changes has been debated, but enhanced reliance on animal foods and the adoption of food processing technologies were likely both important drivers.

Daily energy budgets expanded in early *Homo*. Fossils indicate enlarged adult body size, especially in females, who would have been acutely sensitive to energetic supplies associated with the high costs of reproduction. Locomotor adaptations appearing at this time suggest intensification of energetically demanding behaviors like long-distance running. In addition, increased relative brain size implies higher basal energy requirements or compensatory reductions. Two kinds of compensatory reductions have been proposed: the expensive tissue hypothesis argues that metabolic costs of an enlarged brain were met by a reduction in similarly expensive gut tissue; the expensive brain hypothesis argues that encephalization costs were met through higher energy intake and lower investments in locomotion, growth, and reproduction. Although the relative merits of these two ideas remain under discussion, both hypotheses argue that ancestral humans must necessarily have transitioned toward an energy-rich diet.

Coincident reductions in digestive structures suggest that *Homo* was not simply eating more to meet these increased energy needs but was instead eating differently. Compared to australopithecines, early *Homo* had reduced postcanine teeth, slighter mandibles, and more gracile chewing muscles per unit body size. Compared to our nearest living relatives in the genus *Pan*, modern humans have smoother (less sacculated) intestinal tracts and reduced colons that limit our ability to retain and extract energy from foods that escape digestion in the small intestine, like fiber. Our smaller guts seem to have originated in early *Homo*, judging from the emergence of a narrower pelvis and barrel-shaped, rather than cone-shaped, thorax. These features suggest that early *Homo* gained routine access to a diet requiring less chewing effort and less capacity for indigestible nutrients.

Anthropologists have long argued that these adaptations were driven by increased consumption of animal foods. Support for this hypothesis is abundant and diverse: cut and breakage marks on bones, wear marks on stone tools, and assemblage data suggest that humans were butchering animals by 2.5 MYA; bone isotope profiles position early *Homo* between carnivores and herbivores; genetic analysis of taeniid tapeworms that jumped from African carnivores to humans as primary hosts indicate frequent meat consumption prior to 1 MYA; and modern humans have limited ability to synthesize important nutrients available primarily from animal foods, including the sulfonic acid taurine and key polyunsaturated fatty acids necessary for brain growth.

Despite such evidence, increased reliance on animal foods was probably not the sole solution. First, the pursuit of animal foods typically requires a large energetic investment with low rates of success, leading to speculation that hunting by ancestral humans was only made possible through access to a consistent alternative source of energy-rich food that buffered against the consequences of hunting failure. Second, it has been argued that seasonal depletions of body fat in prey animals would have placed human ancestors at risk of "rabbit starvation," a condition of negative energy balance that can arise in omnivores deriving a large proportion of their calories from protein, due to the high costs of protein digestion and limited capacities for urea synthesis. Third, a high intake of meat would have presented a chewing challenge, since ancestral and modern *Homo* share blunt molars with rounded cusps that cannot efficiently fracture compliant animal tissues. Finally and importantly, empirical data from modern raw foodists suggest that diets incorporating raw animal foods remain energetically inadequate, even in the absence of seasonal constraints on supply or quality.

These concerns have focused attention on the complementary role of food processing in explaining human digestive adaptations. Most theoretical development to date has centered on cooking, which has been shown to raise the energetic value of plant and animal foods by increasing digestibility and lowering the metabolic costs of mastication and digestion. By improving consistently available plant items in addition to animal items, cooking would have conferred a predictable increase in energy, relaxing constraints on the coevolution of larger total energy budgets and smaller digestive capacities. A key challenge for the "cooking hypothesis" is timing, however: major digestive adaptations were apparent in humans beginning ~2 MYA, but the earliest widely accepted evidence for controlled fire dates to ~1 MYA (Wonderwerk Cave, South Africa), with direct evidence for cooking in the form of hearths and burned bones dating to just 250 KYA. One potential explanation is that traces of fire often vanish too quickly to be faithfully preserved in the archaeological record. Another possible explanation with recent empirical support is that the widespread adoption of simple nonthermal processing techniques like pounding could have conferred early improvements in dietary quality; the subsequent adoption of cooking would greatly enhance these benefits.

Further work to quantify the energetic gains and digestive efficiencies expected from intensified exploitation of animal foods versus the adoption of thermal and nonthermal processing technologies will help to clarify the pathways by which humans arrived at our biological commitment to a high-quality diet. In addition, emerging studies of the many dietary interactions between humans and the microbial inhabitants of our bodies promise insight into human digestive capabilities that have evolved in genomes beyond our own.

See also Bioarchaeological Analysis; Fire and the Development of Cooking; Fire and the Development of Cooking Technology; Meat; Paleodietary Analysis; Paleonutrition; Plant Processing; Teeth, Diet, and Human Evolution; Wonderwerk Cave

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■RACHEL N. CARMODY

DINING

See Food and Dining as Social Display

DISTILLATION

The art of distilling, the concentration of liquid concoctions through heating, has been practiced for millennia. Distillation represents the most complex form of alcohol production. The production of distilled spirits requires not only fermentation, but also the added steps of heating and regulating the fermented compounds in an alembic or still to produce a concentrated alcoholic beverage with a high alcohol content. In ancient times it was used to produce medicinal mixtures and fragrances. The ancient Egyptians, for example, distilled rose water for its aromatic and pharmacological qualities. The distillation of alcoholic beverages is a more recent phenomenon. While it is widely accepted that the distillation of alcoholic beverages began in Europe in the 16th and 17th centuries, archaeological evidence may challenge this Eurocentric narrative. In South Asia, for example, distinctive ceramic pots at 2,500-year-old village sites in northern India and Pakistan have been interpreted as alembics. If correct, the pots would represent the earliest evidence of alcohol distillation in the world.

The large-scale distillation of alcoholic beverages is most notably a fixture of the modern age and has been the focus of historical archaeological inquiry in the New World. Distilling equipment has been recovered from Martin’s Hundred, a 17th-century Virginia settlement, and from nearby James Fort in Jamestown. Given the relative novelty of alcohol distillation in the early 17th century and the rather limited consumption of distilled spirits in Britain at this time, these stills were probably used for making medicinal compounds rather than alcoholic beverages.

The expansion of distilling industries in the later 17th century was driven in part by the expansion of sugar production in the Caribbean, which provided an enormous amount of base material (molasses) for local Caribbean distillers as well as distillers in Europe and North America. Investigations on Tobago show that the process of rum distilling and the layout of the natural terrain dictated the location of structures on Caribbean sugar estates. Rum distilleries have also been investigated at colonial and post-Revolutionary sites in North America. Unlike the factory-in-the-field operations found in the Caribbean, rum distilling in early New York and New England was an urban industrial enterprise that used imported Caribbean molasses as its fermentable base material.

Historical archaeologists have explored other types of distilleries, including bourbon whiskey distilleries in Kentucky and a whiskey distillery at George Washington's home at Mount Vernon, Virginia (USA), demonstrating the role of distilling as both an ancillary economic activity and a primary economic focus. Brandy, made from distilled grape wine, has been investigated archaeologically at the Vergelegen estate in South Africa and in Buenos Aires, Argentina. The brandy distillery in Buenos Aires was an independent operation that distilled raw base material imported from distant locations, especially from rural vineyards and wineries located outside of the city.

See also DISTILLED SPIRITS; FERMENTATION; FOOD AS A COMMODITY; SUCROSE

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■FREDERICK H. SMITH

DISTILLED SPIRITS

Distilled spirits are concentrated alcoholic beverages produced in stills. Rum, gin, brandy, whiskey, vodka, and various other concentrated forms of alcohol are different from low-alcohol-content fermented beverages, such as wines and beers. Emerging in the 17th century with the growing knowledge of alcohol distillation in Europe and the increasing efficiency of distilling technology, spirits have left their mark in the archaeological record and have helped provide insights into colonialism, capitalism, sociability, ethnic identity, class anomie, and many other aspects of life in the early modern era. Evidence of distilled spirits has been recovered from a variety of archaeological contexts, including taverns, saloons, military sites, slave villages, boardinghouses, and work camps. Textual sources and ethnographic studies have helped archaeologists understand the uses and meanings of the glass bottles, stoneware storage containers, crystal drinking vessels, porcelain punchbowls, brass spigots, iron barrel hoops, and various other forms of material culture associated with distilled spirits found on archaeological sites. The archaeological study of distilled spirits has increased our understanding of the economic impact of distilled spirits and their role in sustaining emerging trade networks, especially with indigenous peoples. The study of specialized places for the consumption of distilled spirits has also revealed important information about sociability. And the material culture of distilled spirits has shed light on the way that identity formation and class conflict play out in different archaeological contexts.

The vessels used for the storage and transport of distilled spirits reveal colonial ventures and trade networks that connected disparate parts of the globe. In colonial North America, alcoholic beverages played an integral role in creating and sustaining the European-Indian fur and skin trades. Although prior to European contact North America was one of the few areas of the world that did not produce alcoholic beverages, Native Americans quickly embraced European-introduced alcoholic drinks, especially rum and whiskey. They incorporated alcohol into traditional social and spiritual activities, and used it to cope with the unsettling changes that accompanied European colonialism. Historical archaeologists have recovered glass bottles and ceramic storage jars from Native American sites that highlight the extent to which Native North Americans were engaged in the global alcohol traffic. For example, at 18th-century Creek and Cherokee sites in the southeastern United States, archaeologists found glass bottles and ceramic storage jars that testify to the prominent role of spirits in the fur and skin trades.

The liquor trade between Europeans and indigenous peoples was not limited to North America. The introduction of large quantities of liquor into a volatile environment of colonial domination disrupted traditional indigenous social structures, even in areas with long-standing traditions of alcohol use. For example, before the arrival of Europeans, fermented alcoholic beverages made from cassava played a central role in the social and spiritual worlds of the indigenous peoples in the Orinoco Delta region of South America. In the 16th and 17th centuries, European-introduced alcoholic beverages began to penetrate the Orinoco region. Fragments of European glass bottles and ceramic storage containers, once used to hold alcoholic beverages, especially high-alcohol-content distilled spirits, represent a substantial part of the artifact assemblages from contact-period indigenous sites along the Orinoco River. Archaeological evidence shows that European-introduced alcoholic beverages and the European alcohol trade undermined traditional indigenous social structures in the Orinoco. The introduction of distilled spirits, especially rum, also disrupted life along the West African coasts, and the fragments of European glass bottles at colonial sites in West Africa testify to the extensive role of alcohol in the African slave trade.

Taverns, saloons, and other drinking spaces offer insights into the role of spirits in sociability, especially in frontier settings. One of the most comprehensive studies of saloon life in the western United States reveals the importance of whiskey in sustaining social bonds on the western frontier. Identity and sociability are also linked to particular types of spirits. For example, fragments of whiskey bottles have been recovered from Irish tenement sites in New York City that may indicate the residents' attempts to maintain connections to their Irish homeland. The presence of imported Chinese liquors at Chinese laundry-worker sites in Oakland and Chinese miner sites in Sacramento may also represent attempts to maintain cultural links across the Pacific. The relationship between alcohol and identity formation is a topic of particular interest for archaeologists and anthropologists.

Drinking also reveals important information about class identities and the tensions between workers and employers in the early industrial era. Perhaps the most important research projects to examine these tensions are the archaeological investigations into the lives of 19th- and early 20th-century workers at the Boott Cotton Mills in Lowell, Massachusetts, which revealed insights into the alcohol-related changes that accompanied industrial capitalism. Mill owners practiced a system of moral policing that sought to restrict the drinking of mill workers. A program of corporate paternalism was meant to produce a structured, diligent workforce and reduce the likelihood of labor unrest. The presence of alcohol bottles in the archaeological record from boardinghouses at the Boott Cotton Mills indicates that attempts to curb drinking were not entirely successful and shows that workers clandestinely took control of their leisure pursuits and challenged the social controls of the mill owners.

See also Distillation; Food and Identity; Immigrant Foodways; Military Sites; Taverns/Inns; Trade Routes

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■FREDERICK H. SMITH

DNA ANALYSIS

Deoxyribonucleic acid (DNA) is one of life's basic molecular building blocks and contains vast amounts of data that specify the characteristics of all living things. The analysis of DNA in living organisms and archaeological materials can provide detailed information not only about foods consumed but also about the different types of subsistence strategies employed by humans during prehistory.

The analysis of DNA was revolutionized 30 years ago by the development of the polymerase chain reaction, which enables tiny amounts of DNA to be amplified millions of times. This method has made it possible to analyze ancient DNA (aDNA) in archaeological material, though this can be difficult because of the degraded nature of aDNA. Next-generation sequencing (NGS) is enabling the analysis of even older material and has greatly increased the sequence data recovered. Through NGS it is now possible to analyze the whole genome of an ancient specimen; this new field is called paleogenomics.

aDNA can be extracted directly from archaeologically recovered animal bones and plant macrofossils, and can also be recovered from coprolites, the gut contents of well-preserved bodies, and dental plaque, enabling the identification of particular foodstuffs consumed by humans when morphological identification is not possible.

The comparison of DNA sequences from different individuals or populations allows family relationships to be elucidated, and different types of DNA markers can be used to address different questions. For example, the analysis of short sequence repeats (SSRs), mainly in regions that do not encode protein sequences, can be used to study the relationships between a crop in particular areas and its dispersal from its site of domestication, while the analysis of single nucleotide polymorphisms (SNPs) in coding regions sheds light on the function of various genes, such as those determining the physical characteristics of an organism.

Analysis of DNA from modern human populations can also be used to make inferences about the past. For example, the presence of genetic mutations causing lactase persistence (continued presence of the enzyme lactase in adulthood) in human populations lends support to a long history of dairy consumption in particular regions such as northern Europe.

See also Animal Domestication; Biomolecular Analysis; Dental Analysis; Lactase Persistence and Dairying; Paleofecal Analysis; Plant Domestication

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■DIANE L. LISTER

DOCUMENTARY ANALYSIS

Drawing on techniques developed in fields such as ethnohistory, historical anthropology, cognitive anthropology, semiotics, and literary criticism, archaeologists use, analyze, and interpret historical documents of all sorts, whether retrieved from archives or from archaeological sites. Documents studied by archaeologists include written records on paper or other media as well as excavated "documents" like clay tablets, cylinder seals, seal-impressed vessels, ostraca (potsherds with writing on them), graffiti, and inscriptions. Both excavated and archived documents may require deciphering and transcription. At times archaeologists mine documents for correspondences between excavated data and the written record, but many documentary archaeologists seek information that documents convey inadvertently about attitudes, beliefs, and actions as well as evidence of the character and standpoint of documents' authors, recorders, or subjects.

Text-aided or documentary archaeology involves first "constructing the archive" for a given research project by assembling as much data as possible from all available sources. Laurie Wilkie, in her essay "Documentary Archaeology," observes that elements of the archive constructed for a given research project may provide overlapping, conflicting, or entirely different insights into the past that require resolution and integration to account for differences in scale, completeness, representativeness, and temporality. The analytical process is aimed at developing contexts for interpreting archaeological evidence through close critical readings and content analysis of documents. While documentary archaeologists may not treat each line of evidence (e.g., the site matrix and the data it contains, artifacts, documents, images, maps, oral history), they do consider all forms of evidence as equally deserving of critical analysis. Understanding the relationships among different source materials is key, fostering integration of sources in ways that permit the archaeologist to write accurate narratives; access to multiple lines of documentary and oral historical evidence at times allows the archaeologist to construct alternately parallel and conflicting narratives reflecting multiple voices from the past. Documentary archaeology is an analytical approach that allows elucidation of embodied practices, embraces ambiguity and multiple meanings, and examines closely how objects figure in discourses both at the intimate, one-to-one level between a person and artifact as well as at broader institutional or global scales.

A documentary archaeology of food might incorporate a diverse set of textual sources, including provisioning lists, account books, inventories, and other documents, to determine what foodstuffs were available in particular geographic and temporal contexts. Through contextual analysis of seals on Early Bronze Age ceramics (EB IV) from western Syria, objects previously thought to be transport jars sealed with emblems of the Ebla state (~2400-2000 BC), Sarah R. Graff identified the vessels instead as specialized cooking pots used in domestic rituals. Though often biased and even ideological in nature, textual sources, analyzed critically in conjunction with archaeological data and oral accounts, have contributed significantly to the interpretation of foodways of enslaved African

Americans, for example, as well as corporate foodways in boardinghouses in 19th-century Lowell, Massachusetts (USA). Close readings of recipes, cookbooks, and personal accounts permit reconstruction of meals, dishes, table etiquette, and other food-related practices, or even of particular events (e.g., feasts), within specific cultural contexts. Textual sources have been used to develop a ceramic typology employing emic terms for food-related material culture, for example, in the colonial Chesapeake (USA), along with the contexts for the use, consumption, and meanings assigned to foods and food-related material culture by their users.

See also Cookbooks; Food and Capitalism; Food Production and the Origins of Writing in Mesopotamia; Material Culture Analysis; Recipes; Slave Diet, on Southern Plantations

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■MARY C. BEAUDRY

DOMESTIC SITES

Some of the most significant locations for foodways in archaeological contexts are domestic sites. Indeed archaeologists throughout the world excavate more domestic sites than any other site types. They can be found within urban settlements but also in rural contexts, and at military sites such as Roman forts and fortresses (e.g., soldiers' barracks and commanding officers' residences). Within domestic sites, everyday food practices—the storage, processing, and food consumption activities of all members of the household—are often the most identifiable of all household activities, through structural, material-cultural, and bioarchaeological evidence. In contrast, day-to-day, domestic food practices from the earliest historical periods are probably the least well documented in the textual sources. Such written records are more usually concerned with exceptional cooking and eating practices, such as special banquets and feast days. Beginning with the medieval period, a range of documentary sources provides details of household foodways, from account books and ledgers, to receipt books, to manuscript recipes and published cookbooks. For example, we have lists of food from the Westminster Abbey kitchens that give us insight into the rich diets of medieval monks.

For most archaeological sites, it is not always possible to distinguish everyday food activities from exceptional food-related practices, although it is widely assumed that evidence for exceptional or luxury foods (e.g., thousands of oyster shells in a single deposit at the urban site of Silchester in Roman Britain) or high-quality dining vessels (e.g., silver vessels as were found in the House of the Menander in Pompeii) documents special banquets and feasts.

Another important aspect of domestic sites is that, in addition to the physical remains of dwellings and evidence for their contents, such sites often include refuse areas where household rubbish was dumped. These materials can often include food waste and also waste from food preparation and consumption (e.g., ceramic remains). This rubbish can be dumped in pits within the domestic structure or can be discarded farther away. For example, at the Old Kinchega Homestead, a 19th- to 20th-century homestead in outback New South Wales, Australia, an extensive area of household refuse covering 16,000 square meters was located some 200 meters from the homestead complex. This refuse area produced a wealth of evidence for foodways at this site and particularly for those practices that involved more formal dining and perhaps tea drinking and socializing at a rural location where the nearest potentially like-minded neighbor was about 60 kilometers away. Indeed such refuse areas often provide good insights into household practices, but they are less useful for discriminating between the foodways of different members of the household. In situations where there are no specific documentary sources outlining the food-related activities of the different household members at an archaeological site, we need to draw on ethnographic or historical analogy, but with caution. For example, tea drinking is a particularly important social ritual for women in domestic contexts in the British Empire. This is not exclusively the case, however.

Domestic sites in all contexts—for example, urban, rural, military—can be made up of a number of different spaces in which different domestic activities could potentially have taken place. We should not assume, however, that domestic space and domestic activities in all past societies, and in all contexts, were differentiated along similar lines. Fixtures, decoration, material culture, and bioarchaeological remains within domestic sites can often give greater, and often surprising, insights into how household activities, including food-related practices, were organized at particular sites.

See also ARCHAEOLOGY OF HOUSEHOLD FOOD PRODUCTION; ARCHITECTURAL ANALYSIS; COMMENSALITY; COOKBOOKS; DOCUMENTARY ANALYSIS; FOOD AND DINING AS SOCIAL DISPLAY; HERCULANEUM AND POMPEII; HOUSEHOLD ARCHAEOLOGY; MIDDENS AND OTHER TRASH DEPOSITS; MILITARY SITES

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DOMESTICATION

See Animal Domestication; Plant Domestication; Sedentism and Domestication

E

ENVIRONMENTAL RECONSTRUCTION

See Landscape and Environmental Reconstruction

ETHNOARCHAEOLOGY

Ethnoarchaeology is the study of material remains that result from present-day human practices for application to the study of human behavior in the past. It encompasses ethnographic observations based on a clear archaeological research question. This process is followed by the formation of relational analogies pertaining to the patterns expected at archaeological sites that result from various human practices. Ethnoarchaeological research thus records human activities and their material signatures in their social, economic, and ideological contexts. Food acquisition, preparation, consumption, storage, discard, exchange, and trade are important research topics, and ethnoarchaeology has become an integral part of the archaeological study of food.

Food acquisition includes all forms of human subsistence—hunting, gathering, herding (including butchering and milking), plant cultivation, and exchange/trade. It involves all types of food, both animal and vegetal, as well as consumption of inorganic mineral materials (e.g., salts and soil). The vast majority of ethnoarchaeological studies revolve around food acquisition, for example, the study of the decisions taken by hunters in relation to animal size, distance of kill from the base camp, and sharing of butchered animal parts. Another example is the study of plant crop processing, from harvesting in the fields through decisions relating to which plant parts will be brought into the settlement and how different plant parts will be processed. By observing human practices relating to food acquisition, archaeologists are informed about the operational sequences that determine which portions of food raw material are brought into human habitation sites, and which are left behind.

Food preparation involves a large variety of activities, including butchering, preparation of dairy products, heating (roasting, toasting, stewing, boiling, baking, etc.), sieving, grinding, pulverizing, cutting, mixing of several ingredients, brewing, and salting. Ethnoarchaeological studies in this category tend to concentrate on preparation of plant-based foods and beverages—for example, preparation of acorns for human consumption, a process that involves detoxification by prolonged soaking and later pulverization, or the chain of operations related to beer brewing. Recent ethnoarchaeological studies of cooking installations included measurements of temperatures produced in ovens and open hearths, their effect on installation walls, and whether the use of different fuel types (namely wood vs. animal dung) affects cooking efficiency (figure 20). Other ethnoarchaeological studies look into identification of food preparation areas through analysis of chemical elements in the soils/sediments on which food preparation took place. These include studies in domestic contexts such as kitchen areas, but also studies in open-air locations—for example, sites used for drying fish.

Figure 20. Temperature measurements conducted during cooking (stewing) in Uzbekistan as part of an ethnoarchaeological study to aid in the identification of cooking installations in the archaeological record. Thermometers were used to measure the temperature at the fuel area and at the bottom of the cooking utensil (Gur-Arieh et al. 2013). Courtesy of Ruth Shahack-Gross.

Food consumption is relatively little studied ethnoarchaeologically, presumably because this activity leaves little, if any, evidence. A few studies deal with food taboos, an interesting topic in itself that may leave archaeological evidence if it involves consumption (or lack of it) of foodstuffs that leave durable materials (such as bone, shell, or charred seeds). For example, zooarchaeological studies at archaeological sites in Israel have shown that the pig taboo in Jewish tradition may have already been present in the Iron Age, some 3,500 years ago.

Food storage, though an important topic, especially in the context of the transition from hunting and gathering to agriculture, has received less attention. While storage has been studied from the point of view of human behavior, storage facilities as such (pits, bins, large pots, house rooms) have not been extensively studied.

Food discard includes rubbish accumulation following preparation and consumption. Ethnoarchaeological studies of ephemeral hunter-gatherer (and pastoral) camps have shown that discard is mostly informal, while in long-term (sedentary) settlements, discard patterns are formal, with special-purpose trash accumulations (middens). In essence, except for rare occasions of rapid site abandonment or destruction (e.g., Pompeii), most archaeological finds are in fact discarded food (and other) items.

Exchange and trade of food items is a topic of interest. This involves introduction of foreign foodstuffs into geographical regions where these items have not been present before (e.g., introduction of maize from Central America into North America). The process itself is not well studied ethnoarchaeologically, yet certain studies among eastern and southern African hunter-gatherer groups do examine the introduction of domestic livestock into hunter-gatherer societies.

Ethnoarchaeological research is also extremely valuable for understanding which materials introduced as food items into human settlements will survive the ravages of time to form part of the archaeological record. Generally, organic materials do not preserve unless waterlogged, in permafrost, or under conditions of extreme aridity. Remains of animal foodstuffs in the form of bones, teeth, and shells are often preserved, as well as charred vegetal foodstuffs. Ethnoarchaeological studies have shown that not all parts of animal bones discarded after consumption will survive to enter the archaeological record. Specific bone patterns have been recorded in assemblages that have been chewed by dogs, for example. Bones and shells buried in acidic soils/sediments will be partially or completely dissolved. Charred plant materials often represent only foodstuffs that have been close to a fire source (i.e., cooking installations) and not the whole plant diet at a settlement.

See also Archaeobotany; Archaeology of Cooking; Architectural Analysis; Experimental Archaeology; Food Storage; Material Culture

ANALYSIS; MIDDENS AND OTHER TRASH DEPOSITS; PLANT PROCESSING; PREFERENCES, AVOIDANCES, PROHIBITIONS, TABOOS; SUBSISTENCE MODELS; ZOOARCHAEOLOGY

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■RUTH SHAHACK-GROSS

ETHNOGRAPHIC SOURCES

Studies of living populations provide important comparative data and insight into past food practices. Food-related research occurs most often in the context of ethnoarchaeology, in which direct ethnographic observation is used to examine the material residues of human behavior for application to the archaeological record. Such studies have focused heavily on subsistence practices as a central economic activity; recently, however, increased attention has been given to the social structures and cultural beliefs that imbue particular foods, materials, behaviors, and spaces with significance.

Ethnoarchaeological studies are a particularly important source of analogs for interpreting the material remains and behaviors associated with prehistoric hunter-gatherer and forager subsistence, though studies of pastoral and agricultural societies, as well as preindustrial populations, are increasingly common. In this context, ethnographic studies have been used to investigate the range of material culture forms, technologies, and practices associated with the procurement, production, and preparation of food, including cooking and baking technologies (e.g., the tandur oven), food processing and preservation, and harvesting and threshing technologies. Because attention also is given to food preparation and processing in households and domestic spaces, ethnographic studies provide evidence of women's activities that received less scholarly attention in the past. Other work has focused on the role of status or hierarchy—gendered, economic, political, social, age-based, or other—in feasting, commensal dining, and alcohol consumption.

The integration of ethnographic and archaeological data is fraught with analytical and theoretical pitfalls, but notable examples include a study of indigenous yam gardens in Australia, including scheduling, use rights, and land management practices; a comparison of griddle technology in Ethiopia with bread baking in Africa and the Near East to investigate the ways that technological constraints and the physical properties of available ingredients shaped past food preparation methods and preferences, as well as the social aspects of domestic labor associated with food production; and an examination of shifting food markets and forms of economic exchange following an earthquake in southeastern Iran that provided comparative data for the modeling of prehistoric exchange.

See also ETHNOARCHAEOLOGY; FOOD AND STATUS; FOODWAYS AND GENDER ROLES; INFORMAL ECONOMIC EXCHANGE; OVENS AND STOVES; SUBSISTENCE MODELS

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■KAREN BESCHERER METHENY

EXCHANGE

See Informal Economic Exchange; Markets/Exchange

EXPERIMENTAL ARCHAEOLOGY

Experimental archaeology traditionally refers to field experiments conducted with the aim of replicating the material fingerprints of ancient human activities, structures, and crafts. These experiments are generally conducted under relatively uncontrolled conditions (i.e., unlike controlled experiments in laboratories).

Research questions vary widely. Experiments related to Paleolithic archaeology mostly focus on issues such as use marks on stone tools and effects of burning on various materials (e.g., bones). Experiments related to Neolithic and later periods tend to focus on issues such as house construction, crafts such as metalworking, and agricultural practices including crop cultivation and animal husbandry. Most experiments involve (re)creation of tools/structures based on archaeological/historical data. These are then used to replicate past human activities. Certain studies may involve post-experiment, mostly laboratory-based analyses such as stable isotope analysis of cooked food residues or extraction of phytoliths or starch granules from residues within cooking installations.

In the context of food, experimental archaeology contributes to our understanding of food acquisition and preparation. Questions related to food acquisition include, for example, whether there is a clear impact damage to spear points used in animal hunting, how many grains of wild food plants can be harvested in a given amount of time, or what parameters affect the formation of gloss on sickle blades. Certain experiments are also designed to test hypotheses related to processes of plant domestication.

Experimentation is vast in relation to food preparation. Experiments that involve the preparation of meat may include butchering of animals using stone tools, examination of the use-wear on stone tools resulting from butchery activities, determination of which tools were best designed for skinning versus filleting, examination of the cut marks left by stone tools on butchered animal bones, determination of whether burnt bones indicate meat roasting, and more. Studies concerning the preparation of vegetal foodstuffs have included experiments involving the detoxification of certain foodstuffs, determination of whether cooking promotes or destroys the adsorption of organic molecules into clay-based pottery vessels, and the extraction of such adsorbed cooking residues for organic residue analysis. Experiments may be conducted as part of ethnoarchaeological studies, for example, testing the amount of time needed to grind a measured weight of maize grains as one step in the preparation of maize for brewing *chicha* beer.

Experiments that are related to food technology include studies of the function of cooking installations. Hearths are often prepared experimentally in order to investigate parameters that relate to temperature and fueling—for example, the study of temperature variation within hearths and the depth of penetration of heat below hearths. Experiments have shown that bones may serve as a fuel source in addition to wood. Other experiments have shown that animal dung is a fuel source comparable to wood in characteristics such as maximum temperature and fire duration. Still others have tested the differences between the use of green versus dead wood. All these have important implications for understanding archaeological finds associated with hearths.

A recent set of experiments looked into a special type of hearth from the Iron Age in Israel that is associated with the Philistine culture (figure 21). These “Philistine hearths” include a layer of limestone pebbles on which charcoal and ash have been found. Experiments with either new or archaeological pebbles have shown that fire lit directly on the pebbles causes pebble shattering that is closely associated with the location of highest temperatures. This led archaeologists to look for the exact location of shattered pebbles within archaeological hearths, which indicated that fire was lit across the whole area of Philistine hearths, and not just on their center. This information may be used to suggest how cooking on these hearths may have been conducted in the past.

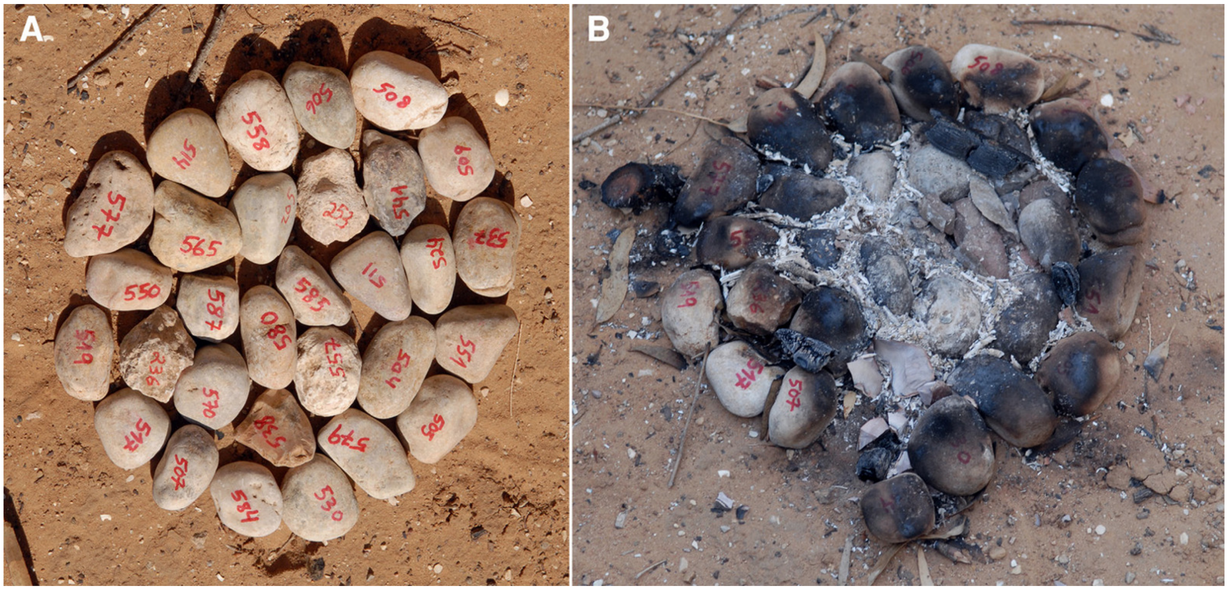

Figure 21. An experimental pebble hearth designed to test the location of pebble shattering in relation to temperature. The study demonstrated that open fires were built directly on Philistine pebble hearths (Gur-Arieh et al. 2012). Courtesy of Ruth Shahack-Gross.

Experimental archaeology in relation to food is expanding in scope. It appears that experimentation related to food consumption, storage, discard, and trade/exchange is still relatively rare. While studies of butchering in relation to prehistoric hunting societies and on thermal characteristics of hearths have been central to experiments in food processing, increased attention centers on grain processing, bread baking, and the brewing of alcohol.

See also Bread; Brewing/Malting; Butchery; Clay Cooking Balls; Fermentation; Fire and the Development of Cooking Technology; Fire-Based Cooking Features; Food Preservation; Food Storage; Milling; Ovens and Stoves; Philistine Foodways; Plant Processing; Residue Analysis, Blood; Residue Analysis, Starch; Use-Wear Analysis, Lithics

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■RUTH SHAHACK-GROSS

F

FACTORIES

Factory food production is a relatively recent phenomenon in human consumption patterns. The term is derived from the 16th-century Latin *factoria*, referring to factors or merchants conducting business, usually in foreign countries. The term later was applied to places of business involving large-scale production, as opposed to cottage industry. Early mechanized grain milling technology, such as waterwheels, is known from Greece in the first century BC, and milling sites at Herculaneum in the first century AD inform on large-scale Roman production.

Factory production and large-scale farming for business rather than for limited household use or to support military exploits are traceable to European plantation systems arising during the early 16th century. Initially, Spanish and Portuguese sugar enterprises in the Caribbean and Brazil were really no larger than Greek and Roman examples. The first mill was erected in Hispañola in 1513 and another animal-driven mill was excavated in Jamaica, at Sevilla la Nueva. Ever increasing production of luxury food items, such as sugar—the dominant commodity of the Atlantic trade in the 18th century—brought about the modern factory. Coffee and tea stimulated the demand for sweetener in Europe.

At least four characteristics distinguish factory food: scale of production, centralization of processing, distribution control, and the concentration of labor. A further distinction is that supplies may originate in many different locales or be imported from distant shores to be combined in the final product; factory landscapes are therefore intimately linked to trade infrastructure.

Each factory type generates signature footprints on the landscape recognizable in the spatial ordering of facilities (production units and distribution systems), buildings or spaces designated for power generation or for specific aspects of production (which may also include ordered residences for laborers), and specialized technologies and instruments unique to production. Factory operations have been applied to slaughtering and meatpacking (especially beef and pork) since 1865. The Armour and Swift factories in Chicago were infamous. Dairy products, sauces, and condiments reached markets after 1880 owing to improvements in canning technology. Canneries processed and packed salmon, fruits and preserves, and vegetables from the mid-19th century. The Nestlé factory in Ashbourne, Derbyshire, England, investigated by industrial archaeologists, exemplifies a late-19th-century dairy factory, while archaeology at the site of the first production of Tabasco Sauce (1868) on Avery Island, Louisiana (USA), unearthed foundations of the laboratory/house where the popular product was invented.

An example of production landscapes can again be drawn from the sugar industry, which required land for cultivation, milling houses, and specialized equipment for processing. Archaeological analyses of food factory landscapes must take into account necessary supply chains, related peripheral industries, and associated infrastructure. Facilities were located close to the fields in order for harvesting and crushing phases to be managed with minimal wastage. Milling operations with vertical or horizontal crushers were powered by animals—horses, oxen, even camels—or by water or wind. Other characteristic structures include clarification tanks, boiling houses, and cisterns, all situated adjacent to milling structures. Multistoried structures were allotted for curing or storage prior to distribution. Fuel was needed for the fires beneath the boiling cauldrons and, in the years after 1825, for steam engines as well. Until the mid-17th century, sugar processing was achieved with a so-called Spanish Train, with individual fires beneath a series of kettles of diminishing size known as coppers. The Jamaica Train was a technological breakthrough employing a single fire at one end of the boiling table and a flue at the opposite end drawing heat under the cauldrons. These changes are easily recognized archaeologically in reconfigured boiling house architecture. During the first quarter of the 19th century, steam-powered mills brought considerable predictability to processing. With steam engines came new configurations for boilers, steam pipe systems, and fuel dumps. Chimneys added to the unmistakable factory landscape of the Industrial Revolution. Excavated or archaeologically documented sites include the Hamilton Estate and Bush

Hill Estate on Nevis, in the West Indies, with extant architecture and in situ steam engines; the Central Aguire works in Puerto Rico (USA); and numerous sites in Florida (USA). The Dummet Sugar works near Tomoka State Park, for example, and the Cruger-Depeyster works in New Smyrna Beach exhibit masonry remains of the boiling houses, and in the case of Dummet, the associated distillery. Successful experiments to refine sugar from beets, which can be grown in temperate climates with less labor and delivered by railroad to receiving stations at processing plants, all but led to a collapse of traditional cane sugar plantations in the late 19th century. Thus factory landscapes, through modification and design, physically document changing technology, consumer trends, and economic conditions. The layout of these and other sites reflects the synergism of production with societal values and evolving patterns of consumption as food producers struggled to find a market niche or to control the market itself against competitors.

During the 19th century, grains were milled at factory scale, stimulated in part by mass bread production to sustain soldiers during the American Civil War. Turbine mills eventually supplanted watermills of traditional design, requiring significant landscape modifications. General Mills, Kellogg, C. W. Post, Graham, Pillsbury, and others established large-scale facilities at various sites adjacent to rivers across the American Midwest, harnessing waterpower for milling. Battle Creek, Michigan, made famous by the Kellogg brand, for instance, had over 40 competing cereal companies at the start of the 20th century. Factories were constructed near rivers not just for power but to facilitate transportation. The Mill Ruins Park, a National Register site on the Minneapolis riverfront, interprets flour milling powered by the Mississippi’s St. Anthony Falls and illustrates the extent to which landscapes are configured by factory production. Social movements in the 19th century advocating healthier diets and the virtues of whole grains contributed to the growth in cereal production. Grain elevators came to be as common a sight as chimneys. Steam milling allowed mills to be located farther from water. Rail lines complemented and later supplanted the need to be adjacent to waterways or canals. Transportation networks connected various manufacturing locations with distribution sites and markets on a national and increasingly global basis. With decentralization as early as the

18th century, a family was likely to have food on the table from distant shores and, as today, from factories halfway around the world.

See also Architectural Analysis; Distillation; Food and Capitalism; Food as a Commodity; Globalization; Herculaneum and Pompeii; Industrialization of Food and Food Production; Milling; Sucrose

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FAMINE

A famine is generally defined as a period of severe food shortage that results in a significant mortality rate, normally caused by infectious diseases rather than starvation, on a local or regional level. Famine often has a socioeconomic dimension wherein the most vulnerable and disenfranchised groups in society are at greatest risk. While the ultimate cause of a famine is lack of foodstuffs, such events are generally a consequence of a multitude of factors that are both independent and interrelating. Throughout history, famines have occurred following the appearance and spread of plant diseases, climate changes, and volcanic eruptions leading to crop failures, as well as from political and economic reforms, war and conflict, and demographic circumstances. Famines have been common since the introduction of agriculture, as populations became increasingly dependent on crop production. The earliest of the surviving ancient textual sources mention famines, such as the *Epic of Gilgamesh* (ca. 2000–1400 BC), which told the story of a famine as a consequence of overpopulation, and the Famine Stela from Ptolemaic Egypt (332–31 BC) that describes in hieroglyphs a seven-year-long period of famine as a result of drought during the reign of King Djoser (ca. 2720–2700 BC) of the Third Egyptian Dynasty.

Direct studies of famines in archaeological societies often require broad contextual and interdisciplinary approaches. Key research questions generally focus on aspects of social, cultural, economic, and biological adaptations and consequences. These have included the material culture and landscape manifestations of cultural changes resulting from depopulation and societal decline. As a catalyst of change, famines are believed to have contributed to the complete collapse of whole civilizations and communities such as, for example, the Classic Ancient Maya culture (ca. AD 250–900) and the Norse colony in Greenland (AD 985–1450).

Recent studies have focused on bioarchaeological evidence, examining both victims and survivors for famine-induced skeletal stress and migration patterns. Paleopathological analyses of victims of famine include, for example, the study of nearly 1,000 victims of the Great Famine (AD 1845–1852) in Ireland that have been excavated from mass burials in Kilkenny City. This analysis revealed high rates of so-called famine diseases such as metabolic pathological conditions resulting from nutritional deficiencies, and also skeletal manifestations of infectious disease and other stress markers such as hypoplastic defects on the enamel of teeth. Isotopic analyses and analyses of carbon (^{13}C) and nitrogen (^{15}N) ratios in bones and teeth have been used to detect both the human physiological response to starvation and dietary change resulting from famine. The latter relates to the use of “famine foods”—forced alternative food sources in periods of subsistence crises that are highly dependent on cultural preferences. Such indications of alternative foodstuffs also are potentially detectable in the archaeobotanical, zooarchaeological, and archaeoentomological evidence. Famine-induced shifts in consumption may even be manifested in archaeological cases of cannibalism, such as the cut marks observed on the skull belonging to an adolescent female whose corpse, it is believed, was partly consumed during the so-called starving time in the winter of AD 1609–1610 at Jamestown in the colony of Virginia (USA).

Additionally, famine-induced mortality rates—generally the direct result of epidemics—often display a specific pattern with high death rates among the most frail and vulnerable members of a population (i.e., the children and the elderly). Life-table and paleodemographic analyses of skeletal populations are therefore a potential means for studies of famines in archaeological societies, particularly if integrated within a multi- and interdisciplinary approach.

See also Bioarchaeological Analysis; Cannibalism; Food and Inequality; Insects; Jamestown; Multi- and Interdisciplinary Approaches; Paleodemography; Paleopathology; Stable Isotope Analysis

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■JONNY GEBER

FARMANA (INDIA)

See Curry

FARMING

See Agriculture, Origins of

FAUNAL ANALYSIS

See Zooarchaeology

FEASTING

Feasts, broadly defined as the communal consumption of food and drink outside the context of a daily meal, have stimulated lively debates and inspired methodological and theoretical developments in archaeology over the last two decades. Since the publication of Michael Dietler and Brian Hayden's edited volume *Feasts: Archaeological and Ethnographic Perspectives on Food, Politics, and Power*, archaeologists of every theoretical persuasion—from cultural ecologists to political economists to practice theorists—have considered the explanatory potential of feasting when framing their research questions and interpretations of the material record. The study of feasts is also a highly collaborative and interdisciplinary endeavor involving contributions from paleoethnobotanists, zooarchaeologists, bioarchaeologists, ceramic and lithic analysts, ethnographers, and historians.

While debates continue as to what exactly constitutes a feast, these special or unusual events typically leave behind a rich and distinctive material record that distinguishes them from daily meals. In order to facilitate their identification and comparison across time and space, archaeologists have developed a number of feasting signatures. For example, evidence of feast preparation may include the following: storage facilities for feasting foods and beverages; special constructions such as suprahousehold kitchens; large or numerous cooking and brewing features or facilities (e.g., hearths, roasting pits); special or large types of vessels used in preparing feasting foods or beverages; exotic or labor-intensive foods and beverages; and wasteful behaviors during food preparation (e.g., unprocessed bones). Also, particular cooking techniques may be reserved for special meals. For example, the Taraco Archaeological Project found that boiling was common for both daily and special meals, but roasting and steaming were reserved for feasts during the Formative period in the Lake Titicaca Basin. Feast consumption, the focus of many early ethnographic and archaeological studies, has been identified through the following: the presence of special structures, sometimes with display components for food or prestige items; evidence of feasting outside of habitation areas (e.g., public spaces, monuments, tombs); large quantities, unusual sizes, or special serving vessels for both food and beverages (e.g., decorated or made of rare materials); and the presence of ritual paraphernalia such as costumes or masks. Finally, feast disposal can be distinguished from the accumulation of discarded remains from daily meals. Archaeologists have identified middens with high densities of special foods (sometimes burned); dumps associated with feasting locations; and evidence of destruction of prestige or wealth items in the context of the feast. For example, accumulated refuse from a series of feasting events was recovered from a stratified midden associated with the principal plaza at the Mississippian center of Cahokia. While there are general frameworks for classifying archaeological feasts that seek to facilitate cross-cultural comparison, there are also those who argue that feasts should be treated on a case-by-case basis to avoid obscuring differences in their identification and interpretation.

Why did (or do) people feast? Early studies primarily focused on commensal politics—large and elaborate meals used to create and maintain political relationships—and the role of feasting within complex societies. Over the last two decades, however, feasting has been implicated in virtually every major debate in archaeology, including the origins of domesticated plants and animals, technological innovations in crafting and cooking, shifts in food preference and cuisine, reorganization of household economies (e.g., labor mobilization, sponsorship of specialist production), identity formation, and ritual performance. While feasts are often interpreted as contexts for competition and individual aggrandizement, they may also serve to reinforce group identity and reproduce social norms, as has been documented through communal potluck-style feasts in the prehistoric American Southwest. Also, it is essential not to assume that all suprahousehold meals were politically or ritually significant. For example, evidence for large-scale meal preparation has been interpreted as a component of the economic and social negotiations among a diverse group of craft producers at Huaca Sialupe on the north coast of Peru. Last, scholars emphasize that the study of feasts must consider both the intended short-term and unintended long-term consequences of financing, hosting, and participating in these events.

Archaeological evidence for the communal consumption of food now dates to as early as 12,000 BP (the burial cave of Hilazon Tachtit in Israel), and archaeologists are recovering new evidence of feasting practices from contexts across the globe. As indicated by the steady stream of case studies and edited volumes over the last decade, efforts to understand the ubiquity and relevance of feasting have encouraged new perspectives and more holistic approaches to prehistoric foodways. For example, household-level or daily meals have gained new attention outside of the traditional discussions of subsistence practices and diet. Quotidian practices of food preparation and consumption are now recognized as important contexts for exploring the relationship between food, identity (e.g., gender, class, and ethnicity), and politics at the household level. Also, as the archaeological correlates of daily meals continue to be refined, this will contribute to more systematic approaches to differentiating and interpreting other types of meals, including feasts.

See also Agriculture, Origins of; Commensality; Food and Identity; Food and Politics; Food and Ritual; Foodways and Religious Practices; Hilazon Tachtit

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FECAL ANALYSIS

See Paleofecal Analysis

FEDDERSEN WIERDE (GERMANY)

The Feddersen Wierde belongs to a very special group of settlements that are situated in the salt marshes along the German and Dutch North Sea coast. They are dwelling mounds (*wurten*) that were continuously built up through extended occupation and in response to the rising sea level. The Feddersen Wierde, located north of Bremerhaven, is the only dwelling mound to have been completely excavated. Seven habitation layers with complete villages on top of each other reached a height of around four meters above the surrounding surface. Occupation levels span the period from the first century BC to the fourth–fifth centuries AD.

The combined assemblage from the Feddersen Wierde suggests that the inhabitants of this site subsisted on agricultural produce and the meat and secondary products from their domesticated livestock, supplemented by fish and fowl, for half a millennium. Altogether, 205 farmhouses were identified. The inhabitants lived mainly on cattle that they raised. This was confirmed by the excavation of more than 50,000 animal bones. Domesticated species made up 98 percent of the assemblage, including cattle (50 percent), sheep (29 percent), horse (11 percent), and pig (10 percent). Wild mammals, both marine and terrestrial, constituted only 2 percent of the faunal material.

The salt marshes around these dwelling mounds were regularly farmed. Food production was extremely difficult, however; the soils were regularly flooded with salt water in wintertime and sometimes in spring. Only crop species that were to a certain degree salt-resistant could be grown; winter crops were excluded. Farmers cultivated small fields on slightly elevated levees around the village. Plow marks were recorded, and both crop plants and weeds were identified in archaeobotanical samples, confirming that the food plants that were recovered from the site were grown in the salt marshes around the settlement. This interpretation is further supported by the recovery of large amounts of the vegetative parts of these plants, in particular stems from *Vicia faba* (broad or fava bean) (figure 22). Cereal threshing was documented on-site as well. Because of environmental constraints, only a few crop species were grown; most important were *Vicia faba*, hulled *Hordeum vulgare* (barley, for bread), *Avena sativa* (common oats), *Camelina sativa* (dodder, used for oil), and *Linum usitatissimum* (flaxseed, a fiber). In addition, small amounts of *Panicum miliaceum* (common millet), little *Triticum dicoccon* (emmer wheat), and *Isatis tinctoria* (woad, for dyeing) were recorded.

Figure 22. Left: Carbonized specimens of *Vicia fabia* (broad or fava bean), one of the two most important cultivated plants grown in the brackish environment surrounding Feddersen Wierde, a dwelling mound located on the North Sea. Farmers inhabited the mound from the first century BC to the fourth–fifth centuries AD. Right: A sample of fruit stones from Damson plums (*Prunus domestica* spp. *insititia*) from the Viking Age site of Haithabu in Germany. Courtesy of Niedersaechsisches Institut fuer historische Kuestenforschung.

Despite considerable evidence for animal husbandry and agricultural production, there is no evidence at the Feddersen Wierde or other dwelling mounds for the exchange of food products with neighboring areas outside the salt marshes. *Secale* (rye), for instance, was a very important cultivated plant, used primarily for bread, in contemporary settlements built on Pleistocene upland less than four kilometers from the Feddersen Wierde, but is completely absent at this site as well as the other dwelling mounds. Other species such as *Corylus avellana* (hazelnut), though known at these nearby settlements, were extremely rare at the Feddersen Wierde as well. Despite the presence of nonfood trade goods, the combined evidence suggests that the farmers of Feddersen Wierde subsisted on food they produced themselves.

See also AGRICULTURE, PROCUREMENT, PROCESSING, AND STORAGE; ANIMAL HUSBANDRY AND HERDING; ARCHAEOBOTANY; BARLEY; CEREALS; LEGUMES AND PULSES; MACROREMAINS; WHEAT; ZOOARCHAEOLOGY

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■KARL-ERNST BEHRE

FERMENTATION

Fermentation is one of the oldest methods of food preparation and preservation practiced by human societies. Although it is not known when humans consciously started making fermented food and drinks, controlled food fermentation dates back to the earliest agricultural settlements. Trial and error, and the need for foods in times of scarcity, probably resulted in the first attempts. Initial efforts possibly involved food preservation in seawater or (evaporated) salt.

Ferments modify the physical structure of molecules, such as protein and starches. Inside the human body these nutrients become more accessible for enzymatic digestion or fermentation in the body. Outside the body, if plant and animal foods are exposed to microbes, fermentation occurs naturally. The outside action of living organisms also takes place if foods are deliberately exposed to microbes or microorganisms. This exposure softens food, makes it easier to bite and chew, is known to increase taste and texture as well as the shelf life of foods, and can increase nutrient value. The fermentation process reduces cooking times, denatures toxins, and makes raw foods palatable for humans.

The wide spectrum of fermented foods predates modern science and the recognition of the existence of microorganisms (e.g., bacteria, yeasts, molds) and encompasses alcohol, puddings or pastes, breads, vinegar, pickled fish and vegetables, cheeses, yogurts, and sausages. Fermented foods are organized into classes (beverages, cereal products, dairy products, fish products, fruit and vegetable products, legumes, and meat products), by commodity, or by type of fermentation. The lines between classes are not always distinct.

Most fermented foods leave no archaeological traces. Consequently, to understand their role in prehistory, researchers rely upon the detection and identification of residues within dental calculus and coprolites, in (cereal) seeds and other preserved foodstuffs, and in residues on stone tools, pottery, and other artifacts. The earliest evidence of food fermentation comes from the Solomon Islands in the Pacific; phytolith and starch remains on stone tools were dated to 28,700 BP and provide evidence for the exploitation of roots and tubers. Excavations at the wetland archaeological site of Kuk Swamp (Papua New Guinea), one of the world's oldest centers of agricultural development, recovered stone pestles and mortars from around 10,200 years BP. These were used to pound taro (L. *Colocasia*) and other plants to produce starchy fermented pastes or puddings such as those still prepared in the Pacific region today. Indigenous communities also have used pit fermentation for roots and tubers such as cassava, taro, yam (L.

Dioscorea), sweet potatoes and potatoes, breadfruit (L. *Artocarpus*), coconut, and bananas. This type of lactic acid fermentation turns foods into fermented pulps, pastes, or porridges. It is used on most continents, and although its origins have not yet been established, pit fermentation is believed to be one of the oldest methods of fermentation used by humans. Examples of lactic acid fermentation include pickles (cucumbers, radishes), sauerkraut (cabbages), and milk products such as kefir, yogurts, and cheeses, but also soybeans, fish, sausages, and pork. This method was used to process a range of foods in the past, most notably vinegar (rice), wine, beer, and (sourdough) breads from cereals. Early evidence for leavened breads comes from Egypt and Neolithic Europe.

In Asia the Chinese exposed cooked grains to a wide variety of molds, yeasts, and bacteria to make alcoholic beverages (e.g., rice wines) and to produce a wide variety of soybean, vegetable, meat, and fish preserves. Fermented soy and fish sauces were important condiments in Chinese cuisines. The soybean was perceived as a primary grain, and consumed as *tou fan* or *tou chu* (bean conge). Soybean fermentation (tofu) dates back to the early Han period (165 BC). There is evidence for *Tou chiang* (soy milk) during this period as well. The Chinese people also came in contact with milk products such as soured milk, cream, butter, and kumiss or koumiss from the nomadic people from the northern steppes.

Since the domestication of milk-producing mammals around 10000 BC, dairy foods have constituted a vital part of human diet. The earliest use of milk fermentation dates to ca. 8000 BC and comes from archaeological findings in Mesopotamia, Egypt, and the Indian subcontinent, where the ancient Veda scriptures and Ayurvedic texts mention the fermented milk *dadhi* (modern *dadi* or *dahi*) and buttermilk. Other ancient traditional fermented milks include Scandinavian *villi*, Russian kefir and koumiss, eastern European yogurt, Middle Eastern *laban* (or *leben*), and Turkish *ayran*.

Acetic acid or vinegar fermentation is mentioned as early as 4000 BC in Babylonian texts describing date vinegar. Vinegar was also used as a pickling agent for fish, vegetables, and meat. In antiquity it was a poor person’s drink. The Romans produced four kinds of vinegars as condiments, preservatives, and medicine and introduced vinegar making in northern Europe. Most cultures used locally available produce to prepare vinegars, including barley (malt vinegar), grapes (balsamic vinegar), and apples (cider vinegar).

The use of salt to conserve and flavor foods dates back to the Neolithic. The origin of salty (fermented) soy sauce stretches back to the Chinese Han Dynasty, as noted, and the development of fermented fish products in Southeast Asia dates to the Jōmon period. Around the Mediterranean, fish sauce was ubiquitous. Fish sauce appeared in Greek cuisine in the fourth century BC, and the Romans produced and traded several kinds (*garum*, *liquamen*, *allec*, and *muria*). Before its destruction in AD 79, Pompeii was well known for manufacturing fish sauce. Both the Greeks and Romans understood salting as a means of preservation and produced hams in brine and sausages with salt and fat. The Romans introduced these and other food preservation techniques to northern Europe.

See also Biomolecular Analysis; Bread; Condiments; Dental Analysis; Food Preservation; Food Storage; Legumes and Pulses; Manioc/Cassava; Milk and Dairy Products; Phytolith Analysis; Residue Analysis, Dairy Products; Residue Analysis, Starch; Root Crops/Tubers; Salt; Sweet Potato; Taro; Umami/Glutamates; Yam; Yeast

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FERMENTED BEVERAGES

See Beer; *Chicha*; Mead; *Pulque*

FERTILIZER

See Manures and Other Fertilizers, Identification and Analysis; Manuring and Soil Enrichment Practices

FIRE AND THE DEVELOPMENT OF COOKING

Although traditional hunter-gatherers use fire for a variety of applications, cooking is likely the most common. Currently, however, there is surprisingly little reliable evidence upon which archaeologists can base an understanding of when cooking first appeared in prehistory. This is mainly because basic fire residues, charcoal and ash, preserve very poorly. There are a small number of claims for other types of fire residues (such as burned bone or heated lithics that have better preservation potential) associated with early hominin sites in Africa dating to ~1.5 MYA (e.g., Swartkrans in South Africa and Koobi Fora in Kenya) and 800 KYA at Gesher Benot Ya'aqov in Israel. However, all early claims are contentious because of the difficulty in distinguishing anthropogenic fire residues from natural fire residues (wild fires are frequent in Africa). Recent work at Wonderwerk Cave in South Africa has uncovered burned bones dating to 1 MYA that are deep inside the cave where natural fires could not reasonably occur.

Several researchers have pointed out that cooking improves the digestibility of meat and plants. The result is improved efficiency in the extraction of calories and a net increase in energy to run the body. Based on this, it has been suggested that the advent of cooking could explain the sudden increase in body and brain size associated with *Homo erectus* around 1.5 MYA. The very small number of *possible* examples of fire dating to before 250,000 years ago makes this theory highly questionable.

Currently, the earliest examples of undoubted hearths are at Qesem Cave (~300 KYA) and Hayonim Cave in Israel (~250 KYA). Determining the use of such fires is not straightforward, however. Most researchers assume that early fires were used, at least in part, for cooking, but it is very difficult to demonstrate this. The presence of burned bones might be the result of cooking meat, but there is good evidence that people sometimes used bone as a fuel, especially when wood was scarce. It has also long been assumed that the earliest evidence for fire use/cooking marks the point at which these activities became permanent and widespread. This is also questionable as some hominin groups may have begun using fire while others did not, and hominins in general may have depended on natural sources of fire (lightning strikes) for a long time before they developed fire-making techniques.

Although fire and potential evidence for cooking continue to become more common during the Middle Paleolithic period, there is still a significant percentage of archaeological sites with no fire residues. For example, researchers have long assumed that Neanderthals (250 to 30 KYA) were regularly cooking meat because they were successful hunters and sometimes used fire. Many of the layers from their cave sites that contain evidence of intense occupations have little or no evidence of fire, however. That Neanderthals sometimes cooked food is supported by the identification of cooked starch grains in Neanderthal dental calculi. However, it is also clear that they were not cooking all the time.

In the Upper Paleolithic (starting 40 KYA), when modern humans appear in Eurasia, fire use became more common and there is much better evidence for cooking. Stone-lined hearths appear and people began constructing earth ovens for baking plants (e.g., tubers) and meat and boiling pits for extracting fat from animal bones. Besides cooked meat, bone grease was likely a major source of nutrition among later prehistoric cultures, especially in colder environments. Good examples of this can be seen in late prehistoric sites in the North American Plains where archaeologists find the remains of boiling pits. These were dug into the ground, lined with a hide, and filled with water that was brought to a boil with heated stones. Bones were smashed up and dropped in, releasing the bone grease that could then be skimmed off the surface.

Other important food processing techniques are drying and smoking, which can make foods (especially meats) storable for extended periods. These techniques are widespread ethnographically but are also difficult to identify in the archaeological record. There is no good evidence for smoking/drying prior to the Upper Paleolithic; although, if it were done on a small scale prior to this, it is likely that identifiable traces would not survive.

A major cooking innovation, pottery, appeared in East Asia 20,000 years ago. Pottery made cooking easier as more control was possible over temperature, quantities, mixing of ingredients, and cooking methods (e.g., boiling, steaming, baking). Because of its fragility, however, pottery does