CHAPTER NINE

The Beginnings of Cereal Cultivation and Domestication in Southwest Asia

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1 Introduction

Cultivation began independently in several areas of the globe, including Central, South and North America, northern and southern China, southeast Asia, Africa, and southwest Asia. Each area had a different set of native plants that were brought into cultivation from the wild and then spread as cultivation diffused into new areas. The area in southwest Asia which concerns us here includes southeast Turkey, Syria, Israel and Jordan, and the Zagros area of Iraq and Iran. This area has attracted much attention because the plants that were adopted laid the economic foundations for a highly successful agricultural system based on nine native Near Eastern, hard-grained, annual plants that spread rapidly westward into Mesolithic Europe and eastward into Central Asia. It was these plants that fueled the development of city-states in Mesopotamia and Egypt. The economy of Greece and Rome was based on the same set of crops and animals, which ultimately spread around the globe. Hunter-gatherers who came into contact with these farmers either adopted farming or were forced into marginal zones, resulting in an often drastic reduction in their numbers.

Cultivation, when its diverse origins are considered, might be defined as assisting the reproduction and hence multiplication of plants. It does not necessarily imply field systems and tillage. In the long term, cultivation developed to make plant products available far from their natural habitats and in ever-larger quantities, which laid the way to an increase in the density of human populations and

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urbanization. The term domestication is defined by archaeobotanists as selection of traits in cultivars, for example the loss of the dispersal mechanism. When examining the origins of agriculture, we first need to distinguish between the nurturing of plants, which is a kind of incipient cultivation, and established cultivation, which may be considered a production economy. Humans who rely on gathering have a detailed knowledge of the ecology and biology of a large number of plants (which probably exceeds that of the average professional botanist). Nurturing of plants is practiced by modern gatherers such as native Australians or the Bushmen of the Kalahari, who may encourage the reproduction and multiplication of the plants they gather in order to avoid exhausting resources and thereby assuring future supplies (for more detail on this kind of plant manipulation, cf. Harris 1977; Steensberg 1986; Harlan 1995). Given that modern gatherers manipulate plants in this way, it would be wrong to assume that Upper Paleolithic gatherers had no knowledge of how seeds germinate and tubers multiply. So it is probable that nurturing or incipient cultivation may have been practiced by Paleolithic gatherers. However, this kind of plant manipulation would probably be impossible for archaeologists or archaeobotanists to detect in the archaeological record. It therefore follows that the first archaeobotanical signs of cultivation in the archaeological record represent an already elaborated form of cultivation.

The physical evolution of *Homo sapiens* was essentially conditioned within a hunter-gatherer economy, cultivation having been adopted (in the sense of a production economy) only in the last 12,000 years and then only by certain groups of humans. So the period during which humans have been farming represents less than 10 percent of the known history of the species. Human physical evolutionary development triggered by farming is probably very limited; examples of physiological adaptation such as gluten and lactose tolerance were selected as a result of changes in diet associated with farming.

Why did humans not adopt cultivation and a production economy earlier? Cultivation is a symbiosis in which a particular relationship develops between two species, giving them both an advantage (Rindos 1984). However, for this relationship to develop, prerequisite environmental and behavioral conditions are necessary. These conditions were only met at the end of the Pleistocene and the beginning of the Holocene. It is hoped that this chapter will provide some explanations.

2 Early Research on the Origins of Cultivation in the Near East

The history of the study of the origins of agriculture was provided with a head start by V.G. Childe more than 80 years ago. Like many scholars who followed, he lacked detailed, hard data and so proposed a model based on the small amount of information available at the time. Influenced by Marx's concept of social revolution, he coined the term "Neolithic Revolution." Today we would not consider the adoption of farming revolutionary because it was extremely slow. However, the consequences of the adoption of farming might be considered revolutionary. During the decades that followed World War II, American scholars such as Clark, Binford, and Flannery were influenced by the new science of ecology and hypothesized in terms of theories based on ecological equilibrium, broad-spectrum revolutions, and population pressure (Flannery 1969; Rindos 1984). However, as more sites were excavated, and with an increasing number of radiocarbon dates, scholars had more hard data on which to base their theories. This hard data was provided in large part by archaeobotanical studies, or more precisely by the study of charred plant remains which are common on most archaeological sites in the Near East. In contrast to uncharred plant materials, which undergo natural decomposition rapidly in the aerobic archaeological deposits of open-air sites, charred plant remains resist oxidation. Charred seeds contain carbon that was absorbed during a single year and can be directly dated using the accelerator mass spectrometry (AMS) radiocarbon method. Pioneering archaeobotanical studies were carried out in the 1960s by Hans Helbaek at Çatal Höyük and by Maria Hopf at Jericho. They also studied impressions of cereal chaff used as a temper in building earth, which is frequently found on archaeological sites. During the 1970s the use of flotation to recover charred remains became a common practice and was used on an ever-increasing scale. Willem van Zeist analyzed charred remains recovered by flotation at several Neolithic sites and was the first to publish detailed reports of his findings accompanied by meticulous drawings of the seeds, grains, fruits and chaff elements. His high standards set a precedent for future work. At the same time, Gordon Hillman, working in Turkey, provided an equally important contribution. His original approach included not just the analyses of charred plant remains but also detailed studies of contemporary, pre-industrial cultivation and crop processing as a basis for interpreting archaeobotanical assemblages. Hillman's archaeobotanical studies, which started in the early 1970s, culminated in his publication of the Late Natufian plant remains from Abu Hureyra (Hillman 2000). Following the work of these pioneers, some 50 sites which cover the period of the origins of agriculture in the Near East have been sampled and have provided hundreds of thousands of well-preserved remains from which hundreds of taxa have been identified. This excellent preservation on Near Eastern sites contrasts sharply with the temperate and tropical areas of the world, where bio-perturbations do not allow this kind of preservation.

3 The Contributions of Agronomists and Geneticists

In parallel with research on charred plant remains recovered from archaeological sediments, geneticists and agronomists have made important contributions to our understanding of the origins of agriculture through the study of the wild living ancestors of the domesticated crops. These progenitors grow today in their natural habitats in the Near East and are little changed from those species that were first taken into cultivation in the Near East at the end of the Pleistocene/beginning of the Holocene. The biological attributes of these plants played an important role in the way they behaved under cultivation and therefore in how they were domesticated. For example, the fact that wheat, barley, and the pulses are self-pollinated means that favorable genes are readily transmitted to future generations. Dormancy inhibits germination and is particularly important for understanding the domestication of the pulses. Some cereals require vernalization, which necessitates that sowing be carried out before the winter season. In addition, tolerance to moisture, temperature, and soil types were all factors that would have played a role in the domestication process and would affect how, when, and where the wild progenitors of cereals and pulses might have been brought into cultivation. Morphological characteristics such as height, grain size, and ear architecture were also important elements. Pioneering studies were carried out in the 1960s by Jack Harlan and Daniel Zohary (Harlan 1967; Zohary 1969), who studied the physiology of domestication and the wild progenitors of which there are nine (Table 9.1) and were the first to provide an outline of geographical distributions. However, we still lack detailed knowledge of the habitat limits and ecology of wild progenitors. There is an urgent need for future research on living progenitors because their habitats are seriously threatened by ever-increasing human impact.

Geneticists and agronomists have theorized about how rapidly wild progenitors such as einkorn or barley might have adapted to their new habitat, which was the cultivated field. Some of these specialists have argued that morphologically wild plants would have been under high selective pressure because they had biological attributes which are a disadvantage under cultivation. The most observ-

Table 9.1 The nine founder plants which were the basis of early farming in the Near East

Wild Progenitor	*Cultivar*	*English name*
Triticum urartu	?	
Triticum boeoticum	*T. monococcum*	einkorn
Triticum dicoccoides	*T. dicoccum*	emmer
Hordeum spontaneum	*H. distichon*	barley
Lens orientalis	*L. culinaris*	lentil
Pisum humile	*P. sativum*	pea
Cicer reticulatum	*C. arietinum*	chickpea
Vicia ervilia	*V. ervilia*	bitter vetch
?	*Vicia faba*	broad bean
Linum bienne	*L. usitatissimum*	flax

able of these is seed dispersal, which results in seeds or grains being lost when they fall to the ground at maturity, unless the cultivator harvests them before they ripen. A second attribute is dormancy; this is a major handicap for the cultivation of wild pulses, which have high levels of dormancy, so a large proportion of seeds will not germinate but will lie dormant for two, three, or more years after they have been sown. This is an advantage in the wild when populations are reduced during years of drought because it provides a reserve of seeds which will germinate the following year. These disadvantages led agronomists and geneticists to suppose that selective pressures would be so high under cultivation that wild populations would evolve rapidly by natural selection. Mutant genes which deactivated these traits were selected under cultivation. Thus natural selection in the long term led to the evolution of domestic populations which retained their seeds after maturity and germinated in the first year. Estimates based on mutation rates and selection pressure suggested that the number of generations needed to transform a morphologically wild population into a morphologically domestic population varied from a few to 200 years (Hillman and Davies 1990). In archaeological terms these estimates imply that the domestication process would have been "archaeologically" instantaneous. In other words, the beginnings of cultivation were synchronized with morphological domestication. These estimates were based on a simplified model where a single population was taken into cultivation and then kept in isolation.

Since the early 2000s, this scenario of rapid domestication has been rejected by several scholars who have suggested that the adoption of cultivation and domestication involves a complex and protracted processes. Wild populations may not only have been taken into cultivation at different times and in different places, but may also have been lost or abandoned. Domestication or the selection of favorable traits is no longer seen as an event or even events, but as a gradual, continuous process (Fuller 2007). Finally, recent studies demonstrate that wild types occurred alongside domestic types in ancient field systems long after the first domesticates appeared, which strongly suggests that the process of selection and domestication was slow (see below).

4 Gathering During the Paleolithic

Archaeological evidence for the use of plants during the Paleolithic is limited because plant materials do not survive for long periods. While Lower and Middle Paleolithic societies are seen primarily as hunters, this may be more apparent than real, simply because bones survive frequently and plants rarely do. The gathering of small seeds as a source food by living hunter-gatherers has been widely recorded in different parts of the world. It appears to be a form of subsistence well adapted to arid and semi-arid areas, but we have very little evidence for this prior to the Neolithic. The earliest finds of plant foods in the Near East

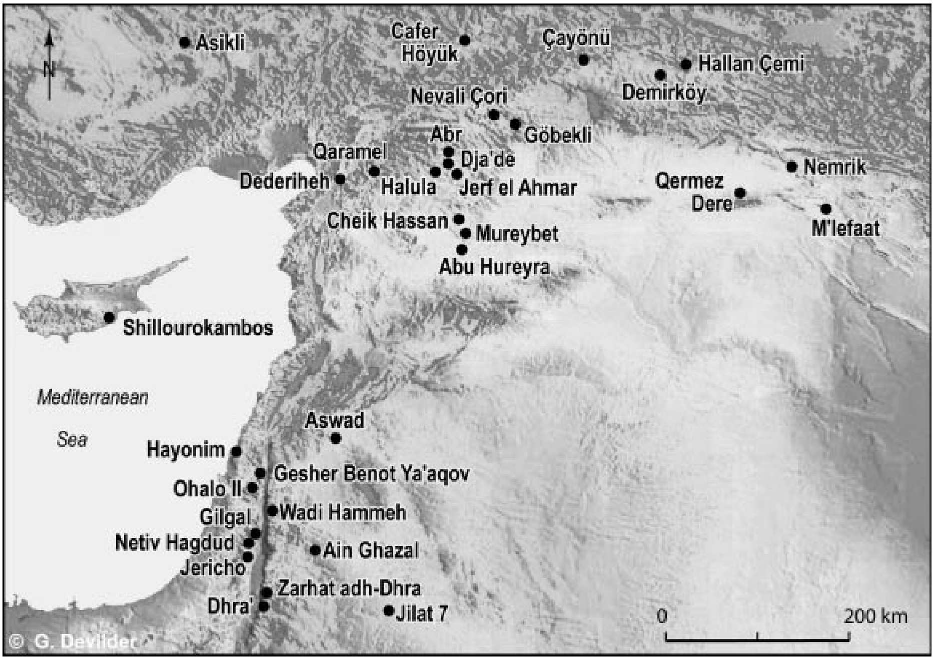

Figure 9.1 Locations of the major sites mentioned in the text with altitude contours.

Table 9.2 Approximate dates in BP (before present) calibrated calendar years (minus 2,000 years for BC cal dates)

Cultural period	*Economy*	*cal. BP*
Upper Paleolithic	First known gathering of wild wheat and barley	23,000
Natufian	First known permanent dwellings	14,000–12,000
Khiamian and PPNA	Earliest signs of pre-domestic cultivation	12,000–10,700
Early PPNB	First signs of domestication of cereals	10,700–10,200
Middle PPNB	Surface area of sites increases dramatically	10,200–9,500

(Figure 9.1 and Table 9.2) come from the Acheulian site of Gesher Benot Ya'aqov, dated to about 750,000. Situated on the shores of Lake Hula in the northern Jordan Valley where very unusual conditions favoured the survival of plant remains, the site yielded 224 fruits and seeds; for example, acorns (*Quercus*), pistachio nuts (*Pistacia atlantica*), water chestnut (*Trapa natans*) and seeds of prickly water lily (*Euryale ferox*) were found as well as wood charcoal from wild almond trees (*Amygdalus*) (Goren-Inbar et al. 2002). Following a long chronological gap, the Upper Paleolithic site of Ohalo II (c.23,000 BP) produced at least 60,000 identified plant remains including wild cereals, emmer (*Triticum dicoccoides*) and wild barley (*Hordeum spontaneum*) (Kislev et al. 1992). This chronologically and geographically (for the period) isolated site provides the earliest evidence to date for the gathering of wild grasses. It owes its survival to exceptional preservation conditions. The gathering of grass seeds was certainly not limited to one site during this period, but to date this is the only site of this period which has produced plant remains. This was followed by another gap until further evidence for plant use was found in the Natufian period.

5 The Question of Cultivation During the Natufian

Natufian sites in the southern Levant have thin deposits which are not conducive to the survival of charred plant remains. Therefore it is difficult to reach a conclusion concerning the plant economy. Only a few cereal grains were found at sites such as Wadi Hammeh and Hayonim. In the northern Levant two Natufian site have produced a profusion of plant remains, Abu Hureyra on the Euphrates and Dederiyeh in northwest Syria. Weiss et al. (2004) demonstrated how cereals increased in the diet of humans in the Near East from the Late Pleistocene to the Early Holocene. Table 9.3 presents a summary of their data on the volume of cereal compared to wild grasses, to which preliminary results from Dederiyeh have been added.

This increase is a sign of more reliance on cereal, but at what point did cultivation begin? Indeed, identifying cultivation of morphologically wild plants is problematic. How can we distinguish gathering from cultivation? Hillman

Table 9.3 Relative volume of cereals compared to grasses in the PPNA

Site	*Date*	*% volume*
Ohalo II	23,000 Kebarian	65.4
Dederiyeh*	12,500 Natufian	80.0
Abu Hureyra I	12,500 Natufian	78.2
Jerf el-Ahmar	11,300 PPNA	90.0
Mureybet I, II	10,800 PPNA	98.6
Netiv Hagdud	11,000 PPNA	82.9

*Preliminary results

Note: The right column gives the volume of cereals compared to grasses recovered from each site which can be seen to increase between the Late Pleistocene and the beginning of the Holocene. This increase coincides with sites where pre-domestic cultivation has been identified.

Source: data from Weiss et al. 2004; work currently under way by Tanno, Willcox, and Nishiaki; Willcox et al. (2008)

discussed the possibility of rye and einkorn being cultivated during the Late Natufian at Abu Hureyra 1 (Hillman et al. 2001). He suggested that these cereals were gathered near the site during the early phases of occupation there, but during the later phases increased aridity (during the Younger Dryas, see below) resulted in a shift of rye and einkorn habitats far to the north. The extinction of local cereals provided an incentive for the inhabitants to cultivate locally in favorable microhabitats. He also noted that a few charred rye grains from the site were plump, resembling domestic rye. These interpretations were the first to attempt to trace foraging to farming at a single site using archaeobotanical data. Recently, they have been questioned. For example, the onset of the Younger Dryas may have in fact coincided with the beginnings of Abu Hureyra 1. There is also the question of the distance the inhabitants would be prepared to travel in order to gather their cereals. Could the river have been used as a means of transport? In the case of the plump grains, they are a minority compared to the typical wild grains, and could be the result of puffing due to charring. The arable weed assemblage is not as well developed as at other sites. In conclusion, while we should not exclude the possibility of cultivation at Natufian Abu Hureyra, the evidence in favor of it is slim, suggesting that if it did take place, it was practiced on a small scale.

6 Pre-Domestic Cultivation and Large-Scale Cereal Exploitation: The PPNA

Pre-domestic cultivation has been proposed for a number of Pre-Pottery Neolithic A (PPNA) sites where wild cereals have been found at high frequencies. In Table 9.4 we list the sites and the references where pre-domestic cultivation has been proposed.

What is the evidence for pre-domestic cultivation for PPNA sites? Willcox et al. (2008, 2009) found six archaeobotanical lines of evidence which support the hypothesis of cultivation before morphological domestication. These are outlined below. Individually they would not stand up to scrutiny; however, when they occur together, as they do at PPNA sites on the Euphrates in northern Syria, the argument for cultivation of wild cereals is persuasive. It is probable, too, that gathering continued to be practiced, particularly during famine years when the inhabitants would be forced to consume seed stock and then would have to gather from the wild to renew their stock in order to continue cultivation.

The first line of evidence is a decline of gathering marked at Jerf el-Ahmar by a gradual reduction in gathered plants from the lower to the upper levels at the site. Frequencies of small seeded grasses such as *Stipa*, Panicoid types, and other, small-seeded grains such as Cyperaceae and *Polygonum/Rumex* decline (Willcox et al. 2008). The decrease in gathering of these seeds was compensated for by an increase in the use of founder crops, notably barley, emmer, einkorn, lentil,

Table 9.4 Sites where pre-domestic cultivation has been proposed

Sites	*Period*	*References*
Mureybet, Syria	PPNA	Van Zeist & Bakker-Heeres (1984) Colledge (1998)
Çayönü, Turkey	PPNB	Van Zeist & Roller (1994)
Netiv Hagdud, West Bank	PPNA	Kislev (1997)
Abu Hureyra, Syria	Natufian	Hillman (2000)
Zahrat adh-Dhra, Jordan	PNNA	Edwards et al. (2004)
Jerf el-Ahmar	PPNA	Willcox et al. (2008)
Tell Abr	PPNA	Willcox et al. (2008)
Dja'de	PPNA/B	Willcox et al. (2008)
Jerf, Dja'de, Tell Abr	PPNA	Willcox et al. (2008)
Gilgal, West Bank	PPNA	Weiss et al. (2006)
Dhra', Jordan	PPNA	Kuijt & Finlayson (2009)
el-Hemmeh, Jordan	PPNA	White & Makarewicz (in press)

and pea, which were probably cultivated. It appears that these changes in plant use represent an increasing reliance on cultivation.

The second line is the introduction of crops from elsewhere. In order to observe this, we need to compare the presence of cereals and pulses across a wide chronological sequence in the Euphrates region of northern Syria. Thus we see that rye and two-grained einkorn were the only cereals present at Late Pleistocene Abu Hureyra. At later sites such as Jerf el-Ahmar and Dja'de, first barley and then single-grained einkorn and emmer were introduced in that order. Pulses were also introduced; this can be seen at Dja'de, where *Vicia faba* and *Cicer* appeared for the first time far from their natural habitats.

The third line is the presence of weeds of cultivation. Weeds of cultivation, or arable weeds, are plants which thrive when the soil is disturbed by cultivation. They have been evolving since the Neolithic and increasing in numbers as agriculture spread into new habitats. They should not be confused with ruderals, which grow around habitations sites where there is trampling and/or nitrogen-rich soil. Of the known weed taxa, one only was found at Ohalo II. This is not surprising because these plants occur naturally in or near wild stands of cereals. However, the numbers of weed taxa increase during the Natufian and show a sharp increase during the PPNA. The number of arable weed taxa on PPNA sites is equal to, or in some cases higher than, that found on Middle PPNB sites. Thus the weed flora was already well developed by the PPNA.

The fourth line is an increase in grain size. An increase in grain size is often cited as a sign of domestication (Hillman et al. 2001). A study of barley grain size at Jerf el-Ahmar and Dja'de demonstrated that there is a small increase in thickness and breadth between the lower and upper levels at these sites, but that in the same geographical area there is no further increase for several millennia (Willcox 2004). Is this size increase due to phenotypic changes resulting from improved growing conditions where a higher proportion of grains reached full development, or to genetic selection of larger grains? (A third possibility is the introduction of a plump-grained population from elsewhere.) Genetic selection for plump grains is more complex than selection for non-shattering ears, because the former involves multiple genes compared to the latter (loss of dispersal) which involves one or two genes. For this reason, it has been argued that this size increase is due to cultivation. However, Fuller (2007) argued that this increase in grain size was due to genetic selection. Only further data will resolve this issue.

The fifth line is the location of sites beyond wild cereal habitats. At many PPNA sites in the Near East, the ancient cereals identified correspond to the wild cereals that grow locally as part of the present-day vegetation near the sites. But this is not true of all sites, for example at Zahrat adh-Dhra in the Jordan valley and on the Euphrates in northern Syria. At the former, emmer was found on the site, which is situated in an area far too dry for this plant to grow naturally. At the Euphrates sites, wild einkorn and wild rye were found about 200 kilometers south of present-day wild rye habitats and between 100 and 150 kilometers south of wild two-grained einkorn habitats at PPNA Mureybet and Jerf el-Ahmar. It has been argued that, even taking into account the cooler conditions of the Early Holocene, it is improbable that these cereals could have grown in these areas naturally (Van Zeist and Bakker-Heeres 1984). This leads to the question of whether it was possible to cultivate these cereals in areas where, as we have seen, they would not have been able to grow naturally in the wild. The answer is yes, because under cultivation, fields would have been chosen on edaphically favorable land where moisture was retained and competition from other plants and animals was removed, creating a favorable microhabitat in a hostile region. Several scholars have discussed an alternative explanation, the possibility of transportation of grain. This of course is a possibility, but has the disadvantage of being precarious and would not last as a subsistence strategy in the long term.

The sixth line is large-scale cereal exploitation. This will be discussed with special reference to Jerf el-Ahmar on the Euphrates. At this site 15,727 remains of charred wild barley, wild rye, and wild einkorn were recovered from occupation layers. This represents more than half of all the seed and fruit remains, indicating that cereals were a major component of the diet. Frequencies alone give a limited picture of the role of different food plants in the diet, but by combining archaeobotanical and archaeological evidence of cereal use we get a much more comprehensive picture (Stordeur and Willcox 2009). First, large-scale milling is indicated by the arrangement of querns at the site (Figure 9.2). These were used for grinding cereals (Willcox 2002b) and many were found in situ inside the buildings, frequently occurring three to a room, suggesting that grinding was being practiced in an organized manner with three querns working simultaneously in a single architectural and social unit. The querns were stabilized

Figure 9.2 A room in the PPNA site of Jerf el-Ahmar (northern Syria) showing three quern bases in a line that were used to grind cereal grain on a large scale.

by being set into solid bases. The layout of the querns suggests that cereals played an essential role in the everyday economy of the site and that cereal processing was probably intertwined with the social structure of village life. Second, cereal chaff, the inedible residue, was found in vast quantities in the form of impressions in building earth at Jerf el-Ahmar, Tell Abr, and Mureybet. The building earth was made of a mixture of fine sediment to which cereal chaff was added as a tempering medium in order to reduce shrinkage and increase strength (Willcox and Fornite 1999). This technique is still used today in many parts of the world, including northern Syria. When the buildings burned at Jerf el-Ahmar (a frequent occurrence), the earth was baked and hardened leaving perfect impressions of the chaff, consisting of awns, glumes, lemmas, and spikelet bases which were finely fragmented. Examination of large quantities of building earth showed that chaff was systematically used as a tempering medium. Given the size of the buildings at Jerf el-Ahmar and the fact that they were regularly maintained, destroyed, and rebuilt, chaff must have been available in massive quantities at the site. The quantity is surprising if we consider that the dehusking of hulled cereals, particularly barley, produces a low proportion of chaff to grain. Third, large-scale, collective storage occurred in communal buildings where large quantities of pure charred cereal grain were found. In building 30 at Jerf el-Ahmar, small cells or silos provided storage facilities (Stordeur et al. 2000). Fourth, rodent infestation was evidenced at Jerf el-Ahmar by charred rodent droppings, many of which correspond in size to those of the domestic house mouse (*Mus musculus domesticus*). Indeed, six archaeozoological finds of domestic mouse were identified at Dja'de and one at Jerf el-Ahmar (Cucchi et al. 2005). These mice most probably fed on stored grain. In total, 51 charred droppings were found at Jerf el-Ahmar and 221 at Dja'de. Other early village sites where domestic house mice have been found include Hayonim B and Netiv Hagdud in the south and Mureybet and Cafer Höyük in the north. Fifth, sickle blades used for harvesting show an increase in the intensity of a characteristic gloss caused by the build-up of a film of plant silica on the cutting edge of the tool. At Jerf el-Ahmar and contemporary sites on the Euphrates, there is an increase both in size and quantity of these tools compared to earlier sites (Abbès, personal communication). So these five different categories of evidence all point to intensive cereal use during the PPNA.

7 Early PPNB Sites and the Earliest Signs of Morphological Cereal Domestication

Sites of this period are not well represented in the archaeological record. It was during this period that we see the first signs of morphological domestication, albeit still not totally confirmed. Morphological domestication can be identified by the loss of the dispersal mechanism in barley and hulled wheats. This is visible when examining the abscission scar where part of the upper spikelet adheres to the scar, indicating an artificial break. The earliest finds of einkorn domestication date to approximately 10,500 BP and have been reported from sites such as Nevali Çori, and Cafer Höyük in the northern Levant, but at these sites only low proportions of domestic spikelets were found compared to wild types. Further south at Aswad, in the southern Levant, Van Zeist's early work suggested that domestication had already taken place during the PPNA, but new excavations at the site (Stordeur 2003) revealed that these layers were later. The grains from his samples have been subsequently radiocarbon-dated. The earliest levels date to the Early PPNB and contain domestic barley and possibly emmer wheat. Domestication of emmer and barley was also reported at Wadi el-Jilat 7. At the time of writing, the dating and the status of identifications at many of these sites need to be re-examined.

Evidence from Cyprus demonstrates that emmer, einkorn, and probably pulses were introduced from the mainland, possibly before they were domesticated. We know that emmer and einkorn were introduced there because these species are not native to the island. This is the first sign of a diffusion of agriculture, including sheep, goat, and cattle, which were morphology wild. With this agricultural package came the domestic mouse, presumably introduced accidentally with grain supplies. The introduction of mice at sites such as Shillourokambos implies that important stocks of cereal were being regularly imported (Cucchi et al. 2005).

It is significant that when domestic cereals first appear during this period they are always accompanied by high proportions of wild types (Tanno and Willcox 2006). Domestication appears to have arisen independently in the northern and southern Levant and perhaps elsewhere – e.g., on Cyprus. Evidence of domestication in Iran occurred about two centuries later.

8 Mega-Sites, the Middle PPNB and Established Farming Communities

This period saw the development of sites which cover a much larger surface area. The early levels at these sites, which may represent the transition from the Early PPNB, are not well understood. This is because, as the sites developed, the overlying strata combined with lateral expansion obscured the lower levels, hindering access by excavators. The levels which have been excavated demonstrate that established farming communities had developed. It was a production economy that allowed these sites to expand. The site plans illustrate densely packed habitations, suggesting population increase. These sites are characterized by high frequencies of domestic cereals, including new cultivars such as naked wheat and an extinct variety of glumed wheat. Flax was cultivated alongside the cereals and pulses, and herding of sheep and goat was practiced. Middle PPNB mega-sites include Halula and Abu Hureyra on the Euphrates, Aswad and Ain Ghazal in the southern Levant, and Aşikli in Anatolia. They mark the end of the history of the origins of farming in the Near East because these sites represent full-scale farming villages. Demographically, these sites had probably reached a threshold at which the food requirement exceeded what the natural environment could supply from gathering. Societies had passed a point of no return and had become totally dependent on farming for their subsistence. Wild plant and animal resources may have already started to diminish through over-exploitation. The expanding economy, no longer contained within the confines of the Near East, spread to new lands in Anatolia and Iran.

9 Climate Change in Relation to the Beginnings of Agriculture in the Near East

How did climate change affect the availability of food plants and the beginnings of agriculture in the Near East at the end of the Pleistocene and beginning of the Holocene? Paleoclimatic data from the Near East come mainly from analyses of lake-bed sediments, but they are rather sparse and poorly dated. Given that climate change is a global phenomenon, we may look elsewhere, in particular to high-resolution data from Greenland and Antarctic ice cores. These give information about global temperature change from oxygen isotope oscillations, providing an indispensible and solid backdrop to the limited data available locally (Willcox et al. 2009).

The favorable conditions of the Late Glacial was a crucial factor in allowing societies in the Near East to settle in permanent dwellings. Analyses of sediments recovered from cores at Lake Hula at 70 meters and Lake Ghab at 240 meters above sea-level indicate that deciduous oak and grass pollen frequencies increased after the Glacial Maximum (Baruch and Bottema 1999; Yasuda et al. 2000). For the Euphrates region (280–500 meters above sea-level) in northern Syria, charcoal and seed analyses from the earliest levels at Abu Hureyra indicate a forest steppe vegetation consisting of *Pistacia atlantica* trees, grasses, and occasional oaks. Thus, between the end of the Glacial and the beginning of the Younger Dryas, forest vegetation expanded in low-lying areas. Temperatures were probably lower than at present and there was more available moisture for plants. These conditions were favorable for the expansion of oak, *Pistacia atlantica*, almond, and the grasses, including wild cereals. The vegetation was more luxuriant than that occurring today, providing abundant food resources for animals and humans. The land had a high carrying capacity, especially in the southern Levant, with plentiful high-energy foods, namely cereals, nuts, and meat. The grains and nuts were easily storable. This subsistence economy allowed Late Paleolithic hunter-gatherers to become settled in permanent dwellings.

This favorable period was followed by a return to glacial conditions, called the Younger Dryas. This can be discerned from lake-level changes in the Near East. The climate was cooler and drier than today. The aridity may have been offset because low temperatures would have meant less evaporation and less transpiration by plants. Isotope data indicate that the Younger Dryas was more severe at the high-altitude continental sites than at those nearer the Mediterranean vegetation zones, and sea-levels were lower than today. Evergreen oak and olive pollen were absent or rare at lakes Hula, Ghab, and Acigöl during the Late Pleistocene and did not increase until the Holocene. In the Euphrates area during the Younger Dryas at Mureybet 1 and 2 (290 meters above sea-level), *Pistacia*, grasses, and oak were exploited (Willcox et al. 2008; Van Zeist and Bakker-Heeres 1984), so these resources were still available despite climate deterioration. During the Younger Dryas, many Natufian sites were abandoned, particularly in the southern Levant.

The Younger Dryas was followed by a period of climate amelioration. This was the beginning of the Holocene and the start of more stable climatic conditions. The Late Pleistocene and the Younger Dryas were periods with high amplitude oscillations in the climate record, indicating climate instability. These conditions were not favorable to cultivation. Climate variability leads to a high frequency of failed harvests. So if humans did cultivate before the Holocene, it is unlikely that a reliable and sustainable economy could have developed. The Early Holocene was characterized by an increase in both temperature and rainfall. Data from low altitude lake sites and marine cores indicate forest expansion in the Near East. This can be seen at the Euphrates valley sites by the finds of *Pistacia* and *Amygdalus* charcoal and fruits at Jerf el-Ahmar and Dja'de (Hillman 2000; Willcox et al. 2008). With this warming came more stable climatic conditions. It has been argued by many scholars that this stability allowed cultivation to develop into a reliable subsistence economy (Feynman and Ruzmaikin 2007). This change in the economy is reflected in architectural developments in northern Syria. Compare, for example, the humble pit dwellings at Natufian Abu Hureyra with the large, communal buildings that were used for storage at Tell Abr, Jerf el-Ahmar, and Mureybet in the PPNA.

10 A Center or No Center for Domestication?

There are two models: the first suggests that domesticated cereals spread rapidly from a center or core area resulting from an event; the second suggests that the process of domestication was protracted, occurring independently over a wide geographical area. At the time of writing, the second model has gained the favor of most specialists because the archaeobotanical information reveals that (a) local populations of cereals were taken into cultivation independently in different regions, as demonstrated by the fact that charred cereal assemblages vary from region to region corresponding to the known wild cereal distributions and hence the availability of locally occurring wild cereals; (b) within different areas the assemblages show continuity from the PPNA to the Early PPNB – that is, for at least 1,000 years; and (c) domestic varieties arose independently in different areas. The taking into cultivation of local stock is not surprising because local cereals would have been the best adapted to local conditions. Indeed, prior to adaptation by selection, emmer from the southern Levant would have grown poorly in Anatolia, just as einkorn from Anatolia would not have been adapted to the southern Levant. We do not know exactly when the plants started to acclimatize, as early farmers started to exchange preferred varieties which would have led to the diffusion of crops. But during the Middle PPNB the fact that emmer was adopted at many sites would appear to be the first indication.

DNA fingerprinting has been used in an attempt to locate where original stock might have come from by comparing the DNA of modern cultivars with modern wild homologues (Salamini et al. 2002). The two crops which interest us the most are emmer and barley, although much work has been done on einkorn. The difficulty in these studies arises because the sample is modern and may not be representative, since both the wild progenitors and the cultivars have been drastically reduced over millennia. Today's cultivated wheat and barley represent survivors of long chains of speciation. Many varieties have become extinct. Indeed, a number of archaeobotanical morphotypes have no modern homologues – for example, the early naked wheat, a glumed wheat, and a two-rowed einkorn from northern Syria which is possible *Triticum urartu* (see Table 9.1). This suggests that we should be cautious when trying to pin down a locality using DNA fingerprinting. A study by Özkan et al. (2010) looks at the evidence for emmer wheat.

11 Why Was Morphological Domestication Slow to Become Established?

Theoretically, less than 200 years of cultivation could have been enough time to select cereals which retained their spikelets after maturity (Hillman and Davies 1990). Yet there is no evidence for this; cereals or pulses remained unchanged despite a prolonged period of cultivation, up to 1,000 years. Why, then, did domestication not appear earlier? One reason is that seed stock may have been regularly replenished by gathering from wild stands when reserves were diminished following famine years. These might result from disease, pillage, or drought, the latter probably a frequent occurrence in the Near East. Another reason is that harvests would have been carried out before the ears shattered, which would mean that the probability of selection for the rare mutants that had lost their dispersal mechanism would be extremely slim. With premature harvests, non-shattering ears would have had little advantage; plants with ears that shatter compete well with non-shattering forms in cultivated fields. This is demonstrated by wild einkorn and barley, which are common weeds of cereal fields in the Near East today.

Rapid domestication has the disadvantage that it would drastically reduce biodiversity, resulting in a population more susceptible to natural catastrophes and with a poor yield stability from year to year as compared to wild populations. In addition, rapid domestication requires the wild crops to have been isolated from their wild homologues. This would be extremely difficult for farmers to attain because early agriculture sites are situated within the habitat areas of the wild progenitors.

In the archaeobotanical record, we see that wild types continued as part of the crop long after domestic forms appeared, so wild and domestic types were cultivated together in the ancient field systems for a millennium or more. This continued admixture suggests that during the Early Neolithic, non-shattering and shattering forms were inseparable and so similar that Neolithic farmers treated them both as part of the crop. Studies on a wider geographical scale and for rice and millets exhibit the same phenomenon (Fuller 2007), also indicating that morphological domestication was slow to be established and mixed populations of wild and domestic cereals persisted side by side for long periods (Tanno and Willcox 2006).

12 Conscious vs Unconscious Selection

Farmers who cultivate plants with vegetative reproduction such as tubers or fruit trees produce cloned crops. They may consciously choose a variety or trait which will appear in the following generation. But this is not the case for annual grain crops such as the founder crops of the Near East. One reason is that domestic traits are not readily visible to the naked eye, and a second is how would selection take place? The only effective way to select consciously is to build up a single line population from a single seed. This would require keeping the descendants isolated from other plants, which would have been difficult. This single line population would have the disadvantage of reducing genetic diversity which was necessary to create healthy crops with stable, year-to-year yields. Most preindustrial farmers appreciate variety and diversity in their crops, because they know that in order for healthy crops to develop they would need to have numerous landraces, each with its own advantage.

As we have seen, wild and domestic crops were cultivated side by side, as cultivators did not succeed in separating them. Without a plant breeder's hindsight, cultivators probably felt secure and confident with the crops as they were, and it did not occur to them to attempt crop improvement. Finally, we should not confuse choice with selection. Early farmers may have chosen crops or landraces for which they had a preference – for example, wheat over barley – or they may have exchanged varieties, but this is not selection.

13 Major Questions

The when, where, and why questions for the origins of agriculture were, until a decade or so ago, seen in rather simplistic terms, some scholars favoring environmental determinism and others development of human behavior as pivotal factors affecting the adoption of cultivation. Until the 1990s, Jericho was seen as the center of origin for farming; ten years later, this switched to Göbekli Tepe (Ch. I.8) as the center, with Jericho on the periphery. Natufian Abu Hureyra was reported to be the earliest site inhabited by cultivators, but today some might refute this. These answers are dependent on the available evidence at the time of writing. So what is the consensus at present? Let us try briefly to answer each question.

When did cultivation begin? Paleolithic peoples may have assisted in the multiplication of food wild plants. During the Upper Paleolithic in the Near East, cereals were being gathered 23,000 years ago. This would have resulted in unintentional cultivation when grain accidently spilled onto the ground during processing and germinated the following year. For the Natufian period that follows, the archaeobotanical record is poor in the southern Levant and in the northern Levant only one of the two relevant sites has been studied to date, so it is difficult to reach any firm conclusions. By the beginning of the Holocene, about 11,500 years ago, the inhabitants of PPNA villages across much the Near East were taking local, wild cereals and pulses into cultivation; this is the phase of pre-domestic cultivation. In areas where wild cereals were abundant, such as southeastern Anatolia, cultivation may have been adopted more slowly, while in areas away from wild cereal habitats, such as the dry steppe areas of northern

Syria and Jordan, cultivation was adopted more rapidly. By the Middle PPNB, a production economy, consistent morphological domestication, and established, fully fledged farming communities arose concurrently across the region. The mega-sites are the unequivocal evidence of this.

Where did cultivation start? Agriculture developed totally independently in many different regions of the world. This may have happened because the knowledge of plant husbandry (assisting in the multiplication) was part of the human collective memory going back into the Paleolithic. So it is not surprising that, on a smaller scale, plants were also taken into cultivation independently in different areas of the Near East. The mega-sites arose from small PPNA villages, not just in one central area but across the geographical extent of the Near East. These sites were culturally distinct, indicating that they evolved independently of each other. Thus, there is no evidence that the mega-sites originated from a single center or core area. On the contrary, they evolved independently in different regions along with local crops.

Finally there is the "why?" question. Could the development of belief systems and the social structures which accompany them be, in part, responsible for the shift to farming? This is difficult to answer. Were the complex social systems at sites such as Jerf el-Ahmar or Göbekli Tepe a consequence of cultivation or, on the contrary, were they a necessary prerequisite? It could be argued that the evolution of complex societies and farming were so interwoven that we cannot put one before the other. A more pragmatic approach might be to suggest that Natufian or Upper Paleolithic societies had the potential to cultivate, but that in the Near East cultivation was adopted in the long term only when there was a lack of easy access to desired wild stands combined with stable climatic conditions. At individual sites, over-exploitation of wild stands, competition from inhabitants of neighboring sites, choice of cereal species, and the desire to stockpile may have been additional reasons why humans adopted cultivation.

GUIDE TO FURTHER READING

For a comprehensive introduction to the biology and history of the founder crops used in the ancient Near East, which is co-authored by a geneticist and an archaeobotanist, see Zohary and Hopf (2000). A similar authoritative work on the same subject, but with a different angle, is given by the American agronomist Jack Harlan (1995). More details on climate issues, including methods and techniques written by a geographer, can be found in Roberts (1998). Climate change specifically relating to the beginnings of agriculture in the Near East is treated in Willcox et al. (2009). A broad view of the origins of agriculture can be found in Mithen (2003: chs 3–6). A book which gives solid archaeological information combined with an original hypothesis for adoption of farming in the Near East is Cauvin (2000). In the same spirit, and inspired by Cauvin's book but relying more on evolutionary psychology, is Lewis-Williams and Pearce (2005).