7 What Did They Eat?
Subsistence and Diet

Having discussed methods for reconstructing the environment, we now turn to how we find out about what people extracted from it. The study of subsistence is one of the most technically developed fields of archaeology. Subsistence is the most basic of all necessities. Although the term sometimes includes fuel and clothing – topics found in Chapter 8 and elsewhere – it is usually taken to mean the quest for food, documented almost everywhere by the waste products of food preparation, both plant and animal. In addition, there have been significant recent developments in the study of human remains, mainly human bone, as a source of information about diet.

In discussing early subsistence, it is useful to make a distinction between *meals*, direct evidence of various kinds as to what people were eating at a particular time, and *diet*, which implies the pattern of consumption over a long period of time.

So far as meals are concerned, the sources of information are varied. Written records, when they survive, indicate some of the things people were eating, and so do representations in art. Even modern ethnoarchaeology helps indicate what they *might* have been eating by broadening our understanding of their range of options. And the actual remains of the foodstuffs eaten can be highly informative.

For the much more difficult question of diet, there are several helpful techniques of investigation. Some methods focus on human bones. As described in this chapter, isotopic analyses of the skeletal remains of a human population can indicate, for example, the balance of marine and terrestrial foods in the diet, and even show differences in nutrition between the more and less advantaged members of the same society.

Most of our information about early subsistence, however, comes directly from the remains of what was eaten. Zooarchaeology (or archaeozoology), the study of past human use of animals, is now big business in archaeology. There can be few excavations anywhere that do not have a specialist to study the animal bones found. The Paleo-Indian rockshelter of Meadowcroft, Pennsylvania, for example, yielded about a million animal bones (and almost 1.5 million plant specimens). On medieval and recent sites, the quantities of material recovered can be even more formidable. Paleoethnobotany (or archaeobotany), the study of past human use of plants, is likewise a growing discipline, with a number of techniques for determining the plant species recovered. In both areas, a detailed understanding of the conditions of preservation on a site (Chapter 2) is a first prerequisite to ensure that the most efficient extraction technique is adopted. The excavator has to decide, for instance, whether a bone requires consolidation before it is removed, or whether plant material can best be recovered by flotation (Chapter 6). In both areas, too, the focus of interest has developed to include not just the species eaten, but the way these were managed. The process of domestication for both plants and animals is now a major research topic.

Interpretation of food remains requires quite sophisticated procedures. We can initially reconstruct the "menu" available in the surrounding environment (Chapter 6), but the only incontrovertible proof that a particular plant or animal species was actually consumed is the presence of its traces in stomach contents or in coprolites (fossilized feces), as will be seen in the section on human remains below. In all other cases, one has to make the inference from the context or condition of the finds: charred grain in an oven, cut or burned bones, or residues in a vessel. Plant remains need to be understood in terms of the particular stage reached in their processing at the time they were deposited. Bone remains have to be considered in terms of butchering practices. Plants that were staples in the diet may be underrepresented thanks to the generally poor preservation of vegetable remains. Fish bones likewise may not survive well.

In addition to these questions, the archaeologist has to consider how far a site's food remains are representative of total diet. Here one needs to assess a site's function, and whether it was inhabited once or frequently, for short or long periods, irregularly or seasonally (season of occupation can sometimes be deduced from plant and animal evidence as well). A long-term settlement is likely to provide more representative food remains than a specialized camp or kill site. Ideally, however, archaeologists should sample remains from a variety of contexts or sites before making judgments about diet.

WHAT CAN PLANT FOODS TELL US ABOUT DIET?

Macrobotanical Remains

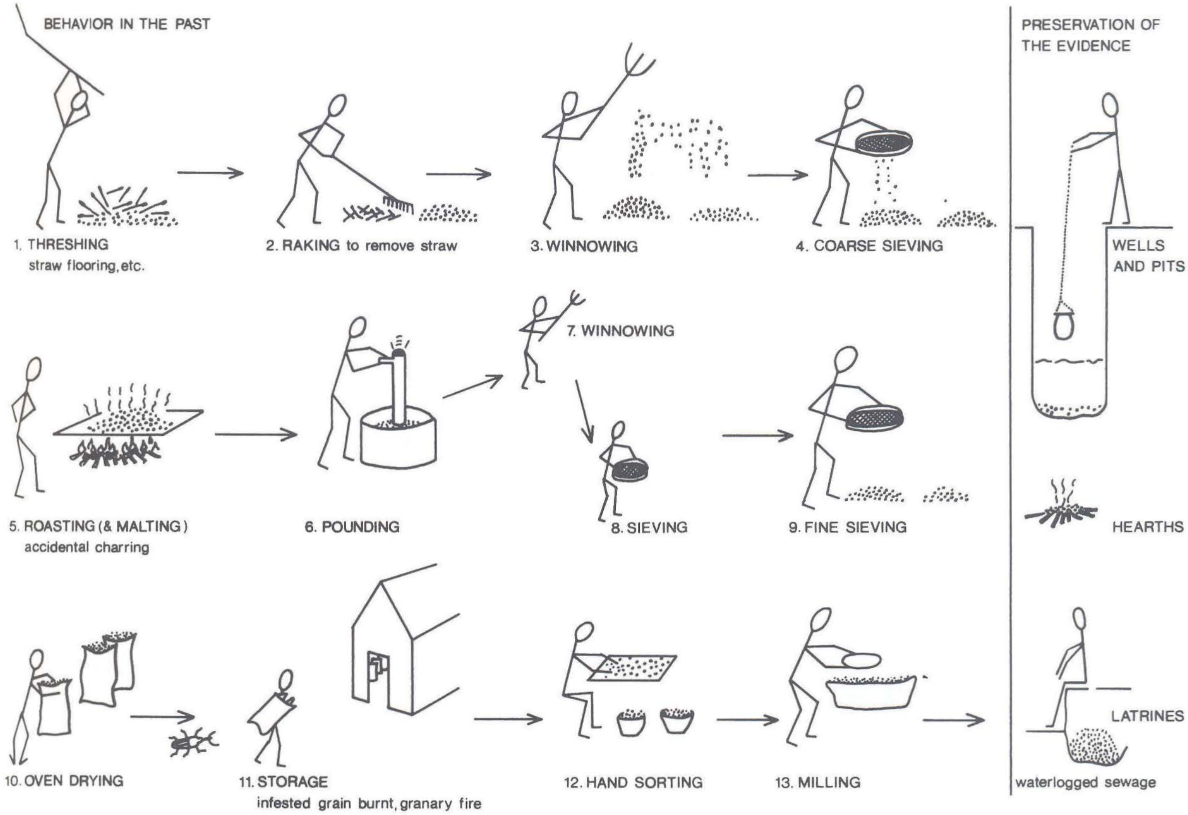
The vast majority of plant evidence that reaches the archaeologist is in the form of macrobotanical remains: they may be desiccated (only in absolutely dry environments such as deserts or high mountains), waterlogged (only in environments that have been permanently wet since the date of deposition), or preserved by charring. In exceptional circumstances, volcanic eruption can preserve botanical remains, such as Cerén in El Salvador (see p. 63 and p. 257) where a wide variety have been found carbonized, or as impressions, in numerous vessels. Plant remains can also survive by being partly or wholly replaced by minerals percolating through sediment, a process that tends to occur in places like latrine pits with high concentrations of salts. Charred remains are collected by flotation (Chapter 6), waterlogged remains by wet sieving, desiccated by dry sieving, and mineralized by wet or dry sieving according to context. It is the absence of moisture or fresh air that leads to good preservation by preventing the activity of putrefactive microbes. Plant remains preserved in several different ways can sometimes be encountered within the same site, but in most parts of the world charring is the principal or only cause of preservation on habitation sites.

Occasionally, a single sample on a site will yield very large amounts of material. Over 27 kg (60 lb) of charred barley, wheat, and other plants came from one storage pit on a Bronze Age farm at Black Patch, southern England, for example. This can sometimes give clues to the relative importance of different cereals and legumes and weed flora, but the sample nevertheless simply reflects a moment in time. What the archaeologist really needs is a larger number of samples (each of preferably more than 100 grains) from a single period on the site, and, if possible, from a range of types of deposit, in order to obtain reliable information about what species were exploited, their importance, and their uses during the period of time in question. It is primarily the flotation machine (see p. 245) which makes it possible to obtain these samples.

Having obtained sufficient samples, one needs to quantify the plant remains. This can be done by weight, by number of remains, or by some equivalent of the Minimum Number of Individuals technique used for bones (see below). Some scholars have suggested dispensing with percentages of plant remains in a site, and simply placing them in apparent order of abundance. But numerical frequency can be misleading, as was shown by the British archaeobotanist Jane Renfrew in her study of the material from the Neolithic settlement of Sitagroi, Greece. She pointed out that the most abundant plant in the sample may have been preserved by chance (such as an accident in the course of baking) and thus be overrepresented. Similarly, species that produce seeds or grains in abundance may appear to have an exaggerated importance in the archaeological record: at Sitagroi, 19,000 seeds of *Polygonum aviculare* or knotgrass barely filled a thimble; and it makes little sense to equate an acorn with a cereal grain or a vetch seed. Quite apart from size differences, they make very different contributions to a diet.

Interpreting the Context and the Remains. It is crucial for the archaeologist or specialist to try to understand the archaeological context of a plant sample. In the past attention used to be focused primarily on the botanical history of the plants themselves, their morphology, place of origin, and evolution. Now, however, archaeologists also want to know more about the human use of plants in hunting and gathering economies, and in agriculture – which plants were important in the diet, and how they were gathered or grown, processed, stored, and cooked. This means understanding the different stages of traditional plant processing; recognizing the effect different processes have on the remains; and identifying the different contexts in the archaeological record. In many cases it is the plant remains that reveal the function of the location where they are found, and thus the nature of the context, rather than vice versa.

In a farming economy, there are many different stages of plant processing. For example, cereals have to be threshed, winnowed, and cleaned before consumption, in order to separate the grain from the chaff, straw, and weeds; but seed corn also has to be stored for the next year's crop; and food grain might also be stored unthreshed in order to get the harvested crop



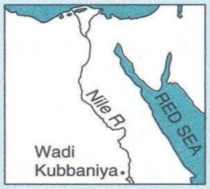
Cereal crop processing: waste products from many of these stages may survive as charred or waterlogged remains.

out of the rain, and would then be threshed only when needed. Many of these activities are well documented in our recent agricultural past, before mechanization took over, and they are still observable ethnoarchaeologically in cultures with differing degrees of efficiency and technological capability. In addition, experiments have been carried out in crop processing. From these observations it is known that certain activities leave characteristic residues with which archaeological samples can be compared, whether they are from ovens, living floors, latrines, or storage pits.

There are two main approaches to crop remains. Most archaeobotanists now use "external evidence," and proceed from ethnographic observation of, or experimentation with, plant-processing activities to an examination of the archaeological remains and contexts. In some cases, however, the archaeologist uses an "internal analysis," focusing almost exclusively on the archaeological data: for example, in his study of the plant material from the Bulgarian Neolithic site of Chevdar (6th millennium BC), the British archaeologist Robin Dennell noted that samples from the ovens had been processed, as one might expect, and were being either dried for storage or cooked when they were accidentally charred. Samples from floors, on the other hand, contained a higher percentage of weed seeds, but no spikelets (small, spike-shaped subdivisions of an ear of grain), suggesting that they were still in the process of being prepared, but had already been threshed and winnowed. The number and variety of weed species present can give clues to the effectiveness of the processing. Most samples show some mixing of different crops, and archaeologists need to bear this in mind when interpreting the data – indeed, the crops may have been mixed at the sowing stage in a fail-safe strategy of growing everything together in the hope that at least something would ripen.

In short, it is desirable, as mentioned earlier, to take samples from as wide an area as possible in the site, and from a variety of contexts. A species that dominates in a number of samples and contexts may be reckoned to have been important in the economy. Change through time can be assessed accurately only by comparing samples from similar contexts and

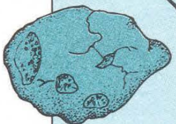
PALEOETHNOBOTANY: A CASE STUDY



The recovery and identification of plant remains from archaeological contexts are merely the first steps in a wide-ranging series of research issues that make up paleoethnobotany, also known as archaeobotany.

Such issues encompass not only the reconstruction of past environments (Chapter 6) and economies, but also the origins and spread of agriculture (see box, pp. 296–97) and human use of – and impact on – plant communities in the broadest sense. In addition to studying the plant remains themselves, archaeobotanists can learn a great deal from ethnoarchaeological observation among human groups still practicing traditional methods of plant use or farming, and from assessing the natural potential of the plants in the relevant ecological settings.

A good way to gain an insight into these methods is to look in detail at a recent successful case study.



Wild nutgrass (Cyperus rotundus). *Sketch of the living plant, with a few of its edible tubers. (Above left) One of the charred tubers found at Site E-78-3, during excavations at Wadi Kubbaniya.*

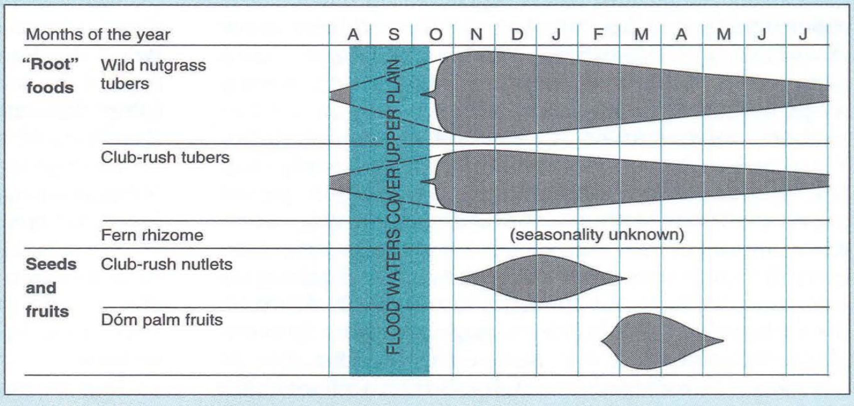
Wadi Kubbaniya

Four sites dating to between 19,000 and 17,000 years ago were excavated by Fred Wendorf and his associates at this locality northwest of Aswan in Upper Egypt. The sites have produced the most diverse assemblage of food plant remains ever recovered from any Paleolithic excavation in the Old World. The material, which owes its good preservation to rapid burial by sand and the area's great aridity, is concentrated around hearths of wood charcoal, and is dominated by charred fragments of soft vegetable foods, a category of plant that normally has very low archaeological visibility. Flotation (Chapter 6) proved useless for this material, because the fragile, dry remains disintegrated in water; instead, dry sieving had to be employed. Small roasted seeds were also found in what appear to be the feces of human infants.

Analysis of the charred remains by Gordon Hillman and his colleagues at London's Institute of Archaeology has led to the identification of over 20 different types of food-plant brought into the sites, indicating that the occupants' menu was markedly diverse. By far the most abundant food-plants were tubers of wild nutgrass (*Cyperus rotundus*). Other species included different tubers, as well as club-rushes, dóm palm fruits, and various seeds. A study was carried out to ascertain what contribution the nutgrass tubers were likely to have made to the Paleolithic diet.

Investigation of the plant's modern locations, its yields, and its nutritional value suggested that literally tons of tubers could have been obtained easily each year by means of digging sticks. Annual harvesting stimulates the rapid production of abundant young tubers. Since prehistoric people would certainly have noticed this phenomenon, it is by no means impossible that they evolved a system of management, or proto-horticulture, to bring it about consciously.

Ethnographic evidence was available from further afield. Among farming



Possible seasons of exploitation of major plant foods at Late Paleolithic Wadi Kubbaniya – assuming no storage of food. The varying widths of the bands indicate seasonal variations in the availability (and likely exploitation) of each plant, based on modern growth patterns and known preferences of modern hunter-gatherers. For two months floodwaters probably covered most of the plants, making them inaccessible during that time.

populations in West Africa, Malaysia, and India nutgrass tubers have become a famine food, eaten when crops fail. In some desert areas of Australia, Aborigine hunter-gatherers exploit the tubers as a staple resource. As long as they are cooked to make them digestible and non-toxic, they can be the principal source of calories during the months when they are available. Ethnographic evidence also shows that tubers are preferred over seeds because they involve less work in processing.

The next step at Wadi Kubbaniya was to use the plant evidence to study whether occupation at the site was seasonal or year-round. Nutgrass tubers were probably available for at least half the year; but they are at their most palatable during the period of active growth, from October to January. Wadi Kubbaniya has no evidence of storage which might have prolonged the tubers' availability, but their growth period together with that of the other species identified at the site would have ensured a food supply for the full year. This does not prove that occupation was not seasonal, but shows that year-round occupation was feasible on the basis of plant resources alone.

Finally, it should be noted that animal-product resources were also in evidence at the site (e.g. fish bones, molluscs), and that many plants prominent in the area today but unrepresented in the remains could have been of importance (e.g. additional palm fruits, rhizomes, leaves, and roots). What is clear, however, is that nutgrass tubers were the dominant resource – the only plant present in all levels at all four sites – and therefore were probably a dietary staple, if not *the* staple resource.

One of the four Wadi Kubbaniya sites (designated E-78-3) under excavation.

processing stages, because the plant remains recovered in a site are not random in composition, and may not necessarily reflect the full crop economy. This is particularly true of charred samples, for many important plant foods may never undergo charring. Plants that are boiled, eaten raw, or used for juices and to make drinks may well not undergo charring, and will therefore be underrepresented or totally absent in an assemblage. If the charring is caused by some accident, the sample may not even be representative of that season's harvest, let alone the site's economy. Indeed, at some sites, such as Abu Hureyra in Syria (pp. 296–97), many of the charred seeds may well come from animal dung being burned as fuel. This again emphasizes the importance of obtaining a variety of samples.

Reconstruction of the crop system that produced the samples is particularly challenging, since entirely different crop systems using the same resources can produce very similar pictures in the archaeological record. Furthermore, it is likely that a great deal of plant refuse was left in the field, used as fuel, or fed to animals. Thus we may never know for certain, without literary evidence, precisely what system of fallow or crop rotation was employed at a particular site. But information about questions of this sort has been obtained from experimental work at Butser Farm in southern England (see box; and similar ones in Denmark, the Netherlands, Germany, and France), where different agricultural techniques are tried out – cultivation with and without manure, various alternations of crops and fallow, etc. This long-term work will take years to provide full results, but already short-term experiments have produced valuable data on crop yields, different types of storage pits, use of sickles, and so on.

Microbotanical Remains

These can also be of help in the reconstruction of diet. Some of the minute particles of silica called ***phytoliths*** (Chapter 6) are specific to certain parts of a plant (to the root, stem, or flower), and thus their presence may provide clues to the particular harvesting or threshing technique employed on the species. As will be seen below, phytoliths can also help in differentiating wild from domestic species.

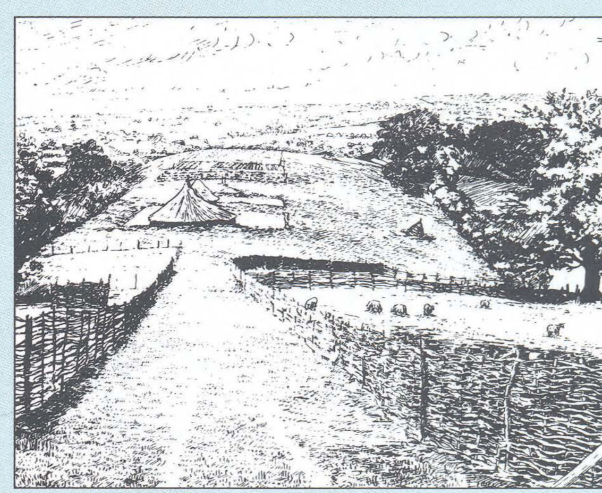
The Japanese scientist Hiroshi Fujiwara has found phytoliths of rice (*Oryza sativa*) incorporated in the walls of the latest Jomon pottery of Japan (*c.* 500 BC), which shows that rice cultivation already existed at that time. The same scholar has also located ancient paddy fields through the recovery of rice phytoliths from soil samples, and used quantitative analysis of the phytoliths to estimate the depth and areal extent of

BUTSER EXPERIMENTAL IRON AGE FARM

In 1972 Peter Reynolds established a long-term research project on Butser Hill, Hampshire, in southern England. His aim was to create a functioning version of an Iron Age farmstead dating to about 300 BC: a living, open-air research laboratory on a 6-ha (14-acre) area of land. Results were to be compared with evidence excavated from archaeological sites. The farm has since moved to a nearby location, but the project continues.

All aspects of an Iron Age farm are being explored – structures, craft activities, crops, and domestic animals. Only tools available in this prehistoric period are used. Likewise, prehistoric varieties of crops or their nearest equivalents have been sown, and appropriate livestock brought in.

Several houses of different types have been constructed. The designs have to be inferred from the posthole patterns that are our only clues to the form of Iron Age houses. Much has



Artist's impression *of Butser Ancient Farm. Hurdle fences in the foreground enclose sheep pens. Beyond lie the two round houses of the farm itself.*

Replica Iron Age round house at Butser with its thatched roof.

been learned about the quantities of timber required (more than 200 trees in the case of a large house), and about the impressive strength of these structures, whose thatched roofs and walls of rods woven between upright stakes have withstood hurricane-force winds and torrential rain.

The farm is intended to be a long-term project, and results so far are only preliminary. But it has already been established that wheat yields are far beyond what was considered likely for the Iron Age, even in drought years, and this may cause a radical revision of population estimates. In addition, the primitive wheats used, such as einkorn (*Triticum monococcum*), emmer (*Tr. dicoccum*), and spelt (*Tr. spelta*), were found to produce twice as much protein as modern wheats, and to thrive in weed-choked fields without modern fertilizers.

The farm's several fields have been tilled in different ways, such as by an ard (a copy of one found in a Danish peat bog) which stirs up the topsoil but does not invert it. Various systems of crop rotation and fallow are being tested, both with and without manure, and with spring and winter sowing. Also successfully tried out has been a replica of a "vallus," a kind of reaping machine dating to AD 200 that comprises a two-wheeled vehicle pulled by a draft animal and guided by one person.

Peter Reynolds' team have conducted experiments to assess the effects on grain when stored in different types of pit. One conclusion, supported by ethnographic observations of storage pits in Africa and elsewhere, is that if the seal is impermeable, unparched grain can be stored for long periods without decaying and the germinability maintained.

As for animals, Soay sheep – a type that has remained virtually unaltered for 2000 years – were brought from some Scottish islands. They have proved difficult to keep because of their ability to leap fences. Long-legged Dexter cattle, similar in size and power to the extinct Celtic Shorthorn, have also been installed, and two of them trained for use in traction (pulling the ard).

The Butser Project, which is open to the public, gives us a fascinating glimpse of the Iron Age brought to life, a working interpretation of the past.

***Dexter cattle** being trained as traction animals to pull the Iron Age ard or plow. After training, two men are sufficient, one to guide the cattle and another the ard.*

the fields, and even their total yield of rice. Thus, for example, the Itazuke site in Kyushu district, the oldest paddy field in Japan (final Jomon period, mid-1st millennium BC), had a total yield of 1530 kg (1.5 tons), while the Hidaka site in Kanto district (late Yayoi, first centuries AD) yielded 1440 kg (1.4 tons) – the annual yield cannot yet be estimated since we do not know for how long the fields were in use, and it is not yet possible to compare these figures with modern yields.

In addition, phytoliths found adhering to the edges of stone tools may provide information about the plants on which the tools were used, although it must be remembered that such plants may not have figured in the diet, unlike phytoliths extracted from the surface of both animal and human teeth.

Pollen grains often survive in coprolites, but most of them were probably inhaled rather than consumed, and thus they merely add to the picture of the contemporary environment, as shown in Chapter 6.

Chemical Residues in Plant Remains

Various chemicals survive in plant remains themselves which provide an alternative basis for their identification. These compounds include proteins, fatty lipids, and even DNA. The lipids analyzed using infrared spectroscopy, gas liquid chromatography, and gas chromatography mass spectrometry, have so far proved the most useful for distinguishing different cereal and legume species, but always in combination with morphological criteria. DNA offers the prospect of eventually resolving identification at an even more detailed level and of perhaps tracing family trees of the plants and patterns of trade in plant products.

Plant Impressions

Impressions of plant remains are quite common in fired clay (Chapter 6), and do at least prove that the species in question was present at the spot where the clay was worked. Such impressions, however, should not be taken as representative of economy or diet, since they constitute a very skewed sample and only seeds or grains of medium size tend to leave imprints. One has to be particularly careful with impressions on potsherds, because pottery can be discarded far from its point of manufacture, and in any case many pots were deliberately decorated with grain impressions, thus perhaps overemphasizing the importance of a species. Imprints in other objects can be more helpful, such as those in clay bricks from the 3rd millennium BC in Abu Dhabi on the Persian Gulf which represent two-row barley. It is worth noting that large amounts of straw in mudbrick can provide good evidence for local cultivation of cereals.

Turning now from such "passive" evidence, what can be learned from objects that were actually applied to plant materials?

Tools and Other Equipment Used in Plant Processing

Tools can prove or at least suggest that plants were processed at a site, and on rare occasions may indicate the species concerned, and the use that was made of it. In some parts of the world, the mere presence of pottery, sickles, or stone grinders in the archaeological record is taken to prove the existence of cereal farming and settled agricultural life. But in themselves they are inadequate indicators of such features, and require supporting evidence such as remains of domesticated plants. Sickles, for example, may have been used to cut reeds or wild grasses (and a polish or "sickle-sheen" on them is sometimes seen as proof of such a use), while grinders can be employed to process wild plants, meat, cartilage, salt, or pigments. Objects from more recent cultures often have clearer functions – for example, the bread ovens (containing round loaves) at the bakery of Modestus in Pompeii, the flour-grinding mills and wine-presses of the same city, or the great olive-crushers in a Hellenistic house at Praisos, Crete.

Analysis of Plant Residues on Artifacts

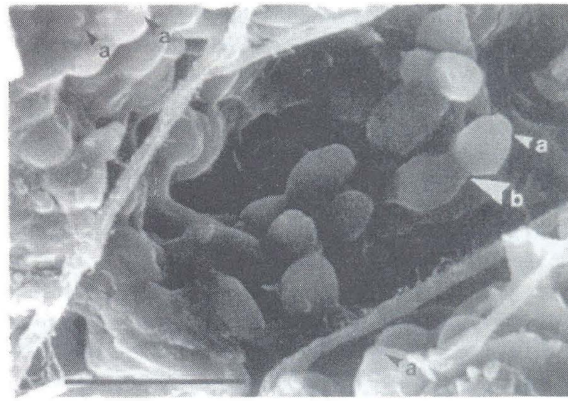
Since most tools are fairly mute evidence in themselves, it follows that we can learn far more about their function – or at least their final function before entering the archaeological record – from any residues left on them. Over 65 years ago the German scientist Johannes Grüss was analyzing such residues under the microscope, and identified substances such as wheat beer and mead in two North German drinking horns from a peat bog. Today this sort of analysis is taking on an increased importance.

As we shall see in Chapter 8, microwear analysis of a tool edge can identify broadly whether the tool was used to cut meat, wood, or some other material. Discovery of phytoliths, as mentioned above, can show what type of grasses were cut by a tool. Microscopic study can also reveal and identify plant fibers. Recently it has revealed identifiable starch residues on stone tools from Kilu Cave in the Solomon Islands, Melanesia, some of which date back to 28,700 years ago and constitute the world's oldest evidence for consumption of root vegetables (taro). Another method is chemical analysis of residues on tool edges: certain chemical reagents can provide a means of proving whether plant residues are present on tools or in vessels – thus, potassium iodide turns blue if starch grains are present, and yellow-brown for other plant materials. Starch grains can also be detected by microscope and, for example, have been extracted with a needle from crevices in the surfaces of prehistoric milling stones from the humid tropics of Panama. The grains can be identified to species level, and show that tubers such as manioc and arrowroot – which do not usually leave recoverable fossilized remains – were being exploited here *c.* 5000 BC.

Chemical investigation of fats preserved in vessels is also making progress, because it has been found that fatty acids, amino acids (the constituents of protein), and similar substances are very stable and preserve well. Samples are extracted from residues, purified, concentrated in a centrifuge, dried, and then analyzed by means of a spectrometer, and by a technique known as chromatography which separates the major constituent components of the fats. Interpretation of the results is made by comparison with a reference collection of "chromatograms" (read-outs) from different substances. By these means, not only the "menu" but even individual "recipes" from the past can sometimes be identified.

For example, the German chemist Rolf Rottländer has identified mustard, olive oil, seed oils, butter, and other substances on potsherds, including specimens from Neolithic lake dwellings. In work on sherds from the German Iron Age hillfort of the Heuneburg, he has been able to prove that some amphorae – storage vessels usually associated with liquids – did indeed contain olive oil and wine, whereas in the case of a Roman amphora the charcoal-like black residue proved to be not liquid but wheat flour. This important technique not only provides dietary evidence, but also helps to define the function of the vessels with which the fats are associated. Ever more refined techniques are currently being developed for identifying food species from protein, lipid, and DNA biochemical analysis of small fragments of plant material.

And from the condition of the starch granules in residues in Egyptian vessels, British scientist Delwen Samuel has been able to reconstruct the malting process used, and hence precisely how the Egyptians brewed beer around 1500 BC. In fact, a British brewery which had helped sponsor the research used her data to produce a beer which turned out to be "delicious, with a long, complex aftertaste." She has also discovered precisely how the ancient Egyptians baked bread from optical and scanning-electron microscopic analysis of starch granules in desiccated original loaves, and has produced very similar bread.



Yeast cells from an ancient Egyptian brewing residue in a pottery vessel from Deir el-Medina, Thebes. Bud scars (a) are visible on some cells and others were budding (b).

Chemical and infrared spectroscopy analysis of a yellowish residue inside a pottery jar from the Neolithic site of Hajji Firuz Tepe, Iran, dating to about 5400–5000 BC, identified it as tartaric acid, found in nature almost exclusively in grapes, and also detected a resin. This has therefore been taken as evidence of a resinated wine, the earliest in the world, 2000 years older than previously thought. Similarly, the tomb of one of Egypt's first kings at Abydos, dating to *c.* 3150 BC, was found to contain three rooms stocked with 700 jars; chemical analysis of the yellow crusts remaining in them confirmed that they had held wine – a potential total of 5455 litres (1200 gallons).

A further extension of chemical techniques involves isotopic analysis of organic residues, with particular reference to nitrogen and carbon isotope ratios. It is known that beans and other legumes obtain their nitrogen by means of bacterial fixation of atmospheric nitrogen, whereas all other plants obtain it from the soil. Since all legumes are terrestrial, and marine plants do not fix atmospheric nitrogen in this way (but have a distinctive ratio of carbon isotopes), it follows that isotopic analysis can divide plants into three groups: legumes, non-leguminous terrestrial plants, and marine plants.

Through this method, plant residues which were previously unidentifiable can now be characterized. The technique has been applied by Christine Hastorf and Michael DeNiro to prehistoric (200 BC–AD 1000) material from the Upper Mantaro Valley in the central Peruvian Andes which was extracted by flotation but proved to be too burned for normal identification on the basis of morphology. Instead, encrusted organic matter was scraped from some potsherds for examination. Analysis in the scanning electron microscope indicated an absence of bone fragments, which suggested that it was plant material. Isotopic analysis (carbon and nitrogen) was compared with known values for plants from the region, and revealed that the residues came from tubers, including potatoes, which had been boiled and mashed before charring. This accounted for the even distribution of the encrustation on the pots, while the fact that it was limited to the plainest types of pot suggested that such food was probably typical of daily domestic cooking. This is a good instance where, thanks to a new technique, material that was useless to the archaeologist until recently now reveals information on diet and cooking processes. The analysis results corresponded well with modern practices in the same region.

It is not even necessary for actual residues to be visible in a vessel, since we now know that deposits such as oils and resins actually percolate into the clay's fabric and remain there indefinitely. A sherd can be pulverized, and treated with solvents to isolate any trapped organic residues; these are then analyzed by spectrometers and chromatography, which reveal minute amounts of the vessel's contents. Using these techniques, British chemist Richard Evershed and his colleagues have detected the presence of leafy vegetables (probably cabbage) in pots from a Late Saxon/medieval site at West Cotton, Northamptonshire, dating to the 9th–13th centuries AD; and British chemist John Evans may even have discovered traces of opium in a 3500-year-old vase from Cyprus, showing that our Neolithic ancestors were probably as interested in drugs as we are today, and suggesting the existence of a drug trade in the eastern Mediterranean at that time.

Strategies of Plant Use: Seasonality and Domestication

Many plants are only available at certain times of the year, and can therefore provide clues about when a site was occupied. For example, early Neolithic fish traps at Muldbjerg in Denmark were made from willow and hazel twigs less than two years old and cut in early June. Plant remains can also help indicate what was eaten in particular seasons – ripe seeds give an indication of harvest time, and many fruits are limited to certain seasons. Of course, such evidence of ***seasonality*** has to be extrapolated from modern representatives of the plants in question, and evidence of food storage may indicate that occupation of a site continued beyond the seasons when particular resources were available.

One of the major areas of debate in modern archaeology concerns the question of human management of

Wild and domestic cereals. Left to right: wild and domestic einkorn, domestic maize, extinct wild maize. The wild einkorn is shedding its spikelets, which break off easily thanks to the brittle rachis at each spikelet's base. With a tougher rachis, the domestic form shatters only when threshed.

plants. A prime factor is the status of the species in question, i.e. whether they were wild or ***domesticated***. In terms of human behavior the dichotomy is artificial and often irrelevant since many types of cultivation do not change the morphology of the plant, and even in cases where such change occurs we do not know how long it took to appear. But measurement of domestication rates in wild wheats and barleys under primitive cultivation suggests that the transition from wild to domestic could have been complete within only 20 to 200 years – without conscious selection on the farmers' part. Any line drawn between wild and domestic plants does not necessarily correspond to a distinction between gathering and agriculture.

There are nevertheless cases where a clear distinction can be made between wild and fully domestic forms. Macrobotanical remains are of most use here. For example, the American archaeologist Bruce Smith found that 50,000 charred seeds of *Chenopodium* (goosefoot), nearly 2000 years old from Russell Cave, Alabama, exhibited a set of interrelated morphological characteristics reflecting domestication. He was thus able to add this starchy-seed species to the brief list of cultivated plants – including bottle gourd, squash, marsh elder, sunflower, and tobacco – available in the garden plots of the Eastern Woodlands before the introduction of maize in about AD 400.

There has been some debate in recent years about whether wild and domestic legumes can be differentiated on morphological criteria, but archaeobotanical work by the British scholar Ann Butler suggests that there is no foolproof way to do this, even in a scanning electron microscope. Cereals, on the other hand, where well preserved, are more straightforward, and domestication can be identified by clues such as the loss of anatomical features like the brittle rachis that facilitate the dispersal of seed by natural agents. In other words, once people began to cultivate cereals, they gradually developed varieties that retained their seeds until they could be harvested.

Phytoliths can be useful here, since they seem to be bigger in some modern domestic plants than in their wild ancestors. Deborah Pearsall used the appearance of a concentration of very big phytoliths as a criterion for the introduction of domestic maize in Real Alto, Ecuador, by 2450 BC. The large phytoliths were similar to those she had extracted from modern cultivated maize, but were absent from its wild ancestors. This criterion has been supported by macrobotanical remains from other regions, but it is possible that other factors such as climatic change are also involved which might affect the size of phytoliths. Together with Dolores Piperno, Pearsall has also measured maize phytoliths from Panama which imply cultivation there as early as 5700 BC; while squash phytoliths from Vegas Site 80, on the coast of southern Ecuador, revealed a sharp increase in size, suggesting squash domestication here by 10,000 years ago – some 5000 years earlier than had been thought, and rivaling the early squash dates from Guilá Naquitz, Mexico (see p. 502).

Pollen grains are of little use in studies of domestication, since they cannot be used to differentiate wild and domestic categories except for some types of cereal. They can, however, provide indications of the rise of cultivation through time. Fossil buckwheat pollen and a sudden increase of charcoal fragments about 6600 years ago discovered in cores from Ubuka bog, Japan, suggest that agriculture began some 1600 years earlier in this part of the world than had previously been thought.

Molecular genetics is now in a position to make a contribution both to the distinction between wild and domesticated species, and to the question of the origins of domestication. Manfred Heun and his colleagues have conducted an elegant study on wild and domesticated einkorn wheat in Western Asia, using 1362 samples of living wheats, both wild and domesticated. Their investigation showed that the DNA sequences obtained did permit the distinction to be drawn between wild and domesticated einkorn. Moreover, the relationships between the analyses give the clear indication that the inferred ancestral variety could be equated with a variety now growing in the Karacadag mountains of southeast Turkey.

In the future it may prove possible to use ancient DNA from early farming sites to confirm these findings. It is interesting that the use of modern samples has permitted inference to be drawn about the origins of cultivation some 10,000 years ago. Moreover, while many scholars now place the earliest cultivation of cereals in the Levant (Jordan, Israel, and Lebanon), the inference here is that southern Anatolia is also relevant in the case of einkorn.

Meals and Cookery

It is now possible even to estimate at what temperature a plant was cooked. Samples of the material recovered from the stomach of Lindow Man, the British bog body discovered in Cheshire in 1984 (see box, pp. 448–49), were identified by the British archaeobotanist Gordon Hillman as charred bran and chaff, thanks to their characteristic cell patterns under the microscope. They were then subjected to electron spin resonance (Chapter 4), a technique that measures the highest temperature to which the material was subjected in the past. It was discovered some years ago that the burning of organic materials produces a so-called radical carbon which survives a long time, and which reveals not only the maximum temperature of previous heating (it can differentiate boiling at 100°C (212°F) from baking at 250°C (482°F)), but also the duration of that heating and its antiquity. In the case of Lindow Man, the technique revealed that whatever he ate had been cooked on a flat, heated surface for about half an hour, and only at 200°C (392°F). This fact, together with the abundance of barley chaff, suggests that the remains are not derived from porridge, but come from unleavened bread or a griddle cake made using coarse wholemeal flour.

Plant Evidence from Literate Societies

Archaeologists studying the beginnings of plant cultivation, or plant use among hunter-gatherers, have to rely on the kind of scientific evidence outlined above, coupled with the judicious use of ethnoarchaeological research and modern experiments. For the student of diet among literate societies, however, particularly the

INVESTIGATING THE RISE OF FARMING IN WESTERN ASIA

The inception of farming (stock rearing and agriculture) was seen as a decisive step many decades ago by Gordon Childe, who in 1941 coined the term Neolithic Revolution. Our interest here, like Childe's, focuses on Western Asia, but we should not forget that comparable developments occurred independently in other parts of the world.

In the postwar years, a succession of multidisciplinary field expeditions have sought to find evidence for, and to extend, the ideas outlined by Childe. Robert J. Braidwood in Iraq, Frank Hole in Iran, Kathleen Kenyon in Palestine, and James Mellaart in Turkey led what one might call the first wave of research. Together their field projects embraced what Braidwood termed "the hilly flanks of the fertile crescent": the slopes of the Zagros Mountains to the east, the Levant Plain to the west, and to the north the slopes of the Taurus Mountains and beyond. Recently, immense improvements in the recovery and analysis of plant and animal remains have transformed our understanding of the farming revolution.

From Jarmo to Jericho

In 1948 Braidwood, of the Oriental Institute in Chicago, led the first of many expeditions to Iraq which set new standards in problem-orientated field research. Braidwood realized that for farming origins the main issue was domestication. When and where had the principal domesticates (wheat and barley, sheep and goat) developed from their wild prototypes? He correctly reasoned that this could only have taken place in or near areas where the wild forms were available. At that time the best guide to the present-day distribution of such species came from rainfall and vegetation maps. But Braidwood knew that in order to establish the occurrence in prehistory of wild or domesticated varieties, he would need to excavate stratified deposits at a suitable archaeological site.

After survey and trial excavation, Braidwood selected the site of Jarmo, in northern Iraq. In his initial project, published in 1960, he enlisted the co-operation of several specialists. The first was Fred Matson, who undertook *technical ceramic studies* (pottery thin sections, see Chapters 8 and 9) and was also in charge of the collection of samples for the then new technique of *radiocarbon dating*.

The geomorphologist Herbert E. Wright, Jr. made a *paleoclimatic study*, which at that time was based largely on soil samples. Later the Dutch palynologist W. van Zeist obtained *pollen sequences* from Lake Zeribar which gave a more detailed and comprehensive picture of climatic change. This work allowed the nature of the environment to be established.

A crucial contribution to the Jarmo project came from Hans Helbaek, a specialist in *paleoethnobotany*. He was able to recognize from charred remains not only early domesticated cereal species, but their transitional forms. Charles A. Reed surveyed the evidence on animal domestication in the early Near East, using in part the faunal evidence from Jarmo. *Archaeozoology* was thus added to help shape the emerging picture.

These results were significantly enhanced by work in the Levant – in Jordan, Israel, Syria, and Lebanon. A number of sites were excavated belonging to the immediately pre-farming period (the culture termed "Natufian"). It became clear that here there was already settled village life prior to domestication. At Jericho, Kathleen Kenyon found a large, walled settlement already in early farming times and before pottery was used. Its size carried significant social implications, while the discovery there of buried skulls, with faces represented in modeled plaster, indicated religious beliefs of a kind beyond those suggested by baked clay figurines found at Jarmo.

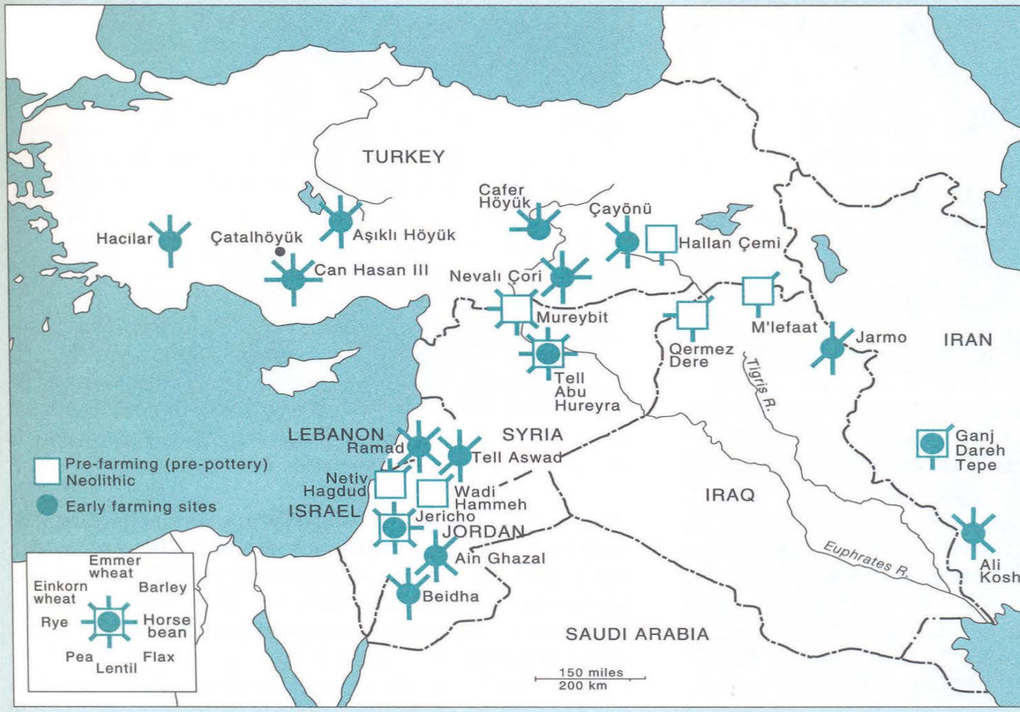
Çatalhöyük to Ali Kosh

This impression of a more complex story was reinforced by James Mellaart's excavations in the 1960s at Çatalhöyük (Çatal Hüyük) on the Konya Plain of Turkey, a 13-ha (32-acre) site, which could perhaps be called a town (see box, pp. 44–45). It too was an early farming site, and it too suggested an intense spiritual life with its frescoes and plastered bulls' heads. It was notable for fine objects (including pressure-flaked daggers and polished mirrors) in the volcanic glass obsidian, found locally in Turkey.

Again in the 1960s, the question of farming origins was set in a more coherently *ecological perspective* through the work of Frank Hole and Kent Flannery, who studied the Deh Luran area of Iran, and excavated the site of Ali Kosh there. They laid stress on the evolution of sheep. The archaeozoologist Sandor Bökönyi deduced that the hornless variety found in early levels could be considered a domesticated form. Hans Helbaek also made significant progress here with recovery methods, introducing *flotation techniques* for the lighter components within the soil, notably charred plant remains.

Pushing Back the Frontiers

In the late 1960s the Cambridge archaeologist Eric Higgs argued that too much emphasis was being given to the distinction between wild and domestic, and that what one was studying were long-term changes in the *exploitative relationship* between people and animals, and in the way humans used plants. He suggested



***Map** showing the location of the principal excavated early farming villages in Western Asia, and the domesticated crops found there.*

that several of the important shifts in behavior went much earlier than the Neolithic period. Gazelle, for example, might have been intensively exploited long before sheep and goat became important. Higgs pioneered, with Claudio Vita-Finzi, the technique of *site catchment analysis* (box, pp. 258–59).

Much progress has been made in the last two decades with the investigation of certain key sites. The waterlogged site of Ohalo II, by the Sea of Galilee in Israel, has yielded the world's oldest known cereal grains: hundreds of charred remains of wild wheat and barley dating to 19,000 years ago, together with many other plants and fruits and a rich faunal assemblage indicating a broad-spectrum economy of fishing, hunting, and gathering.

Israeli archaeologist Ofer Bar-Yosef therefore argues that the harvesting of cereals has roots in Natufian times (12,000–10,000 years ago), which gradually intensified into their intentional cultivation (already in 1932 the discoverer of the Natufian culture, Dorothy Garrod, suggested its significance for agricultural origins). Sediments at Jericho and elsewhere already contain evidence of the cultivation of cereals and legumes by the end of that period, and this is confirmed by microwear on stone tools, suggesting the small-scale cultivation of wild-type cereals in the Jordan Valley. As Bar-Yosef has written: "Sedentism was a prerequisite for cereal cultivation and both were essential preconditions for animal husbandry." Animals may have been domesticated by the 9th millennium BC, but large-scale pastoralism did not emerge for at least another thousand years.

Demographic and Symbolic Factors

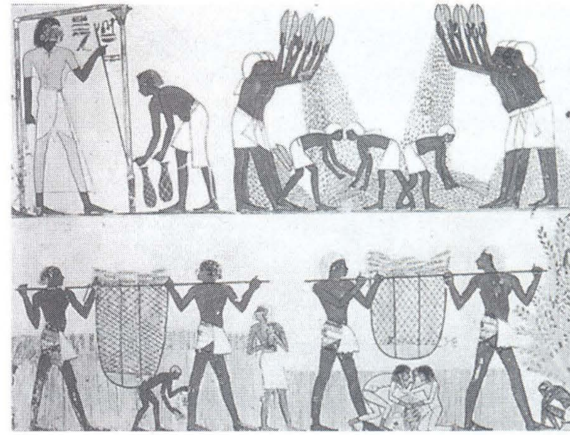
In a 1968 paper Lewis Binford likewise looked at longer-term trends. He laid stress on *demographic factors*, suggesting that it was the development of settled village life in the pre-farming phase which created population pressures that led to the intensive use and subsequent domestication of plants and animals (see box, p. 472).

Barbara Bender in 1978 suggested that the motivating impulse was a social one: the competition between local groups who tried to achieve dominance over their neighbors through feasting and the consumption of resources. Jacques Cauvin in recent work has gone further, suggesting that the Neolithic Revolution was fundamentally a *cognitive development*, where new conceptual structures, including religious beliefs, played a significant role in the development of the new sedentary societies which preceded the transition to food production. A range of symbolic finds from the Pre-Pottery Neolithic, including stone masks from Hebron and Nahal Hemar in Israel and the terracotta statues from 'Ain Ghazal in Jordan (p. 408), underline Cauvin's claim that the Neolithic Revolution was a "mental mutation."

great civilizations, there is a wealth of evidence for domestication of plants, as well as for farming practices, cookery, and many other aspects of diet to be found written in documents and in art. If we take the Classical period as an example, Strabo is a mine of information, while the Jewish historian Josephus provides data on the food of the Roman army (bread was the mainstay of the diet). Virgil's *Georgics* and Varro's agricultural treatise allow an insight into Roman farming methods; we have the cookery book of Apicius; and there is a mass of documentary evidence about Greek and Roman cereal production, consumption, pricing, etc. Even the letters found on wooden writing tablets excavated at the fort of Vindolanda, on Hadrian's Wall, written by serving soldiers to their families, mention many kinds of food and drink such as Celtic beer, fish sauce, and pork fat.

Herodotus gives us plenty of information about eating habits in the 5th century BC, notably in Egypt, a civilization for which there is extensive evidence about food and diet. Much of the evidence for the pharaonic period comes from paintings and foodstuffs in tombs, so it has a certain upper-class bias, but there is also information to be found about the diet of humbler folk from plant remains in workers' villages such as that at Tell el-Amarna, and from hieroglyphic texts. In the later Ptolemaic period there are records of corn allowances for workers, such as the 3rd-century BC accounts concerning grain allotted to workers on a Faiyum agricultural estate. Models are also instructive about food preparation: the tomb of Meketre, a nobleman of the 12th dynasty (2000–1790 BC) contained a set of wooden models, including women kneading flour into loaves, and others brewing beer. Three newly deciphered Babylonian clay tablets from Iraq, 3750 years old, present cuneiform texts containing 35 recipes for a wide variety of rich meat stews, and thus constitute the world's oldest cookbook.

On the other side of the Old World, in China, excavations at Luoyang, the eastern capital of the T'ang dynasty (7th–10th centuries AD), have encountered over 200 large subterranean granaries, some containing decomposed millet seeds; on their walls are inscriptions recording the location of the granary, the source of the stored grain, its variety and quantity, and the date of its storage – thus providing us with data on the economic situation in that period. As will be seen in a later section, the tombs of some Chinese nobles have been found to contain a range of prepared foods in different containers.



Harvesting and processing a cereal crop: scenes depicted on the walls of a New Kingdom tomb at Thebes in Egypt.

In the New World, we owe much of our knowledge of Aztec food crops, fishing practices, and natural history to the invaluable writings of the 16th-century Franciscan scholar Bernardino de Sahagún, based on his own observations and on the testimony of his Indian informants.

It should be remembered, however, that written evidence and art tend to give a very short-term view of subsistence. Only archaeology can look at human diet with a long-term perspective.

Although plant foods may always have constituted the greater part of the diet – except in special circumstances or high latitudes like the Arctic – meat may well have been considered more important, either as food or as a reflection of the prowess of the hunter or the status of the herder. Animal remains are usually better preserved on archaeological sites too so that, unlike plant remains, they have been studied since the very beginnings of archaeology.

INFORMATION FROM ANIMAL RESOURCES

The study of animal bones has evolved in the same way as that of plant remains. What little attention the first archaeologists paid to animal bones was directed primarily to the morphology of different species, and what they could tell us about environment (Chapter 6) or chronology (Chapter 4). But on the question of the interactions between people and animals, few scholars went further than labeling animals as either wild or domestic, and the people as hunters or herders. At best a quantified list of the species found at a site was made.

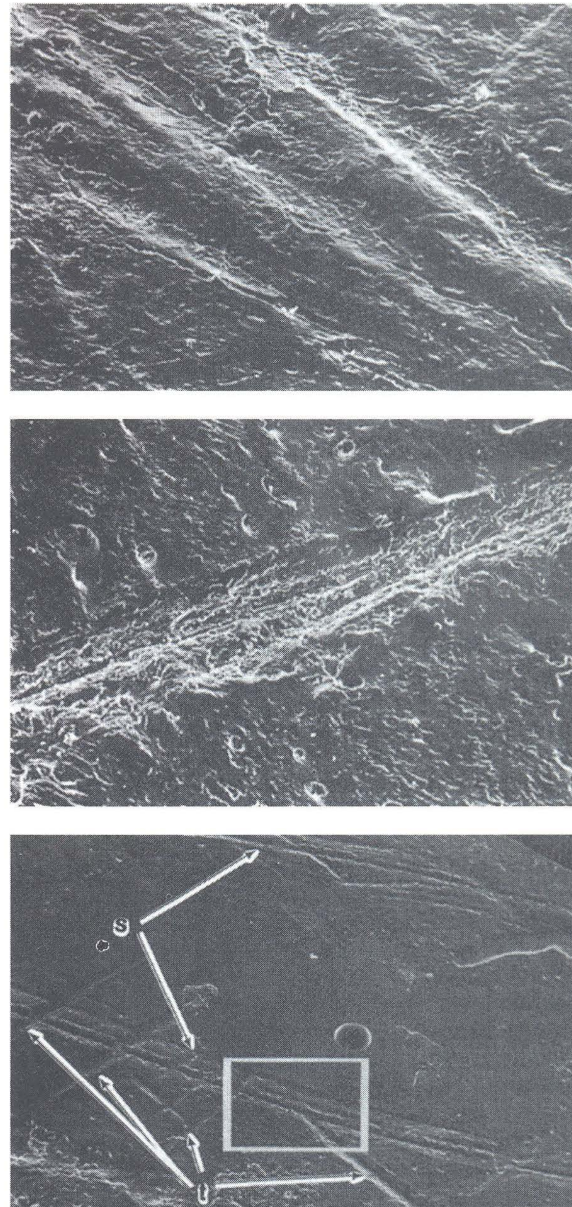
Since World War II, however, animal remains have achieved such a high degree of importance through the influence of a number of scholars (e.g. Theodore White's analysis of butchering practices in North America, and the work of Grahame Clark and Eric Higgs in England) that archaeozoology or zooarchaeology has become a subdiscipline in its own right. Emphasis is now placed not merely on the identification and quantification of animal species in a site, but also on how the remains got there, and what they can tell us about a wide range of questions such as subsistence, domestication, butchering, and seasonality.

The first question the archaeologist must face when interpreting animal remains is to decide whether they are present through human agency rather than through natural causes or other predators (as in the case of carnivore refuse, owl pellets, burrowing animals, etc.). Animals may also have been exploited at a site for non-dietary purposes (skins for clothing, bone and antler for tools).

As with plant remains, therefore, one must be particularly careful to examine the context and content of faunal samples. This is usually straightforward in sites of recent periods, but in the Paleolithic, especially the Lower Paleolithic, the question is crucial; and in recent years the study of taphonomy – what happens to bones between the time they are deposited and dug up – has begun to provide some firm guidelines (see box overleaf).

Methods for Proving Human Exploitation of Animals in the Paleolithic

In the past, association of animal bones and stone tools was often taken as proof that humans were responsible for the presence of the faunal remains, or at least exploited them. We now know, however, that this is not always a fair assumption (see box overleaf), and since in any case many used bones are not associated with tools, archaeologists have sought more definite proof from the marks of stone tools on the bones themselves. A great deal of work is currently aimed at proving the existence of such marks, and finding ways of differentiating them from other traces such as scratches and punctures made by animal teeth, etching by plant roots, abrasion by sedimentary particles or post-depositional weathering, and indeed damage by excavation tools. This is also part of the search for reliable evidence in the current major debate in Paleolithic studies as to whether early humans were genuine hunters, or merely scavenged meat from carcasses of animals killed by other predators, as Lewis Binford and others maintain.



Carnivore marks or toolmarks? Bone surfaces analyzed in the scanning electron microscope by Shipman and Potts. (Top) Round-bottomed groove made on a modern bone by a hyena. (Center) V-shaped groove made on a modern bone by a sharp stone flake. (Below) Fossil bone from Olduvai Gorge that Shipman and Potts believe shows two slicing marks (s) made by a stone flake, and carnivore tooth marks (t) made later.

Much attention has been directed to bones from the famous Lower Paleolithic sites of Olduvai Gorge and Koobi Fora, in East Africa, that are over 1.5 million years old. American archaeologist Henry Bunn claimed to be able to identify cutmarks and hammer fractures, made on some of the bones by stone tools, with nothing more than good light and the naked eye. Cutmarks are v-shaped with straight sides, while carnivore teeth tend to leave broader, u-shaped grooves; roots leave irregular marks; and abrasive particles leave faint, shallow grooves. Bunn supported his findings by comparisons with known butchery marks from more recent periods, and noted that the marks often occurred on bones at key points for butchery.

Pat Shipman and Richard Potts, on the other hand, found that it was necessary at the same sites to use light microscopes and even the scanning electron microscope in order to identify toolmarks, since to the naked eye there were too many similarities with other marks. They even claimed to be able to distinguish different types of tool-use, such as slicing, scraping, and chopping. Their method entails making a high-precision rubber impression of the bone surface, which is then used to produce an epoxy resin replica that can be examined under the microscope. This removes the necessity to handle fragile bones repeatedly, and resin imprints are far easier to transport, to store, and to examine under the microscope.

Like Bunn, Shipman and Potts compared their results with marks produced by known processes on modern bones. They found that many bones from Olduvai had both toolmarks and carnivore scratches, suggesting some competition for the carcass. In some cases, the carnivore marks were clearly superimposed on the toolmarks, but in most cases the carnivores seem to have got there first! Carnivore marks occurred mostly on meat-bearing bones, whereas toolmarks occurred both on these and on non-meat-bearing bones, such as the bottom of horse limbs, indicating a possible use of tendons and skins.

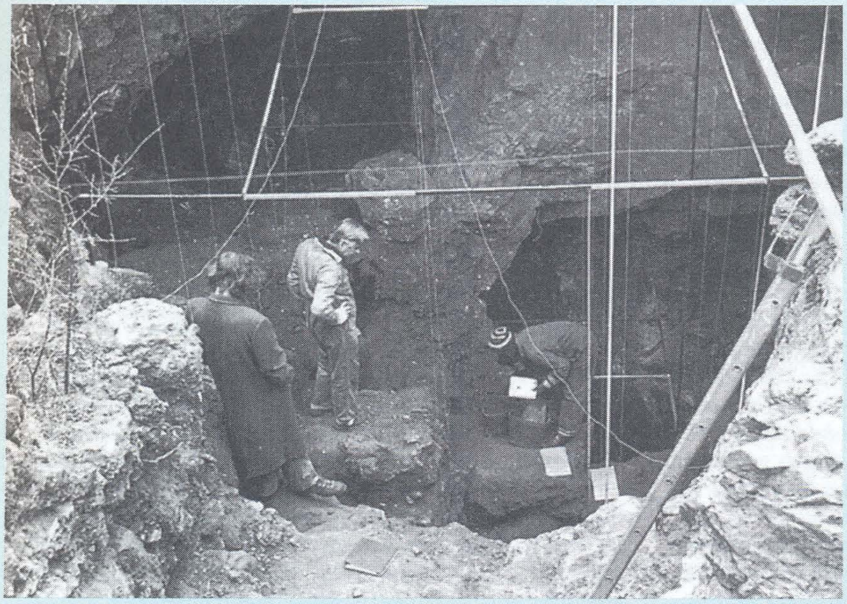
For Shipman and Potts, the diagnostic feature of a cutmark produced by a slicing action is a v-shaped groove with a series of longitudinal parallel lines at the bottom. However, more recent work suggests that very similar marks can be produced by other causes. James Oliver's work in Shield Trap Cave, Montana, indicates that "cutmarks" can be scored on bones through trampling in the cave, producing abrasions by particles, and Kay Behrensmeyer and her colleagues have come to similar conclusions from their analyses. Thus microscopic features alone are not sufficient evidence to prove human intervention. The context of the find and the position of the marks need to be studied too.

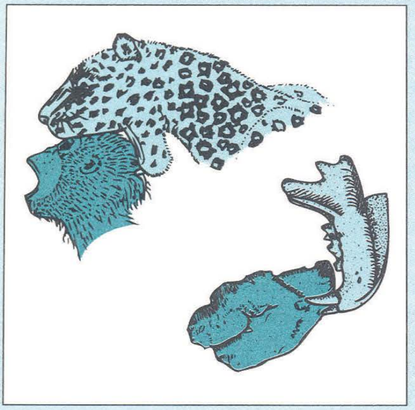
TAPHONOMY

Taphonomy is the assessment of what has happened to a bone between its deposition and its discovery. Although bones have a better chance of preservation than plant material in most soils, they nevertheless survive only under special conditions – for example, if they are buried quickly, or deposited in caves. Those that escape destruction by carnivores, weathering, acid soils, etc., and survive long enough, become mineralized through slow percolation by ground water. Many are transported by streams and redeposited in secondary contexts. Much depends on the speed of the water-flow and the density, size, and shape of the bones. Any analysis has also to assume that taphonomic events in the past were the same as those observed today.

Much work is currently in progress concerning the accumulation and fragmentation of bones by carnivores, in the hope that criteria can be found to differentiate bone assemblages produced by humans from those produced by non-humans. This involves ethnoarchaeological observation of different human groups and carnivores, the excavation of animal dens (to study the bones that animals such as hyenas accumulate), and experimental breakage of bones with and without stone tools.

The pioneer of studies of this kind is C.K. Brain, whose work in South Africa has shown not only the effects of carnivores such as leopards, hyenas, and porcupines on animal carcasses, but also that bone fractures previously attributed to early "killer man-apes" were in fact caused by the pressure of overlying rocks and earth in limestone caves in the Transvaal. Indeed, Brain has demonstrated that the early hominids (australopithecines), far from being hunters, were probably





Early hominids as hunters or the hunted? *Excavation of the underground cave complex at Swartkrans, South Africa (above), has yielded the remains of over 130 australopithecine individuals, together with those of carnivores and herbivores. Originally it was thought that the hominids had preyed on the other animals. But C.K. Brain matched the lower canines of a leopard jaw found in the cave to the holes in an incomplete australopithecine juvenile cranium (left). This hominid, at any rate, had been more prey than predator.*

Brain discovered that modern leopards drag their victims into trees, out of reach of hyenas. Perhaps the remains of the unlucky hominid, once its flesh had been consumed, fell from a tree into the cave.

themselves the victims of carnivores at cave sites such as Swartkrans.

Such studies are not confined to Africa. Lewis Binford, for example, has made observations in Alaska and the American Southwest involving the effects of wolves and dogs on bones. He seeks to differentiate human and carnivore interference by means of the relation between the number of bone splinters and the number of intact articular ends. Gnawing animals attack the articular ends first, leaving only bone cylinders and a number of splinters. A bone collection consisting of a high number of bone cylinders and a low number of bones with articular ends intact is therefore probably the result of activity by carnivores or scavengers. John Speth applied these criteria to the bones from the Garnsey site, a 15th-century AD bison-kill complex in New Mexico. The extreme rarity of bone cylinders indicated that there had been minimal destruction by scavengers, and that the bone assemblage could be assumed to be wholly the result of human activity.

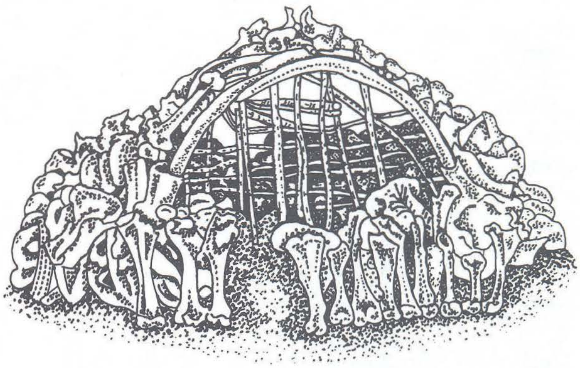
One has to be cautious about comparisons of living carnivore behavior with prehistoric assemblages that may have been produced by a different carnivore perhaps now extinct. Since wide variations exist among living species, the behavior patterns of extinct species are far from easy to ascertain. Moreover, animals such as hyenas can produce faunal assemblages similar to those made by human beings, displaying consistent patterning in breakage, and forming similarly shaped fragments. This is not surprising, because the ways in which a bone can break are limited.

These factors may seem discouraging, but they are helping to establish a much sounder basis for the accurate interpretation of bone assemblages.

Studies of this kind are not new – even the pioneer geologist Charles Lyell, in 1863, mentioned the problem of distinguishing cutmarks made by tools on bone from those made by porcupines – but the powerful microscopes now available, together with a greater understanding of taphonomic processes and carnivore behavior, have enabled us to make major advances in recent years. Nevertheless more work still needs to be done before we can be sure of proving early human activity in this way, and also of identifying episodes where our early ancestors were hunters rather than scavengers.

However, there are other types of evidence that can provide proof of human processing of bones. These include artificial concentrations of bones in particular places, such as the stacking of mammoth shoulder blades in the Middle Paleolithic ravine of La Cotte de St Brelade, Jersey, or the use of mammoth bones for the construction of huts in the Paleolithic of central and eastern Europe. Burning of bones is another clear indication of human processing – for bird bones it may be the only proof of human use, because unburnt bone might have been brought to the site by non-human predators, or might be from birds that inhabited the site or its environs (although identification of the species will often answer this point).

Having demonstrated so far as possible that animal remains were indeed produced by human action, the archaeologist then can move on to try to answer the interesting questions such as what did people eat, in which seasons did they eat particular foods, how did they hunt and butcher the animals, and were the animals domesticated?



Human exploitation of bones in the Paleolithic. Reconstruction from excavated remains of a mammoth-bone dwelling at Mezhirich in the Ukraine, dating from about 18,000 years ago. Over 95 mammoth mandibles were used in the structure.

INVESTIGATING DIET, SEASONALITY, AND DOMESTICATION FROM ANIMAL REMAINS

The most abundant and informative residues of animals are the macroremains – bones, teeth, antlers, shells, etc. Numerous techniques are now available to help extract information from data of this type.

As with plant remains, the archaeologist needs to bear in mind that the bones encountered may represent only a fraction of what was originally present. Bones may have been destroyed by weathering or trampling, cleared away out of the site, boiled for stock, used for tools, eaten by dogs or pigs, or even disposed of ritually (some California Indians avoided disrespect to the salmon by never discarding its bones; these were dried, pounded, ground in mortars, and consumed). Other foods such as grubs or the drinking of blood will leave no trace. In addition, our interpretations are clouded by our own culture's tastes. Although herbivores, supplemented by fish and birds, have usually formed the staple animal foods for humans, other creatures such as insects, rodents, and carnivores may all have made a contribution to diet in some cultures.

And should human remains be included on the list of potential resources? In recent years, there has been a reappraisal (in particular by the anthropologist William Arens) of the archaeological and ethnographic evidence previously interpreted as proof of cannibalism, and all of it has been found open to other explanations. To take one example, the Neanderthal bones from Krapina, Croatia, were found badly broken and scratched, and mixed with animal remains, the flesh assumed to have been cut off the human bones for food. But a reexamination by Mary Russell has shown that the marks on the human bones are quite different from those on defleshed meatbones, but very similar to those found on North American Indian skeletons that have been given secondary burial. In other words, the Krapina bodies were not eaten, but the bones were probably scraped clean for reburial. Recently, however, at the Neolithic cave of Fontbrégoua, southeast France (4000 BC), animal and human bones have been found in different pits, but with definite cutmarks in the same positions; six people were stripped of their flesh with stone tools shortly after death, and their limb bones cracked open. Although there is no direct evidence of consumption of flesh or marrow, Paola Villa and her colleagues have presented this as the most plausible case of prehistoric cannibalism yet discovered. Ethnographic evidence from Australia, on the other hand, suggests that it could well be a mortuary practice. Similarly, a reassessment by German archaeologist Heidi Peter-Röche of numerous claims for cannibalism in the prehistory of Central and Eastern Europe has found absolutely no evidence for the practice, with secondary funerary rituals accounting for all the finds. Recently, dramatic claims have been made for possible cannibalism among the Anasazi of the American Southwest, around AD 1100, but, once again, alternative explanations are readily available for these bone assemblages, involving not only funerary practices but also the extreme violence and mutilation inflicted on enemy corpses in warfare.

Even if cannibalism existed occasionally, the contribution of human flesh to diet must have been minimal and sporadic, paling into insignificance beside that of other creatures, especially the big herbivores.

Analyzing a Macrofaunal Bone Assemblage

In analyzing an assemblage of bones, one has first to identify them (Chapter 6) but then also to quantify them, both in terms of numbers of animals and of meat weight (see box overleaf). The amount of meat represented by a bone will depend on the sex and age of the animal, the season of death, and geographical variation in body size and in nutrition.

A recent illustration of this fact is provided by the Garnsey site, a bison-kill site in New Mexico of the 15th century AD, where John Speth found more male skulls than female, but more female limbs than male. As the kill took place in the spring, when calving and lactating cows are under nutritional stress, the sexual imbalance in the remains suggested that the bones with the most meat and body fat at that time of year (male limbs) were taken away from the site, and the rest were ignored. Seasonal and sexual variation were involved in the nutritional decisions made at this kill site. It follows that where it is necessary to assess the original sex ratio in a collection of bones, the meat-bearing bones are likely to give a misleading picture; only bones with no nutritional value will be accurate.

But if factors of age, sex, and season of death need to be allowed for, how are they established?

Strategies of Use: Deducing Age, Sex, and Seasonality from Large Fauna

Sexing is easy in cases where only the male has antlers (most deer), or large canines (pig), or where a penis bone is present (e.g. dog), or where the female has a different pelvic structure. Measurements of certain bones, such as bovid metapodials (feet), can sometimes provide two distinct clusters of results, interpreted as male (large) and female (small), although in many cases young or castrated males can blur the picture with an intermediate category.

The various mammal species show differing degrees of such sexual dimorphism. In the goat this is very marked, and bone measurements can be used to separate male and female even where the bones are not fully adult. Brian Hesse used this method to show a controlled cull of goats at the site of Ganj Dareh Tepe in Iran, in which most males were killed when still juvenile while females lived well into adult life. This sex and age related difference in survival is a persuasive case for a managed herd under early domestication. In cattle, the separation of males and females by bone measurement can sometimes be good, especially where measurements of later fusing bones are used, though steers can blur the picture. Other mammals like sheep, red deer, and roe deer are more problematic as bone measurements from the two sexes overlap quite significantly. Many of these problems are now under active investigation and it is probable that many of the difficulties will soon be overcome.

The ***age*** of an animal can be assessed from features such as the degree of closure of sutures in the skull, or, to a certain extent, from the fusion between limb shafts and their epiphyses; the latter factor can be studied more closely by means of X-rays. Age is then estimated by comparison with information on these features in modern populations, though differences in geography or nutrition are hard to allow for. However, estimates of the age at which mammals were killed are usually based on the eruption and wear patterns of the teeth. This may be by the measurement of the crown height of the teeth (see box, p. 291), though this method works best on the high-crowned (hypsodont) teeth of species like horse and antelope. Age estimates for those species that have lower crowned teeth are more usually based on the stage of tooth eruption and the pattern of wear on the biting surface, especially where good modern samples of known age are available for comparison. Interestingly, much new work has been done in this field by archaeologists as veterinary sources are seldom of sufficient detail or accuracy. The mandibles are attributed to one of a series of age classes and the number of specimens in each can be used to construct a "slaughter pattern" (or "survivorship curve"), which will show the age distribution within the cull population. This can be revealing about hunting strategies, and can also tell us much about the ways in which domestic mammals were managed.

Aging gives some insights into dietary preferences and techniques of exploitation, but the *season of death* is also a crucial factor. There are many ways of studying seasonality from animal remains – for example, the identification of species only available at certain times of year, or which shed their antlers in specific seasons. If one knows at what time of year the young of a species were born, then remains of fetuses, or bones of the newly born, can pinpoint a season of occupation (see box, pp. 292–93) – though it should be stressed that, while one can sometimes prove a human presence in some seasons in this way, it is very rare that one can positively disprove a human presence at other times of year (since the consumption of stored food is hard to recognize from archaeological evidence) unless climatic conditions, such as at high altitude, would have made this suicidal.

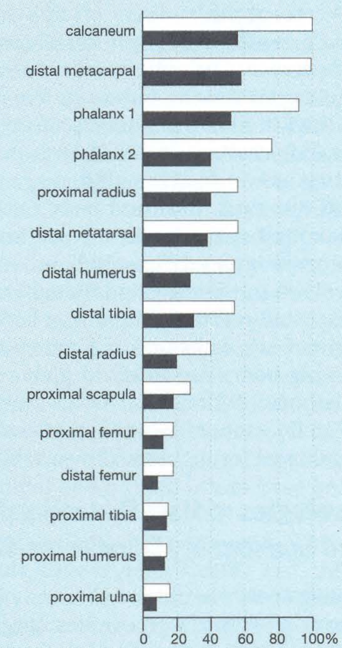
Methods used for the determination of season of death from animal bones and teeth have advanced much in recent years, and this is one of the most interesting recent contributions from faunal studies. Interpretation depends upon appropriate studies of both animal and plant food evidence along with a consideration of the ecology and behavior of the species, and the setting of the site. The methods employed to determine season of death from mammal bones are very like those used in building up age profiles, but are usually restricted to observation of rapid change in the immature mammal such as stages of tooth eruption, bone shaft growth, or the annual cycle of antler growth and shedding. The bones and teeth of mammals go through marked changes as they mature and these changes can yield important information from an archaeological bone sample.

In young mammals, most bone growth takes place at the ends of the bone shaft (diaphysis) and the articular surfaces of the bones are joined only by cartilage. As adult size is attained, the bone extremities "fuse" to the shaft, the cartilage being replaced by solid bone. This takes place in a known order and at broadly accepted ages in mammal species. The measurement of the shaft length of immature bones can provide valuable information on the season of occupation at an archaeological site. This method, pioneered in Germany in the 1930s, has only recently come back into use. In temperate latitudes most of the larger terrestrial mammals give birth in one short season. In the newborn the limb bones are small and most articular ends are not fused to the shafts. The young grow at broadly similar rates and attain mature size at about the same age. There are good climatic reasons for assuming that species such as deer had seasonal births in the past as now, to ensure the best survival of their young. It follows that length

QUANTIFYING ANIMAL BONES

Animal bones are deposited during the formation of archaeological sites after complex processes of fragmentation and dispersal, caused by both humans and carnivores (see box, pp. 284–85). Careful excavation and recovery are essential so that these activities can be taken into account and the bones quantified accurately. A bone sample retrieved by sieving, for example, is likely to have more small bones than one that was not. Conditions for bone preservation also differ greatly from site to site, and even within the limits of one site, so that bone workers must record the degree of surface erosion of each bone as an aid to understanding any possible causes of additional variation.

When working through a sample, bones are recorded either as fully identified fragments or undiagnostic pieces which might belong to one of several species. Various methods are then used to calculate the relative abundance of the different bones and thus of the species represented.



Survival percentages of cattle bones at Moncin, Spain. The white bars show only adult bones, the black ones show juvenile as well as adult. The difference in rates of survival is striking.

The simplest calculation of relative species abundance is based on the **Number of Identified Specimens** (NISP), where the identified bones of each species are expressed as percentages of the total identified bone sample. Though commonly used, the result obtained may be misleading.

The second level of calculation is the **Minimum Number of Individuals – MNI** (or **MIND**) – which expresses the least number of animals that were necessary to account for the bone sample. In its simplest form this calculation is based on the most abundant identified bone for each species, either from the right or left side of the body.

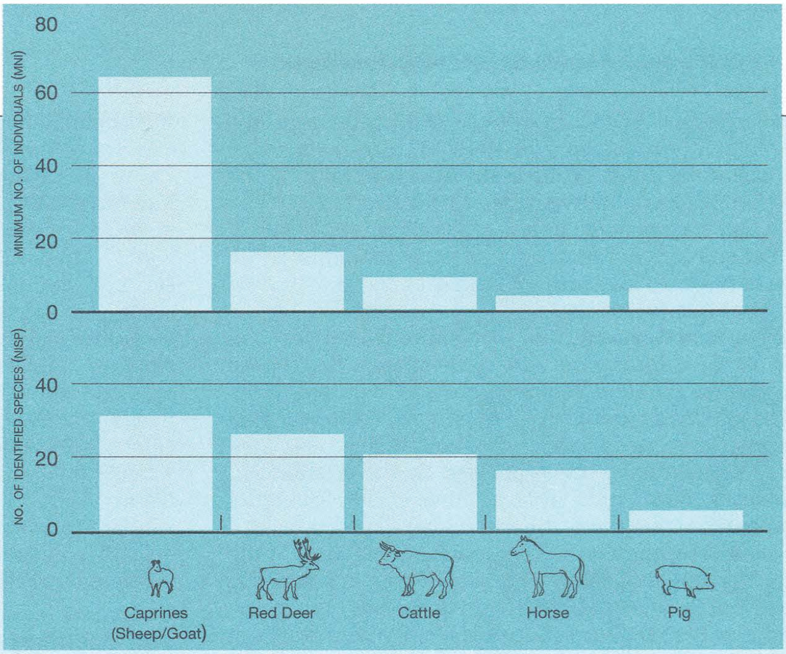
Grimes Graves, England

Some of the problems with the NISP type of calculation can be illustrated from the bone sample excavated from the site of Grimes Graves in Norfolk, England. Here extensive Bronze Age middens were dumped into the hollows of Neolithic flint mines, and two recent excavations allow comparison between different bone samples. In both, the bones were carefully recovered and preservation is excellent.

The NISP calculation of the two common species (cattle and sheep) at Grimes Graves shows that these are equally represented in the total bone count, though cattle would obviously be more important because of their greater body size. The MNI calculation was based on the most abundant identified bone – in this case the mandible, since it is very hard and resists gnawing by carnivores. A count of the mandibles showed cattle to be significantly more numerous at 58 percent, while sheep formed 42 percent of the sample. Thus cattle were of greater importance at the site than the proportions of NISP had shown.

Moncin, Spain

An even more striking example of the disparity in results between NISP and MNI can be illustrated from the site of Moncin, Spain. At this Bronze Age village, the inhabitants kept the usual domestic mammals, but also hunted extensively, in particular taking juvenile red deer for their spotted skins. Few bones of immature animals survived the attention of dogs and, in consequence, the proportions of mammals shown by the NISP and MNI are very obviously different, as shown in the diagram.



Percentage of species represented at Moncin, Spain, as revealed by MNI and NISP methods.

Age, Bone Weight, and Meat Weight

Both NISP and MNI have certain limitations. The MNI figure has little meaning with small samples, and the potential errors in the NISP calculation may be severe when comparing sites with different age profiles, conditions of preservation, or recovery standards.

Some of these difficulties can be overcome by a study of the **ages** at which the different species were killed, as this has a profound effect upon the survival of the bones. Such age profiles are best reconstructed from tooth eruption stages in the young animal and by progressive tooth wear in the adult.

Another method of comparing species abundance utilizes **relative bone weight**. By this means the total weight of identified bone from each species is compared, though the problems of differential bone survival remain. It is important to recognize that the quantification of bones tells us only about the excavated bone sample and this has an unknown relationship to the original fauna at a site. Quantification is most valuable where sites have long sequences or where groups of sites can be compared. In spite of uncertainties, such comparisons can reveal important faunal trends and regional variations.

The final step in any reconstruction of diet is to try to calculate the actual **weight of meat** represented by the bones in the sample. The average modern meat-weight for each species is a good starting point. Logically one might expect to be able simply to multiply this figure by the relevant MNI, as was done in early analyses. But today it is recognized that one has to take into account the fact that not all parts of the animal will have been used. One cannot assume that every carcass was treated alike, since in cases such as mass drives some will have been partly used, some fully, and others ignored (see box, pp. 292–93). Butchering techniques will have varied according to species, size, purpose, and distance from home. Bones thus represent not full animals but butchering units, or skeletal portions.

Where potential causes of bias have been considered it is probable that a fairly realistic picture is obtained from the MNI calculation, especially with large and well-excavated samples.

measurements of the limb bones from a site that was permanently occupied will show all sizes from newborn to fully adult, while a site occupied only in one season will have limb bone lengths which fall into certain size classes while intermediate sizes are absent.

The site of Star Carr was a pioneering example of the use of bones to interpret the season of occupation. The original interpretation was based upon the presence at the site of both unshed and shed antlers of red deer and elk. In these species the antlers are shed during winter and a new set soon begins to grow. It was argued by Grahame Clark that the site must have been occupied during the winter period so that both unshed and shed antlers could have been collected by the inhabitants. However, later study by a number of archaeologists emphasized that these antlers had been made into artifacts or were the waste from their manufacture. If the red deer and elk antlers are regarded as a raw material like flint, they bear little relation to the season of occupation at the site. The small antlers of roe deer were not used as artifacts and were found in the state representative of summer rather than winter.

Further work on the jaws and bones of the different species by Tony Legge and Peter Rowley-Conwy supported this hypothesis. In smaller mammals such as roe deer the adult dentition is complete in less than 18 months and this allows age at death to be closely determined. The mandibles of roe deer at Star Carr showed a peak of killing at about 1 year of age, which falls in early summer. Besides these specimens, some teeth and bones of red deer, roe deer, and elk were from newborn animals, confirming the pattern of early summer killing. This is the birth season for these species, and the hunters appeared to have targeted the young animals precisely at the point when maternal dependence ends and vulnerability to predation is highest. This reinterpretation also better accommodates the evidence of the few bird bones found at the site, which are also those of summer visitors.

By careful measurement and new analytical techniques one can therefore obtain quite precise data on age, sex, and season of death, which helps greatly in the evaluation of how and when people exploited their resources. Teeth alone can sometimes provide all this information (compare box opposite). The Japanese scholar Noriyuki Ohtaishi has studied 1700 recent specimens of Sika deer (*Cervus nippon*) in order to obtain data on tooth eruption, replacement, and development. He has established an age sequence from the period of eruption and the wear patterns on the cheek teeth, and has determined the age and the season of death by examining the cementum and counting its annual layers. He then applied this information to archaeological specimens. With jaws of the same species from Torihama, an Early Jomon site in Japan (3500 BC), he managed to determine their sex through measurements of jaw depth and of the area from the second premolar to the second molar – these were compared with measurements from specimens of known sex; his wear index provided the age at death; and thin-sections of the cementum layer established the season of death. Around 60 percent of the specimens were from old animals (over 5 years of age), a mortality pattern very similar to that from recent deer populations under protected conditions; whereas jaws from later Jomon sites such as Kidosaku (see box, pp. 300–01), Yahagi (2000 BC), and Sambu-Ubayama (500 BC) came mainly from animals younger than 5 years, a pattern similar to a recent hunted population. He was therefore able to conclude that, with time, hunting pressure increased on this species.

The Question of Animal Domestication

The methods just described help to shed light on the relationship between human beings and their large animal resources, on the composition of herds, and on exploitation techniques. An entirely different set of methods, however, is required to assess the status of the animals – i.e. whether they were wild or domesticated. In some cases this can be obvious, such as where non-indigenous animals have been introduced on to islands by humans – for example, the appearance of cattle, sheep, goat, dog, and cat on Cyprus. One criterion of animal domestication is human interference with the natural breeding habits of certain species, which has led to changes in the physical characteristics of those species from the wild state. But there are other definitions, and specialists disagree about which physical changes in animals are diagnostic of domestication. Too much emphasis on the wild/domestic dichotomy may also mask a whole spectrum of human-animal relationships, such as herd management without selective breeding. Nevertheless, domestication, by any definition, clearly occurred separately in many parts of the world, and archaeologists therefore need to differentiate fully wild from fully domestic animals, and to investigate the process of domestication. How is this done?

Bones and teeth are the most abundant kind of animal remains found on archaeological sites, and specialists have traditionally attempted to determine domestication through morphological changes such as a reduction in jaw size and the increased crowding of teeth. However, these have not proved wholly reliable criteria, because as yet we have no idea how long it

THE STUDY OF ANIMAL TEETH

Teeth survive more successfully than bones, and quite accurate assessments of an animal's age are possible from them. Growth rings around a tooth can be counted (see below), but this involves destruction of the specimen, and mineralization can blur the rings. Most assessments therefore rely on eruption and wear.

Investigation of the presence or absence of milk teeth in a jawbone makes it possible to assign a rough age by reference to the eruption sequence in a modern population. Where permanent dentition is concerned, however, only the degree of wear can provide evidence, once again through comparison with a series of jaws from animals of known age.

One drawback to this method is that assessments of degree of wear tend to be subjective. Complete or nearly complete jaws are also required, and these may not exist in some sites. Moreover, tooth wear will depend on the diet, and does not occur at a constant rate. Young, rough teeth wear down more quickly than older, blunted teeth, so that there is no simple correlation between age and degree of wear.

The American paleontologist Richard Klein has devised a more objective method, relying on measurement of cumulative wear, and widely applicable since it can be used on single teeth. A measurement is taken of the tooth's "crown height," the distance between the occlusal (biting) surface and the "cervical line" that separates the enamel from the dentine of the root. Using data for each species concerning the age when a crown is unworn and when it is fully worn away, the age of the tooth's owner at death can be estimated. Klein and Kathryn Cruz-Uribe have developed a BASIC computer program that uses these measurements to generate a mortality profile of the teeth in a site. In theory there are two fundamental patterns. The first is a **catastrophic age profile,** corresponding to what is thought to be a "natural" age distribution (the older the age group the fewer individuals it has). Such a pattern would be found in natural contexts – e.g. flash floods, epidemics, or volcanic eruptions – where a whole population has been destroyed. Where it is found in an archaeological context, it suggests the use of mass drives.

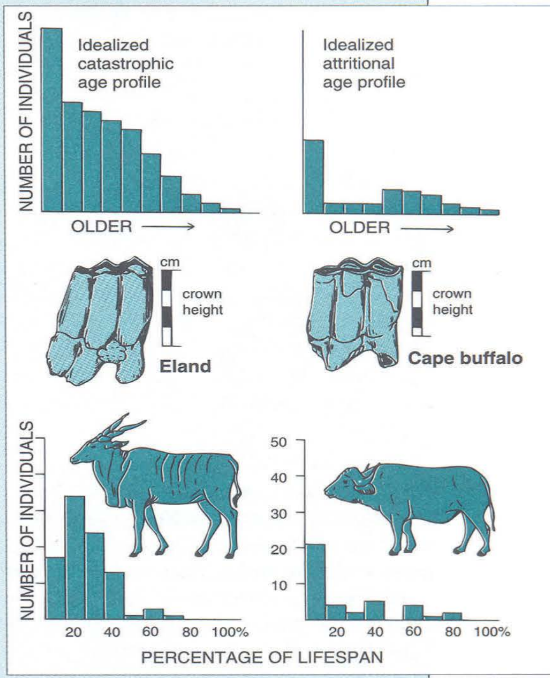
The second pattern, an **attritional age profile,** has an over-representation of young and old animals in relation to their numbers in live populations. In natural contexts it would suggest death by starvation, disease, accident, or predation. In an archaeological context it suggests scavenging, or hunting by humans of the most vulnerable individuals.

Klein has encountered both types of profile in the Middle Stone Age of Klasies River Mouth Cave, in Cape Province, South Africa, where the eland – easily driven – displayed a catastrophe profile, while the more dangerous Cape buffalo had an attrition profile.

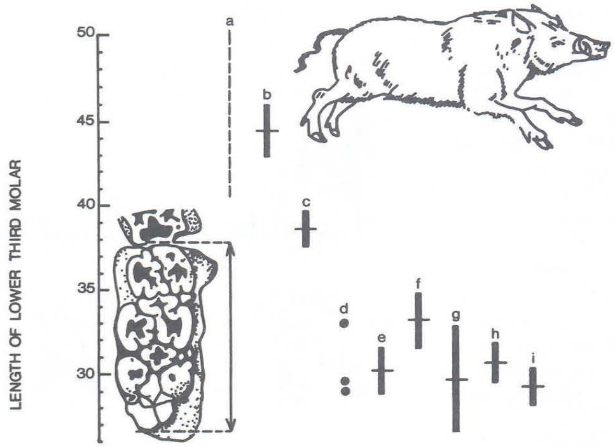
Season of Death

Teeth can also provide clues to season of death through analysis of their growth rings. For example, the archaeozoologist Daniel Fisher studied the tusks and molars of mastodons (primitive, elephant-like animals) that had been killed or at least butchered by Paleo-Indians in southern Michigan in the 11th millennium BC. The layers of dentine formation enabled him to determine, to within a month or two, that the animals had been killed in mid-to-late fall.

In some mammals, annual rings of cementum, a mineralized deposit, form around the tooth roots below the gumline. When a thin-section is taken and placed under the microscope, the layers appear as a series of translucent and opaque bands, representing alternating seasons of want and plenty which cause variation in the rate of deposition. The American scholar Arthur Spiess applied this technique to reindeer teeth from the Upper Paleolithic site of Abri Pataud, France, and proved that the animals were killed between October and March. Computer image enhancement now enables the layers to be distinguished and counted more accurately.



***Ages at death** deduced from crown heights of lower third molars by Richard Klein. (Top row) Idealized catastrophic age profile and attritional age profile. (Bottom row) Evidence from the cave site of Klasies River Mouth, South Africa, showing a catastrophic profile for the eland and an attritional profile for the Cape buffalo. (Postdepositional leaching may have selectively destroyed teeth for the youngest age band, which would account for the lower than expected number of individuals estimated in that group.)*



Decreasing tooth size as an indicator of pig domestication: a diagram based on the work of the British zooarchaeologist Simon Davis. Measurements (scale in millimeters) for (a) and (b) are from Late Pleistocene wild boars in the Levant; (c) represents modern Israeli wild boar. The size difference between (a/b) and (c) suggests an environmentally caused reduction in size at the end of the Ice Age. A further size reduction linked to domestication is suggested by the yet smaller size of domestic pig molars (d–i) from the eastern Mediterranean, as compared with the wild boar molars. (Individual measurements are given as circles, samples as mean averages with their ±95 percent confidence limits.)

took for such changes to take effect after humans began the process of domestication, and intermediate stages have not yet been recognized. Some species have certainly decreased in size through domestication (as suggested, for example, by archaeozoologist Richard Meadow for cattle at the Neolithic site of Mehrgarh in Pakistan), but environmental factors may have played a role here, as many wild species have also undergone a size decrease since the last Ice Age. Furthermore, we do not know the range of variation in wild populations, and there must have been a great deal of contact between early domestic and wild groups, with transmission of genes.

Some changes brought about by domestication occur in features such as skin or fleece that very occasionally survive archaeologically. For example, the arrangement of wool and hair is quite different in the skins of wild and domestic sheep. The British scholar Michael Ryder has been able to identify breeds of sheep from the range and distribution of fibers from skins in Viking textiles and medieval costumes.

In South America, the transition from hunting to herding is difficult to trace, because so few post-cranial skeletal features can distinguish domesticated camelid from wild forms. Since many sites, especially ones at

Mapping bones *at the Boarding School site.*

Excavation *of a group of bison skulls at Gull Lake.*

BISON DRIVE SITES

The driving of bison over bluff or cliff edges was an important periodic hunting method for thousands of years in North America. Much was known from accounts by Indian informants recorded in the first decades of this century, but the picture needed filling out through archaeological investigation of actual drive sites.

The Boarding School Site

One of the first of such excavations was undertaken by Thomas Kehoe in the 1950s at the Boarding School site, Montana. The work was carried out with the help of the local Blackfoot Tribe. Boarding School was not a cliff, but one of the more common, lower but abrupt drops that led to a natural enclosure. In a deep stratigraphy, three main bone layers were found, with well-preserved bison remains that gave insights into the size and composition of the herd, and hence into the seasons of the drives. Bison numbers were assessed using the minimum number of individuals technique (box, pp. 288–89). Ages of the animals came from the eruption sequence and degree of wear on the teeth (box, p. 291), and from bone-fusion, while sex was established on the basis of size and pelvic shape.

The site proved to have been used intermittently for a long period as a temporary camp. Then *c.* AD 1600 (according to radiocarbon dating of charred bone) a herd of about 100 bison was driven over the bluff. Their remains formed the "3rd bone layer," which included a fetal bone but no mature bulls, implying a late fall or winter drive of a herd composed of cows, calves, and young bulls. A season or two later, another herd of 150 were driven in, forming the "2nd bone layer." This had remains of mature bulls, and together with the lack of fetal or new-born calves it indicated a drive of a "cow-and-bull" herd in the rutting season, between July and September, when pemmican (dried meat) had to be prepared for the winter.

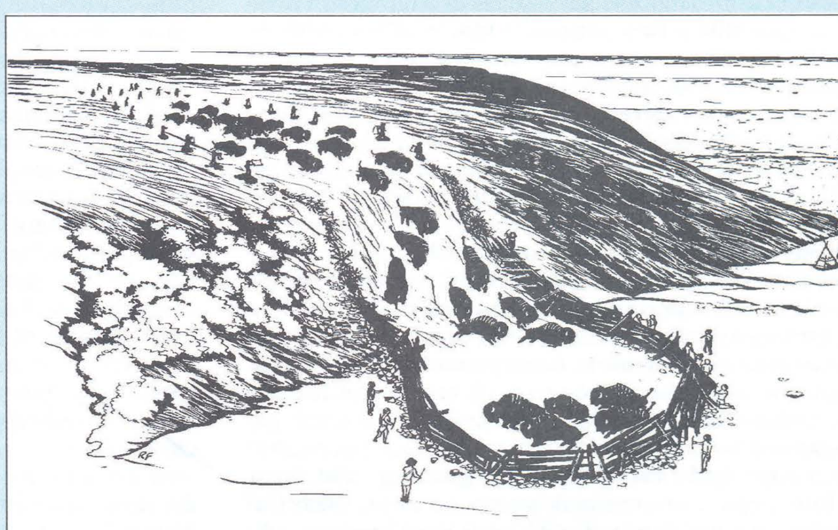
A much later drive (probably just before historic contact), produced the "1st bone layer." Here the remains of 30 bison were subjected to light butchering, probably for transport to a distant camp: much of what was left behind was in articulated units. In the earlier two layers, butchery techniques were similar but far more of each animal was utilized, and much was processed on the spot. Clearly, the distance to the home base was shorter than in the case of the later drive. The lack of pottery at the site emphasized its role as strictly a kill and meat-processing station. Traces of corral poles were found and the total of 440 projectile points suggested an average of 4 or 5 arrows used on each animal.

The Gull Lake Site

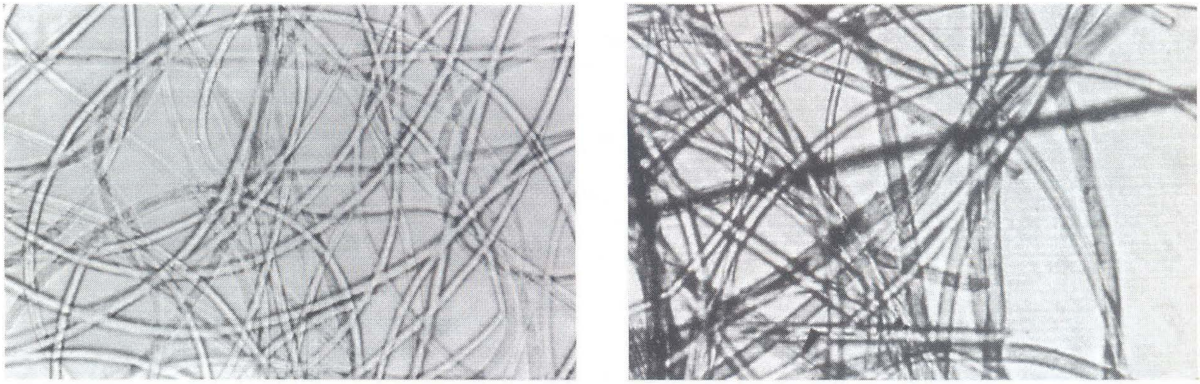
In the early 1960s Kehoe carried out a similar excavation at the Gull Lake site, over the border in southwest Saskatchewan. Here too, bison had been driven over a bluff into a depression serving as a corral. Five bone layers were encountered, one of them (*c.* AD 1300) perhaps representing the remains of as many as 900 bison.

The drives began in the late 2nd century AD, and show little processing of bone: many limb bones and even spinal columns are intact. In the later drives, however, processing was far more thorough, with few articulated bones, and extensive scattering and burning of scrap, indicating a utilization for grease and pemmican.

***Surveying** excavation trenches down the bluff slope at the Gull Lake site.*



***Gull Lake** bison drive (right).*



Microscopic analysis of the fibers of archaeological and modern camelid hairs from South America is being used to distinguish wild from domesticated camelid species. A sample from a present-day vicuña (above left), compared with an archaeological sample (above right) attributed to vicuña, from the site of Inca Cueva, Cueva 4, level 2, dated to around 10,000 years ago.

high altitude, are extremely arid, normally perishable items such as cordage, textiles, and fleece often survive, and Argentinian researcher Carmen Reigadas has undertaken microscopic analysis of fibers and follicles in these. Domestication brings about a decrease in the size of the coarse outer-coat hairs and an increase in the number of the underwool hairs. Measurements of prehistoric fibers compared with those from the four modern camelid types have enabled her to confirm osteological clues to the appearance of domestic forms around 3400 years ago at the cave of Huachichocana III. Fiber analysis is thus proving a useful aid in sites where bone remains are absent or too fragmentary to be of use.

Another approach has been to study changes in animal populations rather than individuals. The introduction of domestic animals into areas where their wild ancestors were not indigenous is a criterion of human interference that is often applied, but our knowledge of the original distribution of wild species is inadequate, made more complex by the frequent development of feral (i.e. former domesticated animals which have run wild) populations. More telling would be a radical shift from one slaughter pattern to another in a short space of time; this would certainly make a strong case for domestication, especially if combined with evidence of incipient morphological change. Here again, however, the theory is not so easy to demonstrate in practice. In the past, it was assumed that a high number of immature or juvenile herd animals in a bone assemblage represented human interference, and differed radically from a supposed "normal" wild population. But now it is known that sex ratios or percentages of juveniles can vary enormously in a wild herd. Furthermore, all predators (not just human ones) hunt selectively, concentrating on the more vulnerable individuals. It follows that a high proportion of immature animals is insufficient evidence in itself for domestication.

A herd's age and sex structure can nevertheless be a guide as to whether the animals were kept primarily for meat or for dairying purposes. A meat herd will contain a high number of adolescent and young adult animals, whereas a dairy herd will consist mostly of adult females.

Certain tools may indicate the presence of domesticated animals – for example, plows, yokes, and horse trappings. An unusual context can also be informative – for instance, a 12,000-year-old human burial found at Ein Mallaha in Israel contains the remains of a puppy, indicating the close links that were forged early on between humans and dogs.

Artistic evidence suggests even earlier possible attempts to control animals. As shown by Paul Bahn, some images from the end of the last Ice Age hint strongly at control of individual animals – most notably the Upper Paleolithic engraving of a horse's head from La Marche, France, with some form of bridle depicted. There is similar evidence from bones: for example the French Alpine rockshelter of La Grande-Rivoire has yielded remains of a brown bear in Mesolithic deposits. A grooved space between the teeth at both sides of its jaw suggests that this animal had been captured as a young cub, 7000 years ago, and wore a muzzle which restricted the growth of its molars. In other words, this was a tamed bear, perhaps even a pet.

In later times art is particularly informative about domestication, ranging from Greek, Roman, and Mesopotamian depictions of their domestic animals, to the Egyptian murals featuring not only farming but also some sort of domestication of more exotic species.

Deformities and disease can provide convincing evidence for domestication. When used for traction, horses, cattle, and camels all sometimes suffer osteoarthritis or strain-deformities on their lower limbs – a splaying of the bone, or outgrowths. Many archaeological examples are known, such as cattle bones from medieval Norton Priory in England. In horses the condition known as spavin has the same cause, and involves a proliferation of new bone around the tarsal bones and the metatarsal, resulting in fusion. Some diseases can be an indication of mismanagement of herds: rickets, for example, indicates a deficient diet or poor pasture, while close-herding and overstocking predispose animals to parasitic gastroenteritis.

Certain diseases may be a direct proof of domestication. In a study of Telarmachay, a prehistoric site in the Peruvian Andes, Jane Wheeler found that at a certain point in the stratigraphy, around 3000 BC, there was a significant increase in remains of fetal and newborn camelids such as llamas and alpacas. From a normal figure of 35 percent there was a jump to 73 percent. It is highly unlikely that these were young wild animals hunted and brought to the site by humans. No hunter would have found it worthwhile to pursue such small creatures, which might in any case have grown into more productive game. It is far more likely that these were domesticated animals, because mortality is very high among domestic llamas and alpacas, where the main cause of death is a kind of diarrhoea probably brought about by the spread of pathogens in dirty, muddy corrals, and not known to occur among wild species. If the massive mortality at Telarmachay was indeed caused in this way, evidence of this type may prove to be a useful indicator of domestication.

Great progress is therefore being made in studies of domestication. Some of the traditional criteria for demonstrating domestication – such as a reduction in size – may have proved to be less conclusive than was once thought. But these traditional approaches are being placed on a much sounder footing, and new scientific techniques, such as microscopic analysis of fibers, as well as studies of deformity and disease, open up promising new ways of looking at the question of animal domestication.

Currently, work is progressing on tracing the history of domestication through DNA (see pp. 431–32), on species from camelids to chickens. For example, DNA from cattle on three continents has already shaken the well-entrenched idea that their domestication spread from one center in the Near East; instead, Irish biologist Daniel Bradley and his colleagues have found evidence for at least two separate domestications of wild oxen, in southwest Turkey and east of the Iranian desert, with a possible third event in Africa. Since the genetic differences between the groups were too great for them to share a common ancestor 10,000 years ago, they must result from independent domestications of different races of wild ox. DNA has also begun to be used to distinguish the bones of sheep from those of goats in archaeological assemblages, which can be difficult on morphology alone.

Small Fauna: Birds, Fish, and Molluscs

Modern excavation techniques and screening or sieving have greatly improved retrieval of the fragile remains of small species. Identification requires the expertise of a specialist, since remains of the different species can be very similar, as indeed can those of some large species, such as sheep and goat (see above), camelids (see p. 292), or bison, buffalo, and cattle.

Birds. Remains of birds consist not only of bones but also guano, feathers, mummified birds in Egypt, footprints, and even eggshell that has survived at several Upper Paleolithic sites in Europe such as Pincevent, France. In some cases, it is possible to examine the shell in the scanning electron microscope and identify the species from the distribution of its pores.

Birds were often exploited for their feathers rather than their meat, and the particular species involved may settle the point. The enormous flightless moa in New Zealand were clearly exploited for meat, as shown by the numerous sites yielding evidence for moa butchery and cookery, with rows of ovens and bone dumps. At Hawksburn, for instance, a site of about AD 1250, Athol Anderson found the remains of over 400 moa; most had been brought in as leg joints, with the less meaty parts of the carcass abandoned at the kill sites. Such mass exploitation and waste helps to explain the extinction of this and other species in the Pacific (see Chapter 6).

Where small birds are concerned, however, it is often likely that their bones were brought to the site by a non-human predator or, in some cases, that they inhabited the site or its environs themselves. Here again, identification of the species involved may help one to solve the issue, but it is necessary to apply certain criteria in order to determine whether the birds were hunted by humans. A bone collection with a bias in favor of certain bones which differs from that in naturally occurring bone assemblages may suggest human intervention. Burning of the extremities of long bones is also a clue, though it will depend on the particular

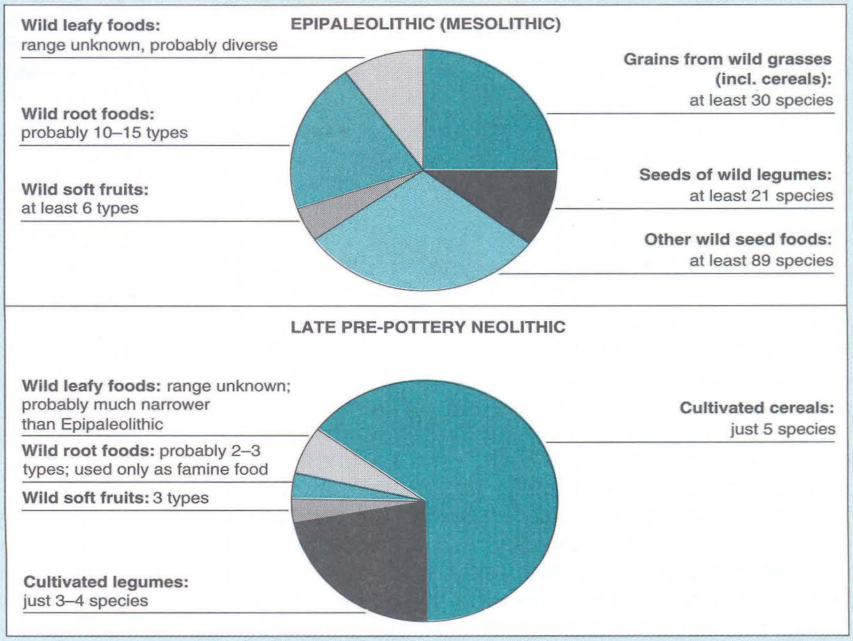
FARMING ORIGINS: A CASE STUDY

An outstanding example of how different types of evidence can be integrated into a rounded picture of a subsistence economy is to be found in the study of Tell Abu Hureyra, a site in Syria excavated by Andrew Moore in the early 1970s, and subsequently drowned beneath an artificial lake. The site's great interest lies in its remarkable assemblages of plant and animal remains from a region and a period crucial to the origins of farming in the Near East.

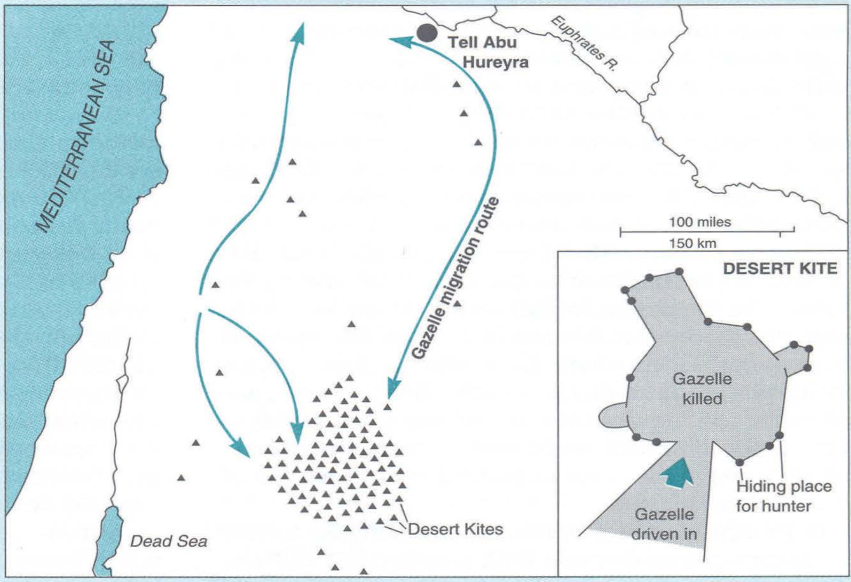
Abu Hureyra is a large mound, 11.5 ha (28 acres) in extent and with an 8-m (26-ft) stratigraphy. The site is located at the edge of the Euphrates valley, and was occupied by perhaps 200 or 300 people in the Epipaleolithic period (Mesolithic; 10th/9th millennia BC), and again in the Neolithic (after 7500 BC) by a population ten times larger. Flotation produced a diverse assemblage of charred plant remains, while dry sieving helped to retrieve over 60,000 identifiable bone fragments. In addition, the charred remains of what are probably the coprolites of infants were recovered.

Plant Remains

Analysis of the varied plant remains by Gordon Hillman and his colleagues at London's Institute of Archaeology involved the collection and study of modern seeds and fruits from the region in order to improve criteria of identification, and to learn about their present distribution and ecology. It was found that even the earliest (pre-pottery) Neolithic levels had fully domesticated cereals. By contrast, the Epipaleolithic layers had only morphologically "wild" forms (e.g. "wild" einkorn and rye). The absence in



***Pie charts** comparing Epipaleolithic and Neolithic plant remains from Abu Hureyra. In the earlier period, 90 percent of the plant-based diet came from 160 species. By the later pre-pottery Neolithic, just 8–9 species supplied a similar proportion of the diet.*



***Likely gazelle** migration routes, reconstructed largely on the basis of the distribution of desert kites, where gazelle may have been slaughtered. In late spring the animals moved north toward the area around Abu Hureyra, where the young were born. At the end of the summer they returned south.*

The site of Abu Hureyra *in northern Syria: spoilheaps and an archaeological trench from the excavations are visible in the distance. (The buildings to the right are modern.)*

the Epipaleolithic period of all the common, toxic-seeded weeds (abundant in Neolithic levels) and the admixture of seeds of plants with which the wild-type cereals would have grown only in wild (natural) vegetation, indicates that the Epipaleolithic cereals were gathered from wild stands and were not under cultivation.

As for seasonality, the Epipaleolithic plant resources would have been available from late April until at least late October. And since seeds can be stored (although the site has no artifactual evidence of storage until the Neolithic), it is possible that there was year-round occupation here, based on a broad-spectrum plant economy, even before the emergence of agriculture. In whatever way the transition to cultivation came about, it seems to have taken only a few centuries. Once farming was fully established, the spectrum of seed-based foods dropped from 150 species down to a mere 8, which may represent a marked deterioration in dietary quality.

Animal Remains

In the faunal assemblage, studied by Tony Legge and Peter Rowley-Conwy, 80 percent of the bones belonged to gazelle, not only in the Epipaleolithic but in the Early Neolithic as well. Although most were adults, there were also (on the basis of tooth analysis and bone fusion) many very young animals, including yearlings and newborn, which suggests that some annual killing took place around April or May when the young were born. Entire herds may have been driven to their deaths in specially built stone enclosures known as "desert kites" (from the shape of their ground-plan – see map), although their date is often uncertain, and some are even thought to be fairly recent structures.

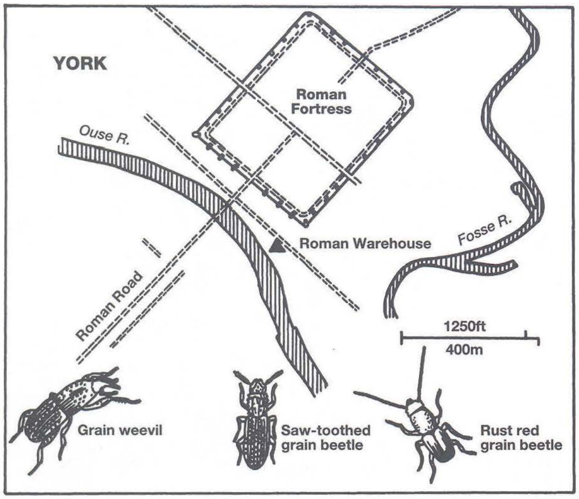
If one relies on the evidence of bones alone, therefore, Abu Hureyra looks like a seasonal camp for gazelle hunting; but the size of the mound and, as shown above, the varied plant foods imply that permanent occupation was quite feasible.

The bones of sheep and goat (whether wild or domestic cannot be ascertained) constitute only 10 percent of the Epipaleolithic assemblage, and the same in the Early Neolithic, when cereal cultivation was underway. Analysis of the animals' teeth suggests that, unlike gazelle, they were killed throughout the year, as one might expect of domestic animals. But they remained of little importance while gazelle were available. In the 7th millennium BC there was an abrupt change, with sheep/goats increasing to 80 percent and gazelles declining to only 20 percent of the bones. The cause may have been overkill of the gazelle, reflected in the proliferation of desert kites which perhaps disrupted the animals' migratory patterns.

Conclusions

An important conclusion is that for at least a thousand years after the first cultivation of morphologically domesticated plants at Abu Hureyra, hunting still played a crucial part in the site's economy. In this region, as in many other parts of the world, farming did not suddenly appear as an all-in-one package, but as a series of steps, adapting to changing circumstances over an extended period.

This example underlines the importance of analyzing all available evidence concerning subsistence. Plants or bones alone may give a distorted view. An integrated approach incorporating paleoethnobotany, archaeology and, where possible, direct dietary clues from human remains, together with archaeological and geomorphological evidence about land-use, will provide the fullest possible picture of subsistence.



Insects and Roman York: grain beetles and other pests were found in huge numbers in the remains of a Roman grain store, which had evidently become infested.

methods of cooking used. Identification of cutmarks under magnification gives evidence on butchery; while if the quantity of bird bones at a site fluctuates through time independently of the fluctuations in microfauna, this suggests that they were not brought in by birds of prey.

Fish. As with the bones of mammals, methods have been devised for calculating the weight of fish from their bones, and hence assessing their contribution to diet. Different types of fish can provide data on the fishing methods utilized – the bones of deep-sea species, for example, indicate open-sea fishing. Salted fish are often well preserved in Egyptian sites, and indeed certain fish were mummified in that civilization, like so many other animals. The Romans, for their part, had fish-ponds and cultivated oysters.

Microfauna and Insects. Remains of *microfauna* such as rodents, or frogs and toads, are poor indicators of diet, since so many of them came into sites through their own burrowing activities or through the attentions of other predators – owl pellets are even known in the Lower Paleolithic cave sediments at Swartkrans, South Africa.

Insects were occasionally eaten – for example, locusts have been found in a special oven in the rockshelter of Ti-n-Hanakaten, Algeria, dating to 6200 years ago – and in cases where their remains survive, they can provide important data on diet and seasonality. Wasp nests, for example, broken open to extract the larvae, have been found in some abundance in refuse layers at the Allen site in Wyoming, which not only points to consumption of larvae but also to summer occupation. At Pueblo Bonito, the well-known pueblo settlement in Chaco Canyon, New Mexico, some pots in graves contained fly pupae and fragments of a beetle whose larvae attack stored cereals; thus the insects revealed the vanished contents of the vessels. Similarly, a grave at Playa de los Gringos, Chile, contained a wooden vessel in which were found pupae cases of a type of fly that lives on meat. And, as mentioned in Chapter 6, the presence of the grain beetle and the golden spider beetle in a Roman sewer at York was sufficient to indicate that it drained a granary; indeed, the remains of a warehouse by the river at York were identified as a grain store because of a soil layer containing an astonishing quantity of grain beetles. Hardly any remains of cereal were found, indicating the damage these pests had caused. So great was the infestation that it caused the Romans to dismantle the store, and to cover its remains and the beetles with a thick clay dump. A replacement store was then built; cereal grains but few beetles were recovered from it, demonstrating that the pest-control policy had been successful.

Molluscs. Midden sites, almost by definition, provide far more direct clues to diet since humans were clearly responsible for most of the material deposited in them. Apart from occasional surviving remnants of crustaceans and echinoderms (the spines of sea-urchins, starfish, etc.), the bulk of marine material in coastal middens usually consists of mollusc shells, together with the bones of whichever animals, birds, and fish were exploited. Similarly, in terrestrial middens, the shells of snails or freshwater molluscs generally vastly outnumber bones. Their predominance is made even greater by the fact that shells survive far more successfully than bones. For this reason, in the past, these ratios were taken to mean that molluscs had formed a staple resource for the occupants at such sites. However, in recent years, studies of the energy yield in calories of different species have revealed that the numerically inferior vertebrate resources were in fact the mainstay of the diet, and that molluscs were often only a crisis or supplementary resource, easy to gather when needed. One calculation showed that a single carcass of a red deer was the equivalent in calories of 52,267 oysters or 156,800 cockles!

In view of the vast amount of shells in most middens – a single cubic meter can contain a ton of material and 100,000 shells – only samples can be analyzed. These are screened (sieved), sorted, and identified, and the meat they represent then calculated from the ratio (which varies with species) of shell to flesh weight. The proportion by flesh weight of different species helps indicate their relative importance in the diet, but it is the calculation of their calorific value that provides the real evidence of their dietary contribution (see box overleaf). It has been found that one person would need to consume 700 oysters or 1400 cockles every day in order to "live by shellfish alone." Such figures, when seen against the timespan of a site's occupation, reveal that the numbers consumed per year could not have supported a large group of people. Calculations of this sort underline the dominant role of other resources in the diet.

Nevertheless, the molluscs present in a midden indicate what people were selecting from the range available. Changes in shell-size through time may reflect environmental fluctuations, but in many cases can reveal overexploitation by humans. The first occupants of the Polynesian island of Tikopia consumed giant shellfish, as well as turtles and wild flightless birds; within a few centuries the birds were extinct, and the turtles and shellfish were far smaller and fewer, and the diet had to be supplemented with other resources.

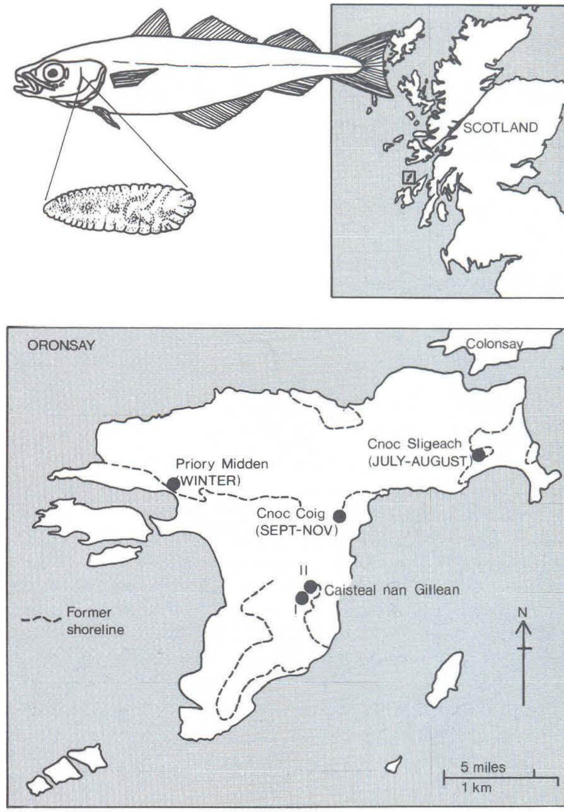
In sites other than middens, shells may be present in small quantities, and in many cases may not have been food at all. Snails, for example, may have lived in or around the site; and people often collected seashells to use as money, trinkets, or jewelry. Many of the seashells found in Upper Paleolithic sites in Europe are from small and inedible species.

Strategy of Use: Deducing Seasonality from Small Fauna

Some species of migratory birds, rodents, fish, and insects are available only at certain times of the year, and thus their simple presence at a site can provide useful information about the seasons in which humans occupied the site.

Although most fish are poor indicators of seasonality, since they can be treated and stored for consumption in lean times, techniques are emerging for extracting data of this type from their remains. Some species such as pike for example have year-rings in their vertebrae, by which one can calculate the season of death.

One new method being developed is the use of fish otoliths (part of the hearing apparatus) as evidence of seasonality. In late Mesolithic (4th millennium BC) shell middens on the island of Oronsay, off the northwest coast of Scotland, 95 percent of the total fishbone



Deducing seasonality from fish otoliths. On the island of Oronsay, Scotland, Mellars and Wilkinson used the varying sizes of coalfish otoliths (top left) from Mesolithic sites to deduce seasons of occupations at those sites (above).

material comes from the saithe or coalfish. A statistical analysis by Paul Mellars and Michael Wilkinson of the sizes of sagittal otoliths (the largest and most distinctive of the three pairs found in the inner ear) has shown that the size distribution gives an accurate indication of the fishes' age at death, and therefore – assuming a standard date of spawning – of the season when they were caught. As usual in studies of this type, they had to assume that we can extrapolate modern rates of growth to the past. Their analysis showed that the coalfish were caught at 1 and 2 years of age. At each of the four sites studied around the island, the size of the fish varied, indicating that they were caught at different seasons of the year. At the site indicating winter occupation, when the fish had left the coast for deeper water, shellfish contributed a much higher percentage of the food than at those sites where coalfish were caught in greater numbers in the warmer seasons.

SHELL MIDDEN ANALYSIS

Over 600 shell mounds of the Neolithic Jomon period are known in the area around Tokyo Bay, Japan, and contain many kinds of food remains. The mound of Kidosaku, on the east coast of the bay and dating from the early 2nd millennium BC, has been analyzed in depth by Hiroko Koike. Her results indicate the wealth of detail about diet, length and season of occupation, and population size that can be obtained from a small shell mound.

Size of population was assessed by studying the 10 circular dwelling pits on the site's terrace. From their overlapping it was established that an average of only 3 had been in use at any one time. The size of the dwellings (11–28 sq. m; 13–33 sq. yd) implies that between 3 and 9 people occupied each house (see Chapter 11), giving a maximum population for the site of 23, and more likely between 12 and 18.

The dwellings appear to have been rebuilt four times, and on that basis (together with pottery evidence for a brief occupation) the site's timespan has been estimated at 20 to 30 years.

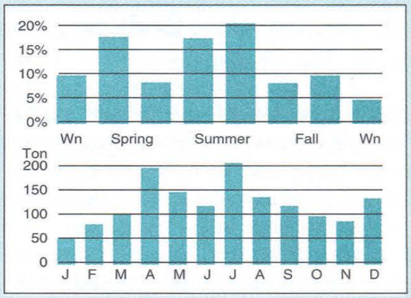
On the fringe of the terrace and down a steep slope were 7 concentrations of shells, each up to a meter thick and yielding a total volume of about 450 cu. m (589 cu. yd). Samples proved to contain 22 species of mollusc, all typical of a tidal assemblage from a sandy bottom.

Although the most abundant shell type was a tiny gastropod, it was the dominant bivalve – the clam *Meretrix lusoria* – which was probably the most important mollusc. About 3 million clams were represented in the site. From their shell heights, Koike was able to calculate the wet weight of the living clams, and reached a figure of 30 to 45 tons of clams at the site.

Analysis of growth structures in shells, especially bivalves, can provide important information on the season of exploitation. Under the microscope, one can see that the shell's cross-section has fine striations – these are the daily growth lines. There is seasonal variation in growth, with the thickest lines in the summer and the thinnest in winter; the temperature of seawater seems to play a major role. The Kidosaku clams had an age composition and a seasonality very similar to those of modern clams collected in the nearby Midori river area, and their modest size indicates a collection pressure as high as that of today. Koike concluded that the Kidosaku clams had been harvested throughout the year as intensively as shellfish are today by modern commercial collectors.

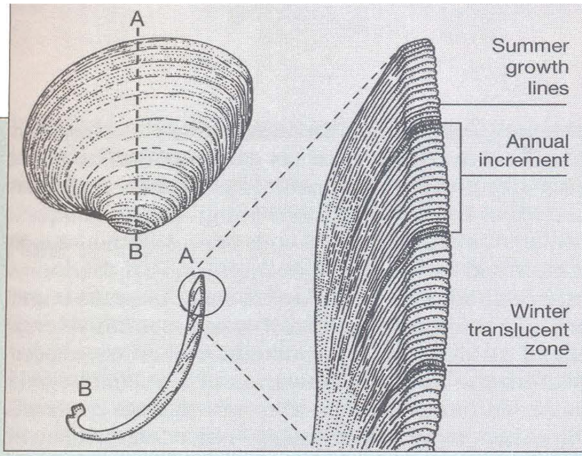
The clams represent only one resource at the site. Apart from the other molluscan species, there were fish remains (retrieved through wet screening) and also mammal bones, dominated by wild boar (minimum no. of individuals 36) and sika deer (MNI 29), together with wild rabbit and raccoon dog. The age composition of the deer suggested that they were subject to high hunting pressure; and Koike has calculated that, with a probable density of 10 per square kilometer, deer could have accounted for 60 percent of the occupant's caloric needs.

Clams, therefore, were an important resource, but by no means the only staple food of the Kidosaku occupants.



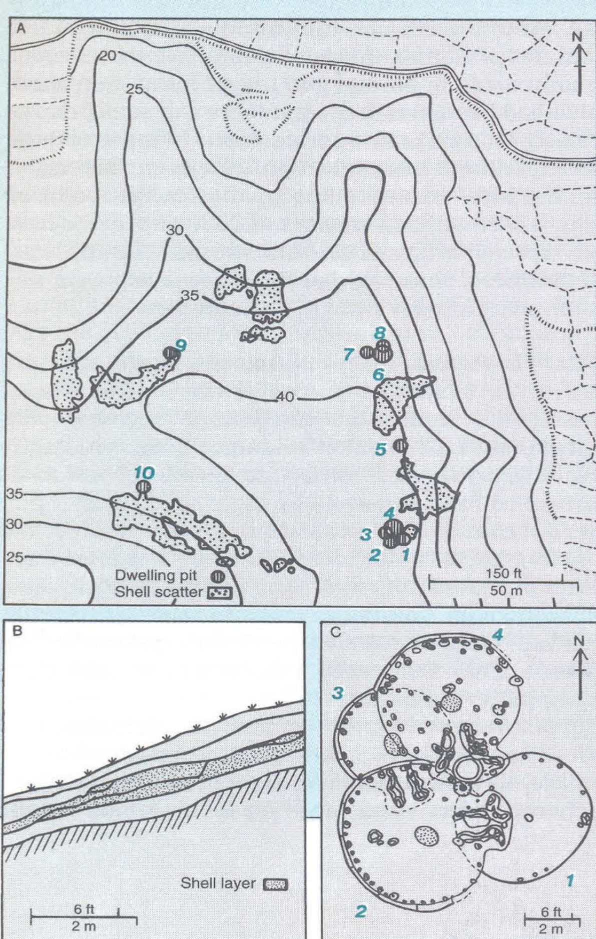
Histograms indicating how the seasonal pattern of clam collection at Kidosaku (top) – with a peak in the summer – is similar to that in the Midori river area today (second row). Collection seasons of the Kidosaku clams were estimated by studying growth lines.

***The Kidosaku** shell mound terrace (left) under excavation.*



Growth lines in a clam record the time of the year it was harvested. In winter the clam hardly grows at all, whereas in spring and summer thicker growth lines mark a daily growth cycle. By sectioning the shell (A–B) and counting the lines in the last annual increment, the scientist can determine the season of death.

The Kidosaku site (below), showing (A) a plan of the shell deposits and 10 dwelling pits; (B) a section across one of the shell deposits; and (C) a plan of overlapping dwelling pits 1 to 4.



HOW WERE ANIMAL RESOURCES EXPLOITED?

Tools, Vessels, and Residues

Direct proof of human exploitation of animal resources is available in a variety of ways from tools, vessels, and residues.

Evidence for Fishing and Hunting Techniques. Stone Age fish traps are known from Denmark, while one of the earliest known European boats (4th millennium BC from Tybrind Vig in Denmark) was specially adapted for eel-fishing: the stern had a fireplace of sand and small stones, so that fires could be lit to attract them at night.

Working out the function of stone tools is less easy, but experiments on tool usage and microwear are at last providing us with a mass of detailed information (see also Chapter 8). Occasional examples of animal bones with points embedded in them, combined with studies of healed and unhealed wounds in bones and experiments on the efficacy of arrowheads and other projectiles against different materials are providing much evidence on hunting weapons and methods. For example, the Danish zooarchaeologist Nanna Noe-Nygaard has analyzed the skeletons of deer and boar from a number of Mesolithic sites, as well as isolated bog finds, in Denmark. She found that injuries inflicted by humans can usually be distinguished from damage caused naturally in, for example, rutting fights by comparison with marks on modern specimens. Her analysis of the size and outline of the fractures suggested that the bow and arrow, as well as the spear, were used in hunting. On shoulder blades, she noted that the unhealed (and therefore probably fatal) fractures were concentrated in the same part of the bone – the thin area covering vital internal organs – whereas the healed fractures from unsuccessful hunts were scattered all over the bone.

Analysis of microwear polishes is starting to reveal something of the uses of different stone tools. Lawrence Keeley, one of the pioneers in this field, found that tools from Koobi Fora, Kenya, dating to 1.5 million years ago, had a greasy wear similar to the traces produced experimentally by cutting meat and soft animal tissue, and two of the tools had been found near a bovid humerus bone with cutmarks.

Trails of Blood. Until recently it would have been difficult to prove on which species tools had actually been used, except in very rare cases where fragments of feathers or hair adhered to the tool and could be identified. But a new and still somewhat controversial technique, developed by Canadian researcher Thomas Loy, apparently now allows us to identify the species in question from the bloodstains left on stone knives. After use of the tool, the blood dries and fixes quickly; and if the tool is not cleaned well after excavation, this residue can be analyzed. The shape of the crystals of hemoglobin – the oxygen-carrying molecule that is found in red blood cells – varies between animal species, and thus provides a kind of molecular fingerprint. Tools are often buried under conditions that provide the right combination of temperature, moisture, and acidity to preserve the hemoglobin, although a certain amount of blood seeps into the soil.

Loy studied 104 tools of chert, basalt, and obsidian from open sites in coastal British Columbia, dating from 6000 to 1000 years ago, and identified hemoglobin of moose, caribou, grizzly bear, the Californian sea-lion, and other species. He also obtained radiocarbon dates from some blood residues, using accelerator mass spectrometry (Chapter 4). Stone tools from the Toad River Canyon site, 2180 years old, were found to have blood and hair on them that came from bison, according to microscopy, protein analysis, and DNA analysis.

Loy has recently extended and improved his technique. He has found that blood residues can survive on tools for at least 100,000 years. For example, it has been claimed (but also disputed) that blood has been found on 90,000-year-old stone tools from Tabun Cave, Israel, together with hair and collagen, suggesting that they were used in animal processing. As will be seen in Chapter 11, he has also discovered traces of human blood on a number of artifacts, including one of that remote date.

The blood residue technique, if confirmed by further testing, will prove invaluable on sites where bones are not preserved, and may give more accurate identifications than feather or hair fragments.

Fat and Phosphate Residues. Other residues are identifiable to various degrees by methods already mentioned in the section on plant resources. Chemical investigation of fats, for instance, can reveal the presence of animal products: an example at Geissenklösterle in western Germany was cited in Chapter 6. Horse fat was identified in layers at the Lower Paleolithic cave of Tautavel, southern France, and reindeer bone-oil at the Upper Paleolithic open-air site of Lommersum, southern Germany. Fish fats have also survived in some sites.

Phosphate analysis of soils can point to animal rather than plant husbandry since phosphorus is very abundant in animal and human fats (phospholipids) and skeletons (phosphates). In some sites, phosphate concentrations can indicate areas of occupation, or places where livestock was concentrated (since phosphate also derives from decomposed dung). This technique is especially valuable for acid soils where the bones have not survived – it can, for example, reveal the former presence of bones in pits – and it underlines the importance of taking adequate soil samples from relevant areas of an excavation. In certain French caves occupied from the Neolithic onward, such as Fontbrégoua, it has been found that the presence of large quantities of so-called calcite spherulites, often associated with phosphate concretions in the floor sediments, is diagnostic evidence for cave-herding, since they represent the mineral residue of the dung of sheep and goats. Archaeological dung deposits can also be identified through the remains of predatory mites, which are characteristic of the droppings of different species: for example, 12 medieval samples from Holland have been found to include specimens from horse.

Use of manure on fields can also be detected. In an experiment carried out at Butser farm (see box pp. 274–75) cow dung was added to part of a field over a period of 13 years, and then the soil was chemically analyzed two years after the last muckspreading. Large quantities of stanols (long-lived fatty molecules which are only made in animal guts) were found in the area which had been manured, and these can sometimes be ascribed to particular species such as cattle or pigs. This experiment has made it possible to tackle remains from the past, such as on the small island of Pseira, off Crete, where Minoan terraces of 2000 BC seem to have been spread with household waste. Stanols were detected here, showing that the older layers were rich in manure, probably from humans or pigs.

Residues in Vessels. Where vessels are concerned, residues can be examined in several ways, as for plants. Investigation under the microscope together with chemical analysis enabled Johannes Grüss to identify a black residue on Austrian potsherds of 800 BC as overcooked milk. Analysis by mass spectrometer provides a record of molecular fragments in a residue, and these fragments can be identified using a reference collection of chromatograms. Employing this technique, Rolf Rottländer has found milk fat and beef suet in Neolithic Michelsberg sherds from Germany, fish fat in sites at Lake Constance, and butter and pork fat in Roman pottery vessels.

Egyptian vessels of the 1st and 2nd dynasties (3rd millennium BC) have been found, through chemical analysis, to contain residues of substances as diverse as cheese, beer, wine, and yeast. In Japan, Masuo

Nakano and his colleagues have identified dolphin fat in Early Jomon potsherds (4000 BC) from the Mauraki site, while the edges of late Paleolithic stone scrapers from the Pirika site (9000 BC) had residues of fat which seemed to come from deer. It is worth noting that his technique, which extracts the fats by "ultrasonic cleaning," can also be used to identify from which species tiny fragments of bone have come, which hitherto would have been completely unidentifiable.

An extension of this technique, gas liquid chromatography, constitutes a very sensitive method of measuring components of complex volatile compounds. It has been applied at the prehistoric coastal midden of Kasteelberg in southwest Cape Province, South Africa, which is less than 2000 years old. Potsherds from the midden had a brown, flaky substance on the inside, resembling burnt food, and the nitrogen content of a sample was so high that it suggested the substance was animal. The chromatography technique was applied in order to determine its composition in terms of fatty acids, and the values obtained were then compared with those of modern species of plants and animals. The results pointed firmly to a marine animal, though not to a precise species. The presence of seal bones in the site makes it probable that the substance came from the boiling of seal meat in jars for food or for extracting blubber.

Animal Prints and Tracks. Another type of residue left by animals are pawprints and animal tracks, as we saw in Chapter 6. Many Ice Age tracks may not have been associated with human beings. More informative are the impressions of sheep or goat feet in mud brick from the Near East and Iran, such as those from the 6th millennium BC at Ganj Dareh Tepe. The English Bronze Age site of Shaugh Moor, Devon, revealed tracks of cattle, sheep or goat, and a badger, preserved at the bottom of a ditch by peat. At the mouth of the Mersey estuary in northwest England, tracks of aurochs (wild cattle), red and roe deer, unshod horse, and crane have been found on the mudflats and date to around 3650 years ago. In Sweden, Bronze Age tracks of unshod horses have also been reported from raised fjord sediments at Ullunda, northwest of Stockholm; while in Japan, the remains of prehistoric paddy fields have often preserved prints of wild animals such as deer.

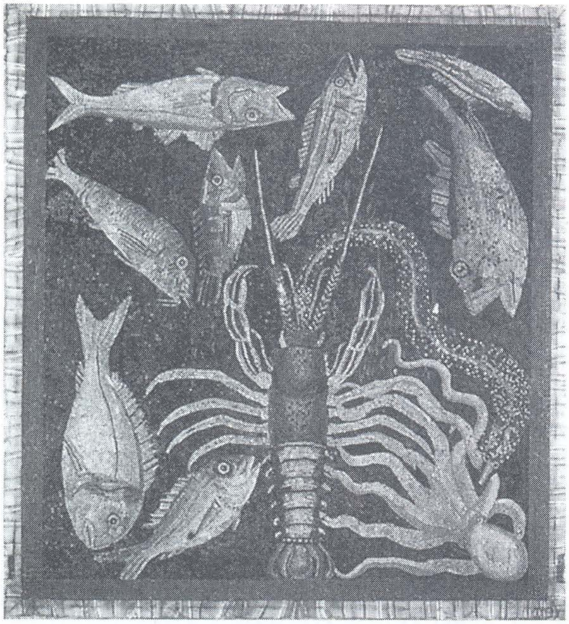
At Duisburg, western Germany, the remains of the medieval city's market square have been found to comprise successive cobbled surfaces interleaved with thick layers of mud and rubbish in which the tracks of cattle hooves, wagon wheels, and human feet have been preserved by being infilled with gravel to support the next layer of cobbles.

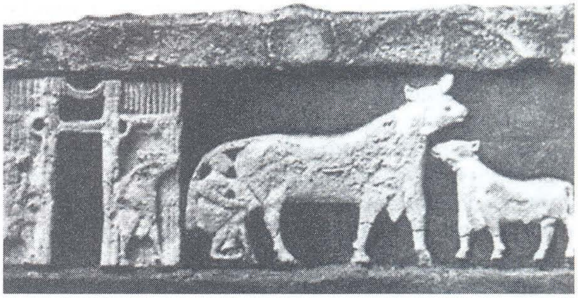
Tracks of aurochs (wild cattle), dating to c. 3650 years ago, in mudflats of the Mersey estuary, northwest England.

However, the best known and most abundant prints are those on Roman roof tiles and bricks – dogs and cats are particularly abundant, as well as birds. Of all the tiles from the Romano-British town of Silchester, no fewer than 2 percent had impressions of this type.

Tools and Art: Evidence for the Secondary Products Revolution

The question of animal domestication, discussed earlier, is one of the key issues in archaeology. British archaeologist Andrew Sherratt looked beyond the initial stage of domestication to ask whether there was not in fact a second and later stage – what he called the Secondary Products Revolution. Sherratt argued that in some parts of the Old World, during the middle and late 4th millennium BC, there was a marked change in the exploitation of domestic animals, no longer solely for the primary products of meat and hides but also for secondary products such as milk and cheese, wool, and animal traction. His evidence consisted to some extent of tools and slaughter patterns of caprines, but primarily of artistic depictions – in Sumerian pictograms from Uruk, Mesopotamian cylinder-seals, in





(Left) The Romans liked to eat seafood. Eleven species are shown in this 2nd-century AD *mosaic from northern Italy. (Above) Milking scene from a frieze at Ur, Mesopotamia, c. 2900* BC*. Use of secondary products may go back to the early Neolithic.*

murals and models – that show plowing, milking, and carts (assumed to have been drawn by animals such as oxen). Sherratt argues that the change was a response to population growth and territorial expansion initiated by the origins of agriculture. People found it necessary to penetrate more marginal environments and exploit livestock more intensively.

However, the American archaeologist Peter Bogucki has shown that in the early Neolithic *Linearbandkeramik* culture of temperate Europe the age and sex structure of the cattle, together with ceramic strainers (interpreted as cheese sieves), indicate the presence of dairying as early as 5400 BC. If this is so, then the "revolution" at the end of the Neolithic must be seen not as a beginning but merely as an intensification of an already existing phenomenon. Perhaps before long analysis of residues in early Neolithic vessels will determine whether they held milk, butter, or cheese, and thus help solve the question of the timing and scale of human exploitation of secondary products.

Art and Literature

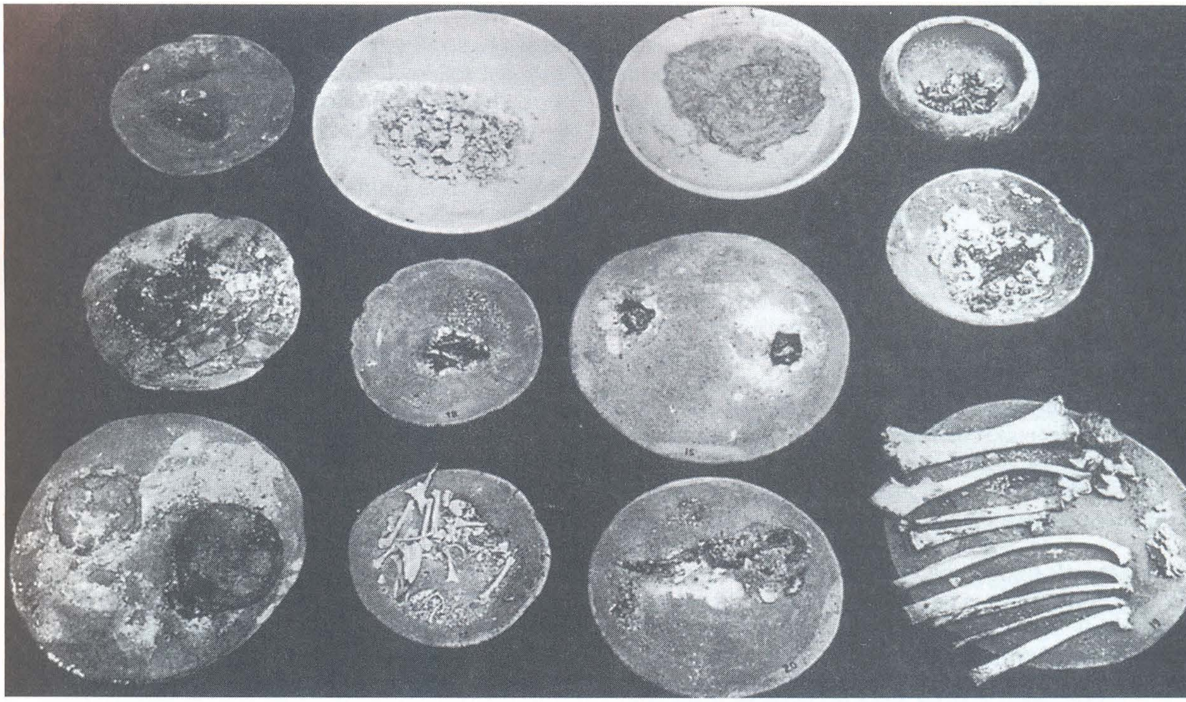
In addition to providing evidence for use of secondary products, art can be a rich source of other kinds of information. To take just one example, the American scholars Stephen Jett and Peter Moyle have been able to identify 20 species or families of fish depicted accurately on the inside of prehistoric Mimbres pottery from New Mexico (box, p. 554). As most of the fish are marine types, and the pottery has been found at least 500 km (311 miles) from the nearest sea, it is obvious that the artists had been to the coast and were very familiar with these resources.

Much information can also be obtained from writings, not only of the sort described in the section on plants, but texts dealing with veterinary medicine, which are known in Egypt from 1800 BC on, and in Hittite and Mesopotamian sites of similar date, as well as from Greek and Roman times. As always, history, ethnography, and the experimental methods being applied to crop and animal husbandry (see box, pp. 274–75) help to flesh out the archaeological evidence.

Remains of Individual Meals

One of the most direct kinds of evidence of what people ate at a particular moment in the past comes from occasional finds of actual meals. At Pompeii, for example, meals of fish, eggs, bread, and nuts were found intact on tables, as well as food in shops. Food is often preserved in funerary contexts, as in the desiccated corncobs and other items in Peruvian graves, or at Saqqara, Egypt, where the 2nd-dynasty tomb of a noblewoman contained a huge variety of foodstuffs, constituting a rich and elaborate meal – cereals, fish, fowl, beef, fruit, cakes, honey, cheese, and wine – which, to judge by the tomb paintings, was not unusual. The Han period in China (206 BC–AD 220) has tombs stocked with food: that of the wife of the Marquis of Dai has a unique collection of provisions, herbal medicines, and prepared dishes in containers of lacquer, ceramic, and bamboo, with labels attached, and even inventory slips giving the composition of the dishes!

We should not, however, let the very richness of these finds cloud an objective judgment that meals



A meal as a funerary offering: the rich and elaborate food remains found in the 2nd-dynasty tomb of a noblewoman at Saqqara, Egypt. These include a triangular loaf of bread (made from emmer wheat); nabk berries (similar in appearance to cherries); cut ribs of beef; a cooked quail; two cooked kidneys; stewed fruit, probably figs; cakes; pigeon stew; a cooked fish. Impressive as such remains are, they are unlikely to be representative of the everyday diet of the ancient Egyptians.

from funerary contexts are unlikely to be representative of everyday diet. Even the meals found so wonderfully preserved at Pompeii are merely a tiny sample from a single day. The only way in which we can really study what people ate habitually is to examine actual human remains.

ASSESSING DIET FROM HUMAN REMAINS

The only incontrovertible evidence that something was consumed by humans is its presence in either stomachs or feces. Both kinds of evidence give us invaluable information about individual meals and short-term diet. The study of human teeth also helps us reconstruct diet, but the real breakthrough in recent years in understanding long-term diet has come from the analysis of bone collagen. What human bones reveal about general health will be examined in Chapter 11.

Individual Meals

Stomach Contents. Stomachs survive only rarely in archaeological contexts, except in bog bodies. It is sometimes possible to retrieve food residues from the alimentary tract of decomposed bodies – the anthropologist Don Brothwell achieved this, for example, by removing the grave earth from the lower abdominal area of some British Dark Age skeletons, and extracting the organic remains by means of flotation; and colon contents have also been obtained from an Anasazi burial of the 13th century AD. Some mummies also provide dietary evidence: the overweight wife of the Marquis of Dai from 2nd-century BC China, mentioned above, seems to have died of a heart attack caused by acute pain from her gallstones an hour or so after enjoying a generous helping of watermelon (138 melon seeds were found in her stomach and intestines).

When stomachs survive in bog bodies, the dietary evidence they provide can be of the greatest interest. Paleobotanist Hans Helbaek's pioneering studies of the stomach contents of Danish Iron Age bogmen showed that Grauballe Man, for instance, had consumed over 60 species of wild seeds, together with one or two cereals and a little meat (as shown by some small bone splinters), while Tollund Man had eaten only plants. But it should be borne in mind that these results, while fascinating, are not necessarily linked to annual diet, since these victims were possibly executed or sacrificed, and thus their last meal – apparently consisting of dense chaff, larger plant fragments, and weed seeds, the residues from sieving in the latter stages of crop processing – may have been out of the ordinary. Such waste crop cleanings were often used as animal feed, as famine food, or were given to condemned criminals.

However, as noted in the section on plant remains, the British Lindow Man (box, pp. 448–49) had consumed a griddle cake before his death, and this rough bread, made of the primary product of crop processing, was nothing out of the ordinary for the period – certainly not a recognizably "ritual" dish.

Fecal Material. Experiments have been done to assess the survival properties of different foodstuffs relevant to the study of ancient diet, and it has been found that many organic remains can survive surprisingly well after their journey through the human digestive tract, to await the intrepid analyst of ***coprolites***, or fossilized feces. Coprolites themselves survive only rarely, in very dry sites such as caves in the western United States and Mexico, or very wet sites. But, where they are preserved, they have proved to be a highly important source of information about what individuals ate in the past.

The first step in any study is to attempt to check that the coprolites are indeed of human origin – this can sometimes be done by analysis of fatty molecules such as coprostanol, and of steroids. Once this has been done, what can coprolite contents tell us about food intake? Macroremains can be extremely varied in a human coprolite, in fact this variety is an indication of human origin. Bone fragments, plant fibers, bits of charcoal, seeds, and the remains of fish, birds, and even insects are known. Shell fragments – from molluscs, eggs, and nuts – can also be identified. Hair can be assigned to certain classes of animals by means of its scale pattern, visible under the microscope, and thus help us to know which animals were eaten. Eric Callen analyzed prehistoric coprolites from Tehuacán, Mexico (the valley studied and excavated intensively by Richard MacNeish in the 1960s), and identified hair from gophers, white-tailed deer, cottontail rabbit, and ring-tailed cats. He also managed to ascertain that some millet grains in the feces had been pounded, while others had been rolled on a metate (grinding stone).

Microremains such as pollen are of less help since, as we have already noted, most of the pollen present is inhaled rather than consumed. Pollen does, however, provide data on the surrounding vegetation, and on the season when the coprolite was produced. The fecal material from the Greenland Eskimo mummies (see pp. 444–45) contained pollen of mountain sorrel, which is only available in July and August. Fungal spores, remains of the nematode worm plant parasites, algal remains, and other parasites have also been identified in coprolites.

Exceptional conditions in Lovelock Cave, Nevada, have preserved 5000 coprolites dating from 2500 to 150 years ago, and Robert Heizer's study of their contents yielded remarkable evidence about diet, which seems to have comprised seeds, fish, and birds. Feather fragments were identified from waterfowl such as the heron and grebe; fish and reptile scales, which pass through the alimentary canal unaltered, also led to identification of several species. Fish remains were abundant in some of the coprolites; one, for example, from 1000 years ago, contained 5.8 g (0.2 oz) of fish bone which, it was calculated, came from 101 small chubs, representing a total live weight of 208 g (7.3 oz) – the fish component of a meal for a single person.

Even where feces have not been preserved, we are now sometimes able to detect and analyze residues of digested food by studying sewers, cesspits, and latrines. Biochemical analysis of ditch deposits near latrines at the Roman fort of Bearsden, Scotland, revealed an abundance of coprosterol, a substance typically found in human sewage, as well as a bile acid characteristic of human feces. A low amount of cholesterol showed that there was little meat in the diet. Numerous fragments of wheat bran in the deposit probably formed part of the feces, and no doubt came from defecated bread or some other floury food.

Coprolites and fecal residues represent single meals, and therefore provide short-term data on diet, unless they are found in great quantities, as at Lovelock Cave, and even there the coprolites represent only a couple of meals a year. For human diet over whole lifetimes, we need to turn to the human skeleton itself.

Human Teeth as Evidence for Diet

Teeth survive in extremely good condition, made as they are of the two hardest tissues in the body. Pierre-François Puech is one of a number of scientists to have studied teeth from many periods in an attempt to find some evidence for the sort of food that their owners enjoyed. The method involves a microscopic examination of the abrasions on certain dental surfaces.

To study food intake, one should examine the lateral or side surfaces which best escape abrasion from inorganic particles in the food, and whose wear instead ought to reflect the movement of the organic food itself within the mouth. A replica is made by pouring a thin film of resin onto the tooth-face; when this is peeled off after solidification, it forms a faithful imprint which can be examined under the light microscope or in the scanning electron microscope. Puech began by studying recent teeth from individuals with known dietary habits. The principle involved was that abrasive particles in food leave striations on the enamel whose orientation and length are directly related to the meat or vegetation in the diet and its process of cooking. Modern meat-eating Greenland Eskimos were found to have almost exclusively vertical striations on their lateral surfaces, while largely vegetarian Melanesians had both vertical and horizontal striations, with a shorter average length.

When these results were compared with imprints from fossil teeth, it was found that from the late Lower Paleolithic onward, there is an increase in horizontal and a decrease in vertical striations, and a decrease in average striation length. In other words, less and less effort was needed in the mastication of food, and meat may have decreased in importance as the diet became more mixed: early people crushed and broke down their food with their teeth, but less chewing was required as cooking techniques developed and improved. There are exceptions, such as a *Homo erectus* individual who seems to have been mainly vegetarian, eating thin, chewy vegetable foods, but on the whole the generalization seems sound.

The biting (occlusal) surfaces of human teeth are of limited help in Puech's technique, since much of the wear here is due to the method of food preparation – meat can be exposed to windborne dust, for example, or food may have been cooked on ashes, and the result is the incorporation of extraneous abrasive particles in the food. Furthermore, our ancestors often used teeth not simply for chewing but as a third hand, for cutting, tearing, and so on. All these factors add striations to the biting surfaces. The lower jawbone of the *Homo erectus* (or "archaic" *Homo sapiens*) individual from Mauer, near Heidelberg in western Germany, dating back some half a million years, has marks suggesting that meat was held in the front of the mouth and cut off with a flint tool that left its traces on six front teeth. Wear on Neanderthal teeth reveals that here too teeth were often used in the same way.

Tooth decay as well as wear will sometimes provide us with dietary information. Remains of the California Indians display very marked tooth decay, attributed to their habit of leaching the tannin out of acorns, their staple food, through a bed of sand which caused excessive tooth abrasion. Decay and loss of teeth can also set in thanks to starchy and sugary foods. Dental caries became abundant on the coast of Georgia (USA) in the 12th century AD, particularly among the female population. It was in this period that the transition occurred from hunting, fishing, and gathering to maize agriculture. The anthropologist Clark Larsen believes that the rise in tooth decay over this period, revealed by a study of hundreds of skeletons, was caused by the carbohydrates in maize. Since the women of the group were more subject to the caries than were the men, it is probable that they were growing, harvesting, preparing, and cooking the corn, while the men ate more protein and less carbohydrate. However, not all scientists accept these conclusions, pointing out that women may have suffered from more caries in a period of high population growth because of greater loss of calcium with the higher number of pregnancies.

Finally, as mentioned above (p. 274), direct evidence of diet can be obtained from phytoliths extracted from the surface of human teeth.

Isotopic Methods: Diet over a Lifetime

Recently, a revolution has taken place in dietary studies through the realization that isotopic analysis of human tooth enamel and bone collagen can reveal a great deal about long-term food intake. The method relies on reading the chemical signatures left in the body by different foods – we are what we eat.

Plants can be divided into three groups – two groups of land plants and one of marine plants – based on their differing ratios of the carbon isotopes ^{13}C and ^{12}C. Carbon occurs in the atmosphere as carbon dioxide with a constant ratio of ^{13}C:^{12}C of about 1:100; in ocean waters, the amount of ^{13}C is slightly higher. When atmospheric carbon dioxide is incorporated into plant tissues through photosynthesis, plants use relatively more ^{12}C than ^{13}C and the ratio is altered. Plants that fix carbon dioxide initially into a three-carbon molecule (called C3 plants) incorporate slightly less ^{13}C into their tissues than do those using a four-carbon molecule (C4 plants). By and large, trees, shrubs, and temperate grasses are C3 plants; tropical and savanna grasses, including maize, are C4 plants. Marine plants photosynthetically fix carbon differently from most land plants, and have a higher $^{13}C/^{12}C$ ratio.

As plants are eaten by animals, these three different ratios are passed along the food chain, and are eventually fixed in human and animal bone tissue. The ratio found in bone collagen by means of a mass spectrometer thus has a direct relation to that in the plants which constituted the main foods. The ratios can show whether diet was based on land or marine plants, and whether on C3 or C4 land plants. Only archaeological evidence, however, can provide more detail about precisely which species of plants or animals contributed to the diet.

Henrik Tauber applied this technique to collagen from prehistoric skeletons in Denmark, and found a marked contrast between Mesolithic people and those of the Neolithic and Bronze Age. In the Mesolithic, marine resources were predominant – even though fish bones were very scarce in the excavated material – whereas in the later period there was a change to reliance on land foods, even in coastal sites.

At coastal sites in other parts of the world, the technique has confirmed a heavy reliance on marine resources. In prehistoric sites on the coast of British Columbia, Brian Chisholm and his associates found that about 90 percent of protein had come from marine foods; little change was apparent over five millennia, and it was noted that adults seemed to eat more food from the sea than did children.

Recently, isotopic analysis of tooth enamel from four *Australopithecus africanus* individuals from Makapansgat, South Africa, revealed that they ate not only fruits and leaves, as had been thought, but also large quantities of carbon-13 enriched food such as grasses or sedges, or the animals which ate those plants, or both. In other words, they regularly exploited fairly open environments (woodlands or grasslands) for food; and since their tooth wear lacks the characteristic scratches of grass-eaters, it is possible that they were indeed already consuming meat, by hunting small animals or scavenging larger ones.

Bone Collagen Studies and the Rise of New World Agriculture. The carbon isotope bone collagen method is particularly useful for detecting changes in diet, and has revolutionized the study of the rise of food production in the New World. Anna Roosevelt used the technique to assess the diet of the prehistoric inhabitants of the Orinoco floodplain in Venezuela. Analysis of samples from a number of skeletons by her colleagues Nikolaas van der Merwe and John Vogel revealed a dramatic shift from a diet rich in C3 plants such as manioc in 800 BC to one based on C4 plants such as maize by AD 400. Although the technique cannot specify the actual plants consumed, the abundant maize kernels and grinding equipment found in the area's sites from AD 400 confirm the insight provided by isotopic analysis.

The technique is even more crucial in North America, where the rise of agriculture was signaled by the introduction of maize, a C4 food native to Mesoamerica, into a predominantly C3 plant environment (in the Near East, where the first domesticated plants were themselves part of the C3 plant environment, the technique is of less use to studies of the origins of agriculture). In some cases, maize's contribution to a diet can be quantified. In skeletons from southern Ontario, Henry Schwarcz and his colleagues found that the proportion of C4 plants (i.e. maize) in the diet increased between AD 400 and 1650, reaching a maximum of 50 percent by about 1400.

Other Bone Collagen Techniques. Some scholars have attempted to extend the carbon isotope technique to apatite, the inorganic and major constituent of bone, in the hope that it could be applied even in cases where collagen has not survived (it often degrades after 10,000 years); others, however, have found this method unreliable, so that the collagen method is the only one whose validity is confirmed for the present.

Nevertheless there are collagen techniques available involving isotopes of elements other than carbon. Ratios of ***nitrogen isotopes*** in collagen, for example, can reflect dietary preferences in the same way as carbon. The ^{15}N isotope increases as it passes up the food chain from plants to animals: a low ratio of ^{15}N to ^{14}N points to an agricultural subsistence, while a high ratio points to a marine diet. One anomaly here is caused by coral reef resources such as shellfish, which, because of the way nitrogen is fixed by plants in reefs, give a low nitrogen value. Thus, in cases where a seafood diet seems likely, the carbon isotope method needs to be employed for confirmation.

The two methods have also been applied together to historic and prehistoric material in East and South Africa by Stanley Ambrose and Michael DeNiro. They found it possible to distinguish marine foragers from people using land resources, pastoralists from farmers, camel pastoralists from goat/cattle pastoralists, and even grain farmers from non-grain farmers. Groups that depended on the meat, blood, and milk of domestic animals had the highest ^{15}N values, those dependent mainly on plant foods had the lowest. The results agreed well with ethnographic and archaeological evidence. Comparison of ^{15}N and ^{13}C levels in Preclassic Maya burials and animal bones from the early village site of Cuello, Belize (1200 BC–AD 250), excavated by Norman Hammond and analyzed by him, Nikolaas van der Merwe, and Robert H. Tykot, has also produced interesting results (see diagram).

Measuring the amounts of ^{13}C and ^{15}N in fossilized Neanderthal bones from the cave of Maurillac, Charente, has led French researchers to the conclusion that their diet was almost exclusively carnivorous. The same carbon and nitrogen isotopes have also been analyzed in other kinds of tissue, such as the skin and hair of mummies from the Nubian Desert, dating from 350 BC to AD 350, and suggest that the population ate goats and sheep, cereals and fruit. Since isotopes show up in hair only two weeks after they are consumed (whereas bone shows what was eaten over a lifetime), different segments of the same hair can show changes in diet, the segments closest to the scalp even indicating the season at the time of death. Locks of hair from 2000-year-old Peruvian and Chilean mummies have even been found to contain traces of cocaine consumption from the chewing of coca leaves.

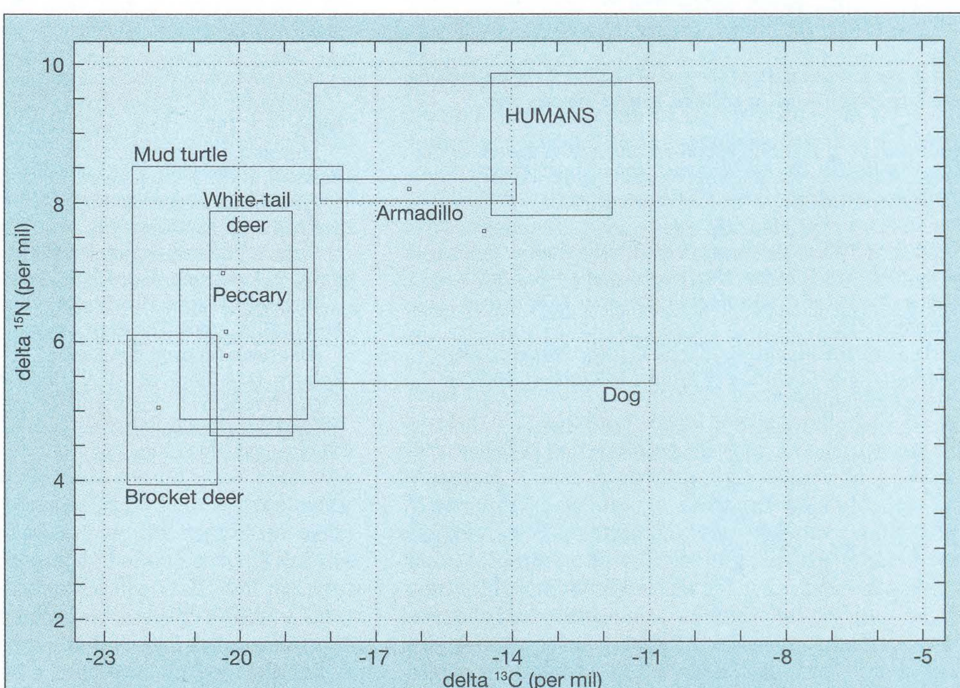
Scientists have also found that concentrations of ***strontium***, a stable mineral component of bone, can provide data on diet. Most plants do not discriminate between strontium and calcium, but when animals eat plants, strontium is discriminated against in favor of calcium; most of the strontium is excreted, but a small constant percentage enters the blood stream and becomes incorporated into bone mineral. The contribution of plants to the diet can therefore be assessed through the proportions of strontium and calcium (Sr/Ca) in human bone – the bigger the contribution (e.g. in a vegetarian), the higher the Sr:Ca ratio, whereas a meat-eater's diet gives a low ratio. South African anthropologist Andrew Sillen has discovered by this technique that *Australopithecus robustus*, formerly thought to have been a vegetarian because of its powerful grinding jaws, did eat some meat and was therefore probably omnivorous.

Analysis by Margaret Schoeninger of strontium levels in bones from the eastern Mediterranean has shown that the proportions of plant and animal foods in the diet did not change radically from the Middle Paleolithic until the Mesolithic, when there was a shift toward a greater use of plant foods. Her results show that people here had a plant-rich diet a considerable time before cereals were domesticated.

Schoeninger has used the same technique to study skeletal material at Chalcatzingo, an Olmec site in central Mexico at its peak around 700–500 BC, where a combination of strontium results and an assessment of grave-goods indicates a ranked society with a differential consumption of meat. She found that the highest-ranked people buried with jade had the lowest bone strontium (and therefore ate plenty of meat); those buried with a shallow dish had a higher strontium level (and thus ate less meat); while a third group lacking any grave-goods had the highest strontium level (and probably ate very little meat).

A different picture emerges where shellfish contributed to diet, because strontium concentrations are far

Bone collagen analysis of Preclassic Maya burials and animal bones from the site of Cuello, Belize, showed that maize formed 35–40 percent of the diet of humans, and of dogs bred for food. The wide range of both ^{13}C and ^{15}N for dogs suggests a mixed diet. Forest species, such as deer, and marine turtles ate only C3 plants, and had a lower protein intake, indicated by the ^{15}N figures. Armadillos have high figures due to eating grubs that themselves eat the roots of maize plants.



higher in molluscs than in plants. Skeletons from an Archaic hunter-gatherer population of around 2500 BC at a northern Alabama site proved to have a higher strontium level, thanks to the molluscs in their diet, than those from an agricultural Mississippian population buried at the same site in about AD 1400.

Recent studies, however, suggest that due to contamination from sediments and ground water in which some bones are buried, strontium values can be misleading and one should keep an open mind until possible pitfalls are better understood. In any case, the technique is only a complement to – not a replacement for – the analysis of carbon isotopes. The Sr:Ca ratio reveals the proportionate amounts of meat and plants in the diet; but isotopic analysis is needed to learn what kinds of plants were being consumed. Archaeology provides the evidence that permits more precise identification of the plant and animal species involved.

SUMMARY

All the methods described in this chapter are providing archaeology with new tools, not to say with "food for thought." The evidence available varies from botanical and animal remains, both large and microscopic, to tools and vessels, plant and animal residues, and art and texts. We can discover what was eaten, in which seasons, and sometimes how it was prepared. We need to assess whether the evidence arrived in the archaeological record naturally or through human agency, and whether the resources were wild or under human control. Occasionally we encounter the remains of individual meals left as funerary offerings or as the contents of stomachs or feces. Finally, the human body itself contains a record of diet in its toothwear and in the chemical signatures left in bones by different foods.

Many of the techniques lie in the domain of the specialist, particularly the biochemist, but archaeologists should know how to interpret the results, because the rewards are enormous for our knowledge of what people ate, how they exploited their resources, and in what proportions. Prospects for future research look good. Since we understand increasingly what a good or balanced diet entails, we can now begin to examine past diets in terms of nutritional value and assess the state of health of our ancestors.

FURTHER READING

Most of the sources given at the end of Chapter 6 are appropriate for this chapter as well. In addition, helpful volumes are:

Brothwell, D. & P. 1997. *Food in Antiquity: A Survey of the Diet of Early Peoples.* Johns Hopkins Univ. Press: Baltimore, MD.

Gilbert, R.I. and Mielke, J.H. (eds.). 1985. *The Analysis of Prehistoric Diets.* Academic Press: New York & London.

Harris, D.R. (ed.). 1996. *The Origins and Spread of Agriculture and Pastoralism in Eurasia.* UCL Press: London.

Harris, D.R. & Hillman, G.C. (eds.). 1989. *Foraging and Farming. The Evolution of Plant Exploitation.* Unwin Hyman: London.

Hastorf, C.A. & Popper, V.S. (eds.). 1988. *Current Paleoethnobotany. Analytical Methods and Cultural Interpretations of Archaeological Plant Remains.* University of Chicago Press: Chicago.

Olsen, S.J. 1970. *Osteology for the Archaeologist.* Peabody Museum: Cambridge, Mass.

Pearsall, D.M. 1989. *Paleoethnobotany: A Handbook of Procedures.* Academic Press: New York & London.

Price, T.D. & Gebauer, A.B. (eds.). 1995. *Last Hunters, First Farmers.* School of American Research Press: Santa Fe.

Reitz, E.J. & Wing, E.S. 1999. *Zooarchaeology.* Cambridge University Press: Cambridge.

Smith, B.D. 1995. *The Emergence of Agriculture.* Scientific American Library: New York.

Zohary, D. & Hopf, M. 1999. *Domestication of Plants in the Old World. The Origin and Spread of Cultivated Plants in West Asia, Europe and the Nile Valley.* (3rd ed.). Clarendon Press: Oxford.