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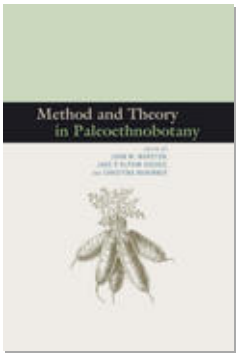
Method and Theory in Paleoethnobotany

Marston, John, d'Alpoim Guedes, Jade, Warinner, Christina



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Laboratory Analysis and Identification of Plant Macroremains

Gayle Fritz and
Mark Nesbitt

The laboratory handling and identification of archaeological plant remains is the crucial step between their recovery in the field (chapters 2–6, this volume) and their interpretation (chapters 9–19, this volume). Accurate identification of plant remains is fundamental to the sophisticated interpretation of foraging and agricultural systems. Inaccurate identification can, at worst, lead to serious errors in the identification of early domesticates or plant introductions, as discussed by Harlan and de Wet (1973) in a classic article that is still relevant today. Even in less extreme cases, poor-quality identifications obscure changing patterns of plant use and present a major challenge to the compilation of regional or supraregional syntheses.

Given the importance of plant identification, and a history of high-quality archaeobotany that extends as far back as 150 years in some regions, it might seem surprising that this essential skill is still highly subjective, based on nuances of shape and texture that are hard to describe, taught by apprenticeship (with varying degrees of support) in an established archaeobotanical laboratory, and then often practiced in isolation. The good news is that work in the last 20 years has addressed these issues, with digital media taking a central role in providing new tools, and enabling easier distribution and exchange of information (Warinner and d'Alpoim Guedes, chapter 8, this volume).

Our aims in this chapter are threefold. First, we set out core practice for the handling and identification

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of (mainly) charred plant macroremains in a manner that will be both useful for the beginner and of interest as a baseline for comparison for experienced practitioners. In the available space we can only seek to complement existing handbooks for the New World (Pearsall 2000) and Old World (Jacomet and Kreuz 1999). Second, we highlight examples of good practice in the development and application of identification techniques. Although many of these are drawn from Europe, the Near East, and North America, reflecting the concentration of archaeobotanists working in those regions, there are lessons applicable to other parts of the world. Third, we offer something of a personal perspective on how identification practice has changed and how we would like to see it develop. As becomes clear in the chapter, there is still much to do, and exciting prospects lie ahead for new researchers.

TAPHONOMY AND PRESERVATION

In most cases only a small proportion of plant parts become incorporated into the sediments of an archaeological site and survive until the present day (Gallagher, chapter 2, this volume). Three agents are at work. Humans select which plants and which parts of plants are brought onto archaeological sites. It is often the case that only the edible portion of the plant, typically a propagule such as a seed or fruit, or storage organ such as a root, is harvested and brought back to the site. Other plant parts will only be brought on site if they need processing to separate them from the useful part, or if the other plant parts are also useful. A good example of both is cereals such as rice and wheat, for which the grains are most efficiently stripped from the culms (stems) by bulk processing at or near the settlement, and whose straw is of value as animal feed, fuel, or as a material for craft production or construction (van der Veen 1999a).

The second agent is that of natural and anthropogenic decay. In tropical and temperate climates plant material that is not consumed by humans will be eaten by animals such as rodents or insects or by fungi and other microorganisms. In arid areas such as the Nile valley, American Southwest, and parts of the Andes where these processes are slowed, the quantity of material surviving can be so great as to be overwhelming (van der Veen 2007a). At the same time, the preservation is so good, extending even to color, that conventional techniques of botanical identification can be applied. A recently published example of such sites (with exemplary color illustrations) is the Roman and Islamic ports at Quseir al-Qadim, Egypt, with fresh-looking

material such as fragments of sugar cane, ginger rhizome, and banana skin (van der Veen 2011). Comparable preservation can occur with frozen plant remains, as in the case of the Alpine Iceman (Bortenschlager and Oeggl 2000). Dry conditions can also occur in wet countries, for example the medieval sheaves of wheat and accompanying weeds found deep inside thatched roofs in northern Europe (de Moulins 2007). Waterlogged, thus anaerobic, conditions can also lead to the preservation of a remarkably wide range of material. The weaker cells, such as starchy endosperm, however, usually decay, leaving flattened plant remains that look very different from fresh material. Cell patterns in wet preserved material are often much more obvious and useful for identification, but will require comparison to reference material treated with acid to replicate the effects of waterlogging. Waterlogged plant remains are locally abundant in northern Europe and in other areas with waterlogged landscapes such as Florida in the southeast United States, but we do not have space to cover their specialized processing and identification in this chapter (Birks 2007).

The most widespread form of preservation is through charring by fire. Even waterlogged and arid plant assemblages contain significant amounts of charred material. Charring converts plant materials to more or less inert carbon, while preserving its shape. Fire is also destructive: the lighter parts of plants, such as leaves and the bracts surrounding the grain, are likely to burn to ash (Boardman and Jones 1990) and not be recovered (except in the form of phytoliths: see Pearsall, chapter 4, this volume). Both the quantity and quality of plant remains vary enormously by site, in relation to what are still poorly understood factors of burning and site deposition. Because charring often occurs in domestic hearths and ovens in which wood is the main fuel, wood charcoal often forms a significant part of the assemblage.

Archaeological recovery is the third and final destructive agency to act before plant remains reach the laboratory. Although water flotation is proven as the most effective way to retrieve charred plant remains dispersed in archaeological matrix, it is inevitably destructive of fragile material such as light chaff and oil-rich seeds (Märkle and Rosch 2008; White and Shelton, chapter 6, this volume; Gallagher, chapter 2, this volume).

In summary, a series of processes intervenes between a human encounter with plants and the deposition of plant material in archaeological matrix. In most parts of the world, this leads to charred wood and seeds (broadly defined here to include other plant parts such as parenchyma) as being the main form of plant macroremains retrieved and studied by archaeobotanists.

TAXONOMIC GOALS AND LIMITATIONS

In an ideal situation, we could identify all or most archaeological plant remains to the level of species or even subspecies or variety, and we could distinguish clearly between domesticated plants and their wild ancestors or weedy relatives. Generations of archaeobotanists have, in fact, devoted considerable research efforts to recognizing anatomical features and other morphological characteristics that enable key species or subspecies-level identifications to be made, including those that signal domestication. Still, real-world assemblages, whether they consist of charred remains recovered by flotation, or waterlogged or desiccated remains, usually include many specimens that are too fragmentary, too eroded, or too obscured by sediment to be recognized beyond a more inclusive level, whether it be genus, family, or even a broad category such as "nutshell" or "parenchyma." In many cases, too, seeds of different taxa may be so similar in appearance that identification will never be possible beyond genus level, regardless of the quality of preservation.

James Massey, former professor of botany and a plant taxonomy instructor at the University of North Carolina at Chapel Hill, referred to paleoethnobotanists as "wizards" given our apparent ability to recognize a species by examining a barely visible speck of charred matter, whereas botanists usually work with at least a herbarium-sized plant specimen containing leaves, stems, roots, and well-preserved flowers, fruits, or seeds. Of course, we are not wizards, and one of the skills gained by experience is knowing when a specimen is unidentifiable and when it is best to categorize it broadly rather than specifically. Archaeobotanical analysis is guided by research questions and goals, as well as by constraints imposed by preservation. In North America, for example, it may make little difference whether or not one distinguishes between the six or more species of wild grapes (*Vitis* spp.) native to a given region, whereas in Southwest Asia and Europe, the presence of domesticated grapes (*Vitis vinifera*) as opposed to wild grapes has significant cultural and economic consequences. The amount of time and attention spent on species-level identification, therefore, varies according to interpretive yield. More time is usually given to unknown seeds that occur in the greatest quantity or ubiquity.

BASIC SORTING PROCEDURES AND EQUIPMENT

Analysis of plant remains recovered by flotation or a comparable, fine-mesh recovery method entails examining like-sized particles under low-power magnification and recording counts, weights, and often measurements or other attributes of items according to taxonomic grouping. The procedures described

here are based on those used in the archaeobotany laboratory at Washington University in St. Louis, but broadly similar procedures are used in most laboratories. Figure 7.1 is an example of an analysis form used at Washington University, and table 7.1 is a list of standard laboratory tools.

Selection of Samples

Where relatively few seeds have been recovered, all samples known to be from secure stratigraphy can be analyzed. However bulk flotation of richer sites, such as those in the Near East, may produce hundreds of samples varying from a few seeds to thousands. Here samples may be chosen on the basis that they are likely to contain at least 500 seeds, as recommended on the basis of statistics (van der Veen and Fieller 1982). Smaller samples might be included because they fill gaps in time periods, or because they come from archaeological contexts of special interest. Any sample might be excluded if its dating is not secure, although AMS radiocarbon dating does allow the dating of individual items of key chronological concern.

Sorting Procedures

If a sample consists of both light and heavy fractions (see White and Shelton, chapter 6, this volume), each is usually analyzed separately, although the numerical data can be combined when reported. Each sample (or each light and heavy fraction) is weighed to the nearest 0.01 g and the contents passed through a series of nested geological sieves, resulting in "splits" of similar-sized objects. It is standard in North America to use a 2.0-mm sieve because this is the cutoff point for complete sorting of larger particles versus removal of selected smaller items that are difficult to identify when smaller than 2.0 mm. When charred items larger than 2.0 mm are very rare, a smaller mesh size can be the cutoff point; however many plant types lose recognizable features with fragmentation below 2.0 mm. All ancient seeds and recognizable seed fragments are pulled from the smaller fractions, regardless of size, along with distinctive plant parts such as gourd rind, maize kernel, and acorn shell fragments, which are too fragile to be well represented in the > 2.0 mm splits. In Europe, where a mesh smaller than 2.0 mm is likely to let through large numbers of cereal grain fragments, the contents of the 1.0 mm sieve may be fully sorted, albeit after subsampling in the case of large samples.

Wood and nutshell might be abundant enough to warrant using as many as four or five splits with mesh sizes larger than 2.0 mm, but samples from sites where charred plant remains are rare or consist mainly of seeds and other

Mound House, IL
Macrobotanical Remains, Center for American Archeology, Paleoethnobotany Workshop

SQ/Fea _____ Level _____ Status (Bag#) _____ Initial Wt. (g) _____

Sample Type (LF or HF) _____ Analyst _____ Date _____

Vol. (Soil floated) _____

SIEVE SIZE		Wt.(g)
# 4	4.75 mm	
# 5	4.00 mm	
# 6	3.35 mm	
# 7	2.80 mm	
#10	2.00 mm	
#12	1.70 mm	
#14	1.40 mm	
#18	1.00 mm	
	0.50 mm	
#40.	0.425 mm	
#45	0.355 mm	
	Pan	

LARGER THAN 2.0 mm:	Count	Wt. (g)
Wood		
Bark		
Stem		
Thick hickory nutshell		
Thin hickory nutshell		
Walnut shell		
Juglandaceae nutshell		
Nutmeat		
Hazelnut		
Acorn shell		
Cucurbita rind		
Lagenaria rind		
Maize: _____		
_____		

SMALLER THAN 2.0 mm:

	Count	Wt. (g)
Thin Hickory to 1.4		
Acorn to 1.4		
Cucurbita rind		
Lagenaria rind		
Maize: _____		
_____		

SEEDS, > 2.0 mm: Total Wt. _____

SEEDS, < 2.0 mm: Count only

Unknown _____
Other (describe):
_____

Bone
Faunal Globule
Snail
Other Shell
Stone/Soil
Sherd
Uncarbonized (wt. only)

COMMENTS:

Residue Weight: _____
(0.7 – 2.0 mm)

Figure 7.1. *Sample analysis sheet for recording data from a flotation sample.*

relatively small items may require no sieves greater than 2.0 mm. Smaller-sized sieves may include 1.0 and .5 mm (or in Europe, often .3 or .25 mm) only, but intermediate splits might be needed, depending on sample size and composition. Once a sample has been passed through the graduated sieves, the largest items are examined under low-power magnification and grouped

Table 7.1. List of basic equipment needed for analysis of macroremains in a paleoethnobotany laboratory

Function	*Equipment*
Microscopy	Microscope(s); light source for each microscope
Sample sorting	Standard USDA (or other) geological sieves; sorting pans or dishes; pouring spout; riffle-type sample splitter
Sample weighing	Weighing scales; analytic balance (optional)
Sample handling	Dissecting needles; featherlight forceps; spatulas; fine paintbrushes
Sample storage	Gelatin capsules and/or plastic centrifuge tubes; glass vials; 2-mL-density plastic bags; metal tins or glass bottles; acid-free paper for tags
Reference materials	Reference manuals; comparative reference collection

according to taxon or plant type, followed by examining the contents of progressively smaller splits. All items greater than 2.0 mm are normally counted and weighed to the nearest 0.01 g, although we do not always count wood when there is a great deal of it. If a taxon such as walnut shell is found only in a < 2 mm split but is nonetheless clearly identifiable, it can be pulled and given a count of 1 and weight of .01 g in order in include it in ubiquity frequencies (% of samples in which a plant type occurs; Marston, chapter 9, this volume). For items greater than 2.0 mm, quantified categories include charred seeds, sorted as close to species-level as advisable, and fragile but clearly recognizable plant parts such as gourd rind or other distinctive cultigens, as discussed above. In North America, seeds less than 2.0 mm are not weighed, but only counted, but in Europe the 1mm fraction may also be fully counted and weighed.

Uncharred seeds are not pulled from assemblages when they are all modern contaminants, and learning to tell the difference between dark-colored modern seeds and their charred counterparts is one of the challenges of archaeobotanical training. But when samples come from unusual contexts in which ancient seeds and other remains survived without charring, a different strategy is obviously necessary. Samples from Cahokia's sub-Mound 51, for example, consist of 1,000-year-old feasting remains that were purposefully, rapidly, and deeply buried under mound fill after the structures in which feasting activities had taken place were partially burned, leaving both charred and uncharred wood and thousands of seeds in both physical states (Pauketat et al. 2002). In these situations, analysis sheets and published tables should be modified to include separate columns for charred and uncharred materials. Reporting

the different frequencies of both uncharred and charred ancient seeds makes it possible to compare results to assemblages in which only the latter are preserved (cf. for ancient Egypt Smith 2003).

Preferences for sorting tools and techniques vary, with choices guided in part by the available microscope base and working area. Plastic dishes or trays are problematic due to static that causes seeds to undergo damage or loss, so glass Petri dishes are used under the microscope. Round metal baking tins, 8–10 cm in diameter, work well for sorting large fractions, but they should not be too dark or so shiny that they blind the analyst with reflected light. Dissecting needles work well for moving items around in the sorting dish, especially if the tip is bent to form an obtuse angle. Some analysts prefer fine paintbrushes for sorting, and these work very well for picking up seeds to transfer them to capsules, tubes, or other containers for curation. Entomologists' forceps serve well to pick up seeds, but must be of the soft ("featherweight") type to avoid breakage. During routine sorting at 10× to 15× magnification, some analysts move fragments across the field of vision, separating them into taxonomic groups. Others recommend dividing the remains according to a grid system and examining them systematically by square (Bohrer and Adams 1977). A small dish filled with clean sand is an essential tool for detailed examination, allowing seeds to be positioned and examined at a variety of angles.

The end result is a set of tins, vials, boxes, tubes, and/or capsules divided into the respective groups of completely sorted (> 2 mm or > 1 mm) plant types, along with all seeds and other "special" remains pulled from the smaller splits, and the resulting residual fragments (< 2 mm or < 1 mm). All containers must be clearly labeled with site name or number and provenience information, and with sample data including plant type, split size, and light versus heavy fraction status. Acid-free paper can be cut into little tags to fit inside capsules or tubes if the containers themselves are too small to label. Careful attention should be given to labeling and storage so that seeds can be restudied. It is also important that the original records of laboratory subsampling and scoring are clear and are retained.

Subsampling

Samples too large to analyze in their entirety can be subsampled by determining the weight of the whole sample and then pouring it through a riffle box sample splitter, using a back-and-forth motion along the length of a riffle box while pouring to divide the sample in half. The procedure is repeated with one-half of the sample in order to acquire a 25 percent subsample. It should not be assumed, however, that all taxa—especially rare ones—will be

represented in each split, or that common taxa will be equally divided into the final groups (see Pearsall 2000:112–13, for uneven results of one sorting test).

Major Pieces of Laboratory Equipment

The most expensive laboratory requirement is a good binocular stereomicroscope with continuous zoom magnification beginning at either 7× or 10× at the low end, going up to at least 30× and ideally higher. One eyepiece should be equipped with an optical micrometer, and a microscope model with a phototube for camera mounting is highly recommended. Desirable extras include a camera lucida, for drawing seeds, and a teaching tube with a second pair of eyepieces, so that two people can look at material together. Student-quality or field-quality microscopes are available with built-in, direct, halogen lighting from above (usually combined with florescent or halogen lighting from below in order to view transparent material through a glass stage), but these cause more eye fatigue than dual-armed fiber-optic light sources, which also allow for angle adjustment. Fiber-optic lighting is also cool and will not damage seeds by heat. Higher-power (40× to at least 400×), phase-contrast, compound microscopes are necessary for analysis of microbotanical remains. A metallurgical ("epi-illuminating") microscope with incident and transmitted light is needed for wood analysis.

A small electronic digital balance that weighs to at least the closest 0.01 g is a required piece of equipment, and archaeobotanists who record the weights of individual seeds or low numbers of small seeds need to invest in a more sensitive, enclosed analytic balance. A set of standard, graduated geologic sieves is the last significant expenditure. We recommend buying high quality, heavy-gauge, brass or steel sieves, eight inches (200 mm) in diameter, with stainless steel mesh, and avoiding smaller, cheaper, plastic versions. Laboratory sieves should never be used for fieldwork or be loaned to colleagues working with sediments that might clog up the finer holes.

IDENTIFICATION TOOLS

Charred plant material loses its original color (an important character in many seed guides written for agricultural or botanical use) but retains its shape and sculpturing, with minor changes (Braadbaart and Bergen 2005; Braadbaart and Wright 2007; Märkle and Rosch 2008), and can therefore be identified by comparison to modern reference material. More subtle characters, such as surface cell patterns, are lost in many cases. Charring, however, can sometimes make them more visible by removing the waxy cuticle.

The basis of archaeobotanical identification is the comparison of unknown to known material, whether in a photograph or as a plant specimen. Familiarity with seed reference material is fundamental to both the learning process and to checking identifications in routine work. At the same time, having a mentor to personally tutor students plays a major role in learning seed identification, both in passing on short cuts for identification of common or difficult types, and in developing confidence.

Books and Manuals

The production of a seed atlas is a major undertaking, both in terms of gathering a comprehensive suite of reference material to be illustrated, and in drawing or photographing it. Traditional, film-based, photography of modern and ancient seed is challenging because of the difficulty in avoiding shadows and in maintaining sufficient depth of focus. As an illustration of the work involved, the pioneer archaeobotanist Hans Helbaek took superb photographs of charred seeds in the mid-twentieth century and personally oversaw the production of lithographic printing plates in Copenhagen to ensure the quality of the published result.

The arrival of digital photography (Warinner and d'Alpoim Guedes, chapter 8, this volume) still allows the taking of bad pictures. Nonetheless, digital photography, when combined with skillfully used software, has enabled the production of seed atlases on a larger scale and of higher quality than could have been imagined twenty years ago. So far the Old World has been the beneficiary of the superb photographic seed atlases produced by René Cappers and collaborators in Groningen (Cappers et al. 2006; Cappers et al. 2009; Neef et al. 2012). Drawings (Bojňanský and Fargašová 2007; Nesbitt 2006) and scanning electron microscopy (SEM) (Knapp 2006, 2010; Schoch et al. 1988) continue to be important, with drawings able to show aspects of morphology that would be obscure in photography, and SEM imagery the medium of choice to record complex surface patterning. Fewer seed manuals have been produced recently in North America, where digital photography has tended to be presented on websites (table 7.2).

Most archaeobotanists work closely with several seed atlases in the lab. Much useful information on specific taxa, particularly crops, also exists in the identification sections of published archaeobotanical reports. Some of this work, for example the exemplary publications of Willem van Zeist relating to the Near East (e.g. van Zeist and Bakker-Heeres 1982), is well-known. However, as the volume of publications increases, and existing bibliographies

Table 7.2. Standard seed identification references[a]

Printed Books and Manuals			
	Title	*Year*	*Authors*
Worldwide	Digital Atlas of Economic Plants, 3 vols.	2009	R. T. Cappers, R. Neef, and R. M. Bekker
	Fruits and Seeds of Genera in the Subfamily Mimosoideae (Fabaceae)	1984	C. R. Gunn
	The Seeds of Dicotyledons, 3 vols.	1976	E. J. H. Corner
New World	Seeds of Amazonian Plants	2010	F. Cornejo and J. Janovec
	Weed Seeds of the Great Plains: A Handbook for Identification	1996	L. W. Davis
	An Illustrated Taxonomy Manual of Weed Seeds	1970	R. J. Delorit
	Seeds of the Continental United States: Legumes (Fabaceae)	1986	R. J. Delroit and C. R. Gunn
	Colorado Weed Seeds	1921	G. E. Eggington
	Identification of Disseminules Listed in the Federal Noxious Weed Act	1988	C. R. Gunn and C. A. Ritchie
	Bobwhite Quail Food Habits in the Southeastern United States with a Seed Key to Important Foods	1976	J. L. Landers and A. S. Johnson
	Seeds of Central America and Southern Mexico: The Economic Species	2005	D. L. Lentz and R. Dickau
	Seed Identification Manual[b]	1961	A. C. Martin and W. D. Barkley
	Seeds and Fruits of Plants of Eastern Canada and Northeastern United States	1977	F. H. Montgomery
	Identification of Crop and Weed Seeds	1963	A. F. Musil
	Arizona Ranch, Farm and Garden Weeds	1958	K. F. Parker

continued on next page

Table 7.2—*continued*

Printed Books and Manuals			
	Title	*Year*	*Authors*
	Seeds of Woody Plants in the United States	1974	C. S. Shopmeyer
	Woody-plant Seed Manual[c]	1948	US Forest Service
Old World	Atlas of Seeds and Small Fruits of Northwest-European Plant Species, Part 4: Resedaceae-Umbelliferae	1994	A-L Anderberg
	Atlas of Seeds and Small Fruits of Northwest-European Plant Species, Part 2: Cypreraceae	1969	G. Berggren
	Atlas of Seeds and Small Fruits of Northwest-European Plant Species, Part 3: Salicaceae-Cruciferae	1981	G. Berggren
	Zadenatlas der Nederlandsche Flora (Seed Atlas of Netherlands Flora)	1947	W. Beijerinck
	Atlas of Seeds and Fruits of Central and East-European Flora: The Carpathian Mountains Region	2007	V. Bojňanský and A. Fargašová
	A Manual for the Identification of Plant Seeds and Fruits	2013	R. T. Cappers and R. M. Bekker
	Digitale Zadenatlas van Nederland/Digital Seed Atlas of the Netherlands	2006	R. T. Cappers, R. M. Bekker, and J. E. A. Jans
	Digital Atlas of Economic Plants in Archaeology	2012	R. T. Cappers, R. M. Bekker
	Ackerunkräuter Europas mit ihren Keimlingen und Samen, 4th ed. (Arable Weeds of Europe and their Sprouts and Seeds)	1999	M. Hanf
	Atlas and Keys of Fruits and Seeds Occurring in the Quaternary Deposits of the USSR [In Russian]	1965	N. J. Katz, S. V. Katz, M. G. Kipiani

continued on next page

Table 7.2—*continued*

Printed Books and Manuals

	Title	*Year*	*Authors*
	Samenatlas, Teil 1: Caryophyllaceae; Teil 2: Ranunculaceae (Seed Atlas, Part 1: Caryophyllaceae; Part 2: Ranunculaceae)	2006	H. Knapp
	Samenatlas, Teil 3: Fabaceae; Teil 4: Hyperiaceae (Seed Atlas, Part 3: Fabaceae; Part 4: Hyperiaceae)	2010	H. Knapp
	Bestimmungsschlüssel für subfossile Juncus-Samen und Gramineen-Früchte (Key to Subfossil Juncus Seeds and Graminae Fruits)	1964	U. Körber-Grohne
	Archaeobotany—Research on Seeds and Fruits [in Chinese]	2008	C-J Liu, J-Y Lin, and Z-C Kong
	Identification Guide for Near Eastern Grass Seeds	2006	M. Nesbitt
	Botanische Makroreste / Botanical Macro-Remains / Macrorestes Botaniques	1988	W. H. Schoch, B. Pawlick, and F. H. Schweingruber

Electronic Resources

	Title and URL[d]	*Authors*
Worldwide	USDA Family Guide for Fruits and Seeds, http://nt.ars-grin.gov/seedsFruits/rptSeedsFruitsFam.cfm	J. H. Kirkbride, C. R. Gunn, and M. J. Dallwitz
	Paleobot.org, http://www.paleobot.org	Open Source
New World	Identification Criteria for Plant Remains Recovered from Archaeological Sites in the Central Mesa Verde Region, http://www.crowcanyon.org/ResearchReports/Archaeobotanical/Plant_Identification/plant_identification.asp	K. R. Adams and S. Murray

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Table 7.2—*continued*

Electronic Resources		
	Title and URL[d]	*Authors*
	Seed Identification, http://seedbiology.osu.edu/seed_id	Dept. of Horticulture and Crop Sciences, Ohio State University
	Laboratory Guide to Archaeological Plant Remains from Eastern North America, http://pages.wustl.edu/fritz	G. Fritz, ed.
	USDA Woody Plant Seed Manual, http://www.nsl.fs.fed.us/nsl_wpsm.html	US Forest Service
Old World	Archaeobotanical Online Tutorial, http://archaeobotany.dept.shef.ac.uk/wiki/index.php/Main_Page	M. Charles, et al.
	Digital Seed Atlas of the Netherlands website, http://seeds.eldoc.ub.rug.nl/?pLanguage=en	
	A Millet Atlas: Some Identification Guidance (2006),[e] http://www.homepages.ucl.ac.uk/~tcrndfu/archaeobotany.htm	D. Q. Fuller
	HYPPA (HYpermedia for Plant Protection Database of European Weeds), http://www2.dijon.inra.fr/hyppa/hyppa-a/hyppa_a.htm	
	Identification of Cereal Remains from Archaeological Sites (2008), 3rd ed., https://ipna.unibas.ch/archbot/pdf	S. Jacomet, et al.
	Photos of Charred Remains from Early Agricultural Sites in the Near East, http://g.willcox.pagesperso-orange.fr/archaeobotanical%20images/index1.htm	G. Willcox

a See bibliography for full bibliographic details.
b A more recent issue of this manual is in print, but the quality of the printed images is not as high.
c A newer print edition is available as USDA FS Agriculture Handbook 727, April 2008, and is also available online (see Electronic Resources section).
d All websites accessed on 09/24/2014.
e Additional helpful resources are also available on the parent website.

become increasingly out-of-date (Delcourt et al. 1979; Jensen 1998; Nesbitt and Greig 1989; Royal Botanic Gardens 1985), there is a risk that existing knowledge embedded in archaeobotanical literature will be forgotten.

Digital Resources

Archaeobotanists have made good use of the Internet as a means to show images (Warinner and d'Alpoim Guedes, chapter 8, this volume) and as a means to distribute laboratory manuals (e.g., from the laboratories of Dorian Fuller, Gayle Fritz, and Stefanie Jacomet; for details see table 7.2). The series of volumes produced by René Cappers is a valuable hybrid, whereby purchasers of the books also have access to a website on which a wider range of images can be searched using selected identification criteria such as seed size.

We consider that printed and digital resources complement each other: books offer easy browsing and a structure that usually stresses plant family affinities—an excellent learning tool, as an understanding of family-level seed characters is the basis of practical identification skills. However, the identification keys in books are usually binary keys that are hard to use on archaeobotanical material that is often fragmentary and missing characters (but see Nesbitt 2006 for an alternative approach to keys). Digital media allow presentation of a far larger number of photographs and are likely to allow more sophisticated searches based on multi-access keys, which are hard to present in printed form.

Automated identification of seeds has been investigated for many years by agronomists, but so far has been largely unsuccessful. Archaeological material is particularly challenging in that seeds all tend to be black, may belong to a wide range of taxa (100–200 species are often found in major archaeobotanical reports), and are often fragmented. Even with restricted data sets and well-orientated and photographed material, as in the case of distinguishing wild and domesticated sunflower seeds, computerized shape analysis has proved unsuccessful (Tarighat et al. 2011). This will undoubtedly change, but probably on the basis of work done in better-funded areas such as face recognition. Careful application of image analysis to cultigens has proved valuable in identifying morphological groups within one taxon that map onto geographical origins, for example in olive, grape, and the date palm (Terral 1997; Terral et al. 2010; Terral et al. 2012), and this technique should be explored further for other crops with subtle variation in seed shape, such as wheat.

Seed Reference Collections

Recently collected seed specimens are the basis of the seed identification aids discussed above, and direct comparison with reference material is always valuable (and often essential) in confirming an identification. Reference material is particularly useful in that it can be cut apart, allowing examination of internal characteristics, which can be particularly helpful if even the plant family cannot be determined using gross morphology (Corner 1976; Martin 1946). Reference material is also useful as seed specimens often bear other plant parts, such as pedicels or bracts, which may also be found in archaeobotanical samples. Finally, a major benefit of regular use of a reference collection is also increased familiarity with seed characteristics by plant family, easing identification of unknown archaeological seeds.

Although we consider the seed reference collection to be an essential resource for seed identification, we also recognize that making a good quality collection is a significant investment (see Nesbitt et al. 2003 for detailed guidance on collection and curation). The seeds may come from different sources: botanic gardens, genebanks, shops, herbaria, and from living plants collected during fieldwork. In general, the ease with which a sample is obtained is in inverse proportion to the reliability of the identification, with seeds from botanic gardens being most likely to be misidentified or mislabeled (Aplin and Heywood 2008). A further advantage of seeds collected directly from the wild or from farmers' fields in the region of interest is that their size will often be more typical of ancient material than that of seeds grown in a garden environment. However, a well-balanced reference collection will draw on all these sources, as some species will be too rare, or even locally extinct, to collect oneself. Building up multiple accessions of the same taxon from different sources has two advantages: first, any incorrect identifications of reference material are more likely to become apparent as specimens will not match each other and, second, the specimens will better represent the diversity of size and shape present in different populations in nature. It is dangerous to build identification criteria on the basis of a single accession of reference material.

The work involved in identifying and housing voucher herbarium specimens (essential for material collected from the field) can be greatly reduced by collaboration with local botanists (for more on voucher specimens and collaboration, see Bye 1986; Nesbitt et al. 2010). At the same time, active participation by the archaeobotanist in collecting seeds and herbarium specimens in the field is an excellent way of increasing understanding of plant ecology and agricultural practices in an area of archaeological interest.

Care must be taken in storing reference collection seeds after field collection. Like all plant material, seeds are vulnerable to pests. They are often stored in clear plastic or glass containers that allow rapid assessment of seed appearance and restrict the movement of insects. The best safeguard for any collection is use: early detection of pests enables rapid treatment, such as freezing to deal with insects or reduction of relative humidity to deal with mold. With the decline of agricultural research, older seed collections in botanical and agricultural institutions are sometimes neglected. Archaeobotanists should seek out these collections; they are often rich in local weeds and crops that are now rare.

BASIC IDENTIFICATION PROCEDURES AND ISSUES

Principles

Seed identification (here *seed* is used in the general sense of non-wood plant remains) depends on both the ability to recognize different shapes and a knowledge of the range of candidate species. Identifying candidate species is important because identification criteria must not only enable matching with a species but also *exclusion* of other candidate species. Identification criteria should be based on a study of all likely species. It will be easier to arrive at a narrowly defined identification if there are fewer species in the study area.

Assessment of candidate specimens requires careful consideration of the ecology and abundance of species: for example, at a lowland site it may be possible to exclude mountain species and rare species restricted to specific habitats. However, it is important to be aware that the distribution of species can change and that this is increasingly true the further back in the past one investigates. Sometimes plants become extinct, as in the case of a suite of North American domesticates such as *Iva annua* var. *macrocarpa* and *Chenopodium berlandieri* ssp. *jonesianum* (Smith 1989). In general crop plants are much more likely to see major changes in distribution because of deliberate transfer through cultivation or trade.

Poorly documented wild plant floras can also lead to confusion: for example, it has only recently become clear that two species within the sedge genus *Bolboschoenus* occur today in the Near East. Nutlets of this genus are abundant in pre-agrarian archaeobotanical assemblages and have previously been identified as *B. maritimus*. Reassessment of the genus by taxonomists has shown that *B. glaucus* is the dominant species of inland areas today, and is also the species represented in archaeological samples (Wollstonecroft et al. 2011). There are important ecological (and, potentially, culinary) differences between

the two species, but the correct identification was impossible until the current day taxonomy and distribution of these species was understood.

Documenting Identifications

It is good practice to include photographs and, if space allows, written descriptions and measurements of seeds in site reports. In short reports these may be restricted to unusual species or cases in which novel identification criteria have been developed. In full reports, it is also desirable to discuss and illustrate common taxa, both to allow the reader to confirm the analyst's identifications and to show the variability in seed size and shape that is always present for the more abundant taxa. Drawings are still useful for highlighting differences between closely related taxa, although time and cost mean they must be used sparingly.

Seeds and Fruits

Family-level characteristics are as excellent a starting point for seeds as they are for whole plants, enabling the bypass of general identification keys and a focus on a smaller part of the plant kingdom. Many families have highly distinctive seeds: for example, the legumes (Fabaceae), daisy family (Asteraceae), grasses (Poaceae), and cress family (Brassicaceae). Once a family has been identified, identification to genus is the next step. This is usually more manageable than for species. For example, worldwide (these proportions will be reflected in the smaller regional numbers) the Fabaceae has 740 genera but 19,000 species. As seeds often differ substantially in appearance at genus level, initial identification may be a matter of relatively rapid scanning of reference specimens or illustrations.

At species levels, identification criteria may be much more subtle, and it is here that our limited ability to describe differences in shape is most problematic. Although botanists have developed an extensive vocabulary for plant morphology (Beentje 2010), it is probably true to say that communication of differences in shape of seeds and surface cell patterns is best carried out using images. Measurements can be valuable, but we have doubts about the blanket application of absolute figures, whether for distinguishing wild species or wild and domesticated forms. Not only does charring introduce significant and unpredictable changes in shape and size, it is also uncommon for simple measurements of plant parts to clearly distinguish species even on fresh whole plants, where there are often overlaps in size between species. Instead, plotting

scattergrams of measurements of archaeological material from one or multiple sites is often an effective way of identifying groups of differently sized seeds that may correspond to different taxa. In other words, absolute differences in size that are visible on fresh material are valuable tools for investigating relative differences in size that are apparent in archaeobotanical material. An example of the problem is the separation of wild and domesticated Old World grape pips (*Vitis vinifera*). Over a century of observations that wild grapes have squatter pips with short beaks have not yet translated into a formula that can distinguish charred material of the two forms across all sites, even though the difference is obvious to the eye, and numerical criteria such as ratios sometimes work within one site (Jacquat and Martinoli 1999; Smith and Jones 1990).

Differentiating between Wild and Domesticated

Crops usually possess a "domestication syndrome" of several characters that make them relatively easy to distinguish from their wild ancestors (Harlan 1975). These characters include larger propagules, loss of ability to disperse seed, and changes in growth habit that, in the case of some plants, such as maize, radically change the appearance of the plant. However, bearing in mind that it tends to be the propagules that end up in archaeological deposits, morphological changes in growth habit, or even in lighter (i.e., more fragile) parts of the fruit such as legume pods, will not be visible. Thus in the case of cereals and legumes, identification of domestication in archaeobotanical macroremains has focused on increase in seed size (in the case of grasses, strictly the grain or caryopsis size), and loss of seed dispersal mechanisms. In the case of amaranths and chenopods, there are clear changes in the thickness of the seed coat, discussed below.

Although a clear size difference is often visible between the seeds or grains of wild and domesticated taxa from recent populations, this difference appears more obscure in early populations of domesticates. In part this is because charred material from early sites is often in poor condition, but it is also likely to reflect the fact that early domesticates are just that: populations that have only been exposed to selection for larger seed size for perhaps a millennium or less, unlike current day landraces of crops that have been exposed to selection over subsequent millennia of agriculture. Further complicating factors include evidence, discussed below, of incomplete domestication processes in early agriculture and the varying effects of charring on seed size (see for example, the case of teff, *Eragrostis tef*, D'Andrea 2008). It is thus rare that

seed or grain size can be used as a simple indicator of domestication at early agricultural sites. However, when individual seed sizes are plotted as scattergrams and compared to those of earlier and later levels, both within one site and at other sites, an overall increase in seed size is visible through time, corresponding to domestication. The application of this technique to wheat and barley grain in the Near East has shown gradual increases in grain size during the Pre-Pottery Neolithic period (Willcox 2004); distinct episodes of increased grain size are also seen in ancient pearl millet (*Pennisetum glaucum*) in Africa and India, after domestication (Manning et al. 2011). In the New World, sunflower achenes have presented similar problems; size differences between wild and domesticated taxa that are clear in modern material are obscure in early material, contributing to the controversy over the location and timing of sunflower domestication (Yarnell 1978).

In principle the loss of seed dispersal mechanisms offers more robust criteria for identification of cereal domestication. For example, in wild wheat, barley, rice and many other cereals, the spikelets disarticulate at maturity to allow the grains to disseminate. This natural disarticulation leads to a smooth abscission scar at the spikelet base. In domesticated forms, the spikelets are torn apart during threshing by farmers, leading to torn abscission scars. There are complications: threshing of immature ears of wild grain can lead to torn scars, and the basal spikelets of wild wheat and barley do not disarticulate in the wild, and thus bear torn scars if threshed (Fuller et al. 2009; Kislev 1997; Tanno and Willcox 2012). The use of low numbers of torn spikelet scars to determine domestication status is therefore unwise. Although chaff remains are usually scarcer than grains in archaeological samples, the application of bulk flotation to early sites in the Near East and in China has led to the recovery of a large number of spikelet remains (Fuller et al. 2009; Kislev 1997; Tanno and Willcox 2012). The persistence of large numbers of wild-type scars in farmer's fields in the millennia following the first domestication of cereals suggests that full domestication was a slower and more complex process than thought a decade ago, with implications for the ease of identification of domesticates by morphological criteria (Fuller 2007b; Tanno and Willcox 2006).

Many crops have seeds that are similar in morphology to those of their wild ancestors. Here, changes in the quantity and distribution of archaeobotanical finds can point toward domestication. It is assumed that an increase in the abundance of a seed or its appearance at sites outside the distribution of the wild ancestor are indicators of domestication. These are inevitably subjective criteria, and can be hard to apply when the distances are small and the distribution of the wild ancestor uncertain. Major changes, however, such as

the move of olives inland from the coastal strip of wild olives in the eastern Mediterranean can be good evidence for domestication (Liphschitz et al. 1991; Neef 1990).

Crops

The biggest challenge in identifying crop remains is that human selection has led to the evolution of myriad closely related taxa that vary subtly in morphology, agronomy, and culinary properties. This led to endless taxonomic problems in the past, when overemphasis was given to relatively minor differences with the description of tens or hundreds of species within what is today considered a single biological species. Modern taxonomy handles this by taking a "lumping" approach in which interfertile taxa are considered to belong to a single species and major morphological variants are then recognized at either subspecies or variety level, or as in the case of sorghum, by informal groups (de Wet et al. 1986; Harlan and de Wet 1971). Within these distinct forms are then thousands of landraces characterized by further minor morphological variations. Wheat, maize, rice, and sorghum are examples of highly variable crops that are abundantly represented in archaeobotanical remains.

Similar problems face the archaeobotanist, and beginners faced with highly variable crop seeds have a strong tendency to over-split, creating too many categories. A useful tool to counter this is to arrange seeds in a series by, for example, increasing length, in order to judge whether the "different" types are in fact simply extreme forms of a continuum. Measurement can also be helpful in deciding if more than one taxon is involved, for example when measurements are plotted as a scattergram to show whether more than group can be distinguished.

Once coherent groups of crops have been identified within a site assemblage, the question arises of whether they can be assigned to current-day taxa. This question of candidate species is simpler for wild taxa; as discussed above, the current wild flora of the region (and reference material collected from that region) is likely to match archaeobotanical material, with some provision for species that have since become rare in the locality. The case of crops is more complex, since taxa may have been widespread in the past that are rare or extinct now, as with a highly robust form of emmer wheat once found in the Near East and parts of central Europe (Jones, Valamoti, and Charles 2000), or the once important sumpweed (*Iva annua* var. *macrocarpa*) and goosefoot (*Chenopodium berlandieri* ssp. *jonesianum*) in eastern North America (Smith 1989). In these cases rigorous and multiple identification criteria were

established that support the identification of a novel taxon. However, it is more often the case that there are only minor morphological differences between archaeobotanical remains and modern reference material, which in matters such as cereal grain size are partly accounted for by the effects of charring. In this case, it is usually better to document the characteristics of the crop and to explain how they differ from other archaeobotanical or modern material, without assigning it to a novel taxon.

Given the difficulties explained above, archaeobotanists have developed good tools for identification of crops to finer detail than simply that of biological species (e.g., for wheat Jones 1998 and for maize Adams 1994). A major factor in this process is the development of regional identification manuals, and the ease with which material can be shown to colleagues via electronic means and at meetings such as the International Work Group for Palaeoethnobotany. However, we believe there is more room to standardize identification criteria, in discussion formats such as the London workshop on wheat identification (Hillman et al. 1996), and by the blind-testing that has led to greater rigor in the identification of microfossils.

Parenchyma and Vegetative Remains

In charred remains, wood and plant propagules (at most sites, seeds and fruits) will account for the majority of the plant remains found. When other plant parts occur, they are often associated with the plant propagules: for example, fruit pedicels. Charred roots and tubers are often present and have become increasingly recognized by archaeobotanists after the pioneering studies of Jon Hather (1993, 2000). Intact tubers superficially resemble fruits, but often have scars where rootlets or scales were attached. Their interior has more or less spherical cells, rather than the elongated cells of wood fragments. Lumps of different cell types aggregated together are also common, and these are probably fragments of charred food. These have been little studied, but preliminary work suggests that their disaggregation and study by scanning electron microscopy would be worthwhile (Hansson 1994; Valamoti et al. 2008).

In waterlogged and desiccated conditions, it is common to find a far more diverse range of plant materials, including non-woody stems, buds, and leaves. Because waterlogging leads to the decay of the waxy cuticle and of fleshy interiors, including endosperm in grass grains, waterlogged remains are often translucent, allowing their cell patterns to be studied through transmitted light microscopy. Reference material may need to be treated by soaking or heating in dilute acid or a solution of potassium hydroxide in order to arrive

at the same translucency. There is an extensive literature on the specialist identification of waterlogged material (Birks 2007; Mauquoy and Van Geel 2007).

Wood and Stem Material

Wood is often abundant in macrobotanical samples, representing fuel and burned architectural features and providing information about the surrounding vegetation and how people of the past used and altered it. Wood anatomy is a specialized field of study and careful analysis of wood requires a higher-powered microscope (at least 400×) than needed for standard sorting of seeds and nutshell. We recommend training with an expert in wood identification of a particular study area, especially in regions of high tree diversity. A start can be made even by nonspecialists by examining transverse (cross) sections of charred wood under a low-power dissecting microscope, with conifers easily distinguished from hardwoods, and ring-porous taxa distinguishable from diffuse-porous ones. Oaks are identifiable by their multiseriate rays (see Pearsall 2000:144–53 and sources cited therein for an excellent overview). Charcoal is usually studied by breaking it so that the structure can be seen in three sectional views, and then examining each section through a high-powered metallurgical microscope.

The structure of charred and waterlogged wood is well preserved. A major difference from seed identification is that work by wood anatomists, under the auspices of the International Association of Wood Anatomists, has led to highly standardized character states that have been recorded for a large number of tree species. Excellent identification manuals exist for many regions and can be used in combination with the comprehensive website *Inside Wood* (2004).

Microbotanical Remains

Palynology has been a fundamental element of archaeobotanical research since the mid-twentieth century (Faegri and Iversen 1975), and it has been joined more recently by the study of phytoliths and starch grains. Combination and integration of macro- and microbotanical remains greatly expand the scope of our understanding of past plant-people relationships, but for one person to acquire the skills and access to laboratory facilities to conduct all of these types of analyses is challenging. Pearsall's (2000) *Paleoethnobotany* handbook contains separate chapters on pollen and phytolith analysis, and

Piperno's (2006b) book on phytoliths is, as the title states, a comprehensive guide. Analysis of starch grains from ancient tools and features is being applied with increasing frequency and exciting results (Messner 2011; Piperno et al. 2004). All of these endeavors utilize potentially caustic chemicals and require scientific laboratory facilities—including fume hoods and centrifuges—for extraction of the remains and preparation of slides, which need to be studied under high-power microscopes (up to 1000×). A cross-polarizing filter is necessary for microscopic analysis of starch grains in order to see the extinction crosses (see Henry, chapter 3, this volume).

Non-Plant Inclusions

Flotation samples frequently contain insect eggs, fecal pellets from very small animals, and fungal sclerotia that can easily be mistaken for seeds by an untrained observer. When archaeologists presort light fractions before handing them over to an expert, considerable time might be wasted pulling hundreds of round, black sclerotia from the smaller-than-2.0 mm splits (figure 7.2). Therefore, we briefly address the morphological characteristics of these ubiquitous objects. Most assemblages including fungal sclerotia will include enough whole ones to demonstrate the lack of any embryo or hilum scar. Sclerotia may be very round and smooth, but vary morphologically by species. Schoen (1983) gives the general size range as 0.5 to 3.0 mm and illustrates a number of different genera and species. Most that we have observed are smaller than 1.0 mm in diameter. The outer rind or cortex layer appears smooth at low magnification, lacking reticulation or other sculpturing commonly exhibited on seed testas. Sclerotia are easily dissected with one's fingernail or razor blade. The inner filling, called the medulla, when present, is a slightly spongy-looking, solid mass that differs from seed endosperm by its homogeneity, absence of cotyledons, and lack of starchiness. Fungal sclerotia are considered in most cases to be background noise in soil, modern contaminants that usually go unmentioned. However, Matsumoto et al. (2010) recently reported carbonized sclerotia from two sites on the island of Hokkaido, northern Japan, that appear to be from good archaeological contexts, including ash-coated fireplace vestiges. The authors, using scanning electron microscopy, identified the objects to the species *Typhula ishikariensis* and inferred that the fungal bodies entered the archaeological record associated with plant material deposited in the fireplace and elsewhere. European sclerotia are usually identified as *Cenococcum geophilum* and are usually considered modern (Alonso and López 2005).

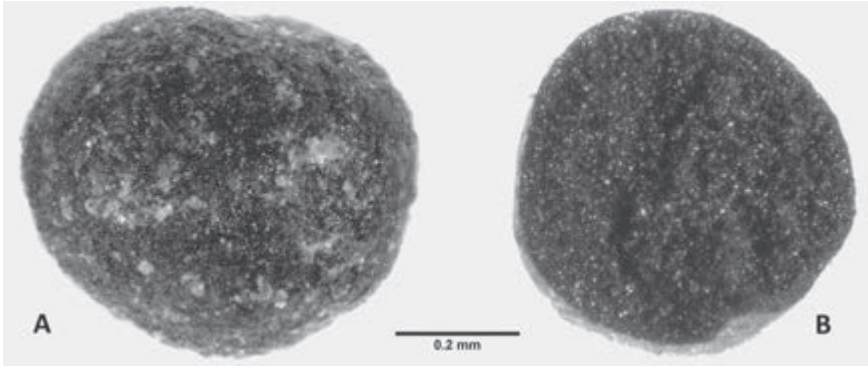

Figure 7.2. *Fungal sclerotia, species unknown, recovered during flotation of sediments from the Berry Site, Burke County, North Carolina, United States. A: outer, convex surface. B: cross section of different, slightly smaller specimen.*

SPECIFIC EXAMPLE: IDENTIFYING AMARANTH

Identification of seeds in the genus *Amaranthus* can be tricky for several reasons. First, wild amaranth seeds are black even when uncharred, so it takes close inspection and sometimes physical pressure using one's fingernail or metal tool to determine if an unbroken specimen is modern or ancient. Second, wild or weedy amaranth species produce seeds that look very much alike, and there may be little research incentive to attempt identification below the genus level. The third challenge involves distinguishing between amaranths and their close relatives, especially species in the genus *Chenopodium* (table 7.3), which often occur in the same deposits. Fourth, there are three domesticated species of amaranth—*A. hypochondriacus*, *A. cruentus*, and *A. caudatus*—all native New World cultigens, making it necessary to detect morphological changes that signal agricultural production rather than wild harvesting (Fritz 2007).

Undomesticated amaranth seeds (figure 7.3) have relatively thick, hard seed coats (testas) that cover the interior perisperms (endosperms) and encircling embryos. Analysts should collect and study the seeds of plants native to their research area and observe how they are borne in inflorescences consisting of clusters of chaffy tepals, bracts, and fruits called pyxes (a pyxis is a single-seeded, circumcisally dehiscent utricle.) Unlike chenopods, amaranth seeds are not covered by adhering pericarps.

Native eastern North American amaranth seeds overlap in diameter with local *Chenopodium* species, but whole amaranth seeds are rarely larger than 1.1 mm, whereas most whole chenopod seeds in this region are bigger. In the

Table 7.3. Means of distinguishing charred amaranth from chenopod seeds

Trait	*Cultigen Amaranth Seeds*	*Wild/Weedy Amaranth Seeds*	*Wild/Weedy Chenopod Seeds*
Seed coat thickness	Very thin(2–15 μm, usually)	Thicker(17–32 μm)	Thick(20–30 μm for weedy; 40–80 μm for wild)
Diameter	c. 1.0 mm, ± a few mm, usually	c. 1.0 mm, ± a few mm, usually	Can be as large as 2.0 mm, but some species are as small as amaranths
Beak morphology	Liplike meeting of embryo ends	Liplike meeting of embryo ends; some species have one end that projects slightly	Distinctly overlapping beak, but varies by species
Pericarp (presence or absence)	No pericarp adhering to seed	No pericarp adhering to seed	Papery pericarp adheres to seed, but rarely survives charring except as fugitive trace
Seed coat texture	Smooth (but *A. cruentus* seed coats are slightly rugose)	Relatively smooth, with some species exhibiting marginal texture, (e.g., diamondlike pattern)	Can be distinctly pitted (alveolate) or caniculate, but varies by species
Dorsal sulcus (presence or absence)	Absent	Absent	Present, running from center to beak, but varies by species
Cross-section shape	Enlarged, oval embryo creates semi-truncate cross-section; One or more ridges may be present around circumference	Biconvex, lenticular, with circular embryo cross-section	Biconvex, lenticular

Figure 7.3. *Scanning electron micrograph of wild/weedy amaranth seed.*

US Southwest, additional chenopod species exist that have smaller seeds than their eastern relatives, increasing the difficulty of distinguishing between genera. However, the embryos of chenopod seeds wrap around and overlap to form a distinct beak (figure 7.4), whereas amaranth embryos meet to form liplike features, although one lip might protrude beyond the other (figure 7.3). The most common North American wild/weedy archaeological chenopod type, *C. berlandieri*, has a distinctly alveolate (pitted) seed coat, unlike any amaranth, and may retain evidence of its reticulate (netlike) pericarp (fruit coat). Amaranth seed coats tend to be smooth except at the margin, where a subtle diamondlike patterning is visible on some wild specimens, especially under high-power scanning electron microscopy. Amaranth seed coats might be slightly undulating, but they do not exhibit the distinct reticulation of *C. berlandieri* or other chenopods. Finally, amaranths lack the dorsal sulcus extending from the beak to the center of chenopods. If seed coats are entirely missing, or if specimens are otherwise in too poor shape for

Figure 7.4. Chenopodium *seed showing distinct beak and reticulate pericarp (fruit coat). Because this is a domesticated chenopod (*Chenopodium berlandieri *ssp.* jonesianum*) from an archaeological rockshelter in the Arkansas Ozarks, it has a truncate rather than rounded margin and a smooth rather than pitted seed coat (here hidden by pericarp).*

these features to be observed, archaeobotanists relegate them to the category of "cheno-am" (figure 7.5).

Identifying domesticated amaranths can be especially difficult because the primary change that occurred through selection was reduction in seed

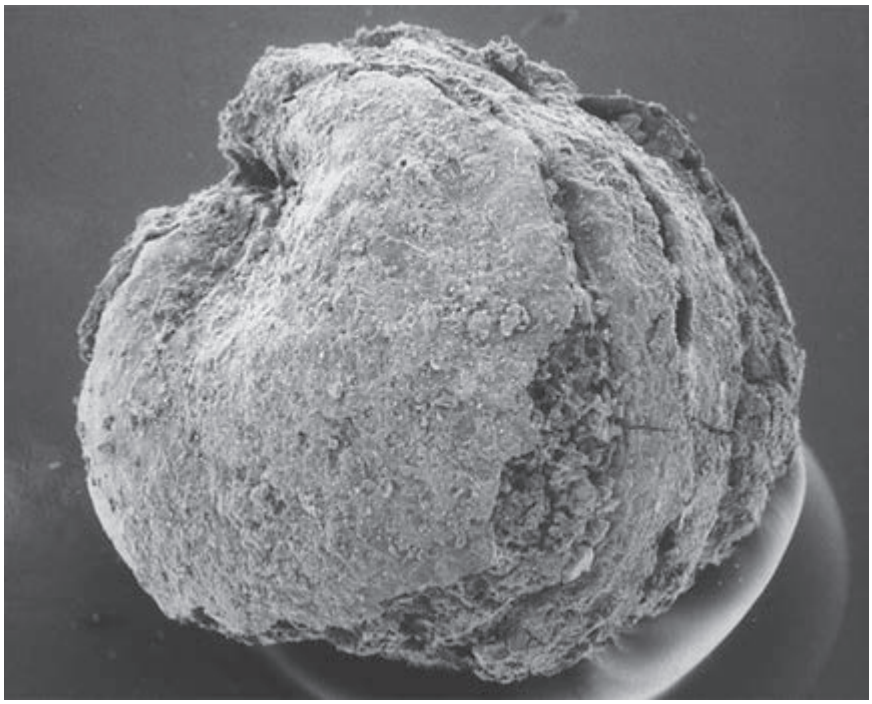

Figure 7.5. *"Cheno-am" perisperm with no seed coat that would enable classification to genus.*

coat thickness, resulting in pale rather than black seeds (figure 7.6), the same process that happened during domestication of Andean quinoa (*C. quinoa*) and the eastern North American cultigen, *C. berlandieri* ssp. *jonesianum* (Fritz et al. 2009; Fritz and Smith 1988; McClung de Tapia et al. 1996; Smith 1984, 1985).

The extremely thin seed coats of cultigen amaranths and chenopods are so fragile that they are poorly preserved, if present at all, after charring, and scanning electron microscopy is needed to obtain accurate seed coat measurements. Seed size increase does not seem to have accompanied testa reduction (Sauer 1993), but embryos of cultigen amaranth seeds are enlarged and oval rather than circular, giving the seeds semi-truncate margins with concentric marginal ridges, rather than being biconvex in cross-section.

Making the effort to separate amaranth seeds from chenopods and to recognize the presence of domesticates, although time-consuming, pays off in research dealing with agricultural origins and intensification in North

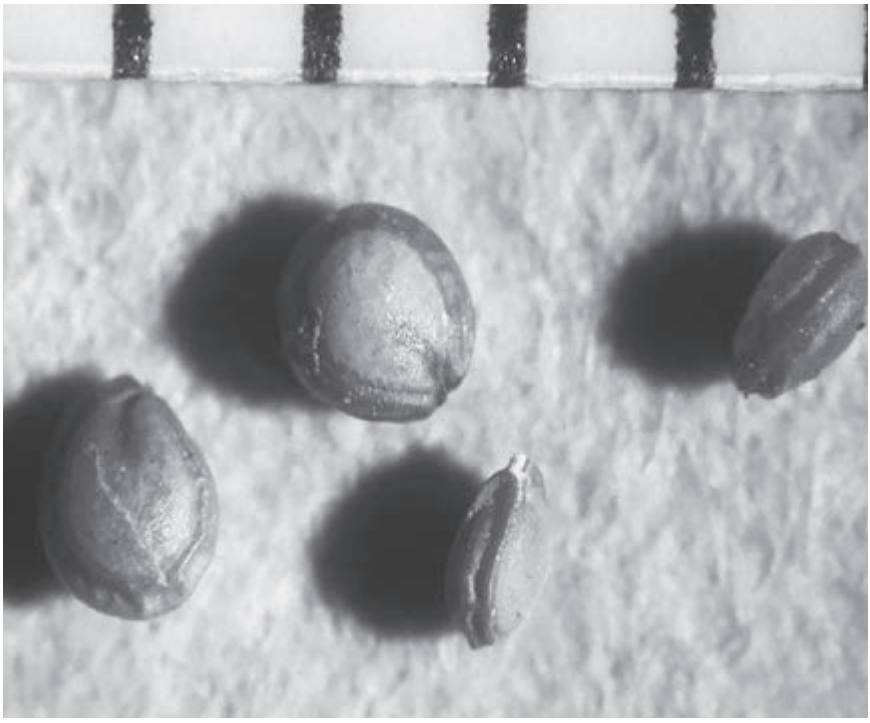

Figure 7.6. *Domesticated amaranth seeds. These specimens came from a 1000-year old storage pit in a dry rockshelter, the Holman Shelter, in the Arkansas Ozarks.*

America, Mesoamerica, and Andean South America (Bruno 2006; Fritz 1984; Fritz et al. 2009).

CONCLUSIONS

Archaeobotanists are continually refining traditional, decades-old practices of laboratory analysis and, at the same time, pioneering new types of research requiring technical skills and equipment not available until recently. Although our field has expanded, a protracted period of one-on-one training in the laboratory is still the ideal method of learning, followed by many years of continuing consultation with colleagues. Communication today, of course, includes options such as the capabilities to attach high-resolution images to email messages and to access websites devoted to archaeobotanical networking (see Warinner and d'Alpoim Guedes, chapter 8, this volume).

Most paleoethnobotanists today are, first and foremost, archaeologists who direct or codirect field projects or, at least, participate fully in research-design planning, excavations, laboratory work, and formulation of results. Ethnographic observations (ethnobotanical, agronomic, culinary, etc.) and experimental activities are increasingly frequent components of our studies. Still, as much as ever, identification of ancient plant remains requires expertise acquired through formal coursework, field biology, and careful scrutiny of reference specimens in comparative collections. The laboratory stage of analysis is a crucial and time-intensive link to interpretive success. This brief chapter covers philosophical and methodological points that we consider fundamental to this step in the pursuit of understanding how human and botanical spheres have intersected and coevolved through the ages.

If we were to choose three conclusions based on the examples and practices discussed in this chapter, they would be:

1. Although useful new techniques are regularly developed—for example, scanning electron microscopy, image analysis, and the extraction of DNA from seeds—none of these have replaced the intensive use of a stereomicroscope and the ability of humans to memorize and compare complex shapes as the main identification tool. The more sophisticated techniques have developed a valuable role, although preservation of DNA in charred material is often poor, limiting its use (Schlumbaum et al. 2008). Image analysis, in particular, merits further application for analyzing variation in ancient crop seeds.
2. Seed reference collections, and the associated knowledge of candidate species based on field experience of the study region, remain central to archaeobotany. Archaeobotanists must not only be archaeologists, but botanists too.
3. Identification cannot be carried out in isolation, and this generation of archaeobotanists is highly fortunate in the ease of travel and the benefits of digital communication available today. There is still scope for further standardization—on a regional basis—of identification criteria, especially for crops, and for blind identification tests. The widespread use in Europe of standardized archaeobotanical recording databases, often based on the ArboDat system developed in Germany (Kreuz and Schäfer 2002), is likely to accelerate the move to more consistent identification.