SETTLING DOWN AND BREAKING GROUND: RETHINKING THE NEOLITHIC REVOLUTION

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In the long trajectory of human prehistory, the transition from dependence on wild plant and animal foods to dependence on cultivated plants and domesticated animals – or, to put it more succinctly, the shift from foraging to farming – is part of a fundamental reorganisation of human society. We know that this transition involved profound changes in the ecological relationships of people to plants, of people to animals, and of people to people, but, despite much recent archaeological effort to elucidate the 'origins of agriculture', we remain largely ignorant of the circumstances in which the transition took place. My purpose in this commemorative lecture is therefore to attempt a new analysis of that transformation in human ecology which archaeologists commonly call the Neolithic or Agricultural Revolution. I am, however, keenly aware of the difficulty of such an attempt, because many authors have developed different and often conflicting explanatory models, and because, since 1950, a mass of varied evidence bearing on the transition to agriculture has been acquired by archaeologists, anthropologists, biologists, and geographers.

CONCEPTUAL ANTECEDENTS

Curiosity about how, when, where, and – most intriguingly – why agriculture arose is, of course, not new. It is an integral part of the Western intellectual tradition. Ancient Greek and Roman philosophers speculated about what came to be known as the 'three stages of man': hunting, herding, and agriculture; and the assumption that mankind had progressed through three or more successive stages of socioeconomic development was revived and reinforced in modern times, particularly by German scholars in the late nineteenth century (Harris 1981, pp. 6-8; Kramer 1967).

By the middle of the twentieth century, when direct archaeological enquiry into the beginnings of agriculture effectively began, the assumption of successive developmental stages had become so entrenched in our intellectual tradition that the presumed progress of mankind from hunting and gathering to agriculture, and thence to urban life, had come to be seen as an ineluctable progression. Thus the 'hunter-gatherer' way of life was regarded as a prelude to the next step on 'the ladder of progress', *i.e.* agriculture; and the corollary of this was to describe hunter-gatherers who had 'survived' into the modern world as living relics or even as cases of arrested development.

It is not my intention on this occasion to explore the sociopolitical implications of this categorisation, which formed part of the mental template of European colonial expansion and which profoundly affected the fate of many indigenous peoples in Africa, Asia, Australasia, and the Americas. But it is necessary to appreciate how it conditioned the aims and expectations of those archaeologists, such as Gordon Childe and Robert Braidwood, who, earlier this century, began to focus attention explicitly on the problem of the origins of agriculture. Because agriculture was conceived as a 'natural' stage in socioeconomic development, they had to face the question of why it had, apparently, not been attained earlier than the Neolithic and more widely through the prehistoric world.

Gordon Childe solved the problem by proposing environmental change as a causal factor or trigger mechanism. In his famous theory of the Neolithic Revolution he suggested that, in prehistoric Southwest Asia a climatic shift toward greater aridity or 'desiccation', following the retreat of the ice sheets of the last glacial period, brought people, plants and animals into close contact in river valleys and around oases, where domestication then took place and an agricultural economy was established (Childe 1936; 1942). He did not, however, specify more precisely the processes involved and nor did he interest himself in the question of the beginnings of agriculture elsewhere in the world – with the exception of Europe, to which he assumed agriculture was introduced from Southwest Asia.

Robert Braidwood overcame the difficulty of the relatively late and geographically limited appearance of agriculture in a different way. He presumed that it was inherent in human nature to cultivate and domesticate useful plants and animals, but that this process of 'settling in' was only achieved when people had become thoroughly familiar with the biota of a particular environment, and, like Childe, he assumed this to have occurred first at the beginning of the Neolithic in Southwest Asia (Braidwood 1960).

During the 1950s and 1960s, archaeologists took up the challenge of investigating the origins of agriculture directly by field survey and excavation. At first attention continued to focus on Southwest Asia where such sites as Jarmo, Jericho, Çatal Hüyük, Haçilar, Ali Kosh, and Beidha were probed for evidence of agriculture, in the form mainly of charred grains of wheat and barley and the bones of domesticated sheep, goat, cattle, pig, and dog. But already by the early 1960s archaeological investigations of early agriculture in the Americas were underway, notably Richard MacNeish's ambitious project in the Tehuacan Valley of Mexico (Byers 1967).

It was not until the late 1960s that the conception of agriculture as a 'natural' stage in socioeconomic development came to be explicitly, and widely, rejected. In retrospect we can recognise 1968 as a turning point in the study of both the beginnings of agriculture and the nature of hunter-gatherer society. Three seminal publications appeared that year – Lewis Binford's paper on 'Post-Pleistocene adaptations', Kent Flannery's on 'Archeological systems theory and early Mesoamerica', and Richard Lee's and Irven DeVore's volume *Man the Hunter* – and in London (at the Institute of Archaeology) the international seminar took place which led to the publication in 1969 of Peter Ucko's and Geoffrey Dimbleby's massive volume on *The Domestication and Exploitation of Plants and Animals.*

During the 1960s anthropological studies of contemporary hunter-gatherers, particularly McCarthy's and McArthur's analysis (1960) of the food quest among northern Australian Aborigines and Lee's investigation of the subsistence ecology of the !Kung Bushmen (1965), had prepared the way for a reversal of the then prevailing view that hunter-gatherers searched unremittingly for food and that their lives were both arduous and precarious. Largely as a result of the publication of *Man the Hunter* in 1968 this view was rapidly replaced by the opposite generalisation: that hunter-gatherers lived easily, obtaining their food with little effort and having abundant leisure, a view that was epitomised by Marshall Sahlins' famous description of them as 'the original affluent society' (1968, p. 85; 1972, pp. 1-39).

As this reassessment of hunter-gatherer life gained acceptance among archaeologists as well as anthropologists, the conception of agriculture as a stage in human development that 'naturally' succeeded hunting and gathering became untenable. After all, if hunter-gatherers could procure their food so easily and reliably, why undertake the more laborious tasks of crop cultivation and livestock rearing? So the question of why agriculture originated needed to be recast. The problem was no longer to try to explain why it did not develop before the Neolithic, and more widely in the world, but to explain why hunter-gatherers ever became farmers. In 1968 Binford encapsulated this reversal of the problem by recasting it. As he said, 'The question to be asked then is not why agriculture and food-storage techniques were not developed everywhere, but why they were developed at all' (Binford 1968, p. 327).

Pervading these radical changes in the intellectual framework of hunter-gatherer and early agricultural studies during the 1960s was a conviction that ecological – including systems-theoretical – concepts could provide new insights into the processes by which plants and animals were domesticated and agriculture arose. Not only did Binford and Flannery employ explicitly ecological concepts in their 1968 papers, but, on this side of the Atlantic, ecologically formulated re-appraisals of 'the origins of agriculture' were independently published in the following year by Higgs and Jarman (1969) and by myself (Harris 1969).

During the next few years, Eric Higgs and his associates at Cambridge began to interpret the archaeological data from the European and Southwest Asian sites that they investigated in terms of biological and economic principles, as well as ethnographic analogies. They focused attention not just on the evidence for domesticated plants and animals in the archaeological record but also on the more basic question of how prehistoric agricultural and non-agricultural economies functioned in their environmental settings. In particular, they questioned the dogma that domestication was no older than the Neolithic and sought to demonstrate instead that it was a process which extended over the last ten or eleven thousand years, from the late Pleistocene to the present day (Higgs 1972; 1975).

At the same time, in a series of papers, I developed an ecological and systems-analytical approach to the study of early agriculture, with particular reference to the tropics, which, like the Higgs' school of 'palaeoeconomy', emphasised the continuities that connected, rather than the differences that separated, hunter-gatherer and agricultural modes of plant and animal exploitation (Harris 1972; 1973; 1976; 1977).

By the early 1970s, the mental barriers which – largely as a consequence of the pervasive influence of Childe's concept of the Neolithic Revolution – had prevented most archaeologists from contemplating the possibility that agriculture might pre-date the Neolithic, had crumbled. Competition to push the origins of agriculture back in time became acute. Who would find the earliest wheat grain or the oldest maize cob? And who dared suggest that horses were tamed in Upper Palaeolithic Europe (Bahn 1978), or gazelle husbanded in Epipalaeolithic Palestine (Legge 1972)? MacNeish brushed the dust of Tehuacan from his boots and headed south for the high Andes, where he hoped to demonstrate that there, too, in the Ayacucho Valley of Peru, agriculture had emerged gradually over many millennia (MacNeish 1977). In Southwest Asia, Higgs' team reported finds of domestic wheat and bitter vetch from Epipalaeolithic levels at the Palestinian sites of Nahel Oren, 'Ain Mallaha and Rakafet (Legge 1986; Harris 1986, p. 7); and from Southeast Asia came news of reputedly cultivated plants at Spirit Cave in northeast Thailand, dated between 9,000 and 11,000 years ago. These latter finds led to the extravagant claim that there had been an earlier agricultural revolution in Southeast Asia than in Southwest Asia, a claim which, unfortunately, overlooked the fact that most of the plant remains recovered from the excavation were useful wild rather than domesticated species (Solheim 1972; Yen 1977).

The pursuit of ever-earlier evidence of agriculture culminated in the late 1970s with the even more dramatic claim that barley and wheat, chickpeas and lentils, dates, capers and olives had been cultivated at Wadi Kubbaniya on the banks of the Nile in southern Egypt between 17,000 and 18,000 years ago. Even before all the botanical specimens had been securely identified, this apparently revolutionary discovery was announced to the scientific world in a book and several papers (Wendorf, Schild and Close 1980; 1982). And so the claim that agriculture began in North Africa in the late Palaeolithic was launched on a career which might have led to it becoming established as an archaeological truth – and not the myth we now know it to be – had not the appropriate archaeobotanical expertise been available, *and* the new technique of small-sample radiocarbon dating by accelerator mass spectrometry been applied to some of the finds. For, when the supposed chickpeas were examined closely (by Gordon Hillman of the Institute of Archaeology in London) they turned out to be the charred tubers of a wild sedge, *Cyperus rotundus*, and when some of the – genuinely domesticated – barley grains and date stones were radiocarbon dated by the accelerator method they were shown to be less than a thousand years old (and therefore intrusive in the deposits) (Wendorf *et al.* 1984; Harris 1986, pp. 6-7).

This cautionary tale not only demonstrates the power of new scientific techniques to falsify an untested hypothesis before it ripens into dogma, but it also exemplifies a conceptual confusion that permeates many debates about the origins of agriculture. This is the tendency to assume that, if the remains of apparently domesticated plants or animals are recovered from a site, then agriculture was definitely practised there. This is unacceptable for at least two reasons. The first is that the crops or domestic animals may have been introduced to the site from elsewhere, as items of trade or in other ways. The second and more fundamental reason is that the terms 'domestication' and 'agriculture' are seldom defined sufficiently precisely to justify regarding evidence of the first as proof of the second. Indeed, one of the main benefits of the ecological approach to the investigation of early agriculture – which was further elaborated during the 1980s, for example by Rindos (1980; 1984), Jarman, Bailey and Jarman (1982), Hynes and Chase (1982), and Ford (1985) – is that it has obliged us to recognise the great diversity and complexity of the interactions between people, plants, and animals which are implied, but not specified, by such general terms as agriculture, domestication, cultivation, and husbandry. We need to define, and use, such terms more precisely if we are to develop a more ecologically refined analysis of the activities through which people have, in the past, exploited and altered both 'wild' and 'domestic' plants and animals in both 'agricultural' and 'non-agricultural' contexts.

As a contribution to this process of refinement, I have recently proposed a classificatory model which defines a range of plant-food yielding systems of exploitation and relates them to a hypothetical continuum of people-plant interaction (Harris 1989, pp. 11-26). The concept of a continuum of interaction could equally well be applied to the exploitation of animals, but on this occasion we are concerned mainly with the analysis of people-plant interaction. Although the model (Figure 1) was devised primarily to clarify the concepts and terminology that we use, it will of course prove more useful if the activities and systems of plant exploitation specified in it can be traced in the archaeological record. Only then may we achieve the central aim of demonstrating more precisely how, when, and where transitions from wild-food procurement to agriculture took place.

Despite the impressive technical advances that have been made in archaeobotany (or palaeoethnobotany) during the last decade, it remains regrettably true that few of the ways in which we know – from ethnographic and historical evidence – plants to have been exploited can be conclusively shown, from archaeobotanical or palaeoenvironmental evidence, to have been practised at particular times and places in the past. Some plant-exploitative activities are amenable to direct archaeobotanical investigation. Thus pollen analysis, and also the stratigraphic analysis of changing frequencies of charcoal fragments, can provide evidence of land clearance and fire history (see, for example, Higham and Maloney 1989, pp. 658-661). Specifically archaeological pollen analysis can yield information about the past presence and absence locally of particular exploited plants. Phytolith analysis, too, has begun to demonstrate its capacity to provide data on past plant distributions and crop histories (see, for example, Piperno 1989). Excavation on site sometimes reveals evidence of storage structures, although it is not always possible to determine whether they were used for plant foods, and, if so, whether for the products of gathered wild plants or cultivated crops. Field (or landscape) archaeology can sometimes provide direct evidence of agricultural and even non-agricultural systems of irrigation and drainage, and it is also capable of demonstrating the existence of mound and terrace construction by prehistoric cultivators. But, in the absence of surviving traces of such features in the modern landscape, it is very difficult to infer whether such activities as irrigation or drainage were practised by the former inhabitants of an archaeological site. Likewise, it is usually impossible to determine whether soils were systematically tilled, unless the remains of implements unequivocally used for tillage, such as ploughs, hoes, or certain types of digging sticks, are recovered, or plough or other cultivation marks happen to be preserved and subsequently identified.

Our general inability to recognise soil tillage archaeologically is particularly limiting if, as I recommend, it is regarded as a criterion of cultivation. Considerably more effort has been devoted by archaeobotanists to the development of criteria for determining whether particular plants recovered archaeologically represent wild or domesticated taxa. This is crucial to the recognition of agriculture, as opposed to cultivation only, on the continuum of people-plant interaction. The distinction between cultivation and agriculture rests on the presence or absence of domesticated crops (cultivars) in the system of plant-food production, domestication being defined as having occurred when the reproductive system of the plant population has been so altered by sustained human intervention that the cultivars have become dependent upon human assistance for their survival. Therefore, if it can be shown archaeologically that the plant remains recovered at a given site are from domesticated taxa (and if the possibility of their having been imported from elsewhere can be excluded), then there is a secure basis for inferring that agriculture was practised in the vicinity of the site. Archaeobotanical criteria for separating cultivars from their wild relatives are relatively well developed for the major cereal crops, but they are poorly established for most other crops, including even such agriculturally important groups as the pulses (Butler 1989) and the domesticated roots and tubers (Hather 1988; Martins-Farias 1976).

We therefore still have a long way to go in developing techniques for recognising the range of plant-exploitative activities distinguished in the model, although some activities can confidently be inferred. Distinguishing archaeologically between the four plant-food yielding systems identified – wild plant-food procurement or foraging, wild plant-food production, cultivation with systematic tillage, and agriculture – is even more difficult, but agriculture *can* be inferred from the presence of cereal crops and/or other identifiable cultivars, and systematic tillage can occasionally be demonstrated from field-archaeological evidence. Furthermore, a new experimental approach to the problem of determining when soils were first tilled, in Southwest Asia, has recently been developed by Romana Unger-Hamilton (1985, 1989), who carried out harvesting experiments on a range of wild grasses, legumes and other herbs, domesticated cereals and pulses, and weeds, in the Levant, using experimentally made sickle blades freshly knapped from various types of flint. She then compared the microwear produced on the experimental blades with that on a collection of Epipalaeolithic (Natufian) and Neolithic sickle blades from sites in the southern Levant. The preliminary results suggest that particular striations on the blades may be the result of cutting (close to the ground) grasses growing on tilled as opposed to untilled soils. If this were confirmed by more comprehensive experiments it could provide a new method for determining when grasses (wild or domesticated) were first cultivated in Southwest Asia.

The emphasis that I place on systematic tillage, as a criterion for defining cultivation on the continuum, can be justified in terms of the major increase of human energy per unit area of exploited land that its practice implies. As Figure 1 indicates, the continuum is also conceived as a *gradient* of increasing input of energy into the exploited area. We can postulate thresholds along the gradient where more human effort is invested in particular activities. Thus foraging, which involves such relatively low-energy activities as burning, gathering, and protective tending of plants, can be separated from the more energetically demanding system of wild plant-food production which incorporates a range of more labour-intensive activities such as planting, sowing, weeding, harvesting, storage, and even irrigation and drainage.

The practice of systematic tillage focuses still more human effort on particular patches of land within the exploited area and directs even more energy toward the acquisition of plant foods. The effort required to till soils regularly is more intensive and more concentrated in time and space than the lower input of energy needed to exploit plants without tillage. Also, the fact that tillage is, when first practised (and repeatedly so under systems of shifting cultivation), preceded by the clearance of vegetation, accentuates the second energy threshold, which separates wild plant-food production with minimal tillage from cultivation (Figure 1).

Although the model draws attention to the progressively greater inputs of human energy demanded along the continuum from foraging to farming, it is not intended to address the question of how the increased inputs were provided. This potentially introduces into the discussion a wide range of demographic and social variables which should be considered when we seek to *explain* how and why foraging gave way to more energetically demanding systems of plant-food production. For example, one might invoke such variables as population increase, changes in the sexual or age-related division of labour, or the development of social ranking and stratification and of the concept of land ownership, but this would take us beyond the main purpose of this model, which is to be primarily descriptive rather than explanatory. Figure 1 does, however, suggest possible correlations between the energy gradient and such broad socio-demographic trends over time as increases in sedentary settlement, in population density, and in the complexity of social organisation.

Ideally, the next step in developing, and testing the utility of, the model should be to try to calibrate it chronologically and relate it to sets of archaeobotanical and other relevant archaeological data drawn from as many parts of the world as possible. In practice this is not feasible, because our knowledge of the chronology of plant exploitation and of corresponding socio-demographic changes is everywhere so inadequate. But there are a few regions of the world where sufficient evidence has been acquired to allow a tentative start to be made on building chronologies of secular changes in systems of plant exploitation. Such could be attempted, very provisionally, for parts of Southwest Asia and Europe and for parts of Middle and North America. However, any attempt at regional synthesis is likely to be severely hampered, not only by the overall lack of evidence but also by the lack of strict comparability between sites within a region, in terms of methods of recovery, analysis, and dating of the evidence. I will not, therefore, attempt any such regional synthesis. Instead, I will examine, briefly and more theoretically, the possible relationship between trends toward increasingly sedentary settlement and the development of agricultural production.

FROM MOBILE TO SEDENTARY FORAGING

This brings us – at last! – to the twin title of this lecture: Settling Down and Breaking Ground. It has often been hypothesised that sedentary life – in the sense of the year-round, long-term occupation of a site – preceded the practice of agriculture. Until recently, however, it has seldom been possible to identify archaeologically, with any degree of confidence, pre-agricultural sedentary occupation. It is still very difficult to determine whether any particular late Pleistocene/early Holocene site was occupied year-round over long periods of time. But in recent years many archaeologists have sought to develop criteria for demonstrating sedentary occupation (for example, Rafferty 1985; Edwards 1989), and it is now widely accepted that – at least in regions that are relatively well known archaeologically, such as Southwest Asia and Europe – some pre-agricultural sedentary settlements did exist, supported exclusively by the exploitation of wild plant and animal resources.

The criteria that have been used to infer sedentary occupation of these settlements include depositional, structural, artefactual, and bioarchaeological evidence, and although the strength of inference varies from site to site, the sites themselves do appear to share certain locational characteristics that may particularly have favoured the development of year-round, long-term occupation. The locational common denominator of these sites is their positioning at ecotonal boundaries between ecosystems that yield contrasted plant and animal resources, for example at the junctions of uplands and lowlands, and where terrestrial and aquatic ecosystems meet, along riverbanks, lakeshores, and coasts.

In Southwest Asia, the non-agricultural Natufian sites of the southern Levant, where structural and other evidence suggests sedentary occupation (Henry 1986; Davis 1983) are typically located at the junction of (formerly) wooded hills and grassy plains at locations close to sources of fresh water, flint, and limestone (Henry 1989, p. 184). From these sites such resources of the two ecosystems as gazelle, grass seeds, tree nuts, and deer could readily be procured without the need for long-distance foraging. Similarly, in northern Syria, the sites of Abu Hureyra and Mureybit, at both of which there are strong indications of sedentary occupation in the Epipalaeolithic, are situated on the sharp topographic and vegetational boundary between the steppe and the floodplain channel of the Euphrates. Despite suggestions to the contrary, there is no definite evidence of domesticated cereals or other cultivars in the Epipalaeolithic levels at these sites, and at both a wide range of wild plant and animal resources could easily be procured locally. Indeed, the analysis of the abundant plant remains from the Epipalaeolithic levels at Abu Hureyra, which was recently undertaken at the Institute of Archaeology in London, has shown that over 150 species of wild edible-seed and fruit-bearing plants from the local steppe, woodland, and floodplain environments were exploited by the inhabitants of the site before crop cultivation began there during the succeeding aceramic Neolithic period (Hillman, Colledge and Harris, pp. 258-261). Parallel analysis of the animal bones from Abu Hureyra (Legge and Rowley-Conwy 1987) has demonstrated that the Epipalaeolithic occupants depended for meat primarily on gazelle, and that gazelle hunting was replaced by the rearing of domestic sheep and goats during the Neolithic, several centuries after domesticated cereals and pulses (einkorn and emmer wheat, lentil, chickpea, and broad bean) recovered from the deposits indicate that agriculture had begun to be practised locally.

The bioarchaeological evidence from Mureybit is meagre compared with that from Abu Hureyra, but it is consistent with the conclusion that the site was occupied year-round long before agriculture was practised there. In fact, the remains of einkorn wheat and barley from the aceramic Neolithic levels at Mureybit II are from morphologically wild forms rather than true cultivars (van Zeist and Casparie 1968; van Zeist and Bakker-Heeres 1984), suggesting that, although wild grasses may have been *cultivated* rather than just gathered, agriculture (as defined here) was not yet established. Thus, in terms of the interaction model (Figure 1), *if* cultivation with systematic tillage was practised at this time, the second but not the third energy threshold would have been crossed at Mureybit by *c.* 8,000 bc. Or, to put it another way, the inhabitants of the site would not yet have been farming, but they would by then have settled down and been systematically breaking ground.

At present there are very few other sites in Southwest Asia or Europe for which adequate bioarchaeological data exist to test more widely the presumed precedence of sedentary occupation over agricultural production. Therefore, rather than examine such exiguous evidence as we have, I turn instead to the last major question that I wish to consider in this lecture, namely: how may pre-Neolithic sedentary occupation of certain ecotonal, resource-rich sites have led first to the adoption of cultivation involving systematic tillage, and later to dependence on agricultural production incorporating domesticated crops? For it is not enough to show that sedentary occupation could be sustained by the exploitation of wild plant and animal resources. We have to ask why did not that way of life persist, or, conversely, why did it lead on, in some areas at least, to cultivation and agriculture? The answer to that fundamental question will not easily be found, but it is possible, by considering some of the socio-demographic consequences of sedentary life, to formulate a working hypothesis to explain the emergence of agriculture, and to begin to test it against archaeological data.

The proposition that a shift from mobile to settled life leads to increases in the population that experiences it is not new. It was assumed, but not closely examined, by Binford in 1968, and later I attempted to model some of the processes involved, by using demographic data on recently settled hunter-gatherers (Harris 1978). The work of Lee and his associates among the !Kung Bushmen (*e.g.* Howell 1979, Lee 1979) provided crucial data for our understanding of the factors that have maintained small group sizes and low reproductive rates among mobile hunter-gatherers. These factors include long birth intervals of 3-4 years between each child, delayed onset of puberty, which typically occurs between the ages of 15 and 17, and generalised low female fertility, all of which relate to the energetic and nutritional demands on women of the mobile foraging life.

More specifically, prolonged post-partum infertility is thought to be linked to extended periods of breast feeding because suckling triggers secretion of the pituitary hormone prolactin which suppresses ovulation, and it has been observed that among the !Kung for example infants normally suckle on demand to the age of three or more (Lee 1979, pp. 328-330). The late age of puberty among the !Kung has been attributed both to low levels of fat in the diet of young females (Howell 1979) and to the very high energy expenditures required of female foragers which result from gathering, transporting, and processing plant foods and walking long distances carrying children (Bentley 1985). Neither factor is thought wholly to explain the late onset of puberty, but there is little doubt that powerful controls on female fertility were an intrinsic part of the lifestyle of recent, and, by extrapolation, prehistoric mobile hunter-gatherers.

This conclusion helps us to understand why the human population apparently increased very slowly through the Palaeolithic, and why low population densities characterised the areas occupied in more recent times exclusively by mobile hunter-gatherers. It also implies that when a population of hunter-gatherers reduced its mobility and became largely or wholly sedentary the controls on female fertility that are intrinsic to the mobile life would have been relaxed and the population would have increased.

A shift from residential mobility to sedentary settlement can thus be postulated as the first in a sequence of changes that could, but would not necessarily, lead to cultivation and agriculture. Increases in the population of hunter-gatherer groups that 'settled down' in resource-rich locations are likely, in the early stages at least, to have been supported by the intensified exploitation of locally available wild foods. If and when resource scarcity began to be experienced, as is likely to have occurred first at critical 'hungry' seasons of the year, several responses would have been possible. Four types of response may be suggested: (i) the whole population could migrate; (ii) the population could divide and some groups leave to settle in new areas; (iii) population growth could be brought under control by direct means such as contraception, abortion, and infanticide; and (iv) local resource exploitation could be further intensified. These alternatives, which (except for the first) are not mutually exclusive, are represented by pathways D, E, F, G and H in the second model presented here (Figure 2).

For our purposes there is no need to consider each of these responses in detail. It is sufficient to recognise them as possible modes of change, all but the first of which allow part or the whole of the population to remain settled at the existing location. Our main concern is with the further changes that can ensue when local resource exploitation is again intensified (pathway H in Figure 2). The ways in which this could occur will depend intimately upon the nature of the local environment and on the resources available in it. More particularly it will depend upon whether the food resources available to the population are inherently capable of sustaining, locally, more intensive exploitation.

INTENSIFIED RESOURCE EXPLOITATION

This is a very complex question in view of the great diversity of resources exploited for food, and it can only be touched upon here. But if we consider some of the major categories of plant and animal foods on which humans have for long depended, such as the seeds of grasses and herbaceous legumes, the seeds or 'nuts' of trees and shrubs, those fleshy underground storage organs of plants that we loosely refer to as 'roots and tubers', and the meat and other edible products of such animals as the social ungulates or 'herd animals', aquatic mammals and reptiles, and fish, it is possible to generalise about their relative capacity to sustain intensified exploitation by settled human communities.

Many factors affect the capacity of plants and animals to sustain intensive exploitation (or predation), and, conversely, the perceptions and preferences of the humans bring differential selection pressures to bear on the plants and animals that are exploited. One important factor is the reproductive rate of the plant or animal. In general, populations of organisms with high reproductive rates, such as annual plants and many small and medium-sized mammals, are better able to withstand intensive exploitation by humans than organisms with low reproductive rates, such as perennial trees and shrubs and large mammals. In this context, it is interesting to note that in the domestication of cereals and tuber-bearing plants annually-reproducing forms have generally been selected from perennial wild ancestors; and the pattern of early prehistoric domestication among the herd animals shows preferential selection of medium-sized animals with a high reproductive rate, notably goats and sheep, and rather later domestication of larger, more slowly reproducing animals such as cattle and camels. There are of course many other factors, such as differences in territorial behaviour and in the tendency for rapid flight when alarmed, that help to explain why not all herd animals with high reproductive rates were domesticated. Such factors, for example, may account – in part at least – for the lack of deer and gazelle among the prehistoric animal domesticates of Southwest Asia in contrast to the early appearance in the archaeological record of domesticated goats and sheep (exemplified by the evidence from Abu Hureyra; and see Clutton-Brock 1981, pp. 55-56).

Likewise, in the plant domain, there is an obvious contrast between the capacity of annually reproducing grasses, herbaceous legumes, and tuberous plants to sustain intensified exploitation as compared with long-lived trees that produce edible seeds or fruits, such as oaks and many other nut- and fruit-bearing species. In the context of prehistoric Southwest Asia, where both acorns and grass and legume seeds are likely to have been staple wild foods for pre-Neolithic populations, it is not surprising that some of the grasses and legumes were domesticated and become the cereal and pulse crops of early agriculture, whereas oak trees were not domesticated. As grain cultivation and livestock husbandry increased, acorns as human food would have diminished in importance as the oak woodlands were progressively degraded and cleared as a result of the combined effects of cutting, felling, burning, browsing, grazing and cultivation.

This is not to suggest that trees have not been domesticated and responded to intensified exploitation by increased production, but this has happened relatively infrequently. In Southwest Asia and adjacent regions, where such fruit trees as the date palm, olive, fig and pomegranate have become important crops, the problem of their low rates of reproduction has been obviated by the development of techniques of vegetative propagation. Like cattle and camels in relation to goats and sheep, these tree crops appear to have undergone domestication and become part of the evolving agricultural economy of prehistoric Southwest Asia considerably later than the cereals and pulses (see, for example, Zohary and Hopf 1988, pp. 128-151).

These observations on some of the factors that differentially affect the capacity of food-yielding plants and animals to sustain more intensive exploitation ignore the role of cultural perceptions and preferences in the interplay of selection pressures. This too is a complex topic, which cannot be analysed in detail here, but it is worth stressing two obvious factors that have played an important part in the selection of domesticates from among the great diversity of wild plant and animal resources. These are the contribution that the plant or animal product makes to the energy and nutrient needs of the human population, and the suitability of the product for long-term storage.

If sedentary settlement is to be sustained, the population is obliged not only to obtain its basic supplies of food relatively locally but also to store sufficient quantities to tide the people over 'hungry' seasons and other periods when fresh supplies of food fail. The plant and animal resources which best meet both these needs are therefore likely to be preferentially selected, and, other things being equal, to attain the status of fully domesticated crops and livestock.

It has often been pointed out that the seeds of grasses and many other herbs represent easily stored, nutrient-rich packages of food which became staple crops of early agriculture in many temperate and tropical regions of the world. Tree nuts also offer humans nutritious and readily stored packages of food, but, as we have seen, the low reproductive rates of most nut-yielding trees have in general militated against their domestication. 'Roots and tubers' provide mainly carbohydrate, characteristically give high yields per plant, and, as domesticated crops, often represent the main source of energy in the daily diet, especially in tropical regions; but they are not easy to store for long periods, and, unlike cereals, they do not make a balanced nutritional contribution to the diet. Whether gathered in the wild or harvested as crops, they tend to be complemented nutritionally by proteins and fats derived from domesticated or wild mammals and also fish; and, unlike cereals and pulses, they have not functioned as the principal crops of intensive agricultural systems sustaining large prehistoric urban settlements.

The role of terrestrial and aquatic mammals, reptiles, and fish in the diet of early sedentary communities was to provide protein and fat, but the meat and other edible products they yield are not inherently suited to long-term storage. Once such herd animals as goats, sheep and cattle were domesticated, the potential for storage 'on the hoof' in or near the settlement could be realised more effectively than when wild herds were hunted, particularly when techniques for confining and feeding livestock in fields, compounds or stalls were developed. But the most important innovation in the exploitation of domestic livestock was the practice of milking and the subsequent development of cheese and other secondary products. This not only extended the 'storability' of animal products; it also gave humans access to an infant weaning food which, especially when combined with nutrient-rich gruels derived from cereals and pulses, released latent capacity for population growth by reducing periods of breast feeding and hence the average birth interval. Access to milk- and cereal-based foods also greatly improved the chances of infants surviving their first critical year of growth.

The potential of aquatic animals to sustain early sedentary communities and respond to intensified local exploitation was necessarily limited to settlements close to lakes, rivers and the coast, but in such locations they could make an important contribution to the supply of protein and fat. The reproductive rates of most freshwater and inshore fish are sufficiently high to sustain intensive local exploitation, as archaeological and ethnographic evidence of fish traps, weirs, and ponds suggests. It is of course inherently difficult to domesticate animals that live and reproduce in water and very few species have been bred artificially, the carp being the most conspicuous example of controlled breeding, for food and display, in the artificial environment of fish ponds. The large marine mammals and reptiles, such as whale, seal, dugong, and turtle, have low rates of reproduction and are vulnerable to over-exploitation, although they have contributed substantially to the diet of some sedentary coastal communities, probably from early in the Holocene.

This brief consideration of how the major categories of human food vary in their capacity to sustain intensified exploitation locally may help us to understand why sedentary settlements arose early, and continued to develop, in some parts of the world and not in others. Although such settlements may have become established in many resource-rich ecotonal locations, they would be likely to develop and endure only in environments well endowed with food resources that could sustain progressively intensified exploitation, including domestication, over the long term. Southwest Asia may have been uniquely well suited to an evolutionary trajectory of settlement and subsistence which incorporated the domestication of plants *and* animals to an extent not attained elsewhere in the world and which made possible the early emergence there of urban civilisations.

FROM SEDENTARY FORAGING TO FARMING IN SOUTHWEST ASIA

The argument that I have developed in this lecture leads us then – perhaps unexpectedly – back to the scene where Gordon Childe set his Neolithic Revolution. In trying to rethink how the revolution may have come about, I am driven to the conclusion that the late Pleistocene/early Holocene environment of Southwest Asia *did* offer unique opportunities for the long-term development of sedentary agricultural settlements. This novel way of life was associated with sustained, if intermittent, population growth, and its continuance depended on local access to a cluster of plant and animal resources which could respond to progressively intensified exploitation by increased production, and which provided nutritionally complementary and inherently storable supplies of food. The process of intensification demanded increased inputs of human labour into food production and processing, involving systematic tillage of the soil and the incorporation of a suite of plant and animal domesticates into what became an agricultural economy.

Only in Southwest Asia were domesticated herd animals fully integrated into the process of agricultural production, as beasts of burden and traction, as consumers of agricultural wastes and surpluses, and as providers of meat, milk, manure, horn, hides, hair and wool. This integration led eventually to the emergence of the highly productive system of mixed grain-livestock farming which, in later prehistoric times, provided the foundation for the development of European agriculture. We do not yet have sufficient bioarchaeological data from Southwest Asian Neolithic sites to speak with any confidence about where and precisely when within the region herd animals first became an integral part of evolving agricultural systems, but it is probable that in the early stages agriculture was based primarily on cereal and pulse cultivation, in systems of dry (rain-fed) farming and, possibly, floodwater farming. These crops – principally einkorn and emmer wheat, barley, rye, lentil, pea, chickpea, bitter vetch and broad bean – would in themselves have provided a sufficiently nutritious food supply (supplemented with protein and fat from hunted or herded animals) to support the growing populations of the first farming villages (Figure 3).

The establishment of human control over the reproduction of herd animals, particularly cattle, is likely to have been a slow process involving transitions from hunting to free-range management to selective breeding in confinement (Harris 1977: 220-232). It probably took many centuries for domestic cattle to become sufficiently numerous and docile to become regular providers of meat and milk and to be changed from crop robbers into draft animals and beasts of burden working in the fields: a transformation that may not have been completed until the fourth millennium bc. In contrast, there is widespread evidence for the domestication of Southwest Asian cereals and pulses by the eighth millennium bc, and a recent experimental study of domestication rates in wild einkorn wheat suggests that one of the main morphological changes typical of cereal domestication – the shift from brittle to non-brittle rachis – could well have become dominant in an einkorn population under cultivation in 20-30 years, at most within 200 years; and emmer wheat and barley are very likely to have been domesticated equally rapidly (Hillman and Davies 1990).

With these speculations in mind we can, in conclusion, return to the model of the transition from mobile foraging to settled farming presented in Figure 1, and elaborate it with specific references to Southwest Asia (Figure 4). This third model is offered as a tentative chronological outline of how agricultural systems may have evolved and differentiated in the region from soon after the Pleistocene-Holocene transition to the emergence and early development of the first urban civilisations. The suggested sequence in which such agroecosystems as irrigation, arboriculture and horticulture were added to the developing agricultural economy is based on very inadequate archaeological evidence, but I believe that the model is not inconsistent with such data as are presently available.

More than five decades have passed since Gordon Childe first proposed his theory of the Neolithic Revolution, and yet, despite the acquisition since his time of a mass of new archaeological evidence, we still have a very imperfect understanding of the processes and chronology of the transition to agriculture. We need to gather much more evidence, but 'facts' alone will not answer the question of how the transition took place. The search for factual evidence needs to be guided by particular hypotheses, which should themselves be part of an explicitly stated conceptual framework. My aim has been to refine and elaborate the concept of the Neolithic Revolution by taking a closer look at some of its component parts and processes. I have not solved the mystery of how, let alone why, prehistoric people ceased to forage and turned to farming as the mainstay of their existence. But I hope that the models I have presented may help us toward a better understanding of this revolutionary chapter in the history of humankind's tenure of the Earth.

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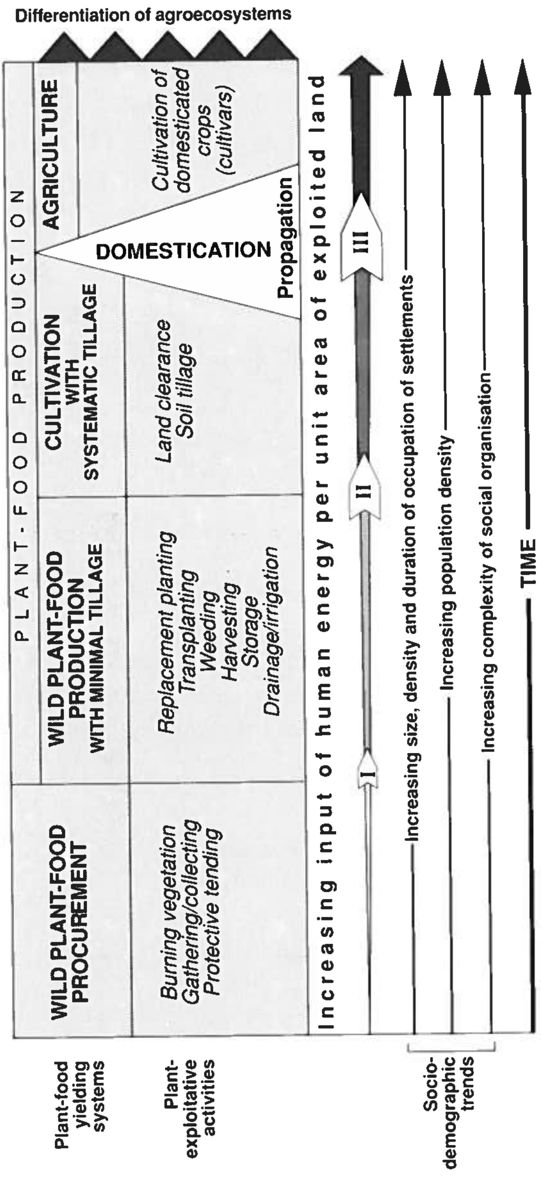


Figure 1. A classificatory and evolutionary model of plant-food yielding systems (modified from Harris 1989, p. 17). The Roman numerals indicate postulated thresholds in the input of human energy.

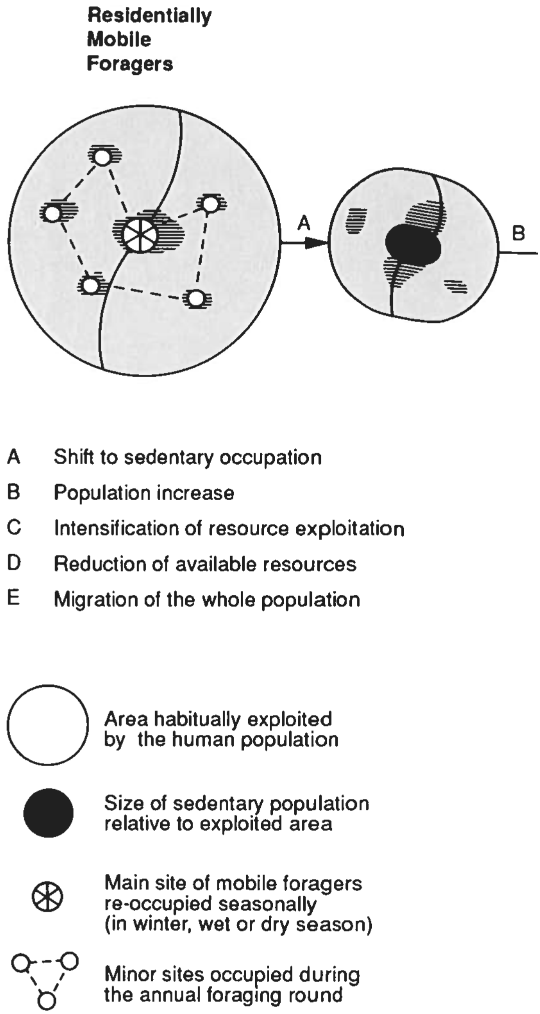
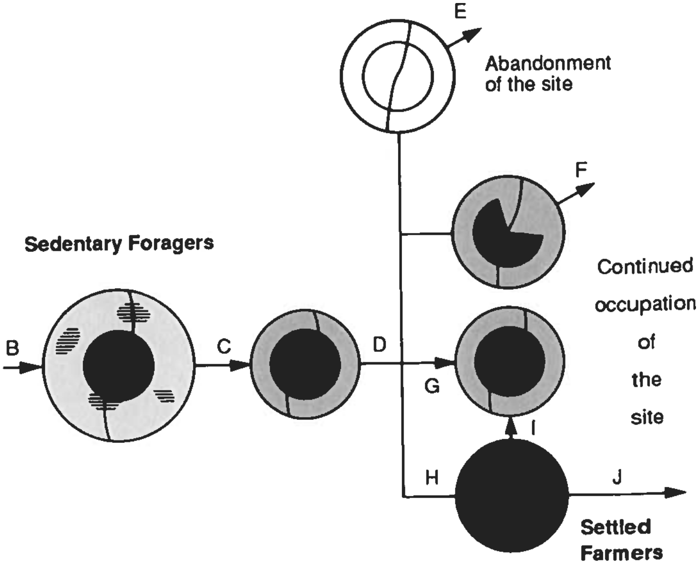


Figure 2. Model of a transition from mobile foraging to settled farming in a hypothetical late Pleistocene-early Holocene settlement system.



F Migration of part(s) of the population

G Regulation of population size

H Futher intensification of resource exploitation

I Further regulation of population size

J Trend toward cultivation, domestication and agriculture if appropriate resources available

Resource-rich ecotone (upland/lowland, land/water, etc)

Localised resource exploitation

Generalised resource exploitation

Intensified resource exploitation: 1st phase

Intensified resource exploitation: 2nd phase

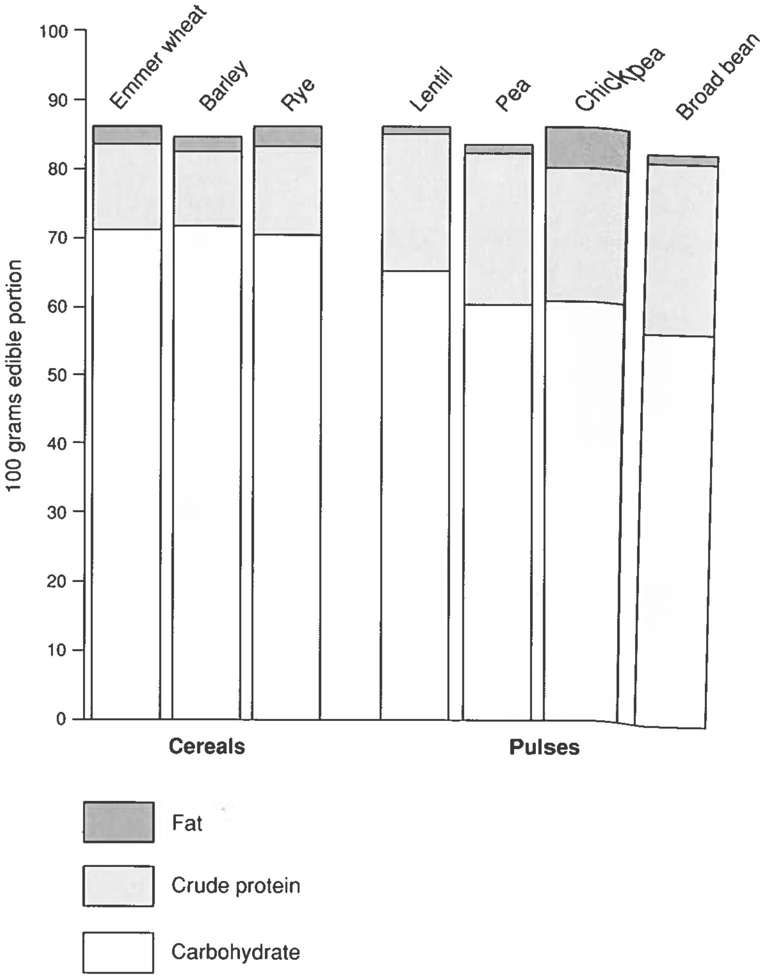


Figure 3. Major nutrients contributed to human diet by the principal cereal and pulse crops of early Neolithic agriculture in Southwest Asia. Nutrient values derived from Leung 1968 and Leung et al. 1972; values not given for einkorn wheat and bitter vetch.

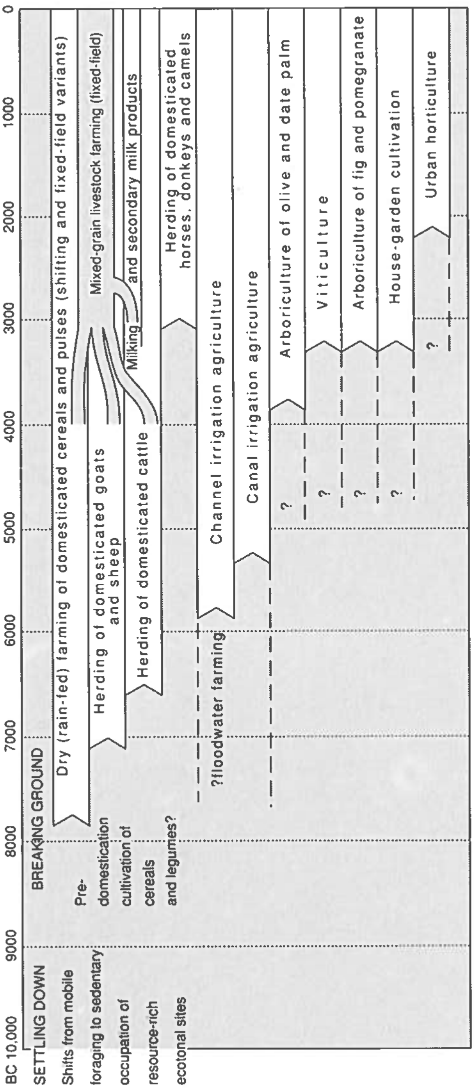


Figure 4. Tentative chronology of the evolutionary differentiation of agricultural systems in prehistoric Southwest Asia. The bioarchaeological and chronological evidence on which this model is based is very inadequate, but it is more plentiful and reliable for the beginnings of cereal agriculture and livestock herding than for the other agricultural systems. The principal sources used in the construction of the model were Clutton-Brock 1981, Davis 1987, Harris 1977, Legge and Rowley-Conwy 1986, Oates and Oates 1976, Simoons 1971 and Zohary and Hopf 1988.

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