Grewia occidentalis	Lavender Star Flower	Tiliaceae	S. Africa
Harpullia pendula	Tulipwood	Sapindaceae	E. Africa
Hedychium coronarium	Butterfly-Lily	Zingiberaceae	India, Malaysia
Hibbertia scandens	Guinea Gold Vine	Dilleniaceae	Australia
Hibiscus rosa-sinensis	China-Rose	Malvaceae	China
Iva hayesiana		Asteraceae	San Diego Co.; Baja Ca.
Lantana camara	Lantana	Verbenaceae	Trop. Amer. to TX, GA
Lantana montevidensis	Trailing Lantana	Verbenaceae	S. Amer.
Lavatera assurgentiflora	Malva Rose	Malvaceae	Santa Barbara Islands
Lonicera japonica var. *halliana*	Hall's Honeysuckle	Caprifoliaceae	E. Asia
Lonicera hildebrandiana	Giant Honeysuckle	Caprifoliaceae	Myanmar (Burma)
Mahonia aquifolium	Holly Mahonia, Barberry	Berberidaceae	Brit. Col.-Idaho;Oregon
Myrtus communis 'Compacta'	Myrtle	Myrtaceae	W. Asia, Mediter.
Nandina domestica	Heavenly Bamboo	Beriberidaceae	China, Japan
Nemesia fruticans		Plantaginaceae	
Nerium oleander	Oleander	Apocynaceae	Mediterranean to Japan.

Nephrolepis cordifolia	Sword Fern	Polypodiaceae	Tropics and subtropics
Phaedranthus buccinatorius	Blood Trumpet Vine	Bignoniaceae	Mexico
Philodendron selloum		Araceae	S. Brazil
Photinia fraseri		Rosaceae	S. & E. Asia
Phyllostachys aurea	Golden Bamboo	Poaceae	China, Japan
Pittosporum rhombifolium	Queensland Pittosporum	Pittosporaceae	Australia
Pittosporum tobira	Mock Orange	Pittosporaceae	Australia
Pittosporum tobira var. *variegatum*	Japanese Pittosporum	Pittosporaceae	China; Japan
Prunus cerasifera		Pinaceae	
Punica granatum	Pomegranate	Punicaceae	S. Asia
Pyracantha sp.	Firethorn	Rosaceae	SE Europe, Asia
Raphiolepis indica	Indian Hawthorn	Rosaceae	S. China
Raphiolepis umbellata f. *ovata*	Yeddo Hawthorn	Rosaceae	Japan, Korea
Saccharum officinarum	Sugar Cane	Poaceae	prob. Asia or E. Indies
Solandra maxima	Cup o' Gold	Solanaceae	Mexico
Sphaeroptis cooperi	Australian Tree Fern	Cyatheaceae	Australia
Strelitzia reginae	Bird of Paradise	Strelitziaceae	South Africa
Syzygium paniculatum	Australian Brush Cherry	Myrtaceae	Australia
Tabebuia rosea	Rosy Trumpet Vine	Bignoniaceae	Mex. - Venez., Ecuador
Tecomaria capensis	Cape Honeysuckle	Bignoniaceae	South Africa
Trachelospermum jasminoides	Star Jasmine	Apocynaceae	China
Tupidanthus calyptratus		Araliaceae	India to Cambodia
Viburnum tinus	Lauretinus	Caprifoliaceae	Mediterranean region
Wisteria sinensis		Fabaceae	China

GENERAL REFERENCES ON CULTIVATED PLANTS:

Bailey, L. H. 1951. Manual of Cultivated Plants. Macmillan Publishing Co., Inc., New York.

Bailey, L. H. 1976. Hortus Third. Macmillan Publishing Co., Inc., New York.

Graf, A. B. 1976. Exotica, Series 3. Pictorial cyclopedia of exotic plants from tropical and near-tropical regions. 9th ed. Roehrs Company, Inc., E. Rutherford, New Jersey, U. S. A. [NOTE: A more updated version is available in the science reference section of the library.]

Graf, A. B. 1986. Tropica. Color Cyclopedia of Exotic Plants and Trees. 3rd Edition. Roehrs Company, Inc., E. Rutherford, New Jersey, U. S. A.

Ritter, M. 2011. A Californian's Guide to the Trees Among Us. Heyday, Berkeley, California.