

Phenophase Primer for Plants

Understanding Plant Phenophases for *Nature's Notebook*

USA-NPN Education & Engagement Series 2016-002 June 2017
DRAFT



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PHENOPHASE PRIMER

INTRODUCTION

All plants cycle through a sequence of life stages that brings them through germination, reproduction and senescence. Depending on life strategy, a plant may only complete one cycle if the species has a typical “annual” pattern or it may complete tens to hundreds of cycles, one per year, if it has a “perennial” pattern (like trees and shrubs).

Within these cyclical patterns there are distinct observable stages—or phenological phases—that can be tracked and recorded to help us understand the natural history of the plant. We can place the timing of these phases within the context of environmental data and other information to further understand a plant’s relationship to its environment. Some of these factors might be the regional climate, local weather events, or how animals interact with a plant.

Observers participating in the USA National Phenology Network’s (USA-NPN) *Nature’s Notebook* program select and observe organisms from a large list of plant and animal species. This national effort to collect standardized ground observations of the phenological phases—or “phenophases”—by researchers, natural resources managers, students and volunteers, supports a wide range of scientific applications and management decisions routinely made by citizens and professionals. High quality



data are vital to this effort and this *Phenophase Primer* is meant to acclimate participants to plant phenology information referenced within the *Nature’s Notebook* program.

For each species contained within the *Nature’s Notebook* plant list, a set of significant phenophases is identified and described for regular observation. Plant phenophases include seasonal leaf bud opening, flower bud formation, flower opening and pollen release, fruit ripening, fruit and seed dispersal, and leaf drop. For each phenophase, the observer will be asked to answer yes-or-no questions and record count-category and percentage-category observations to evaluate and report the activity of the chosen plant.

Many of these phenophases overlap and will occur at the same time on a single plant, such that observers should report a “yes” to more than one phenophase at a time. Some phenophases might occur all year round on a single plant in certain circumstances, and an observer might never report a “no” for the phenophase. Many phenophase questions are straightforward and easy to determine, but some are not due to the complexity of the plant. Plants, like all organisms, can have complex strategies and anatomies that are hard to read, and thus, make accurate observations challenging.



The *Phenophase Primer* was generated as a tool to enable observers to become more familiar with the phases and complexities they are asked to evaluate. The content in this *Primer* is based largely on regular questions that the USA-NPN National Coordinating Office staff receive regarding the phenophase protocols. It is not possible to cover in detail each of the 800+ plant species included in *Nature's Notebook*, nor all possible contingencies for unusual circumstances. Instead, we present here the basic principles and common points of confusion with photographic examples from as many species as is practical. You, the observer, will need to apply the principles you learn from this *Primer* to other species or situations to the best of your ability. Even if your species is included in the *Primer*, there is variation from individual to individual so be aware your plant may not look exactly like the one pictured.

The most important part of observing phenology is to catch the transitions between different life stages on a plant—such as that from only closed leaf buds to a least one bud breaking, or only closed flower buds to at least one open flower—yet, pinpointing the exact instant of transition can be tricky. Every observer will at some point encounter an ambiguous situation in the field, and they will need to make a judge-

ment call as to whether or not a phenophase has begun or which count- or percentage-category to report. Utilize your critical thinking skills and do the best you can. If you are unsure whether you are correctly capturing a transition, report a “?” for the status and return the next day, and the next, until you are sure of what you are observing. In some cases you may need to do more research, or observe for an entire year, to feel you understand what the transitions look like on your plant. Remember, this is a long-term process, and over time you will become more and more sure of what you are observing.

Ultimately, the goal of this Primer is to help observers make more accurate and dependable observations, but do not panic or overthink the situation! The data you are collecting in this national-scale program is intended to elucidate the timing of general life cycle patterns regionally, or across the US. If your observation of the start or end of a phenophase is off by a few days on one individual plant, it will have very little effect on the big picture. The valuable time you commit to *Nature's Notebook* is far better spent recording the phenophases for many plants at medium-high accuracy over an extended period of time, than fretting over obtaining perfect accuracy for the phenophases of a single plant. Just



do the best you can— your efforts are appreciated! Most importantly don't forget to have fun observing the seasonal changes of your chosen species!

How to use this *Phenophase Primer*

This Primer was designed to have “facing pages”, as in a printed book. That is, an even-numbered page and its subsequent odd-numbered page belong together; often the subject (a phenophase) covered on the first page continues onto the second page. A digital **.pdf** document allows you to display both pages together if you desire. This can be set up in Adobe Reader by choosing “View” from the top frame menu, then “Page Display” and “Two-page View” or “Two-page Scrolling” from the drop-down menus.

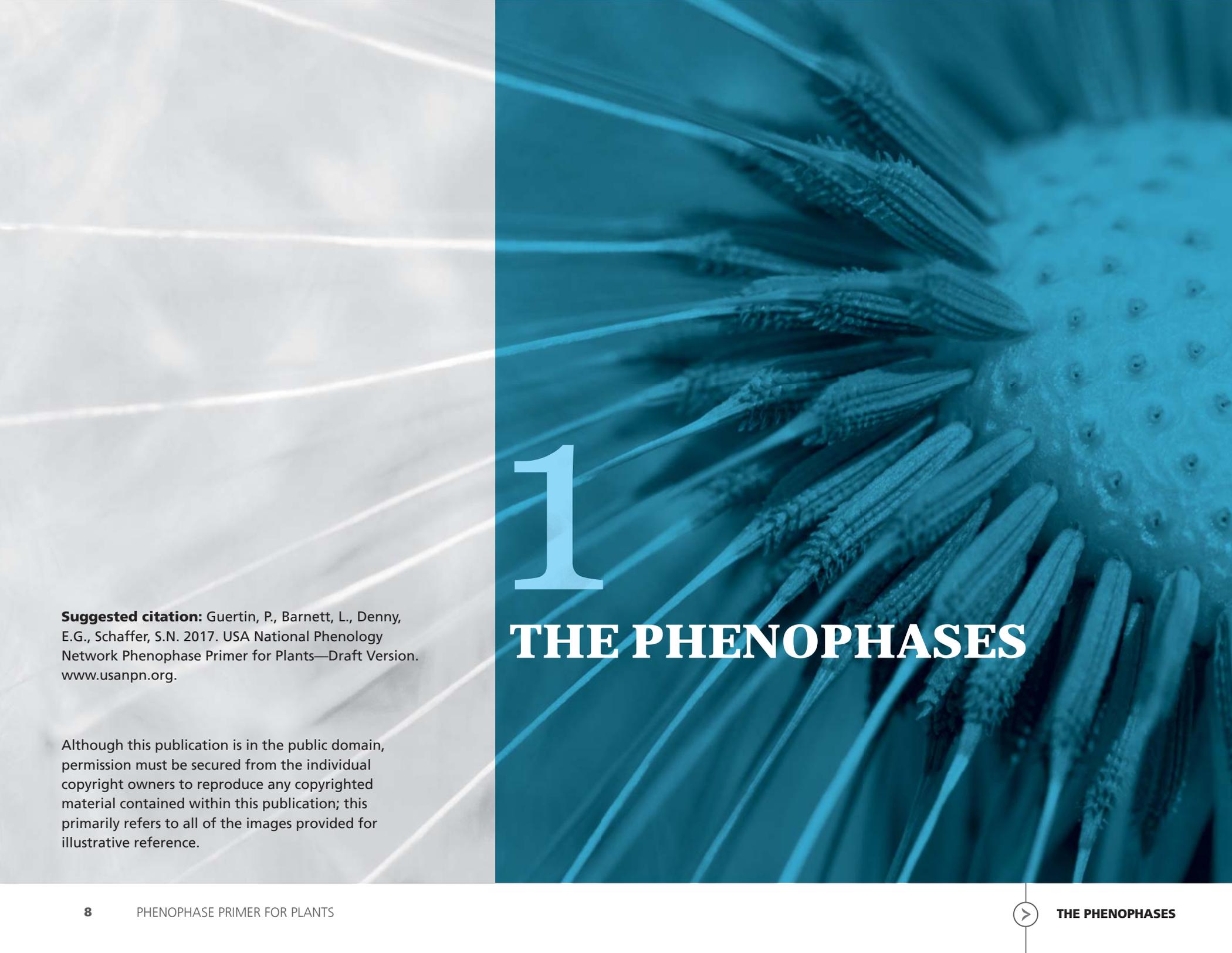
Each image included within will have the plant species' scientific name placed at the lower left hand corner of the image. Within the image credits at the end of each section, a common name will be provided for the plant species. Keep in mind that a plant's common name is often regional in nature and can differ from place to place—so that the name provided on these pages may not be the same name you are familiar with in your region or geographical area. As a rule, it makes sense to reference the

scientific names rather than common names to eliminate any confusion in plant identification.

The *Primer* is broken down into three sections, created to assist observers in making observations as accurately as possible for the National Phenology Database (NPDb) via *Nature's Notebook*. The three sections are 1) The Phenophases, 2) The Functional Groups, and 3) The Intensity Measures.

The USA-NPN's National Coordinating Office is releasing it in three “draft” stages as we continue to work on content for the full *Primer*. Each section will be released separately, as completed, and posted on “Our Reports” page (usanpn.org/pubs/reports) as a downloadable **.pdf** file. Each section of the *Phenophase Primer* has an independent table of contents as a guide to the information included in that section.

Use this *Primer* in tandem with our *Botany Primer: Understanding Botany for Nature's Notebook*, the first *Primer* in the series, which carefully details botanical information to assist in identification of the parts of a plant highlighted in *Nature's Notebook*. Most of all, have fun observing!



1

THE PHENOPHASES

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SECTION 1

INTRODUCTION



Organization and use of Section 1: The Phenophases

Section 1 of this *Primer* takes a look at each of the *Nature's Notebook* plant phenophases, and presents an overview of what observers are asked to look for when making observations of each phenophase. Within the *Nature's Notebook* program, each phenophase is presented as the question “Do you see [name of phenophase]?” which is followed by a definition for the phenophase. When making an observation on a plant, an observer should answer “Yes” if they do see the phenophase occurring on their plant, “No” if they do not see it occurring on their plant, or “?” if they are uncertain whether they see it occurring on the plant.

It is recommended that observers use the “?” until they feel certain of what they see. Observers may also opt to not answer one or more of the phenophase questions if they do not have an adequate comfort level with the species, its natural history, or its phenophase identification.

This section of the *Primer* is designed to help observers gain more confidence in making observations of phenophase status. It includes some of the variation that occurs across plant species, as well as some unusual cases where observation might be particularly challenging. Mostly, it is a

collection of photos—visual information to help an observer understand what they generally should observe for each phenophase.

Section 1—The Phenophases—is organized into two major subsections:

- 1) Angiosperms—or the leafy, more broad-leaved plant phenophases
- 2) Conifers—or needle-leaved conifer phenophases (still in development)

Within each major subsection, the phenophases are organized first by new growth and leaf and needle phenophases, second by flower and immature cone phenophases, and third by fruit and mature cone phenophases. Each of these phenophase types has a specific color used for the title and headings to easily understand their general category: green for the leaf and needle phenophases, orange (or brown) for the flower and immature cone phenophases, and red for the fruit and mature cone phenophases.

Pages are organized sequentially as life stages generally occur in plants, and include “phenophase pages” for each of the *Nature's Notebook* defined phenophases, and “informational pages” for more general information and for life stages that occur between defined phenophases.

“Phenophase pages” are titled with the name of the phenophase, such as





"Initial growth" or "Breaking leaf buds". Underneath the title, a specific plant "functional group" will be identified followed by its specific phenophase definition.

Plant functional groups were defined by the USA-NPN to organize species by phenological similarities.

The major functional groups for angiosperms are:

Cactus, Forb, Grass, Sedge, Rush, Tree or Shrub

Groups for conifers are:

Evergreen Conifer (excluding pines), Pine, Deciduous Conifer

Some of the *Nature's Notebook* phenophases will have several different phenophase definitions, each specific to a different plant functional group. Other phenophase definitions will include all of the plant functional groups under one definition (see box at right). Note that abundance and intensity questions are not covered here; they will be discussed in Section 3 of this *Primer*.

The "phenophase page" set-up

The page's heading "*Nature's Notebook* Phenophase Definition" identifies this page as a "phenophase page" (white arrow). The colored title "Flowers or flower buds" identifies the specific phenophase name that is focused on and defined on the page (yellow arrow).

Below, the plant functional groups are identified for which the page's phenophase definition applies: "Cactus, Forb, Tree or Shrub" (red arrow). Immediately below the functional group names is the phenophase definition for those plant functional groups (green arrow).





The page titles found in the Table of Contents and on the footer of each phenophase page will identify the phenophase's name, such as "The Phenophase for Flowers and Flower Buds."

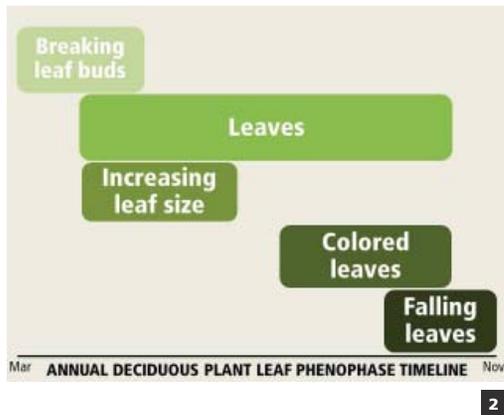
Between-phenophase "informational pages" are included to provide more details about what an observer may see while observing, related to timing and what to expect next. Such between-phenophase pages are identified in the Table of Contents and on a page's footer with a title such as "An Overview of Dormant and Swelling Leaf Buds". The subtitles on these pages are typically a question such as "What do they look like?". The information provided on these pages is intended to help an observer understand other aspects and characteristics of plant growth that occur before and after some of the *Nature's Notebook* phenophases. These pages should help those unfamiliar with the details of plants and their natural history to better identify when a phenophase is approaching or is completed.

For both the phenophase and the informational pages, many photos or groups of photos are provided as visual information to support the definition of the phenophase. Short text descriptions accompany the photos, as needed, and arrows are included to help focus on phenophase details that may need highlighting (see box on right).

For many pages, white or black arrows or circles will highlight the specific area of focus for the phenophase. **Blue arrows** are used to display a progression of the phenophase and the entire image is to be considered. On some pages, the arrows have colors and focus on specific activities, such as **red arrows** for male activity and **orange arrows** for female activity. In these cases of specific activity, a note within the page's text will alert the reader to these activities. Diagrams are also provided, as necessary, for details that might be too tiny or complex to easily see or understand for the plant.

An overview of vegetative (leaf) phenophases

How are they related to one another?



The vegetative phenophases for *Nature's Notebook* plant species are organized into two broad categories

1. Growth *before* the first leaf has unfolded. These phenophases characterize the period when a plant begins to respond to seasonal signals, but before it exposes much tender leaf tissue to a potentially damaging environment, such as freezing temperatures.
2. Growth *after* the first leaf has unfolded. These phenophases characterize the period when a plant is photosynthesizing, including a ramping up at the beginning of the growing season and a slowing down at the end.

Each plant functional group has a specific set of phenophases to be observed, each type differing from one another. Thus, not all phenophases listed here will be included in any one species' set of phenophase observations. Refer to a species' profile webpage or its datasheet for a species' pertinent observations.

Before the first leaf has unfolded—includes the *Nature's Notebook* phenophases:

- “**Initial growth**” is a phenophase that observers will watch for when their chosen plant is an annual or perennial forb or grass, sedge or rush. It captures the first growth and emergence of leaves from a germinating seed or from a dormant plant at the beginning of a plant's active seasons. Occurrence of this phase ends when each of a plant's shoots (or buds in a few cases) have at least one leaf unfolded (Image 1).
- “**Breaking leaf buds**” is a phenophase that observers will watch for when their chosen plant is a tree or shrub whose buds are covered with bud scales or display a particular unfolding of protective leaves. It captures the first emergence of leaves from a bud of a dormant plant at the beginning of a plant's active seasons. Occurrence of this phase ends when each of a plant's buds have at least one leaf unfolded (Image 3).

You will notice that many species of desert and dryland regions, such as cactus, are not assigned the “Breaking leaf buds” phenophase because their buds are structurally different or they have buds that are too small to see. For these species, the first phenophase that *Nature's Notebook* will ask an observer to report is “Young leaves”, which begins after the first leaf has unfolded.

After the first leaf has unfolded—includes the *Nature's Notebook* phenophases:

- “**Leaves**” is a phenophase that observers will watch for in all species except evergreen forbs, trees and shrubs (which by definition *always* have leaves present). It captures the entire period of time that live leaves are present on the plant, from the unfolding of the first leaf to the dropping or dying of the last leaf. Depending on the species, there might be other vegetative phenophases that observers are asked to watch for while these live, unfolded leaves are present on the plant. If this is the case, the observer should be reporting “yes” to “Leaves” at the same time they are reporting “yes” or “no” to these other phenophases (see Diagram 2: overlapping phenophases).
- “**Young leaves**” is a phenophase that observers will watch for in evergreen forbs, and in tree and shrub species that have old and new leaves on the plant at the same time. It captures the period of active leaf growth.



Occurrence of this phase ends when the size, color and/or texture of all of the newer leaves are no longer distinguishable from those of the older leaves on the plant (Image 4).

- **“Increasing leaf size”** is a phenophase that observers will watch for in deciduous trees and shrubs that tend to have a single, large flush of new leaves at the beginning of the growing season. It captures the period of time when this first flush of leaves is actively growing to full size, and it represents the period of time it takes the deciduous plant to ramp up to full photosynthetic capacity. Occurrence of this phenophase ends when most of the leaves of that first major flush appear to be full size. Note that growth of new leaves at the end of each branch generally occurs throughout the growing season. This type of growth should be ignored for this phenophase.
- **“Colored leaves”** is a phenophase that observers will watch for in deciduous, drought deciduous and semi-evergreen trees and shrubs. It captures the period of time when leaves begin to deteriorate and lose their green color, in some species turning brilliant shades of yellow, orange or red. Often it represents the period of time when the deciduous plant is ramping down photosynthetic capacity towards the end of the growing season. However, this phenophase may also occur during times of extreme drought or insect infestations. Occurrence of this phenophase generally ends when either all the leaves have dropped off the plant, or if some remain on the plant, when they have dried up and become brittle. However, this phenophase may come and go during the senescent season if all colored leaves drop off the plant yet green ones remain and subsequently turn color (Image 5).
- **“Falling leaves”** is a phenophase that observers will watch for in deciduous, drought deciduous and semi-evergreen trees and shrubs. It captures the period of time when live leaves are dropping off the plant as they senesce. Observers most likely will not actually see leaves falling off the plant while they are observing, but if they notice that leaves have fallen since their last observation, they should report that “Falling leaves” has occurred. Occurrence of this phenophase ends for the season when no live leaves are left on the plant (although dried, dead leaves might still be attached).

There are several things to note about this phenophase. First, summer wind storms often cause a few handfuls of healthy green leaves to fall off the plant. These can be ignored and not reported as “Falling leaves”.

Second, the occurrence of “Falling leaves” might not be continuous from observation to observation. For instance, it might cease during a spell of mild weather but start up again with cold or windy weather. If this is the case, the observer should report “no” to “Falling leaves” if none appeared to fall since their last observation.

Third, while the three previously-outlined phenophases occur simultaneously with the “Leaves” phenophase, the last observation of “Falling leaves” in a season will most likely occur alone. That is, no leaves are left on the plant (“Leaves” is not occurring), but the observer noticed that the last leaves had fallen since the last observation (“Falling leaves” did occur).



Initial growth

Forb

New growth of the plant is visible after a period of no growth (winter or drought), either from above-ground buds with green tips, or new green or white shoots breaking through the soil surface. Growth is considered “initial” on each bud or shoot until the first leaf has fully unfolded. For seedlings, “initial” growth includes the presence of the one or two small, round or elongated leaves (cotyledons) before the first true leaf has unfolded.



Podophyllum peltatum

1



Fragaria virginiana

2



Crocus sp.

3

Perennial forbs

At the beginning of a plant's active season, observers will watch the plant for new sprouts or the emergence of leaves from underground rhizomes, bulbs or corms, crowns, or at stem nodes located along above ground stolons (row 1).



Raphanus sp.

4



Proboscidea parviflora

5



Lactuca sativa

6

Annual forbs

For seedlings of annual plants, new growth from the seed first appears as cotyledons (seed leaves)—one or two depending on the species—or new leaf growth if the cotyledon is hidden below ground (row 2). When new “true” leaves emerge from between the cotyledons and become unfolded—the plant is no longer in the “Initial growth” phenophase (for in-detail explanations, see the section “An overview of unfolded leaves”).

Initial growth

Grass or Sedge

New growth of the plant is visible after a period of no growth (winter or drought), either as new green shoots sprouting from nodes on existing stems, new green shoots breaking through the soil surface, or re-greening of dried stems or leaves. For each shoot, growth is considered "initial" until the first leaf has unfolded or has fully re-greened.

Rush

New growth of the plant is visible after a period of no growth (winter or drought) as new green shoots breaking through the soil surface. For each shoot, growth is considered "initial" until the exposed, green portion of the shoot has reached approximately 2 inches (5 cm) in length.



Sorghum halepense 7

Summer annual Poaceae sprout 8

Summer annual Poaceae sprout 9



Eragrostis lehmanniana 10

Digitaria californica 11

Setaria macrostachya 12



Carex sp. 13

Carex sp. 14

Placeholder genus-species 15

Needed: rush
photo - Initial
Growth phase

Grasses

In Image 7, the grass seedling's first leaf has emerged but has not yet unfolded so it is still considered in the "Initial growth" phase. However, an annual grass' seedling often emerges as an unfolded leaf and its single cotyledon is usually left hidden underground. In this case an observer may not see "Initial growth" because the leaf very quickly unfolds (Images 8-9). For a detailed explanation, see the section "An overview of unfolded leaves".

Perennial grasses show bits of green when renewed growth initiates. Check plants early and often—by the time green is obvious at a distance, the plant may be past the "Initial growth" phase. New growth can appear on last year's stems at the base of the plant, or at the stem nodes, or in some species it can initiate in odd places on the plant from intercalary meristems at the base of dry stems or leaf sheaths and blades (Images 10-12). It is considered "Initial growth" until the first new leaf has unfolded.

Sedges and rushes

New growth emerges as a sprout from underground rhizomes in both sedges (Images 13-14) and rushes (Image 15). It is considered "Initial growth" in sedges until the first leaf unfolds, and in rushes until the sprout reaches about 2 inches (5 cm) tall.

An overview of dormant and swelling leaf buds

What do they look like?

On these two pages we take a look at dormant and swelling leaf buds—buds that are resting or those beginning to swell just before buds break open. We will take a look at species that have bud scales to protect the embryonic leaves and those that do not have bud scales. Just for botanical reference—bud scales are also called cataphylls.

Those species whose buds have no bud scales—called naked buds—fall into two categories: those that tightly cover their embryonic leaves with tiny immature leaves (often in warm climates) and those that cover their embryonic leaves with immature leaves having dense hairs, parts of the plant stem or other leaf tissues (often in cold climates).

Although dormant or swelling leaf buds are not phases for which a *Nature's Notebook* participant would record observations, becoming familiar with the leaf buds of your observed species—and their subtle characteristics and activities—will enable you to make accurate observations when the buds become active after a dormant phase.

Buds with bud scales

Buds with scales that are overlapping (imbricate):

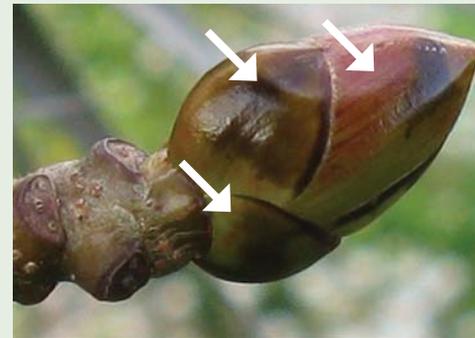
To the right (Images 1-7) are examples of species for which the dormant leaf bud has bud scales that have an imbricate structure—the scales overlap each other like the shingles on a roof. Image 1 shows a bud that is beginning to swell—with bud scales that have begun to shift and loosen around the enclosed embryonic tip.

Buds with a single scale:

Some species (like willows) only have a single bud scale that covers the embryonic leaves (Images 8-10). The buds in Image 10 have broken and have unfolded leaves—this image is included here so that one can see the position of the bud scales on the twig.

Buds with two scales that meet but do not overlap (valvate):

Some species have valvate buds (Images 11-12), where two bud scales meet tightly together and do not overlap each other.



Liquidambar styraciflua

1



Acer pseudoplatanus

2



Quercus alba

3



Acer saccharinum

4



Alnus viridis

5



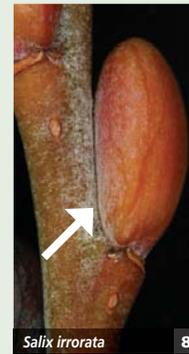
Fagus grandifolia

6



Amelanchier utahensis

7



Salix irrorata

8



Salix sitchensis

9



Salix sp.

10



Viburnum lentago

11



Liriodendron tulipifera

12



Naked buds (no bud scales) in cold-climate plants

There are several cold-loving plant species that have naked buds, that is, buds that are not covered and protected with bud scales during the cold weather months, but instead covered by tiny immature leaves tightly enclosing tinier embryonic leaves at the tip of the twig. These protective leaves are often covered with dense or woolly hairs (Images 13-17).

Naked buds (no bud scales) in warm-climate plants

Often in the warmer temperate-climate regions, perennial plant species—especially evergreen species—can have resting embryonic tips at the end of twigs that are hidden and covered tightly by many tiny immature leaves. These half-developed leaves are the only protective covering at the ends of branches and twigs, and leaf axils. These “buds” wait until the conditions are right for seasonal leaf growth to begin (Images 18-19).

Other bud types

Other variations of bud architecture that occur in flowering plants (the angiosperms) include buds covered and protected by the leaf stipules—that is, tiny leaf-like appendages situated on both sides of the leaf’s petiole at the petiole base (Image 22 shows leaves emerging through the protective covering of stipules). Or leaf buds that are covered by the base of the leaf’s petiole—subpetiolar (Image 23)—which may still have protective scales once the old leaf falls off and they are exposed (Image 24). Or leaf buds that are partially hidden or fully imbedded within the stem tissue and located above a leaf scar in the axil of the leaf node (Image 25).



Breaking leaf buds

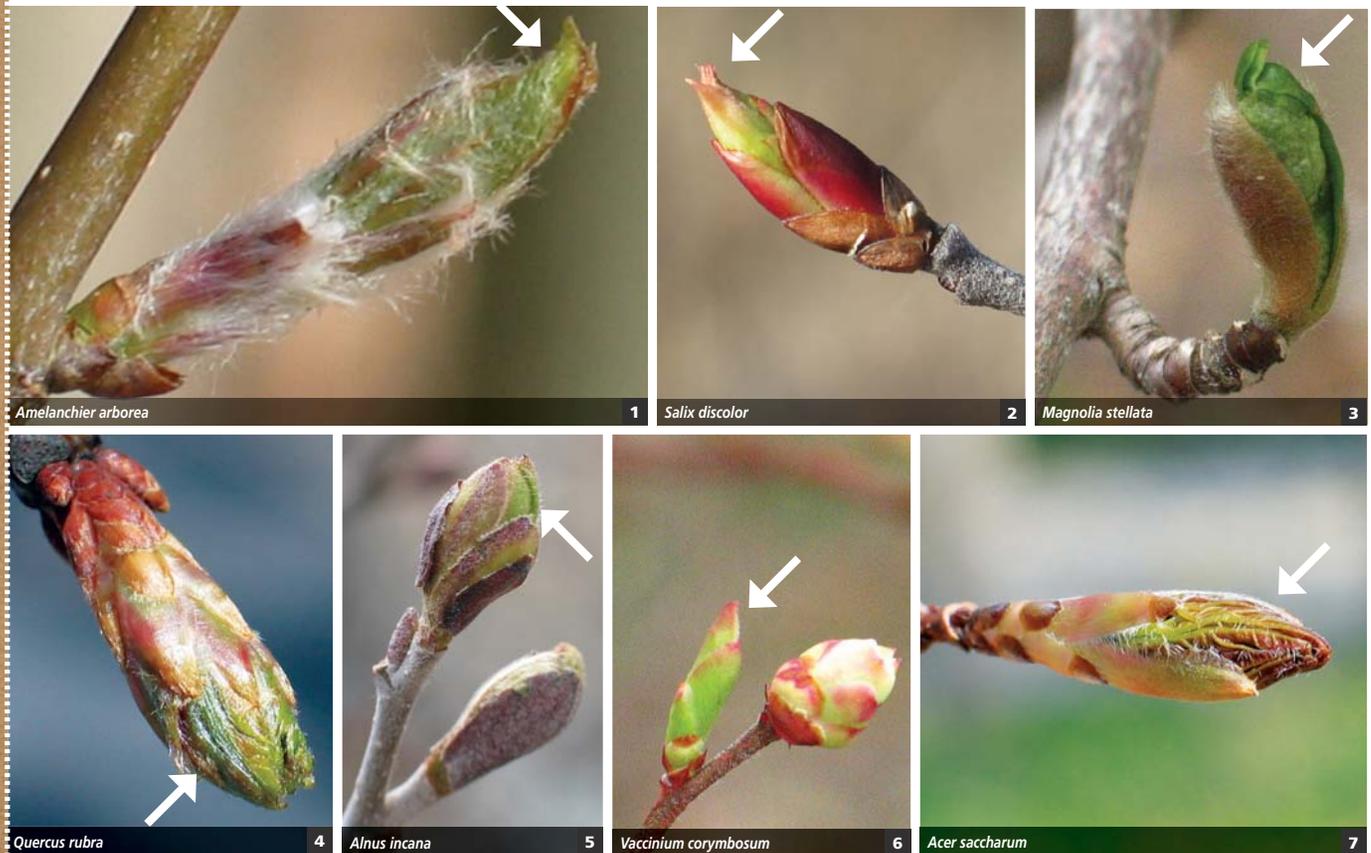
Tree or Shrub

One or more breaking leaf buds are visible on the plant. A leaf bud is considered "breaking" once a green leaf tip is visible at the end of the bud, but before the first leaf from the bud has unfolded to expose the leaf stalk (petiole) or leaf base.

The phenophase "Breaking leaf buds" captures the first emergence of leaves on a dormant plant at the beginning of a plant's active seasons. When all the buds on a plant have at least one unfolded leaf, the phenophase ends for the observed plant (for detailed explanations, see the section "An overview of unfolded leaves").

Deciduous trees and shrubs with scaled buds

Deciduous species whose buds have protective scales that cover the embryonic leaves of growing (meristematic) areas during a resting (dormant) phase, will "swell", signalling the plant's renewed activity. That is, the tight covering of bud scales over the embryonic leaves will loosen and expand—the bud appears to be swelling—gradually separating open so that the newly green and growing leaves can be seen at the bud's tip (some species' new leaves will appear yellow or reddish instead of green). At the point an observer sees newly growing leaves exposed between the scales of the bud, they should report "yes" for "Breaking leaf buds" (arrows in rows 1-2).





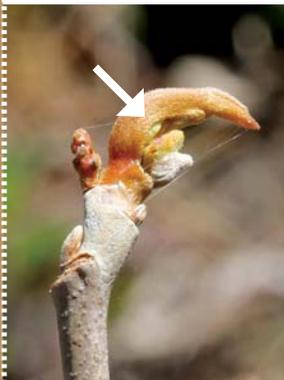
Rhododendron sp. 8



Arctostaphylos sp. 9



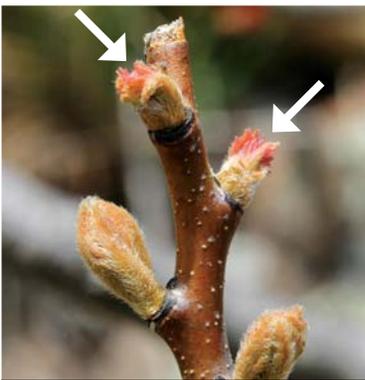
Kalmia latifolia 10



Toxicodendron radicans 11



Asimina triloba 12



Rhus glabra 13



Hamamelis virginiana 14



Rhus typhina 15

Evergreen trees and shrubs with scaled buds

Although evergreen trees and shrubs will retain leaves all year, their scaled buds will behave identically to those of deciduous species after a period of no leaf growth. The buds will begin to swell following a resting or dormant phase, and the scales will gradually separate and open so the newly growing leaves can be seen at the bud's tip (row 1).

Deciduous trees and shrubs with naked buds (no bud scales)

Images 11-15 illustrate species that lack bud scales, where protective leaves (of naked buds) are sometimes brown and remain that way during the dormant period. When the bud becomes active and begins to swell, the brown leaves begin to grow and get larger, yet remain their dormant color brown. The bud is considered "breaking" when the first green can be seen on the leaf's surface (arrows in Images 11, 12, 14). In some cases this first hint of leaf color could be red and not green (arrows in Images 13, 15). Once the first leaf's petiole or leaf base becomes apparent or, if it was apparent while in its dormant stage, once the leaf unfolds or unrolls enough to appear more or less a small version of the adult leaf, that bud is no longer in the "breaking" stage.

In tall trees, it may be very difficult to discern "Breaking leaf buds" and the observer may not be certain whether this phenophase has occurred until fully unfolded leaves are visible. If this is the case, the observer could report "?" for this phenophase if they suspect it is occurring but are not yet certain.

An overview of unfolded leaves

When is a leaf considered "unfolded"?

At the point when a leaf has "unfolded", *Nature's Notebook* considers the bud or shoot as transitioning from "Initial growth" or "Breaking leaf buds" into the next vegetative phenophase, either the "Leaves" phenophase or the "Young leaves" phenophase, depending on the type of plant it is. The definition for "unfolded" differs slightly depending on whether your plant species is a forb, grass, sedge, rush, or tree or shrub. Getting familiar with your plant species—in this case the characteristics and behaviors of its leaves—and its definition for an "unfolded" leaf will help you to determine the transition into the new phenophase, and enable you to record consistent, quality observations.

Note that each bud or shoot on a plant may transition to the "Leaves" or "Young leaves" stage at a different time. Therefore, an observer will often see "Initial growth" or "Breaking leaf buds" on their plant at the same time they see "Leaves" or "Young leaves", and when that is the case they should report "yes" to both.

Forbs

On this page are several series of images illustrating both annual and perennial forb species moving through "Initial growth" up to the point of the first "unfolded" leaf or leaves—arrows point out the unfolded leaf. Annual and perennial species differ slightly in their phenophase definition for an unfolded leaf, which is usually a small version of the mature leaf. Each species will have their own characteristic "look".

Annual forbs

Annual forbs shoots (row 1) begin as a germinating seed, pushing or pulling two cotyledons (seed leaves) above the soil surface. Between the two cotyledons one or two "true" leaves will emerge—generally minatures of the species' characteristic mature leaf shape. When an observer can first see an expanded true leaf blade, although it may still be tiny, the first leaf is considered to have "unfolded" (Image 3).

Perennial forbs

Perennial forbs (rows 2-4) begin their new seasonal growth as a new sprout pushing through the soil or from an above-ground stem node. When an observer first sees an expanded leaf blade, although it may not yet be full size, the first leaf is considered to have "unfolded" (Images 7, 9, 12, 16).



Evergreen forbs

Although evergreen forbs are generally not assigned the “Initial growth” phenophase, there may be a period of growth before the first new leaf has “unfolded” after a period of no leaf growth (row 1). Some species even have scaled buds that break. The definition for the first unfolded leaf in evergreen forb shoots is similar to that for perennial forbs—when you can see the first expanded leaf blade from the newly growing bud or shoot, even though it may not yet be full size (arrows in Image 20).

Graminoids

Despite the fact that each of the graminoid plants seems to have very similar leaves, they have different characteristics of leaf development. For each, being “unfolded” is slightly different.

Grasses

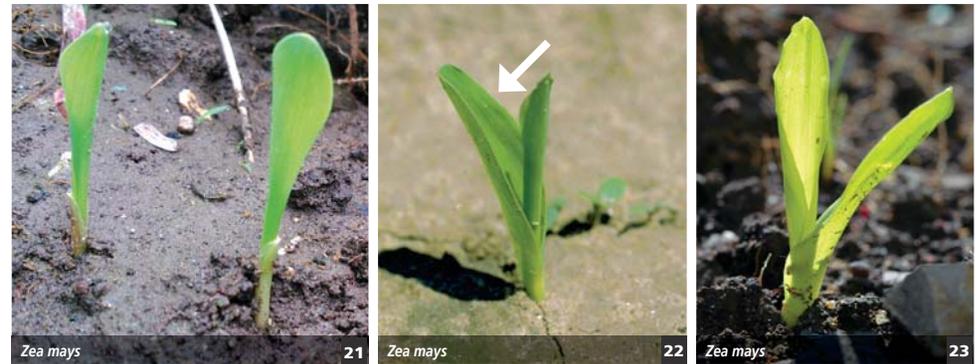
The first leaf of a shoot, initially wrapped tightly around the stem, is considered unfolded once it unrolls slightly from around the stem and begins to fall away at an angle. Row 2 illustrates the sequence with the arrow indicating the first unfolded leaf.

Sedges

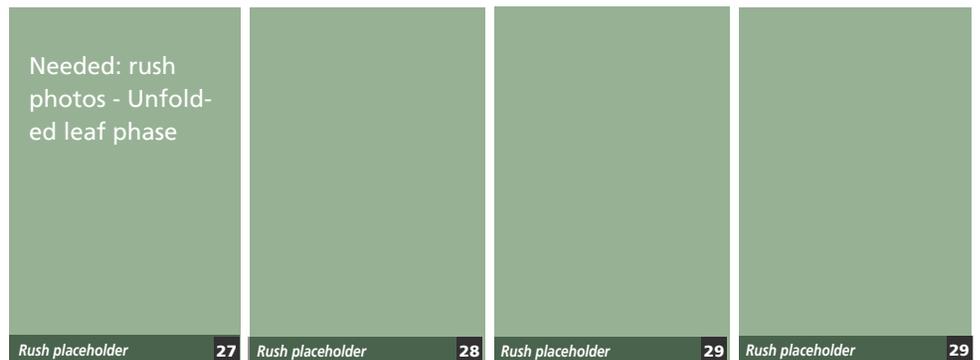
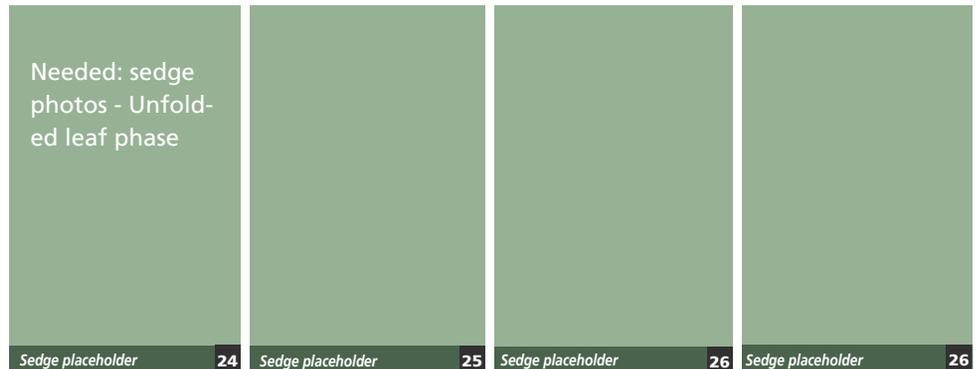
The first leaf of a shoot, initially folded tightly in half, is considered unfolded once it has grown long enough that the two halves of the leaf blade have begun to spread apart like the opening of a book. Row 3 illustrates this with the arrow indicating the unfolded leaf.

Rushes

A new leaf blade is cylindrical and does not really unfold in any way, it just gets taller. Therefore, to distinguish the transition between the “Initial growth” and the “Leaves” phenophases, we define “unfolding” as having occurred once the leaf blade has grown to 2 inches (5 cm) in height. Row 4 illustrates this with the arrow indicating the unfolded leaf.



Needed:
better
unfold-
ed leaf
photo
for im-
age 20



An overview of unfolded leaves (con't)

When is a leaf considered "unfolded"?

Generally, for deciduous or evergreen trees and shrubs, the *Nature's Notebook* definition identifies the first "unfolded" leaf as the point at which the leaf stalk (petiole) or leaf base (if there is no petiole) of the first new leaf from each bud or shoot can be seen by an observer. Often this means the leaf base and, or petiole becomes unhidden from between bud scales or other plant parts that protect and hide the tiny, new leaves. The type of leaf buds that are characteristic for any given plant species will influence how the definition is interpreted—as leaf buds having bud scales have a more clear-cut signal than those without bud scales.

Again, remember that each bud on a plant may transition to the "Leaves" or "Young leaves" stage at a different time. Therefore, an observer will often see "Breaking leaf buds" on their plant at the same time they see "Leaves" or "Young leaves" and when that is the case they should report "yes" for both.

Deciduous trees and shrubs

To the right are several image series of deciduous species shown from dormant, swelling or breaking leaf buds to the first unfolded leaf. The arrow indicates the unfolded leaf—where an observer can see the leaf base or petiole.

Deciduous trees or shrubs with scaled buds

Bud scales loosen and separate as the bud comes out of dormancy, and the leaves emerge, expand and unfold (rows 1 and 2).

Deciduous trees or shrubs with naked buds (no bud scales)

Protective leaves loosen and separate as the plant comes out of dormancy and begin to turn green (row 3). Once the first leaf's petiole or leaf base becomes apparent or, if it was apparent while dormant, once the leaf unfolds or unrolls enough to appear more or less a small version of the adult leaf, the first leaf of that bud has unfolded.

Deciduous trees or shrubs with scaled buds and sessile leaves (no petioles)

Bud scales loosen and separate, then the sessile leaves emerge, expand and unfold. An observer will only watch for the leaf base and not a petiole (row 4).



Evergreen trees and shrubs

Evergreen trees and shrubs retain leaves at all times—since each leaf will live one to several years, there is an overlap of older leaves and new leaves on it so that the plant remains green year-round. However, evergreen species often experience periods of no growth, followed by the initiation of new leaf growth. To the right are several series of evergreen species images shown from dormant, swelling or breaking leaf buds to the unfolding of the first new leaf. The arrow indicates the unfolded leaf—where an observer can see the leaf's base or petiole (leaf stem).

Evergreen trees or shrubs with bud scales

Buds swell and the bud scales loosen and separate as the plant's buds come out of dormancy and the new leaves emerge, expand and unfold (row 1).

In some species, the anatomy can differ enough to be visually confusing—such as the mountain laurel's sunken and hidden leaf buds (row 2) which emerge from the base of the petioles of the top whorl of leaves. These valvate buds (buds having two scales in which their edges meet mid-bud) first appear as little flat tongues around the terminal end of the stem and slowly develop. Eventually the two bud scales separate to expose the tiny leaves.

Evergreen trees or shrubs with no obvious bud scales

In some cases, evergreen trees and shrubs have non-typical branch and stem termini that are also called naked buds—when protective leaves tightly surround the embryonic leaves at the end of twigs and branches; these plants are often from warmer, dry habitats. Small, tightly enfolding leaves gradually loosen and separate, and enlarge, as the plant comes out of a rest period or dormancy. Other plant species in this category do not have protective leaves, although may have other protection by other plant tissues (row 3). Tiny leaves begin emerging from the end of a branch or twig at embryonic stem nodes.

Once the tiny leaf's petiole or leaf base becomes apparent or, if it was apparent while dormant, once the leaf emerges or unrolls enough to appear more or less a small version of the adult leaf, or the nubs of leaflets are visible, the leaf has unfolded.



An overview of unfolded leaves (con't)

When is a leaf considered "unfolded"?

Some trees and shrub species seemingly have no leaf buds. Often, these plants fall in a category called drought deciduous plants. Very tiny buds, then leaves, emerge from the stem nodes (the meristems) often located on stem tissue called a short shoot (tiny woody nobs having highly compacted stem nodes with very little or no stem internode between each node). After a period of plant stress or rest, the new leaves emerge quickly from the plant's stem nodes. Some species do this extremely quickly and just as quickly drop their leaves again, thereby minimizing water loss but maximizing their net photosynthetic activity. And as you might guess, what an observer would cue into for an "unfolded" leaf is slightly different for these species.

On these two pages we provide some images and accompanying explanations to guide an observer through these challenging observations.

Drought deciduous trees and shrubs

Drought deciduous trees and shrubs—which grow in desert and other dryland environments—drop leaves when the environment is stressful, and leaf out again when their resource needs are met. They often drop their leaves unpredictably during stressful episodes or predictably during a dormant period to become water efficient. And many have no discernable leaf buds—scaled or naked—but are quickly able to develop leaves from the meristem tissue at their stem nodes in response to sufficient resources, such as after a good rain storm. Often short shoot tissue is present at a stem node, with new leaves (and flower buds) emerging from the densely compressed nodes within this tissue. Watching closely, an observer will see new growth emerging from the nodes or short shoot, but only with experience will an observer be able to determine early if it is new leaf tissue or flower buds, as both can emerge from the same node. In some species the new leaves seemingly appear to emerge fully unfolded overnight and are tiny versions of a mature leaf. There may be no visible period of growth before the unfolded leaves appear.

On this page are four image series to help with visually understanding the "unfolded" leaf stage and some variations within drought deciduous species—each row of images shows a different species. The first image in each series shows dormant short shoot tissue present at a stem node. The arrow in each image series indicates an unfolded leaf for the species. Once a leaf has unfolded, an observer can distinguish the leaf's petiole or leaf base and for those species having compound leaves, the new leaf's leaflets. These plant parts are tiny—often just a quarter of an inch long—so, an observer will need to carefully observe their plant. In Image 67, the node has three separate short shoots, each one in a differing phase—the bottom right short shoot is dormant while the short shoot on the left is beginning activity with new plant tissue emerging at the tip, and the upper right short shoot in this image has new leaf tissue emerging. In Image 66 a short shoot has two areas of leaf tissue emerging—the upper activity is newly emerging leaf tissue while the lower area has a newly unfolded leaf.



Drought deciduous plants with unusual leaf characteristics

Ocotillo (*Fouquieria splendens*)

Ocotillo is a drought deciduous plant which displays two types of leaf growth: one type on the older part of the stems similar to plants discussed on the previous page where leaves emerge from axillary areas on short shoots, and another leaf type on the newly extending branches, at the end of each plant stem.

The first type of leaf growth occurs at the stem nodes on the long, stiff, spiny and often leafless stems that radiate from ground level (row 1 of images). New sessile leaves will emerge at stem nodes, in a spine's axil along the stem after a rain event (arrows in Image 77). As soon as a discernable leaf base is observed, the leaf is considered unfolded. These leaves will be dropped from the plant, sometimes very quickly, as the environment dries. This can occur several times in a year.

The second type of leaf growth occurs once a year as new elongating branches grow at the top of each of the spiny stems (row 2). Typically the new growth will have a reddish hue, with spine-like growths (the leaf petioles) each with a tiny leaf blade angled upwards at its end, that spirally alternate along the new stem. As soon as the tiny leaf blade is recognizable as a leaf, it is considered unfolded (arrows in Image 81). The leaf blade will drop off early as the branch develops, leaving a petiole that will stiffen into a new spine at a stem node with a leaf bud in its axil (Image 82). Stem elongation usually occurs only once a year, so any further leaf development during the year will occur along existing branches at stem nodes within the leaf axils.

Desert ceanothus (*Ceanothus greggii*)

Desert ceanothus (row 3) is an evergreen desert plant having no leaf buds although leaf stipules protect the meristematic regions at the stem nodes. The leaves slowly emerge from ends of the branches at meristems or at existing stem nodes, looking very much like miniature mature leaves early in their development. As soon as a discernable leaf base is observed, the leaf is considered unfolded (arrow in Image 86). In early spring, do not confuse the scaled, hairy flower buds for leaf buds.



Leaves

Forb

One or more live, fully unfolded leaves are visible on the plant. For seedlings, consider only true leaves and do not count the one or two small, round or elongated leaves (cotyledons) that are found on the stem almost immediately after the seedling germinates. Do not include fully dried or dead leaves.



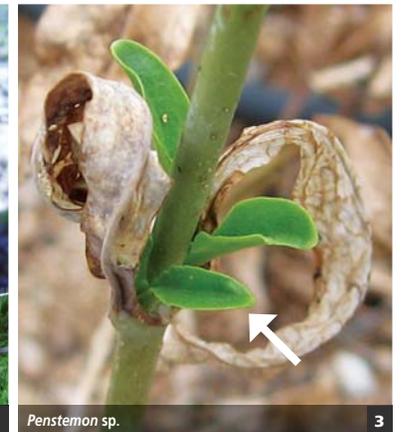
Helianthus annuus

1



Maianthemum canadense

2



Penstemon sp.

3

Forbs

The "Leaves" phenophase encompasses the entire period during which live unfolded leaves are present on an annual or perennial forb. This begins with the first unfolded leaf (see the previous section "An overview of unfolded leaves") and ends when the last leaf on the plant has withered and died. Note that evergreen forbs are not assigned the "Leaves" phenophase because by definition they have leaves all year round.



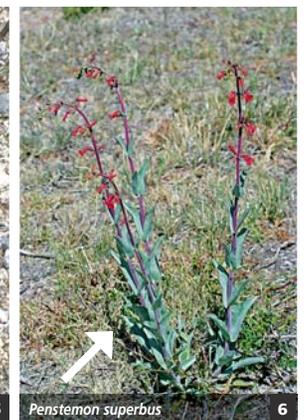
Penstemon palmeri

4



Penstemon sp.

5



Penstemon superbus

6



Leaves

Grass

One or more live, green, unfolded leaves are visible on the plant. A leaf is considered “unfolded” once it unrolls slightly from around the stem and begins to fall away at an angle from the stem. Do not include fully dried or dead leaves.

Sedge

One or more live, green, unfolded leaves are visible on the plant. A leaf is considered “unfolded” once it has grown long enough that the two halves of the leaf blade have begun to spread apart like an open book. Do not include fully dried or dead leaves.

Rush

One or more live, green, unfolded leaves are visible on the plant. A leaf is considered “unfolded” once the exposed, green portion of the leaf (or shoot) has reached approximately 2 inches (5 cm) in length. Do not include fully dried or dead leaves.



Paspalum dilatatum 7



Setaria macrostachya 8

Needed: sedge photos - Leaves phases in sequence

Sedge sp. placeholder 9

Sedge sp. placeholder 10

Sedge sp. placeholder 11

Needed: rush photos - Leaves phases in sequence

Rush sp. placeholder 12

Rush sp. placeholder 13

Rush sp. placeholder 14

Grasses and sedges

The “Leaves” phenophase encompasses the entire period during which green, unfolded leaves are present on the grass (row 1) or sedge (row 2) plant. This begins with the first unfolded leaf (see the previous section “An overview of unfolded leaves”) and ends when the last leaf on the plant dries up and turns brown at the end of the growing season.

Rushes

The “Leaves” phenophase encompasses the entire period during which green, unfolded leaves are present on the rush plant (row 3). This begins when the first new shoot reaches 2 inches in height (see the previous section “An overview of unfolded leaves”) and ends when the last stem of the plant dries up and turns brown at the end of the growing season.



Leaves

Tree or Shrub

One or more live, unfolded leaves are visible on the plant. A leaf is considered "unfolded" once its entire length has emerged from a breaking bud, stem node or growing stem tip, so that the leaf stalk (petiole) or leaf base is visible at its point of attachment to the stem. Do not include fully dried or dead leaves.

Trees and shrubs

The "Leaves" phenophase encompasses the entire period during which live unfolded leaves are present on a tree or shrub. This begins with the first unfolded leaf (see the previous section "An overview of unfolded leaves"), includes the periods while leaves are increasing in size and while changing in color, and ends when the last leaf has fallen from the tree or shrub, or has dried up and died in place on a plant. The following image series include trees and shrubs that are deciduous, drought deciduous, and semi-evergreen. Note that evergreen trees and shrubs are not assigned the "Leaves" phenophase because by definition they have leaves all year round.

Deciduous trees and shrubs

Deciduous trees and shrubs are woody plants having flat leaves during the plant's growing season but drop their leaves during dormant periods, namely winter. And, they have leaf buds that are large enough to observe when the plant is dormant.





Prosopis velutina

24



Prosopis velutina

25



Prosopis velutina

26



Prosopis velutina

27



Olneya tesota

28



Olneya tesota

29



Olneya tesota

30



Olneya tesota

31

Drought deciduous and semi-evergreen trees and shrubs

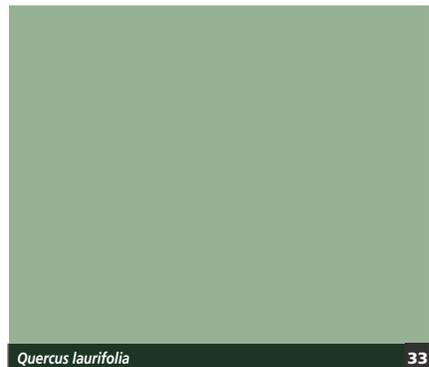
Drought deciduous trees and shrubs (rows 1-2) are dryland-adapted woody plants having flat leaves that may be evergreen, yet also may regularly drop off during stress, namely the dry periods. They have leaf buds that are too small to observe and leaves that develop sporadically, starting and stopping as needed, so that full-sized leaves are difficult to identify. Semi-evergreen trees and shrubs (row 3) are woody plants with flat leaves that may be evergreen in mild climates, but may drop off in more extreme climates or with stress. They have leaf buds that are large enough to observe when the plant is dormant.

Needed: laurel oak photos -
Leaves phases in
sequence



Quercus laurifolia

32



Quercus laurifolia

33



Quercus laurifolia

34



Quercus laurifolia

35



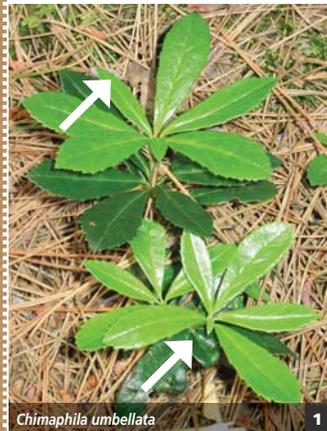
Young leaves

Forbs

One or more young leaves are visible on the plant. A leaf is considered "young" before it has reached full size or turned the darker green color or tougher texture of mature leaves on the plant. Do not include fully dried or dead leaves.

Forbs

This phenophase is included for evergreen forbs because they have last season's old leaves and newly growing leaves occurring on the plant at the same time. Although evergreen forbs retain live leaves all year round, there are distinct seasonal periods when new leaf growth occurs. The phenophase "Young leaves" captures the period of the plant's active growth. The observer can distinguish these young leaves from older leaves on the plant by differences in size, color and/or texture. In these images, the arrow indicates a young leaf that is smaller or a lighter green color than the mature leaves in the image. The phenophase ends when the size, color and/or texture of all of the newer leaves are no longer distinguishable from the older leaves retained on the plant.



Chimaphila umbellata



Goodyera oblongifolia



Sarracenia purpurea



Linnaea borealis



Darlingtonia californica



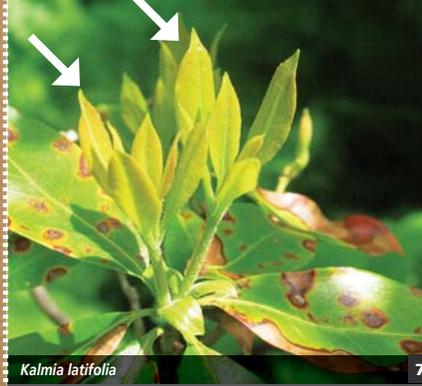
Asclepias subulata



Young leaves

Tree or Shrub

One or more young, unfolded leaves are visible on the plant. A leaf is considered “young” and “unfolded” once its entire length has emerged from the breaking bud so that the leaf stalk (petiole) or leaf base is visible at its point of attachment to the stem, but before the leaf has reached full size or turned the darker green color or tougher texture of mature leaves on the plant. Do not include fully dried or dead leaves.



Kalmia latifolia

7



Larrea tridentata

8



Quercus laurifolia (young leaves)

9



Quercus laurifolia (mature leaves)

10



Ligustrum sinense

11



Chilopsis linearis

12



Acacia greggii

13

Trees and shrubs

Tree and shrub species that usually, or occasionally, retain old leaves on the plant, but also have newly growing leaves on the plant at the same time are assigned this phenophase. During active leaf growth, young leaves can be distinguished from older leaves by differences in size, color and/or texture. In these images, the arrow indicates a young leaf that is smaller or a lighter green color than the mature leaves in the image. This phenophase ends when the new leaves can no longer be distinguished from the older retained leaves.

Evergreen

These species have leaves present all year round, with distinct seasonal periods when new leaf growth occurs (row 1).

Semi-evergreen

These species often behave deciduously in colder areas (drop all their leaves in autumn or winter) and evergreen in warmer areas. The “Young leaves” phenophase is important to record in the warmer areas to identify the seasonal growth period (row 2).

Drought deciduous

These species may or may not have old and young leaves present on the plant at the same time. It varies from year to year and month to month depending on rain and frost events (row 3).

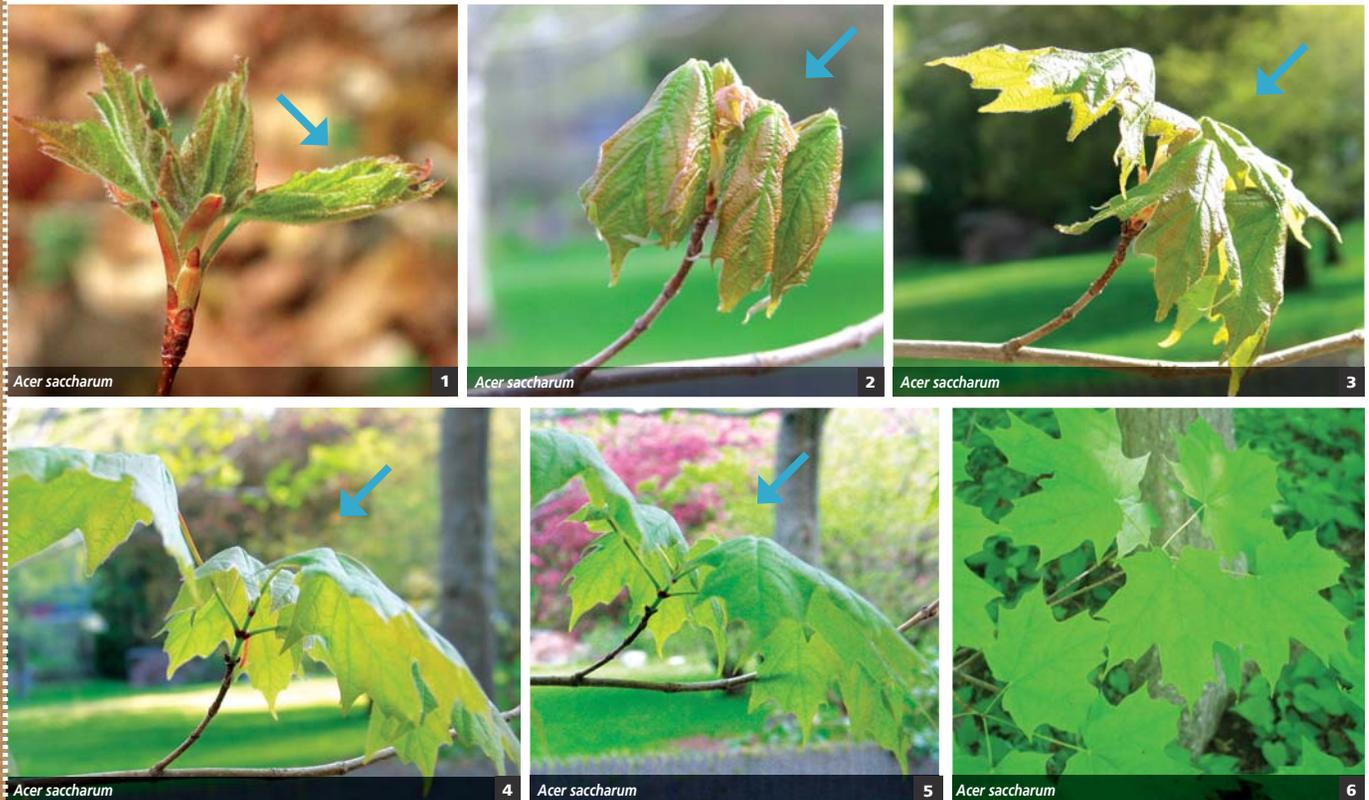
Increasing leaf size

Tree or Shrub

A majority of leaves on the plant have not yet reached their full size and are still growing larger. Do not include new leaves that continue to emerge at the ends of elongating stems throughout the growing season.

For deciduous plants having a single large flush of leaves at the beginning of the growing season, we observe "Increasing leaf size" beginning with the first unfolded leaf and ending when the majority of leaves from that flush have expanded to their full mature size. As they expand, leaves will often gradually change color from a lighter to a darker green and also might change from a soft, thin texture to a tougher mature texture. Each species has its own characteristic shape, size, and texture. Note that leaves on the same plant may grow to different sizes. For example, leaves growing in the shade on lower branches are larger and thinner than leaves growing in the sun of the treetop. Be aware that "full size" for these "sun leaves" will be smaller than the full mature size of "shade leaves" on the same plant. Also note that new leaves may continue to appear and grow from branch tips all season long. Ignore this continuing growth of new leaves in evaluating this phenophase.

The following series highlights sugar maple's development, with the first image showing a newly "unfolded" leaf (Image 1) and the last image showing full-sized, mature leaves for comparison (Image 6). Images 1-5 all exhibit the "Increasing leaf size" phenophase.



Increasing leaf size



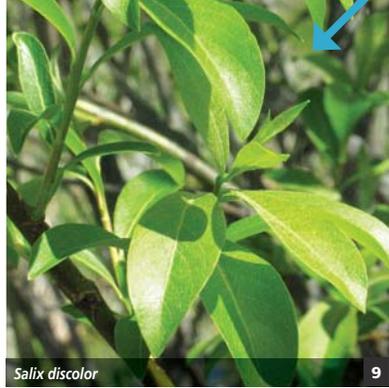
Salix discolor

7



Salix discolor

8



Salix discolor

9



Salix discolor

10

This page highlights additional tree and shrub species as they progress through the “Increasing leaf size” phenophase. The last image in each row shows full-sized, mature leaves of the species.



Vaccinium corymbosum

11



Vaccinium corymbosum

12



Vaccinium corymbosum

13



Vaccinium corymbosum

14



Quercus rubra

15



Quercus rubra

16



Quercus rubra

17



Quercus rubra

18



Quercus rubra

19



Colored leaves

Tree or Shrub

One or more leaves show some of their typical late-season color, or yellow or brown due to drought or other stresses. Do not include small spots of color due to minor leaf damage, or dieback on branches that have broken. Do not include fully dried or dead leaves that remain on the plant.

The "Colored leaves" phenophase captures the period when leaves begin to deteriorate and lose their green color, sometimes turning brilliant shades of yellow, orange or red. For a deciduous plant, photosynthetic capacity is diminishing towards the end of the growing season and generally ends when either all the leaves have dropped off the plant or when remaining leaves have dried up and become brittle. Color changes may also occur during times of extreme drought or insect infestations.

Image 1 captures a magnolia at the start of leaf color change, and Image 2 shows more advanced color change. Images 5-7 show a progression of color change in oak leaves. Image 8 captures the leaf color of desert ironwood, a drought deciduous species, occurring while flower buds are developing in the spring.



Magnolia stellata

1



Magnolia stellata

2



Prunus serotina

3



Rubus sp.

4



Quercus rubra

5



Quercus rubra

6



Quercus rubra

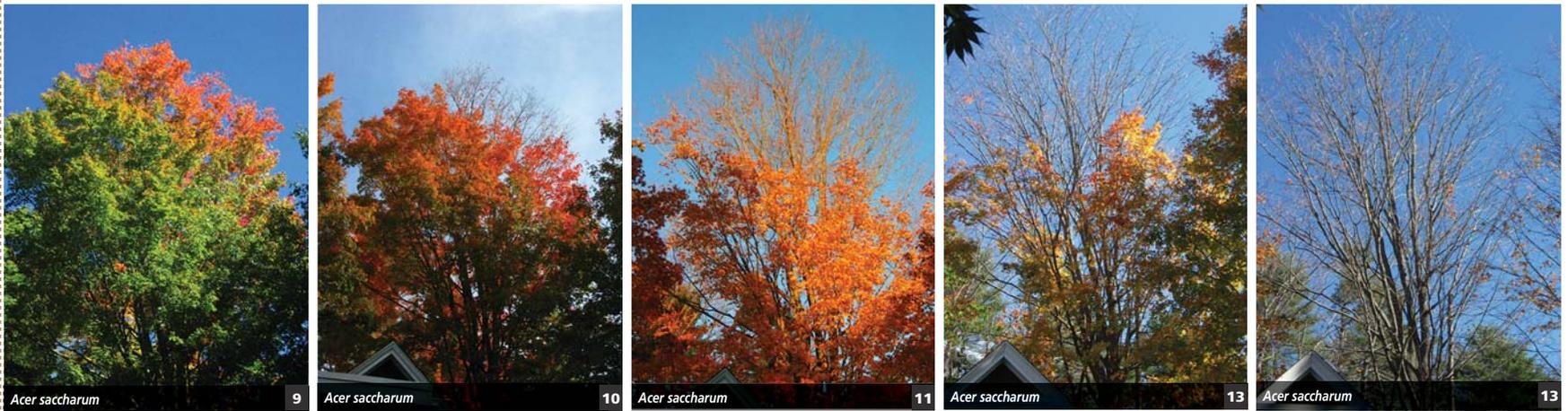
7



Olneya tesota

8





Row 1 shows a progression of end-of-season leaf color on a sugar maple. In some species the "Colored leaves" phenophase can come and go during the senescent season if all colored leaves drop off the plant, such as in a storm, yet green ones remain and subsequently turn color.

For some species, it is characteristic for dead, brittle leaves to remain on the plant for an extended period into the winter season. Other species may hang onto a few for a while, but then they will characteristically drop all of their dead leaves.



Leaves that remain on the tree or shrub yet have dried up and become brittle are no longer alive and not included as "Leaves" or "Colored leaves". When all remaining leaves on a plant have reached this dried and brittle stage, the phenophase has ended for the plant and an observer should report "no" for both "Leaves" and "Colored leaves". However, as long as *one* leaf remains on the plant that is partially alive with changed color, an observer should report "yes" for the "Leaves" and "Colored leaves" phenophases.

Falling leaves

Tree or Shrub

One or more leaves are falling or have recently fallen from the plant.



Hamamelis virginiana



Magnolia stellata



Betula papyrifera



Betula papyrifera



Betula papyrifera



Betula papyrifera



Betula papyrifera



Betula papyrifera

For deciduous, drought deciduous and semi-evergreen tree and shrub species observers watch for "Falling leaves" toward the end of the growing season when dying (senescing) leaves begin to drop from the tree. An observer might actually see leaves drop at the time of their observation, or they might notice that leaves had dropped since the last time they visited, in which cases they should report "yes" for "Falling leaves". They should report "no" for "Falling leaves" if it does not appear that anything dropped since their last observation.

Row 2 shows a progression of leaf fall from a paper birch. An increasing number of fallen leaves can be seen around the base of the tree.

Occasionally, several handfuls of healthy green leaves will fall during a strong spring or summer wind storm. The observer should ignore these and not report them as "Falling leaves".

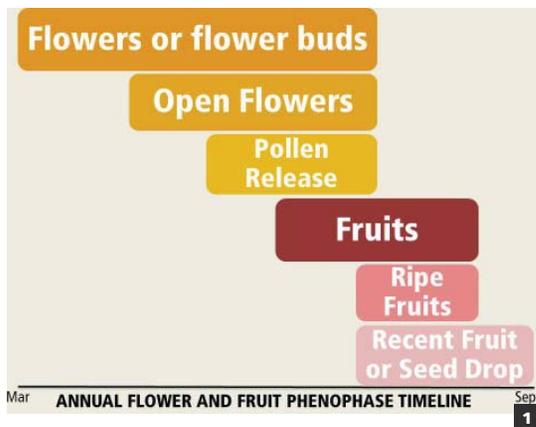




An overview of reproductive (flower and fruit) phenophases

How are they related to one another?

Please be patient with us while we develop the content for the following three pages. We have included these draft pages for readers to know that we plan to cover this information and include it in our final version of the *Phenophase Primer*.



These pages are in development... coming soon

The reproductive phenophases for *Nature's Notebook* plant species

Flowers—includes the *Nature's Notebook* phenophases:

- “**Flowers or flower buds**” is a phenophase that observers will watch for when their chosen plant
- “**Open flowers**” is a phenophase that observers will watch for when their chosen plant
- “**Pollen release**” is a phenophase that observers will watch for when their chosen plant

Fruits—includes the *Nature's Notebook* phenophases:

- “**Fruits**” is a phenophase that observers will watch for in all species
- “**Ripe fruits**” is a phenophase that observers will watch for in all species
- “**Recent fruit or seed drop**” is a phenophase that observers will watch for in all species



These pages are in development... coming soon



1

2

3

An overview of dormant flower buds

What do they look like?

Some thoughts for content:

- How to tell if bud is veg or flower
- have to get to know the plant
- might need to watch for a season to know
- watch closely for flower petals vs. leaf tips as the bud breaks—as soon as you see either part you can report yes for either BLB or FoFB
- When does flowers or flower buds start?
- Regular flowers (e.g. forsythia)
- Catkins
- Key point is to NOT report “yes” for overwintering dormant flower buds—wait until they start to swell

This is a critical element of when to start saying yes to flowers and flower buds.

Many plants set buds late in the fall—so an observer doesn't need to report on these buds until they are actively growing.

Get to know your plant so to understand what is a flower bud and what is a leaf bud, or mixed buds do.

These pages are in development... coming soon
Activity changes in dormant flower buds

Needed: two-photo series to show the dormant flower bud and then when it first starts to swell.

Species placeholder

1

Species placeholder

2

Species placeholder

3

Species placeholder

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Species placeholder

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Species placeholder

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Species placeholder

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Species placeholder

11



An overview of mixed buds

What do they look like?

Some plant species have mixed buds, where both embryonic leaves and flower buds develop within the same protective bud scales. Sometimes the new leaves and flowers will emerge from the bud at the same time, and sometimes one will precede the other. This means the observer must look closely to know when to begin reporting "yes" to "Breaking leaf buds" and "Flowers or flower buds". They should not report "yes" for "Breaking leaf buds" until they see the tip of a leaf emerging from the broken bud or the first green of leaf growing from a naked bud.

For many species that develop mixed buds, not all the buds on the same plant will be of a mixed type. Most likely an observer will also see buds having only new leaves (vegetative bud) or only new flowers (reproductive bud).

Often in species having both mixed and single-type buds, the mixed buds are larger and plumper when compared to vegetative or reproductive buds. Also within mixed buds, developing flowers often can be contained within their own bud covering—a bud within a bud.

Image 1 shows a mixed bud—look carefully to see the bud scales below the recently emerged leaves and flowers. You can see both the leaf petioles and the peduncle of the floral inflorescence emerge from between the same bud scales. For comparison, a careful look at Image 2 shows leaves emerging from within terminal bud scales and the flowers emerging from within two lateral buds' scales; the leaves and flowers are in separate—not mixed—buds!

Mixed buds with bud scales

Images 1, 3-5 show mixed buds with bud scales, their emerging leaves and flower buds or flowers. The observer should report "yes" to both "Breaking leaf buds" and "Flowers or flower buds" because expanding flower buds and leaf tips (but not yet petioles) are visible.

Mixed buds without bud scales

Image 6 shows a species which has naked buds (no bud scales) and has flower buds emerging from between tiny new leaves. The observer should report "yes" to "Flowers or flower buds", but "no" to "Breaking leaf buds" because the leaves have not yet begun to open and show green (see "An overview of unfolded leaves").

Some other variations

Species having leaves without leaf buds can have reproductive (floral) buds that do have bud scales—occurring at the same node! See page 29, Image 85 for an example. Get to know your species so observations are easier and accurate.



Oemleria cerasiformis



Acer rubrum



Sambucus racemosa



Magnolia stellata



Acer negundo



Viburnum lantanoides



An overview of flowers and inflorescences

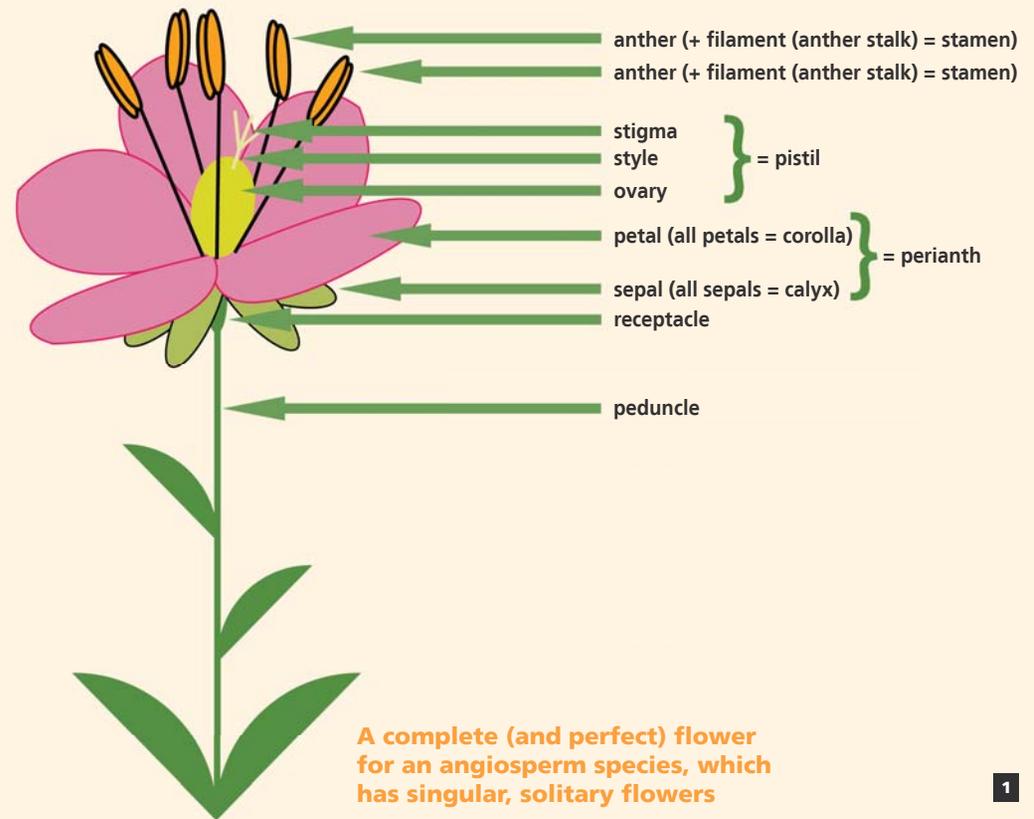
A flower is a highly evolved structure within the angiosperms (flowering plants) that supports an angiosperm species' ability to reproduce, and sustain and promote that species. Over the spectrum of angiosperm species there is enormous variation in floral structures (and reproductive strategies). On these pages we cover only the basics, just enough to familiarize the observer so they can begin to understand what they are seeing on their plant.

This subject is also covered in more detail in the USA National Phenology Network's *Botany Primer* in the section "Flowers and Inflorescences". Look for the chapter titles "About Flowers", "About Basic Flower Variation", and "About Inflorescences or Clustered Flowers". Links can be found to download it on USA-NPN's "Our Reports" webpage (usanpn.org/pubs/reports#Education), or it is available for purchase.

The organization of flowers and their parts

The diagram below offers a glimpse at the basic structure of a *complete* flower, that is, a flower having all of its parts. A typical and common flower type has four whorls of floral parts: the sepals (collectively in one flower called the calyx), the petals (collectively in one flower called the corolla), the stamens (collectively in one flower called the androecium), and the pistil(s) (collectively in one flower called the gynoecium). The sepals and petals in one flower, collectively, are called the perianth and are attached below, and surround, the reproductive flower parts, the stamens and pistils. These floral parts are attached in various ways atop the receptacle, which sits atop the flower stalk (a peduncle if the flower is solitary, or a pedicel if the flower is contained within an inflorescence). Each plant species has its own floral design and alterations, sometimes with parts missing, or combined, or so similar as to not be easily distinguished (as in flowers with identical sepals and petals—then called tepals).

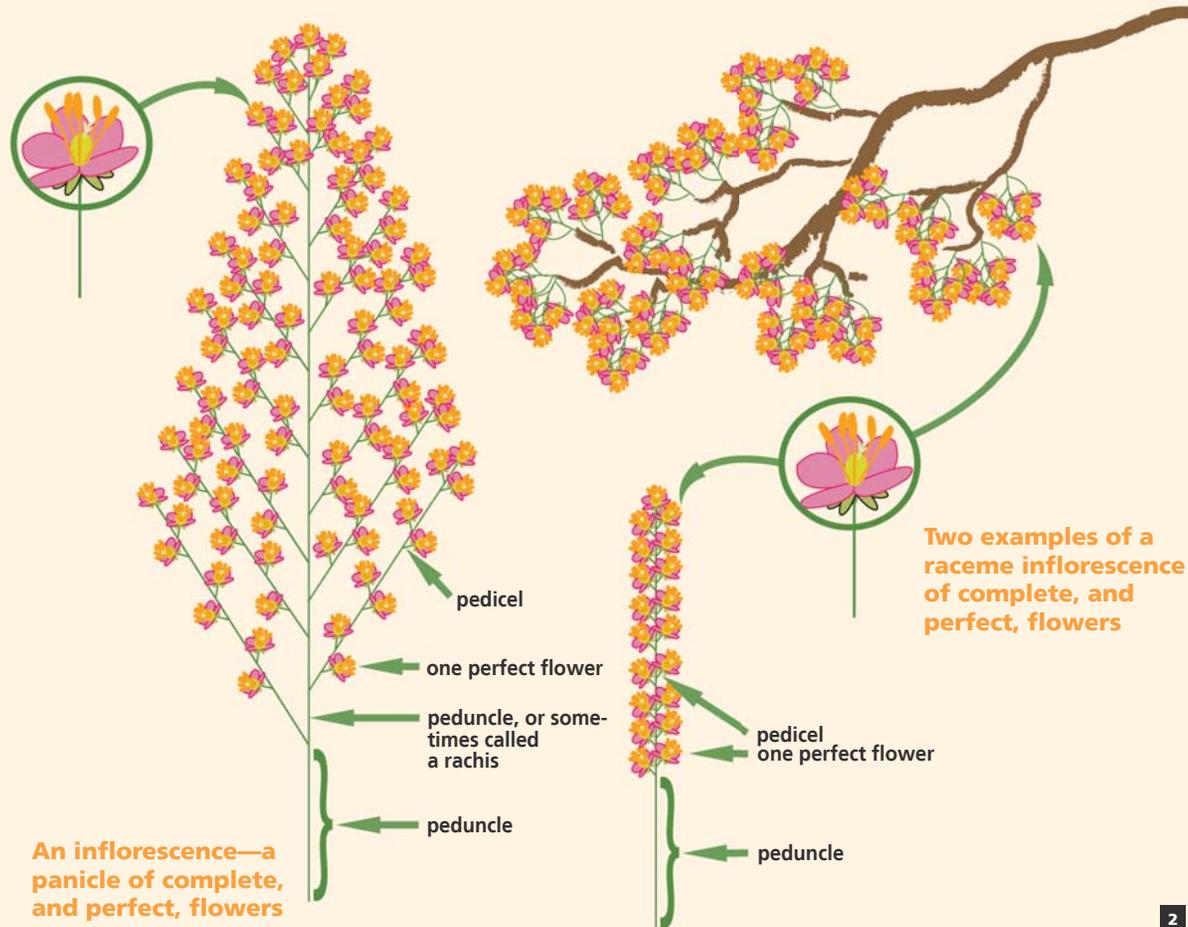
The observer should keep in mind that their species' flowers may be organized differently than in the basic diagrams provided on these pages.



The inflorescence—patterns of clustered flowers

Many species cluster their flowers into simple, or very complex, patterned arrangements—an inflorescence. The intent of these designs and configurations is primarily to create a floral display that increases visibility, and appeal, for the necessary pollinators, or, in wind-pollinated species, to efficiently release and receive pollen. The diagrams below highlight two different types of inflorescences (there are many basic types, and in addition, many complex combinations of the basic types). To the right are a few examples: Image 3 shows a forb with one solitary flower; 4, a tree with many solitary flowers; 5, a spike-like panicle of racemes; 6, a raceme; 7, a catkin; 8, a succulent with a panicle; 9, a tree with many panicles; 10, a capitulum; 11, a corymb of capitula.

Once all the ovaries have been fertilized and fruit begins developing, an inflorescence is called an infructescence.



2



Kallstroemia grandiflora 3



Magnolia x soulangiana 4



Verbascum thapsus 5



Lupinus sp. 6



Prosopis velutina 7



Yucca baccata 8



Sambucus racemosa 9



thistle 10



Achillea millefolium 11



Flowers or flower buds

Cactus, Forb, Tree or Shrub

One or more fresh open or unopened flowers or flower buds are visible on the plant. Include closed and not actively growing (dormant). Also do not include wilted or dried flowers.



For the "Flowers or flower buds" phenophase, an observer should report "yes" as soon as previously-formed flower buds have become active after dormancy or newly-formed flower buds are identified on the plant. An observer should continue reporting "yes" for this phenophase until the last flower on the plant completes its floral activities, and the plant's reproductive effort shifts exclusively to fruit development. The image series on these pages—a cactus above and a forb below, and shrubs and trees on the following pages—show examples of flower development with arrows identifying "Flowers or flower buds". The last image of each series shows a "spent" flower, each species having characteristic signs of the end of active flowering. Becoming familiar with the characteristics of your species will help you to identify and more accurately report the status of flower buds and flowers on your plant.





Kalmia latifolia 13



Kalmia latifolia 14



Kalmia latifolia 15



Kalmia latifolia 16



Kalmia latifolia 17



Kalmia latifolia 18

The two image series on this page sequence the "Flowers or flower buds" phenophase of a representative evergreen shrub (above) and a drought deciduous tree (below). Both of these species have complex floral displays of grouped flowers—in inflorescences. The arrows identify the period of activity to be recorded by an observer for this phenophase: from the initial development of flower buds through open flowers and active reproductive flower parts an observer should report "yes" to "Flowers or flower buds". Each of these species signal the completion of floral activity with wilting and drying flower petals, the last image of each series showing wilted or dried flowers.



Olneya tesota 19



Olneya tesota 20



Olneya tesota 21



Olneya tesota 22



Olneya tesota 23



Olneya tesota 24



Olneya tesota 25



Tiny flowers tightly clustered into a crowded inflorescence

Plant species having very tiny flowers can have their flowers arranged into dense inflorescences that appear to be a single unit, such as a catkin (in pussy willows and other willows, maples, birch, mesquite), a capitulum (daisies) or a spadix (cattails, jack-in-the-pulpit). This page highlights one of these inflorescence types—the catkin. Row 1 of images displays a monoecious species having separate male and female flowers in separate catkins, and whose catkins have a dormant, resting phase during winter (Image 26 shows dormant catkins). Row 2 shows a species that has flowers with both male and female parts in its catkins (perfect flowers) which are fresh, active and ready to develop when they first appear.

For many species with catkin characteristics, a special species-specific description of what to look for is added to the "Flowers and flower buds" phenophase definition in *Nature's Notebook*. For gray alder (row 1), this additional floral description states: "For *Alnus incana*, the male inflorescence is a catkin which is initially compact and stiff, but eventually unfolds to become longer and hang loosely from the branch. The female inflorescence is also a catkin which is very small, reddish, and has leafy scales. Once the female flowers wilt, the catkin turns green and grows thicker as the fruits develop." An observer should start reporting "yes" as the catkins become active after dormancy (male catkins in Images 27-30; female in Images 32-33) and then report "no" for the plant when all the male flowers on the plant have opened, released their pollen, and are showing signs of wilting and/or drying (Image 31), and the all female flowers (or exposed parts such as stigmas) have wilted and/or dried or fruits have begun to develop (Image 34). For images in row 2, an observer should start reporting "yes" when the catkin first appears (Image 35) and continue reporting "yes" throughout the series until all the flowers are wilted (not shown).



Unusual or difficult floral characteristics

Flowers can be inconspicuous by their size, color, or position on the plant. Non-typical flowers can be confusing, such as those missing floral parts or with unusual reproductive arrangements. This page offers a few examples of plant species with unusual and/or difficult-to-observe flowers.

In oak species, female oak flowers are very tiny and hide in the axils of new leaves. They can occur as a single flower or in a small cluster of flowers which still, collectively, are inconspicuous, tucked deep in the leaves, and—to add to the complexity—up high in the canopy of large trees. In some species, they are brightly colored, yet still difficult to see. Their male counterparts are dangly catkins, and despite each of the catkin's flowers being tiny, the long dangly group of them enable them to be visible when they are active. See row 1 for a sample of the flower's location on the tree, and a look at several female oak flowers of different species (arrows).

Jack-in-the-pulpit also hides its tiny flowers (row 2). Its species-specific phenophase definition reads "For *Arisaema triphyllum*, watch for the presence of the brown-striped pulpit (spathe), which contains and hides the flowers. Please do not tear open the pulpit to look for the individual flowers." Therefore, if an observer sees the floral structure shown in Image 45, they should report "yes" for "Flowers or flower buds" without trying to look inside—the cut-away glimpse of the female flowers in Images 46-47 is offered solely for observer information (the male flowers occur on a separate plant for this species).

Desert hackberry (row 3) also has flowers that are easy to miss; tiny green, non-showy, unisexual flowers (described as inconspicuous) that are missing floral parts and hidden within the leaves (arrows in Image 48). Image 49 shows the teeny male flowers, and Image 50, the tiny female flowers. Look carefully at your plants to get to know their flowers!



Quercus pacifica

42



Quercus rubra

43



Quercus imbricaria

44



Arisaema triphyllum

45



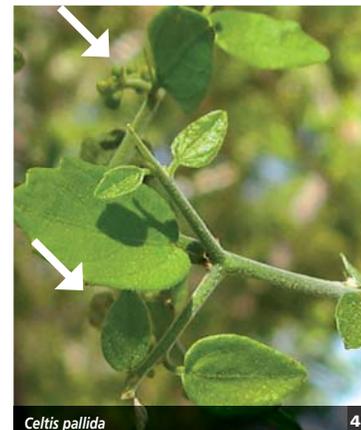
Arisaema triphyllum

46



Arisaema triphyllum

47



Celtis pallida

48



Celtis pallida

49



Celtis pallida

50

An overview of grass flowers and flower heads

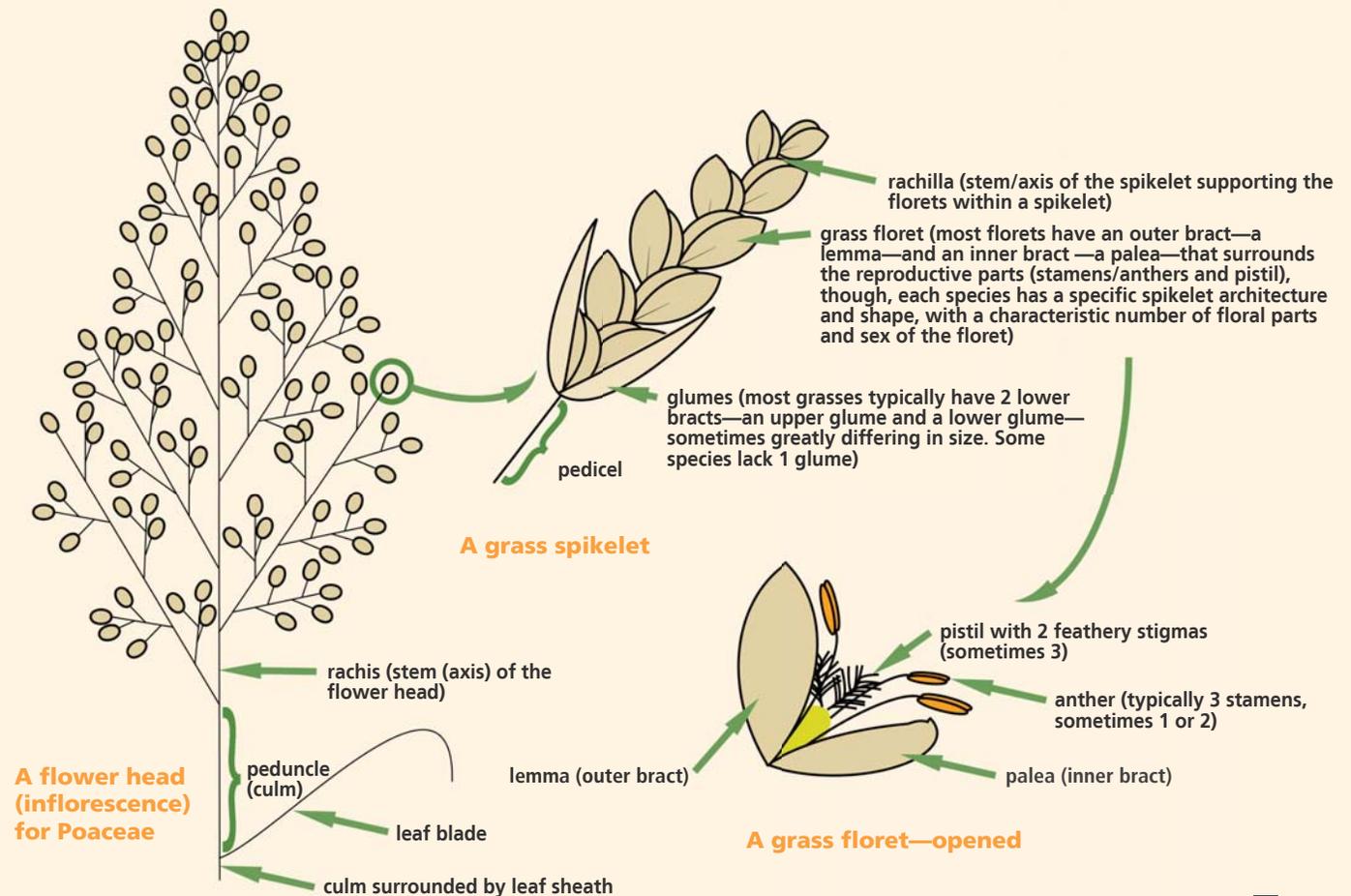
These pages provide a glimpse at graminoid (grass-like) flowers and flower heads (inflorescences). Grasses, sedges, and rushes all belong to the angiosperm (flowering plants) group of plants, yet their flowers are highly modified and sometimes difficult to interpret. These tiny, inconspicuous flowers are often wind pollinated, foregoing showiness for efficiency in their reproductive effort.

Becoming familiar with the anatomy for these types of plants will enable you to determine when your plant becomes reproductively active, and make accurate phenophase observations for the grasses' flowers.

Grass flowers—called florets—are very tiny and inconspicuous, and grouped into a uniquely basic and compact, characteristic structure—a spikelet—that has bracts attached below the one to many tiny florets. These spikelets are again clustered into a larger group—the flower head or inflorescence—which holds one to hundreds of spikelets in a unique and characteristic arrangement diagnostic for each species in the grass family, Poaceae.

The organization of grass flower parts in the family Poaceae

The diagram below very generally illustrates a grass inflorescence and the floral parts that comprise it; each species has its own unique architecture and size—and floral variations. The spikelet and florets diagrams are only a very general example for all grasses—to familiarize observers with the basic floral structure of grasses.



1



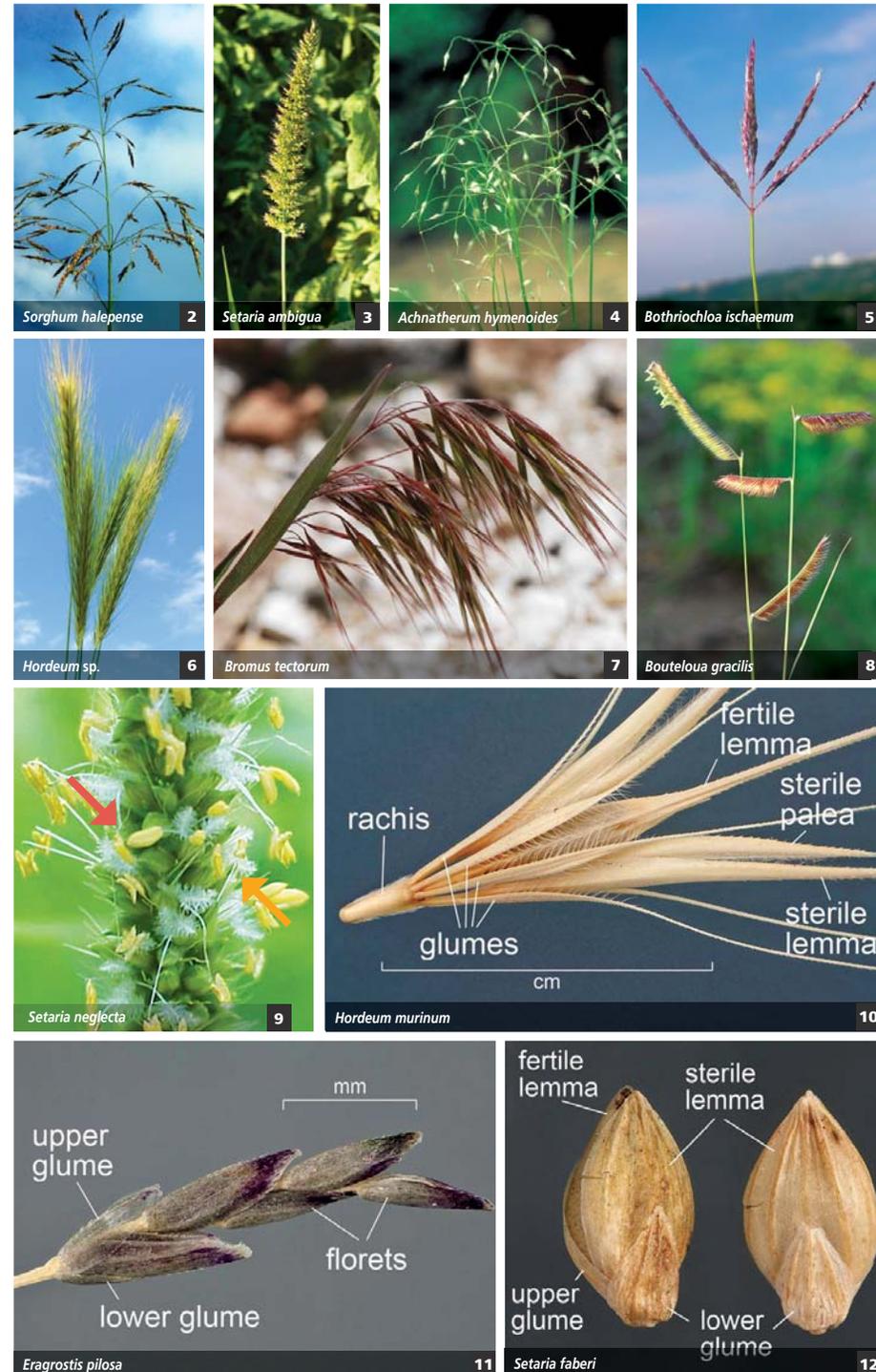
The variety of grass flower heads (inflorescences) in the Poaceae plant family

There are a wide array of arrangements in grass inflorescences (flower heads) in the grass plant family—rows 1 and 2 are a small sampling of the variety (Image 2, a panicle; 3, a spike-like panicle; 4, a panicle with flexuous branches; 5, a panicle of sub-digitate racemes; 6, a spicate raceme; 7, a pendulous panicle; 8, a panicle of spike-like branches that are one-sided and double-rowed racemes). As the diagram on the previous page shows, the basic floral unit is the spikelet and many spikelets are clustered in various patterns and grouped within an inflorescence. The number of glumes contained in one tiny spikelet along with the number of florets—and their sex and how they are arranged—is unique and characteristic for each species. In addition, a number of species are monoecious—that is, male and female flowers occurring in different areas within a single inflorescence. There also are dioecious species (unisex plants), and often the separate plants and their inflorescences can be dimorphic—that is, they have a distinctly different appearance from one another despite being the same species.

The florets and spikelets

As described, a grass spikelet is the most basic unit of the clustered florets found within a grass inflorescence and found on its pedicels and branches. The spikelets may occur singly along a branch or may also be clustered in various arrangements along the stem or branch. Spikelets have a great variety of forms—yet there is a basic structure of the spikelet for all grasses. That is: two glumes (an upper and lower) at the base of the spikelet attached just below the florets (Image 11), and each floret having one lemma (lower floral bract) and one palea (upper floral bract) and reproductive parts (pistils and stamens). Depending on species, spikelets may be missing parts—usually due to evolutionary developments. For grass florets, bracts replace petals and sepals—grasses have two floral bracts, the lemma and the palea which surround and protect the reproductive parts. When bracts are present but have no functional reproductive parts to protect, the floret is referred to as "sterile" or "reduced" (see sterile lemma and palea in Images 10, 12).

See Image 9 for a look at florets with extended feathery stigmas (orange arrow) and yellow anthers (red arrow). When the reproductive parts are extended like this, an observer should report "yes" for the "Open flowers" phenophase. If florets are sterile, they will never have "Open flowers".



An overview of sedge flowers and flower heads

Sedge florets are similar to grass florets—their flowers are highly modified and sometimes difficult to interpret. Sedges, as grasses, are also referred to as "graminoids". Their tiny, inconspicuous flowers are often wind pollinated, foregoing showiness in their reproductive effort.

Despite their similarities to grasses, the anatomy of sedges is slightly different. Becoming familiar with these plants will enable you to make accurate observations when your plant's flowers do open or become reproductively active.

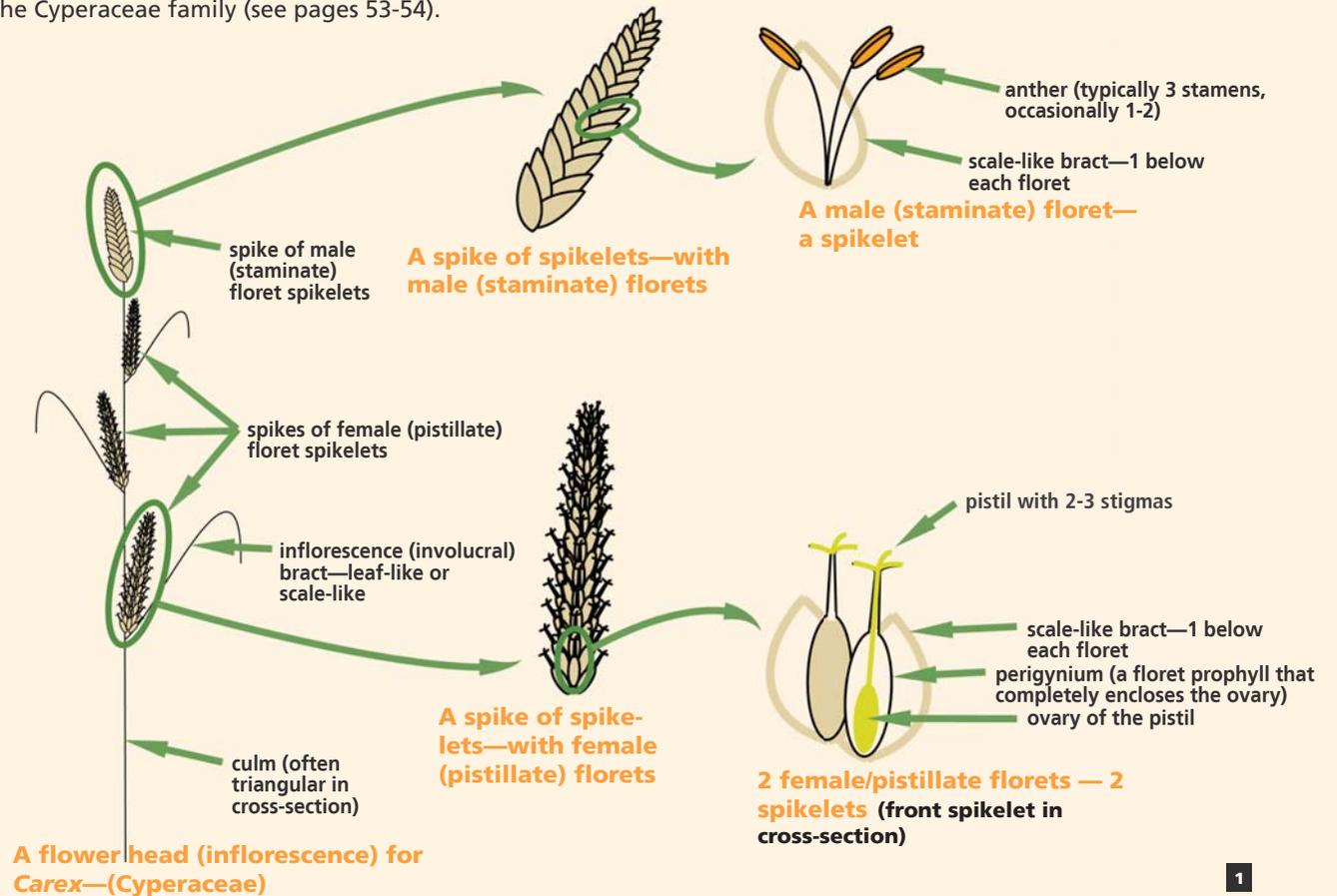
Sedge florets are very tiny and inconspicuous, and grouped into a unique, characteristic structure having one to many florets. Each floret often has a scale leaf attached at the base of each flower, and may have bristles or a scale-like bract attached beneath the reproductive parts (depending on species)—the scale-like bract replaces, or bristles are, the perianth (petals and sepals) of the flower.

There are several different floral patterns for the sedge family, Cyperaceae. The diagrams over the next four pages provide a glimpse at some generalized structures of different types an observer might come across.

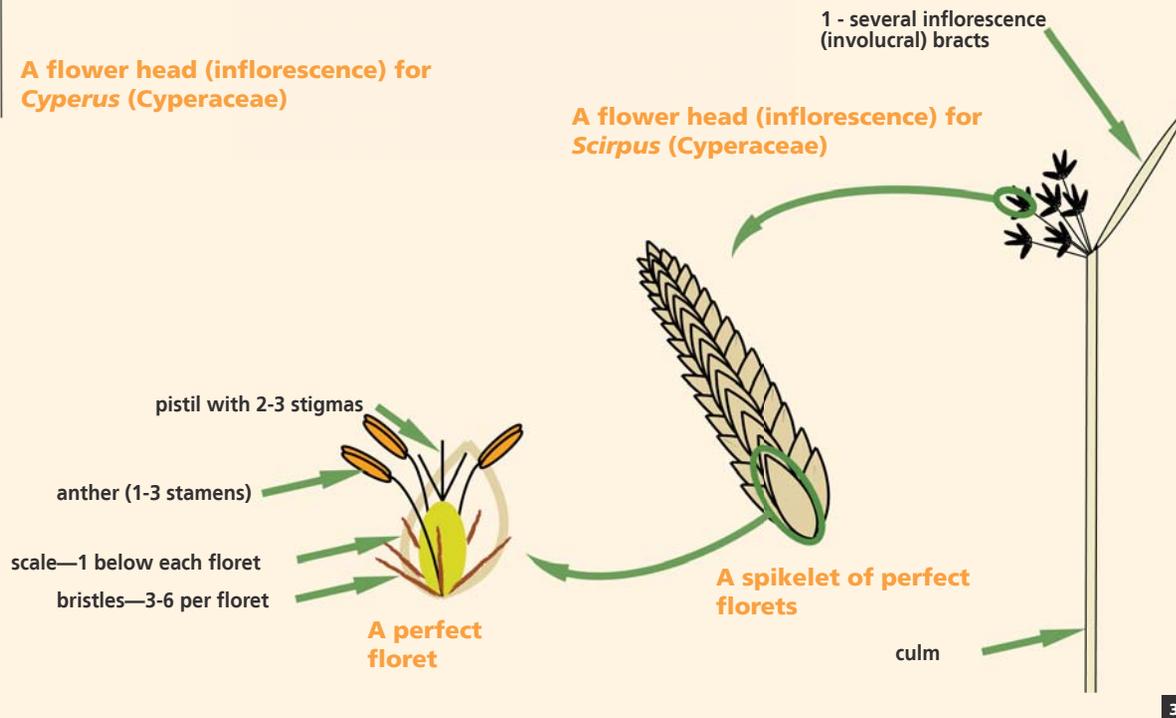
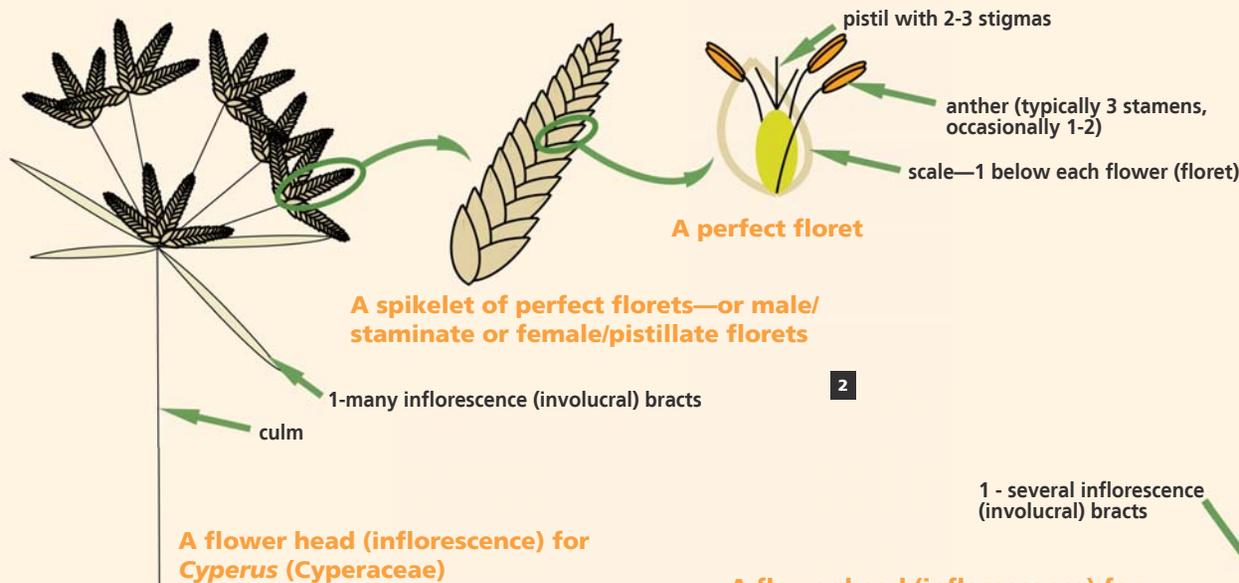
The organization of sedge flower parts in the genus *Carex*

The diagram below illustrates a generalized sedge inflorescence specifically for the genus *Carex*, and the floral parts that comprise it. Keep in mind each species has its own unique architecture and size and floral variations; the spike, spikelet, and floret diagrams shown here are a very general example. The common characteristic, though, is the monoecious (male or female) flowers arranged in various patterns within a spike. Also, for female flowers of *Carex*, a modified, bottle-like or bag-like bract (perigynium), occasionally flattened, completely surrounds the pistil with stigmas protruding from an opening at a top. The male and female spikes are then arranged into a larger grouping—the flower head or inflorescence—which is comprised of one to several spikes in a characteristic arrangement diagnostic for each species.

This characteristic grouping of florets and their specific terminology differs in the genus *Carex* from the other genera in the Cyperaceae family (see pages 53-54).



The organization of sedge flower parts in the genera *Cyperus* and *Scirpus*



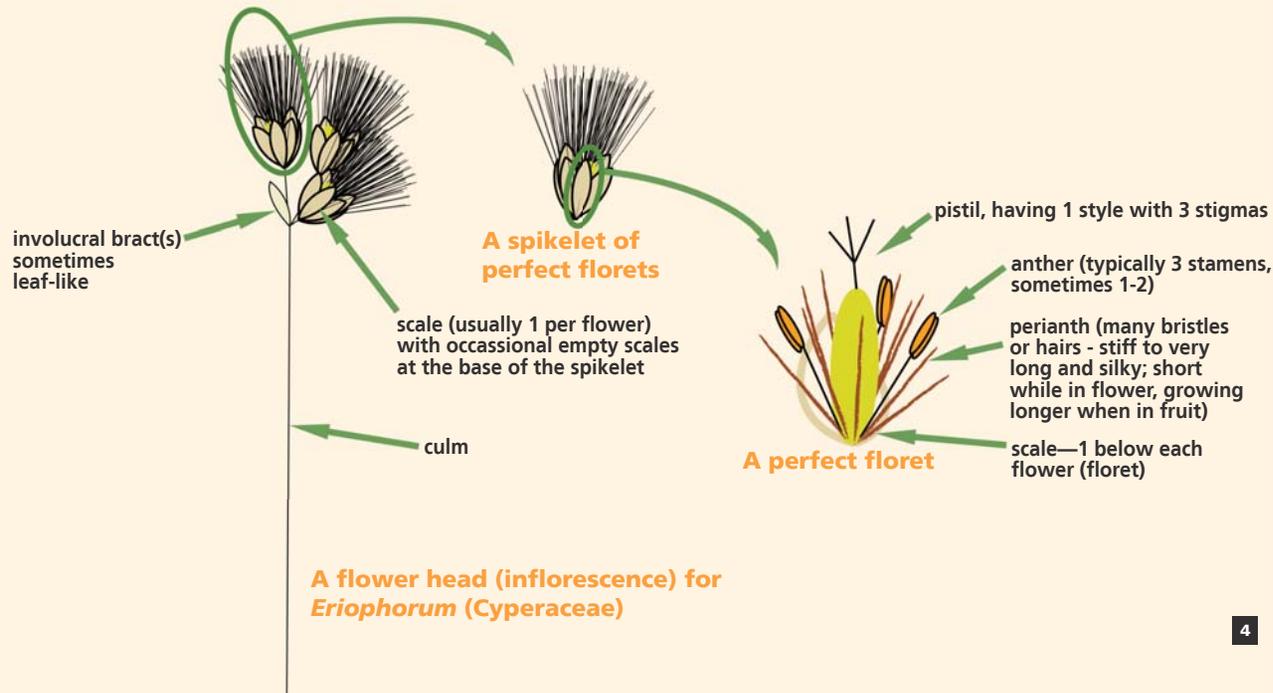
Most other genera in the Cyperaceae plant family do not have a perigynium that surrounds or partially encloses the pistil, as the genus *Carex* does. Nor are many species monoecious or dioecious, having unisexual florets. For most genera in this very large plant family the florets are perfect—that is, they have both male and female reproductive parts within each floret. The two illustrations on this page highlight genera that have inconspicuous, highly modified flowers or florets, yet are perfect. Genera and species like Diagram 2 have no perianth (petals, sepals, tepals, bristles), yet genera and species similar to Diagram 3 do have a perianth typically comprised of various types of bristles.

Although most sedge species' florets other than *Carex* are perfect (bisexual), there are a few exceptions in every genera. Occasional species within a genera having perfect florets may be monoecious or dioecious—and when monoecious, their spikelets may contain only one sex of florets, or may have other combinations. Generally, male (staminate) florets occupy the top tier of the spikelet and female or pistillate florets are below them.

Getting to know the species you have chosen will be helpful with your phenophase observations.

The organization of sedge flower parts in the genus *Eriophorum*

The sedge species having florets with bristles (for a perianth) differ tremendously. The bristles are typically short during the "Open flower" phenophase, and in many species remain short, or they slightly elongate or fall off as the fruit develops (such as those of Diagram 3). Conversely, for many species in the genus *Eriophorum*, once the fruit begins developing, the bristles often elongate into silky, cottony strands that catch the wind and obscure the floral scales and fruits (see Diagram 4 below and Image 31 on the next page). So pretty!



Open flowers in a sedge

The images on the right offer glimpses of "Open flowers" of various types in the family Cyperaceae. Row 1 of images includes species in the genus *Carex*; row 2, *Scirpus*; row 3, *Cladium* and *Cyperus*; and row 4, *Eriophorum* (red arrows indicate male reproductive parts, orange arrows indicate female reproductive parts). It is not unusual for the male and female flower parts to be active at separate times. As long as one sex is active in a flower, the flowers are considered "open". This separation of activity encourages cross-pollination and supports recombination of genetic material. An observer should report "yes" for the "Open flowers" phenophase if they see fresh and active male or female reproductive parts.



The variety of flower heads (inflorescences) of various genera of the Cyperaceae plant family

There are numerous inflorescence arrangements for sedge, bulrushes, and the grass-like sedge species—to the right is a very small sampling of the wide variety of architectures of inflorescences found in Cyperaceae.

Row 1 of images shows some of the variations of *Carex* species (commonly called "sedge") inflorescences. The floret is always monoecious (only male or female), but each spike may have only male or female florets—or may have both types—depending on a species' unique characteristics. Often each of the florets has a tiny leafy scale beneath it. And, each of the female florets has a modified scale called an perigynium (also called a "utricle") that completely surrounds the pistil of the flower; they have a bottle-like shape, although occasionally are flattened (see Diagram 1 on the previous pages in this section for details). They have no perianth (petals or sepals).

Row 2 highlights *Scirpus* and *Schoenoplectus* ("bulrush") inflorescences. Each of the tiny flowers in a spikelet may have a scale leaf under each floret, and each floret is perfect having both male and female reproductive parts. Each floret has 0 to 6 bristles, depending on species, that surround the pistil and stamens of the flower (see Diagram 3). The bristles replace the petals and sepals of the flower, and are of various types depending on species. Row 3 highlights plant species in the genus *Cladium* ("sawgrass") and *Cyperus* ("flatsedge"). These florets may each have a scale below and are bisexual, but differ from the bulrushes by not having bristles surrounding the pistils and stamens (see Diagram 2). There is no perianth.

Row 4 highlights an *Eriophorum* ("cottongrass") inflorescence. Each of the florets in a spikelet are perfect. And, below each of the florets is a scale leaf. Also, the florets have bristles that surround their pistil and stamens (see Diagram 4 for details). The bristles are typically short while the flower is open, but grow longer, often very long, silky and/or fluffy when the fruit develops—thus, "cottony".



An overview of rush flowers and flower heads

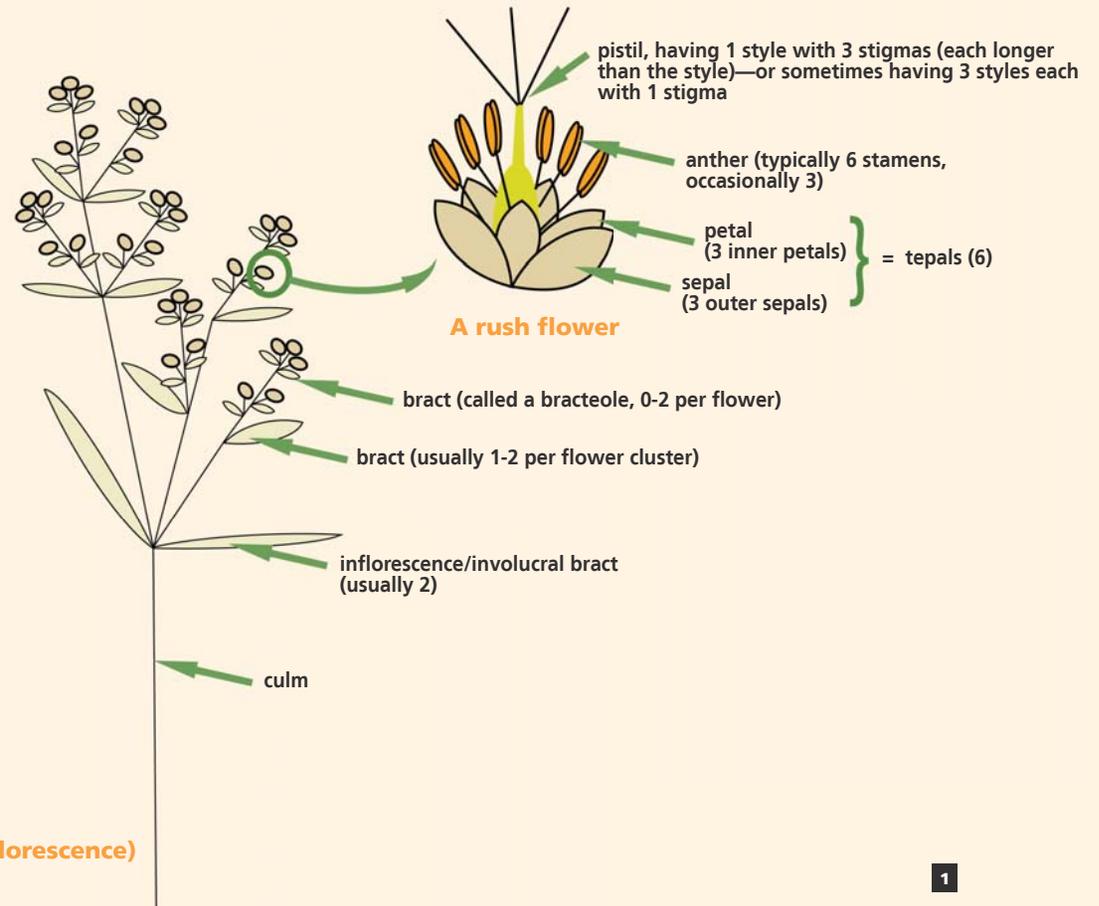
Rushes are another graminoid of the angiosperms (flowering plants) and in the plant family Juncaceae. As with grasses and sedges, their flowers are tiny and modified and sometimes difficult to interpret, although these inconspicuous flowers resemble many large flowers with which we are familiar when looked at closely. They are often wind pollinated, foregoing showiness while flowering.

Becoming familiar with the anatomy of these species will enable an observer to make accurate observations as the plant's flowers become reproductively active.

Rush flowers are very tiny and inconspicuous, and clustered into a uniquely characteristic structure that has leafy bracts attached below both the individual flowers and also the clusters of many tiny flowers. The flowers resemble many other familiar flowers, except that they are tiny and hard to see. Unlike the grasses and sedges, they have petals (3) and sepals (3), and as other familiar plant species (e.g. magnolias and tulips), the petals and sepals look alike, so are called "tepals". The tiny flowers are organized into larger groups—the flower head or inflorescence—which has one to hundreds of flowers organized within a unique arrangement, characteristic to species.

The organization of rush flower parts in the family Juncaceae

The diagram below illustrates a rush inflorescence, although each species would have its own architecture and size. The inflorescence and flower diagrams are only a very general example for all rushes. Most of the species in this plant family have flowers that are bisexual (having male and female reproductive parts).



1



The variety of rush flower heads (inflorescences) in the Juncaceae plant family

As with the other graminoids, rushes have a diversity of arrangements of inflorescences (flower head or seed head)—Images 2-9 include a very small sampling of the wide variety of architectures and forms of rush flower heads to be found.

The flowers

A rush inflorescence is an organized unit of clustered flowers. Most rush species have bisexual flowers within an inflorescence, although a few species are dioecious and have male and female flowers located on separate plants (ensuring cross-pollination).

Images 10-16 are close-ups of the tiny flowers of various rush species with open flowers (orange arrows for female, red arrows for male). An observer would look for the male or female reproductive parts showing between the outer flower parts—in rushes, the tepals. See Image 10 for orange arrows highlighting the pinkish stigmas of the pistil and red arrows for the yellowish anthers of the stamens in a flower.

Most rush species have timed the female and male activity in their flowers to occur at the same time, but a number of species have coordinated their activities differently. The female reproductive parts of some species become active before the male parts. This activity causes a display similar to Image 16 where the tepals have not fully opened but have begun to open just enough so that the stigmas can protrude from between the tepals to collect pollen, and potentially be fertilized. This activity and strategy is called protogyny and supports cross-pollination, postponing the flower's own pollen from pollinating and fertilizing its own ovules. Shortly, the tepals will fully open and the stamens will become active, the anthers opening and releasing pollen. If the stigmas of the pistil are still active at the time of stamen activity, it may be that they have not received pollen earlier or the ovules have not been fertilized. In this case, the stigma may then receive the flower's own pollen—if the species has the capacity to accept its own pollen (called self-compatibility)—and may self-fertilize. Some plant species utilize this strategy as bet-hedging during the reproductive effort.

An observer should report "yes" for the "Open flowers" phenophase even if they see only female reproductive parts (Image 16). A comment could be included to note that only the female flower parts are active for this flower.



Flower heads

Grass or Sedge

One or more fresh flower heads (inflorescences) are visible on the plant. Flower heads, which include many small flowers arranged in spikelets, emerge from inside the stem and gradually grow taller. Include flower heads with unopened or open flowers, but do not include heads whose flowers have all wilted or dried or begun to develop into fruits (grains).



Phalaris arundinacea 1



Phalaris arundinacea 2



Phalaris arundinacea 3



Phalaris arundinacea 4



Phalaris arundinacea 5



Phalaris arundinacea 6

For the "Flower heads" phenophase, an observer would report "yes" as soon as an inflorescence is initiated and visible on their plant. An observer would continue reporting "yes" for this phenophase until the last flower on the plant wilts and/or dries, and its reproductive effort turns exclusively to fruit development. Row 1 of images shows flower head development for a grass species and row 2, for a sedge species. In both series the last image is of wilted, dried flowers to which an observer should report "no" for "Flower heads".

Needed: sedge
photos - Flower
head phases in
sequence

Carex placeholder 7

Carex placeholder 8

Carex placeholder 9

Carex placeholder 10

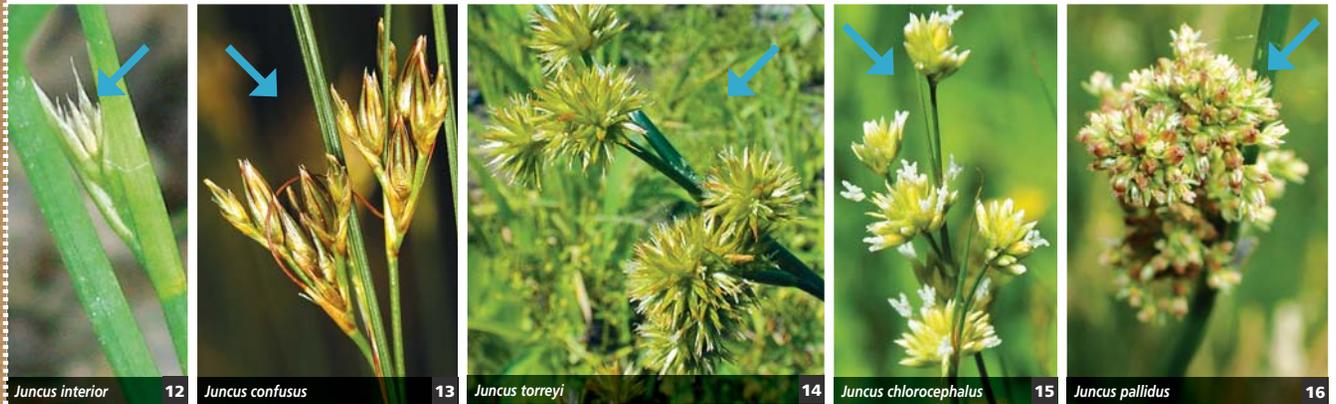
Carex placeholder 11



Flowers or flower buds

Rush

One or more fresh open or unopened flowers or flower buds are visible on the plant. Include flower buds or inflorescences that are swelling or expanding, but do not include those that are tightly closed and not actively growing (dormant). Also do not include wilted or dried flowers.



Rushes

Although rushes are graminoids, the flowers are more similar to non-graminoid flowers, therefore it has the "Flowers or flower buds" phenophase instead of the "Flower heads" phenophase used for grasses and sedges. Similar to grasses and sedges, an observer should report "yes" as soon as an inflorescence is initiated and visible on their plant. An observer should continue reporting "yes" for this phenophase until the last flower on the plant turns its reproductive effort to fruit development. The image series on this page presents an example of what an observer may see.



Row 1 of images is a composite of several rush species. The images flow from inflorescence initiation and flower bud formation (Image 12) to the point where the floral clusters still have some open flowers but also some flowers that have transitioned into fruit development (Image 16).

The transitioning of the flowers from the "Open flowers" phenophase into fruit development is subtle. Drying stigmas and anthers can be one clue, but each species has their individual characteristics. Image 17 highlights an inflorescence showing signs of this shift for one species, and Image 18 shows fruits developing.

Open flowers

Cactus, Forb, Tree or Shrub

One or more open, fresh flowers are visible on the plant. Flowers are considered "open" when the reproductive parts (male stamens or female pistils) are visible between or within unfolded or open flower parts (petals, floral tubes or sepals). Do not include wilted or dried flowers.

The "Open flowers" phenophase would seem self-explanatory. As the definition states, an observer would simply look for the male and female reproductive parts between fresh flower petals and sepals, and then, it's done! That is true for most species and flowers, and generally, observing for "Open flowers" is quite straight forward. Yet some species have other characteristics to consider. We cover some of those details on these next few pages.

The images below highlight some of the easier flowers that an observer might come across on the pages of *Nature's Notebook*. These flowers are often larger, but when tiny, they have floral parts that are easy to recognize. For these images, the red arrows point to the male reproductive parts and the orange arrows point to the female reproductive parts. An observer would not necessarily see both at one time, but should report "yes" for "Open flowers" when seeing activity from either male or female, or both, of these floral reproductive parts.



Carnegiea gigantea



Opuntia santa-rita



Penstemon superbus



Ceanothus greggii



Kalmia latifolia



Sambucus racemosa



Yucca baccata



Magnolia x soulangiana



Parkinsonia microphylla



Observing challenging flowers

As an observer develops a good technique for observing a typical "open" flower, it may become easier to understand challenging flowers. This page highlights a sampling of "difficult" flowers; those having an unusual structure, or are tiny, crowded, inconspicuous, or have hidden or missing parts (such as petals or sepals or both).

Some flowers can be perplexing. It helps to know where the flowers are located on the plant that you are observing. Are they separate and complete like those on the previous page? Or are they hidden within an inflorescence that mimics a flower, such as the tiny, crowded flowers in the center of showy bracts as in some dogwoods? Or are they very tiny—often looking like petals—and very crowded with many others into an inflorescence that mimics one big flower—like a sunflower? Or, are they very tiny, petal-less, unisexual, and crowded into dangly catkins? (The sunflower family is discussed on the next page.)

When it gets down to it—despite how atypical a flower may be—an observer is specifically looking for the flower's reproductive parts for the "Open flowers" phenophase: the stamens and/or the pistil(s)—or stigma—if the ovary of the pistil is hidden. For the images to the right, red arrows indicate "open" male parts; orange arrows, "open" female parts; and white arrows, both parts. If your plant species has challenging flowers, get the specifics of their flowers. Find reliable sources and get your questions answered!

For some of these difficult flowers, a species-specific description is added to the species' "Open flower" phenophase definition. For flowering dogwood (Image 10) this description reads: "For *Cornus florida*, ignore the four large, white bracts and watch for the opening of the small flowers in the center of the bracts."

In tall trees, it may be impossible to determine whether reproductive structures are visible. In this case the observer might have to report "?" for "Open flowers".



Cornus florida 10



Passiflora sp. 11



Asclepias subulata 12



Plantago sp. 13a

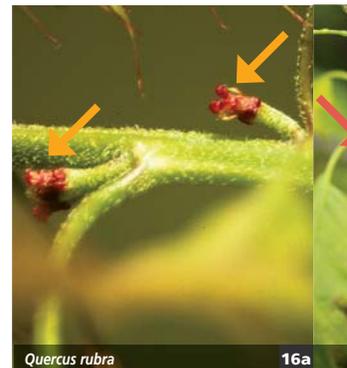


13b



Plantanus racemosa 14

15a



Quercus rubra 16a



16b



Simmondsia chinensis 17a



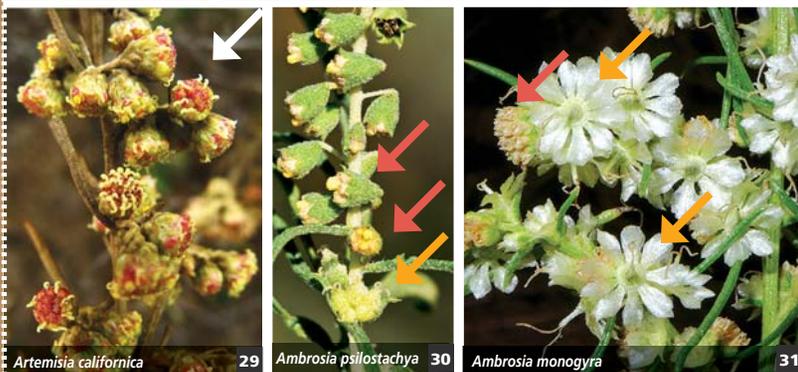
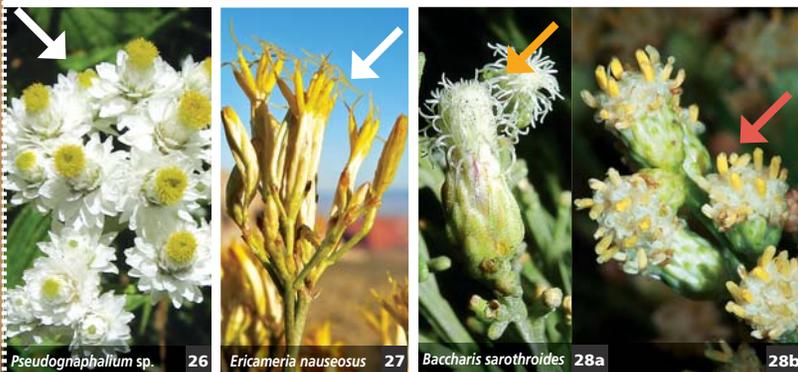
Atriplex canescens 18a



18b



Typha sp. 19a



Open flowers in the sunflower family

In the plant family Asteraceae—which include daisies, sunflowers and the like; dandelions, lettuce and the like; gayflowers, cocklebur, ragweed, sagebrush, burrobrush; thistles and the like; goldenrods, rabbitbush and the like—the flowers require a closer look to decide whether they are "open". What may look to be a single flower is an inflorescence—called a capitulum. Very simply, a capitulum is comprised of a few to lots of teeny flowers supported on the capitulum's receptacle, and surrounded by one to several rows of involucre bracts (phyllaries)—called the involucre. In this type of inflorescence, some of the tiny flowers might resemble a flower's petals and the phyllaries resemble a flower's sepals.

The two basic types of flowers found in capitula are disc florets and "petalled" ray florets. Image 20 shows a ray floret on the left, and disc florets, in male and female phases, on the right side of the image. Disc and ray-type florets generally have a corolla (petals) and a modified calyx, and vary in having male and female reproductive parts. Their modified calyx (called a pappus) is a ring of hairs, bristles, awns, scales (used to disperse the fruits) or it may be absent. The corolla is either a fused tube of five tiny petals for the disc florets or strap-shaped petal or petals for the ray florets. The calyx and corolla are attached at the top of the ovary—an inferior ovary—and surround the stamens and style. In most species, the five stamens are a fused tube that surround the style, which has two stigmatic branches at the top. The anthers become active first (protandry), releasing pollen before the style extends up between the stamens. The stigma becomes active as the style pushes up between the stamens. See Images 20-21 for a look at examples of what each reproductive phase might look like (red arrows are male phase, orange arrows, female phase). As described by the "Open flowers" phenophase definition, it is the stamens' and stigma's activity an observer will look for to determine "open" flowers; report "yes" if either phase is active.

In the Asteraceae family there are many floral tribes, each have a specific combination of floret types that comprise a capitulum. Some species have many capitula further arranged within a complex inflorescence (Images 23, 26-31), the arrangement specific for the species. In Images 22-31, white arrows indicate male or female activity; red arrows, florets in male phase; orange arrows, florets in female phase.

Open flowers

Grass, Sedge

One or more open, fresh flowers are visible on the plant. A flower is considered "open" when reproductive parts (male anthers or female stigmata) can be seen protruding from the spikelet. Do not include flowers with wilted or dried reproductive parts.

Rush

One or more open, fresh flowers are visible on the plant. Flowers are considered "open" when the reproductive parts (male stamens or female pistils) are visible between or within unfolded or open flower parts (petals, floral tubes or sepals). Do not include wilted or dried flowers.



Row 1 shows open florets in grasses, row 2 shows sedges, and row 3 shows rushes. Arrows point to the reproductive parts in each image with red arrows for the male reproductive parts and orange arrows for the female reproductive parts.

If the tiny graminoid flowers are confusing to you, take a look back at the informational pages provided for grasses, sedges, and rushes. Diagrams focus on the florets and flowers in order to get a more solid understanding of what to look for when observing the flowers of these species.

Also, get to know your species well enough to know if the flowers are perfect, or monoecious or dioecious. For Images 34-40 male and female flower parts occur in separate florets. Images 33, 37, 40 show flowering strategies in which mostly only one sex is active at a time (protandry, protogyny).

Pollen release

Forb, Grass, Sedge, Rush, Tree or Shrub

One or more flowers on the plant release visible pollen grains when gently shaken or blown into your palm or onto a dark surface.

The "Pollen release" phenophase is included for those plant species that have been reported to cause allergies in a large number of people in our population, such as maple, oak, mesquite and privet, ragweeds, and grasses.

Several methods may work for an observer to detect pollen release. The best method to use will depend on each species' characteristics and its pollination strategy, although allergen species commonly have abundant and easily detected pollination events. That said, some species may offer a challenge when detecting pollen; it can sometimes be tricky.

To start, an observer simply might look carefully and closely at the plant for evidence of pollen residues within flowers or dusted onto leaves, such as in Images 1-3. If they choose this method, they must make sure the plant's anthers are fresh. If they are long-dried and withered with only small amounts of pollen present, the pollen might have come from other sources. But, as the definition suggests, an observer might gently shake the plant to see if pollen grains are released, such as in Image 4 where clouds of pollen are evident. For plants that have very tiny flowers an observer might be able to gently shake or tap the plant over a dark surface, such as in Image 5.

For tall trees an observer might find that flowers are too far above them to detect pollen release. If this is the case, they will have to report "?" for this phenophase unless they see clouds of pollen being blown by the wind, as often occurs in conifers.

Grasses are generally tricky plants on which to make observations. The next page offers some insights to grass pollen release and detecting activity or senescence of anthers. Also, some images are offered to show the surprising variation of pollen colors and packaging. Not all pollen gets released as loose grains!





Pollen release in grasses

Row 1 of images illustrates several grass species in the process of releasing pollen. In Image 6 several grass flowers have extended anthers indicating pollen is being released. Yet, if you look more closely, you might notice that several of the anthers have split open, having previously released their pollen but not yet withered and dried (yellow arrows). At least one of the anthers is still closed and is extended out from the flower (white arrow)—so it will not be too long before it also splits open to release the pollen grains (each species has their own anther-opening mechanisms). Some grasses can be tricky if an observer does not look closely. At a distance the anthers, dangling from their flowers, could be withered and dried having released all of their pollen grains some days ago. Just to be sure, the observer should take a closer look at their plant to make sure pollen release is in fact occurring in at least a few of the flowers or florets within the inflorescence when reporting "yes" for this phenophase.

Unusual pollen colors and packages

Although we do not usually ask for this phenophase for these kinds of flowers, here are some examples of other types of pollen. Each species has differently shaped anthers, dispersal methods, and timing strategies that supports the species' reproductive success. Some of the less common physical differences an observer may come across include vibrant anther and pollen colors (Images 11-14) and unique pollen packaging (Images 15-16) compared to what we commonly see—loose pollen grains that are various shades of yellow. Several plant families have unique ways to disperse their pollen, mostly these methods involve pollen packaging that attaches to insect pollinators and is efficiently relocated. Image 15 highlights a pollen string where pollen grains are strung together by viscin threads into chains of pollen, and Image 16 shows pollinia (white arrows)—tiny masses of pollen—from a milkweed flower (orchids also) clinging to a bee's leg. Yellow arrows point to the anthers that surround the stigmatic disc of the flower.



An overview of "spent" flowers

When is a flower "spent"?

For the "Open flowers" phenophase the definition alerts an observer to look at the fresh flowers, eliminating from an observer's assessments any flowers no longer active, and having wilted or dried reproductive parts. This is straightforward and easy to understand. For the most part, as anthers complete pollen release and ovaries are fertilized, the petals and sepals, anthers, stigma and style dries and often falls off (often described as being "deciduous" in floral descriptions). There are some exceptions—as usual!



The activity sequence, and completion, of a flower's effort

The flower's activity sequence, and signals for completion of its effort, differs from species to species, but generally within a species the signals will be consistent. As a flower's activity wanes and freshness diminishes, pollination ends, fertilization is complete or, in most species, nearing completion; the flower is "spent". Depending on the species, this can happen within hours, days, or over months. The sepals and petals may change color, close up, wilt and/or dry, fall off or remain. The anthers may dry quickly after releasing their pollen. A subtle color change will cue an observer to the drying (such as a fresh intense yellow when full of pollen to a dull, dry, whitish-yellow once the pollen is released and the anthers are empty). In some species the stamens or anthers quickly fall off.

Across species, flower's female reproductive parts display a greater diversity of patterns. The stigma and style may dry and fall off or dry but remain attached to the developing fruit, and linger on the ripe fruit. Or it may remain green or change in color, yet stay fresh and well developed attached to the developing fruit. See the row of images for an example of one species' sequence of being "open" for gene exchange and then, the cessation of floral activity.

For the above species' sequence, as the flower petals open (Image 1)—and before they are completely open—the anthers open and release pollen (Image 2). The stigma may, or may not, be receptive at this point as it slowly extends upward. Then, all floral parts are completely exposed and seemingly active (Image 3); the anthers still look fresh although a closer look shows that most of the pollen has been released. Next (Image 4), the stamens begin to wilt and dry, as the petals, still mostly fresh, also begin to show signs of drying—and yet the style and stigma remain fresh and seemingly receptive. As the flower deteriorates, the petals fall off and the stamens are empty and dry (Image 5); the flower is "spent". Next, the stigma and style dries and falls off the developing fertilized ovary—the fruit (Image 6).

An observer should report "yes" for the "Open flowers" phenophase, by definition, for Images 2-4. Image 5 is a "spent" flower, no longer "fresh" or active—having withered and dried floral parts, petals drying and dropped off.



Variation is the norm; cessation of an open flower phase differs by species

As the "open" phase fades for a flower—after pollen has been released and stigmas are no longer receptive to pollen (although unseen pollen tubes may still be growing down through the style into the ovary of the pistil)—a sequence of floral activities occurs. Typically these hardly-noticed events involve the drying and/or dropping off of floral parts that are no longer of use. Otherwise these floral parts would take energy to sustain freshness away from the plant, or would get in the way of potential fruit development. Rows 1-3 offer some of the different cues that might be seen by an observer.

A species' may signal cessation with petals that change color indicating the flower is spent (Images 7-9); or petals wilt, some close up, then dry but stay attached for a while (Image 10, 14, 15); petals fall off fresh and immediately (Images 11-13); or flower heads may close their bracts (phyllaries) up over the spent florets (Image 16), or not, and the ray flowers dry up as the individual spent disc florets begin drying (Image 17).

Plants which may need a closer look

Row 4 of images highlights several instances where an observer might need to look more closely at their plant. This is especially relevant when the plant has dense inflorescences of tiny flowers. It may seem that the group of flowers are "spent", but a closer look could uncover a few fresh flowers that remain reproductively active and even a flower bud or two, surrounded by spent flowers. A quick glance may not be enough to discover what appears to be a general cessation of flowering on the plant, especially when the flowers or florets are very tiny (arrows point to still open and active flowers amongst the spent flowers).



An overview of new fruits

When has a fruit initiated from a flower?

As with all other plant activity discussed earlier in this document, fruit initiation is species' specific—its characteristics unique to a species—and yet, also dependent on the conditions at the time of pollination and fertilization. Some species are very quick at fertilizing and starting fruit development after receiving pollen, and others have evolved unique delayed strategies that best serve the success of the species.

Pinpointing the beginning of fruit development and the start of the "Fruits" phenophase is often very difficult. This section highlights what an observer might consider when trying to determine the start of this phase.

We offer some early signals an observer might watch for; yet, given that each species' fruit development is unique, your acquired knowledge of your plant will be your best tool. The experience you gain by careful observation of your plant, over time, will be your best source of information. Often there are consistent cues, sometimes subtle, that indicate fertilization has taken place and the flower has successfully transitioned into fruit development.

What are some early signals an observer might watch for?

Begin by understanding where the flower's ovaries are located within the flower for the plant species. Close inspection of the plant's flowers, or searching out good information sources, should reveal an ovary's position. Knowing the position of the ovaries will help with fruit onset observations; is the ovary superior (petals and sepals attached below the ovary(s)), inferior (petals and sepals attached at the top of the ovary(s)), or are the petals and sepals attached to a floral cup (hypanthium) that surrounds the ovary—often hiding the lower part of the ovary but leaving the upper part in view? And remember, a superior ovary can also be deeply hidden between its enclosing petals.

Read the species' fruit development descriptions that follow the "Fruit" phenophase definition provided on the species' profile page in *Nature's Notebook*. Further, consider some of the cues offered here that might help to reveal fruit onset a bit earlier. Primarily, an observer would be watching for ovaries that remain a green color and enlarge as the flower changes. Some ovaries do not get fertilized, then dry, shrivel or fall off.

An observer should only report "yes" for the "Fruits" phenophase if they are confident of what they are seeing—a live ovary that has been fertilized, and is developing into a fruit. They could also report "?" if fairly sure, but still need more evidence.

Ovaries that remain green

In Image 1, a green ovary (the fruit; inferior ovary) of a spent evening primrose flower is only days old and already showing distinct signs of developing (staying green and alive, and enlarging) despite all other floral parts drying and dropping off.

In some species, the stigma may remain attached for a prolonged period, with the style remaining and drying as the fruit ripens and dries (Image 2). Watch for the steady enlarging of the ovary (the fruit) over time, quick or slow—depending on the species.

Ovaries that are hidden between persistent alive or drying plant parts

For some species, it may take a bit longer to detect fruit development (Images 3-4). For eastern Mohave buckwheat (Image 4), the "Fruits" definition states: "One or more fruits are visible on the plant. For *Eriogonum fasciculatum*, the fruit is tiny and capsule-like, partially enclosed in a spent flower base (calyx), with many such spent flower bases tightly clustered together. The spent flower base changes from green to light brown or rusty brown as it dries out." For this species with hidden fruits, this visual cue of flower color change identifies the beginning of potential fruit development—the point when an observer should report "yes" for the "Fruits" phenophase.



Some species are quick quick quick to initiate fruit

There are quite a few species in nature that "set" fruit very quickly. An observer would have to be watching their plant closely, and regularly, to catch this event (Images 5-10). The ovaries can be seen enlarging soon after the flower parts drop or dry—sometimes pushing through the barely dry flower parts (Image 10). On occasion in some species, the flower hardly seems spent when the ovaries show signs of developing further (Image 8).

Some species delay fruit initiation for a while... sometimes quite a while

Some species delay fertilization as part of their strategy... some for a surprisingly long time. Fertilization can be suspended a few weeks following pollination (Images 11-12). Witchhazel is one of those species that is delayed for a longer time: pollination occurs at flowering in the late fall to early winter, yet fertilization is delayed and does not occur until the following spring (Image 13). Once an observer understands the patterns of their species, it will be easier to estimate how to watch their plant to catch the "Fruits" phase, and fruit initiation, as early as possible.

It bears repeating

All of our observers are learning, even the most experienced. Take your time to learn the basics for your plant species so that your observations are as accurate as possible. Be comfortable, and confident, with what you report. It provides quality data.

An observer should only report "yes" for the "Fruits" phenophase if they are confident of what they are seeing—a live ovary that has been fertilized, and is developing into a fruit. They could also report "?" if fairly sure, but feel they need more evidence.



Solanum lycopersicum



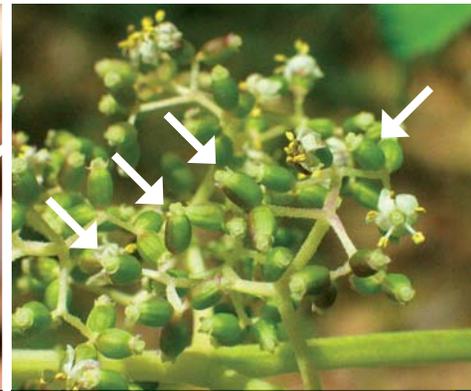
Penstemon albomarginatus



Cucumis melo



Lepidium lasiocarpum var. *lasiocarpum*



Sambucus racemosa



Olneya tesota



Quercus rubra



Corylus cornuta ssp. *californica*



Hamamelis virginiana



Fruits

Cactus, Forb, Grass, Sedge, Rush, Tree or Shrub

One or more fruits are visible on the plant.

See each Nature's Notebook species profile for a species-specific description of fruit development.



The "Fruits" phenophase encompasses the entire period during which fruits are present on a plant. The *Nature's Notebook* definition is identical for all plants. The "Fruits" phenophase begins with the first observation of the plant's first initiated fruit for the season (see the previous section "An overview of new fruit") and ends when the last fruit on the plant has ripened and released its seeds, dropped off or has been removed from the plant.

Cacti and forbs

The first image in each row show early fruit initiation and the last image show a ripe fruit as defined in their species-specific description of fruit development (row 1, a cactus; row 2, a perennial forb).



Needed: grass photos - Fruits in sequence

Grass placeholder

9

Grass placeholder

10

Grass placeholder

11



Scirpus cyperinus

12



Scirpus cyperinus

13



Scirpus cyperinus

14



Scirpus cyperinus

15

Needed: rush photos - Fruits in sequence

Rush placeholder

16

Rush placeholder

17

Rush placeholder

18

Rush placeholder

19

Graminoids

Three image series are offered as examples for the graminoid plant groups, that is, the grasses, sedges, and rushes. Row 1 highlights a grass; Row 2, a sedge; Row 3, a rush.

For graminoids, fruit development is mostly hidden within plant parts, and will take some experience to acquire an understanding of this phenological stage for these plants. Reading over the fruit definitions for these species will only offer a basic description for the observer; an inexperienced observer should take a season for careful observation before reporting on graminoid fruit phenophases. For example, the grass "Fruits" definition: "For *Aristida purpurea*, the fruit is a grain, hidden within tiny bracts and grouped into small clusters that are closely arranged along many branches on a large, narrow or wide and open-branched plume (or seed head), that changes texture from soft or watery to hard and drops from the plant. Do not include seed heads that have already dropped all of their grains." If you are not familiar with grass fruit development, take it slow, compare your observations to plant changes over time (take notes or photos for yourself), and ask questions.

Once we get grass photos for this page, we will use the def for whatever species is depicted



Trees and shrubs

This page offers a few image series of larger species—a shrub and some trees (row 1 is a shrub, rows 2-4 are various tree species). Despite being larger, the fruit types can be similar, if not identical, to forbs (such as berries, capsules, pods), cacti (fleshy fruits), and rushes (capsules). Several types of fruits are displayed in these images: capsules that split open and release their seeds, winged fruits that drop when ripe, and nut-type fruits that change color and often drop from the tree when ripened.

As noted on previous pages, the species' description of fruit development for each plant species is included with the "Fruits" phenophase definition, and provides a simple guide and overview for what an observer could expect for that species. The "Ripe fruits" phenophase definition will identify the cues an observer would watch for to determine the end of fruit development for each species. Each of these image series examples for the "Fruits" phenophase starts with newly initiated fruits (Images 20, 24, 28, 33) and ends with the ripe fruit phase (Images 23, 27, 32, 37). An observer should report "yes" for the "Fruits" phenophase from fruit initiation through ripe fruits on a plant, until all the ripe fruits have dropped off or lost all of their seeds.



Kalmia latifolia 20



Kalmia latifolia 21



Kalmia latifolia 22



Kalmia latifolia 23



Betula nigra 24



Betula nigra 25



Betula nigra 26



Betula nigra 27



Acer rubrum 28



Acer rubrum 29



Acer rubrum 30



Acer rubrum 31



Acer rubrum 32



Quercus rubra 33



Quercus rubra 34



Quercus rubra 35



Quercus rubra 36



Quercus rubra 37



An overview of aborted fruits

What does an aborted fruit look like?

Interruption and cessation of fruit development can occur as a result of a random episode in a plant's life cycle or as a species' reproductive strategy. It is not unusual to see one or two ovaries or immature fruits that have discontinued development, but some species mass eliminate—so as to settle into a balance of producing a crop of healthy fruits and insuring its own plant health.

How can an observer be sure the fruit has been aborted before ripening. Should an observer record what they see?

A few examples are offered here just to alert an observer to the potential of this event occurring. For most species, the cessation of a fruit's development is relatively rare, for others, it is a strategy used to reduce the size of the fruit crop to maximize success of the remaining fruits during its fruiting effort.

Examples of aborted fruits

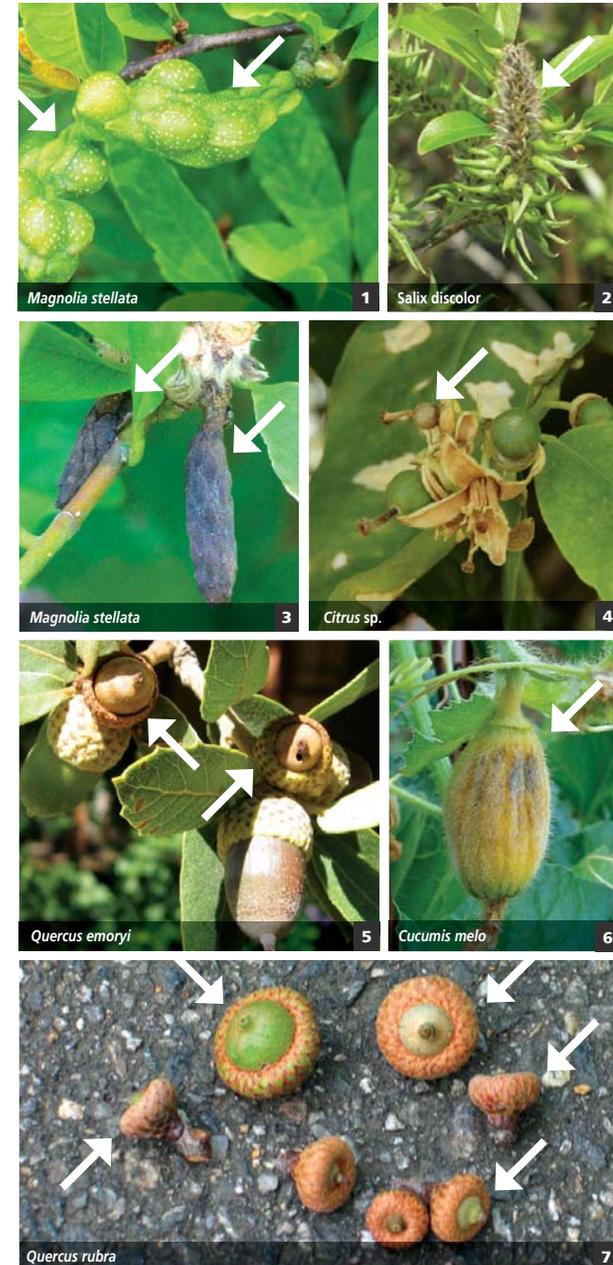
Not all ovules get fertilized after flower pollination, and not all fruits that are fertilized continue to develop into fully ripe fruits. Their development can be interrupted and the fruit dies before ripening. There are many potential reasons for this; competition within the plant for necessary resources, abnormalities, disease or injury, local weather, and competition from without that severely limits environmental resources needed to provide the energy it takes a plant to develop its fruit. Fruit development takes a lot of the plant's energy.

The events causing cessation of fruit development typically would involve just a few of a plant's fruits. When an observer catches this event—if they understand what they see—a note could be entered into the species' observation comments field reporting that some fruits have been aborted. On occasion, a mass abortion event could take place (some species do this regularly). An event of this sort might reduce an observer's counts of fruits over time because fruits that have clearly been aborted should no longer be considered "Fruits" for the purpose of monitoring with *Nature's Notebook*.

Just for comparison, row 1 provides examples of where not all pistils within a flower, or flowers within an inflorescence, were fertilized following pollination. In species with multiple, accessory, or aggregate fruits, a distorted fruit may result when only some of the pistils that occur within a single flower are fertilized (Image 1). If not all flowers within an inflorescence are fertilized, the infructescence would have empty spaces between those flowers that were fertilized and initiated fruits (Image 2).

Rows 2-4 show aborted fruits; the arrows point to those aborted. Compare Image 3 to Image 1: they are the same species, yet the partially unfertilized fruit versus the aborted fruits look very different. In some instances, aborted fresh, underdeveloped, fruits drop and can be found lying underneath a plant (Image 7).

There is no way of knowing the cause of these events (unless you are knowledgeable about the species)—there can be many reasons. Yet, it is important that our observers be aware of aborted fruits, simply so they are disregarded when reporting on the plant's fruit.



Ripe fruits

Cactus, Forb, Grass, Sedge, Rush, Tree or Shrub

One or more ripe fruits are visible on the plant.

See each Nature's Notebook species profile for a species-specific description of ripe fruits.



Each plant species can display a unique set of characteristics as the fruit develops and becomes ripe. There are many fruit types, such as capsules which change color and split open when ripe (sometimes explosively), berries which become fleshy and change various colors before reaching their ripened color, pods which change color as they ripen but do not open, or nuts hidden in hulls in which the hull changes to a ripened color and drops from the plant. *Nature's Notebook* provides a description for each species of their developing fruit (following the "Fruits" phenophase definition) and their ripening fruit (following the "Ripe fruits" definition). An observer need only read this species' specific description that will describe the fruit's typical sequence of development. As you watch your plant over time, you may discover it differs a bit from the description. Use this acquired knowledge for your future observations in subsequent years.

Row 1 shows a sequence for pussy willow, and an arrow points to the observation of the first ripe fruits according to its "Ripe fruits" definition: "One or more ripe fruits are visible on the plant. For *Salix discolor*, a fruit is considered ripe when it has dried and split open to expose seeds with white fluff. Do not include empty capsules that have already dropped all of their seeds." Image 5 shows an infructescence of capsules that have dropped all of their seeds.

Row 2 shows a sequence for highbush blueberry, and an arrow points to the observation of the first ripe fruits according to its "Ripe fruits" definition: "One or more ripe fruits are visible on the plant. For *Vaccinium corymbosum*, a fruit is considered ripe when it has turned blue or blue-black."



This page contains image pairs to offer some examples of different kinds of fruit an observer might come across. The left image of each pair is the unripe stage, the right image of each pair is at the "Ripe fruits" phase.

Some of the types of ripe fruit an observer might come across on various plant species are capsules (or capsule-like) that dry and split open with or without fluff attached to the seeds (Images 12, 14, 16, 30); capsules and seed-like fruits that dry or change color and do not split open (Images 18, 20); pods that dry and do not split open—the color change is their indicator of ripeness (Image 22); fleshy fruits that change color (Image 24); fleshy fruits with rinds that change color (Image 26); or dry fruits such as "nuts" that change color or grains that change texture and color (Image 28). The arrows identify the ripe fruit.

As with the examples on the previous page, each species' "Ripe fruit" phenophase definition will describe and alert an observer to the cues of its ripe fruit stage.



An overview of ripened, persistent fruits

When should an observer stop reporting on the current fruit crop?

It can be confusing for an observer to know when to stop reporting "yes" for those ripe fruits left on a plant—especially those that are lingering into, and persistent through, another season—months after having fully ripened. The information on this page should help clear up those observational dilemmas.

When to stop reporting "yes" for the "Ripe fruit" phenophase

The initial step would be to determine if the lingering fruits on the plant have dropped all their seeds or had their seeds removed—leaving empty hulls, capsules, pods, or skins and rinds of fleshy fruits (Images 1, 2, 5, 7, 8). If seeds are no longer present, the fruits are no longer viable and the observer should report "no" for "Fruits" and "Ripe fruits". For species such as those in rows 2-3, persistent, seedless, old fruit might be present along with fresh flowers and new fruit (Images 5 and 3, respectively), and sometimes remain on the plant well into the next season (Image 8). In tall plants, if fruits are too high to be inspected, the observer will have to report "?" for these phenophases once they suspect the seeds might have dropped or been removed from the fruits.

But what of those persistent fruits still holding onto their seeds? For capsules and pods, the drier fruits, that retain seeds, the observer should continue to report "yes" for the "Fruits" and "Ripe fruits" phenophases until all the seeds have been removed from the plant.

And what of fleshy fruits, such as berries and rose hips, that remain on the plant and begin deteriorating with no clear endpoint for reporting "yes"? It depends. An observer might think about it from an animal's or bird's perspective:

- Continue to report "yes" for "Fruits" and "Ripe fruits" as long as these fruits seem plump, edible and appealing to wildlife (Images 9-10).
- But—when the fruits begin to dry up and deteriorate, it is questionable whether to consider them as "Fruits" and "Ripe fruits". Once they seem inedible or unappealing to wildlife (Image 11), report "no" for these phenophases and place a note in the comments section that deteriorated fruit persists on the plant.

Image 11 will be replaced with fruits that are much more deteriorated (mummified!).



Ilex verticillata



Chimaphila umbellata



Chimaphila umbellata



Chimaphila umbellata



Chimaphila umbellata



Hamamelis virginiana



Hamamelis virginiana



Hamamelis virginiana



Ilex verticillata



Ilex verticillata



Ilex verticillata



Nature's Notebook
PHENOPHASE DEFINITION

Recent fruit or seed drop

Cactus, Forb, Grass, Sedge, Rush, Tree or Shrub

One or more mature fruits or seeds have dropped or been removed from the plant since your last visit. Do not include obviously immature fruits that have dropped before ripening, such as in a heavy rain or wind, or empty fruits that had long ago dropped all of their seeds but remained on the plant.



Acer rubrum 1



Olneya tesota 2



Erythronium americanum 3



Salix discolor 4



Typha sp. 5



Asclepias subulata 6



Betula nigra 7



Ilex verticillata 8

The fruits of some species drop from the plant as soon as they ripen, in which case an observer may easily miss the chance to report the presence of "Ripe fruits" on the plant. For this reason, the "Recent fruit or seed drop" phenophase was added to *Nature's Notebook*. If a plant's fruit obviously ripened and dropped since the last visit, the observer should report "yes" for this phenophase.

Carefully examine the plant and the fruits for evidence of fruit or seed drop. It may be that there are pedicels with no fruit, that previously held ripening fruit (Image 1). Or a few—or all—of the seeds missing from a capsule or pod that was full of seeds on the last visit (few, Image 2 and all, Images 3-4), or fruits that seem to be blowing away (Images 5-7), or even the skin of a fleshy fruit that is left after a bird or other animal snacked on the insides (Image 8). Or ripe fruits, or seeds, lying directly beneath the plant that were not there at the last visit (row 3).



Betula papyrifera 9



Magnolia stellata 10



Ilex verticillata 11



Quercus emoryi 12



IMAGE CREDITS AND DETAILS

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PAGES 5-7: THE INTRODUCTION FOR THE PHENOPHASE PRIMER

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- 14 *Ficus* sp.—fig (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 15 *Asclepias subulata*—desert milkweed (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 16 *Carnegiea gigantea*—saguaro fruit (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

17 *Malvaceae* sp.—flower (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 13-15: THE INTRODUCTION FOR SECTION 1

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8 Conifer sp. from Maine (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

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10 *Sambucus racemosa*—red elderberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

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14 *Dodonaea viscosa*—Florida hopbush (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

15 *Podophyllum peltatum*—mayapple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

16 *Dalea bicolor*—silver prairie clover (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

17 *Encelia farinosa*—brittlebush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



PAGES 16-79: THE ANGIOSPERMS

PAGES 16-17: AN OVERVIEW OF VEGETATIVE (LEAF) PHENOPHASES

- 1 *Rhaphanus* sp.—radish sprout (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2 Deciduous Plant Leaf Phenophase Timeline (Sara Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
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PAGES 18-19: THE PHENOPHASE FOR INITIAL GROWTH

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- 9 Summer annual Poaceae sprout (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 10 *Eragrostis lehmanniana*—Lehmann lovegrass (Saguaro National Park via Wikimedia Commons; Creative Commons Attribution 2.0 Generic License, <https://creativecommons.org/licenses/by/2.0/>)
- 11 *Digitaria californica*—Arizona cottontop (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
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- 13** *Carex* sp.—Oregon coast sedge sprout (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 14** *Carex* sp.—California high-elevation sedge sprout (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 15** *plantspecies placeholder* (credit placeholder—license placeholder)

PAGES 20-21: AN OVERVIEW OF DORMANT AND SWELLING BUDS

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PAGES 22-23: THE PHENOPHASE FOR BREAKING LEAF BUDS

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- 3** *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
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- 11** *Toxicodendron radicans*—eastern poison ivy (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <http://creativecommons.org/licenses/by/3.0/us/>)
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PAGES 24-29: AN OVERVIEW OF UNFOLDED LEAVES

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- 8—9** *Cornus canadensis*—bunchberry dogwood (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 10—12** *Erythronium americanum*—dogtooth violet (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 13—16** *Fragaria virginiana*—Virginia strawberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 17** *Chimaphila umbellata*—pipsissewa (© Daniel Carter via EOL; Creative Commons Attribution-NonCommercial-ShareAlike License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 18** *Chimaphila umbellata*—pipsissewa (Bjoertvedt via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 19** *Chimaphila umbellata*—pipsissewa (©2009 Gary A. Monroe; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 20** *Chimaphila umbellata*—pipsissewa (© brewbooks via Flickr; Creative Commons Attribution-ShareAlike 2.0 Generic (CC BY-SA 2.0) License, <https://creativecommons.org/licenses/by-sa/2.0/>) (CC BY-SA 2.0) License)
- 21** *Zea mays*—corn (Kembangraps via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 22** *Zea mays*—corn (Howard F. Schwartz, Colorado State University, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 23** *Zea mays*—corn (Amada44 via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 24—29** *Sedges, and rushes plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 30—33** *Acer saccharum*—sugar maple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 34—35** *Alnus incana*—gray alder (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



org/licenses/by-nc/4.0/)

- 36—37** *Fraxinus americana*—white ash (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 38—41** *Hamamelis virginiana*—American witchhazel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 42—43** *Vaccinium corymbosum*—highbush blueberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 44—45** *Salix discolor*—pussy willow (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 46—49** *Rhododendron* sp.—rhododendron (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 50—54** *Kalmia latifolia*—mountain laurel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 55—58** *Larrea tridentata*—creosote bush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 59—61** *Olneya tesota*—desert ironwood (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 62—64** *Parkinsonia microphylla*—yellow paloverde (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 65—66** *Acacia greggii*—catclaw acacia (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 67—69** *Prosopis velutina*—velvet mesquite (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 75** *Fouquieria splendens*—ocotillo (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 76** *Fouquieria splendens*—ocotillo (Frank Vincentz via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 77** *Fouquieria splendens*—ocotillo (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 78** *Fouquieria splendens*—ocotillo (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 79** *Fouquieria splendens*—ocotillo (Leslie Seaton via Wikimedia Commons; Creative Commons Attribution 2.0 Generic License, <https://creativecommons.org/licenses/by/2.0/>)
- 80** *Fouquieria splendens*—ocotillo (credit placeholder; license placeholder)
- 81** *Fouquieria splendens*—ocotillo (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 82** *Fouquieria splendens*—Ocotillo (© Jesse Rorabaugh via iNaturalist; Creative Commons Attribution 3.0 Unported (CC BY 3.0) License, <https://creativecommons.org/licenses/by/3.0/>)
- 83—86** *Ceanothus greggii*—Desert ceanothus (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



PAGES 30-33: THE PHENOPHASE FOR LEAVES

- 1 *Helianthus annuum*—Common sunflowers (Amada44 via EOL; Public domain)
- 2 *Maianthemum canadense*—Canada mayflowers (Fungus Guy via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 3 *Penstemon* sp.—penstemon (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4 *Penstemon palmeri*—Palmer's penstemon (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 5 *Penstemon* sp.—penstemon (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 6 *Penstemon superbus*—superb penstemon (Russ Kleinman, Western New Mexico University Department of Natural Sciences and the Dale A. Zimmerman Herbarium; for permission of image usage, see <http://www.wnmu.edu/academic/nspages/gilafiora/index.html>)
- 7 *Paspalum dilatatum*—dallisgrass (Joseph M. DiTomaso, University of California—Davis, Bugwood.org; Creative Commons Attribution-NonCommercial 3.0 United States License, <https://creativecommons.org/licenses/by-nc/3.0/us/>)
- 8 *Setaria macrostachya*—plains bristlegrass (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 15—17 *Acer rubrum*—red maple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 18 *Acer rubrum*—red maple (Gaoyuan via Wikimedia Commons, Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 19—23 *Hamamelis virginiana*—American witchhazel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 24—25 *Prosopis velutina*—velvet mesquite (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 26 *Prosopis velutina*—velvet mesquite (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 27 *Prosopis velutina*—velvet mesquite (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 28—31 *Olneya tesota*—desert ironwood (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 32 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 33 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 34 *Quercus laurifolia*—laurel oak (© Mary Keim, via EOL; Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic (CC BY-NC-SA 2.0) License (<http://creativecommons.org/licenses/by-nc-sa/2.0/>))
- 35 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

PAGES 34-35: THE PHENOPHASE FOR YOUNG LEAVES

- 1 *Chimaphila umbellata*—pipsissewa (Superior National Forest via Wikimedia Commons; Creative Commons Attribution 2.0 Generic License, <https://creativecommons.org/licenses/by/2.0/>)
- 2 *Goodyera oblongifolia*—western rattlesnake plantain (© seakay via iNaturalist; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0) License (<http://creativecommons.org/licenses/by-nc-sa/3.0/>))
- 3 *Sarracenia purpurea*—purple pitcherplant (Copyright Daniel Carter via EOL; Creative Commons Attribution-NonCommercial 3.0 Unported (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 4 *Linnaea borealis*—American twinflower (© 2010 Craig Althen; for permission of image usage, see [http://biology.burke.washington.edu/herbarium/imagecollection.php?FullName=Craig Althen](http://biology.burke.washington.edu/herbarium/imagecollection.php?FullName=Craig+Althen))
- 5 *Darlingtonia californica*—California pitcherplant (©2001 Steven Thorsted; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 6 *Asclepias subulata*—rush milkweed (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 7 *Kalmia latifolia*—mountain laurel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 8 *Larrea tridentata*—creosote bush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9 *Quercus laurifolia* (young leaves)—laurel oak (© Mary Keim; Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic (CC BY-NC-SA 2.0) License, <http://creativecommons.org/licenses/by-nc-sa/2.0/>)
- 10 *Quercus laurifolia* (mature leaves)—laurel oak—common name (© Rolling Meadows Farm; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11 *Ligustrum sinense*—Chinese privet (©2005 Luigi Rignanese; Creative Commons Attribution-NonCommercial 3.0 Unported (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 12 *Chilopsis linearis*—desert willow (© maggiegabq via iNaturalist.org; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 13 *Acacia greggii*—catclaw acacia (©Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 36-37: THE PHENOPHASE FOR INCREASING LEAF SIZE

- 1—6 *Acer saccharum*—sugar maple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 7 *Salix discolor*—pussy willow (Silk666 via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 8—10 *Salix discolor*—pussy willow (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11—14 *Vaccinium corymbosum*—highbush blueberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 15—19 *Quercus rubra*—northern red oak (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



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PAGES 38-39: THE PHENOPHASE FOR COLORED LEAVES

- 1** *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2** *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 3** *Prunus serotina*—black cherry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4** *Rubus* sp.—blackberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 5—7** *Quercus rubra*—northern red oak (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 8** *Olneya tesota*—desert ironwood (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9—13** *Acer saccharum*—sugar maple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 14** *Quercus rubra*—northern red oak (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 15** *Fagus grandifolia*—American beech (Famartin via Wikimedia Commons; Creative Commons Attribution-Share Alike 4.0 International License, <https://creativecommons.org/licenses/by-sa/4.0/deed.en>)

PAGE 40: THE PHENOPHASE FOR FALLING LEAVES

- 1** *Hamamelis virginiana*—American witchhazel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2** *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 3—5** *Betula papyrifera*—paper birch (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 42-43: AN OVERVIEW OF REPRODUCTIVE (FLOWER AND FRUIT) PHENOPHASES

- 1** Flowers Phenophase Timeline (Sara Schaffer, Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 3** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 4** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 5** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 6** *plantspecies placeholder*—common name (credit placeholder; license placeholder)



- 7 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 8 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 9 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 10 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

PAGE 44: AN OVERVIEW OF DORMANT FLOWER BUDS

- 1 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 2 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 3 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 4 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 5 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 6 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 7 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 8 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 9 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 10 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

PAGE 45: AN OVERVIEW OF MIXED BUDS

- 1 *Oemleria cerasiformis*—Indian plum (Jennifer Wheeler, BLM, Arcata Field Office; Public domain)
- 2 *Acer rubrum*—red maple (©2016 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 3 *Sambucus racemosa*—red elderberry (© Sarah Carline via iNaturalist.org; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <http://creativecommons.org/licenses/by-nc/4.0/>)
- 4 *Magnolia stellata*—star magnolia (Alpsdake via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 5 *Acer negundo*—boxelder (©2016 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 6 *Viburnum lantanooides*—hobblebush (© Kent McFarland via Flickr; Creative Commons Attribution-NonCommercial 2.0 Generic (CC BY-NC 2.0) License, <https://creativecommons.org/licenses/by-nc/2.0/>)

PAGES 46-47: AN OVERVIEW OF FLOWERS AND INFLORESCENCES

- 1 Flower illustration (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2 Inflorescence illustration (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



- 3** *Kallstroemia grandiflora*—Arizona poppy (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4** *Magnolia x soulangiana*—Chinese magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 5** *Verbascum thapsis*—woolly mullein (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 6** *Lupinus* sp.—lupine (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 7** *Prosopis velutina*—velvet mesquite (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 8** *Yucca baccata*—banana yucca (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9** *Sambucus racemosa*—red elderberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 10** thistle (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11** *Achillea millefolium*—common yarrow (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 48-51: THE PHENOPHASE FOR FLOWERS OR FLOWER BUDS

- 1-6** *Opuntia santa-rita*—Santa Rita pricklypear (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 7-8** *Eschscholzia californica*—California poppy (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9** *Eschscholzia californica*—California poppy (H. Zell via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 10** *Eschscholzia californica*—California poppy (Eugene Zelenko via Wikimedia Commons; Creative Commons Attribution-Share Alike 4.0 International License, <https://creativecommons.org/licenses/by-sa/4.0/deed.en>)
- 11-12** *Eschscholzia californica*—California poppy (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
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- 26-30** *Alnus incana*—grey alder (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 31** *Alnus incana* ssp. *rugosa*—speckled alder (Kenneth Dritz. USDA NRCS. 1995. Northeast wetland flora: Field office guide to plant species. Northeast National Technical Center, Chester, PA. Courtesy of USDA NRCS Wetland Science Institute; Public domain)
- 32-34** *Alnus incana*—grey alder (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



- 35—41** *Prosopis velutina*—velvet mesquite (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 42** *Quercus pacifica*—Channel Island scrub oak (©2014 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 43** *Quercus rubra*—northern red oak (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 44** *Quercus imbricaria*—shingle oak (© Gerrit Davidse, Tropicos.org. Missouri Botanical Garden. 22 Aug 2016 <<http://www.tropicos.org/Image/100194018>>; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 45** *Arisaema triphyllum*—jack in the pulpit (Meneerke bloem via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 46** *Arisaema triphyllum*—jack in the pulpit (© Yuri Huta via Finding Species; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 47** *Arisaema triphyllum*—jack in the pulpit (© 2005 Steven J. Baskauf, <http://bioimages.vanderbilt.edu/>; Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) License, <https://creativecommons.org/licenses/by-nc-sa/4.0/>)
- 48** *Celtis pallida*—desert hackberry (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 49** *Celtis pallida*—desert hackberry; male flowers (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 50** *Celtis pallida*—desert hackberry; female flowers (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 52-53: AN OVERVIEW OF GRASS FLOWERS AND FLOWER HEADS

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- 2** *Sorghum halepense*—Johnson grass (Tau’olunga via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 3** *Setaria ambigua*—barbed bristlegrass (©2008 Luigi Rignanese; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 4** *Achnatherum hymenoides*—Indian ricegrass (Dave Powell, USDA Forest Service, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <http://creativecommons.org/licenses/by/3.0/us/>)
- 5** *Bothriochloa ischaemum*—yellow bluestem (Petr Filippov via Wikimedia Commons; Creative Commons Attribution 3.0 Unported License, <https://creativecommons.org/licenses/by/3.0/deed.en>)
- 6** *Hordeum* sp.—barley (Alina Zienowicz via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 7** *Bromus tectorum*—cheatgrass (©2008 Gary A. Monroe; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 8** *Bouteloua gracilis*—blue grama (©2008 Robert Sivinski; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 9** *Setaria neglecta*—African bristlegrass (©2011 Zoya Akulova; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)

- 10** *Hordeum murinum*—mouse barley (D. Walters and C. Southwick, CPHST, Bugwood.org; Creative Commons Attribution-Noncommercial 3.0 United States License, <https://creativecommons.org/licenses/by-nc/3.0/us/>)
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- 12** *Setaria faberi*—Japanese bristlegrass (D. Walters and C. Southwick, CPHST, Bugwood.org; Creative Commons Attribution-Noncommercial 3.0 United States License, <https://creativecommons.org/licenses/by-nc/3.0/us/>)

PAGES 54-57: AN OVERVIEW OF SEDGE FLOWERS AND FLOWER HEADS

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- 3** *Scirpus* inflorescence illustration (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4** *Eriophorum* inflorescence illustration (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 5** *Carex barbarae*—Santa Barbara sedge (Russell Huddleston; Public domain)
- 6** *Carex concinna*—low northern sedge (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 7** *Scirpus pendulus*—rufous bulrush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 8** *Scirpus microcarpus*—panicked bulrush (©2003 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 9** *Cladium mariscoides*—smooth sawgrass (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 10** *Cyperus esculentus*—yellow nutsedge (© Kenneth Bader; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11** *Eriophorum virginicum*—tawny cottongrass (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
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- 13** *Carex luzulina* var. *ablata*—woodrush sedge (©2010 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/us/>)
- 14** *Carex pendula*—drooping sedge (Franz Xaver via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>; GNU Free Documentation)
- 15** *Carex concinna*—low northern sedge (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 16** *Carex sprengei*—long-beaked sedge (©2016 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/us/>)



- 17** *Carex stipata* var. *stipata*—owlfruit sedge (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/us/>)
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- 19** *Carex breweri*—Brewer's sedge (©2010 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/us/>)
- 20** *Schoenoplectus lacustris*—lakeshore bulrush (Fabelfroh via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 21** *Schoenoplectus americanus*—chairmaker's bulrush (©2009 Robert Sivinski; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
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- 24** *Scirpus pendulus*—rufous bulrush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 25** *Cladium mariscoides*—smooth sawgrass (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <http://creativecommons.org/licenses/by/3.0/us/>)
- 26** *Cladium californicum*—California sawgrass (USDI Bureau of Land Management, United States, NV, Clark Co.; Public domain)
- 27** *Cyperus esculentus*—yellow nutsedge (© Kenneth Bader via iNaturalist.org; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 28** *Cyperus eragrostis*—tall flatsedge (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 29** *Eriophorum vaginatum*—tussock cottongrass (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 30** *Eriophorum vaginatum* in flower—tussock cottongrass (Krzysztof Ziarnik via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported license, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 31** *Eriophorum vaginatum* in fruit—tussock cottongrass (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)

PAGES 58-59: AN OVERVIEW OF RUSH FLOWERS AND FLOWER HEADS

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- 3** *Juncus laccatus*—shiny rush (©2007 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 4** *Juncus ensifolius*—swordleaf rush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 5** *Juncus dubius*—mariposa rush (©2015 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)



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- 6 *Juncus bufonius*—toad rush (©2011 Jorg & Mimi Fleige; Creative Commons Attribution-NonCommercial 3.0 Unported (CC BY-NC 3.0) License, <https://creativecommons.org/licenses/by-nc/3.0/>)
- 7 *Juncus bolanderi*—Bolander's rush (©2003 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 8 *Juncus longistylis*—long-styled rush (©2015 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 9 *Juncus chlorocephalus*—greenhead rush (©2003 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 10 *Juncus balticus*—Baltic rush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
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- 12 *Juncus ensifolius*—swordleaf rush (©2015 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 13 *Juncus howellii*—Howell's rush (©2015 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 14 *Juncus mertensianus*—Mertens' rush (©2007 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 15 *Juncus nevadensis*—Nevada rush (©2003 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 16 *Juncus orthophyllus*—straightleaf rush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)

PAGES 60-61: THE PHENOPHASE FOR FLOWER HEADS (GRASSES, SEDGES) & FLOWERS OR FLOWER BUDS (RUSHES)

- 1 *Phalaris arundinacea*—reed canarygrass (James Lindsey at Ecology of Commanster via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 2 *Phalaris arundinacea*—reed canarygrass (Maja Dumat via Flickr; Creative Commons Attribution 2.0 Generic (CC BY 2.0) License, <https://creativecommons.org/licenses/by/2.0/>)
- 3 *Phalaris arundinacea*—reed canarygrass (Kristian Peters via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 4 *Phalaris arundinacea*—reed canarygrass (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/us/>)
- 5 *Phalaris arundinacea*—reed canarygrass (James Lindsey at Ecology of Commanster via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 6 *Phalaris arundinacea*—reed canarygrass (Leslie J. Mehrhoff, University of Connecticut, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <http://creativecommons.org/licenses/by/3.0/us/>)
- 7 *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 8 *plantspecies placeholder*—common name (credit placeholder; license placeholder)



- 9** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 10** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 11** *plantspecies placeholder*—common name (credit placeholder; license placeholder)
- 12** *Juncus interior*—inland rush (© 2010, Craig Althen; for permission of image usage, see <http://biology.burke.washington.edu/herbarium/imagecollection/imageinfo.php?imageNumber=31066&TaxonID=2289&SourcePage=taxon>)
- 13** *Juncus confusus*—Colorado rush (©2015 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 14** *Juncus torreyi*—Torrey's rush (© John Hilty; for permission of image usage, see http://www.illinoiswildflowers.info/files/photo_use.html)
- 15** *Juncus chlorocephalus*—greenhead rush (©2010 Barry Breckling; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 16** *Juncus pallidus*—pale rush (© Tony Wills; Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) License, <https://creativecommons.org/licenses/by-sa/4.0/>)
- 17** *Juncus torreyi*—Torrey's rush (© schock1 via iNaturalist.org; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 18** *Juncus tenuis*—poverty rush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)

PAGES 62-65: THE PHENOPHASE FOR OPEN FLOWERS

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- 2** *Opuntia santa-rita*—Santa Rita pricklypear (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
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- 14** *Platanus racemosa*—California sycamore (Eugene Zelenko via Wikimedia Commons; Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) License, <https://creativecommons.org/licenses/by-sa/4.0/>)
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- 16b** *Quercus rubra*—northern red oak (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
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- 17b** *Simmondsia chinensis*—jojoba (Stan Shebs via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
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- 18b** *Atriplex canescens*—fourwing saltbush (©2010 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
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- 21** *Helianthus niveus* ssp. *tephrodes*—Algodones sunflower (©2014 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
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- 24** *Taraxacum officinale*—common dandelion (Uoaei1 via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 25** *Cirsium occidentale* var. *californicum*—California thistle (©2015 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 26** *Pseudognaphalium* sp.—everlasting (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 27** *Ericameria nauseosus*—rubber rabbitbush (Stan Shebs via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)



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- 28b** *Baccharis sarothroides*—broom baccharis (©2015 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 29** *Artemisia californica*—California sagebrush (©2008 Jorg Fleige; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 30** *Ambrosia psilostachya*—western ragweed (©2014 Richard Spellenberg; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 31** *Ambrosia monogyra*—single-whorl burrobrush (©2014 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 32** *Bromus inermis*—smooth brome (Fabelfroh via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- 33** *Pennisetum setaceum*—crimson fountaingrass (©2011 Zoya Akulova; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 34** *Tripsacum* sp.—gamagrass (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 35** *Carex concinna*—low northern sedge (Rob Routledge, Sault College, Bugwood.org ; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)
- 36** *Carex aurea*—golden sedge (©2003 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 37** *Scirpus microcarpus*—panicled bulrush (©2003 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 38** *Juncus balticus*—baltic rush (©2008 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 39** *Juncus howellii*—Howell's rush (©2015 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 40** *Luzula hitchcockii*—Hitchcock's wood rush (©2010 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)

PAGES 66-67: THE PHENOPHASE FOR POLLEN RELEASE

- 1** *Opuntia versicolor*—staghorn cholla (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2** *Kallstroemia grandiflora*—Arizona poppy (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 3** *Typha* sp.—fourwing saltbush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4** *Pinus* sp.—Pine (Tangopaso via Wikimedia Commons; Public domain)
- 5** *Atriplex canescens*—fourwing saltbush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



- 6** *Aegilops cylindrica*—jointed goatgrass (©2014 Al Keuter; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 7** Poaceae species—grass (David Cappaert, Bugwood.org; Creative Commons Attribution-NonCommercial 3.0 United States (CC BY-NC 3.0 US) License, <https://creativecommons.org/licenses/by-nc/3.0/us/>)
- 8** *Saccharum spontaneum*—wild sugarcane (Scott Bauer via Wikimedia Commons; Public domain)
- 9** *Paspalum quadrifarium*—tussock paspalum (Chris Evans, University of Illinois, Bugwood.org; Creative Commons Attribution-NonCommercial 3.0 United States (CC BY-NC 3.0 US) License, <https://creativecommons.org/licenses/by-nc/3.0/us/>)
- 10** *Tripsacum dactyloides*—eastern gamagrass (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11** *Anthoxanthum odoratum*—sweet vernal grass (©2008 Zoya Akulova; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 12** *Gilia tricolor*—bird's-eye gilia (©2015 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)
- 13** *Calochorus* sp.—mariposa lily (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 14** *Calochorus kennedyi*—desert mariposa lily (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 15** *Oenothera speciosa*—pinkladies (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 16** *Asclepias asperula*—antelope horn milkweed (LevyRat via Wikimedia Commons; Creative Commons CC0 1.0 Universal Public Domain Dedication, <https://creativecommons.org/publicdomain/zero/1.0/deed.en>)

PAGES 68-69: AN OVERVIEW OF “SPENT” FLOWERS

- 1-6** *Citrus* sp.—orange (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 7** *Opuntia engelmannii*—cactus apple (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 8** *Eriogonum fasciculatum*—eastern Mojave buckwheat (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9** *Anaphalis* sp.—everlasting (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 10** *Ferocactus wislizeni*—candy barrelcactus (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11** *Eschscholzia californica*—California poppy (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 12** *Fouquieria splendens*—ocotillo (Ciar via Wikimedia Commons; Public domain)
- 13** *Penstemon superbus*—superb beardtongue (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 14** *Punica granatum*—pomegranate (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



mons.org/licenses/by-nc/4.0/)

15 *Acacia berlandieri*—guajillo (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

16 *Grindellia* sp.—gumweed (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

17 unknown Asteraceae (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

18 *Eriogonum fasciculatum*—eastern Mojave buckwheat (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

19 *Chrysothamnus* sp.—rabbitbrush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

20 *Schoenoplectus americanus*—bulrush (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 70-71: AN OVERVIEW OF NEW FRUITS

1 *Oenothera elata* ssp. *hirsutissima*—hairy evening-primrose (©2013 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)

2 *Ranunculus uncinatus*—woodland buttercup (©2011 Jean Pawek; for permission of image usage, see http://calphotos.berkeley.edu/cgi/img_query?enlarge=0000+0000+0811+2603)

3 *Acacia greggii*—catclaw acacia (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

4 *Eriogonum fasciculatum*—eastern Mojave buckwheat (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

5 *Solanum lycopersicum*—tomato (Slick via Wikimedia Commons; Creative Commons CC0 1.0 Universal Public Domain Dedication, <https://creativecommons.org/publicdomain/zero/1.0/deed.en>)

6 *Penstemon albomarginatus*—whitemargin beardtongue (©2014 John Game; Creative Commons Attribution-ShareAlike 3.0 (CC BY-SA 3.0) License, <https://creativecommons.org/licenses/by-sa/3.0/>)

7 *Cucumis melo*—cantalope (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

8 *Lepidium lasiocarpum* var. *lasiocarpum*—shaggyfruit pepperweed (Stan Shebs via Wikimedia Commons; Creative Commons Attribution-Share Alike 3.0 Unported License, <https://creativecommons.org/licenses/by-sa/3.0/deed.en>)

9 *Sambucus racemosa*—red elderberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

10 *Olneya tesota*—desert ironwood (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

11 *Quercus rubra*—northern red oak (DAVID LEE, Bugwood.org; Creative Commons Attribution-NonCommercial 3.0 United States (CC BY-NC 3.0 US) License, <https://creativecommons.org/licenses/by-nc/3.0/us/>)

12 *Corylus cornuta* ssp. *californica*—California hazelnut (©2010 Barry Breckling; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <http://creativecommons.org/licenses/by-nc-sa/3.0/>)



13 *Hamamelis virginiana*—American witchhazel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 72-74: THE PHENOPHASE FOR FRUITS

1 *Opuntia santa-rita*—Santa Rita pricklypear (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

2 *Opuntia santa-rita*—Santa Rita pricklypear (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

3-4 *Opuntia santa-rita*—Santa Rita pricklypear (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

5-8 *Fragaria virginiana*—Virginia strawberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

9 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

12-15 *Scirpus cyperinus*—woolgrass (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

16 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

17 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

18 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

19 *plantspecies placeholder*—common name (credit placeholder; license placeholder)

20-23 *Kalmia latifolia*—mountain laurel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

24-27 *Betula nigra*—river birch (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

28-32 *Acer rubrum*—red maple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

33-36 *Quercus rubra*—northern red oak (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

37 *Quercus rubra*—northern red oak (Tom DeGomez, University of Arizona, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)

PAGE 75: AN OVERVIEW OF ABORTED FRUITS

1 *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

2 *Salix discolor*—pussy willow (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

3 *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

4 *Citrus* sp.—orange (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



nc/4.0/)

5 *Quercus emoryi*—Emory oak (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

6 *Cucumis melo*—cantalope (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

7 *Quercus rubra*—northern red oak (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

PAGES 76-77: THE PHENOPHASE FOR RIPE FRUITS

1—5 *Salix discolor*—pussy willow (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

6—10 *Vaccinium corymbosum*—highbush blueberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

11—12 *Ceanothus* sp.—ceanothus (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

13 -14 *Penstemon superbus*—superb beardtongue (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

15—16 *Asclepias subulata*—rush milkweed (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

17—18 *Xanthium strumarium*—rough cocklebur (Jan Samanek, Phytosanitary Administration, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)

19—20 *Baileya multiradiata*—desert marigold (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

21—22 *Prosopis velutina*—velvet mesquite (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

23—24 *Cornus canadensis*—bunchberry dogwood (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

25—26 *Cucumis melo*—cantalope (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

27—28 *Setaria* sp.—bristlegass (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)

29 *Juncus confusus*—Colorado rush (©2012 Gary A. Monroe; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)

30 *Juncus confusus*—Colorado rush (©2012 Steve Matson; Creative Commons Attribution-NonCommercial 3.0 (CC BY-NC 3.0) License, <http://creativecommons.org/licenses/by-nc/3.0/>)

PAGE 78: AN OVERVIEW OF RIPENED, PERSISTENT FRUITS

1 *Ilex verticillata*—common winterberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



- 2** *Chimaphila umbellata* ssp. *umbellata*—common pipsissewa (©2016 Keir Morse; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 3** *Chimaphila umbellata*—pipsissewa (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4** *Chimaphila umbellata*—prince's pine (©2010 Jean Pawek; for permission of image usage, see http://calphotos.berkeley.edu/cgi/img_query?enlarge=0000+0000+0910+1820)
- 5** *Chimaphila umbellata*—pipsissewa (©2012 Barry Rice; Creative Commons Attribution-NonCommercial-ShareAlike 3.0 (CC BY-NC-SA 3.0) License, <https://creativecommons.org/licenses/by-nc-sa/3.0/>)
- 6—8** *Hamamelis virginiana*—American witchhazel (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9** *Ilex verticillata*—common winterberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 10—11** *Ilex verticillata*—common winterberry (Rob Routledge, Sault College, Bugwood.org; Creative Commons Attribution 3.0 United States (CC BY 3.0 US) License, <https://creativecommons.org/licenses/by/3.0/us/>)

PAGE 79: THE PHENOPHASE FOR RECENT FRUIT OR SEED DROP

- 1** *Acer rubrum*—red maple (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 2** *Olneya tesota*—desert ironwood (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 3** *Erythronium americanum*—dogtooth violet (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 4** *Salix discolor*—pussy willow (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 5** *Typha* sp.—cattail (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 6** *Asclepias subulata*—rush milkweed (© Sara N. Schaffer; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 7** *Betula nigra*—river birch (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 8** *Ilex verticillata*—common winterberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 9** *Betula papyrifera*—paper birch (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 10** *Magnolia stellata*—star magnolia (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 11** *Ilex verticillata*—common winterberry (Ellen G. Denny; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)
- 12** *Quercus emoryi*—Emory oak (Patty Guertin; Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License, <https://creativecommons.org/licenses/by-nc/4.0/>)



REFERENCES

Bell, Adrian D. *Plant Form: An Illustrated Guide to Flowering Plant Morphology*. Portland: Timber Press, Inc., 2008. Print.

Bold, Harold C., Constantine J. Alexopoulos, and Theodore Delevoryas. *Morphology of Plants and Fungi*. Harper & Row, Publishers, New York. 1987. Print.

Denny, Ellen G., et al. *Standardized phenology monitoring methods to track plant and animal activity for science and resource management applications*. International Journal of Biometeorology. May 2014, Vol. 58:4, pp 591-601.

Flora of North America online, at www.efloras.org [accessed between 2011-2016]: Flora of North America Editorial Committee, eds. 1993+. *Flora of North America North of Mexico*. 20+ vols. New York and Oxford.

Harris, James G., and Melinda Woolf Harris. *Plant Identification Terminology: An Illustrated Glossary*. Spring Lake: Spring Lake Publishing, 2001. Print.

Ingrouille, Martin. *Diversity and Evolution of Land Plants*. Chapman & Hall, 2-6 Boundary Row, London. 1992. Print.

Jepson Flora Project (eds.) 2016. Jepson eFlora, <http://ucjeps.berkeley.edu/eflora/> [accessed between 2012-2016].

Raven, Peter H., Evert, Ray F., and Susan E. Eichhorn. *Biology of Plants*. New York: Worth Publishers, 2009. Print.