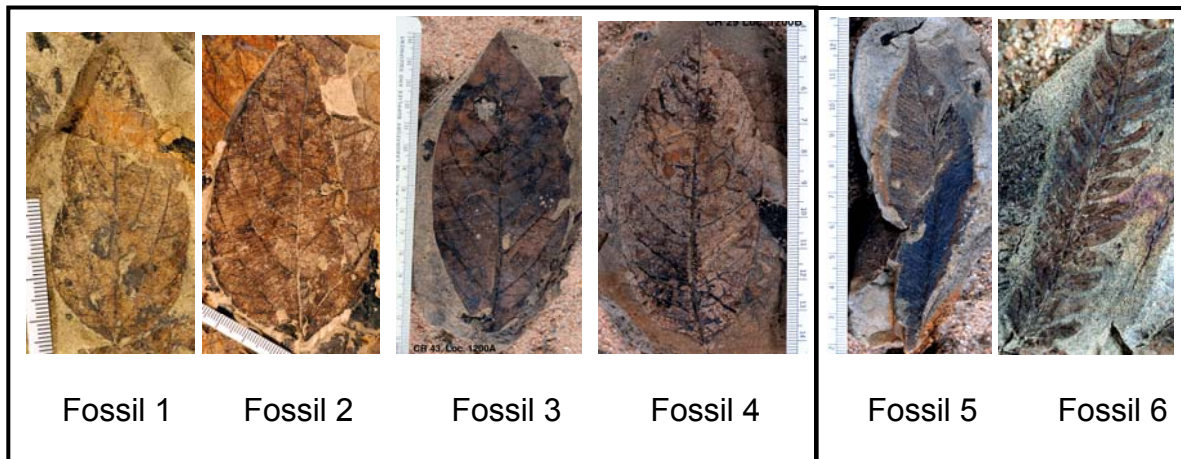


Denver Museum of Nature & Science

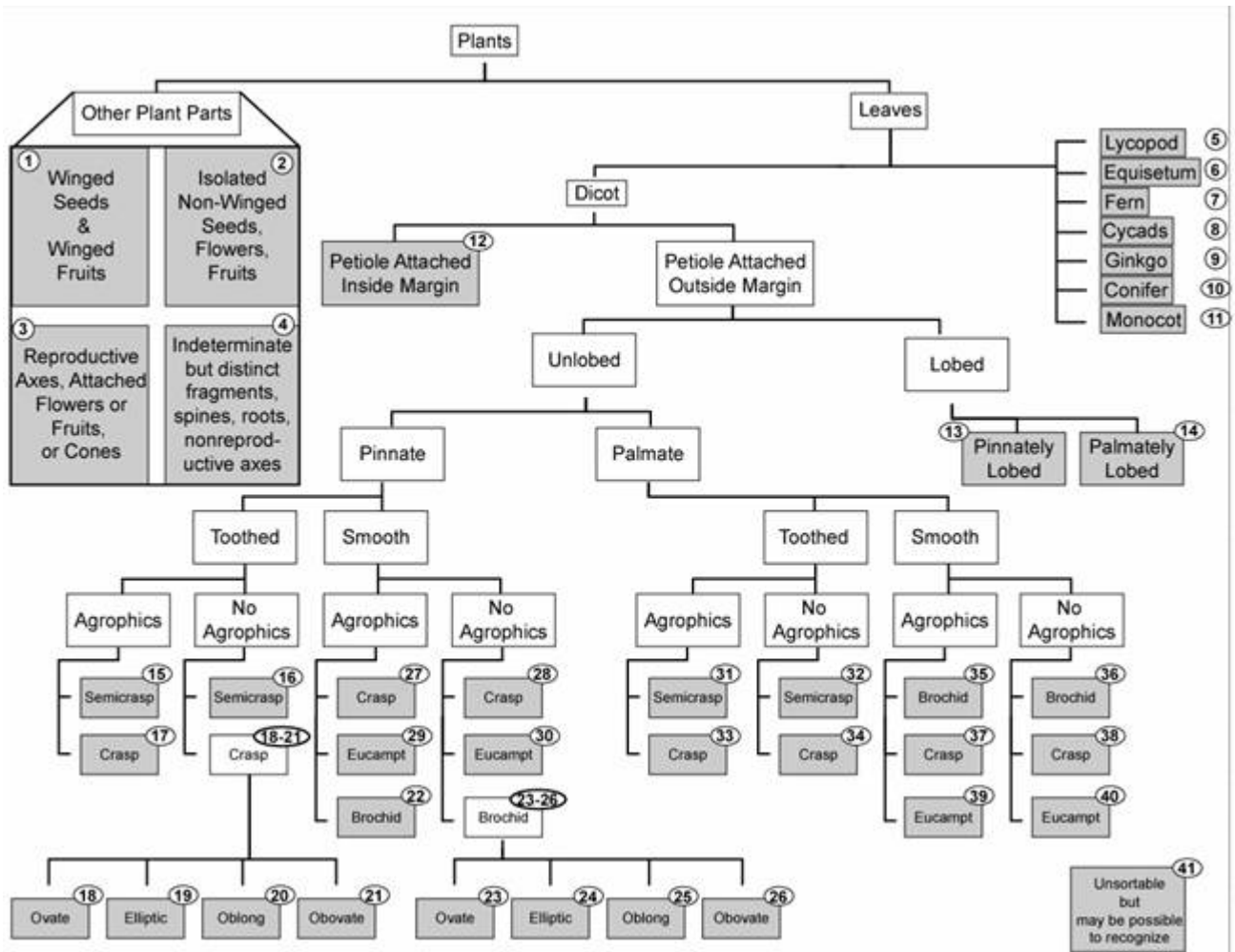
Guide to morphotyping (or binning) a fossil flora (step-by-step)

1. **Prepare and number specimens:** Label each specimen with a locality number and prepare it in the lab so that the features of the leaf are as visible as possible. Create a specimen label that contains the locality and accession data for the specimen. Create a second “morphotype tag” to keep track of the fossil’s morphotype number, your initials and the date. It is useful to place each specimen in a specimen tray so that the labels remain with the specimen.

2. **Bin the flora:** Sort the fossils into groups based on shared leaf-architectural characteristics following the binning flowchart below. (For a more detailed description, see [guide to binning](#) under the identification tab.) Begin by separating the specimens into three groups: non-leaves, non-dicots and dicots. Below is an example using a very small locality that contains 6 fossils. Of this group, fossils 1-4 are dicots and fossils 5 and 6 are ferns. First, separate the ferns – they belong in bin 7.



Next we divide the dicots with the [bin flow chart](#) in hand. The initial sorting of dicots is done on the basis of the presence and type of lobes, toothed versus entire margins, and primary and secondary vein patterns. These characters are usually stable within morphotypes. Less reliable characters are leaf size and shape.



Flowchart depicting structure of the identification menus of this website
(Category “bins” are numbered for easy reference.)

In our six leaf example, fossils 1-4 are all dicot leaves with petioles attached outside the margin. They are unlobed and the primary vein is pinnate. Fossils 1 and 2 have a toothed margin but fossils 3 and 4 are smooth. Thus the fossils are split into two groups.

Fossils 1 and 2 have toothed margins, agrophic veins and the secondaries veins are semicraspedodromous so they go to bin 15. Fossils 3 and 4 have smooth margins, no agrophic veins, brochidodromous secondary veins and an elliptic shape. Thus they both go to bin 24.

3. **Subdivide the specimens in each bin:** Once the fossils are grouped into bins, it is much easier to separate them by higher-order venation pattern and tooth type [see LAWG 1999, Hickey 1973, 1979 and Hickey and Wolfe, 1975]. Here’s the breakdown for our example flora:

Bin 7: Although they are both ferns, fossil 5 and 6 are different ferns. Therefore fossil 5 will be labeled 7.1 (first morphotype in bin 7) and fossil 6 will be labeled 7.2 (second morphotype in bin 7).

Bin 15: Although minor differences can be noted, fossils 1 and 2 are examples of the same morphotype. They will both be labeled morphotype 15.1 and fossil 1 will be designated the holomorphotype. Fossil 2 is just another example of the morphotype.

Bin 24: Fossils 3 and 4 are different from each other. The angle of the secondary veins is steeper on fossil 3 and the brochidodromous loops occur closer to the margin on fossil 4 than fossil 3. Thus, fossil 3 becomes 24.1 and fossil 4 becomes 24.2, both are holomorphotypes.

One major distinction between **holotype** specimens (the single specimen that bears a Linnaean name) and **holomorphotype** specimens (the informal numbering-bearing specimen in this system) is that holotypes are formal and permanent where holomorphotypes are informal and may be replaced with better specimens or sunk into other morphotypes.

4. **Describe the morphotypes:** The next step is to completely describe the diagnostic features of the morphotype. (We use the terminology found in the Manual of Leaf Architecture as a guide.) This is typically done by designating a single quarry holomorphotype that best represents all of the characteristics of the morphotype and describing how to distinguish it from other morphotypes found at this quarry. In the process of morphotyping a flora, you may discover that some morphotypes are not easily represented by a single holomorphotype because of the range of variation exhibited by the specimens. In this case, a holomorphotype is still designated but the description of the morphotype is expanded using additional specimens that show clear overlap in their morphological characters with the holomorphotype specimen, to completely describe the morphotype.

Learning how to look at venation patterns takes practice. To highlight the characters that differentiate the fossils within your bins, it is very helpful to sketch and/or photograph the holomorphotypes and note diagnostic features and the range of variation. It is useful to print photos or scanned slides as full page images that can be mounted on the wall of your work area. This increases familiarity with the various morphotypes.

5. **Comparing leaves from multiple localities:** At DMNS, we try to collect a minimum of 300 leaves from a single quarry (more if the flora is very diverse). With this data, we can estimate paleoclimate and diversity parameters for each locality without needing to name the fossils.

To manage all of these fossils, we use the bin system to sort the fossils from a **single** quarry. Thus, multiple quarries can have a fossil labeled 24.1 even though they do not represent the same morphotype across quarries. This has two advantages. The first is that students can participate in the process by morphotyping a single locality without needing to have mastered all of the existing fossils in the basin. The second is that the morphotypes

can then go through a second filter (called the Holomorphotype Quality Index) which further separates the quarry holomorphotypes based on their completeness and quality of preservation. This helps to sort fossils which are well enough preserved to be named from fossils which provide data for paleoclimate analysis but not taxonomy. The fossils which pass this quality filter are called Basin Morphotypes and a Basin Holomorphotype is designated, usually with a two letter prefix followed by a three digit number. (For example DB016.)

6. Holomorphotype Quality Index (HQI): Score your dicot leaf holomorphotypes, giving one point each for the presence of lobes, complete base, peltate base, complete apex, margin, 3rd order veins, 4th order veins, and 5th order veins. The maximum a leaf can score is 7. Note that all of these characters must be present on one single specimen (the holomorphotype).

If a fossil scores a “4” or higher, it is usually well-enough preserved to describe so it is assigned a Basin Holomorphotype number. In some cases, when over 60 examples of a fossil are present at a quarry and no single leaf meets the “4” standard but several leaves can be put together to meet the standard, we would elevate this fossil to basin holomorphotype status based on the large numbers of specimens. In this way, fossils can be compared across a large geographic area without needing to be placed in the Linnaean system. Only fossils that meet the Basin Holomorphotype standard are included in the on-line Paleobotany Project. Basin morphotype numbers consist of a two letter prefix followed by three numbers. DMNS keeps the master list of morphotype numbers.

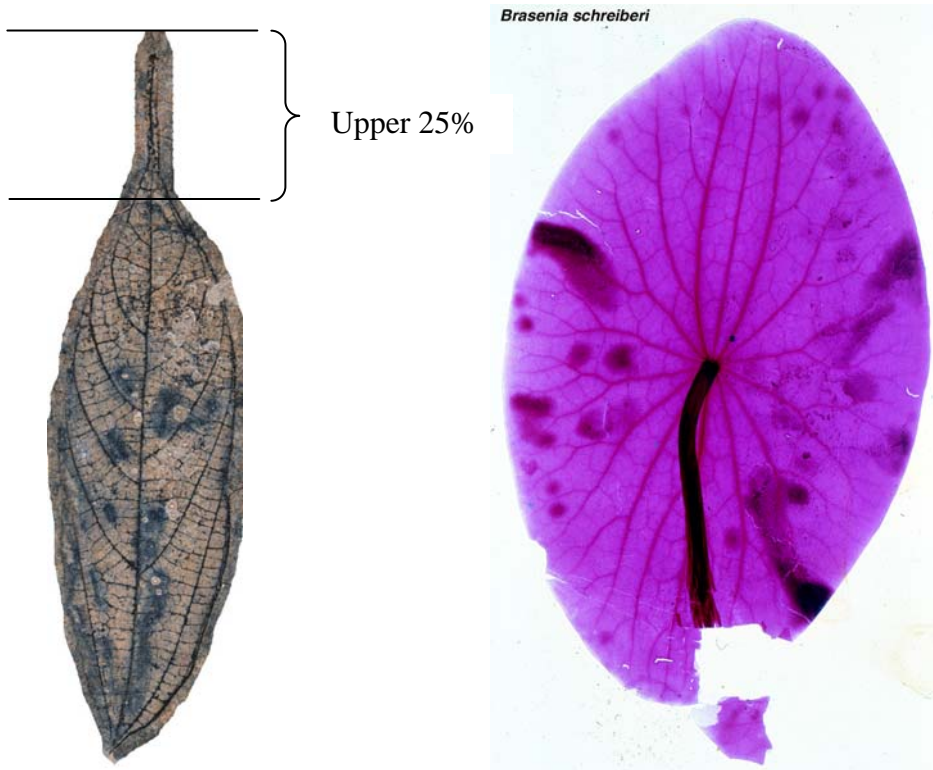


Lobes

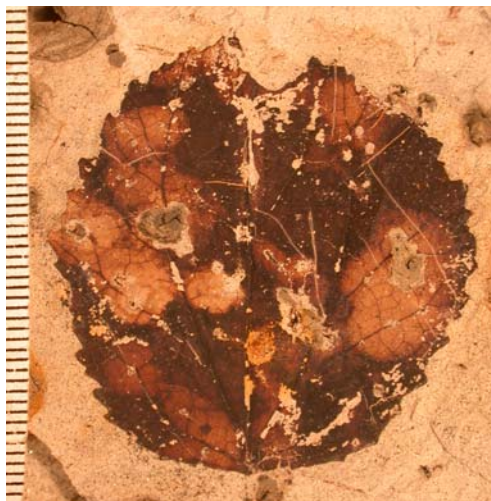


Complete base

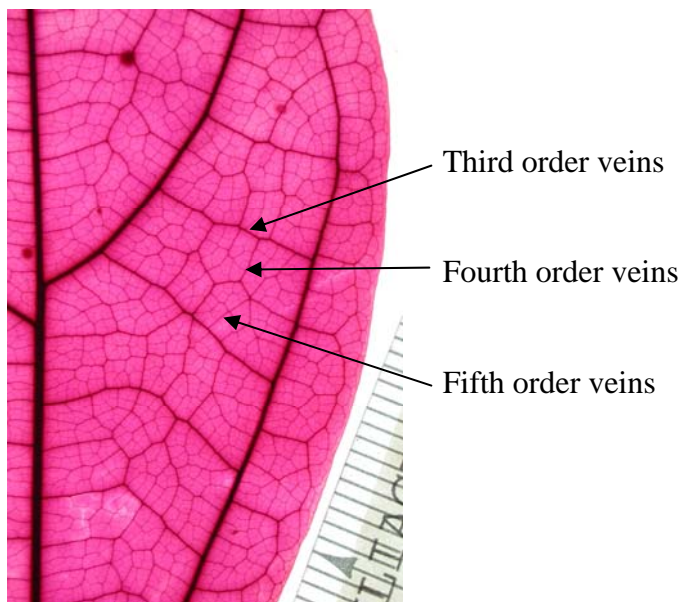
Lower 25%



Complete apex or peltate base (yes, base is being scored twice in this case but this is a very distinctive feature and often these leaves do not have an apex.)



Margin (need to be able to tell if fossil has teeth or not)



high order venation (1 point each for third, fourth and fifth order)

6. **Formally naming fossil plants:** This is a difficult and time consuming process. To formally name a fossil, first, you need to research the literature to make sure that it has not been named before. For the purpose of submitting fossils to the DMNS Paleobotany Project, you can assign a published name to your fossil and include the reference where the name was published. To produce a monograph of a flora, you would need to do the following additional steps.

Case 1 – the fossil has been described before: If you find a description (and hopefully a picture) of your fossil in the literature, you need to show that your fossil shares the characteristics that demonstrate biological affinity with the previously named species. Then, you need to verify that the name is valid, meaning that it's been correctly published in accordance with the International Code of Botanical Nomenclature (ICBN). If you determine that the name is incorrect, you need to rename the fossil following the rules described in the ICBN. In the process of doing this research, you will create a synonymy, which documents each instance when a scientist changed the name as well as any historical fossils that match your fossil and were misidentified.

Case 2 - the fossil is new to science: To determine that your fossil represents a novel species, you first need to distinguish your fossil from other species that have been previously described and share similar characteristics. Next, you designate a type specimen, which will bear the new name. Unlike the basin holomorphotypes discussed previously, this fossil is only one specimen and can never be replaced. It must be repositied in a recognized public institution and be accessible to future researchers. A formal name is a Linnaean binomial (genus species) in Latin. To be valid, the name must be published with an illustration of the type specimen, a written description and a diagnosis. A diagnosis describes the elements that are essential for identification of the new species and they are repeated in the description. Although it's not necessary to place the fossil into a full taxonomic framework, researchers typically strive to document as much of the higher taxonomy as possible.

Glossary of terms

Accession - the process a museum uses to legally acquire a specimen.

Bin – a collection of leaf architectural characters. Bins are used to separate large numbers of fossils into manageable groups based shared characteristics for identification.

Locality – a place where a fossil was collected. At DMNS, each locality gets a memorable name, a field number and an institutional number. We record our coordinates in decimal degrees and use NAD27 as the map datum.

Morphotype – in simplest terms, this is a description of the “body plan” of a leaf, seed or other part of a plant. There can be multiple examples of a morphotype but each must share a set of common, diagnostic characteristics. A **holomorphotype** is the single specimen that most completely documents the diagnostic features of the morphotype.

Morphotypes are informal and act as proxies for formal species while they are being studied. Note that when the study is completed, a species may be represented by more than one morphotype. For example, on a single tree, some *Sassafras* leaves are lobed while others are not. The lobed and non-lobed varieties have different “body plans” so they are considered different morphotypes using the “body plan” definition. Once the lobed and non-lobed varieties are found attached, they are recognized to be from the same species and are regrouped into one morphotype with a range of leaf architectural characteristics. Although finding lobed and non-lobed leaves on a single tree is rare, all morphotypes (and species) have a continuum of variation in their character states. For this reason, we strive to collect enough specimens from one quarry (300-500 specimens) to document the variation of the most common fossils.

Quarry holomorphotype– the single specimen that most completely documents the diagnostic features of a morphotype within a quarry.

Basin holomorphotype – a quarry holomorphotype that has passed the quality test (HQI ≥ 4) and is well- enough preserved to be formally named and compared across multiple quarries

Quarry – a discrete hole in the ground that produces fossils. A typical DMNS quarry is about 5 square feet. The thickness of the fossiliferous layer depends on the outcrop but it typically less than 1 foot thick.