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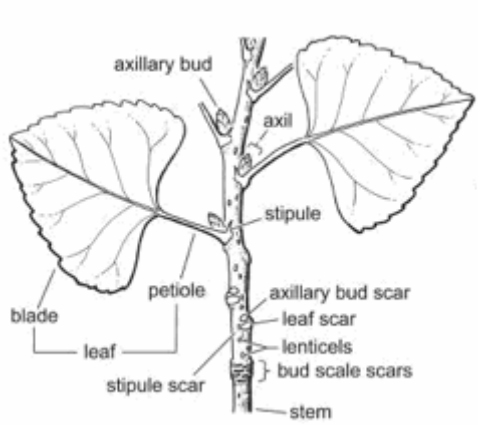
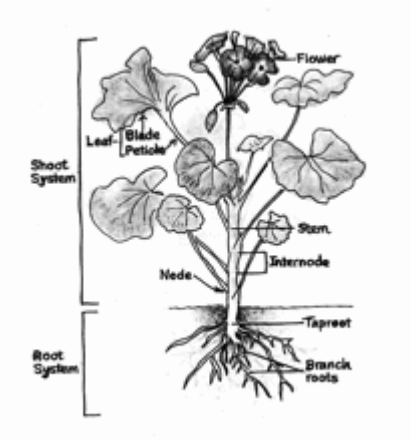
Part 1. Vegetative and Inflorescence Morphology

Station 1. Whole plant structure





Differences between roots, stems, and leaves:

Often, the most important differences between roots, stems, and leaves are those that cannot be seen by the naked eye. They are anatomical, developmental, and functional differences. When faced with an unfamiliar plant, it is often difficult to decide what is root, what is stem, and what is leaf.

Stems are the local "mode of transport" in plants. Being sessile organisms, plants cannot get up and move around. Plants explore the atmosphere with their stems and or leaves. Stems provide structural support for the leaves, and in the case of trees and vines, stems can travel a good distance from the original starting point of a plant. Within stems are tissues that transport water and nutrient throughout the plant. The places along a stem where leaves emerge are called **nodes**. The regions between nodes are called **internodes**. Unlike many roots, stems are usually colored.

Leaves differ from stems in function. They are usually the main location of photosynthesis, the process where sunlight is converted to carbohydrates via the molecule chlorophyll (the green pigment in plants). However, there are colorless underground leaves (on rhizomes) or leaves that are modified into spines that do not photosynthesize. The small leaves that occur in the inflorescence (the flowering parts) are often called **bracts**.

Often, in the angle between the leaf base and the stem (the **leaf axil**) there is a little protuberance called a **bud**. The bud consists of very young shoot tissue that may become a branch or an inflorescence (flowering branch). The presence of buds is a good way to determine where a leaf begins. The small, brownish, overlapping structures that cover the over-wintering buds of woody plants are modified leaves called **bud scales**. Note: unopened flowers are called flower buds, but they are not covered with bud scales.

Roots absorb water, minerals, and nutrients from the soil, and they anchor the plant to the ground or other substrate. They often lack coloration, but sometimes they may be highly colored (carrots for example). They lack leaves, nodes, and internodes. Roots are often found at the very bottom of the plant, below the soil level. However, they can also emerge from stem tissue - often at nodes (think of the ivy plants that you see around town - their roots anchor their climbing stems to the walls of fences or houses).

Examine the mustard plant and woody branch at Station 1. Identify the following plant regions or parts of the mustard plant and woody branch:
a) stem b) root c) leaf (or leaf scar - where the leaf was attached) d) node e) internode f) leaf axil g) axillary bud (this may be hard to see on the mustard plant unless it is beginning to expand into a branch or inflorescence).

Station 2. Stem modifications

Stems can be modified in many ways. The following are only a few examples:

Wood: The most common change that occurs in stems is secondary growth (as opposed to primary elongation growth), which is the thickening of stems by the addition of vascular tissue - commonly called "wood". Plants that live one year may become "woody" towards the end of the growing season, especially towards the base of the plant. Trees and shrubs that live for many years usually have woody stems.

Stem succulents: Stem succulents, such as cacti, are stems that are modified for water storage. Cacti are desert plants that store water in their stems during the rainy season, so that they have a water supply for the dry season. The spines on cacti are modified leaves.

Rosettes: Sometimes a stem has very short internodes with many leaves clustered together; these stem regions are called "rosettes". Many winter annuals form a rosette at ground-level in the fall and then continue to grow in the spring. Some perennial herbs put out a rosette of basal leaves each spring and then an inflorescence. Dandelions are a good example of a perennial herb that is a rosette plant. Agaves are perennials with rosettes that last for many years.

Stolons are above-ground lateral stems that leap-frog from one rooted node to the next. Stoloniferous plants are generally perennial herbs. Strawberries are the classic example of a stoloniferous herb. We have a false strawberry plant for you to examine. Note that the stolon has nodes and internodes. At each node, there is one leaf, and in the axil of the leaf there is a shoot that becomes an upright rosette stem, bearing many leaves clustered together. These little rosettes can become independent strawberry plants. From the leaf axils of the rosettes arise new stolons.

Underground Stems:

The following are examples of underground stems that are typical of perennial herbs. Perennial herbs die back to underground structures during part of the year.

Rhizomes are usually horizontal stems that travel beneath the ground. They give rise to shoots at their nodes that emerge above the ground. Ferns and irises have slow-growing rhizomes with very short internodes. Other rhizomes grow more quickly and have longer internodes. Some rhizomes bear colorless leaves underground. Rhizomes can act as

over-wintering storage stems.

Corms are very short, upright, underground storage stems. A good example is the underground stem of blue dicks (*Dichelostemma capitatum*).

Tubers are enlarged underground storage stems such as potatoes. How do you know that this is a stem and not a root? (hint: what are the potato eyes?)

Bulbs are very short, upright, underground stems with very short nodes bearing fleshy storage leaves or buds. Typical bulbs are onions and garlic. In an onion the leaves act as storage organs, while in garlic, it is the axillary buds that have become fleshy storage organs. Examine the cut onion. Find the short stem at the base of the bulb, and note that most of the bulb consists of the fleshy leaves.

Station 3: Types of roots

The first root that develops on a seedling is called the primary root. In dicotyledons and gymnosperms this root develops into a **tap root** that grows downward and gives rise to branch roots (lateral roots); the tap root and its laterals are collectively called the **tap root system**. In monocotyledons (grasses - for example), the primary root is usually short-lived, and the roots that subsequently develop and persist arise from the lower part of the plant stem. Stem-borne roots (also called adventitious roots) give rise to a **fibrous root system**. Stem-borne roots are also common in rhizomatous and stoloniferous plants, and they are present in some climbing plants, such as ivy and orchids. Some perennial dicotyledons have tap roots that are modified into **storage tap roots** such as those found in carrots. In the case of sweet potato, fibrous roots are modified into storage roots called "**root tubers**".

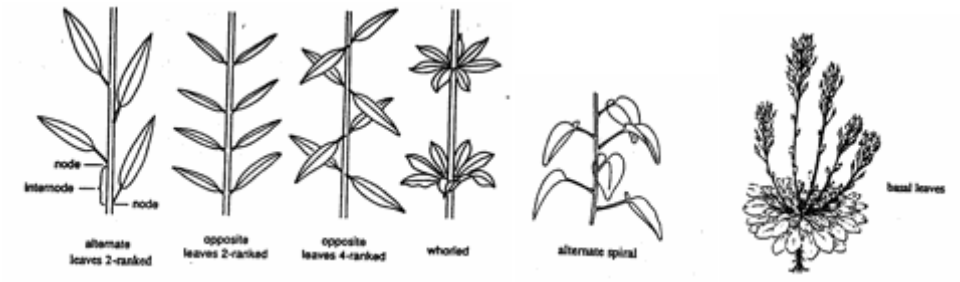
Examine the roots at Station 3. Using the drawings and descriptions above, decide what root types are present.

Station 4. Life forms

Life form terms:
Annual - a plant that lives only one year
Biennial - a plant that lives for two years
Perennial - a plant that lives for three or more years (sometimes people use this loosely for plants that live for two or more years). Note*** In the Jepson Manual, the term "perennial" refers to perennial herbs only.
Tree - a perennial woody plant of considerable stature at maturity with one or a few main trunks. A rather loosely used but fairly well understood concept.
Shrub - a woody perennial plant, smaller than a tree, usually with several basal stems.
Herb - a plant whose above-ground growth is mostly herbaceous (non-woody) and therefore dies back at the end of the growing season. **Annual herbs** last only one season, with the whole plant dying. **Perennial herbs** have persistent stems (or roots) either underground (for example rhizomes, bulbs, or corms) or just at the soil surface (for example stolons or short rosette stems).

Examine the pictures of plants on the table at Station 4 that illustrate the above life form terms.

Station 5. Leaf arrangement (phyllotaxis)



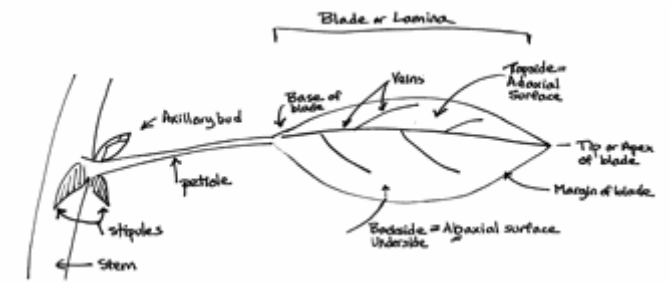
Leaves may emerge at nodes singly, in pairs, or in whorls.

If they arise singly, they are called **alternate leaves**.
If they arise in pairs, they are called **opposite leaves.**
If they arise in whorls of 3 or more, the are called **whorled leaves.**
If leaves are closely arranged at the base of an upright stem they are called **basal.**
If the leaves emerge in 2 lines along the stem, they are called **2-ranked**.
If the leaves emerge in 4 lines along the stem, they are called **4-ranked**.

The most common way for alternate leaves to emerge is in an **alternate spiral**, although many grasses have leaves that are **alternate and 2-ranked**.

Examine the material available, and decide if the leaf arrangements are alternate, opposite, whorled, or basal. Note: Sometimes in new stems, the leaves emerge very close together (the internodes on new branches are short). In these situations, it is often difficult to determine the phyllotaxis by examining the leafy stems, and one needs to look at the rest of the plant. Look at a leafless stem - how could you determine the original phyllotaxis by looking at the bud arrangement and branching pattern?

Station 6. Leaf parts



The basic parts of a leaf are the **base**, the **petiole** (stalk), and the **lamina** (blade). The leaf base or petiole base sometimes has small leafy structures attached to it that are called **stipules**. When leaves lack a petiole, they are called **sessile**.

Examine the leaves in front of you and identify the basic parts of each leaf; also, decide which leaves are petiolate, which are sessile, which are stipulate, and which are exstipulate (without stipules). Note: Most of the fresh leaves we have provided at this station do not have good examples of stipules. The terminal bud of *Magnolia* is actually covered by a stipule (an outgrowth of the leaf base), rather than by overlapping bud scales. The *Ficus* leaves also have small stipules that fall off easily. Look at the herbarium specimens that we have provided to see other examples of stipules. Also, when looking that the compound leaves of *Vicia* and *Trifolium* at Station 9, note the well developed stipules at their petiole bases.

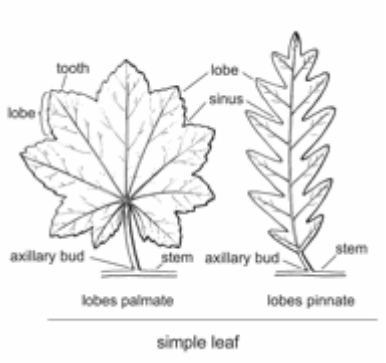
Station 7. Leaf venation

Look carefully at the veins on the leaves in front of you. There are many possible patterns. The minor veins of leaves (the small veins that are difficult to see) can usually be described as either **parallel** or **branching**. Sometimes branching veins rejoin at their tips, and this is known as a **reticulate or netted** pattern.

Sometimes it is useful to speak of only the pattern of the largest leaf veins. Look at the leaves on the table and using the

illustrations below, decide if the major leaf veins are **parallel**, **pinnate**, or **palmate**.

Station 8. Leaf lobing

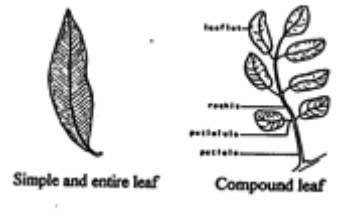


Leaf laminas often become lobed or dissected in distinctive ways (a leaf with an unlobed lamina is called an **entire leaf**). The pattern of lobing usually follows the pattern of the main leaf veins. **If the primary (or main) veins of the lamina are palmately arranged, the main lobes of the lamina will be arranged in a palmate fashion, and the leaf is called palmately lobed. Likewise, if the primary veins of the lamina are pinnate, the main lobes of the lamina will be pinnate, and the leaf is called pinnately lobed.** If the lobing of the leaves is very deep and the segments are small, the leaf blade lobing is sometimes referred to as **dissected**.

Examine the leaves in front of you and decide if the laminas are palmately or pinnately lobed, cleft, parted, divided, or dissected.

Station 9. Compound leaves

Compound versus simple leaves:
Sometimes a leaf lamina is separated into smaller segments that themselves resemble leaves. Leaves of this type are called **compound leaves**, and the small leaf-like segments are called **leaflets**. Leaves that are not divided into segments are called **simple leaves**. **In order to decide if you have a compound leaf or a simple leaf, remember to locate your landmarks - leaf axil, bud, petiole, lamina (which may be divided into segments).**



Types of compound leaves:

Compound leaves may be grouped into two categories similar to those we discussed above: **palmately compound** (where the leaflets are arranged palmately and all attach together at the same point) and **pinnately compound** (where

the leaflets are arranged pinnately along an axis called a **rachis**). If a pinnately compound leaf has a terminal leaflet, it is called **odd-pinnate**, and if it has an lacks a terminal leaflet, it is called **even-pinnate**; these terms are somewhat confusing, because an odd-pinnate leaf may not actually have an odd number of leaflets. Compound leaves may be just once compound or subdivided one or more times (two to three times compound). In the case of pinnately compound leaves, one can say **1-pinnate, 2-pinnate, etc.**

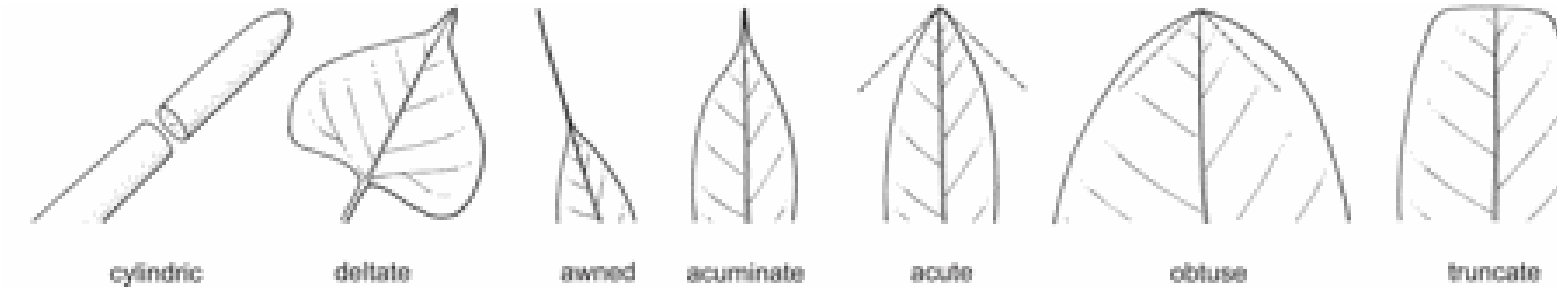
Compound leaves with three leaflets:
In the case of leaves with three leaflets, you will sometimes see the terms **palmately trifoliolate (or ternate)** and **pinnately trifoliolate**. The difference between these two situations is that there is a small rachis in pinnately trifoliolate leaves and no rachis in palmately trifoliolate leaves.

Examine the leaves in front of you and decide if they are pinnately or palmately compound. If pinnately compound, are they 1-pinnate, 2-pinnate or more?

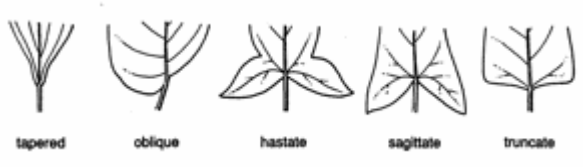
Station 10. Lamina shape, tips, bases, and edges (Fig. 10)

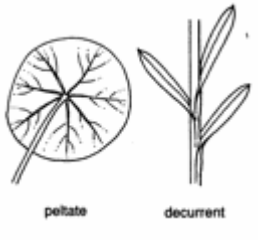
There are many botanical terms for describing lamina shapes, and there are special terms for describing lamina tips and bases, and edges (the **margins**). **Using the terms given here, use botanical terminology to describe the lamina characteristics of four of the leaves on the table.**

Leaf Tips (Apices)

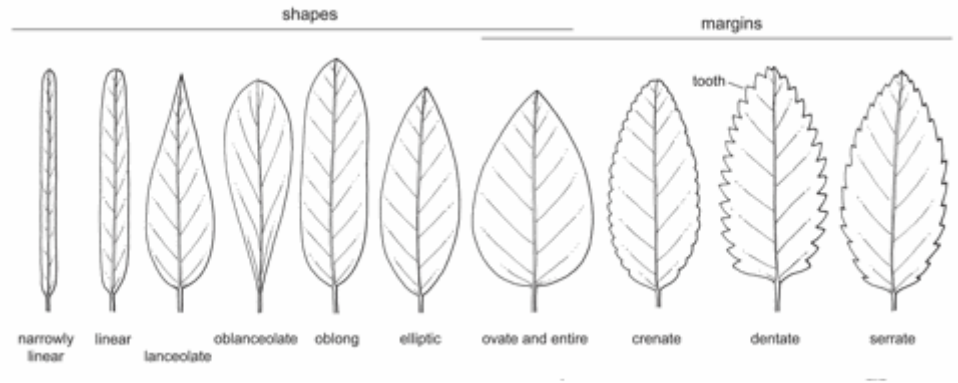


Leaf Bases



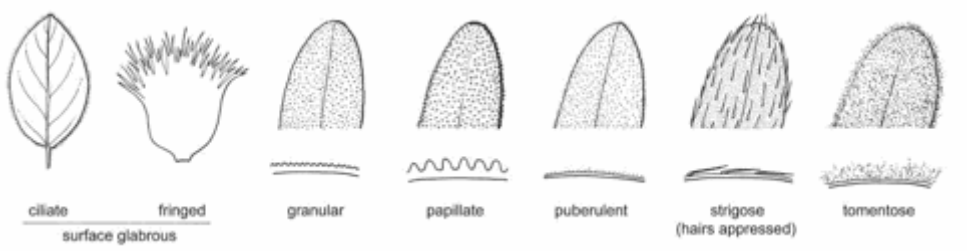


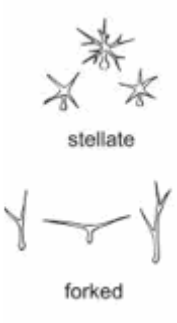
Leaf Shapes and Margins



Station 11: Surface terms

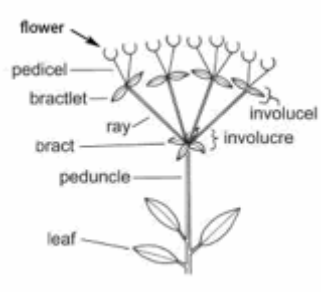
There are many descriptive terms for plant surfaces and hairs (**pubescence**). Plant surfaces without pubescence are called **glabrous**. Most hairs are **"simple"** or unbranched, but there are many descriptive terms for simple hairs, such as **hispid**, **pilose**, **villous**, and **tomentose**. Hairs with branches may be called **branched** or **stellate** (with all the branches emerging from the same point). Hairs that excrete a sticky substance are called **glandular**. **Using the illustrations below, examine the two examples of leaf hairs set up for you under the microscopes, and decide what hair types are present.**





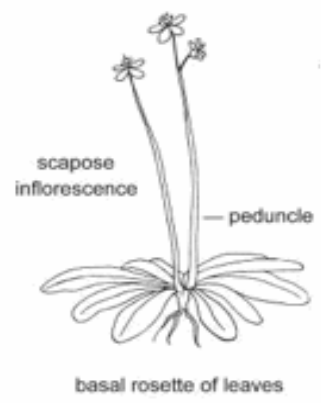
Station 12: Inflorescences

The part of the plant bearing the flowers is called the inflorescence. Inflorescence terminology is murky and inexact, because where an inflorescence begins and ends on a plant is sometimes difficult to determine (you will find this out in this lab). Here we explain and illustrate some of the terminology that is important for keying and identification.



Peduncle - the stalk of an entire inflorescence (ie. the stalk of a solitary flower or leading to a cluster of flowers).

Pedicel - the stalk of a single flower within an inflorescence of more than one flower. If the flowers lack pedicles, they are said to be sessile on the inflorescence axis.

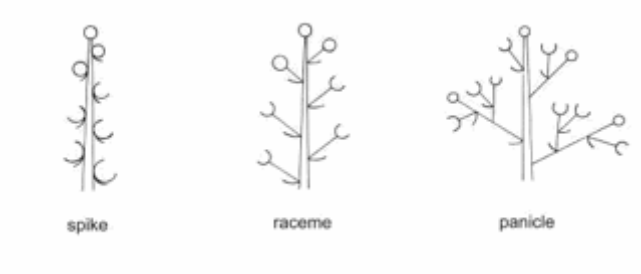


Solitary flower: An inflorescence consisting of one flower, either terminal or axillary.

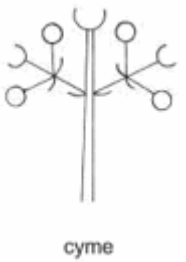
Scape: A peduncle arising from ground-level (often from a rosette of basal leaves) either terminating in a solitary flower (ex. tulip) or a flower cluster (ex. onion, blue dicks). The branching within the flower cluster can be any of the types listed below.

As explained in lecture, inflorescences may be either **indeterminate** or **determinate**. The flowers of **indeterminate** inflorescences are the product of lateral buds formed by a continuing apical meristem of a vertical axis. The apical meristem continues to produce lateral buds until the inflorescence is fully formed and growth stops. When indeterminate inflorescences are examined closely, one sees that the most mature flowers are at the base of the inflorescence or its branches, while the youngest flowers (or buds) are near the terminus of the inflorescence or its branches. The basic indeterminate inflorescence type is the **raceme**.

Raceme: One vertical axis with pedicillate flowers. *Lupinus*.
Spike: One vertical axis with sessile flowers. *Plantago*.
Panicle: A branched raceme, with each branch repeating the raceme development pattern. *Brassica*.



In **determinate** inflorescences, the tip of the apical meristem differentiates into a flower, and the axis can no longer grow vertically. Therefore, continuation of the inflorescence can only occur by branching below that terminal flower. Branching can be two-sided or one-sided, but each branch terminates in a flower. When a determinate inflorescence is examined, one can see that the central flower is the most mature, while lateral flowers are less mature. The basic determinate inflorescence type is the **cyme**.



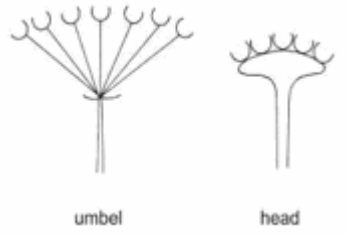
Coiled or one-sided cyme

Cyme: Consisting of one terminal flower (maturing first) subtended by one to two lateral branches, each of which terminates in a flower (and may be subtended by further branching, etc.).

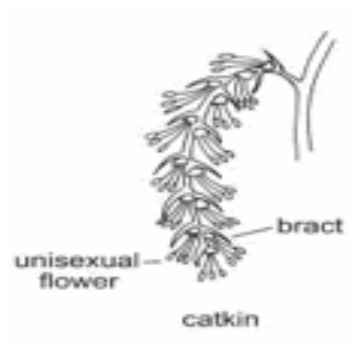
Coiled or one-sided cyme: A cyme with branches emerging on only one side each time the axis terminates in a flower. Young coiled cymes are curled over, like a scorpions tail. With maturation, the cyme uncoils. Typical of many Boraginaceae.

The following inflorescence types may be either determinate or indeterminate:

from a common point. In digitately from one point secondary or tertiary *Hedera*.



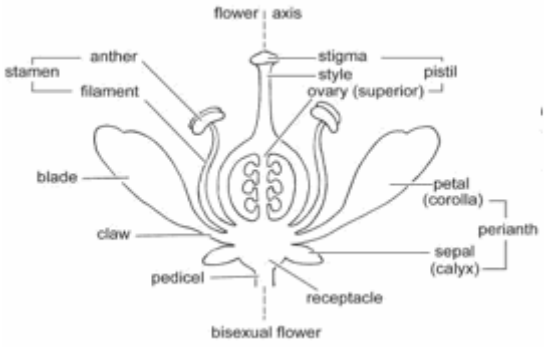
Umbel: An infloresence in which three to may pedicels arise a **simple umbel**, all of the pedicels in the inflorescence emerge like the spokes of an umbrella. A **compound umbel** has umbellate branching within the main umbel. Apiaceae,



Head: Like a simple umbel, but the flowers sessile. *Trifolium*, Asteraceae.

Catkin: A spike of unisexual flowers with inconspicuous perianth, sometimes pendant, often with bracts subtending the flowers.

Part 2. Floral and Fruit Morphology



Flower Terminology
Peduncle vs Pedicel - (peduncle is the stalk of entire inflorescence or solitary flower, while pedicels are the stalks within a larger inflorescence).
Receptacle - floral axis, think of a flower as a rosette-plant, and all the flower parts are modified leaves. The receptacle, although perhaps a small area, is really a stem with very short internodes.

Perianth - the outermost, sterile parts of a flower (not bearing reproductive structures).

If you can recognize two distinctly different whorls of perianth:
Sepals are the outermost whorl of 'leaf-derived" structures, and these are often greenish. All the sepals together are called the **calyx**. They may be fused or free of one another.

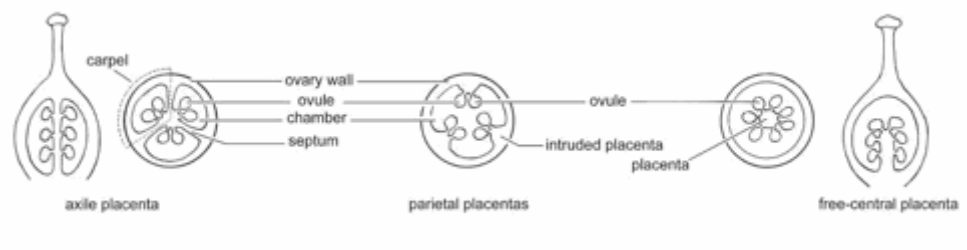
Petals are the next whorl of "leaf-derived" structures, but are generally colored by various pigments. All the petals together are called the **corolla**. They may be fused or free.

If you can't see two distinctly different whorls of perianth:
Sometimes just one whorl is present, with between 3 and 5 leaf-like structures (or lobes on a fused structure), then you are missing a whorl, and the whorl that is present is usually called the calyx; the corolla is assumed to be missing, and the flower is called **incomplete**. If you have many perianth parts (6 or more), or it is obvious you have two whorls, but all the leaf-like structures look the same, then one cannot distinguish calyx from corolla, and the structures are called **tepals**. This is common in lilies and magnolias.

Stamens: The whorl of "leaf-derived" structures interior to the perianth consists of the **stamens**; each stamen usually has an **anther** and a stalk called a **filament**, although some just have anthers. The anthers are the pollen-bearing structures, and pollen gives rise eventually to sperm cells. Thus the stamens are sometimes called the male part of the flower and all together are called the **androecium**. (andro=male). Flowers may have few to many stamens. Anthers release their pollen **(dehisce)** by opening by slits (very common), pores, or flaps (uncommon).

Pistils: In the Jepson manual, the so called "female" unit of a flower is called the **pistil**, and this structure is found in the center of the flower. There is usually just one pistil per flower; having more than one pistil, is unusual and is found in such groups as Magnolias, buttercups, and some Rosaceous genera. All the pistils together are called the **gynoecium**. Each pistil has an **ovary** which bears the **ovules** (which become the seeds), and a **stigma** (or stigmas) which receives the pollen. Many pistils also have a stalk connecting the stigma and ovary called the **style**. A pistil can have one or more styles. If there is just one style, it may be branched. Each style or style branch tip has a stigma.

Carpels
Evolutionary theory holds that all flower parts evolved from leaf-like structures. This is true of the gynoecium as well. The original pistil was a single leaf that bore ovules along its edges. Imagine then that this leaf rolled up, and the ovules then occurred in a single line inside the leaf, much like a pea pod. This hypothetical leaf-like structure, with ovules in one line, is called a **carpel** and is really the true basic unit of the gynoecium - like the stamen is the basic unit of the androecium.



Some pistils, such as those in legume flowers are made up of only one carpel, and are called **simple pistils**. **Any time you have more than one pistil per flower, each one of those pistils is a simple pistil**. However, during the evolution of the flowering plants there was a trend toward fusion and reduction of parts in some flowers. Carpels fused with one another creating what we call a **compound pistil**. The best way to understand this is to eat an orange. **Each section of an orange is a carpel.** But in the orange flower, the carpels have become fused into a compound pistil. The seeds of each carpel are in one line.

When carpels fuse into a compound pistil, the ovaries of the carpels always fuse; the styles, however may or may not; And if the styles fuse, the stigmas may or may not. For example, if you have three carpels fused, you may have three styles, one style with 3 stigmas, or one style with one stigma. It depends on the amount of fusion.

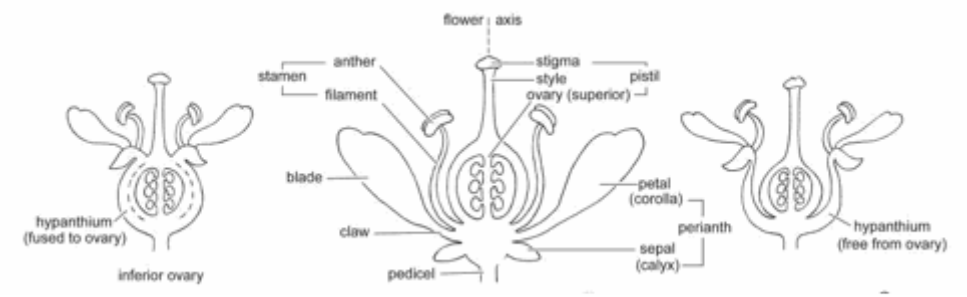
Placentation

If you take a cross-section of an ovary of a compound pistil derived from 3 carpels, there are several possible ovule arrangements that you could see. These arrangements are called **placentation** patterns and the chambers in the ovary are called **locules.**

Fusion of floral parts

Connation - when parts within the same whorl become fused, they are said to be connate to one another. For example: connation of petals into a tubular corolla (sympetally); connation of sepals into calyx tube; connation of stamens into staminal tube; connation of carpels into a compound pistil.

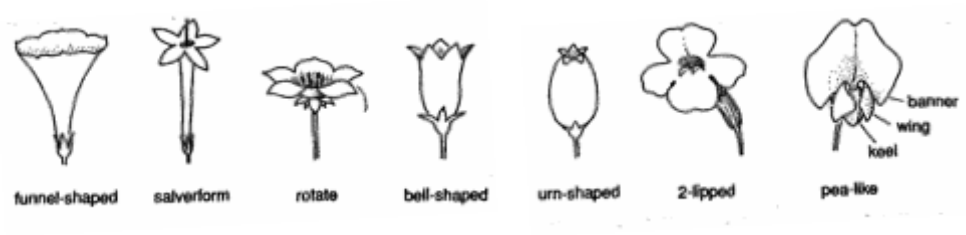
Adnation - when parts between whorls become fused, they are said to be adnate (for example stamens adnate to corolla).



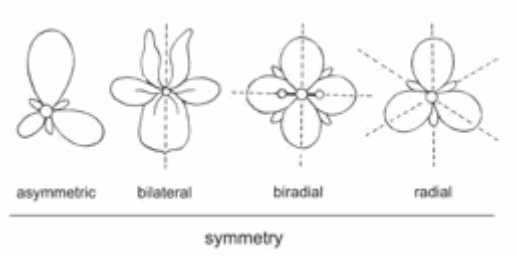
Hypanthium (or floral tube) - this is a special case of adnation and connation, in which the calyx, corolla, and staminal filaments all become fused into a tube. This is very common in the rose family.

Superior vs inferior ovaries
Usually, the stamens, corolla, and calyx are clearly attached to the receptacle to the outside of or below the pistil(s), and in these cases, the ovary is said to be **superior**. Sometimes, in cases where there is just one pistil, the ovary of that structure becomes either embedded in the receptacle or fused to a hypanthium. In these cases, it appears as though the stamens, corolla, and calyx begin above the ovary and the ovary is said to be **inferior**.

Floral Shapes - These are a sample of possible floral shapes



Floral Symmetry



Symmetry - In order to describe the shape of flowers, we often speak of the symmetry of the flower. For example, if one looks down at a buttercup flower, with many whorls of petals, stamens and carpels, you can dissect the flower into many planes of symmetry (plane of symmetry = bisecting an object into 2 mirror images). Buttercups have **radial** symmetry.

If on the other hand, one looks at an orchid flower, with its highly derived characteristics, one can only find one plane of symmetry. This is **bilateral symmetry.**

There are cases, such as in the mustard family, where one commonly finds two planes of symmetry, and this is **biradial symmetry.**

And there are cases where flowers are so asymmetrical that there are no planes of symmetry, and this is **asymmetrical.**

Floral Formulas

In the lecture, we discussed the use of flora formulas as a shorthand for describing floral structure. You are not required to use floral formulas, but we will use them in the lectures and some students find them useful. Refer to the lecture on this topic for details.

Fruit Types

As the ovary matures into fruit, the ovary wall becomes "the pericarp." The pericarp can sometimes be divided into three layers. The outermost layer is called the exocarp. The middle layer is called the mesocarp. The inner layer, closest to the seed(s) is called the endocarp. Your TA will guide you through the different fruits that we have on display in the lab.

Indehiscent fruit types:

Fleshy fruits:

Drupe – one seeded fleshy fruit with a stony endocarp

Pome – fleshy fruit from a compound inferior ovary and its surrounding hypanthium

Berry – fleshy, multiseeded fruit derived from a compound ovary lacking a stony endocarp

Dry Fruits:

Achene – indehiscent, one-seeded, dry fruit

Winged achene – an achene with one or two wings

Nut – indehiscent, dry fruit with a hard pericarp

Dehiscent fruit types (all dry):

Capsule – dehiscent, dry fruit, generally with many seeds, derived from a compound pistil

Follicle – dehiscent, dry fruit derived from a simple pistil, dehiscent only along one side

Legume – dehiscent, dry fruit derived from a simple pistil, dehiscent along two sides

Either indehiscent or dehiscent

Aggregate – group of fruits derived from more than one pistil in the same flower

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