REPRODUCTIVE MORPHOLOGY OF FLOWERING PLANTS

Flowers represent the reproductive organ of flowering plants, and are very important in identification because they typically provide characters that are consistently expressed within a taxon (either at the family, genus, or species level). This is because floral characters are under strong genetic control and generally are not affected by changing environments. Certain floral characters may remain the same throughout a family or genus, while other characters are more variable and are used only to differentiate species. For example, floral symmetry, ovary position, type of placentation, and kind of fruit, usually are used to differentiate families or genera, while petal color or shape and size of floral parts are more commonly used to distinguish species.

Flowers arise from the apical portion of a stem in a region called the receptacle. They may be borne directly on a main stem axis or rachis (sessile) or on a slender stalk or stem called a pedicel. They usually consist of four whorls of parts that develop in the following series, from the outer whorl to the inner: sepals, petals, stamens, and carpels. These whorls of parts may develop in discrete cycles, or be more or less continuous and spirally arranged. If all four whorls of floral parts are present, the flower is complete; if one or more whorls is missing, the flower is incomplete. The symmetry of flowers usually can be defined as radial (actinomorphic) or bilateral (zygomorphic). In a few groups the flowers are termed irregular (asymmetric) when the petals or sepals are dissimilar in form or orientation.

Floral diversity is achieved by numerous variation patterns resulting from changes in 1) symmetry, 2) numbers of each floral part, and 3) degree of fusion of the parts. If like parts are fused, they are connate; if unlike parts are fused, they are adnate. Prefixes such as gamo-, sym-, and syn- denote connation, as in gamopetalous and sympetalous (fusion of petals to each other) and syncarpy (fusion of carpels). The prefix epi- refers to adnation, as in epipetalous stamens (stamens fused to the petals). In floral morphology, the prefixes poly- and apo- represent the lack of fusion, as in polypetalous (separate petals) and apocarpy (separate carpels).

The two outer whorls of the flower, sepals and petals, are sometimes called accessory in that they do not produce the sex cells so are not directly involved in the sexual life cycle. These two parts are known collectively as the perianth. The two inner whorls, stamens and carpels, are the essential parts of the flower because they produce the sex cells or gametes that are part of sexual reproduction. When stamens and carpels are both present, the flower is perfect or bisexual; if either of these two is missing, the flower is imperfect or unisexual. For example, a flower that lacks only stamens is imperfect and incomplete, whereas a flower that lacks only petals is perfect, but incomplete.

The sepals usually resemble small, greenish leaves and comprise the outermost whorl of the flower. The sepals are known collectively as the calyx and appear to serve a protective function for the inner parts of the flower.
The next whorl of parts in a flower consists of petals or, collectively, the **corolla**. The petals often are showy and serve to attract animal pollinators to the flowers and may, in some cases, serve to protect the inner reproductive structures. Petals may be separate (polypetalal) or fused to each other (sympetalal or gamopetalal) and may form a wide array of forms. In some plants, mutations or genetic changes may result in a doubling or multiplication of the number of petals. This event is sometimes accompanied by the failure of the sex organs to form normally. Horticulturists often have selected such showy mutants for commercial distribution as ornamentals if the plants can be successfully propagated.

Inward from the petals are the stamens, which represent the male reproductive structures. The stamens are known collectively as the **androecium**. Typically, a stamen is differentiated into a **filament** or slender stalk and an **anther**, which is terminal to the filament and produces pollen in male sporangia. In some groups of flowering plants, particularly those that have many primitive features, stamens may not be differentiated to form a filament and anther but will bear sporangia instead on the surface of an expanded leaf-like structure (laminar stamen). Stamens may be fused to each other (connate) by filaments (monadelphous condition) or anthers (syngenesious), or they may be fused to other floral parts (adnate), particularly to the petals (epipetalal).

The fourth and innermost whorl of the flower is made up of carpels, collectively known as the **gynoecium** and representing the female reproductive structures in the life cycle. Carpels are believed to be derived from modified leaves folded lengthwise (conduplicate) that enclose the female sporangia. **Pistil** is the term for an individual structure in the gynoecium. A **simple pistil** consists of a single carpel; one or more simple pistils may make up the gynoecium of an individual flower (apocarpous condition). In a **compound pistil** the carpels are fused (syncarpous condition). Fusion of carpels to each other (connate) usually involves the ovaries, and may also include the styles and even the stigmas. When carpels are separate, the number of carpels equals the number of pistils. When carpels are fused, there is only one pistil, albeit a compound one, but there are two or more carpels comprising it.

A carpel of most flowering plants has three parts: **stigma**, **style**, and **ovary**. A primitive carpel, often termed conduplicate, may have just a stigmatic area or crest and an ovary. The style normally attaches to the top of the ovary, but in a few plant families (e.g., Boraginaceae and Lamiaceae), the style is gynobasic and is attached to the receptacle at the base of the ovary as well as to the surrounding carpels or nutlets. The stigma is the terminal part of the carpel and is often sticky and receives pollen during the pollination process. The style separates the stigma and ovary and may, in some cases, function by extending the stigmatic surfaces beyond the other floral parts so pollen is more easily received; pollen tubes grow through the style to get to the ovary. The ovary is the basal part of the carpel and contains one or more **ovules** borne on a **placenta**. An ovule will contain an embryo sac, which produces the egg and polar nuclei essential for double fertilization in flowering plants.
The position of the ovary in relation to the other floral parts is often used as a character to
distinguish taxa, especially families. If the ovary is borne above the insertion of the
sepals, petals, and stamens, the ovary is superior. If the ovary is borne below the
attachment of the other floral parts, it is inferior. If the sepals, petals, and stamens are
borne on a hypanthium or floral cup around the ovary, the ovary position can be either
superior of half-inferior or inferior. The hypanthium is a floral cup or ring formed
usually from the fusion of the lower parts of the calyx, corolla, and androecium. In some
instances, the hypanthium may be derived from the receptacle. Flowers may be
described as hypogynous (with a superior ovary), epigynous (with an inferior ovary), or
perigynous (with a basal disk or hypanthium distinct from the ovary).

Within the ovary, ovules are positioned on a placenta. In a simple pistil, the ovaries are
separate and the included ovules occur on marginal placentae. In a compound pistil,
ovules may occur on a placenta that is axile (centrally placed in an ovary with two or
more locules or cavities), parietal (on the wall of a unilocular ovary), free-central (on a
free-standing column in a unilocular ovary), apical, or basal. The type of placentation
often is used as a character to differentiate flowering plant families. Axile placentation is
derived when two or more carpels fuse; the ovules are borne in vertical rows near the
center of the ovary on a central axis and the walls of the original carpels remain evident
as septae. Modifications of axile placentation can give rise to the other types of
placentation found in compound pistils. Parietal placentation may be derived by loss of
septae and the central column and attachment of the ovules on the wall of the ovary.
Free-central placentation may arise by the loss of septae and the upper part of the
central axis and the retention of ovules on the central column. Apical or basal
placentation may be derived by the loss of septae, the central column, and parietal
ovules.

The flowers on a given plant may occur singly or aggregated into clusters called
inflorescences. The stalk or supporting stem of the inflorescence or of an individual
flower is called a peduncle. The types of inflorescences are of two main types:
determinate, in which the oldest flowers are in the center or above others (e.g., cyme),
and indeterminate, in which a terminal flower is lacking and where the flowers usually
are axillary from leaves or bracts and mature from the base to the top (e.g., corymb,
panicle, raceme, spadix, spike, and spikelet). Certain inflorescences (e.g., catkin,
head or capitulum, and umbel) may be either determinate or indeterminate, depending
on the plant group. Inflorescences may assume various shapes and may or may not
show branching. Identification of the type of inflorescence is made by determining where
the oldest flowers are, the nature and extent of branching (if any), whether or not pedicels
are present, and the general shape of the structure.

The inflorescence type often is closely correlated with the means of pollination (transfer
of pollen from a stamen to a receptive stigma). For example, a flat-topped, sturdy
inflorescence often signals pollination by beetles or other insects that land before
foraging for pollen, nectar, or special food bodies. Some plants form showy, sterile
flowers at the margin of a flat-topped inflorescence to attract pollinators to the inner fertile
flowers. In these instances, the small individual flowers form a compact inflorescence
(usually a corymb, head or capitulum, or umbel) called a pseudanthium (= false flower) in which the inflorescence mimics a single flower. An elongate raceme may have showy flowers oriented at right angles to the stem to facilitate visitation by a hovering hummingbird. After pollination occurs and is followed by fertilization, the seeds begin to form and the ovary starts to enlarge and ripen, often changing color and texture as it develops into a fruit. The other parts of the flower, the perianth and stamens, may change color and either become reflexed or drop off.

A fruit represents a ripened ovary that contains one or more seeds and may have other floral parts adherent to it. The pericarp or wall of the fruit (ripened wall of the ovary) may be either fleshy or dry. Dry fruits may be dehiscent (splitting open at maturity) or indehiscent (closed at maturity). Fleshy fruits are usually indehiscent and may be formed from a single ovary or from multiple ovaries of one or more flowers. In both dry and fleshy fruits, the number of carpels comprising the ovary (simple or compound) may be useful in identifying the type of fruit.

Indehiscent, dry fruits include the following one-seeded types: achene, caryopsis, cypsela, nut, nutlet, samara, and utricle. The achene usually is formed from a single carpel, but may be formed in a compound ovary in which only one carpel is functional; the pericarp of the achene can be readily separated from the seed coat. Modifications of the achene produce the other types of dry, indehiscent one-seeded fruits. A caryopsis is a type of achene in which the pericarp is completely fused to the seed coat; it is derived from a 2-3 carpellate, superior ovary and is found only in the grasses (family Poaceae). A cypsela is an achene similar to a caryopsis, except that it is derived from a 2-carpellate inferior ovary and often is equipped with a pappus; it is found only in the composites (family Asteraceae). A nut is hard and bony, and larger than but otherwise similar to an achene, while a nutlet is a small nut. A samara has a wing, enabling it to be wind dispersed. A utricle is similar to an achene, except that the pericarp is inflated and appears like a bladder.

Dehiscent, dry fruits include: capsule, follicle, legume, loment, schizocarp, silicle, and silique. A capsule is always derived from a compound pistil and splits open at maturity along one or more lines of dehiscence. A follicle is derived from a single carpel, has one or more seeds, and splits open at maturity along the dorsal (front) line of fusion. Fruits of the Fabaceae are called legumes or loments and are derived from single carpels. A legume dehiscs on both sides at maturity, while the loment breaks apart into one-seeded segments. A schizocarp splits apart at maturity into one-seeded parts (mericarps) that represent its separate carpels. Silicles and siliques are specialized capsules found only in the Brassicaceae; each of these has a membranous partition that separates the two locules and each is formed from a two-carpellate gynoecium. A silicle usually is less than two times longer than wide, while a silique usually is more than two times longer than wide.

Fleshy fruits may be formed either from a simple or compound ovary and include: berry, drupe, pome, and sometimes follicle or capsule. A berry may have few or many seeds embedded in a pulpy matrix with a thin outer wall. A drupe is derived from a
simple or compound ovary and has one or more seeds enclosed in a stony endocarp (the inner wall of the pericarp or ovary). A pome is formed from a compound pistil in an inferior ovary; the fleshy part of the pome is derived from the pericarp and hypanthium. Follicles, derived from single carpels, and capsules, derived from compound gynoecia, are typically dry fruits, but may be fleshy in certain genera or families.

Fleshy fruits derived from several ovaries include the **aggregate** and **multiple** fruit types. In the aggregate fruit, the unicarpellate ovaries of a single flower are coherent at fruit maturity, as in blackberries and raspberries. Multiple fruits are formed by the coalescence of several flowers, as in mulberry or pineapple.

Fruits may serve as the dispersal unit or they may dehisce, allowing the seeds to be dispersed. The unit of dispersal, either fruit or seed, may be transported by wind, water, or an animal. Fruit types generally are consistent within a genus and often within a family, thereby providing useful characters for plant identification. To be able to key flowering plants, it is important to become familiar with the nature of variation shown by all parts of a flower (sepals, petals, stamens, and carpels). Learn the terms on the following diagram.

### TABLE OF FRUIT TYPES

The principal features of fruit types are summarized. The number of carpels per ovary is given in parenthesis following the fruit type.

<table>
<thead>
<tr>
<th>DRY FRUITS</th>
<th>FLESHY FRUITS</th>
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<tbody>
<tr>
<td>Indehiscent</td>
<td>Dehiscent</td>
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<tr>
<td>achene (1+)</td>
<td>capsule (2+)*</td>
</tr>
<tr>
<td>nut (2+)</td>
<td>follicle (1)*</td>
</tr>
<tr>
<td>nutlet (2+)</td>
<td>legume (1)</td>
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<tr>
<td>samara (1+)</td>
<td>loment (1)</td>
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<tr>
<td></td>
<td>schizocarp (2+)</td>
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<td>silicle (2)</td>
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<td>silique (2)</td>
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<tr>
<td>berry (1+)</td>
<td>drupe (1+)</td>
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<td>aggregate (1+)</td>
<td>multiple (2+)</td>
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<tr>
<td>pome (2+)</td>
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</table>

*less commonly fleshy*
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FLORAL SYMMETRY

Actinomorphic or radially symmetrical; regular flower

Zygomorphic or bilaterally symmetrical; irregular flower

COROLLA SHAPES

Rotate or wheel-shaped
Campanulate or bell-shaped
Urceolate

Infundibular or funnel-form
Salverform
Tubular

Papilionaceous (butterfly-like)
Bilabiate or two-lipped
Ligulate or strap-shaped
OVARY POSITION
1. SUPERIOR: Ovary borne above the insertion of the perianth (or hypanthium if present).
2. HALF-INFERIOR: The sepals, petals, and stamens or hypanthium inserted around the ovary; the hypanthium adnate only to the lower part of the ovary.
3. INFERIOR: Ovary borne below the attachment of the sepals, petals, and stamens, due to the adnation of the hypanthium to the ovary wall or to the recession of the ovary into the receptacle.

PERIANTH (and ANDROECIUM) POSITION
1. HYPOGYNOUS: Sepals, petals, and stamens attached below the superior ovary
2. PERIGYNOUS: Sepals, petals, and stamens inserted on a hypanthium, the hypanthium attached either below a superior ovary, or the lower half adnate to a half-inferior ovary.
3. EPIGYNOUS: Sepals, petals, and stamens, or a hypanthium bearing the perianth and stamens, attached to the top of an inferior ovary.

HYPANTHIUM (noted by shaded areas)
CARPELS or PISTILS

One carpel (simple pistil)
Cross-section of ovary
Two or more carpels (compound pistil)
Cross-sections

Styles and stigmas distinct
Only stigmas separate
No external indication that gynoecium (pistil) is compound

TYPE OF PLACENTATION

Ovary simple, only one marginal placenta
Compound ovary, two parietal placentas
Compound ovary, placenta parietal
Compound ovary, placenta axile

Compound ovary,
Compound ovary,
Compound ovary,
INFLORESCENCE (positions and arrangements of flowers)

- Flowers solitary
- Cyme (terminal flower opens first)
- Flowers axillary (leaves not reduced in size)
- Raceme (leaves reduced to bracts; pedicels present)
- Corymb (racemose; flat- or round-topped)
- Umbel (racemose from very short rachis; pedicels appear to arise from a common point; flat-topped)
- Compound Umbel
Panicle
(part raceme, part compound raceme)

Spike
(elliptic, pedicels lacking)

Head or Capitulum
(flowers closely aggregated and borne directly at apex of peduncle; pedicels and rachis both lacking)

Spikelet
(a secondary spike, usually part of a compound inflorescence in grasses and sedges)

Catkin
(a dense, bracteate spike, raceme or cyme with a nonfleshy rachis, usually with many small, naked or apetalous, often unisexual flowers)

Spadix
(a fleshy spike, usually surrounded by a large colored leaf called the spathe)
What to look for in flowers while identifying plants.
Observing the organization and number of floral parts is the key to identifying plants and recognizing plant Families. Linnaeus developed his entire classification system around the numbers of sexual parts (stamens and carpels) in flowers and the way they are organized without any understanding that evolution may have been responsible. That so many of the groups he recognized as Families are still recognized as such 250 years later, has to do with the fact that floral reproductive characters are highly ‘conserved’ in an evolutionary sense. That is, they don’t change much over time, because they are so important for successful reproduction that most changes prove to reduce reproductive success and, therefore, disappear. Historically, Families, as a taxonomic rank, tended to be recognized at a level in the phylogenetic hierarchy where consistency of floral form is still strong. At the next more inclusive rank, Order, too much variation often exists for flowers to look very much alike. In recent years, as the emphasis on taxonomic groupings has increasingly become linked to phylogenetic trees, some Families have been found to not be monophyletic, even though they do exhibit consistent floral morphology. In these cases, the groups often have been split into smaller Families, or lumped with other families that are closely related, but which have quite different floral morphology.

Some of the floral characteristics that one should look for first are the symmetry of the corolla (actinomorphic or zygomorphic), whether all four whorls (sepals, petals, stamens, and carpels) are present as distinct parts or are fused together or to parts in other whorls, the number of parts in each whorl, and the position of the ovary relative to the point of attachment of the other floral parts. Some other important things to look for are whether the flowers have both male and female parts or are unisexual, what type of fruit is formed (if fruits are present), and the way that the ovules (seeds) are attached inside the ovary (fruit).

In the laboratory, there are several flowers available for your study. After you have dissected the flower of the first "unknown" and filled in the appropriate places in the following chart, your lab instructor will then help you key the unknown. Using a manual, key the plant to family, then to genus, and finally to species. Once you have identified the first unknown, proceed to analyze and key the others.

<table>
<thead>
<tr>
<th>Unknown</th>
<th>Symmetry</th>
<th># of Sepals</th>
<th># of Petals</th>
<th># of Stamens</th>
<th># of Carpels</th>
<th>Ovary position</th>
<th>Fruit type</th>
<th>Family &amp; scientific name</th>
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