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Use in Environmental Archaeology

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Introduction

Environmental archeology concerns the study of vegetation (flora) and animals (fauna), which lived in association with people of the past, and the way in which humans interacted with these other living organisms (Wilkinson and Stevens, 2003). The study of once-living organisms in archeology is termed bioarcheology and forms part of the 'archeological sciences' (Fig. 1).

Within these, archeobotany or paleoethnobotany is the study of ancient plant remains (as proxy-data) preserved on, or in association with, archeological sites ('on-site data'; Kreuz, 1995; article of Barker in Albarella, 2001; Jacomet and Kreuz, 1999; Pearsall, 2000). This is a contrast to paleoenvironmental approaches because plant remains from archeological sites are 'ecofacts' and there as a result of human action. As paleoeconomic studies are carried out on archeological material that happens to be biological, the approach is a combination of archeology and the biological sciences. It is for this reason that developments in archeological theory have much greater relevance to paleoeconomic studies

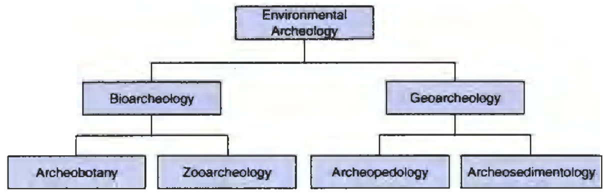


Figure 1 Subdivisions of Environmental Archaeology. Reproduced with permission from Wilkinson and Stevens 2003, p. 17, fig. 3.

(Wilkinson and Stevens, 2003). Today therefore, environmental archeologists are both archeologists and natural scientists and should have trained in both areas.

Environmental archeology is mainly interested in the activities carried out by past populations (**Tables 1 and 2**). It usually covers the time period in which modern humans interacted somehow with their environment (ca. the last 40,000 years). Here again, the period in which sedentarism arose – at around 10,000 calendar years (cal yr) ago in different parts of the world (Diamond, 2002) – is by far the best represented. This covers mainly the present interglacial period, the Holocene (**Table 3**).

The timescale used in this article is that which is most familiar to archeologists, namely calendar years AD resp. BC. Dating is partly based on calibrated radiocarbon dating and partly on dendrochronology.

Methodological Basics

Types of Remains

The most important macroremains (average size >0.1–0.2 mm) from archeological sediments are seeds, fruits, parts of infructescences (like cereal chaff; **Figs. 2 and 3**), and wood. In certain cases they are found as imprints (**Fig. 4**) or in 'products' such as bread or coprolites. Theoretically every part of a plant can be found as an ecofact. Although in the following we deal only with macroremains, it should be emphasized that also microremains (pollen, fungal spores, etc.) in archeological structures are ecofacts and their spectra and amounts are to a high degree a result of human action. For more details see Dimbleby (1985); Pearsall (2000); and Jacomet and Kreuz (1999). (see also **Table 6**).

Taphonomy

Archeologists use the term taphonomy to explain the processes that lead to the preservation (often

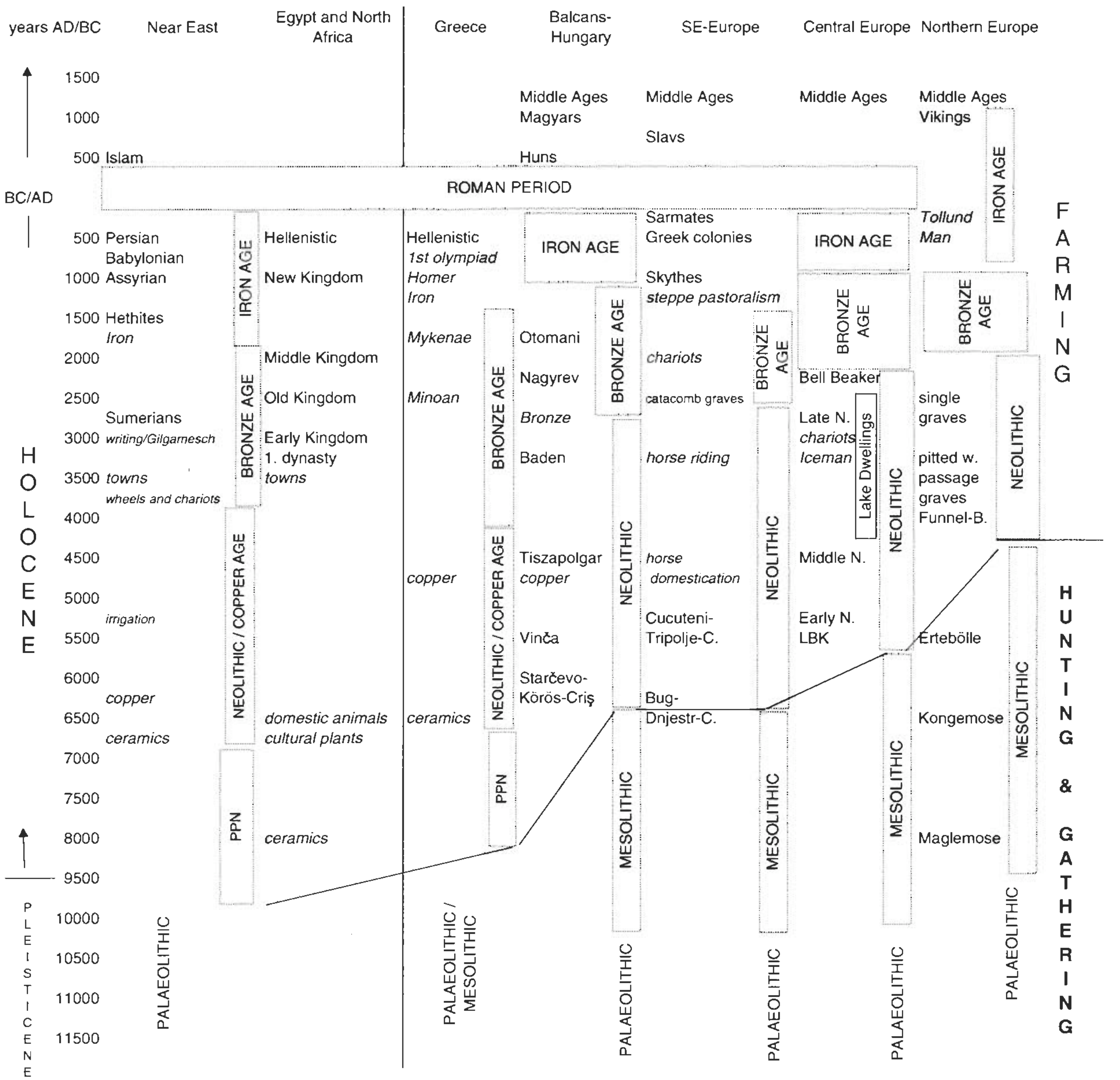
Table 1 The stages of food-provision, indicating for each phase the processes involved, the location where activities take place, and the key influencing cultural factors. The precise order of stages, particularly those between procurement and consumption can vary. Also the preparation stage may occur in more than one step. For example, raw resources may undergo preliminary modification prior to storage or distribution. Reproduced with permission from Samuel, D. 1999. Bread making and social interactions at the Amarna Workmen's village, Egypt. *World Archaeology* 31, 121–144 (Taylor and Francis Ltd, http://www.tandf.co.uk/journals)

Processes	*Stages*	*Location*	*Dominant cultural factors*
Collecting/ hunting/fishing	Procurement	Hunting/gathering/ fishing area	Economics: primary production; work organization; Technology of food production.
Cultivating/growing/animal husbandry		Farm/fishery/garden	Belief systems: what is/is not food.
Allocating/storing	Distribution	Granary/market	Politics: rent/tribute/tax/potlatch; divisions in domestic unit; decisions-on seed, sale, consumption; control of resources.
Processing	Modification/Preparation	Inside/outside dwelling Kitchen/other areas	Social: division and stratification of labour. Economics: technology of preparation.
Eating	Consumption	Table/eating area	Social: how organized; who participates; what is served. Belief systems: allocation of particular foods; prohibitions.
Clearing up	Disposal	Eating area/kitchen/rubbish area	Social: what is disposed of vs. consumed. Belief systems

Table 2 The archeological and supporting data which relate to each stage of food-provision. The table shows the potential abundance of the evidence which can be applied to the study of ancient food systems. Reproduced with permission from Samuel, D. 1999. Bread making and social interactions at the Amarna Workmen's village, Egypt. *World Archaeology* 31, 121–144 (Taylor and Francis Ltd, http://www.tandf.co.uk/journals)

Food provision stage	*Types of material remains*	*Supporting data*
Procurement	– plant remains – animal remains – resource procurement tools – human remains	– ethnography – experimental replication – biology
Storage	– silos – bins – storage vessels	– ethnography
Preparation	– hearths, ovens – other preparation installations – tools e.g. mortars, querns, flint & metal blades – vessels: pottery, metal, basketry – house layouts – food residues and remains – butchery marks	– ethnography – experimental replication – biology
Consumption	– vessels – house layouts – gut contents: known individual, short time – coprolites: unknown individual(s), short time – cess: known/unknown individual/group, variable time span – human remains: individuals, variable span	– ethnography – experimental replication (for digestive processes) – biology
Disposal	Remains disposed of: – vessels – preparation by-products – leftovers Condition of remains – e.g. whole vs. cracked bones Disposal patterns within/around settlement	– ethnography

Table 3 Chronology-Table: The last ca. 10,000 years are covered by most of the archaeobotanical investigations. Compiled by S. Jacomet © IPNA Basel University, based partly on P. Bogucky and P. J. Crabtree (eds.) 2004. *Ancient Europe 8000 B.C. – A.D. 1000.* Encyclopedia of the barbarian world, Vol. 1, The Mesolithic to the Copper Age (c. 8000–2000 B.C.)



fossilization) of biological remains (Schiffer, 1987; Jacomet and Kreuz, 1999, figure 4.8, p. 79). There are two aspects to consider when evaluating archeobiological data: structural and depositional evidence. Structures are what people construct (buildings, fences, wells, ditches, and pits). Deposits result either from deliberate human action, as for example storage of grains in pits or in disposing of rubbish, or they may result from indirect processes that are not intentional by humans, such as silting of ditches. Deposits will contain the vast majority of biological remains that are studied by environmental archeologists. These remains belong to different categories depending on how they reached the site (**Fig. 5**). Negative features (like pits) commonly become infilled following their abandonment (**Figs. 6** and **7**).

Figure 2 (A) Taking samples on an excavation (Biesheim-Kunheim, Alsace, France, Roman period, mainly 1st/2nd century AD): visible is a pit lined with wooden planks and filled with rubbish and cess, the preservation is waterlogged in the deeper areas of the pit (brownish sediments with high organic content). In the foreground, the wooden planks are sampled, in the background a white bucket is visible in which the soil samples are filled. (B–D) Examples of subfossil macroremains from the same site. (B) seed of *Vaccaria pyramidata*. (C) seed of *Agrostemma githago*. Both are weeds of winter-sawn crops. As far we know, *Vaccaria* was introduced by the Romans to the northern parts of Europe, whereas *Agrostemma* reached this region in late Neolithic times. (D) olive-stone (*Olea europaea*). Olives were imported from the Mediterranean in Roman times. Photographs made by S. Jacomet (A) and G. Haldimann (B, C and D), © IPNA Basel University.

The processes by which a site is buried will have a major impact on how well archeological and biological remains survive. Generally, material will be best preserved when burial is rapid and the energy levels by which the burying medium is deposited are low. A good example is the Roman town of Pompeji which was very rapidly buried by the eruption of the volcano Vesuvius in 79 AD, but we can find rapid burial also in Neolithic lakeshore and mire settlements in the lowlands surrounding the Alps (**Fig. 8**). The converse of the rapidity/energy correlation is also true: slow burial and high energies make for poor preservation and biological preservation is, therefore, likely to be minimal (Schiffer, 1987).

Preservation

Preservation of plant material from excavations may be different from that in natural sediments (**Fig. 9** and **Table 4**). Charring is the most common of all archeobotanical preservation types. It preserves plant material after it has been subjected to burning (or smoldering), transforming the plant parts (particularly the dense or woody parts) from a carbon-based compound to almost pure carbon (**Fig. 10**; Jacomet and

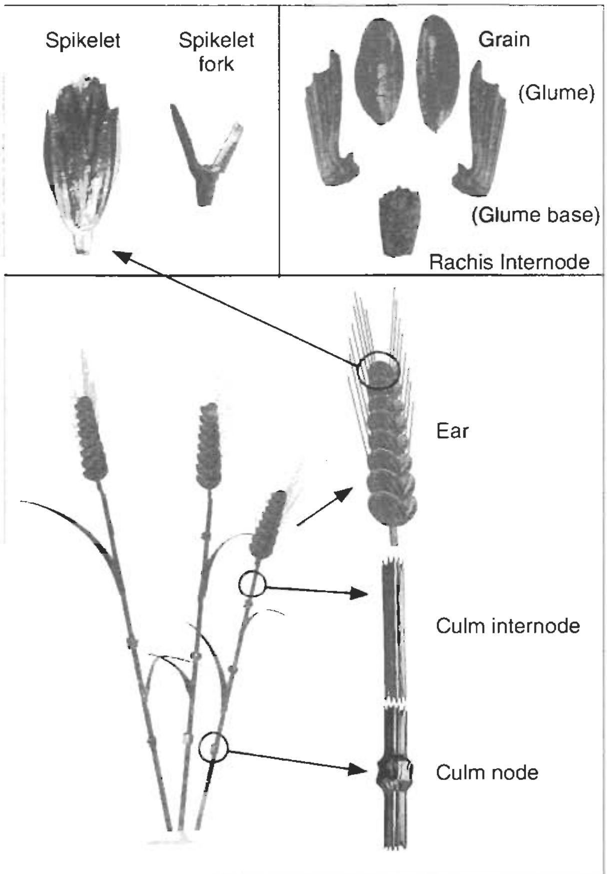


Figure 3 Cereal remain types, the example shows the component parts of hulled wheat. Reproduced with permission from Wilkinson and Stevens 2003, fig. 62, p. 159.

Figure 4 Impression of a cereal ear at the bottom of a pot. The example shows a tetraploid naked wheat (*Triticum durum* Desf./*turgidum L.*) or emmer (*T. dicoccum* Schübl.) from the Neolithic lake shore settlement Arbon Bleiche 3 (3384–3370 BC) at Lake Constance (Switzerland). Similar remains may also be preserved in burnt daub. The original biological fragment has been combusted during firing. Reproduced with permission from Jacomet, S., Leuzinger, U. and Schibler, J. 2004. *Die neolithische Seeufersiedlung Arbon Bleiche 3. Umwelt und Wirtschaft.* (Archäologie im Thurgau 12). Frauenfeld: Amt für Archäologie des Kantons Thurgau. Photograph made by D. Steiner, © AATG.

Kreuz, 1999; Wilkinson and Stevens, 2003). Potentially charred material can be recovered from any archeological site where fires have burnt or to which fire waste has been brought (so most commonly in settlement sites, but also, for example, in incineration graves). The most common type of charred plant remains is wood charcoal because wood is usually used to fuel fires. In addition, the most frequent charred remains are those resulting from the processing of food plants (like cereal grains, chaff, and the weed seeds that were accidentally harvested). Charred plant parts belong to different classes, according to the nature of their deposition (Table 5). Identifying which type is present on a site is a prerequisite in interpreting charred plant remains.

Mineralization usually occurs when minerals carried in solution are deposited around plant cell surfaces or within inner voids, effectively encasing the plant structure (Wilkinson and Stevens, 2003; Jacomet and Kreuz, 1999). The most common form of mineralization on archeological sites is as a result of calcium phosphate precipitated from cess. Therefore, mineralized remains are commonly found in middens, cesspits, latrines, sewerage systems, and comparable conditions and help to reconstruct what people were eating (Fig. 11). However, mineralization by other materials such as the metals bronze and iron have also been recorded. Note that plant remains are differentially preserved by mineralization, and some remains are not preserved at all. Those of edible species whose seeds and pips are often ingested and so associated with cess are overrepresented; examples are seeds of figs, grapes, blackberries/raspberries, *Apiaceae* (like fennel or coriander), and *Rosaceae* (like

Figure 5 Reconstructed farm houses ('pile-dwellings') of the 4th millennium BC at the open air Museum in Unteruhldingen (Germany): Primary material consists of building materials and tools. Secondary material would include charcoal from fires and by-products from construction, while tertiary materials would consist of re-worked primary and secondary material. Photograph © S. Jacomet.

plum and apple pips). However, cereal grains are rarely preserved by this mechanism.

Waterlogged plant remains are recovered from archeological features that contained water when they were dug, such as wells, cesspits, sewers, moats, and ditches (Fig. 7). But also whole layers may be preserved under the water table, like in the case of the circumalpine Neolithic and Bronze Age lake dwellings (Fig. 8). Waterlogging has the potential to preserve a much greater range of plant material than where plant material is preserved 'only' by charring or mineralization (Fig. 9 and Table 4).

Plant remains preserved by desiccation are commonly found in arid situations like deserts, but also in totally dry caves or rock shelters or inside houses (e.g., in false ceilings; Jacomet and Kreuz, 1999). Desiccation occurs when moisture levels are too low for the organisms responsible for organic decomposition to survive. Desiccation can also preserve remains

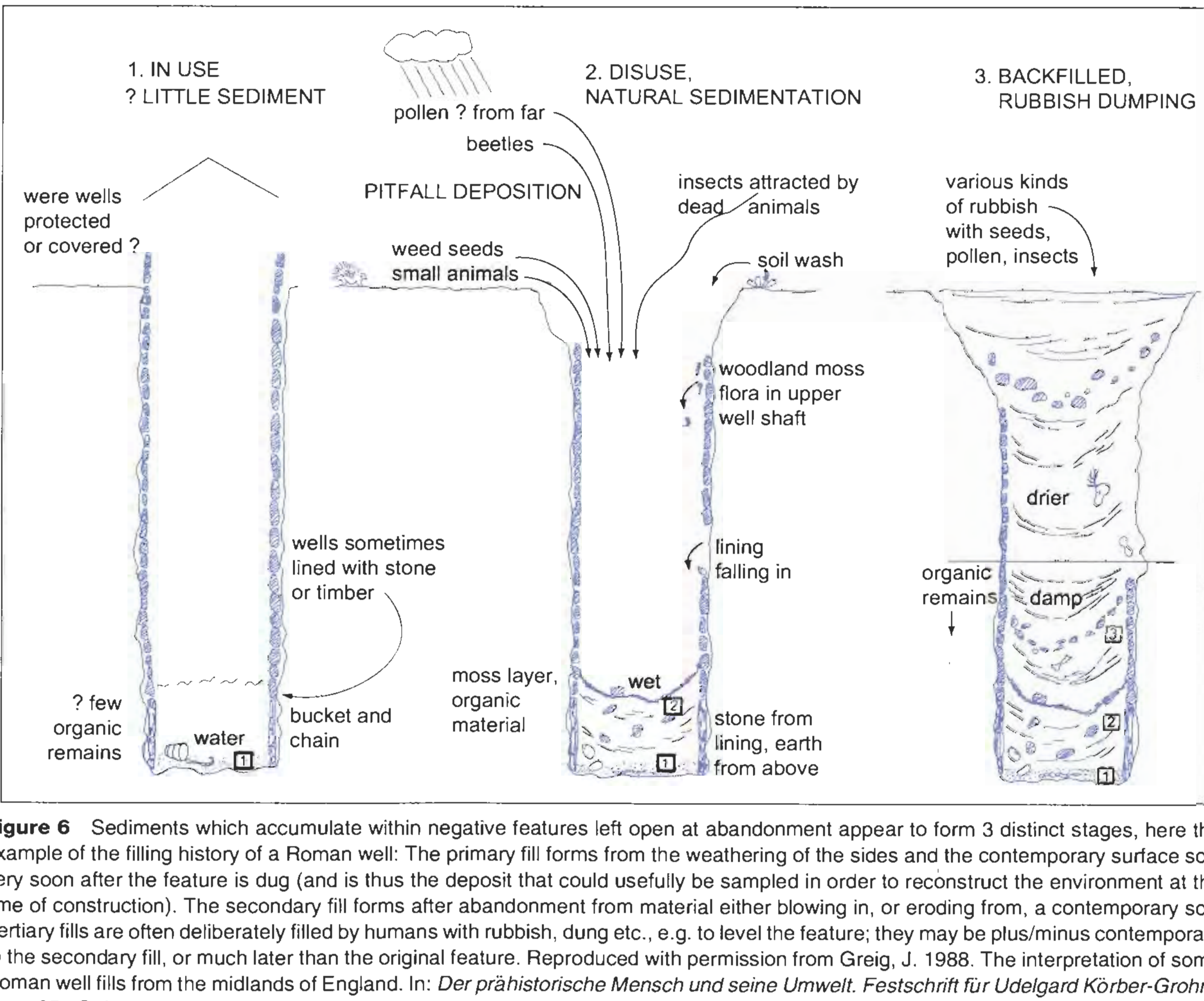


Figure 6 Sediments which accumulate within negative features left open at abandonment appear to form 3 distinct stages, here the example of the filling history of a Roman well: The primary fill forms from the weathering of the sides and the contemporary surface soil, very soon after the feature is dug (and is thus the deposit that could usefully be sampled in order to reconstruct the environment at the time of construction). The secondary fill forms after abandonment from material either blowing in, or eroding from, a contemporary soil. Tertiary fills are often deliberately filled by humans with rubbish, dung etc., e.g. to level the feature; they may be plus/minus contemporary to the secondary fill, or much later than the original feature. Reproduced with permission from Greig, J. 1988. The interpretation of some Roman well fills from the midlands of England. In: *Der prähistorische Mensch und seine Umwelt. Festschrift für Udelgard Körber-Grohne zum 65. Geburtstag* (*ed.* Küster, H.), (Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg Vol. 31), p. 367–378. Stuttgart: Konrad Theiss Verlag.

Figure 7 Wooden figure of a he-goat, made of oak-wood from a late Celtic (Iron-Age) pit at Fellbach-Schmiden (Baden-Württemberg, Germany). Reproduced with permission from Körber-Grohne, U. 1999. Der Schacht in der keltischen Viereckschanze von Fellbach-Schmiden (Rems-Murr-Kreis) in botanischer und stratigraphischer Sicht. In: *Die keltischen Viereckschanzen von Fellbach-Schmiden und Ehningen* (*ed.* Wieland, G.), (Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg Vol. 80), p. 85–149. Stuttgart: Konrad Theiss Verlag.

Figure 8 Parts of the buildings (wooden shingles, made of silver fir, *Abies alba*) in a destruction layer of Neolithic lakeshore settlement Arbon Bleiche 3 (3384–3370 BC), Lake Constance, Switzerland; these remains were embedded very rapidly after the site burned down, therefore they are preserved. Reproduced with permission from Jacomet, S., Leuzinger, U. and Schibler, J. 2004. *Die neolithische Seeufersiedlung Arbon Bleiche 3. Umwelt und Wirtschaft.* (Archäologie im Thurgau 12). Frauenfeld: Amt für Archäologie des Kantons Thurgau. Photograph made by D. Steiner, © AATG.

that are not otherwise found in the archeobotanical record, including whole fruits, flowers, leaves, vegetables (e.g., onion skins in graves of Pharaonic Egypt).

In frozen environments, low temperatures render most decomposing organisms inactive, therefore well-preserved plant remains are common finds. Probably the most famous such find is the Iceman from the Italian/Austrian border near the Similaun Glacier in a height of over 3,200 m above sea level (Dickson *et al.*, 2003). As with other examples of burials, the information from frozen bodies is often personal and concerns the last meal of the deceased, his last journey, the use of plant material for clothing, and artifacts (Fig. 12). However, the Iceman is preserved with his every-day equipment and clothing, thus shedding light on his lifestyle, in contrast to graves that are specially prepared 'death assemblages'.

Types of Plant Assemblages, Sampling

Most of the assemblages found on archeological sites are death assemblages (thanatocoenoses), containing materials from different places around a site and altered by human (or animal) action. Only rarely paleobiocoenoses may be preserved, for example an uncleaned harvest in a burnt layer just after harvesting.

Until it is understood how an archeological deposit formed, and how it was modified since its original placement, none of the paleoecological interpretation models can be used. Before these ideas can be applied we have to be able to assess the effects of processes operating during deposition and following burial, on the preservation, and integrity of archeobiological assemblages (i.e., the likelihood of all material at a particular level having been deposited at the same time).

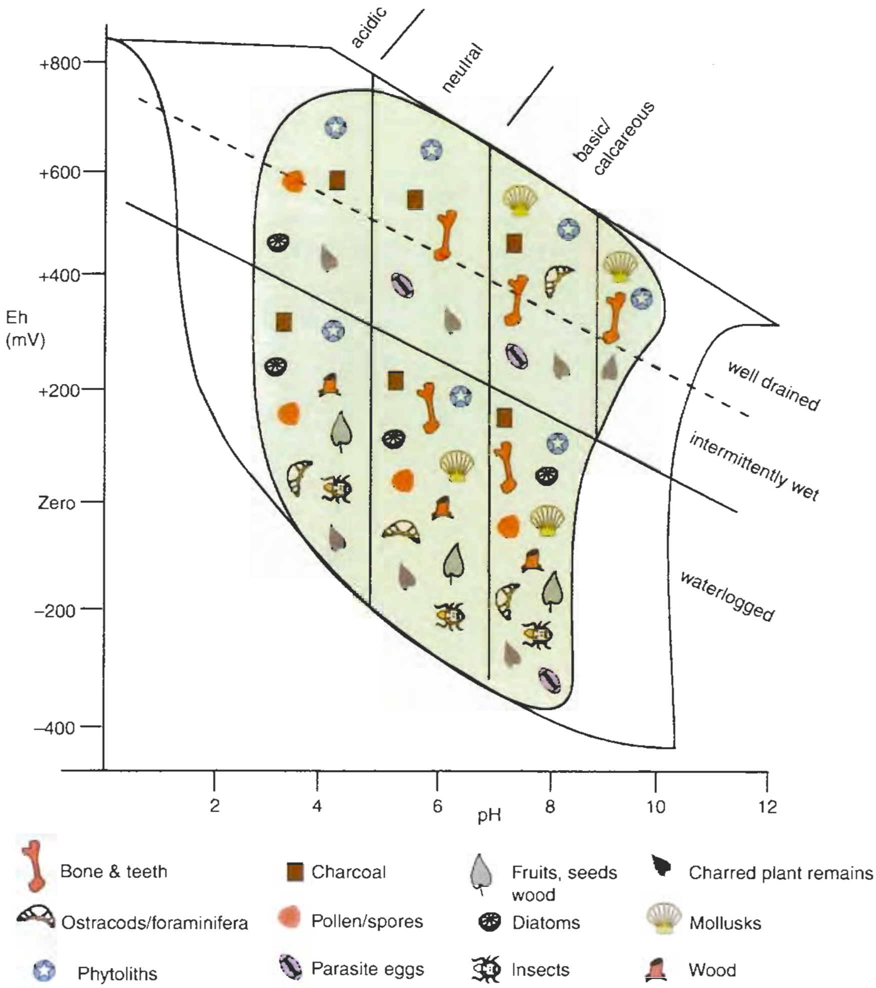


Figure 9 Schematic representation indicating under which depositional environments specific categories of environmental remains can be expected to survive and hence be recovered. If the material is preserved plus minus in its original form and only slightly altered, preservation is called sub-fossil. If the original material is replaced totally e.g. by charring, preservation is called fossil. The former only survive under specially favorable conditions like waterlogging, the latter under very different conditions, ranging from mineral soils to waterlogged and other conditions. The filled area marks an envelope into which most sediments fit. Reproduced with permission from Jones, D. M. 2002. Environmental Archaeology, A guide to the theory and practice of methods, from sampling and recovery to post-excavation. Swindon: English Heritage. © English Heritage 2002.

Knowledge of the formation of archeological plant assemblages is especially important at the stage of sampling. Plant macroremains on excavations are recovered from bulk samples of often many liters of volume, depending on the find densities of the structures excavated (**Fig. 2A**; for more details see Jacomet and Kreuz, 1999; and Wilkinson and Stevens, 2003). Samples should not be taken where their purpose is not understood or contexts are mixed or disturbed. Sampling of the deposits finally has to take account the spatial distribution of the material, to look at variation across a site or a structure (spatial sampling; **Fig. 13**). For mummified or frozen burials/bodies, small samples from the stomach or clothing may be taken (e.g., see Holden in Brothwell and Pollard, 2001 or Dickson *et al.*, 2003).

Recovery of the Plant Remains, Analysis, Identification, and Quantification

In several textbooks and papers the recovery of plant remains is described (**Fig. 14**; Pearsall, 2000; Jacomet and Kreuz, 1999). For the recovery of charred

Table 4 Different representation of plant remains under different preservation conditions. Adapted from Willerding in van Zeist *et al.* 1991, with permission. ch = chaff; st = straw, stems; sp = spikelets, ears etc.; l = leaves; f = fruit remains like capsule parts etc. +++ = commonly found; ++ = often found; + = rarely found. In Neolithic lake dwelling settlements e.g. over 99% of poppy seeds are preserved in uncarbonized state

Preservation / *Plant parts*	*Preservation*			
	Subfossil		*Charred*	
	Seeds	*Other remains*	*Seeds*	*Other remains*
Triticum (glume wheat)	+	ch sp st	+++	ch sp st
Triticum (naked wheat)	+	ch sp st	+++	ch sp st
Hordeum (barley)	+	ch sp st	+++	ch sp st
Secale cereale (rye)	+	ch sp st	+++	ch sp st
Avena (oat)	+	ch sp st	+++	ch sp st
Panicum, Setaria (millets)	++	ch	+++	
Fagopyrum (buckwheat)	+		++	
Pisum sativum (pea)	+	f	+++	
Lens culinaris (lentil)	+		+++	
Vicia faba (horsebean)	+	f st	+++	f
Linum usitatissimum (flax)	+++	f st	+	f
Papaver somniferum (poppy)	+++	f	+	f
Wild fruits (strawberry, blackberry...)	+++	f	+	f
Cultivated fruits (peach, cherry...)	+++	f	+	f
Vegetables	++		+	
Spices	+++	l	+	
Medicinal plants	+++	l	+	
Dye plants	+++	f	+	f
Weeds	+++	st f	+++	f
Other wild plants	+++		+	

remains flotation may be the suitable procedure, however, wet-sieving (combined with a wash-over-technique, see Kenward *et al.*, 1980) may also be appropriate. A pretreatment is necessary when the sediments contain clay (e.g., slow drying under low temperatures in a drying chamber and a subsequent soaking in water or deep-freezing and thawing). Sieving of waterlogged remains must be performed carefully to prevent the destruction of plant material. The best method is the use of the wash-over-technique with a gentle water jet. For strongly compacted organic sediments experiments showed that deep-freezing and subsequent thawing gives excellent results, whereas the use of potassium hydroxide should be avoided because it destroys fine organic parts (**Fig. 15**). In addition, the smallest sieve mesh should be not larger than 250–300 μm. In some cases (high density of desiccated plant remains or charred seeds) the samples may be put straight under the microscope for identification without processing. Those containing some sediment may be first dry sieved. For information about analysis techniques (including subsampling) see the textbooks of Jacomet and Kreuz (1999) and Pearsall (2000). For identification see Körber-Grohne in van Zeist *et al.* (1991). For the identification of wood see Neumann *et al.* (2001) and Schweingruber (1990). Of particular importance is a good reference collection. After identification, the grains, seeds, chaff, nutshell fragments, tubers, etc., are quantified for each sample that was investigated. Before a reliable quantification is possible, units which are counted have to be defined (e.g., one spikelet fork of a glume wheat counts as two glume bases). The resultant data are tabulated on a sample-by-sample basis with individual counts for each identified component. The best way to store data is a relational database, which forms also the basis for evaluations (e.g., see Kreuz and Schäfer, 2002).

Interpreting Proxy-Data from Archeological Sites

There are many differences in how those who study paleoenvironment and those studying paleoeconomy interpret their data. For the latter, it is of fundamental importance to compare sample data spatially and temporally both across a site, and between sites by

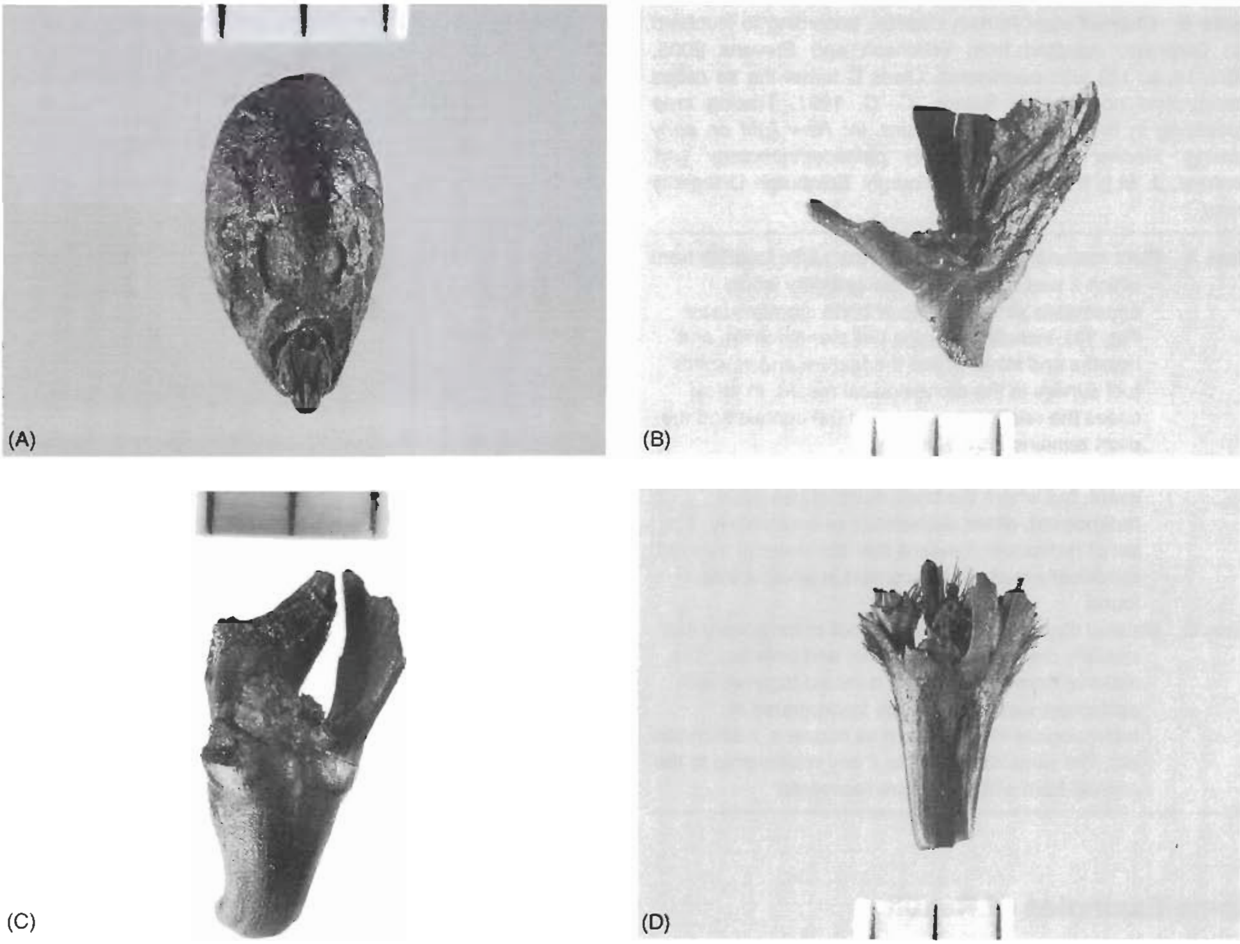


Figure 10 Some examples of carbonised plant remains: (A) Grain of emmer (*Triticum dicoccum*). (B) spikelet fork of emmer. (C) Rachis of tetraploid naked wheat (with bulbs below the insertion of the glumes; *Triticum durum/turgidum*). (D) Rachis of six-rowed barley (*Hordeum vulgare*). All remains come from the Neolithic lake shore settlement Arbon Bleiche 3 (3384–3370 BC), Lake Constance, Switzerland. Reproduced with permission from Jacomet, S., Leuzinger, U. and Schibler, J. 2004. *Die neolithische Seeufersiedlung Arbon Bleiche 3. Umwelt und Wirtschaft*. (Archäologie im Thurgau 12). Frauenfeld: Amt für Archäologie des Kantons Thurgau. Photographs made by G. Haldimann. © IPNA Basel University.

examining the proportions of key components. Comparison may be made by using densities, percentages, ubiquities, or more complex statistical techniques (see the textbooks of Jacomet and Kreuz, 1999, Pearsall, 2000; Wilkinson and Stevens, 2003 and Jones 1987; for different examples see the proceedings volumes of the International Work Group for Palaeoethnobotany conferences like Behre and Oeggl, 1996; Buxó *et al.*, 2005; and Jacomet *et al.*, 2002). Also worth mentioning is the concept of indicator groups (Hall and Kenward, 2003). In doing an evaluation it is important that samples are examined by class (Table 5), considering taphonomical processes.

Studying ancient environments based on on-site data uses similar approaches to other paleoecological studies. However, like natural environments, not all archeological environments have modern analogs as we know from many archeobotanical investigations of class A samples (Table 5). Especially problematic is that of premodern arable environments (G. Jones, 2002). As a result of these problems, few scientists apply uniformitarian principles rigidly. They use it as a method that can be applied when deemed appropriate rather than a piece of underlying theory which is universally applicable (e.g., see Behre and Jacomet in van Zeist *et al.*, 1991). It also recognizes that the scale of processes that operated in the past, both spatially and temporally, may have been very different from those observed at the present. Some new approaches are mentioned below (see Table 6).

Table 5 Charred plant remain classes, according to Hubbard and Clapham. Adapted from Wilkinson and Stevens 2003, Table 14, p. 152 with permission. Class C forms the so called "*background noise*" after Bakels, C. C. 1991. Tracing crop processing in the Bandkeramik culture. In: *New light on early farming. Recent developments in palaeoethnobotany* (ed. Renfrew, J. M.), p. 281–288. Edinburgh: Edinburgh University Press

Class A	Plant material that has burnt in the same location from which it was recovered. This category would encompass several types of burnt storages (see **Fig. 13**), including storage pits that catch fire and hearths and kilns, where the feature and its spent fuel survive in the archeological record. In these cases the relationship between the context and the plant remains is very strong.
Class B	Plant material that is charred during a single burning event, but where the burnt material has been redeposited, either deliberately or accidentally. The act of redeposition means that the material may not specifically relate to the context in which it was found.
Class C	Material that comes from a number of temporally and spatially distinct burning events and activities. The material from these events is mixed together with settlement waste to become incorporated in archeological features such as middens, rubbish pits etc. The remains have little if any relationship to the context from which they are recovered.

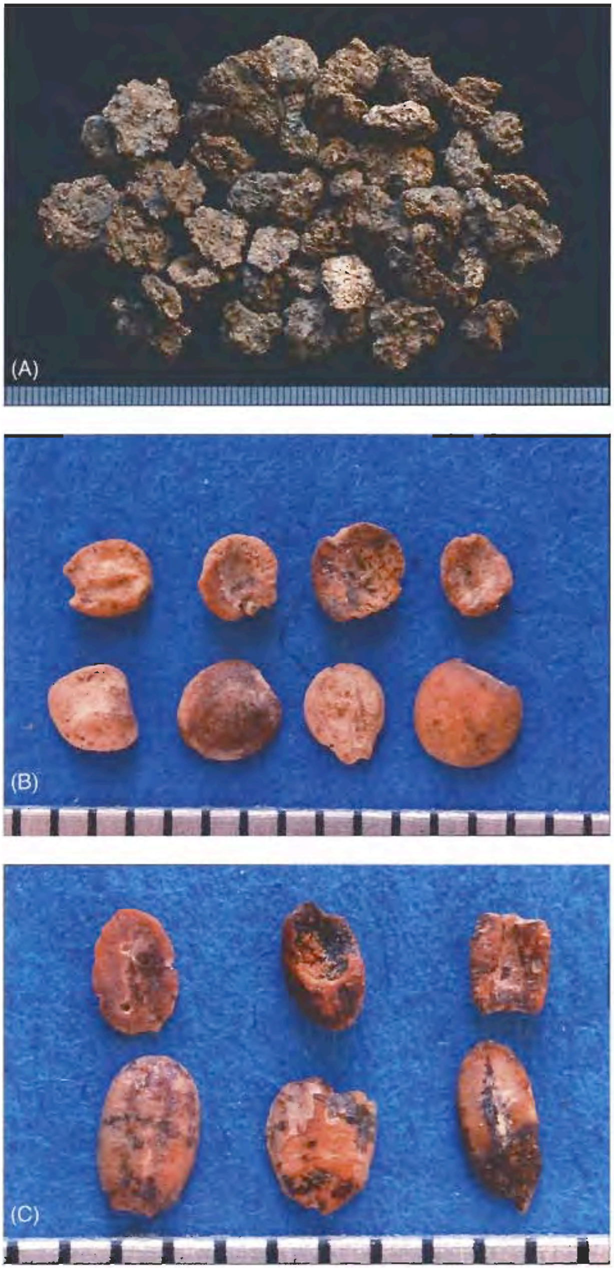


Figure 11 Mineralized cess and plant remains from Roman cesspits in the legionary camp of Vindonissa (Windisch, Switzerland), early 1st century AD. (A) fragments of cess. (B) seeds of coriander (*Coriandrum sativum*). (C) seeds of Apiaceae, probably dill (*Anethum graveolens*). Photographs U. Weber © IPNA Basel University.

Some Examples of Results

One of the prime goals in archeology is the deciphering of ancient society: for this, the study of past economies is of fundamental importance. By 'economy' archeobotanists are usually referring to the way people organized the production of food and how foodstuffs were distributed amongst the people and used (consumption; see Wilkinson and Stevens, 2003; how economy can be understood; see Charles and Halstead, 2001, in Brothwell and Pollard, 2001).

Wild Versus Domesticated Plants

Until around 10,000 years ago humans lived as hunters and gatherers; plant fruits such as almond, pistachio, etc., but also roots and tubers were collected from the wild. Around the transition from the Late Glacial to the Holocene, in several parts of the world people began to domesticate plants (Diamond, 2002). For example in the Near East ('Fertile Crescent') there were many places where sedentary life began in the upper Paleolithic when people still lived as hunter–gatherers (e.g., Tell Abu Hureyra in Syria; Hillman *et al.*, 2001; **Fig. 16**). The regular presence of domesticated plants, detectable on the basis of their morphology (**Fig. 17**), is usually noticed in the 'Pre-Pottery-Neolithic B' stage, from 8,500 cal yr BC onwards (**Fig. 3** and **Table 7**; e.g., Cappers and Bottema, 2002). Recently, new insights into plant domestication have been gained through the results of molecular biology (e.g., see Salamini

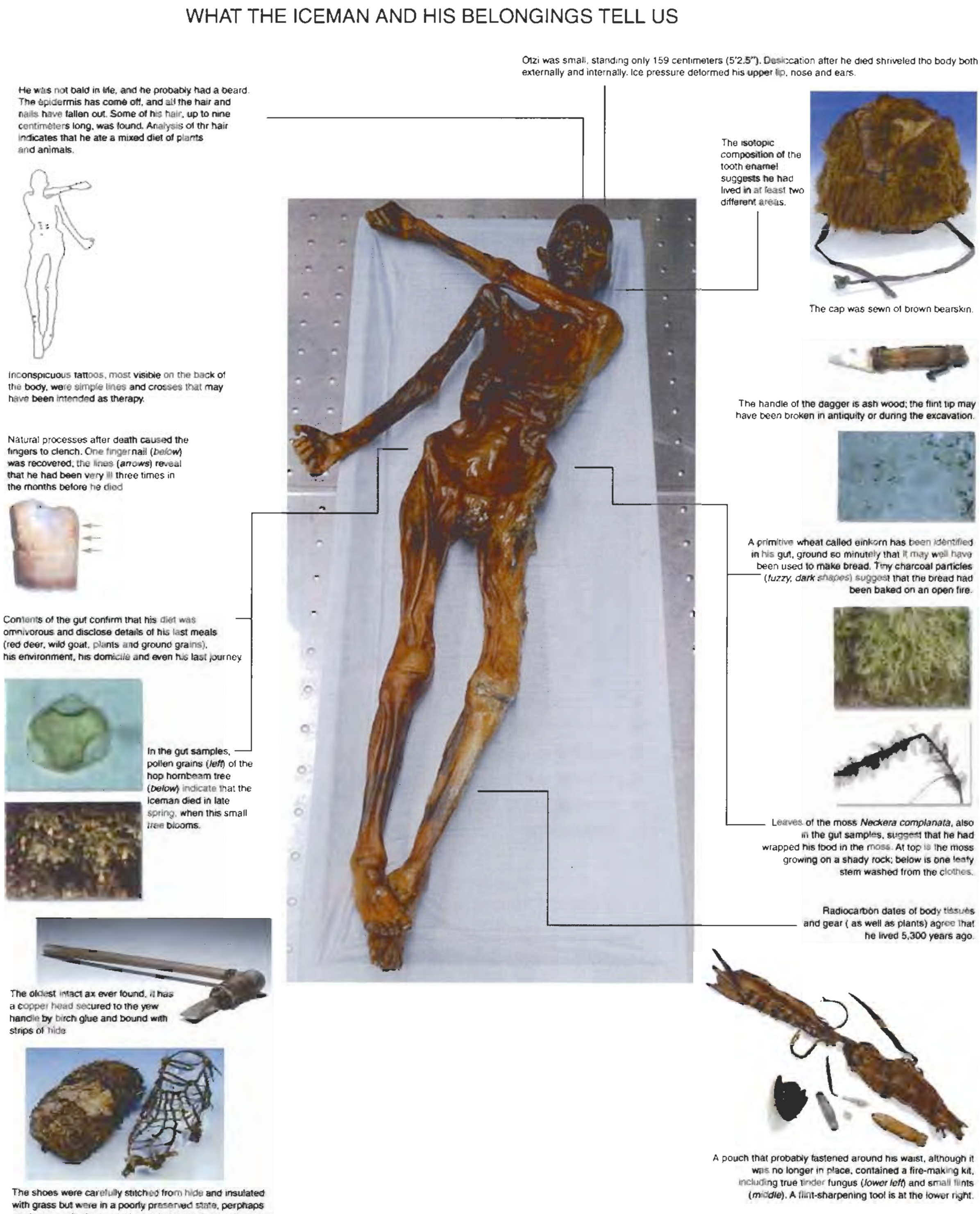


Figure 12 What the Iceman and his belongings can tell us (clothes, equipment etc.). A: The Iceman was small, standing only 159 cm. Desiccation after he died shrivelled the body both externally and internally. Ice pressure deformed his upper lip, nose and ears. He was not bald in life, and he probably had a beard. Some of his hair, up to 9 cm long was found. B: The oldest ax ever found, it has a copper head secured to the yew handle by birch glue and bound with strips of hide. C: The handle of the dagger is ash wood, the sheath is made of limebast-fibers and the lace of grasses. D: Flint sharpening tool made of lime-wood. E: A pouch (made of leather), probably fastened around his waist, contained a fire making kit, including true tinder fungus (*Fomes fomentarius*) and small flints. F: The shoes were carefully stitched from hide (of red deer, the sole of bearskin), inside the net and the isolation was made of grasses. G: The cap was sewn of brown bearskin. The Iceman can be taken as representative of how Neolithic people around 3350 BC would have been dressed and the objects that they would have used. Very few of them are recovered in more conventional archeological settings. Reproduced with permission from Dickson et al. 2003 (for more details see there).

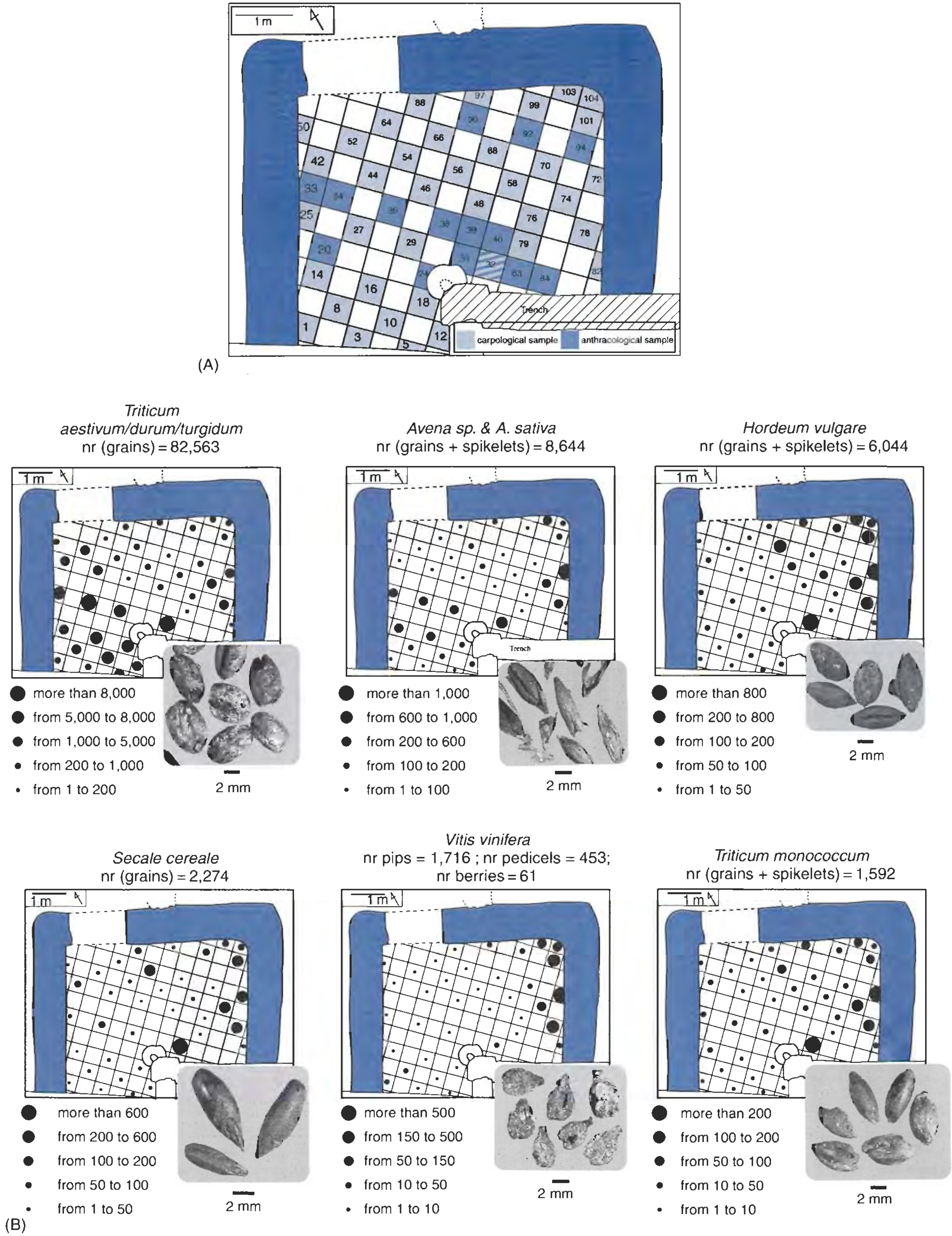


Figure 13 Example of spatial sampling and results: (A) location of the samples analyzed for seed and charcoal remains of a thick layer of carbonized material in an 11th century AD granary from southern France (La Gravette). (B) Spatial distribution of the most important foodplants in the granary (number of plant remains per liter). Reproduced with permission from Ruas, M.-P., Bouby, L., Py, V. and Cazes, J.-P. 2005. An 11th century A.D. burnt granary at La Gravette, south-western France: Preliminary archaeobotanical results. *Vegetation History and Archaeobotany* 14.

Figure 14 Sieving of a sample, using the wash-over technique. Photograph by D. Hager, © IPNA, Basel University.

Figure 15 Pictures of deep frozen (left side) and KOH-treated (right side) subfossil plant remains (rachises of rye, *Secale cereale*). They come from Roman (1st/2nd century AD) waterlogged deposits near Biesheim, Alsace (F). They will be published in Vandorpe, P. and Jacomet, S. in press. Comparing different pre-treatment methods for strongly compacted organic sediments prior to wet-sieving: a case study on Roman waterlogged deposits. *Environmental Archaeology*. Photographs made by G. Haldimann, © IPNA Basel University.

et al., 2002). Many of these results point to single domestication events. However, based on archeobotanical data, there is no evidence for a single center of origin; agriculture arose in widely separated geographic and climatic regions. What forced people to begin cultivation is a matter of debate. (see also Table 8).

History of Plant Growing and the Spread of Agriculture

First of all, in the Near East short-lived (annual) plants like cereals (different wheat and barley varieties), flax, and pulses (pea, lentil, and others) were domesticated (Zohary and Hopf, 2000). This stock of 'founder crops' then spread westwards and reached Central Europe around 5,500 cal yr BC (Fig. 18). Not all the early domesticated plants reached different parts of Europe together, and the spread of single cultivars is far from being fully understood (for details see Colledge and Conolly, in press). Concerning wheat species, the agriculture of the early Neolithic Linear Pottery Culture was based on einkorn (*Triticum monococcum*) and emmer (*T. dicoccum*). During the fifth millennium BC hexaploid naked wheat (*Triticum aestivum*) was an important crop in some settlements. In the fourth millennium BC, in the circumalpine Lake Dwellings, a tetraploid naked wheat (*Triticum durum/turgidum*, Fig. 10C) played a major role. First sure traces of spelt (*Triticum spelta*) cultivation come from the end of the Neolithic period in Central Europe. This robust glume wheat then became very widespread in Europe during the Bronze Age. The same holds also for millets (*Panicum miliaceum*, *Setaria italica*), domesticated plants originating from China. There are large spatial and temporal differences in the importance of the single cultivated plant species as well as their diversity in the Old World (Colledge and Conolly, in press); one of the reasons for this is probably cultural traits.

Only some 1,000 years after short-lived plants, woody plants also show traits of domestication. In the Near East, from the Early Bronze Age onwards (about the fourth millennium BC) figs, vines, dates, and olives belong to the domesticates (Zohary and Hopf, 2000). However, collecting wild plants did not stop after domestication: particularly in northern parts of Europe collecting played a very important role

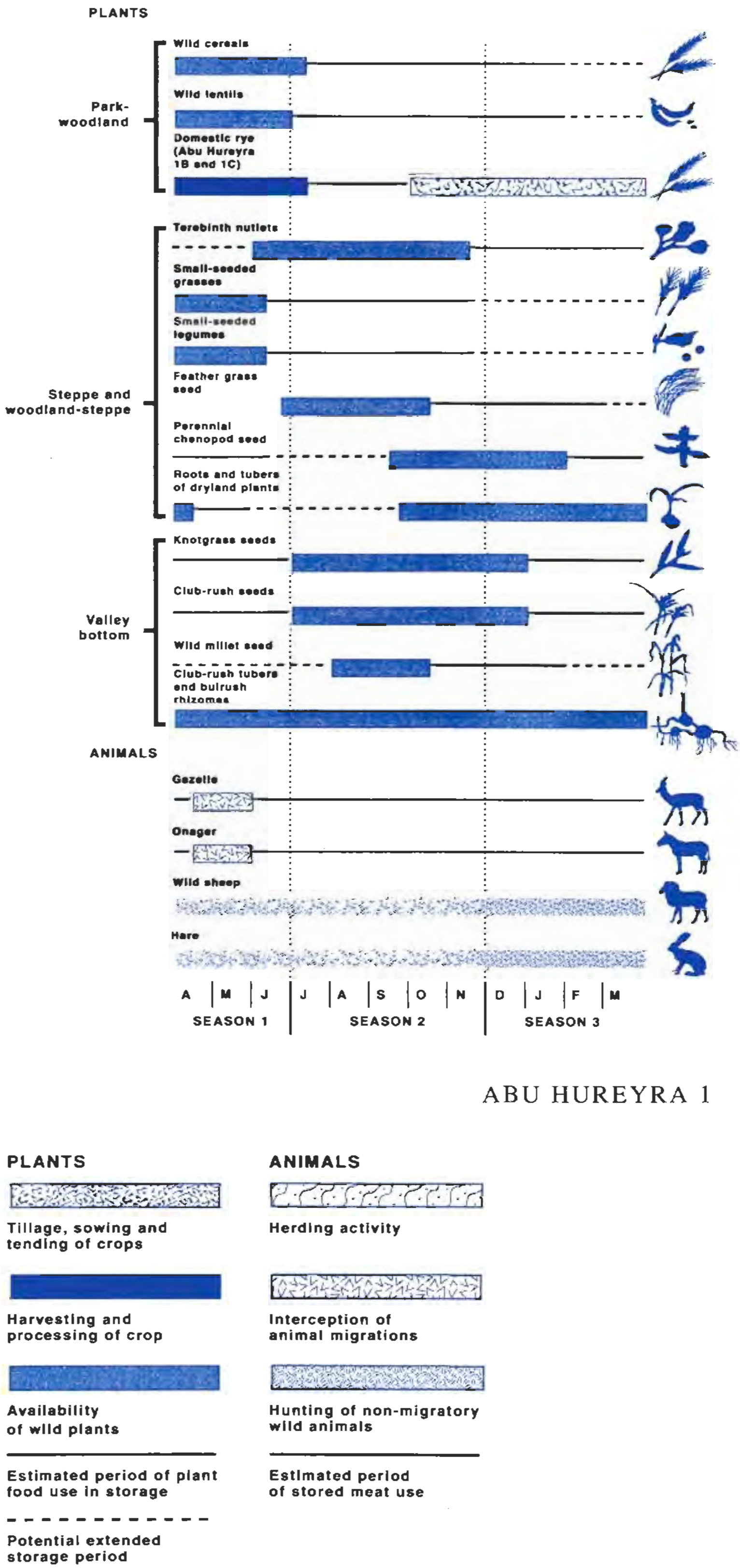


Figure 16 Tell Abu Hureyra, Syria: The seasons of availability and use of the main plant and animal foods, and crops used by the inhabitants during Phase I (before 11,000 BP uncal.), when this was a hunter-gatherer site. The investigation of the plant remains showed that the settlement was occupied year-round. Reproduced with permission from Moore, A. M. T., Hillman, G. C. and Legge, A. J. 2000. *Village on the Euphrates. From foraging to farming at Abu Hureyra.* Oxford : Oxford University Press.

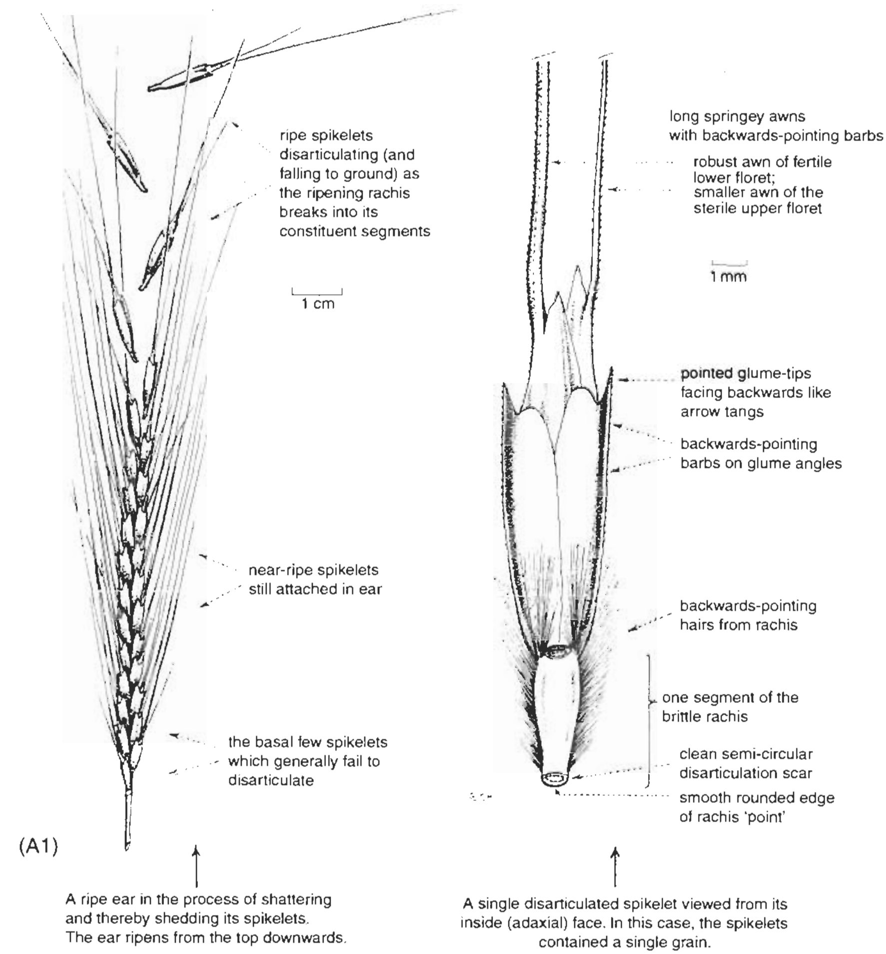


Figure 17 (A) Differences between wild and domesticated cereals. In the case of cereals, the former have brittle rachises and clean, semicircular disarticulation scars, whereas the latter show tough rachises and a rough breakage of rachis, leaving sharp corners which impede penetration. Reproduced with permission from Hillman, G. C. and Davies, M. S. 1992. Domestication rate in wild wheats and barley under primitive cultivation: preliminary results and archaeological implications of field measurements of selection coefficient. In: *Préhistoire de l'agriculture: Nouvelles approches éxpérimentales et ethnographiques* (*ed.* Anderson, P.), (Monographie du CRA Vol. 6), p. 113–158. Paris: Editions du CNRS.

(Fig. 19) until the widespread introduction of gardening during the Roman period. (see also Table 9).

Applying Biological Evidence to Economic Questions

Processing Techniques, Storage, and Food Preparation

The aim of growing a crop is to obtain a clean product that may be further processed into food. Information about how crops were processed and stored comes from both weed seeds and remains of the cultivated plant itself. After harvest of cereals, for example, the farmer is left with a great deal of mostly undesirable weed seeds, chaff, and straw. Ethnographic work (e.g., Hillman, 1984; Fig. 20) has demonstrated that there are relatively few ways (in the absence of modern machinery) in which the processing sequence of cereals can be carried out. Archeobotany successfully tried to assign charred assemblages to a single processing stage (**Fig. 21**). However, often assemblages result from an amalgam of all of the stages needed to obtain clean grain for storage. Then the charred plant remains will only provide information on how much processing had occurred prior to that stage. So, if there were only glumes, grain, and large weed seeds – like in many Roman settlements – it may be concluded that storage was as semiclean spikelets. Alternatively, if there are large numbers of small weed seeds, straw culms, and stems it may be concluded that cereals were stored either as sheaves or as partially threshed ears. After assessing how crops were stored scientists can begin to examine, for example, the spatial distribution of processing activities and storage. One of many examples is the investigation of a thick layer of

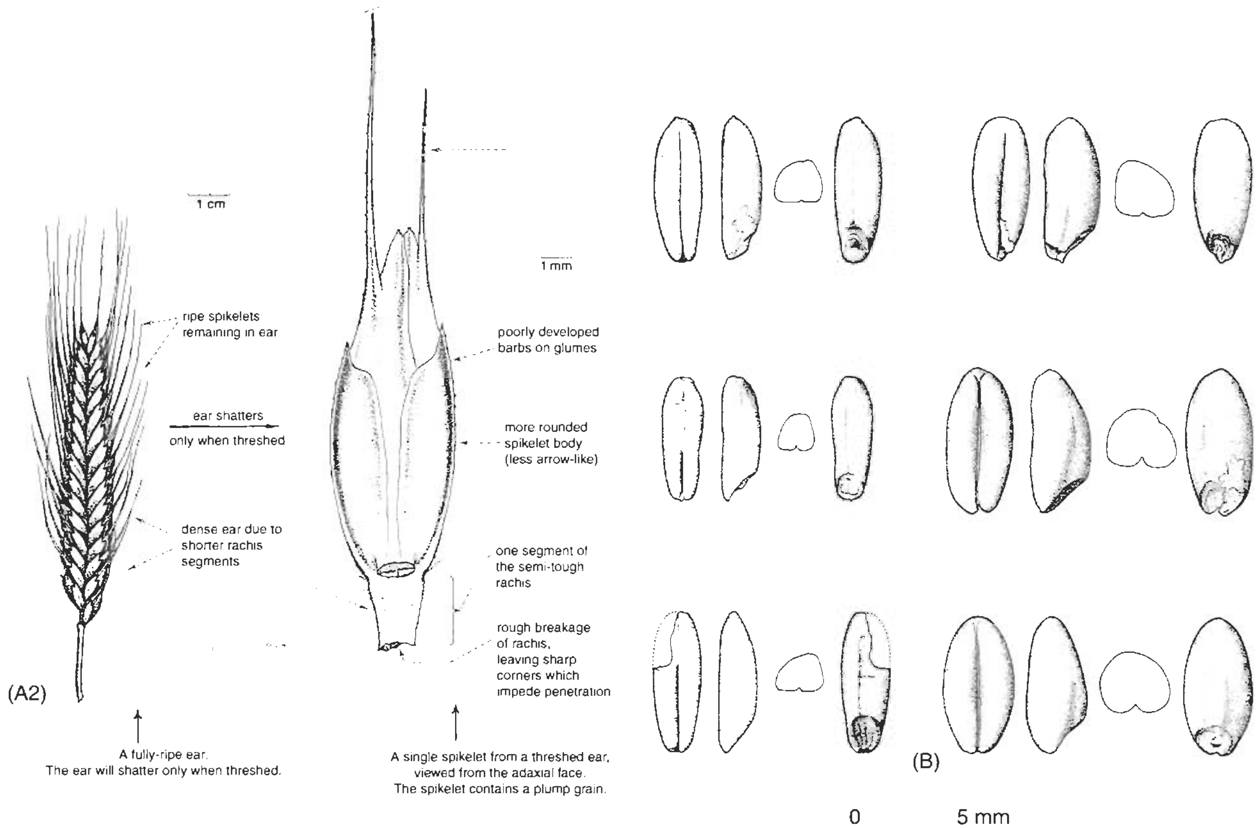


Figure 17 (B) examples of wild (left side) and domesticated (right side) cereal grains (here carbonized specimen of the glume wheat emmer, *Triticum dicoccum*, from Cayönü, Turkey): The former are smaller, the latter larger (Reproduced with permission from Zohary and Hopf 2000). The mentioned differences are visible in the archeobotanical material. However, in early sites it is often difficult to decide to which group a remain should be attributed.

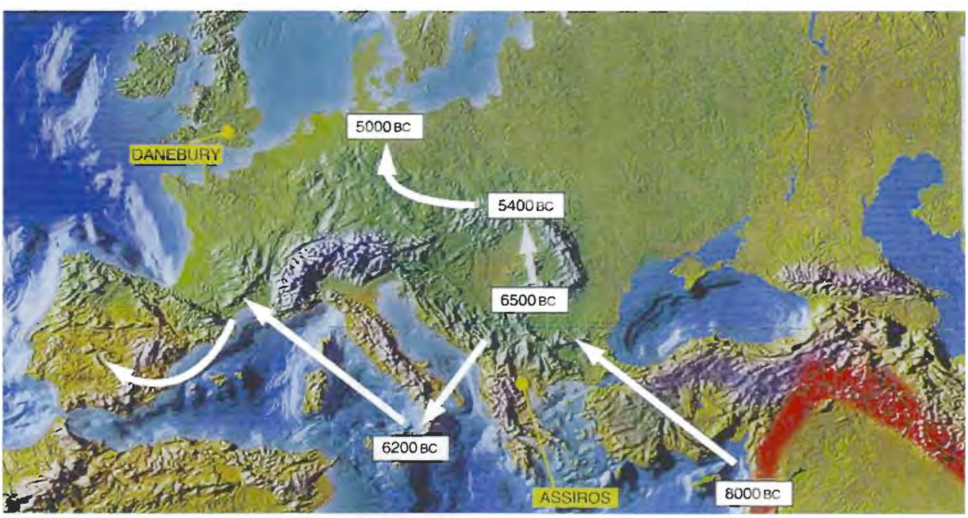


Figure 18 The origins and spread of agriculture from the Near East to Europe. The red shed area is the Fertile Crescent, where agriculture began some 10,000 years ago. Danebury and Assiros are two archeological sites where charred wheat remains containing Ancient DNA have been recovered. Reproduced with permission from Brown, T. und Jones, G. E. M. (2001) *New ways with old wheats*. Molecular Signatures from the Past (ed. by the Natural Environment Research Council) 9, 1–2.

Figure 19 Find of a halved wild apple from the Neolithic Lakshore settlement Arbon Bleiche 3 (3384–3370 BC), Lake Constance, Switzerland. Reproduced with permission from Jacomet, S., Leuzinger, U. and Schibler, J. 2004. *Die neolithische Seeufersiedlung Arbon Bleiche 3. Umwelt und Wirtschaft.* (Archäologie im Thurgau 12). Frauenfeld: Amt für Archäologie des Kantons Thurgau. Photograph made by D. Steiner, © AATG.

carbonized seeds in an eleventh century AD granary from southern France (**Fig. 13**). In the western part of the granary, naked wheat was stored in bulk. In the eastern part, various crops (at least naked wheat, barley, rye, oat, and grape) were stored in small amounts, most of which were probably separated by light, wooden structures made from hazelnut, maple, etc. The cereal crops had largely been processed and cleaned. The stored products probably represent taxes paid to the lord who owned the granary.

Although the procedures of processing seem to be efficient, analyses carried out on archeological bread, dough, excrement, and the contents of the stomachs of bog bodies often show that the operations did not result in clean grain, and bits of chaff, unground grain, and weed seeds still remained in the product eaten by people. Waterlogged plant remains from many bog bodies (at least partly dating to the Late Iron Age) have a rather high amount of weed seeds in their stomachs, as well as cereal chaff; the Grauballe man from Denmark had even whole spikelets of wheat in his stomach (Holden in Brothwell and Pollard, 2001). The excrement of the workers in the salt mines of Hallstatt (Austria; Iron Age) also contained many chaff remains. (see also **Table 10**).

Production and Consumption

Production and consumption are an integral mesh of activities and relationships (Wilkinson and Stevens, 2003). The most important aspect of production is that of food. Almost all foodstuffs derive from plants (salt is an exception). It was once argued that sites involved in the growing (producers) of plants could be distinguished from those receiving (consumers) plant products. On the one hand it was proposed that grain-rich assemblages from Iron Age Britain represent producer sites and weed/chaff-rich assemblages consumer sites. On the other hand it was argued – based on ethnographical data – that producer sites are characterized by the waste from early stages of crop processing. Therefore, a differentiating of consumer- and producer-sites, based on archeobotanical evidence only, is difficult. Variation in charred plant assemblages from the Late Iron Age in England is, for example, more likely to relate to differing storage practices, for example, of surplus-grain than consumption/production. Only when other – archeological – evidence is found (**Table 2**) is a more definitive interpretation possible. However, there are also clear cases of producer units like the Roman *Villae rusticae*. (see also **Table 11**).

Cultivation Techniques

Much of the information about the cultivation techniques comes from weed seeds. Unfortunately, at each stage of cleaning, processing removes more and more weed seeds, so the cleaner the grain when charred, the less evidence there is of cultivation practices. In any case the first step will be to analyze from which stage of cleaning the weed spectrum derives (**Figs. 20 and 21**). Helpful tools in interpreting weed assemblages are also experimental farming or an ethnoarcheological approach.

Weed species may be characteristic of environmental factors such as soil types, drainage, climate, and the specific cultivation practices employed by the farmer like manuring, tillage, sowing times, and weeding. This therefore provides a proxy for determining where past crops were grown (G. Jones, 2002). Based on the application of FIBS (Functional Interpretation of Botanical Surveys; Jones *et al.*, 2005) to Neolithic weed spectra, Bogaard (2004) concluded that in those times cereal farming was practiced on small, intensively worked and manured plots. There are other interpretations, however, including considering shifting cultivation. Larger fields seem to become widespread only from the Metal Ages onwards.

The presence or absence of seeds of weed species from the harvest will depend on the method of

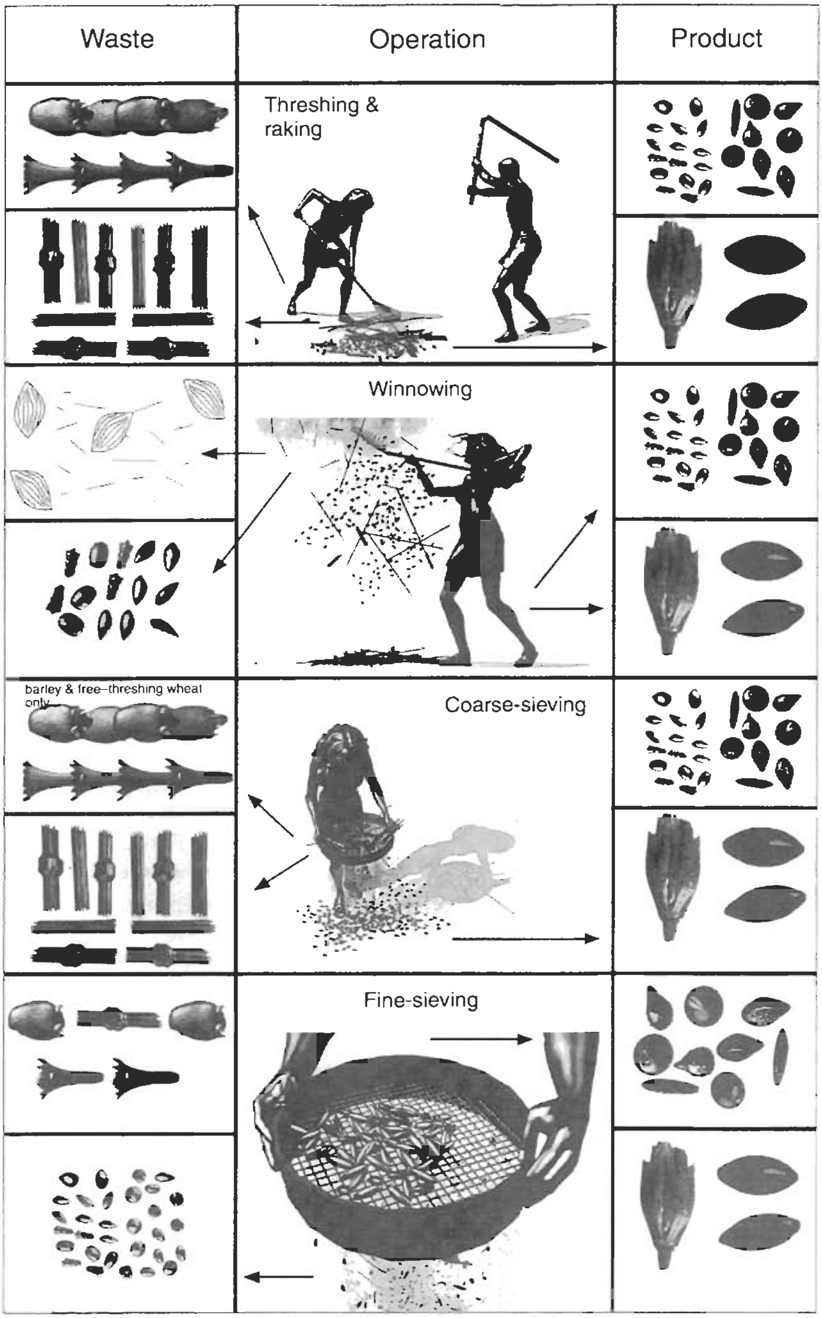


Figure 20 Crop processing stages for wheat and barley showing their effect on charred macrofossil assemblages, based on ethnographic work undertaken by Glynis Jones (Jones, G. E. M. 1983. The ethnoarchaeology of crop processing: seeds of a middle-range methodology. *Archaeological Review from Cambridge* 2, 17–26) and Gordon Hillman (1984) in Greece and Turkey respectively. Each stage produces both a well defined 'product' and 'waste'. Reproduced with permission from Wilkinson and Stevens 2003, fig. 74, p. 196–197.

harvest. For example, harvesting by sickle will remove cereals, rachises, some culms, and weeds. Harvesting low on the culm will bring in not only these weeds but also seeds of low-growing species such as clover (*Trifolium* sp.). Finds of many low-growing weeds from Late Bronze Age and Iron Age settlements in Europe suggest that harvesting was carried out with sickles or scythes (of which also evidence is found) low down the stem whereas in early Neolithic times high-growing weeds prevailed which points to totally different harvesting methods.

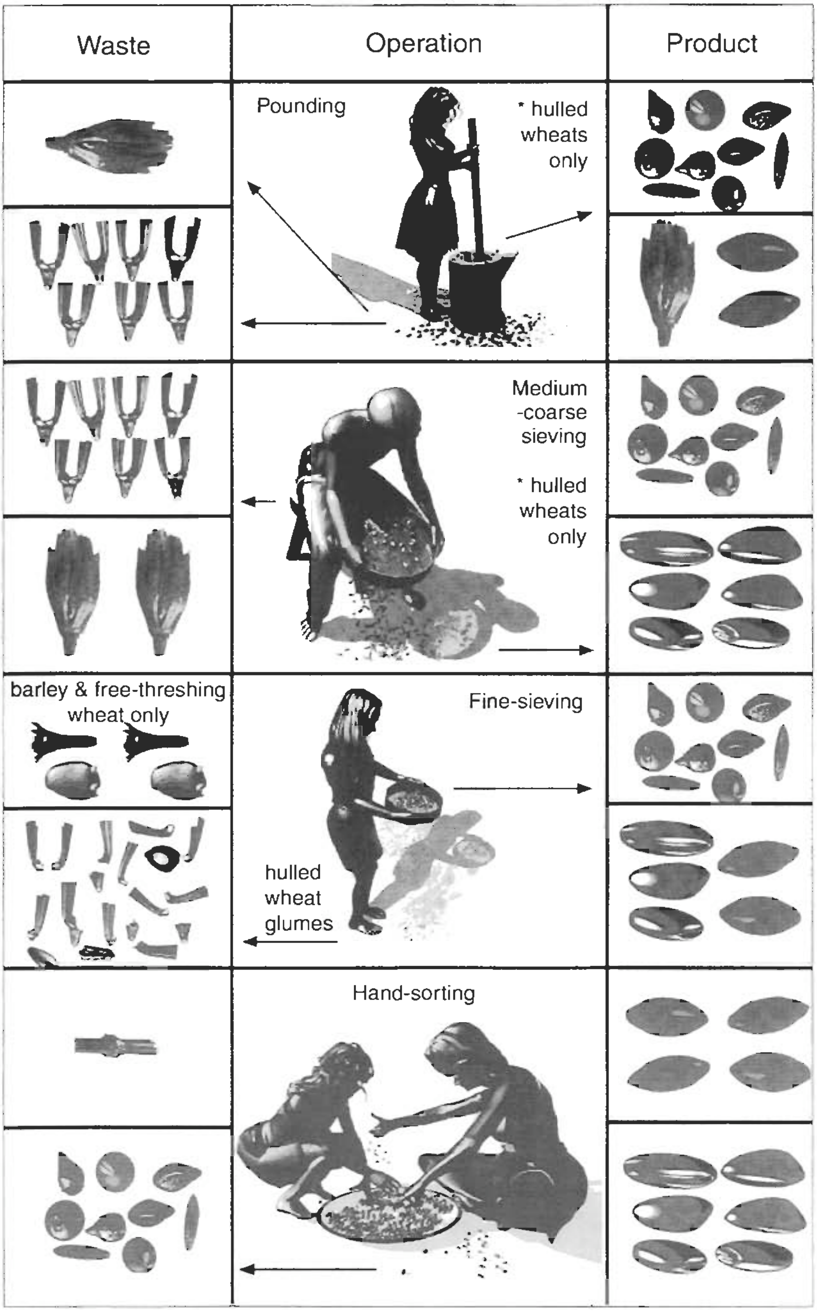


Figure 20 (*Continued*)

Archeobotanical investigations will allow the determination of the weed species composition of an arable field to some extent. However, an interpretation of the ratio of perennial-to-annual weeds concerning the type of tillage is not as straightforward (Bogaard, 2002) as thought. Newest results point to the fact that already in Neolithic times fields were intensely worked even though they contained more species of perennial weeds (e.g., creeping buttercup *Ranunculus repens*); these reproduce from fragments of root stem and so in fact benefit by more effective tillage. Only later, for example in medieval times, were crops with dominating annual species found, pointing to a

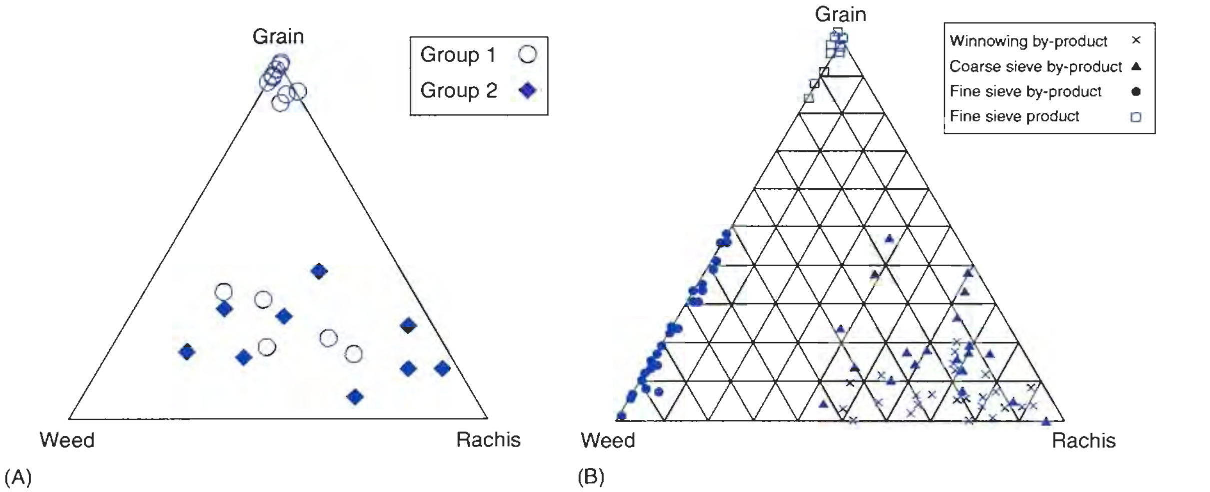


Figure 21 Assessing crop-processing stage from grain, rachis and weed-proportions. Diagrams (A) showing the relative proportions of grains (free threshing cereal only), rachis internodes and weed seeds for two groups of samples: 1: samples with at least 80% of hulled barley, n = 16 and 2: samples with less than 80% hulled barley, but at least 80% hulled barley and free-threshing wheat (n = 9). (B) Diagram showing the proportions of grains, rachis internodes and weed seeds in ethnobotanical samples from Amorgos (Early Bronze Age, Greece) of crop-processing products and by-products for free-threshing cereals (after G. Jones). Reproduced with permission from Charles, M. and Bogaard, A. 2003. Third-millenium BC Charred Plant Remains from Tell Brak. In: *Excavations at Tell Brak, Vol 2: Nagar in the third millenium BC* (*ed.* Oates, D., Oates, J. and McDonald, H.), (McDonald Institute Monographs Vol. 2), p. 302–326. Cambridge: MCDonald Institute for Archaeological Research and British School of Archaeology in Iraq.

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Table 7 Archeobotanical records for cereals in the Epipaleolithic and Pre-Pottery Neolithic periods. Shaded box indicates identification based on chaff (and thus, most reliable); dotted box indicates identification based on grain alone. ? indicates uncertain identification. Abbreviations: EIN Einkorn; EM Emmer; BAR Barley; NAK WHT Free-threshing (naked) wheat; DOM domesticated. Reproduced with permission from Nesbitt, M. 2002. When and where did domesticated cereals first occur in southwest Asia? In: *The Dawn of Farming in the Near East* (*ed.* Cappers, R. T. J. and Bottema, S.), (Studies in Early Near Eastern Production, Subsistence, and Environment Vol. 6), p. 113–132. Berlin: ex oriente.

Site (phase)	Country	Period	Date (uncal. years BP)	Crop status	WILD EIN	WILD EM	WILD BAR	WILD RYE	DOM EIN	DOM EM	NAK WHT	DOM BAR	NAK BAR	DOM RYE
Ohalo II	Israel	Epipal. (Kebaran)	19400	Wild										
Wadi al-Hammeh 27	Jordan	Epipal. (Natufian)	12200-11900	Wild										
Iraq ed-Dubb (below)	Jordan	Epipal. (Natufian)	11200-10800	?										
Hayonim Cave & Terrace	Israel	Epipal. (Natufian)	12300-10000	Wild										
Abu Hureyra (I)	Syria	Epipal. (Natufian)	11500-10000	Wild										
Mureybit (I-III)	Syria	Epipal. & PPNA	10500-9600	Wild										
Qermez Dere	Iraq	PPNA	10150-9600	Wild										
Netiv Hagdud	Israel		10000-9400	Wild										
M'lefaat	Iraq		9900-9650	Wild										
Iraq ed-Dubb (structures)	Jordan		9950	?										
Jerf al Ahmar	Syria		9800-9700	Wild										
Tell Aswad (I)	Syria		9700-9300	?										
Jericho (VIIA-X)	Palestine		9400-9200	?										
Dja'de	Syria	Early PPNB	9600-9000	Wild	?									
Wadi el-Jilat 7	Jordan		9500-9200	?										
Nevalı Çori	Turkey		9250	Dom.										
Çayönü (grill-cobble)	Turkey		9200-8600	Dom.		?								
Nahal Hemar (3-4)	Israel		9200-8100	Dom.										
Cafer Höyük (XIII-IX)	Turkey		9200-?9000	Dom.				?						
'Ain Ghazal	Jordan	Middle PPNB	9200-8000	Dom.										
Beidha	Jordan		9100-8550	Dom.										
Ganj Dareh	Iran		9000-8400	?										
Abdul Hosein	Iran		9000-8400	Dom.										
Abu Hureyra (2A)	Syria		9000-8300	Dom.										
Cafer Höyük (III-IV)	Turkey		9000-8500	Dom.										
Tell Aswad (II)	Syria		8900-8500	Dom.										
Aşıklı Höyük	Turkey		8800-8500	Dom.										
Jericho (Tr I: XII-XXIII)	Palestine		8800-8650	Dom.										
Wadi el-Jilat 7	Jordan		8800-8500	Dom.		?								
Ghoraife	Syria		8800-8300	Dom.										
Jarmo	Iran		8750	Dom.										
Ali Kosh (BM)	Iran		8750	Dom.										
Halula	Syria		8700-7900	Dom.					?					
Tell Sabi Abyad II	Syria	Late/Final PPNB	8500-8000	Dom.										
Wadi Fidan A	Jordan		8500-8100	Dom.										
Ras Shamra (Vc)	Syria		8500-8000	Dom.										
Gritille	Turkey		8500-7800	Dom.										
Can Hasan III	Turkey		8400-7700	Dom.										
Azraq 31	Jordan		8350-8300	Dom.										
Dhuweila (I)	Jordan		8350-8200	Wild										
Tell Bouqras	Syria		8350-7850	Dom.										
Tell Ramad (I)	Syria		8300-8100	Dom.										
Abu Hureyra (2B)	Syria		8300-8000	Dom.										
Wadi Fidan C	Jordan		8100-7600	Dom.										
El Kowm II - Caracol	Syria		7800-7700	Dom.										
Atlit-Yam	Israel		7700	Dom.										

permanent cultivation of larger fields. The presence of winter annuals from Neolithic times onwards points to winter- and summer-cropping.

Usually, there are many evidences that crops were grown separately. However, there are also hints on maslins in several periods. This seems to be reasonable as a risk-minimizing strategy. However, another possibility is that those crops were grown as fodder. (see also Table 12).

Some Other Aspects of Archeobotanical Research

There are many more aspects of archeobotanical research of which only some can be mentioned here. The analysis of plant remains from animal dung allows a thorough reconstruction of the foddering. Wood was carefully chosen depending on its properties. First traces of widespread grassland occurred in

Table 8 Further reading: Hunter/gatherer diet, domestication of plants

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northern parts of Europe from the Bronze and mainly the Iron Age onwards. In parts of Europe, north of the Alps since the Roman period there was a widespread trade. 'Exotic' species like pomegranates, dates, pepper, anis, etc. appear already in early Roman contexts. It is also obvious that gardening was introduced by the Romans in regions outside the Mediterranean. Cultivated cherry, apple, peach, walnut, etc., but also legumes and spices like coriander are regularly found north of the Alps from Roman times onwards. There are hints that some 'luxurious' foodstuffs were eaten only by socially higher ranked people like officers of the army (van der Veen, 2003). There were also fundamental differences between the 'mass production' of food in the roman villas and agriculture outside the Roman empire (e.g., in the Germania libera).

The interpretation of bioarcheological material may allow also the reconstruction of aspects of rituals (Wilkinson and Stevens, 2003). These are actions that are associated consciously or subconsciously with symbolic meaning. For instance, many burials have ecofacts that are buried with them, such as plant remains that accompany artifacts and personal belongings. These may be remains of funeral feasts, food to sustain the individual on their journey to or within the afterlife, or offerings to buy their way in. Desiccated offerings of plant foods are a frequent feature of Egyptian burials. Many plant offerings including figs, dates, grain, sesame, and wreaths of

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lotus, olive, willow, cornflowers, mayweeds, and various fruits were found in Tutankhamen's tomb. In incineration graves from the Roman period many carbonized food remains can be found. From temples, remains of burnt food offerings have been recorded from Roman Europe. (see also Table 13).

Abbreviations

cal yr	calendar year
FIBS	Functional Interpretation of Botanical Surveys

See also: **Dendrochronology**; **Plant Macrofossil Introduction**. **Quaternary Stratigraphy**: Overview.

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