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Hulled Wheat

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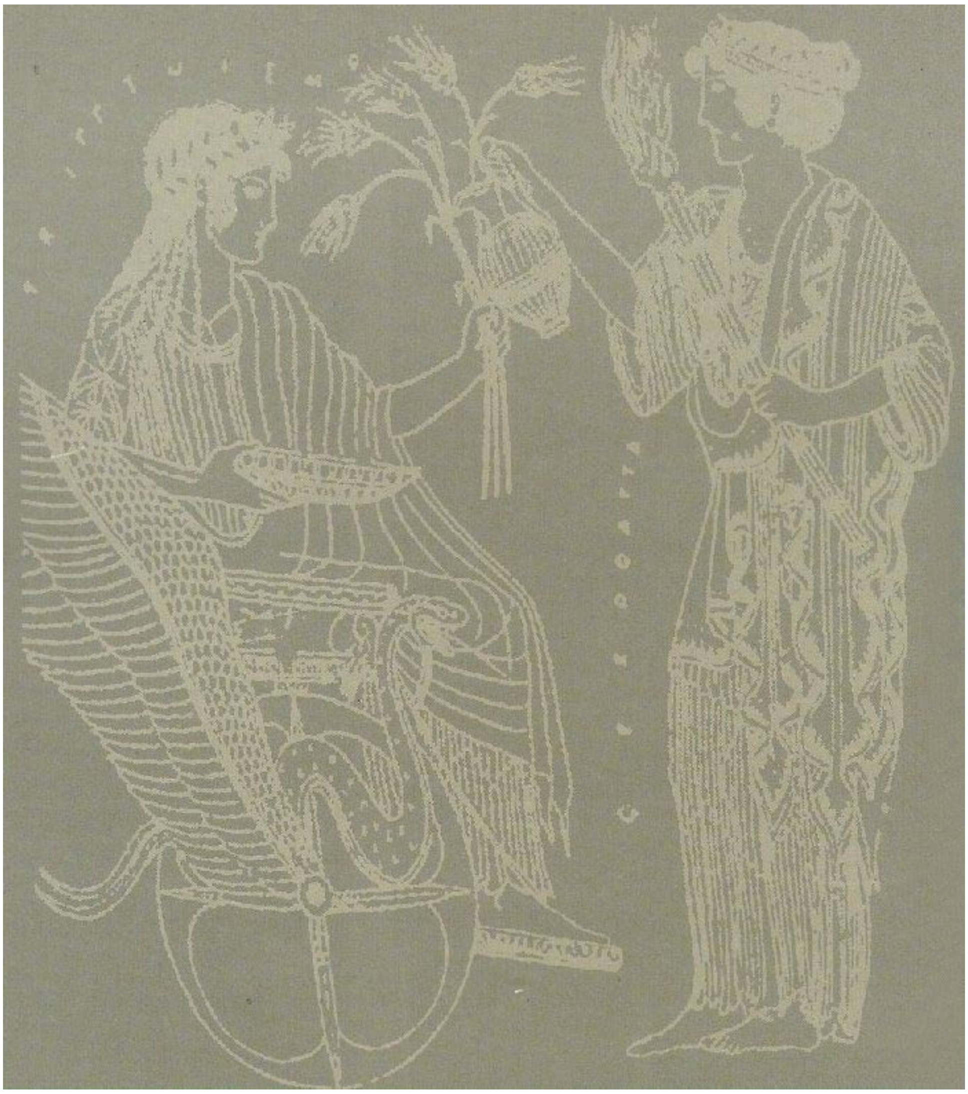

From staple crop to extinction? The archaeology and history of the hulled wheats

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General aspects

Introduction

The importance of the hulled wheats in past societies is hardly reflected in their current status as minor, ever-declining crops in isolated, marginal areas. Yet the hulled wheats were among the earliest domesticated plants, spread over Eurasia from the British Isles to central Asia, and were staple crops for many millennia. Our aim is to outline the history of the hulled wheats from domestication to classical antiquity, focusing on some key research questions. We will concentrate on the evidence of archaeobotany – the study of plant remains from archaeological excavations – because this is direct evidence for the presence and use of hulled wheats in the past. Textual evidence – whether from clay tablets or medieval manuscripts – presents major difficulties in interpretation, some of which are discussed later on.

The history of the hulled wheats is to a considerable extent the history of agriculture. Inevitably we have had to be highly selective in what we cover, and have relied mainly on secondary sources. We hope at least to offer a reasonably comprehensive guide to the general literature, to discuss critical issues in some detail, and to offer some thoughts on how to tackle some of the major problem areas in the history of hulled wheats. Special acknowledgements are due to van Zeist *et al.* (1991) and Zohary and Hopf (1993), on whom we have drawn heavily.

Areas that we have covered in detail include evidence for the domestication of hulled wheats, their spread in all directions from the Near East, and their role in the ancient civilizations of Egypt and Mesopotamia. We end with a brief survey of the place of hulled wheats in the classical world, and their decline in western Europe. Before tackling these topics, we thought it useful to survey some more general areas. Since much confusion has arisen about how the hulled wheats are processed, we discuss this topic at some length, and in particular whether parching is necessary for dehusking. Nomenclature and archaeobotanical identification criteria are also briefly discussed.

The archaeological chronology for Europe and the Near East draws on two sources. Texts provide enough information to allow us to assign approximate calendar dates back to the Early Bronze Age in the Near East and the Classical period in Europe. Before that, most dates depend on radiocarbon dating, which systematically underestimates the ages of ancient objects: for example, a seed radiocarbon dated to about 4500 years ago would in fact be about 5200 calendar years old. Until recently, radiocarbon dates earlier than about 5000 years ago could not be calibrated, but calibrated dates are constantly being pushed back by tree-ring dating. In the archaeological literature there is therefore a (usually unspoken) divide in precision of dates, around 3000 BC. In this paper we show calendar year or calibrated radiocarbon dates as BC/AD, and uncalibrated radiocarbon dates as bc/ad.

Numerous references to the scarcity of archaeobotanical data will be made in this paper; these do not reflect any lack of plant remains at archaeological sites, but rather the very uneven application of the highly effective flotation techniques developed since the 1960s (Nesbitt 1995b). In general, more effort has been made to recover plant remains from early sites (Neolithic or pre-Neolithic), and from sites in the Near East and Britain, the Netherlands, Switzerland and Germany. Recovery of plant remains in other areas is still limited and rarely employs large-scale flotation techniques. It is thus problematical to compare sites, both on a local scale and on a broad geographical scale. This in turn means that patterns of use for hulled wheats over time and in different regions are sometimes difficult or impossible to trace on current evidence.

Nomenclature

The wheat genus (*Triticum* L.) has been subjected to a confusing array of taxonomic treatments (Morrison 1993; van Slageren 1994). Perhaps the only area of general agreement is that none of the existing treatments satisfactorily combines phylogenetic realities with ease of use.

In this paper we will refer to the three main domesticated hulled wheats by their common names: einkorn, emmer and spelt. When wild einkorn is referred to, it usually includes *T. urartu* and *T. boeoticum*; similarly, wild emmer refers to both *T. dicoccoides* and *T. araraticum*. The rarer cultivated species and the other wild wheats will be referred to by their botanical names, following for convenience the traditional concept of wheat species as outlined by Dorofeev and Migushova (1979). Botanical names and common names of hulled wheats are shown in Table 1. We use macaroni wheat to refer to tetraploid free-threshing wheat *(T. durum* Desf. /*T. turgidum* L.) and bread wheat to refer to hexaploid free-threshing wheat *(T. aestivum* L. in the widest sense). Common names for hulled wheats have led to a great deal of confusion in past literature, particularly through the use of ‘spelt’ as an all-inclusive term. Our terminology, as outlined above and in Table 1, represents standard use of these common names today.

The names used for different parts of the spike of hulled wheats are shown in Figures 1 and 2; see also Charles (1984).

What is distinctive about the hulled wheats?

As the name suggests, the main character that separates the hulled wheats from the free-threshing wheats is the persistent enclosing hull. When a spike of hulled wheat is threshed, it breaks up into its component spikelets, each consisting of tough glumes attached to a rachis segment. Each spikelet encloses one or more grains. When a free-threshing wheat – for example, macaroni or bread wheat – is threshed, the rachis segments stay attached to each other, while the glumes and other chaff break, releasing the free grain (Fig. 1). The hulled character is the result of two differences in the structure of the spike: the semi-brittle joints between the rachis internodes, and the toughened glumes. This has major implications for crop processing, discussed in the following two sections.

Hulledness in wheat involves other important characteristics. The thick, tough glumes of hulled wheats give excellent protection to the grains in the field and in storage. The fact that hulled wheats are mainly grown in mountainous areas today is not simply a result of their isolation; hulled wheats do seem especially resistant to poor soil conditions and a range of fungal diseases.

Table 1. Common and botanical names of wild and domesticated hulled wheats, arranged by genetic characteristics. Botanical names are according to Dorofeev and Migushova (1979).

Ploidy level	Common name	Botanical name	Wild or domesticate	Genome formula
Diploid	Wild einkorn	*T. boeoticum* Boiss.	Wild	A
		T. urartu Thum. ex Gandil.	Wild	A
	Einkorn	*T. monococcum* L.	Domesticate	A
Tetraploid	Wild emmer	*T. dicoccoides* (Körn. ex Aschers. et Gräbn.) Schweinf.	Wild	AB
		T. araraticum Jakubz.	Wild	AG
	Emmer	*T. dicoccum* (Schrank) Schübl.	Domesticate	AB
		T. palaeocolchicum Menabde	Domesticate	AB
		T. ispahanicum Heslot	Domesticate	AB
		T. timopheevi (Zhuk.) Zhuk.	Domesticate	AG
Hexaploid	Spelt	*T. spelta* L.	Domesticate	ABD
		T. macha Dekapr. et Menabde	Domesticate	ABD
		T. vavilovii (Thum.) Jakubz.	Domesticate	ABD
		T. zhukovskyi Menabde et Ericzjan	Domesticate	AAG

Even discounting the hulled character, these wheats differ significantly from their free-threshing counterparts. For example, the flour and dough properties of einkorn and emmer are very different from those of macaroni wheat and bread wheat. The hulled wheats also have a thinner pericarp – a property drawn to our attention by Turkish millers, and mentioned by Küster (1985). We have not found any mention of this difference in some standard accounts of food-plant anatomy (e.g. Winton and Winton 1932), but it is real and deserves further study. Since the hulled wheats are clearly separated from the free-threshing wheats by more than just the hulled character, it is appropriate to consider the hulled wheats as a distinctive group.

Parching of hulled wheats

The literature on hulled wheats often refers to the necessity of parching spikelets to render the chaff brittle, in order to free the enclosed grain (for example, Moritz 1955:129; Spurr 1986:11, note 30; Sallares 1995:95 and see references in Meurers-Balke and Lüning 1992:357). As Leonor Peña-Chocarro describes (this volume), this idea may ultimately be based on descriptions in classical texts, such as that in Pliny (1950):97: "...Etruria pounds the ears of emmer, after it has been roasted, with a pestle shod with iron at the end...".

The ethnographic record for cereals in general demonstrates that there are a number of possible reasons for the use of heat, which have nothing to do with dehusking (Hillman 1982; van der Veen 1989; L. Peña-Chocarro, this volume). Fenton (1978:37), for example, lists three reasons for drying grain in Orkney and Shetland: to dry a crop which was harvested slightly unripe; to make malt for brewing; or to harden grain for milling in rotary querns. The classical references to heating of hulled wheats need not therefore refer to parching as an aid to dehusking.

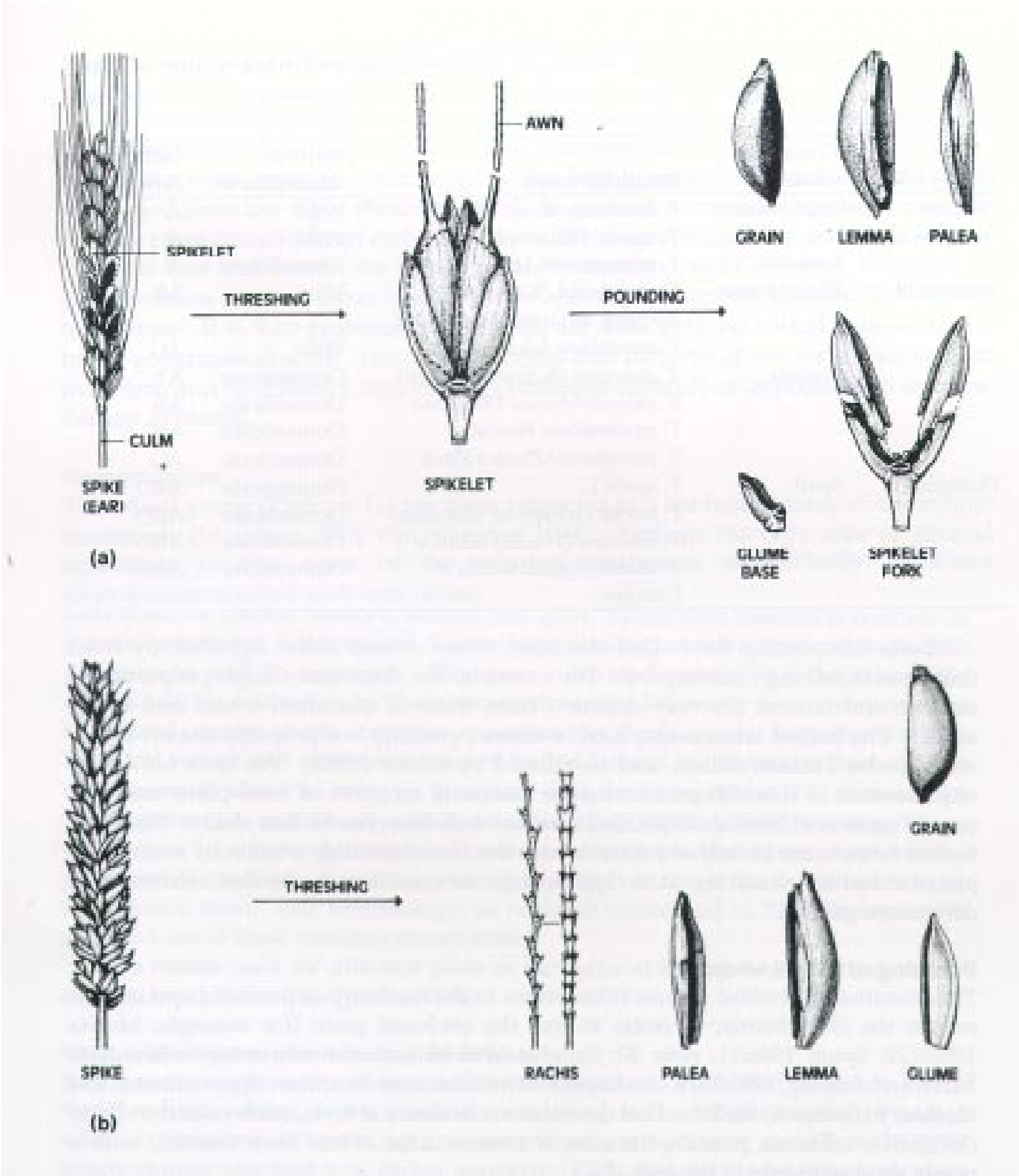

Fig. 1. The anatomy of hulled and free-threshing wheat.

a. Hulled wheat. Upon threshing, the spike breaks up into individual spikelets which must be further vigorously processed to free the grain from the tough chaff.

b. Free-threshing wheat. When threshed, the central rachis remains whole or nearly so. The chaff surrounding the grain separates easily from the rachis and the grain falls out freely.

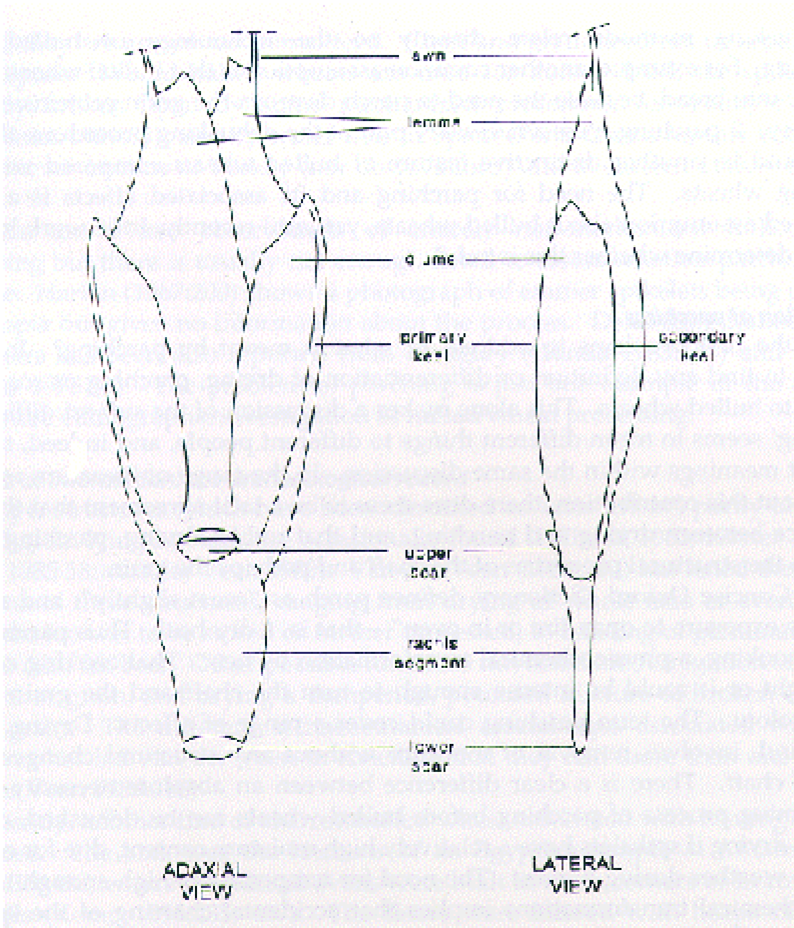

Fig. 2. Schematic diagram of a typical hulled wheat spikelet, showing the constituent parts.

Without detailed descriptions in ethnographic accounts or general discussions, it can be very difficult to distinguish precisely at what stage and why heat is applied to cereals. Vagueness is one reason why most ethnohistorical accounts of hulled wheat processing are not reliable. Since there are a number of reasons why heating might be involved, the attempt to determine whether parching is an integral part of non-mechanized hulled wheat processing using incomplete descriptions is likely to prove misleading, if not impossible.

Recently, a number of archaeobotanists have begun to question the view that it is obligatory to parch hulled wheats before they can be husked. This is an important question for several reasons. If parching was commonly used for dehusking, it would be a potentially important source of charred cereal in the archaeological record. These cereals would be produced at a clearly definable stage in the processing sequence with distinctive results: whole charred spikelets. This in turn would have a direct effect on the interpretation of archaeological contexts. A common assumption is that hulled wheats are over-represented in the archaeobotanical record because the need to parch means they were accidentally charred more frequently than free-threshing wheats.

Dehusking methods relate directly to the technology of hulled wheat processing. For example, another common assumption is that hulled wheats cannot be made into bread, because the need to parch destroys the grain proteins essential for bakery. If parching were a necessary part of the dehusking procedure, then this step would be another distinctive feature of hulled wheats compared with free-threshing wheats. The need for parching and its associated effects is a deeply embedded assumption about hulled wheats, yet until recently, little work has been done to determine whether this is valid.

A definition of parching

One of the first problems to address is: what is meant by parching? It is very difficult to find any definition or differentiation of drying, parching or roasting as applied to hulled wheats. This alone makes a discussion of the subject difficult, for ‘parching’ seems to mean different things to different people, and indeed, takes on different meanings within the same discussion. In the range of literature we quote throughout this contribution, there does seem to be a tacit agreement that there is a difference between drying and parching, and that unlike drying, parching has an effect on the structural properties of the chaff and perhaps the grain.

The Concise Oxford Dictionary defines parch as “roast slightly”, and roast as “cook by exposure to open fire or in oven” – that is, a dry heat. Thus parching is a type of cooking, a physicochemical transformation by heat. That cooking could be very slight or it could be intense enough to turn the chaff and the grain a deep brown colour. The term parching could cover a range of effects. Drying, on the other hand, involves removal of moisture without any structural changes in the grain or chaff. There is a clear difference between an absolute necessity for the transforming process of parching before hulled wheats can be dehusked, and the need for drying if spikelets have a relatively high moisture content, due for example to damp weather during harvest. The need for temperatures high enough to cause physicochemical transformations implies that accidental charring of the spikelets would be more likely for parching than drying.

There are few experiments on how temperature affects the grain and chaff of the hulled wheats. One exception is the work by Lüning and Meurers-Balke (1980:338-339). They found that at 50ºC and 100ºC, no change was discernible. At 150ºC, spelt was unaffected while einkorn and emmer chaff became somewhat brittle. Not until 200ºC was reached did einkorn and emmer chaff become significantly affected, while the more robust spelt chaff started to become brittle.

No work has been done on how length of time affects spikelets during exposure to low temperatures (about 100ºC) but it is possible to hypothesise that physicochemical changes require a threshold energy input before they will occur; that is, they are temperature-dependent (e.g. French 1973:1055). Thus, long exposures to low temperatures are likely to make spikelets very dry, but unlikely to cause any significant structural change which causes the chaff to become brittle and easily shattered. More work is needed to test this.

On the basis of the work done by Lüning and Meurers-Balke (1980), a reasonable distinction is that drying involves temperatures up to about 100ºC, while parching takes place at temperatures above about 150ºC, irrespective of exposure time.

Sources of information: the ethnographic record

One of the greatest barriers to the investigation of hulled wheat parching is the lack of ethnographic information. This stems from the rarity of modern hulled wheat cultivation. Often, in the few areas where hulled wheats still survive and have been studied, they are grown for animal feed. Chaff and grain need not be separated for this purpose. Where hulled wheats are used for human food, the spikelets are generally broken open by some mechanized procedure, for example in Italy (D'Antuono 1989:55), and by water mill in Spain (Peña-Chocarro, this volume), in the Pontic mountains of Turkey (our observations) and in eastern Turkey (Hillman 1984b).

There are a few observations of entirely non-mechanized hulled wheat processing but there is usually not enough detail to assess whether parching plays any role. Harlan (1967:200) shows a photograph of emmer spikelets being pounded in Ethiopia but gives no information about the process. Dehusking hulled wheats in mortars has been also reported from Hungary (Gunda 1983:155) and Slovakia (Markus 1975:35). The problem of parching is just one example of the need for much more ethnographic investigation of hulled wheat processing.

Sources of information: the archaeological record

In Europe, structures which have been identified as 'corn driers', partly because of charred grain lying in them, are occasionally found (Hillman 1982; Küster 1984:310; Küster 1985:58; van der Veen 1989). Van der Veen (1989:303) has listed the possible functions of these structures, ranging from drying of whole ears or even sheaves which are too wet to be stored or further processed, to roasting of germinated grain to make malt for beer. Other possible functions not listed are fumigation of infested spikelets or grain, and drying a dampened, pounded mixture of broken chaff and whole grain. The different archaeobotanical assemblages associated with these structures has led van der Veen to conclude that they had more than one function (van der Veen 1989:316).

Recently, another find of charred hulled wheat associated with heating has been excavated. The area was the kitchens of an Egyptian temple at Amarna, dated about 1350 BC, where cylindrical ovens were built in room corners or in rows along the walls (Kemp 1995:435, 437). The floors were littered with heaps of charred emmer grain and chaff (D. Samuel, unpublished data). Although this and the European finds show that hulled wheats were associated in some way or in several ways with heating, we are faced with problems of interpretation which again are due to lack of ethnographic evidence. In the case of the Egyptian temple kitchens, substantial quantities of barley were also recovered, suggesting the use of processes which were not unique to hulled wheats.

The archaeological record offers a further enigma if parching is a necessity for hulled wheat processing. Küster (1984:310) states that the type of kiln found at Erberdingen-Hochdorf, with charred einkorn spikelets – and apple halves – has rarely been found in Neolithic settlements. Van der Veen (1989:302) points out that British 'corn-driers' are restricted geographically – southern and eastern Britain – and in time – to the Roman period, with the majority of such constructions dating to the 3rd and 4th centuries AD. As Braun (1995:36) points out, emmer was an important crop in Roman Italy, but there are no large kilns or ovens associated with spikelet parching. If parching was an essential processing step, why are apparent parching installations so uncommon?

Sources of evidence: experimental work

Before going on to discuss the experimental evidence, another problem with terminology needs to be clarified. There is frequent confusion between pounding and milling. These terms are not interchangeable, although they are often used as if they were. They describe specific actions which are carried out with specific tools.

Pounding involves an up and down motion applied with some force. It is usually done with a pestle in a mortar. Both these tools may be made of stone or wood and may vary in size.

Milling is the equivalent of grinding. This means using friction, which may include the application of pressure, to break up material between two surfaces. Querns are the tools used for milling cereals and there are two types. The saddle quern is a flat slab, often made of stone, which lies unmoving on the ground or in an emplacement, or may even be a hollowed area in a much bigger rock. The grinding action is done with a smaller hand stone rubbed back and forth along the long axis of the saddle quern surface. Pounding up and down on the saddle quern would be likely to gouge the surface heavily but effective grinding requires a reasonably flat surface. This is the reason that pounding would not be done on a saddle quern. There has been relatively little investigation of these tools (Moritz 1958:18-41; Sumner 1967; Wright 1992).

The rotary quern is made up of a pair of disks, usually of stone. There is a very wide range of shapes, particularly among those from the Roman period (Curwen 1937, 1941; Moritz 1958). The basic form is a pair of disks, one of which rotates above the other around a common axle (Moritz 1958:xxvii). Milling is done by the friction between the flat inner surfaces which fit closely together. Rotary querns were not invented until the Classical period, probably in Italy in early Roman times (Moritz 1958:60-61). All cereal processing before this time was done with mortars and saddle querns.

Irrespective of the terms actually employed in the literature, when pestles and mortars are used, the action is pounding, and when querns of whatever type are used, the action is milling or grinding.

There have been few hulled wheat processing experiments, and of these, not all have aimed to investigate the effect on the spikelets and grains (e.g. Bower 1992). Some work has been done on dehusking with a saddle quern; other work concentrates on the use of mortar and pestle.

Beranová (1986:323), Küster (1984:310-311, 1985:59-50) and Meurers-Balke and Lüning (1992:350) examined hulled wheat dehusking on saddle querns. In all series of experiments, heating did improve the proportion of dehusked spikelets obtained by milling. The optimal temperature for the latter two cases was about 100ºC – a drying rather than a parching temperature. Beranová (1986:323), however, found that dehusking this way was slow and yielded a poor product. Likewise, Meurers-Balke and Lüning (1992:350) concluded that in comparison to pounding, dehusking by milling was much less successful in every parameter. Overall, a mortar was far more effective for dehusking hulled wheats. Similar results have recently been obtained using ancient Cretan processing as an experimental model (Hara Procopiou, pers. comm.).

One of us (DS) investigated ancient Egyptian emmer processing by experiments using actual ancient tools, and replicas based on ancient finds (see **Processing experiments**). There was no need to parch or heat spikelets to achieve a very satisfactory separation of chaff and whole grain using a mortar and pestle. It may be argued that the arid climate of Egypt dried the emmer spikelets sufficiently, so that this step could be omitted. This may be valid, but the results of experiments in Egypt should still be applicable to the Near East, the Mediterranean and other regions of dry hot summers.

Perhaps the experiments best suited to explore whether parching to dehusk hulled wheats is imperative were those made by Lüning and Meurers-Balke (1980) and Meurers-Balke and Lüning (1992), based in the Hambacher Forest between

Cologne and Aachen in Germany. Work in temperate northwest Europe should be as well suited to examine whether parching is required for dehusking hulled wheats in cooler damper climates as anywhere. In a detailed set of studies, Meurers-Balke and Lüning (1992:341-342) concluded that dehusking is best accomplished by pounding in wooden mortars; that there is no need to parch in order to dehusk hulled wheat; and that experimental and archaeological evidence indicates parching was unlikely to have been used by the earliest European farmers.

Summary

The archaeological record suggests that hulled wheats were heated, at least sometimes, during some stage of processing, but not necessarily in order to dehusk spikelets. A variety of experimental evidence shows that hulled wheats can be very effectively dehusked without parching, in both dry climates and temperate European conditions. There are scarcely any data from ethnographic observations in areas which dehusk hulled wheats by mortar and pestle. This is unfortunate, since traditional practitioners are the best source of information. We predict that where hulled wheats are still being processed without mechanization, parching is not part of the dehusking sequence.

Ancient hulled wheat processing

Archaeological and ethnographic evidence

To learn about non-mechanized hulled wheat processing, the archaeological evidence from ancient Egypt provides an excellent case study. Hulled barley was the only other cultivated cereal, but the techniques for dehusking emmer and hulling barley are probably similar. The desiccating action of Egypt's arid climate preserves organic material, including plant remains, outstandingly well (Fig. 3).

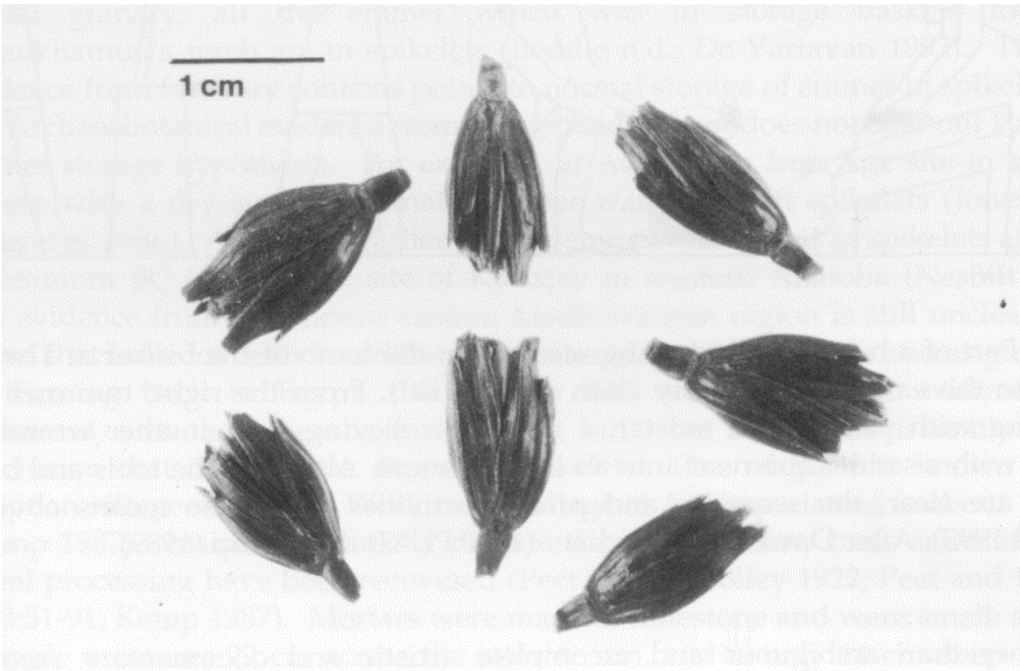

Fig. 3. Whole desiccated emmer spikelets from an unknown ancient Egyptian tomb, courtesy of the Royal Ontario Museum, Toronto. Although these spikelets appear to be twice the size of those shown in Figure 7, a direct comparison cannot be made due to the shrinking effects of charring.

Many plant parts survive, unlike in most regions of the world where botanical material has passed through the filtering and destructive action of charring. An ancient village, the Workmen's Village at Amarna, has been extensively excavated and well enough recorded to draw conclusions about cereal processing installations.

Cereal processing, as part of bread and beer production, has been of interest to Egyptologists for a long time. The subject is a classic example of the difficulties which arise when documentary evidence alone is relied upon with little or no reference to archaeological and ethnographic material. The distinctiveness but rarity of the hulled wheat has also caused problems with interpretation, which have gone largely unrecognized. The abundance of available ancient Egyptian artistic and literary evidence has distracted enquiry away from the archaeological record (Fig. 4). In addition, most scholars who have considered the topic have not been aware of the differences between hulled and free-threshing wheats. The technology and sequence of activities required for processing emmer has usually not been understood. The combination of a non-archaeological focus and the misunderstanding about hulled wheat means that there are many contradictions in most of the literature on ancient Egyptian cereal processing (Samuel 1993:277-278).

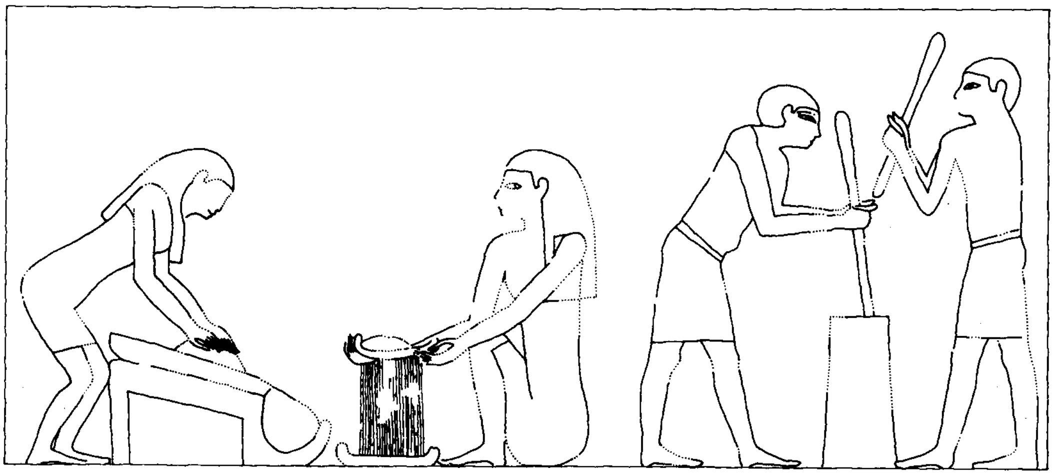

Fig. 4. Part of a baking and brewing scene from the tomb of Intef-inker at Thebes, dating to the early 12th Dynasty (20th century BC). From the right, two men are pounding with pestles in a mortar, a woman is sieving, and another woman is milling with a saddle quern set into an emplacement. Although the tools and basic actions are clear, the sequence and precise activities are by no means obvious (Samuel 1993). After Davies and Gardiner (1920:Pl. XI) and Kemp (1989).

Rather than ambiguous and incomplete artistic and documentary records, archaeology is a more fruitful route of inquiry. The archaeological evidence for cereal processing can only be interpreted with the help of appropriate ethnographic analogies. Although there is little information directly related to hulled wheats, there are relevant ethnographic parallels which can be used. Enough data from Egyptian archaeology and ethnography now exist to interpret this important activity of ancient Egyptian daily life with some confidence. The evidence from ancient Egypt is relevant not only to a specific culture, but also provides insights on hulled wheat processing elsewhere, prior to the invention of the rotary quern.

The key difference between the free-threshing wheats and the hulled wheats is the need to free the hulled wheat grain from the spikelets before it can be processed into food. This means two aspects of cereal processing need to be considered. First, how was the grain stored? Was it dehusked before bulk storage in granaries or was it stored in the spikelet? Second, what tools were used for the vigorous mechanical action required to break up the spikelets?

There is little direct information, in the form of intact Egyptian granaries, to indicate whether emmer was stored as spikelets or as clean grain. Hillman (1981:131, 138; 1984a:8, 11; 1984b:126) has suggested that dry climates would allow people to bulk process their harvest of hulled wheat up to the clean grain stage. Those living in wetter climates such as northern Europe or mountainous regions, on the other hand, would get the harvest into storage as soon as cleaned spikelets were obtained. They could then dehusk in small quantities as needed from day to day. Although this may seem reasonable from the point of view of efficiency, there are numerous strands of evidence which demonstrate that in Egypt, emmer was stored as spikelets.

Model granaries were sometimes placed in tombs, especially in the Middle (2040-1640 BC) and New Kingdoms (1500-1070 BC) to ensure a plentiful supply of grain in the afterlife. A number of these granaries survive, and some still retain their ancient cereal contents. For example, a large model granary from the tomb of Tutankhamun, now in the Cairo Museum (display number 1641, upper floor, gallery 30) contains large quantities of typical emmer spikelets, as well as some hulled barley (see Hepper 1990:54, 66). Emmer occurs as spikelets, not grain, in model granaries now at the Cairo Museum, the British Museum and the Ashmolean Museum, Oxford. The only emmer grain is in a few little dishes. As well as the model granary, all the emmer which was in storage baskets found in Tutankhamun's tomb are in spikelets (Boodle n.d.; De Vartavan 1993). Thus, the evidence from funerary contexts points to normal storage of emmer in spikelets.

Archaeobotanical evidence from sites outside Egypt does not bear out Hillman's emmer storage hypothesis. For example, at Assiros, an Iron Age site in northern Greece with a dry summer climate, emmer was stored in spikelets (Jones 1981a; Jones *et al.* 1986). At a much earlier period, emmer was stored as spikelets at the 4th millennium BC Chalcolithic site of Kuruçay in western Anatolia (Nesbitt 1996b). The evidence from the ancient eastern Mediterranean region is still unclear, but it seems that hulled wheats could have been stored both as spikelets and as grain.

Turning back to Egypt, there is far less archaeobotanical evidence from settlement sites than there is from tombs, but what little there is reinforces the conclusion that emmer was stored in spikelets. One of the few known ancient Egyptian village sites is the Workmen's Village at Amarna, dating to about 1350 BC (Kemp 1987). Inside and directly outside the houses, many tools associated with cereal processing have been recovered (Peet 1921; Woolley 1922; Peet and Woolley 1923:51-91; Kemp 1987). Mortars were made of limestone and were small: a typical example measures 22 cm across the interior rim, and is only 14 cm deep (Samuel 1994:Table 5.1).

Associated plant remains were recovered from around only one of the cereal mortars found still in place. They were composed almost entirely of shredded emmer spikelets, indicating that this mortar was used to dehusk spikelets (Samuel 1989:280-286). The huge quantities of desiccated emmer chaff in the village rubbish dumps demonstrate that emmer was an important food and that large quantities of chaff were generated from processing it. The distance of this village from the riverside cultivation, about 2 kilometres, with dense urban settlement in between, argues against the interpretation that spikelets were processed in bulk after harvest to obtain clean grain, which was then stored.

On the basis of ethnographic analogy (Hillman 1984b:130), the small size of the mortars and the fact that a mortar was found in most of the ancient village houses, it appears that each household processed a limited volume of spikelets at a time. Pounding emmer spikelets may not have been a daily task, but it must have taken place at short intervals. The archaeobotanical evidence of shredded emmer spikelets around a mortar shows that the aim of pounding was not to crush the grain, as has frequently been supposed (e.g. Sist 1987:55-56; Wilson 1988:12-14), but to free the grain from the tough glumes.

Storage in the spikelet, even in dry climates, makes sense. The tough chaff helps protect grain from insect attack. It may also allow longer viability.

In the Near East today, where most relevant ethnographic work has been done, there are few good analogies to dehusking with a mortar and pestle. This makes comparison with pre-Classical times problematic, for only mortar and pestle and saddle quern technology were available then. Mortar and pestle dehusking of hulled wheats in Europe and of other cereals such as millet and sorghum in sub-Saharan Africa still takes place, but this has not been recorded in the detail required to interpret the archaeological record. Gordon Hillman (1984b) discusses the available evidence for dehusking at length, and points out that traditional dehusking of rice in Turkey today is perhaps the closest Near Eastern parallel.

Processing experiments

The archaeological evidence has provided information about ancient Egyptian tools and their function. Ethnographic analogy gives some indication of how they must have been used. Experimentation brings these two strands of evidence together. Experiments can test whether a proposed sequence of actions with a given set of tools will work, and if not, why not. They can highlight gaps or indeed fill them. A number of people have carried out experiments on hulled wheat processing, mostly based on European data. The advantage of experimentation based on ancient Egyptian evidence is that robust ancient stone tools could be used, and the results checked against the archaeobotanical assemblage. In all published experiments of hulled wheat processing based on ethnographic analogy, pounding, not milling on saddle querns, was the technique applied. To understand ancient Egyptian cereal processing technology, one of us (DS) carried out a series of experiments. When it was not possible to use original ancient Egyptian equipment, replicas closely based on archaeological examples were substituted.

In the first experiments, emmer spikelets were pounded dry in a shallow ancient mortar (Fig. 5). Most of them quickly spilled out. Our observations of debranning grain in Turkey with mortar and pestle, as well as those of Hillman (1984b:135-136), were that the workers first sprinkle a little water on the grain before pounding.

Slightly dampening emmer spikelets before pounding in the mortar has two effects on the spikelets. It allows the spikelets to stick slightly and thus to rub against each other. The glumes and light chaff are then stripped from the rachis internodes, freeing the grain which mostly stays intact. Secondly, water softens the chaff and makes it pliable, so that whole grains often pop out of the unshattered spikelet. The experimentally produced chaff assemblage from moist pounded spikelets is very similar to that found around the mortar in the Amarna Workmen's Village, suggesting that this reconstruction is accurate.

The need to dampen spikelets may be related to the shallow mortars. Experimentally dehusking hulled wheat in tall narrow wooden mortars did not require moistening (Bower 1992:238; Meurers-Balke and Lüning 1992:352; Hara Procoupiou, pers. comm.). No experiments have been done to examine the effect of moistening using tall narrow mortars. It would be interesting to know if moistening enhanced the overall breakage of spikelets and decreased the time needed for pounding.

Once the spikelets were either broken up or emptied of grain, the damp mixture of chaff and grain had to be dried. In the hot Egyptian sun this was easily accomplished in a few hours, but excess moisture was probably driven off by artificial warming on colder days or when large quantities were processed. If moistening was used for dehusking in cooler climatic regions outside Egypt, artificial warming was probably required there too. It is at this drying, post-pounding stage that portions of chaff and grain might occasionally have been accidentally exposed to fire and charred, allowing archaeological preservation in non-arid zones. If this were the case, the number of accidents would have been less than those expected had parching been used, since the temperatures required would have been much lower. The method of drying must not normally have used any special installation, since we have already seen how scarce 'corn-drier' constructions are (see **Sources of information: the archaeological record**, above).

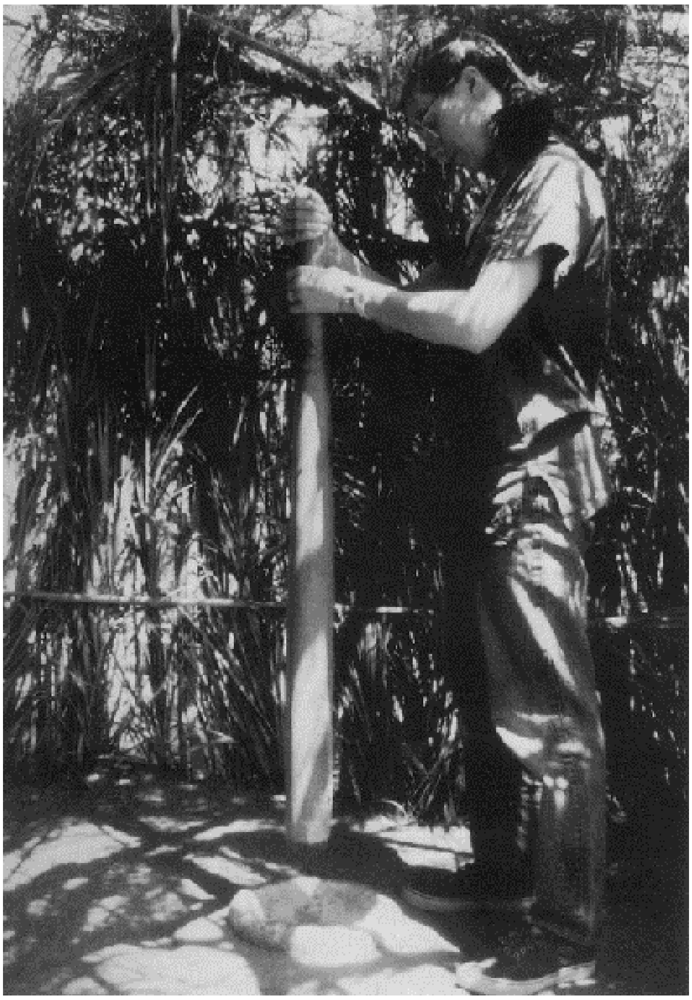

Fig. 5. Experimental reconstruction of ancient Egyptian emmer processing. Slightly moistened emmer spikelets are pounded in an ancient Egyptian limestone mortar. The mortar is set into the ground as are ancient examples. The pestle is a replica, closely based on a wooden pestle found at the Amarna Workmen's village.

The next step is the separation of chaff from grain. Hillman's (1984b) Turkish ethnographic evidence demonstrates that this can be done by a combination of winnowing and sieving. Since replicas of ancient Egyptian sieves and winnowing tools were unavailable, reasonable substitutes were used instead. A grass and palm frond basket made by traditional techniques in a village near Amarna served for winnowing, and a metal sieve with a medium (3 mm) mesh for sieving. Lack of skill and of close replicas for this processing stage led to a relatively large amount of chaff in the cleaned grain. Nevertheless, the experimental work has demonstrated that winnowing and sieving successfully separate chaff and grain. Winnowing and sieving were also used by Bower (1992:238) and Meurers-Balke and Lüning (1992:258) in their experiments although the exact techniques differ.

The combination of archaeological, ethnographic and experimental data shows that if hulled wheats are slightly dampened, they can be dehusked in a shallow mortar with a pestle without crushing the grain. After drying, the chaff is separated out by winnowing and sieving and the clean grain is then ready for further processing (Fig. 6). Variations on this technique must have been used throughout the ancient world prior to the advent of the rotary quern.

Fig. 6. Experimental reconstruction of ancient Egyptian milling. An ancient quartzitic sandstone saddle quern is set into a replica mud brick and mud plaster emplacement, based on archaeological examples. The hand stone is also ancient. The method for catching flour is a modern contingency!

Tool sizes and materials were different: for example, mortars were made of wood in Europe (Meurers-Balke and Lüning 1992:350), but in treeless Egypt limestone was used. Once the rotary mill was invented and mechanization was applied to hulled wheat processing, the range of possible dehusking solutions expanded. Ironically, after well over four millennia of emmer cultivation in Egypt, within about 300 years of the invention of the rotary quern, emmer was hardly cultivated there.

Identification techniques for archaeological remains of hulled wheats

Agronomists and botanists are able to identify present-day wheat taxa using a range of morphological characters, such as spike and glume shape. Where ploidy level is in doubt it can be checked by a chromosome count, while relationships can be checked using chromosome-pairing studies. Identification of archaeological plant remains must overcome two obstacles: the material is dead, and it is usually broken up into small parts. Both of these conditions are linked to the mode of preservation of the plant remains.

Preservation of archaeological plant remains

Plant remains require exceptional conditions to survive being eaten by scavengers or rotting away. Plant remains will be preserved in truly arid conditions such as in the Egyptian desert (Fig. 3), or in permanently waterlogged places, which are common in central Europe. Otherwise, the most frequent means of preservation is charring (Fig. 7). When plant remains – seeds, chaff, tubers, wood among a wide range of materials – come into contact with fire, they may burn to ashes, or they may be charred. Charred plant remains retain their shape and anatomical features and can thus be identified by comparison with modern reference materials. Most archaeological sites are rich in charred plant remains.

Hulled wheats are also represented in archaeological sediments by phytoliths, silica particles that form within plant cells. When the organic portions of silica-rich parts of the plant, such as the glumes, decay, sheets of phytoliths remain. The organization and shape of the cell walls allows identification of the source plant. At present phytolith analysis is in its infancy, and cereal phytolith sheets can only be distinguished to the level of genus (Ball 1992; Kaplan *et al.* 1992; Rosen 1992). The pollen of hulled wheats can not easily be distinguished from pollen of other grasses, particularly in the Near East, and pollen analysis is therefore not a suitable tool for studying the history of hulled wheats (Edwards 1989; Bottema 1992).

Hulled wheat identification criteria

The effects of crop-processing and charring mean that only parts of the hulled wheat spike are usually found: sometimes intact spikelets, more often grain, spikelet forks and glume bases. Spikelet forks and glume bases are produced when the upper parts of the glumes, palea and lemma are removed during crop-processing and/or during charring. When chaff is burnt, the papery parts are destroyed (Boardman and Jones 1990), leaving only the woody rachis segment with the two glume stumps, known as the spikelet fork (Fig. 1).

The development of identification criteria has naturally focused on characters that relate to the parts of the spikelet which normally survive processing and charring. Where whole spikes or spikelets are occasionally preserved, e.g. in the Swiss Lake villages, characters such as the shape of the glume apex can be applied (Jacomet *et al.* 1989). Usually, more subtle characters must be sought in what remains of the spikelet. These primarily relate to the shape and position of the primary and secondary keels and venation on the remains of the glumes. Other characters that can be helpful include the overall shape of spikelet forks, which are generally more gracefully curved in einkorn than in emmer and spelt (compare Fig. 8a with 8c and 8d), and the position of the rachis segment as an aid to distinguishing spelt from emmer. In emmer, spikelets usually disarticulate in ‘wedge’ fashion, with the rachis segment pointing down (as in Fig. 1a), while spelt spikelets sometimes disarticulate in ‘barrel’ style, with the upper rachis segment pressed against the lower spikelet (Fig. 7). This character is inherited from one parent of spelt, *Aegilops* *tauschii*. However, spikelets from modern populations of both emmer and spelt can break either way, so this is not a dependable character on its own.

Not all criteria work effectively across all regions or periods. For example, in prehistoric Europe the primary keel is strong in einkorn and weak in emmer and is a useful identification criterion, while in Near Eastern and Spanish material the primary keel is equally prominent for both taxa. Another example of a regional characteristic is the exceptionally heavily veined glumes of ancient emmer spikelets in the Near East and Spain (de Moulins 1993:197-198, Fig. 1.3). It is possible that the distribution of such characters will eventually give us insights into the spread of the hulled wheats into Europe.

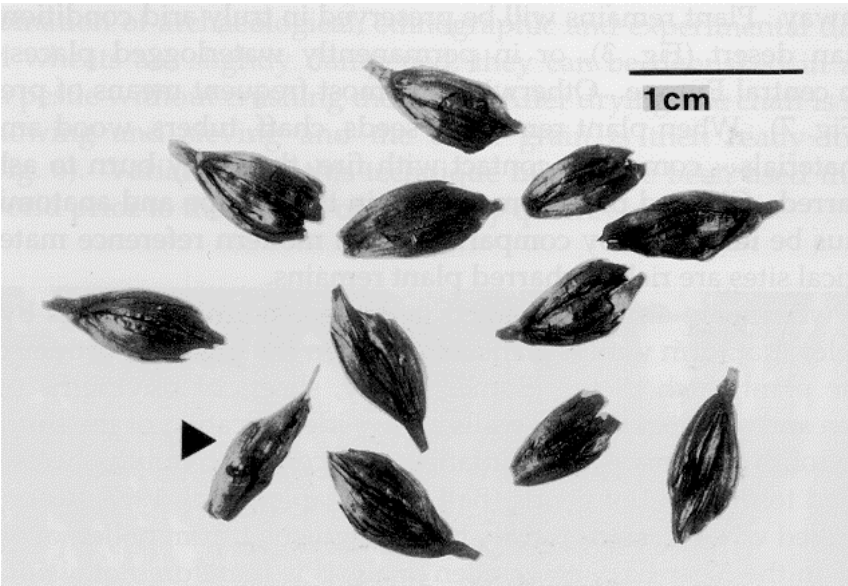

Fig. 7. Whole charred spikelets from an Iron Age pit (mid-1st millennium BC) at Wandlebury, Cambridgeshire, England, courtesy of Chris Stevens. The majority of spikelets recovered from this assemblage are emmer, but a few are spelt, such as that marked by the arrow with its barrel-type breakage. The different breakage patterns of the rachis internode, although distinctive, are not always an accurate guide to identification.

Quantitative characters are often useful; these include the width of the glume in lateral view and the relative width of the upper disarticulation scar, calculated as scar width divided by spikelet width (at scar level) (Helbaek 1970). Ideally, spikelet remains can first be separated using qualitative characters, and then plotted according to the quantitative characters. When the two methods match, this is good support for the separated groups being different (Nesbitt 1993).

Grains present us with much greater difficulties. This is partly because their morphology is more affected by charring; in part because their rounded shape makes it more difficult to identify or describe distinctive differences between taxa; but mainly because there is considerable overlap in form (Fig. 9). For example, einkorn spikelets contain one highly distinctive grain, which is laterally compressed with a spindle shape in dorsal view. However, the terminal spikelet of two-grained emmer usually contains only one grain, which is shaped like an einkorn grain. To confuse matters further, two-grained einkorn – a rare form today – appears to have been more common in the past. The distinction between emmer and spelt grains is particularly problematic, and there is disagreement as to how reliable these identifications are. Fortunately chaff remains are usually found alongside hulled wheat grains, and these offer a valuable cross-check on identifications. Significant differences in surface cell patterns in both chaff and grain have been identified, but as yet these are little used by archaeobotanists working with charred grain (Hopf 1954; Körber-Grohne 1981).

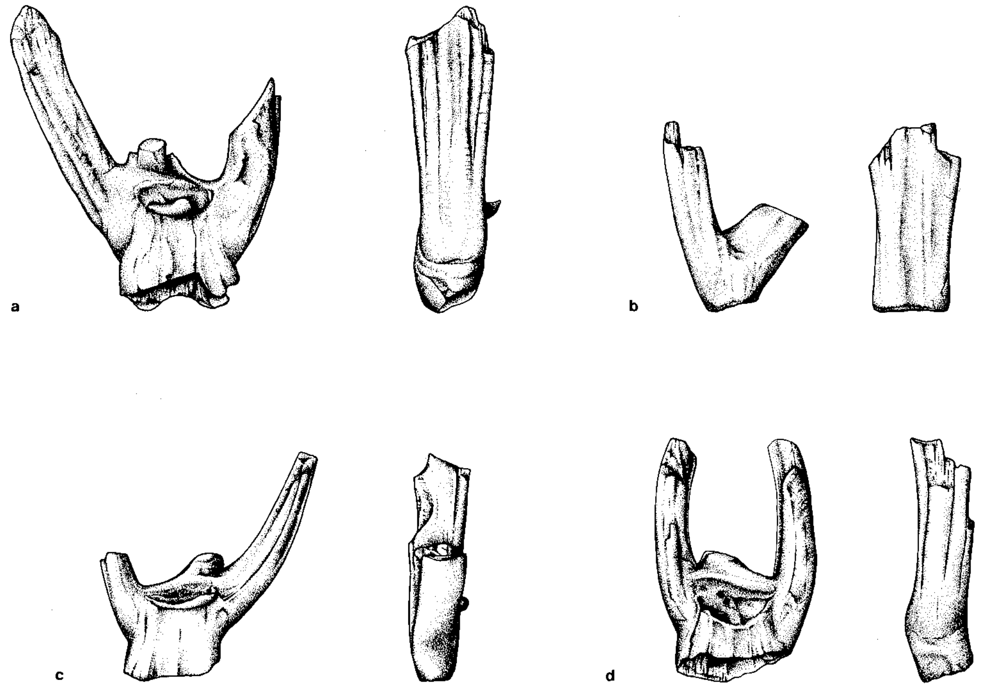

Fig. 8. Charred hulled wheat chaff from Çayböyü, Turkey, dating to the Late Chalcolithic period (4th millennium BC). (a) Normal emmer spikelet fork, which originally came from the middle of the ear. (b) Terminal emmer spikelet fork - originally from the top of the ear. (c) Normal einkorn spikelet fork, with spreading glume bases. (d) Normal einkorn spikelet fork, with parallel glume bases.

There is some agreement among archaeobotanists that well-preserved assemblages of spikelets or spikelet-forks and glume-bases can be reliably separated into einkorn, emmer and spelt. This does involve the assumption that the morphological groups we identify in ancient material match modern taxa. This is undoubtedly true in general terms: current-day einkorn, emmer and spelt can be distinguished from each other by the same character combinations which work on ancient material. However, archaeobotanists would not argue for complete similarity between modern einkorns and ancient einkorn. Our ancient einkorn remains do belong to a hulled diploid wheat, but that does not necessarily imply that they all share ecological characteristics with their modern counterparts. Also, forms of wheat may have existed in the past that are extinct today.

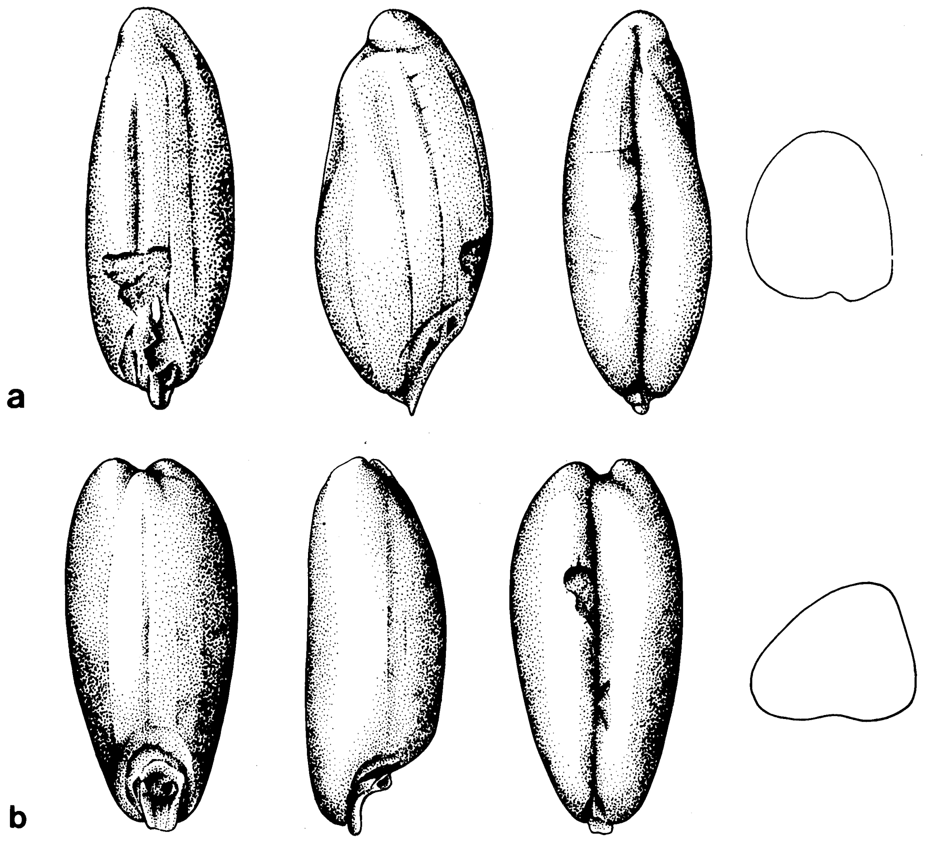

Fig. 9. Charred hulled wheat grains from Çayböyü, Turkey dating to the Late Chalcolithic period (4th millennium BC). The grains show the longitudinal grooves typical of hulled wheats, caused by the tightly investing chaff.
a. Einkorn grain, with the typical spindle shape, pointed apex and pronounced ventral convex curve visible in the middle view.
b. Emmer grain, with a blunter apex and straighter sides in all views. Note the typical asymmetric triangular cross-section.

Identification conclusions

Identification of archaeological wheat remains was discussed at a meeting of 25 archaeobotanists in London in 1992 and the published account is a useful source of more details (Hillman *et al.* 1996). In summary, the reader of archaeobotanical reports should bear in mind three points:

1. All identifications should be critically examined. Identification criteria should be presented in detail and backed up by illustrations. Poorly documented identifications should be treated with even greater caution, and the older literature must always be used with care. Identifications of charred material are not absolute and even desiccated material can be problematic.
2. Glume wheat chaff can, if abundant and well preserved, be identified with greater certainty than grain.
3. Identifications of hulled wheat remains can be identified with some certainty to ploidy level, but the use of terms such as einkorn, emmer or spelt does not imply full equivalency with current-day taxa.

Future prospects for ancient hulled wheat identification

Is there any way that we can check the results of morphological identification criteria using the genotype? Recent work has shown that charring apparently allows – or even promotes – the survival of organic molecules within wheat grains. DNA fragments have been recovered from 2000-year-old Iron Age spelt grains from Danebury, England (Brown *et al.* 1994). Lipids also survive in charred grain (Evershed 1993). Comparison of spectra from ancient and modern grains obtained by infra-red spectroscopy and gas chromatography mass spectrometry suggests that this may be a powerful tool for identification (Hillman *et al.* 1993). Both techniques are in their infancy and need further development and replication in different laboratories before they are widely applied. They are expensive and technically complex techniques; their role will be to confirm the results of morphological criteria rather than to replace them.

Domestication

The hulled wheats will be discussed as two groups. Einkorn and emmer were domesticated from wild ancestors growing in the Near East. These wild ancestors have been identified and much studied, and the area and time of domestication have been established with certainty. Spelt wheat, on the other hand, results from a hybridization that appears to have taken place after the origins of agriculture, under cultivation. It has no single wild ancestor, and the area and date of its domestication are still unclear.

Botanical evidence for domestication of einkorn and emmer

Identification of the wild ancestors

Einkorn

Today wild einkorn and wild emmer seem obvious candidates as wild ancestors of, respectively, einkorn and emmer wheat, because of their morphological similarity and ability to intercross. However, this has only been apparent for a hundred years or so, after a series of botanical discoveries whose history is discussed by Aaronsohn (1910), Schiemann (1956) and Feldman (1977). Wild einkorn (*Triticum boeoticum*) was discovered in Greece and Turkey in the mid-19th century, and by 1900 was widely accepted as the ancestor of domesticated einkorn wheat.

Triticum urartu, the second diploid wild wheat, was named in 1938 by the Armenian botanist, Tumanian. It grows throughout the Fertile Crescent as a minor admixture of *T. boeoticum* on outcrops of basaltic soil (Waines *et al.* 1993). Unlike *T. boeoticum*, it has not spread outside the Fertile Crescent as a weed of disturbed ground. It is morphologically similar to *T. boeoticum*, but *T. urartu* can be consistently distinguished on the basis of anther length, the presence of a third lemma awn and caryopsis colour (Johnson 1975:33-34; Morrison 1993; Waines and Barnhart 1990). Crosses between the two taxa result in sterile hybrids. Overall the evidence points to *T. urartu* as a separate species.

T. urartu is not a candidate species as a wild ancestor for domesticated einkorn (Jaaska 1993; Waines and Barnhart 1990), but may be a parent of *T. dicoccoides* (Dvorak *et al.* 1988).

Emmer

The wild ancestor of emmer was not identified until 1873, when Körnicke found part of a spike of *T. dicoccoides* in a collection of wild barley, *Hordeum spontaneum*, made on Mount Hermon in southern Syria. However, it was Aaron Aaronsohn's discovery from 1906 onwards of abundant wild emmer in Israel that led to general acceptance of its role as the wild ancestor of emmer. Two morphologically distinct forms of *T. dicoccoides* have been recognized (Poyarkova 1988; Poyarkova and Gerechter-Amitai 1991), a narrow-eared, gracile form native to the whole range of wild emmer, and a wide-eared, robust form of more restricted distribution. Although both forms are found in weedy habitats such as roadsides, both mostly grow in primary, undisturbed habitats. Unlike wild einkorn and barley, wild emmer has conspicuously failed to spread outside the Fertile Crescent. Its current distribution is therefore believed to be more representative of its early Holocene distribution than that of the other wild cereals.

As with wild einkorn, wild emmer consists of two morphologically similar but reproductively isolated tetraploid species, *T. dicoccoides* and *T. araraticum*, the latter first recognized in the 1930s and named by Jakubziner in 1947. *T. araraticum* has been identified as the wild ancestor of *T. timopheevi*, a rare domesticated glume wheat found in Georgia.

Distribution of wild ancestors at the time of domestication

Once the wild ancestors of einkorn and emmer had been identified, it became clear that the domesticates would most likely have been taken into domestication in the same area where the wild ancestors grew. We have two main sources of information for the distribution of wild cereals during the period of domestication around 10 000 years ago: the current distribution of wild cereals, and archaeobotanical finds of wild cereals from pre-agrarian sites. In this section evidence from the current distribution will be discussed, while archaeobotanical finds are considered further on.

Given the relatively slight changes in climate over the last 10 000 years, human activities have had the most impact on the distribution of wild cereals in the Holocene. On the one hand, populations of wild cereals have been reduced owing to the impact of deforestation, grazing and the spread of farming on their habitats. Archaeobotanical evidence for the distribution of wild einkorn, discussed below, suggests that the wild wheats may have grown up to 100 km beyond their current range, into the heavily grazed north Syrian steppe. On the other hand, the creation of extensive areas of disturbed habitats – especially fields and field edges – has created opportunities for some wild species to spread with the domesticates.

Harlan and Zohary (1966) established a widely used distinction between primary, relatively undisturbed habitats, and secondary, ruderal or segetal habitats. Areas in which a wild cereal only grows in secondary habitats – for example on roadsides or field edges – are likely to be areas to which it spread as a weed rather than where it grows as a truly wild plant. Given the degree to which humans have used and disturbed virtually every bit of land in southwest Asia, the distinction between primary and secondary occurrences is not always easy to put into practice. Wild emmer is reasonably straightforward: it is not weedy and has not spread outside the Fertile Crescent of hills surrounding the steppe and deserts of Mesopotamia. Wild einkorn grows over a much wider area, and some problems in establishing its primary habitat are discussed below.

Einkorn

Wild einkorn is widespread, growing from the Balkans to Iran (Zohary and Hopf 1993:32-38) in weedy habitats such as roadsides and field edges. Its primary distribution is in areas of oak park-forest and steppe in the northern and eastern parts of the Fertile Crescent, in an arc stretching from northern Syria through southeast Turkey, northern Iraq and western Iran (Fig. 10). Zohary and Hopf (1993:34) suggest that einkorn also grows in primary habitats on the central Anatolian plateau. In our experience wild einkorn in this area is almost exclusively a weed of roadsides and disturbed places, with the exception of a small population discovered in the 1970s by Gordon Hillman on the scree of Karadag, a volcanic mountain on the Konya plain (Hillman and Davies 1990:160). Otherwise, wild einkorn is conspicuously absent from the kind of oak forest or scree habitats in which it thrives in southeast Turkey.

As well as excluding central Turkey from the area of primary distribution, we would perhaps include southern Lebanon. Aaron Aaronsohn found both wild einkorn and wild emmer growing together in truly wild habitats on Mount Hermon in 1907 (Aaronsohn 1910:43-44). The recent discovery of *T. boeoticum* and *T. urartu* in southwest Syria also suggest that the einkorn is native to the western part of the Fertile Crescent (Rifaie *et al.* 1981). However, it is true that stands of *T. boeoticum* and *T. urartu* are sparser and much more scattered than further north (van Slageren *et al.* 1989). Both species are abundant in parts of Armenia and may well grow in primary habitats there (Tumanyan 1929-1930). Unlike *T. boeoticum, T. urartu* seems to be restricted to more or less primary habitats and has not spread into western Turkey or the Balkans. Its presence with *T. boeoticum* on Mount Hermon and in Armenia strengthens the case that these areas are within the primary distribution of wild einkorn.

Emmer

Johnson's (1975) large-scale study of tetraploid wild wheats pointed to a clear division between the distribution of *T. dicoccoides* in the Levant and southeast Turkey, and *T. araraticum* in northern Iraq and the Zagros mountains of Iran. Other studies have shown that although all the Levantine wild wheats are the *T. dicoccoides* form, both *T. araraticum* and *T. dicoccoides* are common in southeast Turkey, while there are occasional populations *of T. dicoccoides* among the predominantly *T. araraticum* wheats of northern Iraq and the Zagros mountains (Tanaka and Ishii 1973), and reflected in Zohary and Hopf's map (1993:41). *T. araraticum* also grows in Transcaucasia. As weedy forms of wild emmer do not exist, all these locations probably form part of the primary distribution. Figure 10 shows the Levantine populations of pure *T. dicoccoides* separately from the mixed areas of *T. araraticum* and *T. dicoccoides* elsewhere in the Fertile Crescent.

Defining the area of origin

Wild einkorn grows most abundantly in the northern and eastern parts of the Fertile Crescent. Its presence in central or western Anatolia cannot be ruled out, but archaeological evidence points to the Fertile Crescent proper as the area of domestication. Although wild einkorn grows rather sporadically in the Levant (in northern Israel and Jordan, and neighbouring areas) it may have been more abundant 10 000 years ago.

It seems likely that there has been no substantial change in distribution of wild emmer since the beginnings of farming. It must have been taken into cultivation somewhere in the Fertile Crescent. The absence of the *timopheevi* type of tetraploid hulled wheat from any population outside Transcaucasia today strongly suggests that the emmer species that spread with the first agriculture was pure *T. dicoccum*. However, we should not deduce from this that emmer was necessarily domesticated in the area where only *T. dicoccoides* grows, the Levant. Although both

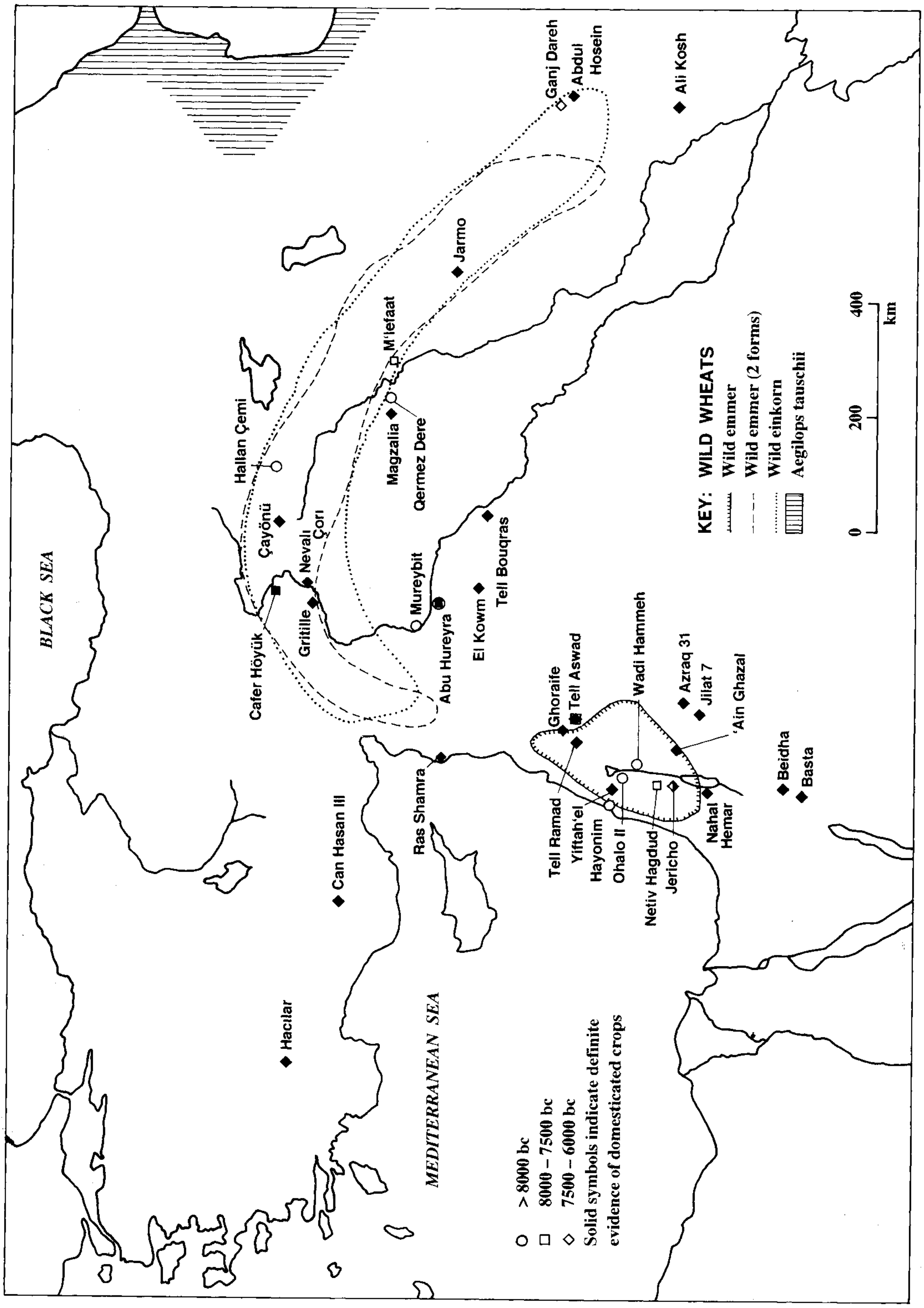
BLACK SEA
MEDITERRANEAN SEA
Ganj Dareh
Abdul Hosein
Ali Kosh
Jarmo
M'lefaat
Magzalia
Qermez Dere
Hallan Çemi
Çayönü
Nevalı Çori
Gritille
Cafer Höyük
Mureybit
Abu Hureyra
El Kowm
Tell Bouqras
Ghoraife
Tell Aswad
Wadi Hammeh
Azraq 31
Jilat 7
'Ain Ghazal
Beidha
Basta
Nahal Hemar
Tell Ramad
Yiftah'el
Hayonim
Ohalo II
Netiv Hagdud
Jericho
Ras Shamra
Can Hasan III
Hacılar
KEY: WILD WHEATS
Wild emmer
Wild emmer (2 forms)
Wild einkorn
Aegilops tauschii
0 200 400 km
○ >8000 bc
□ 8000 – 7500 bc
◇ 7500 – 6000 bc
Solid symbols indicate definite evidence of domesticated crops

Fig. 10. Distribution of archaeological sites in relation to the distribution of wild wheats. Only those Epipalaeolithic and Neolithic sites dating to before 6000 BC with available archaeobotanical reports are shown. Solid symbols indicate definite evidence of domestication; empty symbols indicate sites that are non-agrarian or of uncertain status. Full details are given in Table 2. Distribution of wild wheats in primary, truly wild, habitats is shown, but small populations of wild einkorn on Mount Hermon in southern Lebanon and of wild einkorn and emmer in Transcaucasia are not shown. Note that wild emmer in the Levant consists of pure *T. dicoccoides*; in the northern Fertile Crescent both *T. dicoccoides* and *T. araraticum* are present (indicated by the dashed line). The western extension of primary habitats of *Aegilops tauschii* is shown, around the Caspian sea.

T. araraticum and *T. dicoccoides* grow in southeast Turkey and northern Iraq, populations in this area often consist of just one species and the initial domestication episode could therefore have occurred anywhere throughout the Fertile Crescent.

A number of attempts have been made to narrow the geographical area of domestication; van Zeist and Bakker-Heeres (1982:190-191) suggested that domesticated einkorn, because it usually has one-grained spikelets, must have originated in the area where wild einkorn is primarily one-grained. This is in western Anatolia, rather than in the Fertile Crescent where wild einkorn is primarily two-grained. However, this does not fit well with the archaeological evidence showing that agricultural villages seem to appear later in western Anatolia than in the Fertile Crescent. The comparative rarity in the past and present of two-grained forms of domesticated einkorn strongly suggests that one-grained forms have adaptive value. They could thus have evolved very rapidly from the two-grained wild einkorn. In any case, in two-grained forms of wild einkorn, the lower spikelets are invariably one-grained. Intriguingly, the few ancient finds of two-grained domesticated einkorn are in Greece and surrounding areas (van Zeist and Bottema 1971; Kroll 1992) rather than in the Fertile Crescent.

The area surrounding the Jordan valley is often pinpointed as the location of the first domestication, doubtless in part because of the massive stands of wild emmer that surround Lake Galilee (McCorriston and Hole 1991). While this is a possible location for domestication of emmer, it is not the only possibility, and is an unlikely area for the domestication of einkorn. If anything, southeast Turkey is the area in which wild einkorn and wild emmer both overlap. Without new evidence, trying to narrow down the origins of agriculture to a specific region within the Near East is not possible.

The effects of domestication on einkorn and emmer

What differences did domestication make to the cereals? The main difference is between the fully brittle rachis of wild wheats and the semi-brittle hulled rachis of hulled wheats. Instead of disarticulating at maturity, the spikes of domesticated wheats stay intact and must be broken up by threshing. This is not a trivial difference. Experimental work suggests that at best 80% of a wild cereal can be harvested, with a more typical figure of around 50% depending on harvesting method (Hillman and Davies 1990:182-184); this contrasts with nearly 100% of a domesticated hulled wheat.

Domestication also involves other changes. Grain size increases markedly, but as yield is as much a function of spikelet number, we cannot be certain this led to a change in overall yield. Larger seeds could reduce the effort needed for dehusking, and would lead to larger seedlings that would be more competitive with weeds. A number of other physiological adaptations to higher yield have been noted in domesticated wheats: increased phloem area and leaf area, and changes in the timing of photosynthesis and transport of assimilates within the plant (Bamakhramah *et al.* 1984; Dunstone and Evans 1974; Evans 1976, 1993; Evans *et al.* 1970; Evans and Dunstone 1970). We cannot be certain to what extent these changes occurred as part of the first process of domestication, or are the result of thousands of years of conscious or unconscious selection.

Archaeobotanical evidence for domestication of einkorn and emmer

Identifying domestication of hulled wheats

When hulled wheats were first cultivated, they would have retained their wild morphology. However, controlled harvest and sowing of a wild plant by humans opens the possibility of strong selective pressures. Hillman and Davies (1990) have modeled wild cereal cultivation and have shown that under certain conditions a morphologically fully domesticated crop could be created in 25 years. Certain methods of harvesting in particular, such as cutting by sickle, would favour the mutated forms with tough-rachised spikes. An experiment in cultivation and harvesting of wild einkorn is currently underway in southern France to test this hypothesis (Anderson 1992; Anderson-Gerfaud *et al.* 1991; Willcox 1992). One implication of this for archaeobotany is that we are unlikely to find a site where domestication is in progress; the event may have taken place too quickly.

The characters used to identify full morphological domestication are rachis toughness and grain size. Because wild spikes disarticulate and disperse their spikelets as they mature, the disarticulation scars are smooth and untorn. In contrast, the tough rachis of domesticated hulled wheats requires threshing to break up spikelets. At agricultural sites virtually all the scars are roughly torn. However, as Mordechai Kislev and Gordon Hillman have pointed out, not all wild spikes will disarticulate freely, particularly if they are from the basal part of the ear or threshed soon after harvesting slightly under-ripe ears (Hillman and Davies 1992:157-158; Kislev 1992; cf. Zohary 1992:85). Thus a small proportion (<10%) of torn rachis nodes does not imply domestication.

Both einkorn and emmer show a marked increase in grain size with domestication, but these differences are not always easily observed on early Neolithic plant remains which are usually in poor condition. Archaeobotanists do consider the presence of reasonable quantities of free-threshing wheat grains as a good indicator of domestication because there are no wild free-threshing wheats. However, free-threshing wheats do not appear until around 7000 bc and are therefore not a useful indicator of agricultural communities for the earliest agricultural sites, dating to about 8000 bc.

Archaeobotanical remains of einkorn and emmer

Traditionally, the period around the origins of agriculture has been divided into three: the Epipalaeolithic (ca. 16 000-8000 bc), the Pre-Pottery Neolithic A (ca. 8000-7600 bc), and the Pre-Pottery Neolithic B (ca. 7600-6000 bc). The Epipalaeolithic – equivalent to the Mesolithic of Europe – is generally thought of as a pre-agrarian hunter-gatherer era, while the Neolithic marks the beginning of agricultural societies.

Plant remains from Epipalaeolithic and Neolithic sites (pre-6000 bc) are listed in Table 2. The heavy line separates sites thought to be hunter-gatherer from those thought to be agricultural. At the earlier sites the plant remains represent wild taxa.

Only three of these have produced definite hulled wheat remains: Ohalo II, Abu Hureyra and Mureybit. At Ohalo II, an Israeli site dating to 17 000 bc, 22 grains and nine spikelet forks of *T. dicoccoides* have been reported (Kislev *et al.* 1992). Of the barley rachis segments (*n*=30), four were of torn, non-brittle type. This conforms well to experimental results on threshing wild cereals.

At Abu Hureyra and Mureybit less information is available on the morphology of the rachis segments, but the wheat grains are consistent with wild einkorn morphology. Overall, the plant remains appear wild. The question has arisen whether wild cereals are being cultivated – but at a point before morphological domestication – or are being collected.

At present we have no definite answer to this question, although Hillman *et al.* (1989) concluded from the association of perennial species that the Abu Hureyra grain was probably collected from the wild. Both Abu Hureyra and Mureybit lie around 100 km south of the current-day distribution of wild einkorn, leading to suggestions that it must either have been cultivated or carried in. However, the latest reports on both sites stress how little is known about the past distribution of wild cereals. The presence of wild einkorn at these sites is in fact likely evidence for a more extensive distribution in the past. In view of the arid nature of the north Syrian steppe, it would be no surprise if wild einkorn has disappeared from the area under current grazing pressures.

There are real difficulties in identifying the earliest agricultural sites. First, there are problems with dating: sites such as Jericho, Ali Kosh and Ganj Dareh, once thought to date to soon after 8000 bc, have been re-dated as much as 500 years later after critical analysis of their radiocarbon dates. Dating is still often controversial and more dates made on seed remains would be highly desirable. Second, there is the problem of deciding whether the plant remains belong to an agricultural assemblage: are the remains of morphologically domesticated crops present? Mordechai Kislev (1989, 1992) has argued that reliable identification of domesticated crops in early assemblages can only be made on the basis of the proportion of torn ('domesticated-type') rachis scars in the wild cereals. Grain shape is very ambiguous at this period.

Increasingly, archaeobotanists agree with this view: sites such as Ganj Dareh and the PPNA level of Jericho lack any definite evidence of domestication, either because the plant remains are very few, or because although abundant, they are not distinctive. At Jericho a grand total of three rachis segments and less than 20 grains of cereals were recovered from the PPNA levels (Hopf 1983); at Ganj Dareh several hundred barley grains were collected, but few rachis segments and no wheat remains (van Zeist *et al.* 1986). Grains from wild and domesticated barley are very similar in appearance and thus not diagnostic. The earliest plant remains from Tell Aswad (phase I) are similarly undiagnostic. Plant remains are few because of the failure to apply large-scale flotation techniques at these sites, in contrast to the major efforts at seed recovery made at sites such as Abu Hureyra and Franchthi Cave.

In Table 2 we have indicated which sites seem to be definitely agricultural. The earliest of these are the Neolithic level of Abu Hureyra in northern Syria, and Cafer Höyük in southeast Turkey. At this and other sites details of rachis disarticulation are scarce, but large domesticated-type grains are abundant and agriculture is a reasonable assumption. The need to be cautious is illustrated by the case of Netiv Hagdud, where the presence of 10% domesticated-type rachis scars on the barley rachis segments was at first interpreted as evidence for domesticated barley (Kislev *et al.* 1986).

Table. 2. Plant remains from pre-pottery archaeological sites in the Near East. Note that sites dating to before 7800 BC are apparently pre-agricultural; definite remains of domesticated plants are present at many (but not all) sites from 7800 BC onwards.

Site (phase)	Period	Uncalibrated radioc. dates (bc)	Status	Wild einkorn	Dom. einkorn	Wild emmer	Dom. emmer	Dom. rye	Naked wheat	Hulled barley	Pea	Lentil	Bitter vetch	Source
Ohalo II	Epipal.	17 000	Wild			+				+		+		1
Wadi Hammeh 27	Epipal.	8200-7900	Wild							?		?		2
Hayonim Cave	Epipal.	10300-9000	Wild							+				3
Abu Hureyra	Epipal.	9500-8000	Wild	+								+	+	4
Hallan Cemi	PPN	8600-7900	Wild									+	+	5
Mureybit (I-III)	Epipal.	8500-7600	Wild	+						+	+	+	+	6
Qermez Dere	PPN	8100-7600	Wild							+		+	+	7
Netiv Hagdud	PPNA	8000-7400	Wild							+		+		8
M'lefaat	PPN	7900-7700	Wild	?						+		+	+	9
Tell Aswad (I)	PPN	7800-7300	?				+			+	+	+	+	10
Abu Hureyra	PPN	7700-5000	Agric.		+		+	+		+				4
Cafer Höyük	PPNB	7600-6200	Agric.	+	+		+			+	+	+	+	11
Jericho	PPNA	7400	?				+			+		+		12
Çayönü	PPN	7500-6700	Agric.	+	+	?	+			+	+	+	+	13
Jericho	PPNB	7200-6800	Agric.		+	?	+			+	+	+		12
Nahal Hemar	PPNB	7200-6000	Agric.				+			+		+		14
Nevali Çori	PPNB	7200	Agric.		+		+			+	+	+		15
'Ain Ghazal	PPNB	7250-6500	Agric.				?			+	+	+		16
Ganj Dareh	PPN	?7000-6600	?							+		+		17
Gritille	PPN	7000-6000	Agric.				+			+		+	+	18
Magzalia	PPN	6600-6000	Agric.		+		+		?	+		+		19
Ghoraife	PPN	6900-6100	Agric.		+		+		+	+	+	+	+	20
Hacilar	PPN	6900-6500	Agric.	?			+			+		+		21
Tell Aswad (II)	PPN	6900-6600	Agric.		+		+		+	+	+	+		10
Jilat 7	PPNB	6800-6500	Agric.	+	+		+		+	+		+	?	22
Yiftah'el	PPNB	6800	Agric.									+	+	23
Beidha	PPNB	6750	Agric.				+			+				24
Can Hasan III	PPN	6600-5800	Agric.	+	+		+	+	+	+		+	+	25

Site (phase)	Period	Uncalibrated radioc. dates (bc)	Status	Wild einkorn	Dom. einkorn	Wild emmer	Dom. emmer	Dom. rye	Naked wheat	Hulled barley	Pea	Lentil	Bitter vetch	Source
Abdul Hosein	PPN	6500	Agric.				+			+		+		26
Ras Shamra (Vc)	PPN	6500-6000	Agric.				+			+	+	+		27
Ali Kosh (BM)	PPN	?6400-6000	Agric.		+		+			+				28
Jarmo	PPN	?6400	Agric.	+		+	+			+				29
Azraq 31	PPN	6350	Agric.						+	+				30
El Kowm (A)	PPN	6300-6100	Agric.				+		+	+	?			31
Tell Bouqras	PN	6350-5850	Agric.	+	+		+		+	+	+	+		32
Tell Ramad (I)	PPNB	6350-6100	Agric.	+	+		+			+	+	+	+	33
Basta	PPNB	6200	Agric.				+			+	+			34
Tell Ramad (II)	PPNB	6100-5800	Agric.	+	+		+		+	+	+	+	+	35

Sources: 1. Kislev *et al.* 1992; 2. Potts *et al.* 1985; 3. Hopf and Bar-Yosef 1987; 4. Hillman *et al.* 1989; 5. Rosenberg *et al.* 1995; 6. van Zeist and Bakker-Heeres 1984b; 7. Nesbitt 1995a, Watkins *et al.* 1991; 8. Bar-Yosef *et al.* 1991, Kislev *et al.* 1986; 9. Nesbitt 1996a; 10. van Zeist and Bakker-Heeres 1982; 11. de Moulins 1993; 12. Hopf 1983; 13. van Zeist and de Roller 1991/1992; 14. Kislev 1988; 15. Rainer Pasternak (pers. comm.); 16. Rollefson *et al.* 1985; 17. van Zeist *et al.* 1986; 18. Voigt 1984; 19. Lisicyna 1983; 20. van Zeist and Bakker-Heeres 1982; 21. Helbaek 1970; 22. Garrard *et al.* 1994; 23. Garfinkel *et al.* 1988; 24. Helbaek 1966; 25. French *et al.* 1972, Hillman 1978; 26. Hubbard 1990; 27. van Zeist and Bakker-Heeres 1984a; 28. Helbaek 1969; 29. Helbaek 1959a, 1959b; 30. Garrard *et al.* 1988; 31. van Zeist 1986; 32. van Zeist and Rooijen 1985; 33. van Zeist and Bakker-Heeres 1982; 34. Gebel *et al.* 1988; 35. van Zeist and Bakker-Heeres 1982.

Kislev (1989, 1992) now suggests that this is consistent with the similar percentage of torn rachis scars found in experimental harvests of wild barley. This hypothesis is confirmed by the 13% of domesticated-type rachises found at Ohalo II, dating to 17 000 bc, for which no-one would claim domesticated status.

What is the overall archaeobotanical evidence for the distribution of wild wheats? The remains of wild wheat from Epipalaeolithic sites are still too scattered to throw much light on their distribution, although the Ohalo II wild emmer is welcome confirmation of its presence in the Levant during the last glacial. The absence of any wild wheat so far from Hallan Çemi, sited in the middle of oak forest in southeast Turkey, is surprising, but the plant remains are still under study. We have hints from the presence of wild einkorn at Abu Hureyra and Mureybit that it may have spread further south into Syria than it does today. Although elaborate models have been constructed for the increasing use of wild cereals as a food during the Levantine Epipalaeolithic (Henry 1989), these have not been tested by careful recovery of plant remains from excavations in the region.

Archaeobotanists are becoming more cautious in identifying agriculture. Nevertheless, sites such as Neolithic Abu Hureyra, Cafer Höyük and Çayönü do establish the farming of domesticated einkorn, emmer and barley by 7800-7500 bc. This is broadly in line with the widely used figure of 8000 BC for the origins of agriculture. The concentration of the earliest agricultural sites in and near the Fertile Crescent confirms that einkorn and emmer were first domesticated in this area, at much the same time as barley, pea, lentil and bitter vetch.

It is important to realize just how few sites are represented by plant remains prior to 7000 bc. In view of the small sample size – just seven sites with definite agriculture – we think that any attempt at narrowing down the origins of agriculture within the Fertile Crescent is unwise. There is no evidence that one of the hulled wheats or barley was domesticated before the others, or that domestication took place in one area rather than another. More Neolithic sites are known from the Levant than any other area, but this simply reflects an extraordinary concentration of archaeological work in Israel, Jordan and Syria. Turkey and Iraq are still poorly known, while archaeological fieldwork ended in Iran in 1979. Some authors have argued strongly that agriculture began in the Jordan valley (McCorriston and Hole 1991; Smith 1995), but neither the evidence of the wild ancestors nor archaeobotany allow this conclusion at this stage. Not only is the botanical evidence from early sites scanty, but re-evaluation of evidence for early agriculture suggests that the earliest definite evidence of plant domestication is as much present in northern Syria and southeast Turkey as in Israel and Jordan.

The Near East as the cradle of agriculture

Archaeology has played a vital role in identifying the Fertile Crescent as the area in which wheat, barley and other key Old World crop plants were domesticated. This evidence for the earliest agriculture has been in two forms: evidence for the earliest domesticated cereals, and more generally, for the presence of the earliest farming villages.

If we take 8000-7800 BC as representing the point at which domesticated plants appear, the widespread occurrence of farming sites by 7000 BC points to a rapid spread of agriculture within the Fertile Crescent. Obviously the increased productivity of cultivated land stimulated much of this rapid spread. Not only were yields increased compared with stands, but cultivation could expand into new areas.

In contrast, farming villages do not appear in Egypt, Transcaucasia, the Balkans or Central Asia before 6000 bc. The domesticated crops and animals which appear in these areas are the same as those at early Near Eastern sites. The evidence of relative dating and of a common agricultural basis fits well with a model of agriculture spreading from the Near East. It has often been argued that modern-day distribution of wild cereals may not be an accurate guide to distribution prior to the millennia of massive ecological changes caused by human farming (e.g. Barker 1985:250-256; Dennell 1985:152-168). However, there is no archaeobotanical or botanical evidence for wild einkorn or wild emmer in the Balkans or central Asia, and the archaeobotanical and archaeological evidence clearly shows that the first farming cultures developed in the core Near Eastern area. Although the wild wheats do seem to be native to Transcaucasia, the dating of its earliest farming settlements is also much later than in the Fertile Crescent.

Domestication of spelt

Genetic evidence

Unlike einkorn and emmer, the hexaploid hulled wheat spelt (*T. spelta*) has no wild hexaploid ancestor. Once it was known that both *Triticum* and *Aegilops* existed in polyploid series of diploid (14 chromosomes), tetraploid (28) and hexaploid (42), it was clear by the 1920s that hexaploid wheats must be an allopolyploid of a tetraploid *Triticum* and a diploid *Aegilops*. In a classic experiment McFadden and Sears (1946) showed that *Aegilops tauschii* Coss. (= *A. squarrosa* L.) was the *Aegilops* species involved in the hybrid. The *Aegilops* species were narrowed down to those with the barrel-type breakage pattern, and then to *A. tauschii* because its square-shouldered glumes best matched spelt. Subsequent work using other techniques has confirmed the role of *A. tauschii* as an ancestor of both the hulled and free-threshing hexaploids (Kerby and Kuspira 1987:726).

When wild or domesticated emmer wheat was crossed with *A. tauschii*, and chromosome doubling induced in the first generation, a fertile hybrid resulted that was very similar to cultivated spelt. McFadden and Sears (1946) reported that the hybrid had the domesticated, semi-tough rachis, which would select against survival in the wild. Further crosses between both naked and hulled domesticated tetraploid wheats and *A. tauschii* forms always resulted in hulled, spelt-type hexaploid wheats (Kerber and Rowland 1974). The first hexaploid wheat would, therefore, have been a hulled wheat.

Subsequent work (Sears 1976) showed that the *T. dicoccoides* accession used in the original 1940s experiments was in fact the domesticate *T. dicoccum*. When the cross was repeated with a truly wild *T. dicoccoides*, the resulting hybrid was fragile-rachised. It seems that fragile-rachised, wild hexaploid wheats could have evolved. However, the only known cases of brittle-rachised, wild-type hexaploid wheats are the wild variety of *macha* reported by Dekaprelevich (1961) and a brittle-rachised hexaploid wheat in Tibet (Shao 1983). Both grow only as weeds of cereal fields and are therefore much more likely to be a feral derivative of domesticated wheat than a truly wild species. Overall, several sources of evidence point to the tetraploid parent as being *T. dicoccum* rather than *T. dicoccoides* (Porceddu and Lafiandra 1986:151; Kimber and Sears 1987:161).

Aegilops tauschii grows as a weed of cereals over large parts of the Near East, including areas such as eastern Anatolia omitted from the map in Zohary and Hopf (1993:51). The area in which hexaploid wheats first occurred must be within the ancient distribution of *A. tauschii*, and this perhaps matched its current, more limited, primary habitats. These stretch from west of the Caspian Sea to central Asia in dry grasslands and forest edges (van Slageren 1994).

A. tauschii has been divided by some taxonomists into two subspecies: *strangulata*, with a bead-like arrangement of spikelets, and *tauschii* with cylindrical spikes. Isoenzyme studies suggest that subsp. *strangulata* is the donor of the D genome to the hexaploid wheats. Subspecies *strangulata* has a narrower distribution than subsp. *tauschii*, mainly growing in the southwest fringes of the Caspian Sea (Jaaska 1993). This strengthens the case for the hybridization of tetraploid wheat with *A. tauschii* having occurred in the Caspian region. This westernmost extension of the primary habitats of *A. tauschii* is shown on Figure 10; note that it does not overlap with the distribution of wild emmer or the Fertile Crescent zone of early domestication.

Archaeobotanical evidence

The most abundant and best-documented archaeological evidence for spelt is in Europe. Spelt remains occur at later Neolithic sites (2500-1700 BC) in eastern Germany and Poland, Jutland and possibly two sites in Southwest Germany (Körber-Grohne 1989). During the Bronze Age it spread widely in northern Europe.

Records of spelt from elsewhere are sparse and poorly documented. The earliest archaeological evidence of spelt is from the 5th millennium BC in Transcaucasia (Lisitsina 1984), from north of the Black Sea (Janushevich 1984) and from the contemporary site of Yarym-Tepe II in northern Iraq (Bakhteyev and Yanushevich 1980). Large numbers of glume imprints of spelt are recorded from Moldavia, dating to between 4800 and 4500 BC (Körber-Grohne 1987), while Popova (1991) reports three minor occurrences from the Neolithic and Chalcolithic of Bulgaria.

However all these records from outside Europe share two features: the spelt is usually present as a small proportion of the other wheats, and the identification criteria are poorly documented. It appears that the most common identification criterion is the barrel-type break of the rachis. This has two problems. First, some populations of modern emmer show mixed types of breakage. Second, fragmentary remains of spelt spikelets can be difficult to distinguish from those of the *Aegilops* species that also have barrel-type disarticulation: *A. tauschii*, *A. cylindrica* Host, *A. ventricosa* Tausch, *A. crassa* Boiss. and *A. juvenalis* (Thell.) Eig. Some of these species are common weeds of cereal fields. Although most *Aegilops* species are concentrated in a band stretching from the Mediterranean basin to Central Asia, *A. cylindrica* does grow north of the Black Sea and in the Balkans and could account for some spelt identifications there.

Aegilops spikelet remains have been identified in a number of archaeobotanical assemblages, for example in Bronze Age samples from Shortugai in Afghanistan and Selenkahiye in Syria (Willcox 1991:150; van Zeist and Bakker-Heeres 1985:255), and at early Chalcolithic Can Hasan I in central Turkey (Fig. 11).

Overall, we consider that these records of spelt from outside Europe are still doubtful, particularly bearing in mind their important role in deciding the hotly debated area of origin of ancient (and modern) European spelts.

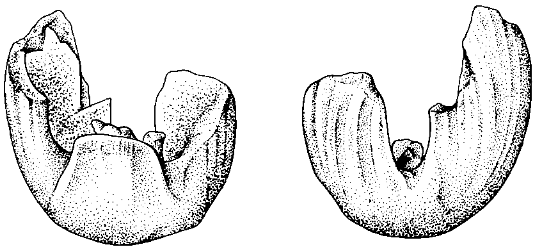

Fig. 11. Charred *Aegilops* spikelet fork dating to the Chalcolithic period (6th millennium bc) from the site of Can Hasan, Turkey. Note that the base of the upper rachis internode is still attached, and the overall robust appearance. In these respects, *Aegilops* chaff is somewhat similar to that of spelt.

Integration of evidence for spelt domestication

Seventy years ago Flaksberger (1925) drew attention to the antiquity of spelt cultivation in Europe and the lack of evidence for spelt in the Near East, and proposed that spelt evolved in Europe from bread wheat (cf. Schiemann 1948). Laboratory crosses of hexaploid free-threshing wheats with *T. dicoccum* have indeed succeeded in reconstructing synthetic spelt which is very similar to cultivated spelt (Mac Key 1966:252-255).

Zohary and Hopf (1993:52-53) consider that the archaeobotanical evidence from Transcaucasia and the Balkans is consistent with the hybridization of emmer and *A. tauschii* near the Caspian, and its travel to Europe by way of the north shore of the Black Sea. It is true that other crops, such as millet, reached Europe by this route. However, it is highly surprising that the ancestral spelt did not spread into Anatolia by way of highland Iran, particularly in view of the increased cold resistance perhaps conferred by the D genome.

Sadly we have no archaeobotanical evidence from the Caspian fringes where hybridization may have occurred. We do have evidence of free-threshing hexaploid wheats found at Near Eastern sites rather earlier than expected. While few free-threshing wheat remains have been identified on good morphological grounds to ploidy level, hexaploid free-threshing wheats have been identified on the basis of reliable rachis criteria at Can Hasan III in south-central Anatolia, dating to ca. 6500 BC (Hillman 1978:168) and at Cafer Höyük in southeast Anatolia, in levels IV-III dating to 7000-6000 BC (de Moulins 1993). This fits poorly with the model in which agriculture and tetraploid cultivated wheats are thought to have reached the Caspian area between 6000 and 5000 bc, allowing the hybridization with *A. tauschii* to occur (Zohary and Hopf 1993:50-52).

The discovery in the 1950s of spelt cultivation in Iran by Hermann Kuckuck, an FAO cereal breeding consultant, caused considerable interest. It was grown by Baktiari tribes over an extensive area surrounding the high (2000-2300 m a.s.l.) plateau of Shahr Kord, some 80 km southwest of Isfahan, central Iran. Both emmer and *T. aestivum* were also important crops in the same area (Schulz 1915; Kuckuck and Schiemann 1957). While the Iranian spelt spikes more often break up as wedge-shaped ‘emmer-type’ spikelets than European spelt, anatomical studies showed no difference in rachis structure (Pohlendt 1958). This discovery of spelt in Iran seemed to solve a critical problem: if spelt originated in the Near East, why was it no longer cultivated there?

Although a range of crossing experiments was carried out soon after the discovery of Iranian spelt (Kuckuck 1960; Gökgöl 1961), little genetic analysis has been carried out using other techniques. It is still unclear whether this isolated island of spelt cultivation is truly an ancient survival, or the result of a recent hybridization. Emmer was apparently brought to the same plateau by Armenian settlers in the 17th century. In view of the successful laboratory hybridization of spelt from emmer and bread wheat (see above), spelt may well have evolved after emmer was introduced to the area.

Conclusions on spelt

Recent publications have put forward a clear model for the history of spelt (Körber-Grohne 1987; Zohary and Hopf 1993). As domesticated emmer spread with agriculture from the Fertile Crescent in the direction of the Caspian Sea, it entered the native area of *A. tauschii* and hybridized with it to form spelt. Archaeological evidence for the earliest Neolithic farmers in the Caspian region suggests this happened around 6000 bc. The migration of spelt to Europe can then be traced by way of archaeobotanical remains in Transcaucasia, Moldavia and Bulgaria. Present-day cultivation of spelt in Iran and *T. macha* in Transcaucasia may be remnants of original spelt forms.

The archaeobotanical data are not fully consistent with this model:

1. Hexaploid free-threshing internodes are present at Turkish sites by 6500 BC, 500 years before the first hybridization of a hexaploid wheat is thought to have occurred. Could *A. tauschii* have been more widespread in the Neolithic than we assume, so that the hybridization could have occurred earlier? Why, if we have early free-threshing hexaploid wheats, are hulled hexaploid wheats absent? Could the original hybridization have occurred in a field of *T. durum*, leading to rapid selection in favour of a free-threshing hexaploid? Such a scenario would explain the absence of spelt from the ancient Near East.
2. Why is spelt absent from the ancient Near East? Even if the first hybridization did occur near the Caspian Sea or in Transcaucasia, it is highly surprising that spelt only spread to Europe north of the Black Sea. One would expect spelt to be well adapted to the highlands of Turkey or Afghanistan, but there are no ancient or modern records from these areas.
3. Archaeobotanical records from north of the Black Sea are poorly documented. The low frequency with which spelt appears to be present could be consistent with its spread as a weed to Europe, at which point it flourished and emerged as an independent crop. Equally, it could represent occasional misidentifications of emmer and *Aegilops* spikelets bearing barrel-type rachis breakage.

We suggest two areas in which research could help resolve the problem of spelt. First, early finds of spelt from Transcaucasia and the Black Sea region need to be re-examined. Second, we urgently need genetic characterization of present-day spelt landraces from Europe in comparison with the existing Iranian and Transcaucasian populations of spelt. Johnson (1972) concluded that the similarity in seed proteins between Iranian and European spelts suggested they shared a common, Near Eastern origin, but cautioned that two separate episodes of hybridization could not be ruled out. Clearly any such study will need to take into account variability between the populations of emmer and bread wheat from which spelt could have emerged. If these are broadly similar in Europe and the Near East, then any resulting forms of spelt will also be similar. The challenge is to separate similarity due to a common ancestral hybridization from similarity due to similar parental material.

The evolution of the Transcaucasian hulled wheats

We end our discussion of domestication with a group of hulled wheats that are restricted to Transcaucasia and adjacent areas.

Close relatives of emmer

Two tetraploid domesticates have been identified that are closely related to *T. dicoccum*. viz. *T. ispahanicum* and *T. palaeocolchicum*. *T. ispahanicum* is a long-glumed hulled tetraploid wheat, rather similar in appearance to the free-threshing *T. polonicum*. It is grown as a pure crop near Isfahan (Heslot 1958; Chelak 1978). *T. palaeocolchicum* was discovered in 1929 in Western Georgia. It is distinguished by a compact ear and strongly zig-zag rachis (Jakubziner 1958). The limited distribution of these taxa, and their close relationship to emmer, suggests that they may have evolved quite recently. Most taxonomists would rank these as subspecies of *T. dicoccum*, rather than as species in their own right.

Timopheevi wheats

T. timopheevi has a much wider, flatter ear than *T. dicoccum* (Dorofeev and Migushova 1979:311, Fig. 24), and grows in a limited region of Georgia. The original description describes it as weedy rather than domesticated (Zhukovsky 1928), and it remains unclear whether *T. timopheevi* grows as a crop in its own right, or is a weed of other wheats. Its wild ancestor is *T. araraticum*, a wild emmer wheat morphologically close to *T. dicoccoides*. Chromosome studies suggest that the domesticate *T. timopheevi* is more likely to have evolved from the Transcaucasian *T. araraticum* subsp. *araraticum* Jakubz. than from the more southern *T. araraticum* subsp. *kurdistanicum* Dorof. & Migusch (Badaeva *et al.* 1990).

The very limited distribution of *T. timopheevi* cultivation suggests it was a secondary domesticate: when emmer cultivation spread to Transcaucasia, local populations of *T. araraticum* could have grown as a weed of the emmer crops and, by being incorporated into the agricultural cycle of harvest and sowing, become domesticated. The lack of weedy habit in *T. araraticum* may explain why this process did not occur more widely across the northern and eastern Fertile Crescent. Although archaeobotanical records of *T. timopheevi* are claimed from the Bronze Age onwards in Georgia, we doubt that these can be distinguished from *T. dicoccum*.

Minor hexaploid wheats

T. macha is a hexaploid hulled wheat, discovered in western Georgia in 1929. In the 1940s Russian botanists suggested that *T. macha* was implicated in the origin of free-threshing hexaploid wheats. However, it appears to be rather distinct from other hexaploid wheats and is probably derived from *T. palaeocolchicum* (Jakubziner 1958). Kuckuck (1970:258) suggested that a brittle-rachised form of *T. macha*, var. *megrelicum* Dek. et Men., could be a genuinely wild hexaploid wheat, and therefore a candidate ancestor species. Dorofejev (1971) suggested that *T. macha* was the surviving form of the original hybridization from which hexaploid free-threshing wheats derived, while the Iranian and European spelts are secondary forms that arose from *T. aestivum*.

Details of the distribution and ecology of *T. macha* are scarce, but it appears to grow only as a minor admixture in fields of *T. timopheevi* and *T. monococcum* (Dekaprelevich 1961). Its fully brittle-eared form, var. *megrelicum*, is not described as growing outside cultivated fields and is therefore not a truly wild wheat, while normal forms are described as being between cultivated and wild wheats in terms of rachis brittleness (Dorofejev 1971:336). In view of its limited distribution and its apparent weed-like status as a minor component of crops, we regard *T. macha*, like the other hulled wheats endemic to Transcaucasia, as local forms that evolved in isolation. We think it unlikely that they played any role in the evolution of the more common wheat species.

T. vavilovii is also a hexaploid hulled wheat. It has elongated rachillae that give the ear a branched appearance (Singh *et al.* 1957). It was discovered in 1929 as a rare admixture of *T. aestivum* near Lake Van, eastern Turkey (Zhukovsky 1933). In view of its close relationship to *T. aestivum*, aside from the two closely linked genes controlling branching and the hulled character, it seems likely that *T. vavilovii* is another local, recently evolved form of wheat that hardly rates species status.

T. zhukovskyi is a hexaploid hulled wheat that carries the G genome and is thus closely related to *T. timopheevi*. It grows in fields in Western Georgia as an admixture *of T. timopheevi* and *T. monococcum*. It apparently resulted from the hybridization of these two species (Jakubziner 1958; Johnson 1968).

Hulled wheats in the ancient Near East

The hulled wheats in Mesopotamia

Textual evidence

Einkorn and emmer are important crops at most Near Eastern sites from the Neolithic onwards. We know little about their significance or use at many of these sites. Archaeobotanical reports are still too scarce in relation to the size of the Near East and the 10 000-year duration of agriculture. Although some patterns are slowly emerging, we are mainly working with snapshots in time rather than coherent models of agricultural change (Miller 1991; Nesbitt 1995b). Even at a domestic level, few studies have been made of food-processing technology and the ways in which hulled wheats could have been cooked and consumed. However, in lower Mesopotamia, in the irrigated plains of the Euphrates and the Tigris, textual evidence has stimulated ideas about the cultivation and role of the hulled wheats as part of agriculture.

Lower Mesopotamia is a semi-arid land that could not be cultivated until irrigation began in the Samarran (Late Neolithic) period, from about 5500-5000 BC onwards (Oates and Oates 1976). Emmer is the most abundant wheat species at Mesopotamian sites, a staple crop second only to hulled barley. Einkorn wheat and free-threshing wheat were less common (Renfrew 1984).

From early as 2900 BC, clay tablets were important instruments in the administration of a complex and highly centralized economic system centered upon temples and palaces. The vast amount of agricultural information is largely concerned with the administration of large enterprises, rather than with individual households.

Hrozný (1913) identified three commonly occurring cereals in the Sumerian texts in his classic study: ‘barley’ (še), ‘emmer’ (zíz) and ‘wheat’ (GIG). These identifications have become widely accepted, but there are still considerable difficulties with the meaning of various derivative terms. Clues to meaning come from the context of words in texts, which may indicate specific properties or that the term belongs to a specific group of words (Powell 1984; Postgate 1984a, 1984b). For example, it has been suggested (Powell 1984:52) that a form of emmer used in soup was equivalent to the German ‘Grünekern’, green kernels of spelt used for making soup. Yet mature grains of emmer are perfectly suitable; indeed, we consumed emmer grain soup during a dinner in Castelvecchio Pascoli, near the city of Pisa, northern Italy. The term is more likely to refer simply to clean, dehusked grains of emmer. Both Postgate (1984b) and Powell (1984) make it clear that there are major difficulties in using the textual evidence to identify most hulled wheat products because of difficulties in translation. It is, however, clear that emmer was used for making beer and groats (Powell 1985:17-18).

Sumerian terms were used as shorthand words (‘sumerograms’) for various terms on clay tablets by the Hittites from the 17th to 12th centuries BC in their central Anatolian empire. One sumerogram has been widely translated as emmer, on the grounds that it retained the same meaning as its earlier use in Sumeria. Hoffner (1974) suggested that the archaeobotanical evidence from the middle and late Bronze Age was lacking in hulled wheats, and that zíz could be better translated as bread wheat or wheat in general. Recent study of plant remains from a middle Bronze Age site in central Anatolia showed that bread wheat was far more common than einkorn or emmer, and that Hoffner’s identification is therefore correct (Nesbitt 1993). This kind of direct comparison between archaeobotanical results and philological analysis is still rare. However, this example shows how important it is if we are to understand both archeological and written evidence of the past.

Salinization and the decline of emmer?

In the 1950s a collaboration of historians, archaeologists and an archaeobotanist put forward the highly influential “theory of progressive salinisation”. They suggested that cereal yields in southern Mesopotamia declined between 3000 and 2000 BC, and that there was a shift from emmer to barley crops. Both trends were due to increasing salinization of irrigated fields, and that this led to the eventual decline of ancient Sumer.

The theory has been widely accepted, but the recent publication of the raw data on which it was based (Jacobsen 1982) has shown that this work suffers from three problems. First, the textual evidence for yields in antiquity or for crop quantities is deeply ambiguous (Powell 1985); second, the archaeobotanical evidence for southern Mesopotamian crops is very scarce and insufficient to demonstrate anything beyond a very general ranking of cereals for the 3rd millennium BC as a whole; third, we know next to nothing of the comparative response of emmer and barley to salinity. The only study we know of to have compared yields found that one variety of Indian emmer wheat yielded much more than barley under a number of salinity levels (Hunshal *et al.* 1990). In view of modern-day emmer’s adaptability to poor soil conditions, it is possible that some forms of ancient emmer were resistant to saline conditions. This combination of ambiguous texts, lack of archaeobotanical data, and lack of agronomic characterization of hulled wheats equally affects virtually all studies of ancient historical agriculture.

The decline of the hulled wheats in the Near East

Today cultivation of hulled wheats in the Near East is restricted to the Pontic Mountains of Turkey (einkorn and emmer) and Iran (emmer and spelt). When and why the hulled wheats fell from their positions as staple crops is one of the big questions in Near Eastern archaeobotany. As more reports on ancient plant remains are published, we are able to pick out more regional variation.

In eastern Turkey einkorn and emmer were replaced by free-threshing wheats abruptly at the beginning of the Early Bronze Age (ca. 3000 bc), and are virtually absent from the archaeobotanical record thereafter (van Zeist and Bakker-Heeres 1975; Nesbitt 1995b). In central Turkey einkorn and emmer appear to be minor crops in Middle Bronze Age samples (1900-1700 bc) from Kaman-Kalehöyük (Nesbitt 1993). In the west, archaeobotanical data are still scarce. However, Schiemann's study of the plant remains from Troy (which supersedes a number of earlier reports on the same material), in which she identified abundant einkorn and emmer, suggests that these were still important in the 2nd millennium BC (Schiemann 1951). Unfortunately the material derives from the 19th century excavations, is poorly provenanced and was destroyed in 1943. Archaeobotanical results from the new excavations at Troy are eagerly awaited.

To the south, in the Levant, einkorn and emmer appear to be limited to minor components in the 3rd millennium BC, and to have disappeared by the 2nd millennium BC (Miller 1991). In eastern Anatolia the disappearance of the hulled wheats may be linked to increasing evidence of hierarchical societies and market economies, leading us to suggest that under conditions of intensification, for example increased manuring, free-threshing wheats replaced them.

The trend towards an increase in the complexity of societies is widespread over the Near East at the beginning of the 3rd millennium, but hulled wheats disappear at different times in different places. An east-west gradient seems to run from eastern Anatolia to the Aegean, when hulled wheats were important until the mid-1st millennium BC. We need more case studies in which we can accurately plot the decline of the hulled wheats. This decline can then be related to changing crop husbandry techniques as tracked through weed taxa and parallel changes in animal husbandry, as well as wider changes in settlement and economy.

Egypt

The arrival of farming

Compared with the Near East, relatively few early prehistoric sites are known in Egypt and there is a striking lack of continuity in their occupation. As a result, we are missing many details of early subsistence patterns and their development. Nevertheless, it is clear that there was no farming economy in Egypt prior to between 6000 and 5000 bc, because it was not until that date that farming villages first appeared in the Delta to the north, and the Fayum oasis to the west of the Nile (Wetterstrom 1993:201). In the Nile valley the earliest settled, food-producing cultures date to 4500 BC (Baines and Málek 1984:30). The idea that agriculture originated in Egypt has a long history but there is as yet no evidence for any indigenous origins. It is possible that domestication or attempts at domestication of various plant and animal species may have taken place after agriculture was introduced but evidence for this has yet to be found.

Archaeobotanical evidence from early farming settlements demonstrates that the farming way of life must have been introduced into Egypt from the Near East. The package of crops found matches the crop complex known at this time in the Levant (Wetterstrom 1993:201). Of the two hulled wheats cultivated in the Levant in early Neolithic times, only emmer has ever been found in Egypt (Täckholm *et al.* 1941:241). Although much of the earlier Egyptological literature, as well as more recent publications, mentions the cultivation of spelt, this temperate northern glume wheat has never been grown in Egypt (Germer 1986). This mistake may have arisen partly from the use of the German term 'Spelzweizen' for the hulled wheats as a whole.

Dominance of emmer

Throughout the long and stable sociopolitical culture of ancient Egypt, there was strong continuity in agricultural practices, especially for the cereal staples. Emmer was the sole wheat which was cultivated from the beginnings of farming until Graeco-Roman times (after the conquest by Alexander the Great, in 332 BC). It was then that emmer was rapidly replaced by free-threshing macaroni wheat, *Triticum durum* (Crawford 1979:140; Bowman 1990:101). Once Egypt came under the control of Mediterranean-based foreign power, the agricultural economy was directed by political decision-making based on outside circumstances rather than purely indigenous factors. During Imperial Roman times, for example, Egypt exported vast quantities of grain to Rome (Bowman 1990:38). Thus emmer wheat lost its primacy as a crop, and it was gradually forgotten (Täckholm *et al.* 1941:241).

There is no good published evidence for the presence of free-threshing wheat in pre-Graeco-Roman Egypt. Although some archaeobotanical specimens have been identified as such, according to Täckholm *et al.* (1941:254-255) nearly all have been shown to be threshed emmer or dehusked barley grains. There are two isolated references to durum wheat identified by reliable archaeobotanists, John Percival and Elisabeth Schiemann, who identified the wheat from 12th Dynasty (1991-1783 BC) Kahun and 18th Dynasty (1550-1307 BC) Deir el-Medina respectively (Täckholm *et al.* 1941:254-255). The textual evidence, based on the interpretation of the word 'swt', cannot be considered reliable (Täckholm 1977:271; Germer 1986:1209). Lexicographical studies will never provide definitive evidence for the use or lack of free-threshing wheat. Even if some archaeobotanical evidence of free-threshing wheat should eventually be found, in comparison with the abundance of emmer which has been recovered, it must have been very scarce, and thus could not have been of any importance in ancient Egypt (Kemp 1994:146).

The primacy of emmer as a wheat crop in Egypt, until strong outside political control caused its rapid replacement, does not follow the pattern of hulled wheat decline elsewhere. Why was emmer the favoured wheat crop in Egypt for so long? There were no agronomic and ecological factors discouraging free-threshing wheat cultivation. The Egyptian climate has not altered appreciably since at least 2200 BC (Vercoutter 1992:28), and the annual inundation of the Nile valley has occurred for very much longer. When durum wheat was finally introduced in Graeco-Roman times, Egypt was able to produce vast surpluses (Bowman 1990:38), and only free-threshing wheats are grown today (Zahran and Willis 1992:338).

Despite Egypt's political isolation, trade and later conquests meant that the country was in contact with peoples who grew free-threshing wheats. Particularly during the New Kingdom (1550-1070 BC), useful new ideas were quickly absorbed by the ancient Egyptians, notably the horse and chariot (Kemp 1994:146). If the ancient Egyptians perceived benefits in the cultivation of free-threshing wheats, they would surely have adopted it.

Examination of the morphology of ancient Egyptian emmer spikelets (Fig. 3) clearly demonstrates that ancient Egyptian emmer was a typical tough-glumed hulled wheat. There is no evidence to support Sallares' (1991:370-372) contention that the long predominance of emmer in Egypt was due to the cultivation of a loose-hulled "more highly domesticated" form.

The explanation for the extended use of emmer wheat, long after neighbouring cultures grew mainly free-threshing wheat, seems to be one of cultural choice. The evidence indicates a definite dietary preference. Towards the very end of its exclusive use, we have one glimpse of this cultural attitude, recorded by an outside visitor. Herodotus, who lived from 495 to 425 BC, mentions that the people of Egypt considered emmer "the only fit cereal for bread" (cited in Täckholm *et al.* 1941:240). As for the details of what that bread was like, relatively little work has been done, but some comments are given in the following section.

Emmer as food in Egypt

The arid climate of Egypt has preserved the debris of food processing, sometimes in the very position where it was produced. Processed food itself has also sometimes survived until the present day. The staple foods of ancient Egypt into which emmer and barley were transformed were bread and beer (Drenkhahn 1975; Kemp 1989:120).

There are two sources of ancient processed foods. One is in tombs where offerings provided necessary sustenance for the afterlife. Most major museums of the world have a few or a large number of tomb loaves, dating to various periods from the predynastic (prior to 3100 BC) to Graeco-Roman times (after 332 BC) (Borchardt 1932; Währen 1960:94, 1961:3, 8, 13, 1963:24-25; Darby *et al.* 1977:520-521, 524-525; Sist 1987:58). Vessels placed in tombs sometimes also contain chaffy contents which are most likely related to brewing (Winlock 1932:32; Bruyère 1937:106, 177, 180).

The second source is from settlement sites. The 14th century BC Workmen's Village at Amarna has many potsherds with adhering residue, and some of these contain shreds of cereal chaff and bran. A Graeco-Roman town which yielded large numbers of pot residues is Gebel Adda. This collection is now housed at the Royal Ontario Museum, Toronto. Some early Christian pottery from Qasr Ibrim in the far south of Egypt also contains residues. Residues are no doubt present on some vessels from any site in very arid regions, but are rarely recorded and collected by archaeologists.

Food remains from settlement sites are particularly interesting because they relate directly to daily life in the past. The funerary material is virtually the only known source of ancient bread, but it is connected to the rituals of death. We have no information about how closely, if at all, these related to food in daily life.

The chaff and grain fragments embedded in the food matrix permit identification of the cereal constituents of ancient Egyptian bread and beer. Only barley and emmer need to be distinguished, so that even small fragments can often be identified. Nearly all the bread which contains identifiable cereal fragments was made from emmer. Barley grain or chaff fragments are so occasional that they must have been accidental inclusions. Evidence from beer residues indicates that either emmer or barley was made into beer, and sometimes a mixture of both.

Irrespective of whether the funerary loaves are indicative of daily practice, it is clear that the ancient Egyptians frequently baked with emmer wheat. The wide range of loaf shapes and microscopic evidence points to a variety of different emmer breads (Samuel 1994), just as there is a wide variety of different bread types made today. The largest type of ancient Egyptian emmer bread measures about 200 mm in length, 175 mm in width and 100 mm in height. Unfortunately, it has not yet been possible to examine any of these particular loaves closely, so ingredients other than emmer flour cannot be ruled out. Most surviving ancient Egyptian loaves are considerably smaller, resembling modern rolls or buns. On average, they range from about 10 to 40 mm thick. Their texture is generally dense with small air cavities. Many of the loaves which have been studied with microscopy show evidence for baking with malted grain (Fig. 12).

Further work is needed to assess with accuracy whether these loaves were leavened. Yeast cells are difficult to detect in bread because they are present in low densities and are easily missed in the dense crumb of emmer bread. A few yeast cells have been identified in some loaves, using scanning electron microscopy. Not enough have been located to determine whether these were chance inclusions or deliberate additions.

Despite the small dimensions compared with modern bread and the use, perhaps frequent, of malt, there is no doubt that ancient Egyptian loaves, with their darker crusts and paler interiors, were baked products as we understand bread. This is a good example of the danger inherent in drawing conclusions about ancient foodstuffs based solely on our own modern food types, or on classical sources. Spongy textured and highly risen the ancient Egyptian loaves were not, but they were certainly bread.

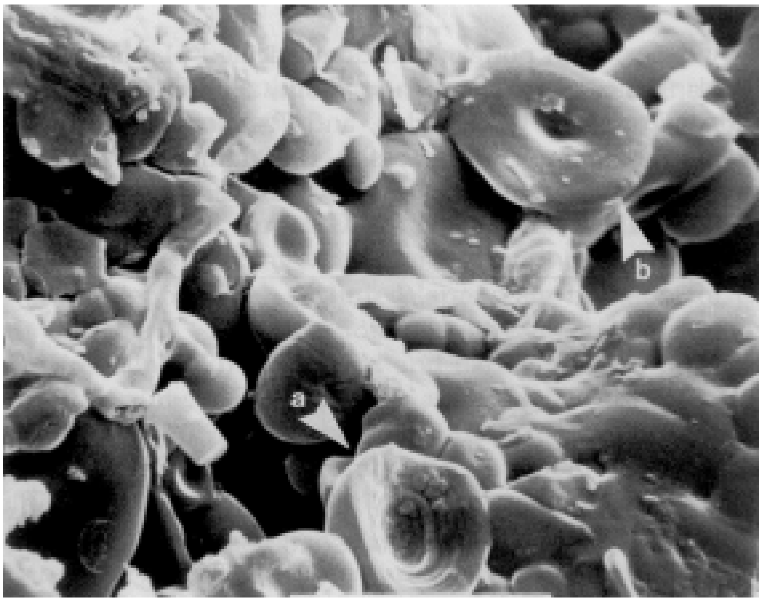

Fig. 12. The microstructure of an ancient Egyptian desiccated loaf. The bread came originally from a tomb at Deir el-Medina, Egypt dating to the 18th Dynasty (1550-1307 BC) and now at the Musée du Louvre (accession number E16410). Individual starch granules are clearly visible. One small granule (a) is hollowed, showing internal concentric layers. This is typical of enzymatic breakdown which occurs when grain is made into malt. Some granules (e.g. b) are swollen and dimpled, caused by heating in moist conditions, while other granules were even more strongly affected and have begun to fuse together (lower right corner). Bar = 10 µ.

The spread to Africa beyond Egypt

N.I. Vavilov's expedition to Ethiopia in 1927 collected a remarkable diversity of cultivated wheats and barleys, including emmer wheat (Vavilov 1951:38). Emmer wheat is still grown in the central and northern highlands as the most important minor crop after *T. durum* and *T. aestivum*, but information on its husbandry or uses is very scarce (Mekbib and Mariam 1990; Demissie and Habtemariam 1991). We know nothing about when or from where emmer came to Ethiopia. Nothing is known of the region's archaeology prior to the famous Axum empire (1st century BC to 3rd century AD), and what little is published on the history of crops in the region is highly speculative (Phillipson 1993). Whether Ethiopia received its wheats and barleys through Egypt – the most plausible route – and when this happened are unknown. It is intriguing that ongoing emmer cultivation is recorded in Yemen (Vavilov 1951:175). This may have been introduced from nearby Ethiopia.

There is evidence of recent cultivation of einkorn and emmer in Morocco (Miége 1924, 1925) and of einkorn and spelt in Algeria (Ducellier 1930; Deloye and Laby 1948). Whether these derive from the spread of early agriculturalists along the Mediterranean or are a later import from, say, the nearby Iberian peninsula is unknown.

The spread of hulled wheat from the Near East to Transcaucasia and the Black Sea

Early farming villages, with pottery and domesticated plants and animals, appear in Georgia and Armenia in the 6th millennium BC (Mellaart 1975:195-207). Although wild einkorn and wild barley, and *T. araraticum*, the wild ancestor of *T. timopheevei*, do grow in Transcaucasia, the dating of the development of agriculture strongly suggests that it spread to Transcaucasia from the Near Eastern Fertile Crescent (Fig. 13).

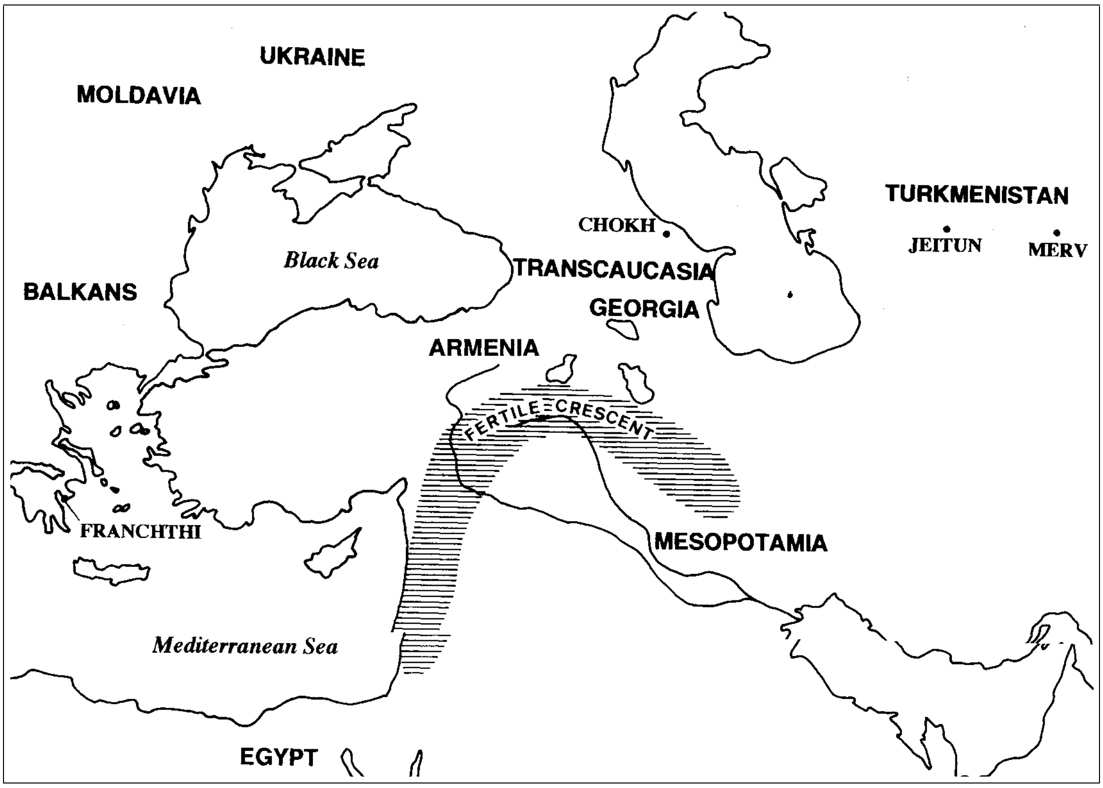

Fig. 13. Regions to which domesticated hulled wheats spread from the Fertile Crescent.

Agriculture in Transcaucasia has always been characterized by great diversity in the range of crops. This must be due in part to isolation of regions within the highly mountainous landscape. The same diversity is found in ancient plant remains (Wasylikowa *et al.* 1991:233-236). However, the morphological basis on which, for example, spelt and *T. macha*, or emmer and *T. timopheevi* have been distinguished are not clear, and these identifications should be treated with caution. Hulled wheats appear to have been important in this region up to the Iron Age (1st millennium BC), but to have declined thereafter.

North of the Black Sea lie the Ukraine and Moldavia. Early Neolithic farming villages appear in this area from 5500 to 5000 bc. Emmer was the most important cereal from the Neolithic through to the Middle Ages, with hulled and naked barley in second place. Einkorn and spelt are sporadically present. In the late medieval period emmer is replaced by free-threshing wheat.

The problem of poorly published data and lack of cultural context is perhaps greater for these areas to the north of the Near East than anywhere else. A fascinating variety of hulled wheats is grown, but we have nothing more than lists of plant species. We know virtually nothing of how the hulled wheats were used nor how their cultivation changed through time and came to cease.

The spread of hulled wheat from the Near East to the East

Central Asia

By the middle of the 6th millennium BC early farming villages were established in the northern foothills of the Kopet Dagh mountains (Mellaart 1975:208-219) in present-day Turkmenistan. Recent excavations by an international team at the key site of Jeitun (6th millennium bc) included large-scale flotation for charred plant remains (Harris *et al.* 1993). These are dominated by einkorn wheat, forming about 90% of the cereal remains. Emmer wheat and barley are also present. The cereal crops were grown on saline, high water-table areas, such as the inter-dune flats near the site. As Harris *et al.* (1993:332) point out, the dominance of einkorn has no parallels elsewhere, and may be a result of its suitability to a marginal, saline environment. This is an interesting contrast to the assumption that barley, of all the cereals, is best suited to such conditions.

By the Bronze Age, from 2200 BC onwards, large-scale irrigation agriculture was well established in the oases of the Karakum desert. In the Merv oasis, plant remains dating to about 2000 BC have been studied from Bronze Age Gonur Tepe by Naomi Miller (Moore *et al.* 1994). Here barley was the dominant crop, with free-threshing wheat second in importance. It is doubtful whether emmer was present. At Late Sasanian Merv (500-700 AD) barley and bread wheat were the main cereal crops and hulled wheats are certainly absent (Nesbitt 1994). The archaeobotanical record of other sites is not easily accessible, but barley and free-threshing wheats are generally the main crops in this region from the Bronze Age onwards. On the basis of current evidence, one can hypothesize that the shift from hulled wheats to barley and free-threshing wheats may have occurred when large-scale irrigation began in the region.

Afghanistan lies to the east of Iran and the south of Turkmenistan. Virtually no archaeobotanical work has been carried out here. The exception is George Willcox's (Willcox 1991) work at Shortugai, an archaeological site on the Amu Darya (Oxus) river. During the 3rd and 2nd millennia BC hulled barley was the most common crop, followed by bread wheat and common millet (*Panicum miliaceum*). Overall the crop assemblage fits well with Bronze Age assemblages from elsewhere in central Asia.

Hulled wheats have not been found in this century by any of the detailed survey of wheat in Afghanistan or Turkestan (Lange-de la Camp 1939; Lein 1949; Ufer 1956). When, at some point prior to the Bronze Age, hulled wheats were displaced by barley and the free-threshing wheats, this was an exceptionally thorough process.

The Indian subcontinent

The earliest evidence for a farming economy is from the Neolithic site of Mehrgarh in Pakistan (6000-5000 bc). The plant remains are dominated by naked barley, but a few impressions resembling einkorn or emmer spikelets were found in very small quantities (Costantini 1984).

In the 3rd millennium BC the great Harappan culture of the Indus valley was characterized by urban centres and massive public architecture, writing systems and long-distance trade with surrounding regions. Little is known of its cultural precursors. Large-scale recovery techniques for plant remains have not been applied at Indian sites, and we still know little of Harappan agriculture. Free-threshing wheat and hulled and naked barley seem to have been the main cereals. Evidence for hulled wheats here or at other sites in India is very scarce (Kajale 1991).

Even more so than in central Asia, we are handicapped by the limited archaeobotanical data recovered or published. Overall, the hulled wheats never seem to have been important in ancient India.

In the 20th century einkorn has not been found in the Indian subcontinent, but emmer has been recorded in scattered areas of India, mainly in the states in the southwest of India: from north to south, Gujarat, Maharashtra and Karnataka (Howard and Howard 1910; Bhatia 1938; Mithal and Kopper 1990). Its persistence in these areas may be due to its resistance to rust diseases, but it is not clear whether there is a close correlation between areas with serious rust problems and areas in which emmer cultivation is still important.

The spread of hulled wheat from the Near East to the West

How did agriculture spread?

Since European archaeobotany has been much more intensively studied than any other Old World region, it is possible to make some attempt to investigate how agriculture spread. We have already seen how the combined evidence of distribution of wild ancestors, and of archaeobotanical evidence for the earliest domesticates, points firmly to the Near Eastern ‘Fertile Crescent’ as the key area of agricultural origins about 8000 bc. By the 3rd millennium BC agriculture had reached Britain, some 3500 km to the west. How and when did this happen?

As soon as radiocarbon dating could be applied to European and Near Eastern settlements, it was clear that there is a clear gradient of agricultural sites from east to west (Fig. 14). The mechanism of this spread is still disputed, but the overall similarity in crops and husbanded animals in each area makes it clear that the plants and animals themselves were spreading, not just the idea of agriculture. Ammerman and Cavalli-Sforza (1984) have put forth the controversial argument that the distribution of certain genes in European populations is consistent with the spread of people – a demic diffusion – rather than a cultural diffusion with methods and crops passed on from one group to another. Demic diffusion would have been the result of the population increase that accompanied the introduction of farming.

This continues to be a hot topic with a large literature (e.g. Renfrew 1987; Zvelebil 1989; van Andel and Runnels 1995).

In Greece we are in the unusual position of having a site, Franchthi Cave, which spans the transition from a hunter-gatherer to farming economy, and at which a large-scale flotation effort was undertaken. The resulting monograph on the archaeobotany is a key document for the spread of agriculture into Europe (Hansen 1991). At Franchthi Cave hunter-gatherers collected a wide range of wild foods, including wild barley and lentils, during the later Upper Palaeolithic and Mesolithic (11 000-5900 bc). At about 5900 bc domesticated sheep and goats, and domesticated barley and emmer (to be followed by einkorn) are present. These domesticates appear abruptly all at the same time, but 2000 years later than in the Near East. This is consistent with the introduction of the Neolithic agricultural 'package' of crops and animals from the Near East, not just the idea of agriculture. Some wild ancestors, such as wild barley and wild lentil, are present beforehand, but critically, not wild emmer. This strongly argues against indigenous domestication. Presumably agriculture spread overland through Turkey. As Hansen (1991:180-181) points out, there is still a puzzling absence of early Neolithic, 7th millennium BC sites in western Turkey. It is quite possible, however, that these and earlier sites, which are inconspicuous and difficult to find, have simply not been discovered yet.

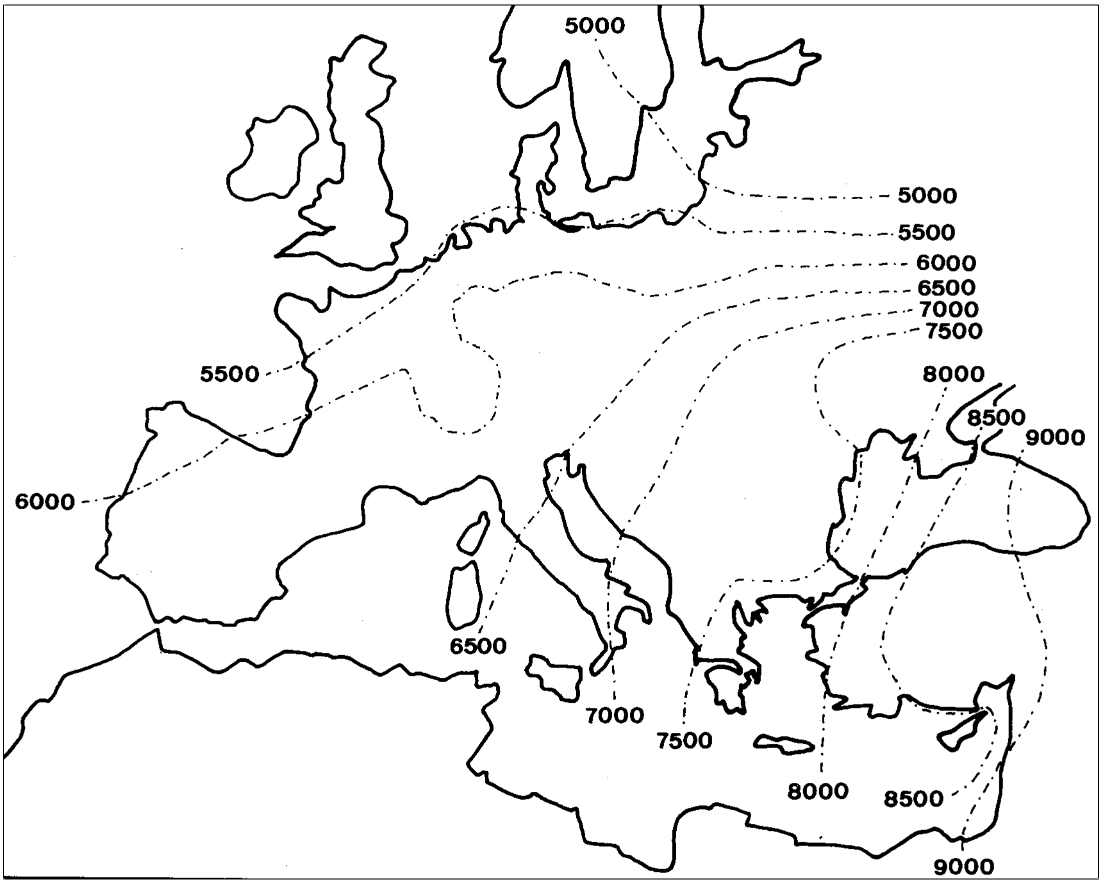

Fig. 14. The spread of agriculture into Europe. The isochrones mark the first appearance of agricultural, Neolithic villages; note that they spread out from the Near Eastern heartland. The isochrones are in radiocarbon years before present. Adapted from Ammerman and Cavalli-Sforza (1984).

From the Balkans to western Europe

After Greece, agriculture spread earliest into the Balkans, reaching the Carpathian mountains and middle Danube basin by 5500 bc. Along the north Mediterranean shore, Neolithic farming villages appear in southern Italy, southern France and Spain by 5000 bc. The first appearance of farming in the belt of Europe stretching from the Netherlands to Germany and Poland is linked to the Linearbandkeramik, a Neolithic culture identified by its distinctive pottery and wattle-and-daub longhouses, which first appears around 4500 bc (Fig. 15). Agriculture did not arrive in the Swiss Alps, British Isles or Scandinavia until 3500 bc (Barker 1985). The staple cereals of most of these early farming cultures were emmer and barley. Einkorn is usually present, but less abundant than emmer.

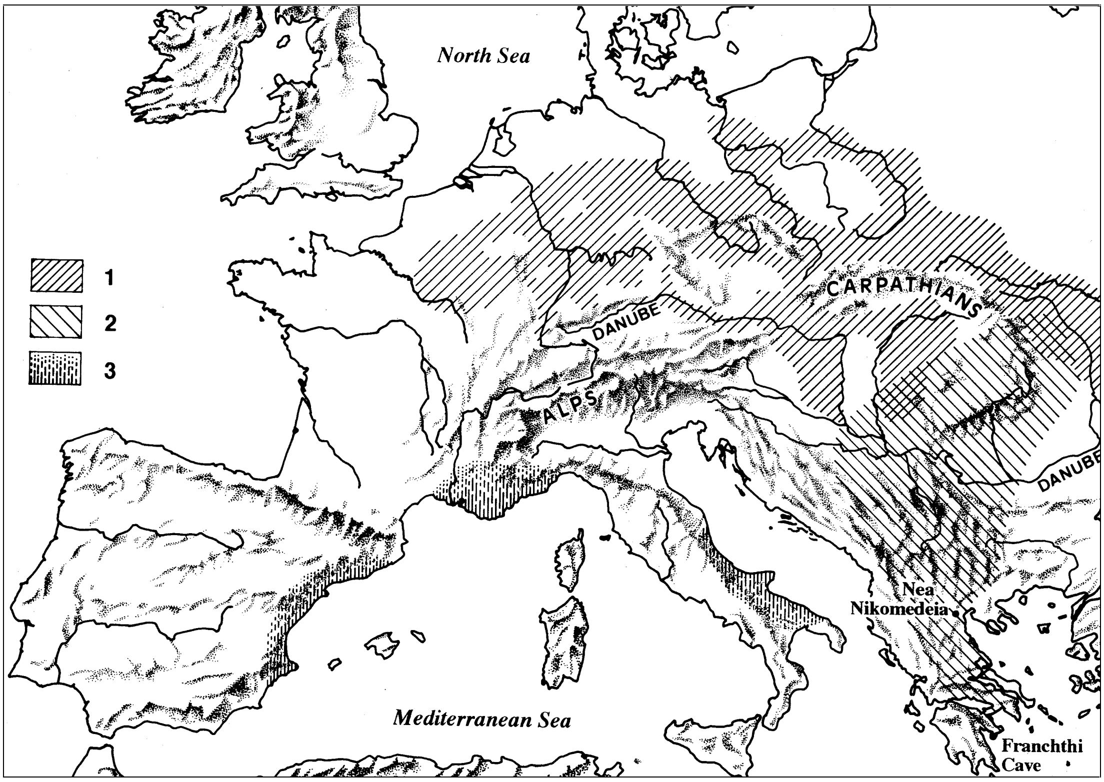

Fig. 15. The earliest agricultural cultures of Europe: 1. Linearbandkeramik; 2. Starçevo; 3. Impressed pottery. Adapted from Renfrew (1987: 155).

What happens to agriculture after its establishment is not clear. Although Barker outlines a general trend towards increasing population density and social complexity, we are still hard pressed to identify evidence for phenomena such as ‘intensification’ through the study of plant remains. Despite the attention to archaeobotany, in most of Europe we are just starting to get some idea of regional variations in crop choice and, rarely, crop husbandry techniques, but find it difficult to explain these (cf. van Zeist *et al.* 1991). In part this is because the evidence is still very patchy; but it is also a result of a historical divide between archaeobotanical data, seen as ‘ecological’ and other archaeological evidence, seen as ‘economic’.

The rise of spelt

In southern Germany and Switzerland, spelt first appears in abundance in the Bronze Age (1800-1200 BC), replacing emmer as the principal wheat species in the Iron Age (750-15 BC) (Küster 1991). A similar pattern occurs in Britain, with spelt appearing at the end of the 2nd millennium BC and replacing emmer at sites in southern Britain by 500 BC (van der Veen 1992). In contrast, emmer continues to be important in northern Germany and the lowlands of western continental Europe, while spelt appears in the uplands.

A key to understanding why this shift occurred lies equally in understanding why it did not occur in some areas. Archaeobotanical work in a number of different areas – southern England (Jones 1981b), northern England (van der Veen 1992) and southern Germany (Küster 1991) – has pointed to a similar trend. The shift to spelt seems to be part of an expansion of agriculture onto poorer soils, linked in some way to more centralized and more stable societies. Exactly why spelt is the crop involved in this change is unclear (see van der Veen 1992:130-133; 145-148 for a full discussion). We do not know if spelt performs better on poor soils. The evidence for the relative performance of spelt is contradictory (Davies and Hillman 1988; Rüegger *et al.* 1990), reinforcing the point that even if differences in yield do exist between particular modern-day varieties of wheat, these need not reflect consistent differences in ecological tolerances between species. It has been suggested that the switch to spelt was also a switch to autumn sowing, but there is no evidence to suggest that emmers are inherently more likely to be spring sown. In view of the higher yields obtainable from autumn-sown crops, it is likely that the main cereal crops were always autumn sown.

Hulled wheats in Greece to classical antiquity

Numerous Neolithic settlements appear in Greece in the early 6th millennium bc. Einkorn and emmer continue to be important crops through to the end of the Late Bronze Age (late 2nd millennium BC), and are joined by spelt at Late Bronze Age Assiros (see Halstead 1994 for a useful review of the prehistoric evidence). At Assiros Touma extensive burnt storerooms have been carefully excavated (Jones *et al.* 1986). About 1350 BC (Late Bronze Age) a fire destroyed several rooms in the settlement, preserving large quantities of charred crops. By comparing the contents of each store, it became clear that emmer and spelt were grown together as a mixed ('maslin') crop. Einkorn, free-threshing wheat, hulled barley and millet were also grown. All three hulled wheats were stored in spikelet form. Cultivation of hulled wheats continues into the Iron Age at a number of sites.

Once we reach the period of classical Greece (roughly 700-300 BC), a wide range of textual evidence becomes available. The vast modern literature discussing this is perhaps more a tribute to the difficulties in translation and interpretation than an indication of how much we know about ancient Greek agriculture. Much of the older literature (for example, Jasny 1944) is unreliable because of the inadequate archaeobotanical data available at the time against which identifications could be tested. However, Jasny's work is the only modern attempt at translating ancient terms for cereals on an explicit, clearly argued basis.

During the classical period the importance of both barley and the hulled wheats seems to have sharply declined, while free-threshing wheats (of unknown ploidy level) replaced them (Amouretti 1986:36; Sallares 1991:346-348). The reason for the decline of barley and the hulled wheats has been a topic of debate for over 50 years.

Jasny (1942) draws a parallel between the decline of spelt in Germany and the decline of the hulled wheats in Greece. In the 19th century spelt was the principal bread-grain crop. Under traditional farming it yielded as much or more than bread wheat, and was therefore worth growing despite the trouble of removing the glumes. With the arrival of commercial fertilizer and modern plant breeding, bread wheat became as productive as spelt and took over as the main crop. Jasny (1942) suggests a similar economic explanation for ancient Greece: some form of agricultural intensification led to free-threshing wheats being more productive.

In contrast, Robert Sallares (1991:313-316) suggests that wheat became more important than barley because population densities fell and there was less need for farmers to concentrate on the more dependable yields available from barley. With regard to the replacement of hulled wheats by free-threshing wheats, Sallares (1991:333-361) suggests that (p. 354) "...the 'productivity' of tetraploid naked wheats gradually evolved to attain a level sufficiently high to become superior to emmer in the eyes of farmers who assessed cereal productivity on the basis of seed size".

There is no evidence, however, for a continuing increase in the seed size of free-threshing wheats in archaeological samples. In any case it seems unlikely that any selection pressure operating on seed size in free-threshing wheats would not also operate on hulled wheats. Overall it seems that the cereals stayed the same, but that economic imperatives changed.

The hulled wheats of ancient Greece were *tiphe* (τιφη), identified as einkorn, and *zeia* (ζειδ) or *alura* (αλυρα), applied to emmer or spelt (Jasny 1944:109-133). In the case of ancient Greece, the archaeobotanical evidence for the presence of spelt, albeit less common than emmer, in the late Iron Age (Kroll 1983) suggests that some ancient references may be to spelt rather than emmer. Since emmer is the most common hulled wheat archaeobotanically, it was doubtless referred to most often.

Hulled wheats in the Roman Empire

Far more literary sources survive from the Roman empire than from ancient Greece, including numerous manuals of agricultural methods and natural histories that include a wide range of agricultural information (White 1970). The main terms used in Roman texts were *tiphe*, which has been translated as einkorn, and *adoreum*, *ador* or *far*, which have been taken to be emmer. A wide range of other, less common, terms were used in different periods (Jasny 1944:112), to designate local forms, or to differentiate between grain in spikelets and clean grain. Translation of these terms is only possible by looking at how they are used; in practice, they are virtually always open to a number of interpretations and definite translation is rarely possible (Jasny 1944:112-116).

The translation of *adoreum*/*far* has been controversial in the past. Older publications suggested spelt, perhaps as a term for the hulled wheats in general. The term may also have been used because spelt was the hulled wheat most familiar to classicists in Germany who were responsible for most of this speculation. Jasny (1944:119-124) identified *ador* and *far* as emmer on two grounds. First, the Greek term *alura* was used for hulled wheat in Egypt; hulled wheat in Egypt was exclusively emmer (true – see above); Pliny identified *alura* with *far*; therefore *far* must be emmer. Second, Jasny believed the archaeobotanical evidence pointed to spelt as a central European species that did not penetrate south of the Po valley.

Archaeobotanical evidence to complement Roman written sources is still scarce from Italy. Although spelt is abundant at the middle Bronze Age site of Fiavé (1400-1200 BC), this site is in the extreme north of Italy (Jones and Rowley-Conwy 1984). Overall, such archaeobotanical evidence as exists does seem to support Spurr's (1986:13) contention that "There can be little doubt that emmer was the most widespread husked wheat in Roman Italy". The translation of *adoreum*/*far* as emmer – in the context of Italy – seems reasonable, and is supported by the evidence of the crops that survived to modern times. Both einkorn and emmer still grow in Italy and are probably the remnants of ancient cultivation; spelt is grown in Italy today but is a recent introduction (D'Antuono 1994).

Based on textal evidence, emmer seems to have been widely cultivated. It was used for making puls (porridge) and alica (groats) (Braun 1995; Währen and Schneider 1995). Although it has often been argued that emmer was not used for bread because parching would have made it unsuitable, we have shown that parching very probably did not take place (see **Parching of hulled wheats**, above). In any case, it is clear that emmer was used for bread elsewhere in the past, notably Egypt. Given the abundant ethnographic evidence for emmer bread, it seems likely that it was also made in Roman Italy (cf. Braun 1995:34-37). Experimental work by cereal breeders has shown that satisfactory risen loaves can be made from hulled wheats (Yamashita *et al.* 1957). Although Le Clerc *et al.* (1918) concluded from their experimental work that einkorn bread was not suitable for yeast-risen bread and emmer bread was barely suitable, it would be a big mistake to judge the quality of cereals by modern standards of fluffy white bread.

It has been suggested that emmer was no longer important for human food by the time of Pliny the Elder (23-79), author of the Natural History (Moritz 1958:xxii). This might be true for urban Rome, but the extensive coverage Pliny gives to emmer suggests it was still widely grown. It is likely that the decline of hulled wheats in Italy was a highly regionalized process as it was still grown in the Medieval period (D'Antuono 1993:42; Toubert 1973) and has survived until the present day. Few agricultural texts survive between the 2nd century AD and the medieval period, so archaeobotanical evidence will be needed to investigate this further. As long as appropriate sites are carefully excavated and the plant remains properly retrieved, this is a question which archaeobotany is well suited to address.

The decline of the hulled wheats in Europe

The 1st millennium AD saw the replacement of hulled wheats by free-threshing wheats over most of Europe. The timing and reasons for this change are unclear. Although the changeover is usually visible by the medieval period, archaeobotanical or textual evidence is usually very scarce for the period between the 5th and 10th centuries AD. As in the Near East, there is no reason to believe the changeover is the result of the sudden import into Europe of free-threshing wheats: both tetraploid and hexaploid forms had been growing alongside hulled wheats for millennia. However, the rise of cereals such as rye may have been a factor. In some areas hulled wheats continued to be grown, most notably in the case of spelt in southern Germany and northern Switzerland (Rösch *et al.* 1992).

Conclusions

We have covered a wide area, geographically and in terms of subject matter. Our conclusions about the current understanding of hulled wheats in the past fall naturally into four topics: domestication, the spread of hulled wheats, their subsequent decline and their distinctive uses.

Domestication of hulled wheats

The combination of botanical evidence for the distribution of wild ancestors, and archaeobotanical evidence of the first occurrences of domesticated hulled wheats, points clearly to the Fertile Crescent of the Near East as the area of domestication of einkorn and emmer. Although the dating of the earliest farming settlements can no longer be assigned so firmly to 8000 bc, they are certainly well established by 7500 bc. Archaeobotanical reports are very much skewed to those areas of the Fertile Crescent where most archaeological fieldwork has been carried out: the Levant and, to a lesser extent, southeast Turkey. The history of farming in northern Iraq and the Zagros mountains of Iran will be obscure until fieldwork resumes in these areas. At present there is insufficient evidence from botany or archaeology to pinpoint domestication in one part of the Fertile Crescent. Crop husbandry spread quickly within the Near East, so we may never know where it began; indeed, it may have developed simultaneously over a large area. It may be that an attempt to determine the precise location of domestication will prove ultimately to be impossible, but there is a great variety of evidence which remains to be explored before such a conclusion is drawn.

The history of spelt domestication is still unclear. Archaeobotanical evidence, particularly the absence of spelt from Near Eastern sites, fits poorly with the model in which spelt formed by hybridization of its two parents near the Caspian and diffused to Europe 2000-3000 years later than the Neolithic package of crops. The paucity and poor documentation of archaeological records of spelt along the proposed migration route, north of the Black Sea, is troubling. Independent evolution of spelt from local populations of bread wheat in Europe still seems highly plausible.

We have also looked at the various hulled wheats endemic to Transcaucasia. Some of these, for example *T. timopheevi* and *T. macha*, appear to occur infrequently as weeds of present-day crops and to be close to wild wheats in rachis brittleness. These are typical characters of feral derivatives of domesticated plants, and we consider these wheats to be a local development that has no significance for wheat evolution elsewhere. However, these are a useful reminder that greater variety of forms may have existed in the past, although the overall similarity of emmer from widely separated areas suggests that less variation has evolved than we might expect.

Although botanical and genetical approaches have unraveled much of the evolution of wild wheats, there is still room for studies that use a wider range of populations, and which look at regional variation in more detail. Modern populations of domesticated hulled wheats in Transcaucasia, Turkey, Iran, Ethiopia, the Maghreb and Europe are still very poorly known. The application of more sophisticated techniques of genetical characterization might well throw light on the interrelationships and spread of these crops.

Spread of hulled wheats

Around 6000 bc, agriculture – by this time often incorporating domesticated animals – had started to spread outside the Near East proper. Evidence from the east is scarce, but 6th millennium Jeitun, in Turkmenistan, is an unusual case in which einkorn is the dominant wheat. In most areas where einkorn and emmer are grown, emmer is consistently the more important crop. There is scanty evidence for hulled wheats in India, or in central Asia from the Bronze Age onwards. It is surprising that the hulled wheats failed to establish themselves in these areas of rugged environments, but as yet we can offer no explanation. The scarcity of prehistoric records of emmer in India suggests that its present-day emmer crops may be a relatively recent introduction.

To the west, the spread of farming from the Near East is clearly shown by the radiocarbon dating of early agricultural villages: the further away from the Near East, the later the arrival of farming. The distribution of different forms of pottery and the location of sites show different routes of dispersal from Greece; on the one hand with the Linearbandkeramik cultures of central Europe, on the other along the Mediterranean coast. There is no evidence from archaeobotany of local domestication of wheat in Europe, nor indeed of the existence of wild wheats to be domesticated. Emmer and einkorn spread with barley and pulses and were staple crops throughout Europe.

The introduction of emmer cultivation into Egypt from the Near East is well documented, but the origin or antiquity of modern populations of hulled wheats in Ethiopia and the Maghreb is totally unknown.

Decline of the hulled wheats

In the late 20th century hulled wheats are no longer a major crop in any area. Throughout Eurasia hulled wheats declined at different times, ranging from 3000 BC in eastern Turkey to the 20th century in southern Germany and northern Switzerland. Explanations for the decline of hulled wheats fall into three groups: economic change, dietary change and the introduction of new crops. There are few detailed case studies of specific regions that do more than note, rather than explain, changing crop patterns. However, we think that such information as exists on the decline of spelt in the last 100 years points to two factors. First, economic pressure for increased productivity seem to select in favour of free-threshing wheats that respond better to increased inputs. Second, acculturation and change in eating habits occur as rural populations are drawn into industrialized food markets. We suspect that both factors were important in the past.

In view of the wide ranges of food uses attested ethnographically for hulled wheats, we are suspicious of arguments based on dietary change (e.g. a shift to leavened bread). The introduction of new species does not seem significant; in most cases hulled wheats have been replaced by free-threshing wheats that were already in the agricultural system. It may be that hulled wheat cultivation is sometimes linked to ethnicity; this needs to be studied further.

A major obstacle to modeling the importance of hulled wheats is our very limited understanding of their agricultural ecology. Assumptions are often made about their differential response to soil fertility, drought, waterlogging and salinity that are not supported by experimental work or studies of present-day cultivation. We urgently need agronomic trials of the widest possible range of hulled wheats, replicated in different locations and using a wide range of populations. Quantification of differences (if any) in agronomic potential between different hulled wheats, and between these and other wheats and barleys, could detect characteristics of value to modern agriculture as well as enhancing our understanding of the past. Although a number of experimental studies of hulled wheats have been undertaken, these usually relate only to trials of a few plants, and do not give us the overall data on yield per unit area that we need.

Hulled wheat uses

There is no doubt that our current dependence on macaroni wheat and bread wheat, utilized in industrial food products, colours our view of the hulled wheats. A wide variety of modern writings suggests that their uses are limited. However, considered as a whole, the ethnographic and archaeological evidence points to an enormous range of uses: as bread (leavened and unleavened), porridge, gruel, in soup, cracked wheat and beer. Different societies have focused on some of these uses rather than others, but it seems that these are for cultural reasons rather than because of inherent technological limitations in the foodstuffs themselves.

The main implication of this wide range of possible uses is that we need to avoid assumptions that particular cereals are linked to particular foods. Such assumptions are pervasive throughout the literature on ancient food, but can rarely be supported. More work is needed on archaeological remains of food and associated food-processing technology. In this area too, the collection of more detailed ethnographic information, while it still exists, would be invaluable for our appreciation of these wheats. An increased interest in the diverse uses of the hulled wheats may help to rescue these crops from oblivion.

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Note added in proof:

Since the paper was completed, an important new publication has appeared:

Harris, David R. 1996. The Origins and Spread of Agriculture and Pastoralism in Eurasia. UCL Press, London.

In relation to emmer as food in Egypt, two more papers are now available:

Samuel, Delwen. 1996. Archaeology of ancient Egyptian beer. J. Am. Soc. Brewing Chemists 54(1):3-12.

Samuel, Delwen. 1996. Investigation of ancient Egyptian baking and brewing methods by correlative microscopy. Science 273 (in press).

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