



ADVENTURE SCIENTISTS

EXPLORE. COLLECT. PROTECT.

**Timber Tracking: Eastern Black Walnut
United States Forest Service
July 2021**

Background

Eastern black walnut, *Juglans nigra*, is a native deciduous tree and among the most valuable hardwood species in North America. Black walnut timber is highly prized for its straight, dark, and fine-grained heartwoods, a popular wood choice for furniture, gunstocks, flooring, coffins, and veneer. Black walnut is actively logged and managed, accounting for over 40 million dollars in export sales to 67 different countries between the years of 1999-2003 alone (USDA-FAS 2004). Due to its high value, black walnut is a common target of illegal timber theft across its range.

The USFS has developed genetic markers to identify individual black walnut trees with the goal of improving forensic tools for investigating black walnut theft. Initial results suggest that experts can extract DNA from black walnut wood samples with relative ease, and a new DNA profiling test shows excellent discrimination between individual trees. Researchers were surprised by the clear “geographic signal” the genetic test revealed, as geolocalization tests show that the provenance can be determined to the state level. However, current sampling schemes are too sparse to reveal whether genetic markers can be used across the full range of black walnut; sampling is also too sparse to permit more precise geolocalization predictions. A denser sampling design will allow the USFS to produce a comprehensive reference library, which will in turn supply prosecutors with the information needed to demonstrate high-certainty identities and source origins within tens of miles. This precision is essential for cases where wood products are transported across state lines for milling or shipping purposes.

The goal of the Timber Tracking: Eastern Black Walnut Project is to create a forensic reference library that demonstrates the uniqueness of individual black walnut DNA profiles. This library will allow our partners to determine the individual and geographic origin of wood and the legality of wood evidence in timber theft cases.

To be effective, the black walnut genetic reference library needs to contain genotypes that reflect the diversity found in natural stands in order to elucidate the connection between genotype and geography. Black walnut has a long history of cultivation, as clones have been transplanted around the United States in boulevards and other municipal landscaping. Our project avoids cloned materials, trees that have been moved long distances, or trees of questionable origin by collecting data in undeveloped areas (i.e., excluding most exurban, suburban, and urban areas) managed by federal, state and local agencies. This range-wide sampling effort on public lands will assist the USFS to vet the genetic test by identifying markers

that are variable across the range, versus markers that show strong differentiation and fixation in cultivated individuals or specific geographic regions.

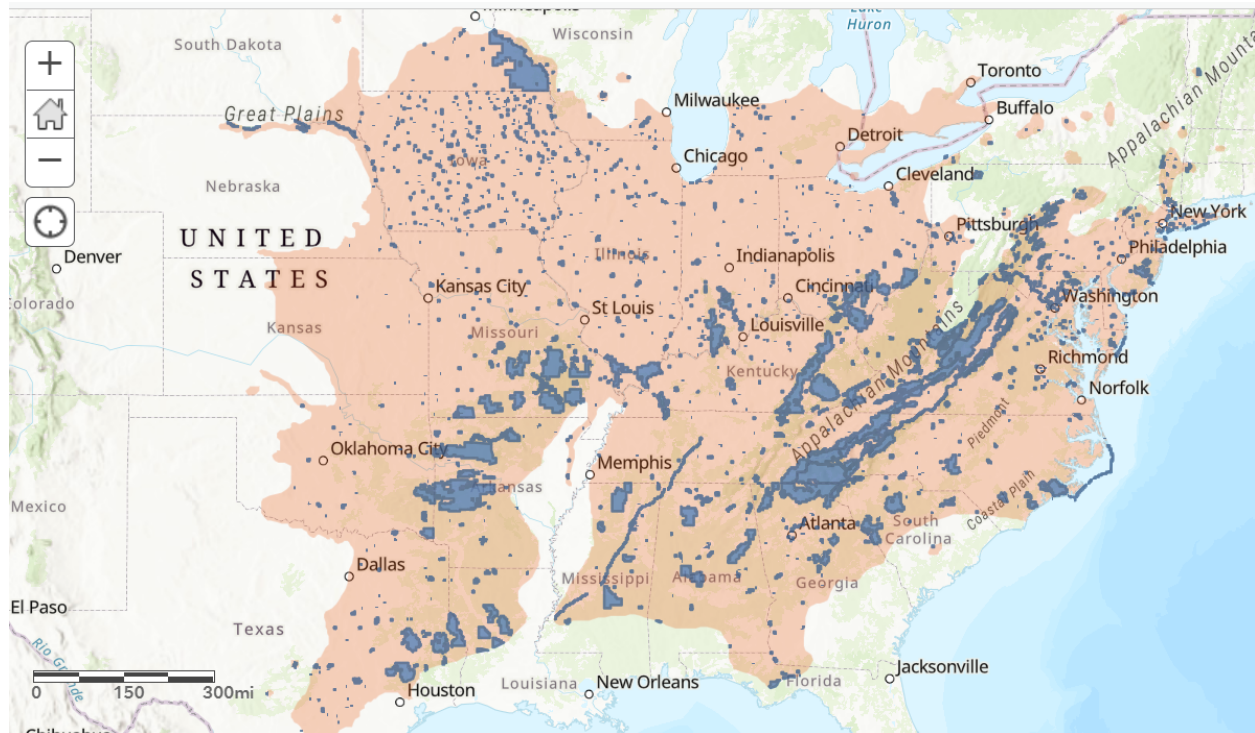


Figure 1: Shows the historical native range of Eastern black walnut, *J. nigra*, (orange) and the distribution of public land parcels (blue), from which we will sample including USFS, NPS, US Army Corps of Engineers, USFWS, State Forests, and State Parks.

Sampling Design

Current black walnut collections allow a wood product source to be determined at the state level. Our project will fill the existing data gaps and allow for a finer scale, population-level provenance to be determined. We will achieve this through an opportunistic sampling scheme that aims to collect between 1,000 to 1,500 samples across public lands in each of the 32 states spanning the species' historic native range (**Figure 1**). For planning purposes, 1,500 samples will be used to define the sampling design, but existing data gaps could likely be filled with fewer samples. To avoid cluster-sampling bias, we will prioritize:

- parcels managed by the US Army Corps of Engineers, as these lands typically fit the preferred habitat type of black walnut;
- parcels managed by USFS and NPS, as these lands have typically experienced less human development; and
- public parcels contained within States around the margins of black walnut's native historic range, as these populations may contain higher genetic diversity.

We will avoid municipal or city parks (e.g., largely manicured and curated for the enjoyment of people), as well as parcels within municipalities that have a history of landscaping (e.g., post offices and historic sites) in order to minimize the probability of collecting a transported or cloned individual.

In order to determine the number of samples per mile, we took the total area (mi²) of all public land parcels that occur within the natural historic range of black walnut and evenly distributed 1,500 samples across that area, and then took the square root.

- Total Area= (57,785 mi²)/1,500 samples
- = 39 samples/mi²
- = 6 samples/mi

We then took the area of each public parcel divided by the number of samples per area to give us a maximum number of samples per parcel. When the resulting sample number was greater than two samples per parcel, we assigned that number of samples to that parcel, while those parcels with a sample number of 2 or less remain two. Two samples per parcel is the minimum number of samples per parcel in order to make efficient use of limited resources and retain even-sample distribution across the landscape.

This sampling design results in 7,446 samples, which is five times greater than the number of samples requested by the USFS. We will reconcile this difference by monitoring and adapting the volunteer-sample registration process as samples are collected, as described below, to ensure that collected samples are evenly distributed across the species range.

All parcels will be displayed on an interactive map (described below) with priority parcels highlighted. Once the maximum sample number is reached, the area will be closed to further sampling. Volunteers will not be allowed to register for specific parcels once 50 samples per state is reached, or once enough volunteers have signed up to collect 2,100 total samples (40% above target sample number to account for volunteer attrition), whichever occurs first. Volunteers will be asked to collect samples six miles apart, but this guidance is not a hard rule due to natural clustering of black walnut trees across its habitat. The permitting process will further reduce our total possible number of samples, as collections from smaller parcels may not be permitted. Furthermore, not all parcels within the historic black walnut range will contain black walnut individuals, further decreasing the total possible sample sites.

This data resolution will allow the origin to be determined at the population or forest level. The following (32) states make up the current natural black walnut range. Italicized states will be prioritized due to their geographic position:

- *Texas, South Dakota, Nebraska, Kansas, Oklahoma,* Louisiana, Arkansas, Missouri, Iowa, *Minnesota, Wisconsin,* Illinois, Kentucky, Tennessee, Mississippi, Alabama, Indiana, *Michigan,* Ohio, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Maryland, Delaware, New Jersey, Pennsylvania, *New York, Connecticut, Vermont*

For a complete list of all public parcels intercepting the historic range of eastern black walnut, along with the parcel's associated number of samples, click here:

https://docs.google.com/spreadsheets/d/1eLJKh6fIHJdl6b9LSf-IXYV2-zVb8IOONqY_0u-oPJ8/e/dit?usp=sharing

Project Build

Volunteer Recruitment & Screening

Given the ease with which researchers are able to derive genetic material from black walnut leaves or shoots, volunteers can collect samples year-round. Continuous field sampling will provide the opportunity to recruit volunteers throughout the year. Sampling will take place from our field collection launch date until January 31, 2022, with the possibility of extending data collection, pending additional funding. Adventure Scientists will manage all volunteer recruitment, communication, and data collection efforts.

Adventure Scientists has been advised by the USFS that 1,500 samples will suffice to fill existing data gaps and allow them to determine the geographic origin of a wood sample at a resolution that meets the needs of law enforcement and prosecutors (data end-users). We anticipate an average of 10-15 samples to be collected by each volunteer team (2+ volunteers/team). Therefore, we estimate the need to recruit up to 300 teams (600 volunteers, this includes an expected 50% attrition). Volunteers will be recruited through earned and owned media. In addition, we will make direct contact with:

- Environmental organizations
- Outdoor communities
 - Hiking Groups
 - River groups
 - Mountain biking groups
 - Fishing groups
- Universities
- Native plant societies
- Arborist groups
- International Society of Arboriculture

We will prioritize accepting volunteers who have experience with GPS navigation, off-trail hiking, access to a smartphone, observational skills, and the ability to follow protocols. Volunteers will apply and be screened through [a similar form](#) as we have used with previous timber tracking volunteers.

Volunteer Training

Once accepted, volunteers will be required to complete a series of training modules. Volunteers will be given access to a project specific volunteer page that will house trip planning tools. The primary tool will be an interactive map of survey plot locations, similar to **Figure 1**, that displays all permitted public land parcels and the maximum number of samples desired from each parcel (unit). Volunteers will register for each unit they expect to sample; units will close once the maximum number of samples allotted to each unit is reached. Each volunteer team will be encouraged to register for a minimum of 10 samples.

All volunteers will be required to complete Adventure Scientists' training designed specifically for the Timber Tracking: Eastern Black Walnut Project. Adventure Scientists utilizes an online learning management system (LMS) to host professional-level courses that we create in-house. The training provides volunteers with the background and skills to understand the goals of a project and ensure data are collected as defined by the protocol. Our team incorporates

educational learning theories into course modules designed to appeal to different learning types and promote content retention. Modules include small sections of digestible content, including short videos, with each followed by a review summary and interactive content, a writing prompt, or a quiz. Quiz checkpoints test content retention and protocol proficiency. Volunteers are required to pass all checkpoints with a score of 100% before they are cleared to collect data. After 6 months all volunteers must take a refresher course.

The following is an outline of the training modules that Adventure Scientists will build for the Eastern Black Walnut Project:

- 1) Project introduction video
- 2) Covid safety
- 3) Background: eastern black walnut and illegal timber harvest
 - a) The field researcher's mind set: how to prepare for field conditions and approach your adventure with realistic expectations
- 4) Project equipment/technology
 - a) Downloading GaiaGPS
 - b) Downloading Survey123
- 5) Sampling location selection: finding trees
 - a) Navigation (w/ GaiaGPS)
 - i) Saving and naming track
 - b) Identification
 - i) What is a dichotomous key?
 - (1) How to use...
 - (a) Customized black walnut dichotomous key applicable to entire species range
- 6) Field methods
 - a) Recording data (Survey123)
 - i) Meta-data & location
 - ii) DBH
 - iii) GaiaGPS track (miles hiked)
 - b) Gear sanitation
 - c) Sampling:
 - i) Leaflet samples
 - (1) Checking for fungus and senescence
 - ii) Coring
 - (1) Increment borer assembly
 - d) Sample processing: preserving and sending samples to AS
 - e) Uploading data records

Technology & Field Equipment:

Adventure Scientists will purchase and manage all gear for this project. The number of increment borers will determine the number of complete "collection kits" available. Currently, Adventure Scientists has the ability to build 75 complete collection kits (including increment borers) to outfit 75 volunteer teams at a time. However, during the permitting process, we anticipate not all public parcels will be permitted for coring; this will allow us to ship additional collection kits that do not include an increment borer. Each volunteer team will be sent a collection kit prior to their field expedition. Each collection kit will include:

- Welcome letter
- Protocol booklet, including customized black walnut dichotomous key

- 1- Increment borer
- 1- tape measure
- 10- Paper straws
- 1- Saw-toss
- 40- Envelopes
- 10 QR Labels
- 1oz vial + alcohol
- 10- Alcohol wipes
- Paraffin wax
- 10- ziplock bags (w/ 1 Tbsp of silica beads each)
- 10- Manila envelopes (sample shipping)
- Return shipping label (for gear)

Adventure Scientists will supply, customize, and build technology to support this project. This includes a customized map layer that will assist in volunteer recruitment and trip planning by displaying permitted public parcels (along with a maximum number of samples and a downloadable permit) throughout the range of black walnut. Volunteers will be able to register for specific parcels, along with an intended number of samples. A similar map layer will be visible on GaiaGPS, provided as an in-kind donation to all volunteers. Volunteers will also enter data through a customized Survey123 app survey that allows them to enter meta-data including: GPS verified waypoint location, circumference as a proxy for diameter at breast height (dbh), mileage, and scan in QR sample codes. Adventure Scientists will also link black walnut observations from iNaturalist on the volunteer project page to provide guidance on trip planning.

Adventure Scientists will maintain a project dashboard that displays volunteer sample location (no dbh data will be published online as these may attract the attention of illegal loggers), number of samples, number of volunteers, number of volunteer hours contributed, and number of miles hiked by volunteers.

Field Methods

Within each sampling unit, volunteers will walk and hike, often off-trail, to locate an individual black walnut tree. Identification of black walnut will be aided by a customized dichotomous key applicable to the entire range along with photographic examples of black walnut phenotypes from various habitats found throughout the species' range (**Appendix 1**). Volunteers will also have access to black walnut observations recorded through iNaturalist, along with locations for those observations. Volunteer tracks will be saved in GaiaGPS during their attempt to locate a tree to sample. Volunteers will name the track consistent with the naming convention of the sample, located on the QR code label (e.g., WZ6_8SEC). Once positively identified, volunteers will enter all meta-data into Survey123, record tree location, and dbh using the provided tape-measure in volunteer collection kits.

Volunteers will use site characteristics to help assist them in finding black walnut individuals and selecting appropriate leaf tissue to collect. Black walnut is found in most woods of the Eastern United States near streams on non-sandy soils (loamy), especially smaller streams and floodplains where inundation doesn't last long (well drained), and along ravines near the floodplain (Baker 1921). Leaflets emerge in mid-April in the southern United States, and in early June in the more northern range. Leaves are present for 115-135 days, they begin senescence in mid-August in the north to early October in the south. Once leaves begin showing signs of fall

senescence (yellowing), volunteers will shift to using non-growing season protocols (described below).

Other environmental factors impacting leaf longevity include summer drought and a foliar fungus, walnut anthracnose; both these factors tend to degrade the quality and quantity of DNA in leaves. Volunteers will avoid collecting leaflets displaying signs of senescence, discoloration, or walnut anthracnose. Senescence is easily identified by a change in colors (yellow to brown); **Figure 2** provides an example of leaf discoloration due to walnut anthracnose.

If volunteers are sampling in exurban, suburban, or urban areas (e.g. within small parks or private property), or if the volunteer suspects trees were planted, as suggested by the presence of an even-aged stand, evenly spaced trees, or a homogenous stand, trees will only be sampled if the dbh exceeds 25" (63.5 cm) (=78.5" circumference). Focused sampling of large diameter trees will minimize the chance of sampling clones or trees planted via human-assisted migration (Baker 1921). Volunteers will avoid collecting more than 2 samples in an area if an individual is suspected of being a clone or occurring as a plantation, as suggested by the evidence above.



Figure 2: Examples of walnut anthracnose, a fungal infection which colonizes leaf tissue of black walnut and can degrade leaf DNA (Voyle 2013).

Volunteers will collect samples throughout the calendar year across growing and dormant seasons. Prior to taking samples, volunteers will sanitize the saw-toss (if needed) and increment borer by using the alcohol wipes to wipe the surface of the saw, threads and shaft of the borer, and core extractor. In addition, volunteers will clean the interior of the increment borer by dripping alcohol into the borer with fingers placed over the ends, invert borer several times to ensure alcohol coats the interior surface. Once sanitized, volunteers will lubricate the increment borer threads and shaft with paraffin wax to minimize friction and borer loss when coring this hardwood species.

During the growing season, volunteers will collect three leaflets, one 4" long terminal stem, and one core as permits allow. Volunteers will place two leaflets into one coin envelope, one leaflet into a second coin envelope, a 4" long stem into a third coin envelope, and one core into a paper straw. Each envelope and straw will be labeled with the provided QR code, each sample's QR code will be scanned into the Survey123 survey, and samples will be placed into a single zip-loc bag containing ~1 tbsp silica gel desiccant. During the dormant season, volunteers will collect two 4" terminal stems placed in separate coin envelopes and one core

placed into a paper straw. Each sample will be labeled with the provided QR code, scanned into the Survey123 survey, and stored in a single zip-loc bag containing ~1 tbsp silica gel desiccant. The 4" long terminal stem contains unique identifying characteristics that allows this material to serve as a voucher sample. Leaf tissue is preferred for genetic material extraction, but may be derived from the terminal stems. **Table 1** summarizes samples volunteers will take from black walnut trees during the different seasons:

	Growing Season	Dormant Season
Leaflets	3 (2 envelopes)	n/a
4" terminal stem	1 (envelope)	2 (2 envelopes)
Core	1, when permitted	1, when permitted
*All envelopes and straws are barcoded with the same code from respective individual trees		
**All envelopes and straws packed into single zip-loc bag containing ~1 Tbsp silica desiccant (sample kit)		
***All sample kits will be shipped to Adventure Scientists		

Table 1: Summarizes what samples volunteers will take in both growing and dormant (non-growing) seasons, how samples should be packed, and what items will constitute a "sample kit".

Volunteers will ship completed sample kits to Adventure Scientists headquarters in Bozeman, Montana. Once received, Adventure Scientists will process each sample to ensure each sample is sufficiently dried and contains no leaves that are senesced or infected with walnut anthracnose. If any samples are determined to clearly have been collected from a tree outside the walnut genus (*Juglans*), the sample will be discarded. Once processed, all samples will be shipped on to the USFS Pacific Northwest Research Station for analysis.

Permits

Adventure Scientists will focus the collection of 1,500 black walnut samples on federal and state lands located through the historic native black walnut range. These ~3,125 parcels are managed by the US Forest Service, National Park Service, US Fish & Wildlife Service, US Army Corps of Engineers, State Parks, and State Forestry Departments. In order to obtain the required permits for our sampling effort, a contractor will be hired to work with contacts at the various federal and state agencies mentioned, complete all paperwork required to obtain permits, and report permit updates back to the project management team.

Our project partners will be vital in this process and have already contributed strategies and contacts to many of the prioritized public parcels. A list of priority parcels and contacts are found here:

https://docs.google.com/spreadsheets/d/1_QwOU8OMp0Dgw036clnrPxEmHM9j23UwfA7ueekWVs/edit#gid=0

Volunteer Liability

By recruiting and screening for experienced outdoor adventurers, we greatly mitigate risks associated with this project. Adventure Scientists requires volunteers to sign an assumption and acknowledgment of risk form when they apply. Adventure Scientists have created an emergency and incident management plan to handle incidents during management phase, and

maintains adequate insurance throughout the project period. Volunteers will travel in groups of two people minimum for safety.

Communications & Media

Adventure Scientists will deploy communication strategies at different project phases. During the project build stage, Adventure Scientists will generate and source photography and video for use in training modules and subsequent recruiting materials, create project-specific web pages, and design the protocol manual. During recruitment, Adventure Scientists will produce and distribute recruiting posters, advertising, social media and other materials. Adventure Scientists will create an annual project report on our Timber Tracking work.

Adventure Scientists will communicate with volunteers, project partners, and our larger community through digital newsletters and other storytelling media that include updates, reminders, and project context. We will host web events to answer volunteer questions and celebrate their achievements. Adventure Scientists will also solicit and curate volunteer-generated video and imagery throughout the course of the project.

Project Budget

Illegal timber harvesting is a global problem that contributes to many negative impacts felt by local communities, national economies, and global environmental efforts. Adventure Scientists sees the value of the tangible conservation impacts as a result of the curation of genetic and chemical materials in a reference library accessible to law enforcement and prosecutors. Given this importance, Adventure Scientists has decided to raise or otherwise cover the costs of the following budget, in hopes that project partners will be able to generate additional needed resources.

<i>Timber Tracking: Eastern Black Walnut Project Budget</i>	
Scoping	\$15,000
Recruiting	\$61,257
Project Build	\$124,615
Project Management	\$50,146
Reporting	\$1,289
<i>Total Project Budget</i>	<i>\$252,306</i>

Additional Option

The current project design for the Timber Tracking Eastern Black Walnut Project is framed by sample collections taking one calendar year with collections taking place entirely on public lands. This framing adequately meets the needs of our project partners by filling data gaps and providing them a number of samples that will result in the desired resolution to determine geographic origin of a wood sample. This approach has taken constraints around the funding and data needs into consideration.

However, due to the geographic context and history of black walnut, there is an opportunity to engage private landowners by recruiting them during a second year to opportunistically sample

black walnut trees of a minimum dbh on their private land. Private landowners would be engaged through the Land Trust Alliance and National Community Land Trust Network, as well as through numerous environmental and citizen science groups. This opportunity would add value to the project by providing even more data to our partners, resulting in a higher resolution dataset, and provide fascinating insight to how black walnut has been cloned and distributed throughout its historic native range. This approach would also allow Adventure Scientists to more widely engage volunteers who may not fit within our typical demographics and provide opportunity to engage a broader public.

Without funding for a second year, this option is less than ideal. Compromises would need to be made on where samples are taken, and how/where collection kits are shipped, which reduces our confidence of capturing naturally occurring black walnut genotypes.

Project Contact

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Appendix A:

Eastern black walnut, *J. nigra*, Field Guide & Dichotomous Key Created by Nick LeBonte USFS, Region 9 Geneticist

General description

Large tree at maturity, codominant with other large canopy trees. Mature bark dark gray-brown, deeply ridged, with uniform color (**Figure 1 & 2**). Juvenile bark lighter gray-brown with cracks and plates appearing on stems >1" diameter and ridging on stems >6" diameter. Branching pattern fairly open and upright (**Figure 3 & 4**). Twigs in canopy thick, with first-year growth about the thickness of a pencil (**Figure 5 & 6**). Crown appears sparse in winter due to lack of fine twigs; branching pattern alternate. In summer, large pinnate-compound leaves with a uniform bright yellow-green color. Immature nuts are roughly spherical and bright green with no visible suture in husk (**Figure 7**).

Site Associations

In the wild black walnut most commonly occurs on rich, moist, but usually well-drained soils associated with temporary or permanent streams or lake plains. It is typically scattered among other trees and very rarely forms even-aged stands as the dominant species. Common canopy associates in these habitats are: silver maple, box elder, hackberry, honeylocust, sycamore, cottonwood, and green ash. Black walnut is usually not found in floodplains that regularly experience long-duration floods. It is often found on lower slopes and ravines adjacent to floodplains.

Black walnut also naturally colonizes drier upland habitats far from streams, especially in areas with a history of grazing or other disturbance. This may include old fields, hedgerows, and young second-growth forests. Walnut's large seeds are dispersed by squirrels into these areas. In this type of environment, black walnut may be associated with a wide range of species, including native and invasive shrubs, white mulberry, black locust, black cherry, bur oak, and upland hickories.

Black walnut is occasionally planted within its native range. Even-aged stands where walnut is the only species, or occurs with one other species, are likely to be planted. Sometimes black walnut is planted with eastern white pine, but they are not natural associates.

Summer dichotomous key

1.a. Leaves pinnately compound (go to **2**)

b. Leaves bi-pinnately compound (Kentucky coffeetree) **2.a.** Leaf arrangement alternate (go to **3**)

b. Leaf arrangement opposite (*Fraxinus spp* or *Sambucus spp*)

3.a. Leaflet margins finely toothed, leaflet number usually less than 20 (go to **4**)

b. Leaflet margins entire, leaflet number often more than 20, distinct unpleasant odor vaguely like peanuts when crushed (*Ailanthus altissima*)

4.a. Terminal leaflets absent, smaller, or about the same size as other leaflets (go to **5**) **b.** Terminal leaflets larger than others (*Carya spp.* or English walnut, *Juglans regia*)

5.a. Individual leaflets symmetrical, same texture on both sides (go to **6**)

b. Individual leaflets asymmetrical; slightly bow-shaped; darker and shiny above (Pecan: *Carya illinoensis*)

6.a. Rachis green, leaf same color on both sides (go to **7**)

b. Rachis reddish, leaves notably whitish on underside, shrubby or thicket forming habit (*Sumac*, *Rhus spp.*)

7.a. Terminal leaflet often absent. Leaflet number usually 16-18. Leaflets with a long tapering point. Black walnut: *Juglans nigra*.

b. Terminal leaflet usually present. Leaflet number usually 11-13. Leaflets oval with a short tapering point. Butternut, *Juglans cinerea* (if leaflet number is >13 but terminal leaflet is obviously present and bark is light gray, most likely a butternut x Japanese walnut hybrid).

Winter dichotomous key

Black walnut dormant season notes: black walnut leaves drop early in the fall and break down very quickly, but the persistent ~12" leaf rachis can be found in the leaf litter until spring to help with ID, along with dark brown, 1" diameter, heavily ridged nut shells depending on the size of the nut crop.

Winter ID key features: bark dark brown on mature trees with regular pattern of narrow interlaced ridges; ridges becoming wider, scallier, and more irregular/blocky on the oldest trees. Branching pattern: upright, symmetrical with angle of main upper limbs and forks usually ~45 degrees, especially in younger and forest-grown trees. Pattern of leaf scars alternate. Twigs relatively large lending crown an open, coarse appearance. Twigs have a distinctive chambered pith with a medium-brown color.

Starting point... tree with relatively large twigs.

1.a. Bud arrangement alternate, (go to **2**)

b. Bud arrangement opposite (*Fraxinus*, *Aesculus*, or *Sambucus spp.*) or whorled (*Catalpa spp.*)

2.a. Terminal bud larger than lateral buds, (go to **3**)

b. Terminal bud not distinct (same size as laterals); *Ailanthus altissima* (Tree-of-heaven), Kentucky coffee tree (*Gymnocladus dioica*), and sumac (*Rhus spp.*)

3.a. One large bud dominates terminal cluster, (go to **4**)

b. 3 to 7 similar-sized buds in terminal cluster, oak (*Quercus spp.*)

4.a. Leaf scar shaped like a "monkey face" with three vascular bundle clusters (**Figure 6**). Often 2 superimposed buds above leaf scar. Chambered pith. (go to **5**)

b. Leaf scar heart-shaped or elliptical without 3 discrete clusters of vascular bundles. Hickory, shagbark, pignut, mockernut, and shellbark hickory have much larger terminal buds than laterals. Bitternut hickory has smaller terminals and finer twigs but a distinct bright yellow color. Pecan is like bitternut hickory but with brown buds and quite similar to walnut except for the chambered pith.

5.a. Twig bark brown, chambered pith medium brown, deep ridges and brown bark on mature trees. Larger, but compact terminal bud (Black walnut, *Juglans nigra*)

b. Twig bark greenish. Terminal but elongated and often “bent” near tip. Shallow ridges and distinctly gray (may be light or dark) bark on mature trees. (Butternut, *Juglans cinerea*).

Note on butternut: This is a rare species, but sometimes occupies the same habitats as black walnut. It is unlikely that collectors will encounter it, but the bark color on mature trees and leaf differences on young trees are the best distinguishing features. Within the black walnut range, butternut is most frequently encountered in areas where limestone occurs near the surface (e.g. the Upper Midwest Driftless Area, Kentucky Bluegrass region, Niagara Escarpment). Butternut is affected by an introduced disease that causes black-colored, weeping cankers on the trunk of saplings and mature trees. This disease does not affect black walnut.



Figure 1: Typical black walnut bark of a mature tree (~18" diameter)



Figure 2: Bark of a very large (>30" diameter) black walnut. Note the increasingly irregular and "scaly" quality of the bark compared to figure 1.



Figure 3: Open-grown black walnut showing upright form, open crown, and branch angles.



Figure 4: Black walnut growing in a more competitive situation tends to have more acute branch angles and may not branch until high above the ground (smaller tree at right). Note that black walnut begins out weeks later than some common associates (here, maple and hackberry).



Figure 5: Detail of twig.



Figure 6: Detail of “monkey face” leaf scar and lateral bud.



Figure 7: Black walnut crown in early fall with nearly mature nuts and senescing foliage. This is not an ideal time for collections, but shows a clear view of the developing nut crop that is useful to note during summer.