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New World Paleoethnobotany in the New Millennium (2000–2013)

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Abstract This article evaluates the current state of paleoethnobotany since Hastorf's 1999 review published in this journal. We discuss advances in methods, ancient subsistence reconstructions, the origins and intensification of agriculture, and how plants inform on issues of political economy and identity. Significant methodological developments in the extraction, identification, and analysis of starch grains and phytoliths have led to advancements in our knowledge of early plant domestication and the transition to food production. Paleoethnobotanists increasingly are using more complex quantitative techniques to characterize their data, which have resulted in more nuanced interpretations of plants that fall within the purview of social archaeology and allow us to address issues related to gender, identity, and ritual practice.

Keywords Paleoethnobotany · Archaeobotany · Plants · Macrobotanical analysis · Microbotanical analysis · New World

Introduction

The subdiscipline of paleoethnobotany has grown significantly since the turn of the 21st century, in both the number of practitioners and the maturation of microbotanical methods, specifically in the realm of starch grain and phytolith analyses. Through a synthesis of nearly 500 publications (not including unpublished

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theses or gray literature), we evaluate the state of the field since Hastorf (1999) published her comprehensive review just prior to the current millennium. We focus mainly on the New World, from Canada to South America and including the Caribbean Islands, because of the sheer volume of literature published since 2000. Our discussion of advances in methods, however, encompasses studies published by scholars practicing archaeobotany worldwide. We organize our review thematically, covering advances in methods and the continuing development of microbotanical approaches, reconstructions of subsistence practices, the origins and intensification of agriculture and the role of maize (*Zea mays*), how plant data are used to understand ancient ritual practices, and the intersection of plant foods with politics and identity.

Following Hastorf and Popper (1988, p. 2; see also Hastorf 1999), we define paleoethnobotany as “the analysis and interpretation of archaeological remains to provide information on the interactions of human populations and plants.” The term *paleoethnobotany* is more commonly used in the New World, whereas *archaeobotany* predominates in the Old World. We use these two terms interchangeably, as do most plant analysts, to refer to the connection between ancient humans and ancient plants. As methods underlie our abilities to recover, identify, and analyze archaeological plant remains, we begin with a discussion of methodological advances in the field since Hastorf’s 1999 synthesis. We focus on macrobotanical, starch grain, and phytolith data and include palynological studies that reference ancient human activities. All dates are calibrated and expressed as BC or AD.

Advances in Methods

Since the publication of *Current Paleoethnobotany* (Hastorf and Popper,1988) and *Paleoethnobotany* (Pearsall 1989, 2000), the subdiscipline has embraced a set of standard procedures for the recovery, identification, analysis, and reporting of macrobotanical data. More recently, there has been a similar development for microbotanical data, with new handbooks outlining standards for the recovery, extraction, identification, and analysis of phytoliths (Piperno 2006a; see also Korstanje and Babot 2008) and starch grains (Torrence and Barton 2006). These texts and increasing numbers of paleoethnobotanical laboratories that process microbotanical data have led to an influx of studies that incorporate phytolith and starch grain data. Many of these labs provide access to their comparative starch grain and phytolith collections via websites and share extraction protocols and identification keys. These advances have significantly dampened the atmosphere of doubt that surrounded phytolith identification in the late twentieth century, when scholars actively debated the accuracy of taxonomic identifications made from phytoliths, especially regarding early domesticated maize (see Hastorf 1999, pp. 69–70).

Taphonomy

An increase in experimental archaeobotanical studies on modern macro- and microbotanical specimens during the last 15 years has expanded our knowledge of taphonomic processes that affect ancient plant remains (Wright 2010). Understanding how postdepositional conditions (e.g., soil pH level, temperature, soil enzymes, fungi) affect ancient plant remains is critical to comprehending what could be missing from our samples and what has been altered beyond our ability to identify it. For example, macroplants are exposed to temperatures during the carbonization process that affect the way in which they survive when subjected to postdepositional processes (Braadbaart et al. 2009; see also Van der Veen 2007). Wood heated in excess of 310°C and then deposited into alkaline soils can fragment into pieces that are too small to allow facile taxonomic identification (Braadbaart et al. 2009). Fungi introduced into wood fuel both before and after carbonization also can affect taxonomic identification by altering the cellular structure of the wood (Moskal-del Hoyo et al. 2010), although in some cases, analysts can still infer the wood's taxonomic identity because certain types of fungus create distinct decay patterns on woods (Moskal-del Hoyo et al. 2010). Earthworms also negatively impact the preservation and identification of macrobotanical remains, particularly small seeds, which they ingest along with the soil they move through; in a controlled experiment, Tryon (2006) recovered only 13 of 200 seeds after four days of burial in soil with earthworms.

Main concerns for the preservation of archaeological starch grains are soil condition (including moisture and pH levels) and context of deposition—for example, starches deposited inside artifacts (e.g., ceramic pots) are more protected than those exposed to wind or rain (Barton and Matthews 2006). Starches deposited directly into a soil matrix are subject to various enzymes that are active in soils of different moisture contents and pH values (Barton and Matthews 2006, p. 82; Haslam 2004). Transitory starches found primarily in leaves are more vulnerable to decomposition than storage starches from seeds, roots, tubers, corms, fruits, and rhizomes (Haslam 2004, p. 1716).

Postdepositional research on plant phytoliths has revealed two main factors that affect preservation: phytolith structure and depositional environment (Piperno 2006a; see also Pearsall 2000). Some phytoliths are less stable than others (e.g., deciduous versus coniferous trees) and are more likely to dissolve over time or when exposed to specific chemical compounds (Piperno 2006a, pp. 21–22). Carbonization also negatively affects phytolith stability (Cabanes et al. 2011). Despite these advances, we still have relatively little knowledge about the stability of phytoliths *after* burial. To address this lacuna, Cabanes et al. (2011) conducted an experimental study of solubility and abrasion on phytoliths from modern and fossil wheat assemblages. In modern wheat (*Triticum aestivum*), the phytoliths from the inflorescence were less stable (more soluble) than those from the leaves or stems. In a comparison of modern versus archaeological wheat (ca. 1050 BC), the archaeological phytoliths were more stable (Cabanes et al. 2011, p. 2485). Although these results are encouraging, different phytolith morphotypes will vary in terms of their relative stability. Mechanical abrasion and partial dissolution of some phytoliths can alter their forms so that they resemble phytoliths with different taxonomic designations (Cabanes et al. 2011; Piperno 2006a). Viruses and bacteria that invaded ancient plants also can alter phytolith morphology (Kistler et al. 2012).

Data Recovery and Extraction

Choosing the appropriate method(s) for extracting macrobotanical and microbotanical remains is essential for ensuring recovery of intact remains and maximizing the identifiability of plant specimens. Pearsall (1989, 2000) extensively documented various flotation systems for macrobotanical recovery. Practitioners continue to refine these systems and develop new methods of extraction. There are even YouTube videos that demonstrate water flotation to recover carbonized macroremains.

The three most common systems for water flotation are the Flote-Tech Machine, the SMAP recovery system, and the basic bucket method (see Pearsall 2000 for descriptions). The Flote-Tech and SMAP are machine-assisted techniques that recycle water and work well for soil samples larger than 5 L. The bucket method works well for samples smaller than 5 L. Because water is not recycled between samples, there also is no possibility of cross-sample contamination. The manual bucket technique also is more time efficient, as multiple samples can be processed simultaneously.

Despite considerable refinement, water flotation is still an imperfect way to recover carbonized plant remains. Wetting and drying leads to specimen fragmentation, and recovery rates are significantly affected by soil texture and composition (e.g., clayey soils have the worst recovery rates) (Wright 2005; see also Wagner 1988). Smaller seeds are subject to higher rates of loss, and increased processing time (typical of machine-assisted systems) often leads to higher fragmentation, particularly with fragile, low-density plant parts (Wright 2005).

When possible, researchers should consider dry sieving their soil samples in place of (or in addition to) water flotation. Carbonized remains are less likely to fragment when samples are dry sieved (Chiou et al. 2013; Pearsall 2000). Even though flotation has a higher recovery rate of small seeds than dry sieving (Chiou et al. 2013, p. 49), the latter may be more feasible on projects where specialists must restrict the size of soil samples and/or where soils are dry and sandy.

Water flotation is a better alternative for highly compact (clayey) or waterlogged soils (Hosch and Zibulski 2003; Pearsall 2000). Wetter soil types physically adhere to carbonized plant fragments, making the fragments less visible and too heavy to float to the surface for light fraction recovery. Hosch and Zibulski (2003) recommend bucket floating for these samples to limit prolonged water exposure and subsequent fragmentation. Deflocculation with sodium bicarbonate also better cleans the adhering soil from the carbonized remains (see Pearsall 2000).

Microbotanical remains can be extracted from soils (and artifacts) through a different process of flotation. The most common method uses heavy liquid flotation (e.g., lithium metatungstate) to extract starch grains, phytoliths, and pollen from a single sample (Chandler-Ezell and Pearsall 2003; Coil et al. 2003; Horrocks 2005; Lentfer and Boyd 2000; Piperno 2006a). Extraction of microbotanical remains is a time-consuming process that involves pouring and decanting liquids from test tubes in between centrifuging the samples, in addition to waiting for particles to settle (see also Jenkins 2009; Parr et al. 2001).

Microbotanical practitioners are well served by establishing efficient methods for extracting different plant parts simultaneously and minimizing the time it takes for gravity sedimentation and centrifugation (Babot 2004; Lentfer et al. 2003). Lentfer et al. (2003) outline particle-settling times for gravity sedimentation and centrifugation, establishing the minimal required times for centrifuging samples during the extraction process. Throughout this process, analysts should avoid introducing contaminants. Preventing sample contamination requires the recognition of potential contaminants (e.g., organic tissues, fibers) and their sources (e.g., unfiltered water, airborne particles; see Fullagar 2006; Hart 2011; Laurence et al., 2011).

Plant Identification and Quantitative Analysis

Adequate reference collections and appropriate microscopy and image software are critical for identifying ancient plant remains. Although there are numerous published seed and wood guides available in paper and electronic formats (e.g., Cornejo and Janovec 2010; Lentz and Dickau 2005), photos and/or drawings are not adequate substitutes for the real thing. Building a comparative collection is not the onus it once was; the USDA provides seed stock gratis to US research institutions through their online germplasm request portal, and there also are private companies that sell heirloom varieties of New World cultigens at reasonable prices (e.g., SeedsofChange.com). Obtaining seeds through these sources, in addition to plant collection excursions, can result in a substantial comparative collection. A sample of these modern specimens also should be carbonized (under varying conditions) to provide a spectrum of seed states that resemble archaeological specimens (see Pearsall 2000). To build a comparative starch or phytolith collection, it is important to take specimens from several parts of the plant, including seeds, stems, leaves, roots, and any starchy underground organs. These plant parts must undergo a process of grinding, ashing, and slide mounting, followed by observation using a high-magnification (400–1000×) polarizing microscope, and digital imaging to build the comparative database (see Barton and Fullagar 2006; Field 2006; Piperno 2006a; Serpa 2008 for more specific guidelines on building starch/phytolith comparative collections).

Since 2000, research pertaining to the identification of macroplant structures has focused on intra- and interspecific differences (e.g., differentiating between the wild/domesticated forms of *Chenopodium*), as opposed to establishing more general categories of identification (Bruno 2006; Lema et al. 2008; Oliszewski 2007; Planella et al. 2011). With respect to *Chenopodium berlandieri*, its domestication has been well documented in the Eastern Woodlands (Gremillion 1993a; Smith 1985) as a relatively straightforward process from wild to domesticate with selection for a thinner seed coat and a truncate seed margin. In the Titicaca Basin of the South American Andes, however, *Chenopodium* domestication is more complicated, given the presence of at least four different species, in addition to subspecies (*C. quinoa*, *C. pallidicaule*, *C. hircinum*, *C. ambrosioides*, *C. quinoa* ssp.

milleanum/C. quinoa var. *melanospernum*) (Bruno 2006, p. 34). In an analysis of *Chenopodium* seeds from Chiripa, Bolivia, Bruno (2006) calculated ratios of testa thickness to seed diameter, determining that domesticates were larger and had thinner seed coats than their wild counterparts. The identification of domesticated quinoa at Chiripa is especially significant as it represents the earliest directly dated (1500 BC) domesticated *Chenopodium* in the Andes (see also Planella et al. 2011).

In a similar study aimed at differentiating between *Cucurbita* species, Lema et al. (2008) note that the primary characteristics used to discriminate modern squashes are color and texture, traits not sustained in archaeological specimens. The study provides guidelines for determining species of archaeological *Cucurbita* seeds from South America, based on a metric analysis of 63 seeds from eight species. Multiple measurements in addition to length/width/thickness were taken on all seeds after hydrating, dehydrating, and charring. These measurements taken on the seeds in different states allowed the authors to discriminate among species based on clear diagnostic macro- and micromorphological characteristics, notable even in the charred seeds (Lema et al. 2008, p. S285).

Because microbotanical techniques are still in their adolescence, practitioners continue to establish comparative profiles for many New World plants. Much progress has been made in the last two decades, and advances in digital technology have made it possible to readily share new images of plant phytoliths and starch grains. Nevertheless, research on postdepositional processes and cooking/processing techniques has revealed the potential for taxonomic misidentification (Cabanes et al. 2011; Kistler et al. 2012; Piperno 2006a). In addition to the distortion effects discussed above, it is also possible to misidentify certain fungal spores (e.g., conidia) as starch grains; conidia are common components of the soil and "exhibit the rotating extinction cross under cross-polarized light commonly diagnostic of starch" (Haslam 2006, p. 114).

As with macrobotany, microbotanical research is concerned with distinguishing wild and domesticated plants (Aceituno and Lalinde 2011; Holst et al. 2007; Perry et al. 2007; Piperno and Stothert 2003). Recent advances have been made in using starches and phytoliths to separate out wild and domesticated morphotypes of maize (*Zea mays*), beans (*Phaseolus* spp.), squashes (*Cucurbita* spp.), and chilis (*Capsicum* spp.). While microbotanical data related to maize domestication are abundant, a recent experiment using pollen, starch grains, and phytoliths to compare modern maize with wild species of teosinte (*Zea mays* ssp. *parviglumis*) and *Tripsacum* (Poaceae) found that starch grains and phytoliths are more distinctive than pollen for determining morphological differences between maize and its wild ancestors (Holst et al. 2007). Starch grains and phytoliths also are useful for distinguishing between wild and domesticated chili peppers and squashes/gourds, respectively, as the domesticated grains/phytoliths are larger in size than their wild counterparts (Perry et al. 2007; Piperno and Stothert 2003). Distinguishing among domesticated and wild morphotypes often requires the use of multivariate statistics as size ranges typically overlap (Aceituno and Lalinde 2011; Iriarte 2003). The best method for identifying starches is to take measurements on a large population of granules to document and assess the range of intraspecific variation (Saul et al.

2012). Wilson et al. (2010) provide instruction on the use of multivariate analysis to identify and classify starches (see also Torrence et al. 2004).

Already a common tool for microbotanical practitioners, multivariate statistics are becoming more common in macrobotany as well. When used at sites with multiple features and contexts, it is possible to use plant data to define the nature of those contexts. Archaeologists often assign feature functions based on other datasets, functions that are accepted by archaeobotanists before conducting archaeobotanical analyses. Instead of *a priori* acceptance of contextual meaning, archaeobotanical data can help archaeologists interpret feature function; rigorous exploratory data analysis involving multivariate statistics has great potential for identifying special contexts outside of the realm of everyday domestic refuse (VanDerwarker et al. 2007; VanDerwarker and Idol 2008). In addition to sorting out functional contexts, multivariate statistics have been useful for quantitatively integrating macrobotanical and zooarchaeological data to understand multiple dietary axes of variation across time and space (Hollenbach and Walker 2010; Peres et al. 2010; VanDerwarker 2010a, b). This quantitative perspective on integrating disparate types of subsistence data to attain a more holistic understanding of ancient diets represents a novel approach to using paleoethnobotanical data.

Experiments in Ancient Food Processing

Postdepositional processes are not the only factors that can alter the form and structure of ancient plants. Food-processing techniques, including drying, pounding, and cooking can transform plant structures in ways that either make them difficult to identify or produce a new structure that is diagnostic of both the species and the manner in which it was processed. Pounding and grinding often render macrobotanical samples unrecognizable; yet pounding/grinding implements are excellent sources of starch grains and phytoliths. Barton (2004) found that raw starches, particularly those found on pounding implements, were often mechanically damaged but still identifiable in some cases. While cooking and drying often damage starch grains, these same techniques can create excellent preservation conditions for macroremains.

Understanding how processing techniques can lead to preservation bias allows for a well-designed study targeting appropriate archaeobotanical materials. Numerous studies have experimented with carbonization to assess how ancient cooking practices produce archaeobotanical assemblages (Barton 2004; Braadbaart et al. 2004; Braadbaart and Poole 2008; Van der Veen 2007; Wright 2003, 2008). This research demonstrates that variable conditions of carbonization differentially affect plants based on their size, density, oil content, etc. (Wright 2003, 2008).

Some cooking techniques actually increase the identifiability of plant remains. Boiling maize (*Zea mays*) kernels in an alkaline solution (using wood ash or lime) removes pericarps and increases nutrient content and overall size; when lime-processed kernels are carbonized, size may shrink somewhat, but overall shape is preserved (Dezendorf 2013; see also Goette et al. 1994; King 1994). In contrast, when untreated kernels are carbonized, the starchy interior matter bubbles and expands beyond the pericarp, resulting in a misshapen, distorted black mass that may not be immediately recognizable as a maize kernel (Dezendorf 2013; King 1994).

Cooking experiments have become common in the microbotanical literature because, unlike macroplants, observers cannot immediately see the effects of food processing on starch grains or phytoliths (e.g., Babot 2007; Barton 2004; Beck and Torrence 2006; Chandler-Ezell et al. 2006; Henry et al. 2009; Messner 2011; Messner and Schindler 2010; Raviele 2011; Saul et al. 2012). Experiments on starch grains have revealed that the primary cooking variables limiting structural survival include temperature and duration. In their investigation of how boiling, baking, parching, and fermenting affect the survival and identifiability of starch grains, Henry et al. (2009) conclude that starches are generally recognizable if they have been boiled for less than 60 minutes and that many (25–50%) of those boiled for less than 10 minutes could still be speciated. Saul et al. (2012) establish specific temperature thresholds for a series of plants at which their respective starches survive cooking and boiling. Further experiments with earth-oven cooking revealed that moisture is also a significant factor in starch grain survival—starches can survive dry heat but cannot withstand steaming (Messner and Schindler 2010). Finally, phytoliths and starch grains are differentially affected by various cooking techniques. An experiment by Raviele (2011) on maize (*Zea mays*) processing determined that the most diagnostic (and abundant) phytoliths derive from fresh, green ears, whereas the most diagnostic (and abundant) starch grains were recovered from dried ears of maize and ground maize flour. In summary, the growth of paleoethnobotanical methods within the last two decades has significantly expanded our ability to construct more complex interpretations of ancient plant subsistence, domestication, and foodways.

Reconstructing Ancient Subsistence Economies

Subsistence reconstruction continues to represent the foundation on which other paleoethnobotanical research is built (Smith 2011b). It is imperative that we understand how ancient peoples collected, produced, processed, and prepared plant foods for daily consumption before we tackle larger social questions. For example, we cannot hope to define ritual uses of plants if we have not first documented daily mundane plants and contexts of use—we cannot define what is special if we do not know what is ordinary. Macroremains continue to provide the bulk of data about ancient diet, although scholars are increasingly using microbotanical data to reconstruct subsistence. As Adams and Smith (2011, p. 157) highlight, the best archaeobotanical records are those supported by a range of proxies for plant use, as different records blend and complement each other to produce a better, more complete understanding of the roles that plants played in the everyday lives of ancient people.

The past decade and a half of research has witnessed increasingly detailed documentation of plant subsistence strategies, particularly in areas where such information has previously been lacking or poorly understood—e.g., the Bahamas (Berman and Pearsall 2000), Bolivia (Bruno and Whitehead 2003; Dickau et al.

2012), and California and the western Great Basin (Gill 2013; Martin and Popper 2001; Reddy and Erlandson 2012; Scharf 2009; Wohlgemuth 2010). The recent upsurge in paleoethnobotanical research in California is significant, given assumptions in the regional literature regarding the importance of acorns (*Quercus* spp.). Scholars in this region have long argued that the shift from manos/metates to mortars/pestles around 4050 BC reflects a shift toward acorn processing (Erlandson 1994; Gamble and King 1997; Glassow 1996, 1997; Moratto 1984). Acorns also have figured into arguments regarding trading relationships between the California mainland and Channel Islands, with the premise that Chumash Islanders would have needed to import large quantities of acorns to meet their dietary needs (Arnold 1992, 2001, 2012; but see Fauvelle 2013). These assumptions have yet to be grounded in actual plant data (but see Gill 2013), which makes this region ripe for targeted archaeobotanical research projects.

In other regions, a great deal of plant data do exist, but the dietary contribution of those plants has been underemphasized (e.g., Hollenbach 2009). Drass (2008, pp. 12–13) argues that plant resources often are overlooked in broader discussions of Plains adaptations in favor of a focus on bison hunting and butchering. Drass's examination of plant data from more than 40 Plains village sites demonstrates the importance of plant foraging and farming alongside a tradition of bison hunting. Plains groups cultivated a variety of plants, including maize (*Zea mays*), beans (*Phaseolus* spp.), squash (*Cucurbita* spp.), tobacco (*Nicotania* spp.), sunflower (*Helianthus annuus*), sumpweed (*Iva annua*), dropseed (*Sporobolus* spp.), little barley (*Hordeum pusillum*), maygrass (*Phalaris caroliniana*), and erect knotweed (*Polygonum erectum*), in addition to collecting a variety of wild plants.

Large archaeobotanical datasets have now been amassed in many areas, which allow authors to synthesize data from multiple sites and summarize findings by region. Various publications highlight temporal and spatial variations in plant use in the Northwest Coast/Plateau (Lepofsky 2004), California (Gill 2013; Hammett and Lawlor 2004; Martin and Popper 2001), the Great Basin (Cummings 2004; Prouty 2004), the southwestern United States (Fish 2004; Huckell and Toll 2004), the Plains (Adair 2003), the midwestern/southeastern United States (Calentine and Simon 2006; Perttula 2008; Simon and Parker 2006), the Northeast (Asch Sidell 2008; Crawford and Smith 2003; Messner et al. 2008), the Caribbean (Newsom 2008; Newsom and Pearsall 2003; Newsom and Wing 2004), the Subarctic (Deal and Butt 2002), and Mesoamerica (VanDerwarker 2006). We also have seen an increase in the number of Latin American scholars conducting paleoethnobotanical research in Baja California Sur (Montufar López and Vázquez 2000), Brazil (Iriarte et al. 2008), Colombia (Morcote-Ríos 2006), Argentina (Bonomo et al. 2011; Llano 2008; Marconetto et al. 2007; Rodríguez 2000, 2004a, b; Rodríguez et al. 2003; Rodríguez and Aschero 2007), and Chile (Belmonte et al. 2001; Muñoz Ovalle 2001; Planella et al. 2005).

A common thread in subsistence reconstruction is the antiquity of resource use. Archaeobotanical analyses allow us to continue refining the debate over Paleoindian subsistence strategies in North America (Hollenbach 2009; Gingerich 2011; Reddy and Erlandson 2012; Rhode et al. 2006), questioning models of generalized foraging (Gingerich 2011) and shedding further light on small seed exploitation in the

Southwest at 5550 BC (Rhode et al. 2006) and on California's Channel Islands around 8000 BC (Reddy and Erlandson 2012). Macrobotanical studies are providing new information on the early uses of a variety of plants, including early wild sunflower (*Helianthus* spp.) at Mammoth Cave, Kentucky (ca. 810–540 BC), Late Archaic (1990 BC) wild cucurbit (*Cucurbita* spp.) in the Northeast (Lovis and Monaghan 2008), early palm (AD 880–1170) in South and Central America (Morcote-Ríos and Bernal 2001; Wake 2006), Preceramic (~2050 BC–AD 450) cherimoya (*Annona cherimolia*) and guanabana (*Annona muricata*) in coastal Peru (Bonavia et al. 2004), and the first domesticated chili (*Capsicum annuum*) seed from the American Southwest/northern Mexico, recovered at Casas Grandes (AD 1200–1300) (Minnis and Whalen 2010).

Phytoliths are increasingly used to document the earliest appearance of various cultigens, particularly in Latin America. Starch grains and phytoliths from Xihuatoxtla rock shelter in Guerrero are the oldest evidence of domesticated maize in Mesoamerica and show that early maize (*Zea mays*) was present in the lowland tropics by ca. 6700 BC (Piperno et al. 2009; see below). These data support a domestication location in the lowland Balsas River drainage, which is also home to maize's ancestor, wild teosinte (*Zea mays* ssp. *parviglumis*), and corroborate recent genetic evidence that points to the Balsas region (Buckler et al. 2006; Fukunaga et al. 2005; Matsuoka et al. 2002). Chandler-Ezell et al. (2006, p. 103) report the earliest record (2800–2400 BC) of cultivated manioc (*Manihot esculenta*), arrowroot (*Maranta arundinaceae*), and lerén (*Calathea allouia*) starch grains and phytoliths from 17 groundstone artifacts and soil samples from a domestic structure at the Real Alto site, Ecuador. Perry (2005) extracted starch grains from ceramic graters in the Orinoco Valley of Venezuela and identified root crops and maize (*Zea mays*) but not manioc (*Manihot esculenta*), a resource long-assumed to dominate early agriculture in the region. Indeed, much debate continues to circulate regarding the prehistoric use of manioc (*Manihot esculenta*) (see Dickau et al. 2012; Pagán-Jiménez and Oliver 2008; Piperno 2006b).

Archaeobotanical studies are increasingly drawing attention to the importance of wild plant foods and complement the extensive literature on domesticated and cultivated plants. Recent volumes that synthesize paleoethnobotanical knowledge for the eastern (Minnis 2003) and the western United States (Minnis 2004) provide a balance between emphasizing production of cereals and collection of wild foods. Both volumes include chapters that summarize the types, uses, and seasonality of wild plants in the eastern and the western United States and present extensive coverage of these topics (Huckell and Toll 2004; Scarry 2003). Recent research at several Middle and Late Woodland habitation sites throughout Wisconsin (Arzigian 2000; Moffat and Arzigian 2000) demonstrates a long history of wild rice (*Zizania aquatica*) exploitation, processing, and use in the region. In some Late Woodland contexts in the area, wild rice is the second-most abundant resource after maize (*Zea mays*), which suggests a significant dietary contribution to the mixed economies of the northern Midwest. This pattern contrasts with the southern Midwest, in which other types of starchy seeds (e.g., Cahokia, lower Illinois River valley) and/or hickory (*Carya* spp.) nuts (e.g., central Illinois River valley) were the primary staples complementing maize (Simon and Parker 2006; VanDerwarker et al. 2013b).

Although maize cultivation crosscuts the broader Midwest by the end of the Late Woodland period, variability in the contribution of wild foods highlights the importance of localized patterns of exploitation and cautions us not to overgeneralize at the regional level.

Another recent trend in subsistence reconstruction is the integration of botanical and faunal data to reconstruct broader dietary trends (e.g., Scarry and Reitz 2005; Scharf 2009; VanDerwarker 2010b; VanDerwarker and Detwiler 2000; VanDerwarker and Stanyard 2009). A recent volume on this topic (VanDerwarker and Peres 2010) reviews qualitative and quantitative methods for integrating these types of data and presents a variety of case studies that combine these datasets. Recent research at the Formative political center of Tres Zapotes integrates plant and animal data to examine status-based foodways in the northwestern uplands of the Olmec heartland (Peres et al. 2010). The independent analysis of macrobotanical data demonstrated that everyone had access to basic plant foods in similar proportions. To assess status-based variation for the broader diet, the authors employ multivariate statistics to integrate plant and animal foods. The results reveal that non-elite diet was dominated by maize (*Zea mays*), fruits, and fish, whereas elites had more access to terrestrial meat than non-elites, specifically dog (*Canis familiaris*) meat and venison (*Odocoileus virginiana*). Although elites certainly ate maize and fruits, they consumed so much deer and dog meat that these foods overwhelm the contribution of plant foods in the results of the multivariate analysis. Peres et al. (2010) would not have documented such clear patterning in status-based foodways if they had not run the principal components analysis and integrated these seemingly disparate datasets. Not all datasets lend themselves to quantitative integration, and not all attempts to integrate data in this fashion produce meaningful results. Nevertheless, it can produce results that push us beyond interpretations we could make from independent analyses, and we should add this method to our toolkit of exploratory data analysis.

Plant Food Processing, Preparation, and Cooking

Food processing encompasses a wide range of activities associated with preparation for immediate consumption or storage, including threshing, winnowing, milling, grinding, baking, boiling, and toasting (Hastorf 1988, p. 125). The documentation of the presence and extent of food-processing activities at archaeological sites can be a critical step in interpreting site function, especially regarding special purpose sites. Analysis of plant remains is especially relevant to document site use among mobile foraging groups, given the potential diversity of site types (e.g., George 2004; King 2004; Levine 2004). At the Middle Woodland site of Dunsfort in Pennsylvania, George (2004) identifies what appears to be the first known prehistoric black walnut (*Juglans nigra*) roasting camp (see also King 2004). Thirty-four pitted nutting stones and associated carbonized nutshells suggest that people used this walnut-processing camp intensively and repeatedly (George 2004, pp. 27–29). This example of recent paleoethnobotanical research demonstrates that foragers' decisions regarding mobility and resource use often are more closely tied to plant exploitation than hunting game (see also Hollenbach 2009).

Careful consideration of plant processing also can reveal the presence of special purpose sites in regions and periods inhabited by sedentary groups. Even farmers must sometimes travel a distance from their communities to hunt game and gather wild plants, and sometimes these two activities coincide. Macrobotanical analysis at the Late Woodland Sandy site in Roanoke, Virginia, led researchers to interpret the site as a short-term occupation geared toward the collection of medicinal plants and the hunting of deer (VanDerwarker and Stanyard 2009). The plant assemblage was dominated by nonfood economic plants, especially bearsfoot (*Polymnia uvedalia*), which is known for its abundant medicinal applications. The faunal assemblage was dominated by low-utility deer (*Odocoileus virginiana*) elements, suggesting that hunters used this location to process game prior to transport.

One of the major themes running through the food-processing literature concerns the identification and use of roasting features for cooking plant foods. These types of features are usually referred to as roasting pits or earth ovens, and the dominant types of plants cooked in these features include starchy underground organs (e.g., corms, bulbs, roots) and cactus buds and fruits (Eskenazi and Roberts 2010; Homsey et al. 2010; Peacock 2002; Smith 2003; Smith et al. 2001; but see Gamble and Mattingly 2012). Many of the studies that consider roasting features are ethnographic or experimental in nature, which are useful in documenting different types of potential roasting features (e.g., Peacock 2002; Salazar et al. 2012) and the residues of plant foods left behind after cooking (Eskenazi and Roberts 2010; Messner and Schindler 2010; Smith et al. 2001). Unfortunately, most archaeological studies that highlight the use of roasting features for processing plant foods argue from indirect evidence (Gamble and Mattingly 2012; Iriarte et al. 2008; Smith 2003). An exception is a study from the Canadian plateau (Peacock 2002) that combines ethnographic, archaeological, and macrobotanical evidence to demonstrate the importance of processing starchy underground organs. Unfortunately, no underground starchy organs were identified in the macroremains recovered from any of the earth ovens identified in the study; this is not surprising given that the identification of edible roots, corms, and bulbs is rare in the macrobotanical record (but see Gill 2013; Reddy and Erlandson 2012). Archaeological studies of earth ovens need to employ more microbotanical methods of phytolith and starch grain extraction to better document the use of starchy resources that are unlikely to preserve in macrobotanical form.

Microbotanical data have become central to examining how various artifacts were used for processing and cooking plants, in addition to identifying plant resources that would otherwise go undocumented in the macrobotanical record (e.g., Capparelli 2008; Moore et al. 2010; Messner and Schindler 2010; Samuel 2006). Analysis of starch grains extracted from ceramic griddles (buréns) from Late Ceramic period (AD 1200–1600) contexts provides the first evidence that prehistoric agriculturalists in ancient Cuba incorporated flour from wild *Zamia* corms into the bread they baked (Rodríguez Suárez and Pagán Jiménez 2008, p. 166). In addition to baking *Zamia* bread, these griddles were used for baking manioc (*Manihot esculenta*) bread. This study is significant not only because it documents use of otherwise ephemeral plants but also because it details the food preparation process, including the ultimate edible structure (in this case, bread) into which the ingredients were transformed. Similar studies have employed a combination of starch grain and phytolith analyses to examine the uses of ceramic graters for processing maize (*Zea mays*), sweet potato (*Ipomoea batatas*), arrowroot (*Maranta arundinaceae*), ginger (*Zingiber* spp.), *Zamia*, and localized small seed crops in Mesoamerica, the Caribbean, and the Amazon Basin of South America (Berman and Pearsall 2008; Dickau et al. 2012; Perry 2005). Finally, extraction of phytoliths and starch granules from dental calculus has potential to further inform about plants consumed by ancient people and the ways in which people processed plants prior to eating them. Since Hastorf's (1999) review of the field, significantly more microbotanical studies on dental calculus have been published (Boyadjian et al. 2007; Gagnon et al. 2013; Reinhard and Danielson 2005; Talbot and Richens 2007; Wesolowski et al. 2010a, b).

Domestication, Cultivation, and Agriculture

The emergence and intensification of food production remains a strong focus in paleoethnobotany. These efforts reflect an emerging consensus that the transition from a foraging to an agricultural economy in the New World was a long, complex, and regionally variable developmental process. Regional syntheses and greater consideration of theoretical models have contributed significantly to our understanding of *how* and *why* early food production occurred throughout the New World. In North America, integration of diachronic datasets from academic publications with an ever-increasing pool of gray literature provides new perspectives on the unique trajectory and nature of domestication and the transition to agriculture in the Plains (e.g., Adair 2003; Youngblood 2008), Southwest (e.g., Adams 2001; Fish 2004; Huckell and Toll 2004; Roth and Freeman 2008; Vierra and Ford 2007), Southeast (e.g., Finney 2000; Fritz 2000; Scarry 2003; Scarry and Scarry 2005; Smith and Cowan 2003; Wagner 2003), and Northeast (e.g., Asch Sidell 2008; Crawford and Smith 2003; Hart 2008; Largy and Morenon 2008; McConaughy 2008; Stein 2008). These syntheses contribute to a burgeoning theoretical literature that emphasizes seasonality, risk management, scheduling, and mixed foraging/farming economies as key components in (primarily) ecologically driven models (e.g., Perttula 2008; Roth and Freeman 2008; Smith 2011a; Smith and Yarnell 2009; Youngblood 2008). Despite a focus on the dynamic relationships between humans and local environments, there is a clear movement away from concepts of carrying capacity, external environmental stress, and circumscription in explaining the initial domestication process and adoption of agriculture in North America. These ideas have been supplanted, to some extent, by greater focus on coevolution, long-term adaptations, and heterogeneous landscapes as critical components of a gradual shift to increasing food production among foraging populations. In Central and South America, regional syntheses emphasize a wide range of themes, including the importance and diversification of local cultigens and tree crops in foraging economies of the Caribbean and West Indies (Newsom 2008;

Newsom and Pearsall 2003; Newsom and Wing 2004; Pagán-Jiménez 2009), as well as evidence of multiple centers of plant domestication throughout Central and South America (Bryant 2003; Iriarte 2007a; Piperno 2011; Rossen 2011). Similar to emerging ecological perspectives regarding plant domestication and agriculture in North America, concepts such as optimization, risk, and intensification drawn from human behavioral ecology (HBE) are central to models for early plant cultivation in Central and South America (e.g., Blake and Neff 2011; Kennett et al. 2006; Pearsall 2007; Piperno 2011; Piperno and Smith 2012; VanDerwarker 2006).

Despite such significant theoretical advancements, many questions remain unanswered regarding the specific character of plant exploitation and cultivation. The majority of current research continues to focus on *when* and *where* people initially domesticated plants as well as defining the first appearance and dispersal patterns of nonlocal cultigens. High-precision direct AMS dating of macroremains, as well as increasing acceptance of microbotanical, isotopic, chemical, and genetic studies, contribute to continual refinement and re-interpretation of the origins and spread of cultigens throughout the New World. These methodological advancements accompany increasing attention to early cultivation of weedy annuals, root crops, and tree crops. This shift in research interests is related, in part, to growing ethnographic, ethnobiological, and archaeological evidence of long-term landscape management practices (e.g., burning, intentional promotion, and active manipulation [transplantation, pruning] of economically useful taxa) that contributed to the process of domestication and niche construction (Adams 2004; Barrance et al. 2003; Lentz 2000; Neff et al. 2006; Peters 2000; Pohl et al. 2007; Smith 2006b, 2007; Wagner 2003).

Indigenous Domesticates

A growing corpus of paleoethnobotanical datasets documents early domestication and the importance of native seed crops throughout the New World. It is now clear that across most of the continental United States (except in the Pacific Northwest, California, and the Great Basin) cultivation of native weedy annuals that produce starchy seeds (e.g., maygrass [*Phalaris* spp.], knotweed [*Polygonum erectum*], goosefoot [*Chenopodium* spp.], little barley [*Hordeum pusillum*], sumpweed [*Iva annua*], and sunflower [*Helianthus annuum*]) preceded initial arrival of nonlocal domesticates (maize [*Zea mays*], beans [*Phalaris* spp.], and squash [*Cucurbita* spp.]) (Galloy et al. 2000; Smith 2006a; Wolforth et al. 2000), and they persisted in importance long after their introduction (Asch Sidell 2008; McConaughy 2008; Zimmerman et al. 2010). These starchy and oily native cultigens constitute what is now commonly regarded as the Eastern Agricultural Complex. Direct AMS dates confirm local eastern North American domestication of sumpweed (*Iva annua*) by ca. 2450 BC and goosefoot (*Chenopodium berlandieri*) by ca. 1750 BC (Smith 2006a). There also is evidence for widespread cultivation (and multiple centers of domestication) of goosefoot (*Chenopodium* spp.) and amaranth (*Amaranthus* spp.) species in South America ca. 1550 BC (Bruno 2006; Bruno and Whitehead 2003; Langlie et al. 2011; Planella et al. 2011; Rodríguez et al. 2006). Lentz et al. (2001, 2008) have recently proposed that Mexico may have been a center of domestication for sunflower (*Helianthus annuum*), a fundamental component of the Eastern Agricultural Complex. Subsequent morphometric and genetic studies confirm that sunflower domestication occurred only once (ca. 2890 BC) in what is now the east-central United States (Blackman et al. 2011; Bonzani et al. 2007; Tarighat et al. 2011). Regardless of any taxon's original locus of domestication, it is increasingly apparent that native seed cultigens contributed significantly to subsistence economies early in the transition to agriculture throughout the New World.

Despite the importance of seed crops, recent research demonstrates that plant domestication in the lowland tropical forests of Mesoamerica and high-elevation Andes of South America was focused more on starchy tubers (root crops) than on seeds (Piperno 2006b, p. 46). Microbotanical and molecular studies (summarized in Piperno 2011) have contributed to understandings of the early economic importance of indigenous root crops, including lerén (*Calathea* sp.), arrowroot (*Maranta arundinaceae*), manioc (*Manihot esculenta*), and yam (*Dioscorea* spp.). Among the first domesticated plants in the New World, lerén, arrowroot, and manioc are common in northern South America and Panama during 8250–5650 BC, which underscores their likely South American origins (Chandler-Ezell et al. 2006; Dickau et al. 2007; Iriarte 2007b; Piperno 2006b, p. 47, 2011, p. S459). Piperno and Dillehay (2008, p. 19,626) also have established the South American domestication of pacay (*Inga feuillei*) by 6850–5650 BC, indicating that people domesticated both tree crops and root crops prior to the domestication of weedy annuals in South America. These data have led researchers to suggest that societies developed significant food production systems in South America by 7250 BC (Dillehay et al. 2007; Piperno and Dillehay 2008). Currently, there is an absence of similar evidence for the timing and location(s) of root crop and tree crop domestication in North and Central America. Given the evidence of long-term tree crop exploitation and management, this topic remains a promising avenue for future investigation (Bonavia et al. 2004; Fritz 2007; Morcote-Ríos and Bernal 2001; Newsom and Pearsall 2003; VanDerwarker 2005; Wagner 2003).

Spread of Garden Crops

Along with a refined understanding of the early importance of native seed, root, and tree crops, recent research also has contributed to the reconstruction of garden crop domestications and dispersals (e.g., chilis [*Capsicum* spp.], squashes [*Cucurbita* spp.], and beans [*Phaseolus* spp.]). These cultigens, along with native root crops and maize (*Zea mays*), constitute an ancient and widespread *Neotropical plant food complex* that predates pottery in many regions (Perry et al. 2007). While it is generally agreed that chili peppers originated in Bolivia, the centers of domestication and dispersal of this condiment remain speculative (Perry et al. 2007). Microbotanical studies indicate that people first cultivated chilis throughout South America and prepared them alongside native root and garden crops as early as 4050 BC (Duncan et al. 2009; Perry et al. 2007; Zarrillo et al. 2008). This discovery places their South American appearance long before evidence of their arrival in the Bahamas ca. AD 700 (Berman and Pearsall 2008) or the southwestern United States ca. AD 1250 (Minnis and Whalen 2010). The arrival of chilis in the Bahamas appears closely related to the spread of the Neotropical plant food complex (Berman and Pearsall 2008); their arrival in the Southwest lacks any such context, perhaps the result of trade activities (Minnis and Whalen 2010).

A significant development in our understanding of garden crop domestications is the recent redating of macroremains recovered from five central Mexican highland caves (Romero’s and Valenzuela’s near Ocampo, Tamaulipas; Coxcatlán and San Marcos in Tehuacán, Puebla; and Guilá Naquitz, Oaxaca). New AMS dates from these caves establish that squashes (*Cucurbita* spp.) were among the first garden crops cultivated in the New World, appearing initially in the south-central Mexican highlands ca. 8050 BC before diffusing northward to Tamaulipas (Erickson et al. 2005; Smith 2000, 2005, 2006a). Phytolith data indicate the presence of domesticated squash in coastal Ecuador between ca. 7050 BC and 8050 BC (Bryant 2003; Piperno et al. 2000; Piperno and Stothert 2003) and in the Balsas River valley by 6750 BC (Piperno et al. 2009, p. 5023), providing further corroboration for Mesoamerican domestication. Nonetheless, morphometric and molecular studies provide compelling new evidence supporting two independent centers of domestication of pepo squash (*Cucurbita pepo*), in the south-central highlands of Mexico by 8050 BC and in eastern North America by 3075 BC (Smith 2006b). Confirmation of this distinct *pepo* lineage, as well as domesticated native seed crops, continues to solidify the status of eastern North America as an independent center of plant domestication (Smith 2006b; Turner 2011).

The current understanding of bean (*Phaseolus* spp.) domestication is less advanced than for other garden crops, and there remain significant gaps in our knowledge about the timing and location of domestication. Despite extensive redating of squash and maize macroremains from the Tehuacán Valley, the earliest known domesticated bean is only 2300 years old (Kaplan and Lynch 1999), which suggests that domesticated beans were adopted relatively late into existing systems of cultivation. Most knowledge of bean domestication comes from genetic evidence, which supports two independent centers of domestication—one in Mesoamerica and the other in the South American Andes (Chacon et al. 2005; Piperno and Dillehay 2008). The newest molecular data indicate a double domestication of the lima bean (*Phaseolus lunatus*), one event in the southern Ecuador/northern Peruvian Andes leading to the large-size lima, and another in the humid tropical lowlands leading to the small-seeded sieve bean (Piperno 2011, p. S454). Within Mesoamerica, there are several bean types, including common bean (*Phaseolus vulgaris*), tepary bean (*Phaseolus acutifolius*), runner bean (*Phaseolus coccineus*), and lima bean (*Phaseolus lunatus*) (Piperno and Smith 2012). A recent genetic study (Kwak et al. 2009) places the early domestication of common beans in moist habitats of west-central Mexico near the likely center of maize domestication in the Balsas River valley (see Piperno et al. 2009). It is thus not surprising that most research related to understanding the dispersal and economic importance of beans continues to emphasize the relationship between beans, squash (*Cucurbita* spp.), and maize (*Zea mays*) (e.g., Bonomo et al. 2011; Hart et al. 2002; Iriarte 2007b).

Maize Cultivation

Preoccupation with the domestication, spread, and intensification of maize (*Zea mays*) throughout the New World remains an overarching theme and a subject of lively debate within and outside the field of paleoethnobotany. There continues to be a general consensus that people probably cultivated maize, like other domesticates, at low levels of intensity for several millennia prior to their full commitment to food production (Smith 2001; see also Flannery 1973). It recently has been suggested that early cultivators initially valued teosinte (*Zea mays* ssp. *parviglumis*) and maize for the sugary pith of their stalks and their sweet green (immature) ears rather than the nutritional qualities of their grains (Iltis 2000, pp. 23–24, 2006; Smalley and Blake 2003); changes in productivity related to cob size and kernel number followed much later. Although this tantalizing hypothesis provides a hint as to *why* maize may have originally been cultivated, the primary focus of investigation continues to emphasize *when* and *where* fully domesticated maize first arose.

Recent genetic studies confirm that maize domestication occurred only once (7150 BC), most likely from a population of wild teosinte (*Zea mays* ssp. *parviglumis*) that grew in the lower Balsas River valley of Guerrero, Mexico (Bennetzen et al. 2001; Matsuoka et al. 2002). Most archaeologists accept this evidence (e.g., Piperno et al. 2009; Piperno and Smith 2012; Ranere et al. 2009; Rosenswig et al. 2013; Smith 2005), even though the earliest directly dated maize macroremains appear substantially later in time (Piperno and Flannery 2001). Extensive redating of desiccated maize macroremains, excavated more than 40 years ago (1954–1966) from a series of dry Mexican caves, has provided direct evidence of early domesticated maize during ca. 2870–2850 BC in the Tehuacán Valley (Benz and Long 2000; Smith 2005) and 2455 BC in Tamaulipas, with the oldest known domesticated maize cob from the Oaxacan highlands dating to 4300 BC (Piperno and Flannery 2001). These dates suggest to some researchers that maize originated in the arid highlands (Eubanks 2001a, b; MacNeish and Eubanks 2000). However, early archaeological sequences from the highlands provide no evidence for teosinte use prior to the appearance of domesticated maize (Piperno and Flannery 2001).

Microbotanical investigations in the Neotropical lowlands document the presence of maize starch grains, phytoliths, or pollen as early as 6750 BC in the central Balsas River valley (Piperno et al. 2009; Ranere et al. 2009), 5150 BC on the Gulf coast of Mexico (Pohl et al. 2007; Pope et al. 2001), and 4550 BC in coastal Chiapas, Mexico (Neff et al. 2006). Microbotanical evidence usually co-occurs with indications of forest clearing and burning (e.g., increased charcoal flux) that are consistent with slash-and-burn farming (e.g., Kennett et al. 2010; Neff et al. 2006). Paleoecological work in Central America indicates evidence of slash-and-burn maize farming as early as 5850 BC in central Panama (Piperno et al. 2007) and 5050 BC in western Panama (Dickau et al. 2007). These findings and an ever-increasing number of microbotanical studies suggest the early domestication of maize and point to rapid dispersal throughout the highly productive Neotropical lowlands of Mesoamerica and Central America after 6750 BC (e.g., Bryant 2007; Holst et al. 2007; Pearsall 2002; Perry et al. 2007; Piperno et al. 2000, 2002; Piperno and

Stothert 2003; Pohl et al. 2007; Pope et al. 2001; Rosenswig et al. 2013; Sluyter and Domínguez 2006; Wahl et al. 2006; Zarrillo et al. 2008).

Microbotanical datasets offer increasing clarity with regard to the dispersal of domesticated maize (*Zea mays*) into South America. Contra hypotheses that maize was introduced relatively late as a ritual plant (*sensu* Staller and Thompson 2000, 2002, see discussion below), directly dated starch grains from food residues in early ceramics from Ecuador affirm the presence of maize and other crops in domestic contexts as early as 4050–3050 BC (Zarrillo et al. 2008; *sensu* Pearsall 2002; Pearsall et al. 2003, 2004; Piperno 2003). Local Peruvian maize varieties identified from macrobotanical and microbotanical remains arose as early as 4750 BC in northern Peru (Grobman et al. 2012) and no later than 2050 BC in Peru's southern highlands (Perry 2007). Evidence of local race diversification (Raffaele 2008) and intensification by 5050 BC (see Dillehay et al. 2005) supports the early arrival (and economic importance) of domesticated maize in South America. Piperno (2011, p. S459) argues that given the number of sites with early maize in the Cauca Valley, Colombia, it is likely that the inter-Andean valleys were major routes for the maize's rapid dispersal after it entered South America.

The adoption and intensification of maize (*Zea mays*) throughout North America was a much more recent, albeit no less complex culturally variable process—still only known in broad outline. Direct AMS dates on maize pollen grains from wood rat middens in the southwestern United States indicate that cultivation of this Mesoamerican domesticate began as recently as 2050 BC (Hall 2010), although directly dated macroremains are slightly younger, at ca. 1750 BC (Roth and Freeman 2008, pp. 322–323). In the Southwest, as in other portions of North America, it appears that people grew maize alongside native cultigens for centuries before adopting it as a staple (Fish 2004; Hart and Lovis 2013). Researchers now argue that widespread adoption and intensification of maize agriculture in the Southwest occurred around AD 550 (Huckell and Toll 2004). After becoming established in the Southwest, maize agriculture began to spread throughout North America (Fritz 2000). Despite increasing efforts to date early maize in the Plains, Southeast, Midcontinent, and Northeast, both macrobotanical and microbotanical evidences of maize cultivation are scarce prior to AD 950 (see Hart and Lovis 2013; Smith and Cowan 2003; see also Simon 2014). Evidence of maize intensification in other regions of North America is highly variable, attributed to local issues such as population pressure, sedentism, European contact, climate change, competitive generosity, and cultural emulation (Hart and Lovis 2013; VanDerwarker et al. 2013b; Zimmerman et al. 2010). When and why maize supplanted native crops in some regions of North America and not in others remain important themes in paleoethnobotanical research.

Agriculture and Mixed Economies

While much of the Mesoamerican and Central American literature has focused on the timing and appearance of early domestication, research in the American Southwest and Southeast has focused on understanding agricultural strategies and the shift from small-scale native crop cultivation to larger-scale agricultural economies. Models that segregate prehistoric subsistence regimes into binary categories of foraging and farming are blurring (see Smith 2005); scholars increasingly recognize that plant cultivation was mixed with hunting and foraging, creating complex "agroecosystems" (Deur and Turner Eds. 2005; Doolittle 2000). Roth and Freeman (2008; see also Roth and Wellman 2001) argue convincingly for an ecological framework that casts maize (*Zea mays*) agriculture as an extension of foraging strategies rather than a radical economic shift in the Formative period of southwestern Arizona (AD 679–1406). Procurement strategies that focused on small seeds did not require substantial changes for people to incorporate maize, and people already possessed appropriate processing technologies that likely facilitated the transition to maize agriculture (Roth and Freeman 2008, p. 322).

Researchers also document experimental agricultural strategies and shifts from small to large-scale agricultural economies from the Archaic period (ca. 8000–2000 BC) onward in the Southeast (Parker 2006; Parker and Scott 2003; Perttula 2008; Simon and Parker 2006; Whittaker et al. 2007; Youngblood 2008). Scholars have examined early gardening practices in the Southeast, particularly within Middle Woodland contexts in the Etowah River valley, Georgia (Branch-Raymer and Bonhage-Freund 2000, 2011), as well as in Ohio Hopewell contexts (Wymer 2009; Wymer and Abrams 2003). Wymer and Abrams (2003, p. 175) argue that the intensification of garden activities through time contributed to the formation of tribal societies. Scholars in the Northeast (Adovasio et al. 2003; Bernstein 2002) also have discussed the issue of intraregional variation in subsistence strategies. In the Late Archaic through Late Woodland Northeast (4000 BC–AD 1500), Bernstein (2002, p. 8) demonstrates that while interior groups in eastern North America specialized their diet around domesticated plant crops by AD 1000, coastal groups maintained broad spectrum diets until European contact; essentially, cultural continuity persisted in regions where subsistence resources were especially diverse (e.g., marine and estuary flora and fauna).

Finally, Scarry and Scarry (2005) caution against dichotomizing farming regimes into mixed-crop stands, small-scale gardens, and large-scale monocropping categories typical of Western systems of farming. They argue that successful plant food production in the Southeast was the result of a mixed-crop, shifting system, yet prehistoric farmers often had large, extensive fields and produced large-scale surplus for storage. Scarry and Scarry urge archaeologists to evaluate varying levels of production, as well as systems of distribution and patterns of consumption, before developing blanket arguments for whole regions about levels of sociopolitical complexity based on a singular subsistence strategy.

Ritual Uses of Plants

Paleoethnobotanists continue to push plants into the realm of social archaeology, particularly in terms of examining how plants articulated with ancient ritual practices. As noted by Morehart and Morell-Hart (2013; see also Morehart 2011; Morehart and Helmke 2008), a focus on ritual diverges from earlier utilitarian emphases in paleoethnobotany that viewed plant remains solely as indicators of ecological settings, subsistence patterns, or economic resources. Within the rubric of ritual practice, plant remains are examined in relation to their roles in the materialization of religious and cosmological beliefs and practices. The examination of the connection between plants and ritual, however, is not a straightforward process—researchers must first appropriately identify special contexts and/or foods, after which they must attribute meaning to the contexts and events they have identified. The first step—ritual identification—must never be taken uncritically, and the burden falls on the paleoethnobotanist to demonstrate that a plant deposit or taxon was indeed connected to ritual practice. To establish the connection between plants and ritual in archaeological deposits requires that we first identify the composition of plant deposits that represent quotidian activities to provide a baseline. The attribution of meaning to ancient rituals and ceremonies involving plants is challenging and requires a broader knowledge of relevant ethnographic and ethnohistorical evidence regarding plant usage, an understanding of active ingredients in nonfood ritual plants, an examination of the sites of ritual activity and contextual associations with other archaeological materials, interpretation within the context of diachronic changes related to social, economic, and political activities, and so forth.

Maize and Ritual

The connection between maize (*Zea mays*) and ritual has been debated throughout the New World, specifically in regards to the adoption of domesticated maize into emerging and existing systems of food production. Scholars increasingly examine the role of ritual practices and early food production, questioning simple associations between maize and the development of political complexity. The upsurge in microbotanical analysis, especially in the lowland tropical areas of Central and South America where macrobotanical preservation is poor, has revealed a protracted period of minimal maize usage (ca. 5000 years) between its initial domestication and its subsequent intensification. This gap between maize's domestication and its elevation to staple status has led many to speculate about maize's function and meaning prior to its intensification, in many cases attributing its early use to the production of beverages for consumption during ritual events (e.g., Staller and Thompson 2002; see also Smalley and Blake 2003).

This topic has developed into an issue of some debate, particularly within the past decade in Ecuador. Responding to Staller's and Thompson's claims that maize (*Zea mays*) entered the Early Formative/Valdivia subsistence economy as a secondary resource that was initially "consumed in liquid form…as a fermented intoxicant" (Staller and Thompson 2002, p. 43), Pearsall, Zarillo, and colleagues (Pearsall et al. 2004; Zarrillo et al. 2008) present phytolith and starch grain data that demonstrate the ubiquity of maize microfossils on domestic pottery and ground stone implements at the Real Alto site. Their data demonstrate that maize was present in everyday household settings in the "earliest ceramic context from Ecuador" (Zarrillo et al. 2008, p. 5006). Staller and Thompson's (2002) phytolith evidence from ritual contexts at the Valdivia-period ceremonial center of La Emerenciana (e.g., mound deposits, ritual offerings, and burials [including dental calculus]) also establishes that maize was part of the rituals that occurred there. It appears that maize played multiple roles during its initial introduction into Valdivia-period foodways, given its presence in both domestic and ceremonial contexts.

Recent research also questions assumptions about the role of maize (*Zea mays*) as an important element of ritual practice within emerging political institutions. Various scholars have highlighted the importance of competitive feasts as a means of attracting and rewarding followers while simultaneously reinforcing status distinctions among participants (e.g., Dietler and Hayden 2001). It is within this paradigm that southeastern US paleoethnobotanists of the 1990s interpreted the adoption/use of maize within early Mississippian polities emerging ca. AD 1050–1250 (Johannessen 1993; Scarry 1993). Twenty years ago there was good evidence that maize had entered the American Bottom region and become common in Late Woodland assemblages postdating AD 750, 300 years before the emergence of the Cahokia polity. Recently, direct AMS dating of maize remains from Late Woodland contexts in southwestern Illinois (including at Cahokia proper) reveals that most of these purported Late Woodland maize macroremains actually date to the subsequent Mississippian period (Simon 2014); Simon's findings suggest that maize entered the record in any abundance only after AD 950, after which time it quickly achieved staple status. In addition, Pauketat et al. (2002, p. 273) analyzed early Mississippian feasting deposit underneath Cahokia's Mound 51 and revealed the insignificance of maize relative to fleshy fruits and indigenous cultigens such as maygrass (*Phalaris caroliniana*) in ritual events that occurred at the time of the polity's initial formation (see also Fritz and Lopinot 2003). Collectively, these findings suggest that maize became a staple fairly quickly after its adoption; there was not a lengthy period of low-level use during which it could have developed deep ritual meaning prior to Cahokia's settlement; and maize was not a key element of ritual practice during Cahokia's emergence.

Feasting

Two trends crosscut the recent paleoethnobotanical literature on feasting—the archaeological identification of feasting contexts and a theoretical shift away from a focus on competitive political feasts toward a broader framework that includes both competitive feasts and communal-oriented events common to less-hierarchical societies. The designation of any deposit as feasting refuse requires a careful spatial analysis of plant remains, in addition to other materials deposited throughout various site contexts. There are two general ways that paleoethnobotanists approach the topic of feasting through spatial analysis. The first approach assigns spatial contexts prior to conducting quantitative analysis of the plant data. In general, these contexts are defined based on analyses of other archaeological datasets. The second approach uses quantitative analysis of the plant remains as the starting point for defining different contexts. In other words, space is not defined according to public/private, quotidian/ritual, or other social or functional categories prior to conducting the analysis of the plant data. Rather, this type of analysis uses plant remains from samples, features, or units as baseline data for an exploratory analysis that seeks to identify deposits that deviate from the central tendency of the plant assemblage. In this way, social/functional categories that are assigned to space (and have relevance for identifying feasting contexts) emerge from the data analysis as outliers or rare contexts that do not fit with the majority of the data. This second approach is preferable because it means that we are not relying on other researchers' assumptions about the use of space, which may or may not be well grounded in the analysis of other datasets.

There are several recent feasting studies in paleoethnobotany that employ spatial analyses to parse out everyday foods from those used in ritual and political feasting (Capparelli et al. 2007; Lema and Capparelli 2007; VanDerwarker et al. 2007; VanDerwarker and Idol 2008). The studies by VanDerwarker and colleagues emphasize this point about defining feasting contexts and events through exploratory analysis of the plant data. Considering that the majority of plant data from habitation sites represents refuse from daily food-processing and consumption events, food refuse from feasting or ritual activities should be less common and produce patterning that differs in nature from most contexts. This exploratory approach is more useful at sites that lack clear evidence of public spaces (e.g., temples or plazas) or political hierarchies. In contrast, sites with clear evidence of ceremonial and elite spaces that are well demarcated and separated from commoner habitation areas facilitate the assignation of social–spatial contexts prior to plant analysis (e.g., Capparelli et al. 2007; Duncan et al. 2009; Lema and Capparelli 2007).

Feasting in the context of sociopolitical display and negotiation continues to be a frequently investigated topic. Many paleoethnobotanists continue to emphasize the political and economic roles of prominent types of ritual negotiation (occurring in the contexts of feasting events) in creating and reinforcing power and status differences (Fritz and Lopinot 2003; Goldstein and Hageman 2009; Iriarte et al. 2008). Duncan and colleagues highlight how aspiring Andean leaders employed feasting as a mechanism to draw in labor for public constructions that served to legitimize and cement political authority (see also Vega-Centeno 2007). Their research at the Preceramic (ca. 2200 BC) ceremonial center of Buena Vista in the Chillón Valley of central Peru examined macro- and microremains from a ritual feature that was centrally located within a sunken niche-walled pit in the Fox Temple on top of a mound; that radiocarbon dates from different levels in the pit were identical suggests the pit was filled rapidly with contents from a single event (Duncan et al. 2009, p. 13,202). In addition to a diverse suite of macroremains, bottle gourd (*Lagenaria siceraria*) and squash (*Cucurbita* spp.) serving implements yielded starch grains of manioc (*Manihot esculenta*), potato (*Solanum* spp.), chili pepper (*Capsicum* spp.), arrowroot (*Maranta arundinaceae*), and algarrobo (*Prosopis* sp.), indicating that food and drink made from these plants were consumed at this event. Based on the unique depositional context of these plants, the authors argue that the remains likely are the refuse from a feasting event related to the ritual killing of the temple itself. Duncan et al. (2009, p. 13,205) argue that both the building and decommissioning of temples in the Preceramic Andes (ca. 4000–1500 BC) were linked with ritual feasting aimed at organizing and motivating labor for these events. During this era, multiple small-scale construction events appear to have been preceded by feasts hosted by informal leaders who lacked the social power to organize large labor parties for more massive building events (e.g., Vega-Centeno 2007). Duncan et al. (2009) argue that the weakly formalized leadership of the Preceramic period needed constant reinforcement through such ritual practices as feasting.

Recent paleoethnobotanical research increasingly questions the simple association between the emergence of social hierarchies and food production linked to status competition/feasting (e.g., production of maize beer *sensu* Smalley and Blake 2003). Rather than having a *causal* role in the emergence of social hierarchies, changes in plant food cultivation likely were embedded in the changing social relations that eventually led to the development of those hierarchies. Moreover, researchers are questioning earlier perspectives that consider activities such as food production and feasting events as exclusively orchestrated by politically savvy elites attempting to *create* social inequalities and political hierarchies. Rather, political consolidations and social inequalities may have emerged from rituals practiced within traditionally accepted parameters that eventually reached exaggerated scales (Pauketat 2000). In many areas of the New World, it is likely that people incorporated intensive food production into a longer history of social and religious negotiations that involved plant foods (e.g., fleshy fruits, other native cultigens) in which surplus production aided the support of craftspeople and the fueling of community events that simultaneously reinforced both status differences and community cohesion.

Many scholars have refocused their research efforts on examining feasting where community solidarity and group identity, rather than prestige, were reinforced (e.g., Mickleburgh and Pagán-Jiménez 2012; Pluckhahn et al. 2006; VanDerwarker et al. 2007). In their examination of plant macroremains from different contexts at Upper Saratown, a contact-period (AD 1650–1710) Sara Indian village in North Carolina, VanDerwarker et al. (2007, pp. 44–45) found that the late-contact-period (AD 1670–1710) residents of Upper Saratown dealt with increased social and physical stresses (e.g., raiding and exposure to European diseases) by eschewing European foods (e.g., peaches [*Prunus persica*] and watermelons [*Citrullus lanatus*]) and refocusing their traditional rituals around traditional staple foods as a means to reinforce and revitalize group identity in the face of significant cultural upheaval. They argue that not all feasts leave archaeological signatures that can be readily identified by the presence of luxury foods or other unusual elements (VanDerwarker et al. 2007, p. 45), especially feasts aimed at creating and maintaining social solidarity. Rather, we can use the combination and sheer quantity of plant foods to distinguish ordinary features from ritual or other special contexts (see also Benz et al. 2006; Bray 2003; Hastorf 2003).

Mortuary and Interment Rituals

The majority of paleoethnobotanical analyses of plant remains from New World mortuary contexts come from South America where mortuary excavations are more common (but see Benz et al. 2006). Most of these studies focus on the identification of well-preserved macroremains as a means of delineating which plants were used as ritual offerings versus burial arrangement (e.g., mosses used as bedding [Morcote-Ríos 2006]). Recent investigations by Belmonte et al. (2001) and Muñoz

Ovalle (2001) have produced evidence of early interment of people with bags of coca leaves (*Erythroxylum coca*) during the Formative Period (500 BC to AD 200) in the Arica region of northern Chile. The ritual and ceremonial importance of coca in Andean communities from prehispanic to modern times has long been recognized (e.g., Allen 1988; Plowman 1984; Rostworowski 1988). Dillehay et al. (2010) provide evidence for coca chewing as early as 6050 BC in the Nanchoc Valley, Peru, and tie its use to emerging specialists who extracted and supplied calcite and lime to communities for coca chewing during the transition from mobile hunter-gathering to sedentary farming.

While it is certainly useful to inventory the types of plants that ancient people interred with their dead, it is perhaps more important to understand how this inventory differs both qualitatively and quantitatively from the plants that people ate or used in their day-to-day lives. Through such comparisons, we can better ascertain which plants had specific ritual purposes pertaining to mortuary practices versus those plants whose roles varied according to context. Cutright (2011) compares plants from domestic and mortuary contexts at the Lambayeque-period (ca. AD 1000) site of Farfán in the Jequetepeque Valley of northern Peru. She considers correlations between foods and ceramic vessels, associations between plant types, and how foods pattern among age, sex, and status. Her analysis indicates that foods recovered from burials and their methods of preparation "represent a restricted subset of daily cuisine" that was specific to funerary contexts (Cutright 2011, p. 83). Ultimately, she argues that ritual foods, including funerary food offerings, were the products of deeply rooted culinary systems rather than mere markers of particular mortuary traditions (Cutright 2011).

The political and ethical issues related to excavating human burials in the United States and Canada make these regions less suitable for the analysis of plants from mortuary contexts. However, a recent study conducted in the upper Tonto Basin of Arizona demonstrates the potential of sampling the soil surrounding skeletal materials for macrobotanical and microbotanical remains (Berg 2002). Berg (2002) employs a novel approach to examine food and medicine offered to the deceased just before death; macroremains surrounding the burial may indicate offerings to the dead, and microremains collected from soil within and around the sacrum may reflect the composition of the deceased's final meal. Of particular interest are the pollen taxa that represent potential stomach contents—the pollen from around the sacral areas were compared to control samples to determine which pollen types are most likely from plants that were intentionally ingested prior to death (Berg 2002, pp. 1357–1358). This approach for sampling microremains that may be indicative of stomach contents can potentially be used in situations where archaeologists cannot or should not fully excavate human remains when they are encountered, due to legal or ethical concerns.

Caves as Ritual Spaces

Most of the recent paleoethnobotanical literature considering caves as ritual spaces has focused on Maya contexts (but see Harrison 2003); not only is the Maya region littered with complex cave systems, the Maya are well known for their use of caves as ritual sites (e.g., Moyes 2013). Recently, Morehart (2011) has focused on delineating between the uses of rural and urban caves as loci of ritual plant offerings. Rural caves were more likely used for private rituals in which food (often immature maize) was offered as symbolic payment to the gods, likely indicative of first fruit offerings related to fertility and harvests. Urban caves yielded more evidence of tree fruits, which Morehart (2011, pp. 114–116) interprets as "wealthy" food remains indicative of elite maintenance of fruit orchards (see also McNeil 2009; Morehart et al. 2005). Morehart et al. (2005, p. 257) also examine the contexts of pine (*Pinus* spp.) charcoal at Maya cave sites, arguing that burning of pine was common in ritual activities as part of "symbolic offerings to sacred entities." They note the ethnographic manufacture of pine resin into incense in the region and also acknowledge that pine wood may have been used as torches to illuminate caves, citing ethnographic evidence for this use as well as torch motifs common in ancient Maya iconography (Morehart et al. 2005, pp. 256, 258, 262–264).

Political Economy, Labor, and Domestic Practice

Apart from special politically and ritually charged feasting events, recent research on household production/consumption, organization of labor, and access to resources allows scholars to consider the interplay of domestic practice, political power, and socioeconomic process in a range of societies with varying levels of political complexity. While archaeologists have traditionally examined political economies in terms of class relations, surplus production, and the financing of political institutions (e.g., Brumfiel and Earle 1987; D'Altroy et al. 1985; Earle 2002; Welch 1991), recent research documents the unique social aspects of manufacture, circulation, and consumption to infer a wider variety of processes by which power was negotiated and contested. An examination of the recent paleoethnobotanical literature on ancient political economy reveals a dual focus on funding/feeding polities and the examination of status-based differences in food production and consumption.

Understanding how leaders exact tribute in the form of produce and labor provides a basis for examining how status-based differences emerge between commoners and elites and manifest between households and across communities. It is often difficult to provide clear evidence for movement and organization of tribute within polities, especially those that are regionally expansive, such as the Wari empire, which covered around 320,000 km^2 at its peak (Schreiber 2001, p. 85). Archaeologists conducting research at the Wari site of Cerro Baúl in the Moquegua Valley have established the presence of an elite-sponsored *chicha* brewery on the mountain's summit (Goldstein and Coleman 2004; Goldstein et al. 2009; Moseley et al. 2005; Sayre et al. 2012). This brewery served as a locus of processing and fermenting molle (*Schinus molle*) drupes, one of the primary ingredients in *chicha de molle*. A site-based spatial analysis of molle remains at Cerro Baúl reveals that elites were the ones primarily engaged in the production of *chicha de molle*. The production and consumption of this drink played an essential role in organizing and legitimizing elite activities, perhaps including the exaction of labor from non-elite households. This examination of molle remains departs from the traditional emphasis on *chicha de maíz* (maize beer) that has loomed large in Andean literature for decades (e.g., Hastorf and Johannessen 1993; Hayashida 2008; Jennings 2004; Johannessen and Hastorf 1994; Logan et al. 2012; Moore 1989; Morris 1979; Nicholson 1960; Valdez 2006).

While the Wari case demonstrates the funding and use of commoner labor parties to contribute to elite projects, a relatively common practice in the ancient Andes, research in Mesoamerica tends to focus on traditional tribute relations in which commoners produced surplus maize (*Zea mays*) that was funneled to the polity's leadership (Morehart and Eisenberg 2010; VanDerwarker 2006). Morehart and Eisenberg argue that elites living in the Postclassic (AD 900–1519) kingdom of Xaltocan increased surplus demands to the extent that farmers reduced their crop diversity to sufficiently increase yields to meet these demands. Morphometric analysis of the maize cupules from this region reveals an increase in maize frequency, an increase in grain size, and a decline in the number of varieties as the kingdom grew in power and influence (see also McClung de Tapia and Martínez Yrizar 2005). Morehart and Eisenberg (2010, p. 107) interpret these patterns to represent a shift toward intensive *chinampa* farming—in the context of growing tribute demands, farmers chose to focus their efforts on larger-grained maize varieties in highly productive raised lakebed fields.

Ancient plant remains also have great potential for illuminating status-based differences in emerging and established political hierarchies. Recent research in the Olmec heartland along Mexico's Gulf Coast has significantly altered interpretations related to the role of maize (*Zea mays*) intensification in the emergence of Early Formative (1400–1000 BC) political complexity in the region (VanDerwarker 2006; VanDerwarker and Kruger 2012). Prior to the collection and analysis of macrobotanical data, Gulf Coast scholars argued that Olmec leaders rose to power through the cooptation of maize surpluses (e.g., Heizer 1960, 1962). Analysis of macrobotanical remains from sites spanning the Formative period (1400 BC–AD 300) in the Sierra de los Tuxtlas approximately 100 km from the Olmec political center of San Lorenzo, however, reveals that farmers did not begin to intensify maize until at least the Late Formative period (ca. 400 BC), well after the Olmec florescence (VanDerwarker 2006). While maize likely was not a source of staple finance for building and sustaining Olmec polities, it nevertheless appears to have played a role in elite activities. A comparative analysis of maize macroremains from Middle Formative (1000–400 BC) Olmec sites throughout the larger region reveals significant variability with respect to maize production and processing; sites with high abundances of maize tend to be located closer to political centers, suggesting that the early use of maize likely was tied to events that occurred in proximity to areas of sociopolitical power (VanDerwarker and Kruger 2012, pp. 526–527). VanDerwarker and Kruger speculate that maize may have been a luxury item (e.g., Hastorf 2003) served as a beverage and used in rituals and/or public events that functioned to establish and reinforce the legitimacy of Olmec political power (e.g., Clark and Blake 1994).

Examinations of status-based foodways, however, should not elevate elite activities over the documentation of non-elite foodways. We cannot truly understand the development and maintenance of status-based differences if we do not evaluate how everyday commoner subsistence practices varied across space and time. As we mentioned above, it is impossible to identify what is special (or, in this case, high status) if we do not have a baseline for what is ordinary. A variety of Mesoamerican studies have examined this relationship between elite and non-elite plant use and documented the privileged access that elites have to faunal resources (Peres et al. 2010), to higher-quality woods for fuel and craft production (Morehart and Helmke 2008), and to distinct varieties and larger ears of maize (*Zea mays*) (Turkon 2006). At Tres Zapotes in southern Veracruz, all plant foods were available to all residents regardless of status, with faunal resources the most important food type for defining social status (Peres et al. 2010). Nevertheless, it appears that non-elites supplemented their diet more heavily with tree fruits than non-elites, likely to make up for the lower levels of meat in their diets. This case also highlights the importance of considering faunal data alongside botanical data to tease out broader patterns of food-related variability in social status.

A consideration of foodways in the context of expanding states and empires allows us to examine how local groups adopt, negotiate, and reject top-down impositions from colonial interlopers. Perhaps the best-documented case is Hastorf's classic example of how the Inka interfered with the local political economy of the Sausa people in the upper Mantaro River valley of central Peru (Hastorf 2001; see also D'Altroy and Hastorf 2001; Hastorf 1990). Hastorf's (2001) analysis of plant data from Sausa house floors dating both prior and subsequent to Inka control reveals a shift in plant diet for local elites and non-elites. Prior to Inka domination, during the Wanka II period (AD 1300–1460), elite and non-elite status was clearly differentiated through plant foodways. Hastorf demonstrates that the shift to imperial control led to a leveling of local status differences. In cases of imperial conquest, it is often in the best interests of the conquerors to undermine local elites as a means to solidify the support of the masses. This review of plant foodways and political economy reveals a great deal of variation in regard to how status differences emerge, how different polities emphasize or suppress status differences, and how chiefly polities, states, and empires finance their political machineries.

Gender, Identity, and Culture Contact

Over the past few decades, archaeology has witnessed an explosion of research on issues of daily household practice, which has set the stage for paleoethnobotanical analyses that examine relationships between food and identity. Since Hastorf's (1991) seminal study of foodways and gender during the Inka conquest, paleoethnobotanists have continued to explore the intersection of gender and food-related activities. Although labor related to foodways has historically been characterized as "women's work" and often has been viewed as drudgery (Janowski 2012, p. 180; Rodríguez-Alegría and Graff 2012, p. 1), these ideas are changing as archaeologists continue to challenge assumptions about normative gendered behavior. Recent studies have attempted to give more agency to the women who were likely responsible for most plant-related subsistence activities in the past.

Given how challenging it is to attribute gender to ancient activities, it is no surprise that most paleoethnobotanical studies that incorporate gender as a primary research topic focus on places and times for which there is some written record (e.g., Martindale and Jurakic 2004; VanDerwarker and Detwiler 2002; but see Gagnon et al. 2013; Turkon 2007). In some cases, we can push gendered interpretations based on the historical or ethnohistorical record further into the past, but this task must never be done uncritically. In other cases, archaeology has the potential to significantly augment what we know from the ethnohistoric record, especially considering the Western male bias of those documents. For example, VanDerwarker and Detwiler's (2002) spatial analysis of the eighteenth-century Cherokee foodways from the Coweeta Creek site in western North Carolina reveals that all plant food processing took place near the public townhouse, which challenges public/private assumptions based on ethnohistoric observations about gendered segregation of space in Cherokee communities. Rather than restricting domestic activities to their houses, women processed plant foods publicly and communally, presumably to provision public events, communal storehouses, and male clan members residing in the townhouse, in addition to basic household storage. While Cherokee women may have provisioned males with food, they appear to have done so in public spaces associated with areas typically considered to be male domains (VanDerwarker and Detwiler 2002, p. 27).

Various researchers report that female status declined within native North American groups as these groups increasingly interacted with Western European traders and settlers (Fiske 1991; Hall 2000; Loren 2008). Because early settlers were primarily male, their interactions were biased toward native men, even in economic transactions that had traditionally fallen under the purview of women's work (e.g., food and land). Nevertheless, recent work by Martindale and Jurakic (2004) demonstrates that some native women capitalized on new opportunities that European contact provided, which elevated their status and that of their families. Their examination of red elderberry (*Sambucus racemosa*) use among two 19th and 20th century native communities in the northern Tsimshian region of Canada reveals that women in extended family networks intensified their collection of these berries as their communities became further entrenched in trade relations with Europeans. Martindale and Jurakic (2004, pp. 273–274) attribute this shift in berry frequency to the agency of women who were attempting to accumulate more wealth for themselves and their families during a time when inequalities were emerging within their communities. Women were actively involved in generating economic surpluses for trade in the burgeoning wealth economy of imported European goods, which the authors interpret as a source of power in the form of control over food-producing lands, food processing, and food storage (Martindale and Jurakic 2004, pp. 273–274). This case of changing gender identities in the context of developing social inequalities prompts us to remember that gender identity is a complex variable and that differences in social status among women and men in vertically stratified communities can lead to very different gendered roles and notions, even within a single gender category (e.g., Turkon 2007).

Culture contact scenarios have far-reaching effects on peoples' lives, communities, and identities, and gender is but one axis of this complicated nexus of intercultural interaction. Scholars have recently begun emphasizing how the cultural and biological disruptions of native-European contact led native farmers to reorganize their subsistence systems entirely. In the context of losing land to Europeans, family and friends to disease and raiding parties, and husbands and brothers to war campaigns, many eastern North American women farmers were faced with insufficient land and labor for producing food. Some women responded to these risks by cultivating a wider variety of plant foods (e.g., Bonhage-Freund et al. 2002), while others significantly reduced field cultivation and primarily foraged for the bulk of their food resources (e.g., VanDerwarker et al. 2013a). For example, Bonhage-Freund et al. (2002) analyze 19th century Ojibwe (Chippewa) assemblages from central lower Michigan; this was a period when the Ojibwe people and their lands were impacted by European colonizers via interaction at trading posts, the introduction of Western goods, and the modification of local ecosystems. Their results indicate that Ojibwe communities continued to rely on maize (*Zea mays*) as a staple food into the contact era but cultivated other species to buffer against risk. Bonhage-Freund et al. (2002, p. 136) argue that Ojibwe peoples continued to consume most of their native foods and only selectively incorporated Western foods, which may have been a strategy to preserve traditional foodways in the face of massive social and ecological upheaval (see also VanDerwarker et al. 2007).

When Europeans and Native Americans interfaced, one common cultural exchange that occurred involved food, especially cultigens. Recent research on this topic by Jamieson and Sayre (2010) supports other studies that have emphasized native adoption of Old World plants when these foods can be easily adapted to existing systems of food production (e.g., Capparelli et al. 2007; Gremillion 1993b; Lema and Capparelli 2007). Jamieson and Sayre's recovery of barley (*Hordeum vulgare*) and quinoa (*Chenopodium quinoa*) from artisan households from a marginal neighborhood in eighteenth century highland Ecuador suggests that lower-class households consumed both Old World and New World domesticates. They submit that indigenous highlanders may have readily adopted barley, an Old World cultigen, as the grain would have fit well into existing food-processing systems and grain-based cuisine that included quinoa (Jamieson and Sayre 2010, p. 209). The impact of European contact on native subsistence systems has been a prominent theme in historic archaeology, but several scholars stress the need to flip the focus of this issue to further explore the socioeconomic contexts in which European colonial communities adopted unfamiliar New World food resources (e.g., Gremillion 2002, p. 117; see also Voss 2008).

Changes in diet and foodways that correspond with increasing contact between Native American groups and European settlers surpass the simple adoption of new foods and can reflect changes in native and nonnative identities as they intersect with gender, ritual, social class, and ethnicity. Bendremer and Thomas (2008) present data from Shantok Village in eastern Connecticut, an Unca/Mohegan village spanning the pre- and postcontact eras. They document changes in foodways during the establishment of the Mohegan reservation, arguing that maize (*Zea mays*) became more symbolically important for Mohegans despite an impoverished diet due to their incorporation of animal husbandry during the contact era (Bendremer and Thomas 2008, p. 188). Despite its low visibility in daily consumption, maize dishes continue to be featured prominently at Mohegan festivals and cultural events today and are considered an important signifier of Mohegan ethnic identity.

Archaeological research focused on the dark history of the American slave era also has great potential for exploring the intersection of food and identity. Recent studies on plantation contexts in North America and the Caribbean explore issues related to the assimilation and negotiation of ethnic identity and tradition, and examine the relationships between subsistence strategies, environment, plantation owners, and enslaved workers to consider the diverse ways in which people responded to plantation slavery (Bowes 2011; Britt 2010; Mrozowski et al. 2008; Trigg and Landon 2010). These studies reveal that, in many cases, there may have been a “creolization” or “blending of knowledge” among enslaved Africans and Anglo-American colonists, as well as Native Americans (Mrozowski et al. 2008, p. 721). The cultivation of house gardens and continued usage of traditional medicinal practices (see Bowes 2011) may have been a means by which enslaved individuals organized family and communal lives in the face of chronic violence and the breakup of kin groups. In all of these identity studies, the value of using archaeobotanical data to supplement historical narratives and oral traditions is clear. Finally, while the majority of scholarship focused on the intersection of food and identity has emphasized colonial and/or plantation contexts, some studies have examined these issues during the precontact era as well (e.g., Allen and Skousen 2009; Bush 2004; Calentine and Simon 2006).

Conclusions and Future Directions

Since the turn of the century, we have witnessed significant methodological updates in paleoethnobotany, within both macrobotanical and microbotanical specializations. Microbotanical research is quickly catching up with macrobotanical research, evinced by further refinement in microbotanical techniques and the growing number of studies that employ both macrobotanical and microbotanical data in their evaluation of various issues. The integration of macrobotanical and microbotanical datasets has expanded the issues paleoethnobotanists can address. Increasing numbers of scholars employ multiple forms of plant data to explore sophisticated theoretical issues that result in the advancement of social archaeology, refinement of our understandings of human impacts on the environment, and increased critical examination of issues such as the shift to food production. The subdiscipline is growing because paleoethnobotanists are embracing multiple theoretical perspectives and multiple methods in their evaluation of humans and plants in the past. As Hastorf (1999, p. 79) remarked nearly 20 years ago, “plant materials can substantively address any and all archaeological questions.” Paleoethnobotanists can lead the way in archaeology if we continue pushing the envelope in our examination of various anthropological issues—gender and identity, domestication and agriculture, environmental sustainability, political economic organization, culture contact scenarios, etc. These issues are not mutually exclusive—reconstructing past environments, ecologies, and subsistence economies often demands an articulation with perspectives from social archaeology, and vice versa. It is through this embracement of multiple perspectives that theories and model building in paleoethnobotany will continue to thrive.

Continued success in the discipline also depends on the use of standardized protocols, rigorous sampling strategies, and quantitative analyses of macrobotanical and microbotanical assemblages to fully realize their potential. As techniques for starch and phytolith extraction continue to be refined, it is critical that we work toward standardizing our laboratory protocols within and across regions. While standardization always has been a goal, there continues to be variability in sampling strategies and data presentation, especially with microbotanical data. Now that most paleoethnobotany laboratories have websites and many practitioners share their work through open-access journals and other websites, there are multiple platforms through which to share field and laboratory protocols. The availability of low-cost and high-quality photography equipment (e.g., Dino-Lite USB digital microscopes) facilitates the sharing of photographs of archaeological and modern specimens as a comparative source for other researchers.

It is encouraging that more paleoethnobotanists are running their own excavation projects than ever before, which ensures appropriate collection and recovery of both macro- and microplant remains. Nevertheless, paleoethnobotanists often work with existing collections and collaborate with other project directors. Thus, it is important to make field-sampling guidelines accessible to nonspecialists. Because sampling strategies may vary based on the nature of a site and its deposits (see Lennstrom and Hastorf 1995; Pearsall 2000), collaboration with paleoethnobotanists during fieldwork is essential for maximizing data collection and interpretive potential. Paleoethnobotanists excel at diachronic analyses of plant data, synchronic comparisons of different sites/regions, and (increasingly) the use of diverse quantitative techniques, from basic standardizing measures to complex multivariate statistics. The more consistent we are in the application of these techniques, the better we can compare datasets to build a more robust picture of past human–plant interactions and foster conversations that crosscut regional boundaries.

Our review and synthesis of the paleoethnobotanical research published since the new millennium has revealed several areas that we think should be prioritized in future research projects. Although we did not include studies of isotope analyses of carbon residues or ancient plant DNA in our synthesis, these are relatively new areas that require further development. Various key isotopes have already been used to productively contribute to our understanding of climate, growing conditions, and crop provenancing. It is likely that with continued efforts stable isotopes of plant remains (especially when multiple isotopes are considered in conjunction) will become an important tool to characterize paleodiets and paleomobility. These advances and future research avenues are discussed in a recently published article (Fiorentino et al. 2015). In addition, Brown et al. (2015) have recently published a review of ancient DNA methods and their applicability to paleoethnobotany. Another type of plant analysis that could be implemented more frequently is the identification of wood charcoal. While this is not a new analytical technique, we believe that it has been relatively underused in comparison to the analysis of ancient foods. Given the recent relevance of studies focused on ancient climate change, we urge more practitioners to incorporate wood identification and analysis into their project plans.

Another call for methodological advancement regards the need for more intrasite spatial analyses of large datasets to tease out the staging of plant processing, preparation, and discard, which has the potential to inform us about the organization of space according to gender, social status, politics, ritual, etc. Too often we rely on other investigators' interpretations of social–spatial contexts before we even analyze our data. That means that we are relying on assumptions made by others about the ancient meanings of spaces—sometimes these assumptions are well grounded in other datasets and sometimes they are not. Another problem with simply accepting another researcher's interpretation of space is that we then fail to acknowledge the power of our plant data—the types of plants, their abundances, ubiquities, densities, and their states of preservation (among other variables) in houses, pit features, middens, mounds, etc.—to interpret the ancient uses of those contexts. We are no longer simply the laboratory specialists who must do what we are told by some grand project synthesizer. Even when we are brought on a project after excavations have been completed, when artifacts have been analyzed, and interpretations of site structure have been made, we can still test those social–spatial interpretations with the plant data we have been given. And when we are running projects, it is imperative that we use our plant data to its fullest potential by giving it the chance to guide our interpretations about feature function and the use of space.

Another methodological recommendation calls for greater data integration, especially in regard to what we refer to as the food specializations—macrobotany, microbotany, zooarchaeology, isotopic analyses, etc. A fair amount of data integration is already taking place in paleoethnobotany. There is also a recent trend toward pairing plant data with faunal data and dietary-related isotopic data. Whether these data are presented as independent lines of evidence or whether scholars attempt actual quantitative integration when appropriate, few would dispute that this type of exercise in weaving multiple lines of evidence together provides a higher level of resolution into ancient economic and social practices than one data source alone.

We urge the continuation of experiments that involve cooking, carbonizing, depositing, and recovering macrobotanical and microbotanical data. Archaeobotanists already actively conduct these types of experiments, the results of which provide critical information for identifying and interpreting the uses of ancient plant remains. These three methodological points—more spatial analysis, increased data integration, and continued experimentation—push subsistence-related data and themes closer into the realm of foodways studies, with the intention of better illuminating ancient people and the social contexts in which they collected, produced, processed, consumed, and discarded their foods.

A final methodological point regards data accessibility. There is a vast gray literature in the United States and Canada that has been produced by archaeobotanists working in the private sector of Cultural Resource Management. Generating, compiling, and sharing paleoethnobotanical databases within regions have the potential to greatly advance our knowledge of local and regional foodways across space and time. The time constraints experienced by our colleagues working in the private sector make it difficult for them to publish all the data that they collect and report. We thus recommend increased collaboration between paleoethnobotanists in the academic and private sectors that can benefit both parties through more frequent publication and accessibility of primary data (Wohlgemuth, personal communication, 2015).

In addition to methodological advancements, paleoethnobotany has made great strides in documenting the transition to plant cultivation and agriculture within the past several decades. This focus on field clearing and cultivation practices, however, has obscured the role and importance of ancient arboricultural practices, especially in tropical locales. Modern studies of subsistence farmers throughout the Neotropics have revealed that forest management is closely tied to the cultivation cycle and variably refer to the forest-farming regime as a "forest garden" (Ford 2008; Hellin et al. 1999), "mosaic" (Alcorn 1981), "agroforestry system" (Barrance et al. 2003; Diemont et al. 2006), "agroforest" (De Clerck and Negreros-Castillo 2000), and "agroforestry experiment station" (Gillespie et al. 1993). This forest-farming regime is most often observed as a cycle that begins with clearing a plot for planting annuals (the *milpa*), followed by a fallow period of regrowth (the managed fallow), leading to regrowth of secondary forest (the managed forest) (De Clerck and Negreros-Castillo 2000; Diemont et al. 2006; Ford 2008; Gómez-Pompa 1987; Lentz 1990; Peters 2000). Forest management systems reflect a variety of practices, including unintentional activities caused by burning, intentional promotion of useful trees, elimination of undesirable trees, active manipulation of trees (pruning, transplanting, etc.), and tolerance of trees that are difficult to eliminate (Barrance et al. 2003, p. 104; see also Gómez-Pompa 1987; Lentz 2000; Peters 2000; VanDerwarker 2005; Wiersum 1997). Despite the importance of this topic, few studies have attempted to address the timing of tree fruit domestication or early forest management practices (but see Piperno 2011, p. 461; Piperno and Dillehay 2008, p. 19626; Piperno and Pearsall 1998). We urge our colleagues to incorporate the topic of tree management and domestication into their future research projects.

The focus on plants as foods or environmental indicators is often emphasized over the use of plants for other purposes, such as medicines, dyes, hallucinogens, symbols, etc. This bias is not that surprising given that many plants have multiple uses that often include food, which can make it hard to determine whether a plant was used for some other nonfood purpose. In addition, when plants are used in primarily medicinal or ritual settings (and not consumed as food), they tend to leave minimal traces that result in small sample sizes. However, in regions that boast large databases of reported plant assemblages, we can begin to assess the uses of nonfood plants that tend to appear in low quantities. Increased and regular sampling for microbotanical remains from all contexts also can increase the visibility of medicinal and ritual plants. In regard to the ritual use of plants, we reiterate how important it is to define ritual plant practices through comparison to quotidian patterns of plant usage. It is impossible to attribute a ritual interpretation to a plant or a context without first demonstrating that it does not fit the pattern of what ordinary daily refuse resembles.

Finally, paleoethnobotany has an important role to play in a decolonized anthropology. By decolonized, we refer to the recent research paradigm that recognizes the colonial foundation on which archaeological interpretations have been built, but seeks to undermine this foundation and the conventions that reinforce it by conducting archaeology that is more representative of and relevant for indigenous communities (e.g., Atalay 2006; Lydon and Rizvi 2010; Oland et al. 2012). On a global scale, decolonizing practices vary widely, but they have largely been grounded in inclusiveness, collaboration, and engagement with descendant communities. Paleoethnobotanists consider the material remains of ancient foodways, but their research is ultimately about people—understanding people's daily lives, the foods they ate, their social and political organizations, their interactions with the environment, and their sense of place in the world. The reconstruction of these aspects of human social life has the potential to make substantive impacts on descendant communities, including politically and economically marginalized groups. Research that documents the deep antiquity of indigenous traditions surrounding food can be used to demonstrate sustainable practices and provide a source of pride to indigenous groups that are increasingly integrated into market economies. The documentation of a wide variety of crop inventories, medicinal plant uses, and the like can be shared with community members, both local and international. Those community members also can be directly involved in the excavations that produce the data that paleoethnobotanists use to reconstruct human–plant interactions in the past.

Paleoethnobotany has moved in exciting new directions in recent years. Researchers are continuing to examine plant remains beyond their dietary and economic significance, using plant data to interrogate the diverse pathways in which belief systems articulated with economic systems to fashion and fix structural inequalities. We also have witnessed a movement away from focusing on purely elite motivations to considerations of community foodways. Increasing studies of domestic labor, including food preparation and consumption, continue to shed light on elements of social reproduction and inequalities in daily life, which often are downplayed in large-scale, structural histories. With theoretical and methodological issues well in hand, paleoethnobotanists are poised to lead the way in advancing the practice of New World archaeology in the current millennium and beyond.

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