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Current Anthropology

THE WENNER-GREN SYMPOSIUM SERIES

THE ORIGINS OF AGRICULTURE: NEW DATA, NEW IDEAS

GUEST EDITORS:
T. DOUGLAS PRICE AND OFER BAR-YOSEF

The Origins of Agriculture
Climatic Fluctuations and Early Farming in West and East Asia
Neolithization Processes in the Levant
Becoming Farmers
The Origins of Agriculture in the Near East
The Neolithic Southwest Asian Founder Crops
The Early Process of Mammal Domestication in the Near East
The Beginnings of Agriculture in China
New Archaeobotanical Data for Origins of Agriculture in China
The Transition from Foraging to Farming in Prehistoric Korea
Advances in Understanding Early Agriculture in Japan
Finding Plant Domestication in the Indian Subcontinent
Holocene Population Prehistory in the Pacific Region
Early Agriculture and Plant Domestication in Island Southeast Asia
Domestication Processes and Morphological Change
Westward Expansion of Farming from Anatolia to the Balkans
The Spread of Agriculture from Central Europe to the Atlantic
Origins of Plant Cultivation in the New World Tropics
Cultural Context of Plant Domestication in Eastern North America
Genetics and Domestication
Agricultural Demographic Transition and the Agriculture Inventions

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The Origins of Agriculture: New Data, New Ideas

Wenner-Gren Symposium Supplement 4

by Leslie C. Aiello

The Origins of Agriculture: New Data, New Ideas resulted from a Wenner-Gren-sponsored symposium held at the Hacienda Temozon, Merida, Yucatan, Mexico, March 6–13, 2009 (fig. 1). The symposium was organized by T. Douglas Price (University of Wisconsin–Madison and the University of Aberdeen) and Ofer Bar-Yosef (Harvard University).

The major aim of the symposium was to better understand the origins of agriculture in light of new fieldwork, new sites, new analytical techniques, and more radiocarbon dates. The global nature of agricultural origins was a key theme, and a major focus of the discussions was on East Asia as well as lesser-known regions such as Papua New Guinea, Africa, and eastern North America, alongside more traditional areas such as the Near East and Mesoamerica. The papers presented in this supplementary issue are designed to provide the latest information on the antiquity of agriculture covering at least 10 different centers of domestication.

The organizers, Price and Bar-Yosef, note in their introduction that emerging data point to an unexpected synchronicity in the timing of the first domesticates around the end of the Pleistocene. They also note that, contrary to earlier thought, the environments in which agriculture originated were not marginal and that agricultural experimentation took place in areas of concentrations of populations and resources. Each major area may also have included multiple loci for domestication. These were major areas of agreement in a meeting that was characterized by lively debate over the variety of hypotheses proposed for agricultural origins and whether global or more area-specific explanations were most appropriate. As in any good meeting, there were more questions than answers, but this is the sign of a dynamic field. The degree of collegiality and collaboration among the diverse symposium participants and the speed at which new data are accumulating are good signs that our understanding of this important period in human adaptation will continue to evolve rapidly.

The Wenner-Gren Foundation has had a long-standing interest in the origins of agriculture and domestication. One of the earliest meetings organized by the Foundation in July 1960 led to the seminal publication Courses toward Urban Life: Archaeological Considerations of Some Cultural Alternates (Braidwood and Willey 1962). Other influential meetings included the Origins of African Plant Domestication (Harlan, De Wet, and Stemler 1972) and Where the Wild Things Are Now (Mullin and Cassidy 2007), which invited anthropologists from all subfields to rethink the concept of domestication in anthropology. Information on these meetings and others can be found on our Web site at http://wennergren.org/history. Most recently, agricultural origins were explored in a special issue of Current Anthropology titled Rethinking the Origins of Agriculture introduced by Mark Cohen (Cohen 2009). The current supplementary issue continues the discussions and debates explored in this earlier contribution but is perhaps more data rich and geographically diverse. Together these two CA issues provide an excellent contemporary overview of the state of research in this exciting area of inquiry.

The Wenner-Gren Foundation is always looking for innovative new directions in the field for future Foundation-sponsored and organized symposia and eventual CA publication. We encourage anthropologists to contact us with their ideas for future meetings. Information about the Wenner-Gren Foundation and the Symposium program can be found on the Foundation’s Web site (http://wennergren.org/programs/international-symposia).

References Cited


The Origins of Agriculture:
New Data, New Ideas
An Introduction to Supplement 4

by T. Douglas Price and Ofer Bar-Yosef

This introduction to the symposium and to this issue of *Current Anthropology* attempts to provide some sense of the topic, the meeting itself, the participants, and some of the initial results. Our symposium brought together a diverse international group of archaeological scientists to consider a topic of common interest and substantial anthropological import—the origins of agriculture. The group included individuals working in most of the places where farming began. This issue is organized by chronology and geography. Our goal was to consider the most recent data and ideas from these different regions in order to examine larger questions of congruity and disparity among the groups of first farmers. There is much new information from a number of important areas, particularly Asia. Following a review of the history of investigation of agricultural origins, this introduction summarizes the results of the conference. There are at least 10 different places around the world where agriculture was independently developed, and the antiquity of domestication is being pushed back in time with new discoveries. Our symposium has emphasized the importance of a multidisciplinary approach to such large questions in order to assemble as much information as possible. We anticipate that the results and consequences of this symposium will have long-term ripple effects in anthropology and archaeology.

In the middle of March 2009, we were part of a group of 22 individuals that included archaeologists, archaeobotanists, archaeozoologists, a geneticist, and a physical anthropologist that took a 6-day trip to a lovely hacienda near Merida in the Yucatan of Mexico. We were well cared for and well fed, but it was an intense and demanding journey and at the same time one of those rare opportunities for like-minded individuals (we use that term loosely) to get together and explore a subject of shared interest, even fascination. We spent those days trying to better understand the origins of agriculture. The people were passionate, the ideas powerful, the information thought provoking, and it is small meetings like this that are the ones that we remember, that leave an imprint, and that generate messages and ideas that form and transform our views of the past.

We, the coorganizers of this symposium, first met in 1968 at the Paleolithic site of 'Ubeidiya in the rift valley of Israel. It was about 120°F in the shade. Doug was a graduate student visiting from another excavation. Ofer was digging in the hot sun and seemed to enjoy it a lot. We next spent a week together at a School for American Research Seminar in Santa Fe in 1993. We had a small, fine meeting on the earliest farming. We have been talking ever since, and a few years ago we decided that there was so much new information on agriculture that another meeting was needed, and we approached the Wenner-Gren Foundation.

Wenner-Gren has organized more than 140 symposia, so they have a pretty good feel for what works and for how to run a successful academic meeting. However, one of the complexities of small, intensive workshop meetings is that each participant arrives with his or her own set of perspectives, experiences, and biases that provide insight but that can also act as blinders. The insight is of course important, but the blinders can impede broader synthesis. We observe only the world we know. For example, Doug does archaeology in northern Europe, and from that perspective he witnesses only the arrival of farming, not its origins. But the larger questions

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are often the same. Why do hunters become farmers? Why is agriculture so dynamic in changing human adaptation and behavior?

Our symposium brought a number of biases: there was an Old World bias, an East Asia bias, a plant bias, a male bias, and an age bias; someone even suggested an anticamel bias. Specific individual knowledge and bias were critical for our discussions. At the same time, most of the participants did manage to put aside their blinders and take a wider point of view.

The biases at our symposium can be documented in part by a brief glimpse at the background of the participants. There were 22 scientists invited to the symposium—nine archaeologists, six archaeobotanists, five archaeozoologists, a physical anthropologist/demographer, and an archaeological geneticist. These individuals came from eight countries and work in many major areas of agricultural origins and/or spread. A brief biography of each participant (in alphabetical order) may provide some sense of the perspectives at the symposium. Coauthors who did not attend the meeting are not included.

Ofer Bar-Yosef is an archaeologist and MacCurdy Professor of Prehistoric Archaeology at Harvard University. Among many other interests, he has investigated the origins of agriculture in both Southwest Asia and China. Anna Belfer-Cohen is professor of archaeology at the Hebrew University in Jerusalem with interests in the transition to farming in the Near East. Peter Bellwood is an Australian archaeologist and professor at Australian National University. His interests focus on Southeast Asia and the Pacific, and he is a proponent of the connectedness of culture, linguistics, and human biology. Jean-Pierre Bocquet-Appel is an anthropological demographer and research director at Centre National de la Recherche Scientifique in Paris. His current interest concerns the agriculture demographic transition worldwide.

David Joel Cohen is an archaeologist and adjunct assistant professor at Boston University, where he helped establish the International Center for East Asian Archaeology and Cultural History. His current research focuses on the origins of agriculture in East Asia. Gary W. Crawford is an archaeobotanist and professor at the University of Toronto Mississauga, Canada, and is interested in the origins and intensification of agriculture in China, Japan, Korea, and Eastern North America. Tim Denham is a research fellow at Monash University in Victoria, Australia. Over the past decade his research has focused on the emergence of agriculture in Papua New Guinea.

Dorian Q. Fuller is a lecturer in archaeobotany at the Institute of Archaeology, University College London. His research focuses on the origins of agriculture in South and East Asia. A. Nigel Goring-Morris is an archaeologist at Hebrew University in Jerusalem. His interests are in the beginnings of complexity in the Near East and Neolithization processes. Greger Larson is a research fellow at Durham University in the United Kingdom. As an archaeological geneticist, his interests are concerned with ancient DNA and the evidence for domestication. Gyung-Ah Lee is an assistant professor at the University of Oregon. Trained as an archaeobotanist, her interests focus on the origins of agriculture and its impact in East Asia, including Korea, China, and Japan.

Fiona Marshall is a professor at Washington University in St. Louis, where she directs research in African prehistory and zooarchaeology. Her interests are in domestication, pastoralism, climate change, and mobility. Mehmet Ozdoğan is an archaeologist and chair of the prehistory department at Istanbul University. His research for the past 2 decades has focused on the emergence of early food-producing sedentary communities and the spread of agriculture from Anatolia to Europe.

Dolores R. Piperno is Senior Scientist and Curator of Archaeobotany and South American Archaeology at the National Museum of Natural History in Washington, DC, and the Smithsonian Tropical Research Institute, Balboa, Panama. Her interests are in domestication and tropical archaeology and paleoecology. T. Douglas Price is Weinstein Professor of European Archaeology at the University of Wisconsin–Madison and 6th Century Chair in Archaeological Science at the University of Aberdeen. His major interests involve the transition from hunters to farmers in northern Europe and archaeological chemistry. He is director of the Laboratory for Archaeological Chemistry in Madison. Peter Rowley-Conwy is a professor at Durham University, United Kingdom, and an archaeozoologist with interests in the spread of pigs and agriculture across Europe. Bruce D. Smith is Curator of North American Archaeology and Senior Research Scientist in Archaeobiology at the National Museum of Natural History in Washington, DC. He is currently interested in integrating biological and anthropological approaches to documenting plant and animal domestication.

Jean-Denis Vigne is an archaeozoologist with interests in mammal domestication in Eurasia. He is employed by Centre National de la Recherche Scientifique, Paris, and is in charge of the laboratory of archaeozoology and archaeobotany at the French National Museum of Natural History. Ehud Weiss is a senior lecturer and the director of the archaeobotanical laboratory at Bar-Ilan University and the Weisman Institute of Science in Israel. He is interested in the beginning of plant domestication in the Near East through the prism of archaeobotany. Melinda A. Zeder is Senior Research Scientist and Curator of Old World Archaeology and Zooarchaeology at the National Museum of Natural History in Washington, DC. Her interests concern the domestication of animals in general and the social and environmental implication of early agriculture in the ancient Near East more specifically. Zhijun (Jimmy) Zhao is a staff scientist at the Institute of Archaeology, Chinese Academy of Social Sciences, Beijing. His research is focused on the origins of agriculture in China and East Asia using archaeobotanical evidence.
Definitions and Dates

Definitions

To enhance consistency in our discussions we have tried to define some terms of common usage. There was not universal agreement on the meaning of these words, of course, and the individual authors use these definitions or not as they find appropriate in the following articles. Our purpose here is not to set the final definitions of important terminology but rather simply to try to use these words consistently in the papers presented here. A number of authors have suggested definitions for these terms over the years (e.g., Harris 1996, 2007), but there are still no widely accepted meanings. In the papers in this issue of Current Anthropology, the following definitions will be used unless noted by the individual authors.

Mobility and sedentism. These are relative terms that describe a range from completely mobile to completely sedentary. Sedentism is difficult to measure in the archaeology of the last hunters and first farmers, and this definition attempts to recognize that. It was suggested that the presence of commensals, such as house mice, and the seasonal distribution of plant foods within the same site may indicate an annual long-term occupation.

Management. Manipulation and some degree of control of wild species (plants or animals) without cultivation or morphological changes. In the 1970s this kind of treatment was referred to as “cultural control.”

Cultivation. Intentional preparation of the soil (Oxford English Dictionary) for planting wild or domesticated plants. Identified in many cases by arable weeds in cereal caches (Bogaard et al. 1999; Harris 2007). The term is often used to indicate cultivation of wild plants before domestication.

Domestication. Morphological or genetic changes in plant and animal species. Archaeozoologists also use criteria such as age profiles, milking, and osteological pathologies.

Farming. Utilization of domestic plants and/or animals for food as well as other resources.

Agriculture. Farming and/or herding predominate the activities of a particular community and determine the main diet, although hunting and gathering may continue.

There were also a number of terms that were not used often at the symposium. Words such as “horticulture,” “arboriculture,” “herding,” “pastoralism,” “husbandry,” “storage,” “agropastoralism,” and “intensity of food production” may also be important and useful to scholars of early agriculture in both the Old and New Worlds. Bruce Smith and others, for example, found utility in the concept of “low-level food production” (Smith 2001). In an ideal world, all of these terms would have fixed meanings that could be used easily in discussions of the first farmers, but for the present such consensus does not exist.

Dating

Also for purposes of consistency, the authors in this issue have been asked to report radiocarbon dates in terms of calibrated years before present (BP cal) with ±1 SD, unless otherwise noted. Authors were also asked to note the calibration program that was used.

The Organization of This Issue

Because of the number of participants and the size and format of this publication, we are limited to brief contributions and a few illustrations each. For these reasons as well, our introduction will be brief. All of the papers have been rewritten following the symposium to incorporate the ideas and input from our discussions. These revisions clearly reflect the impact of the discussions on the participants and the stimulus that was provided by the symposium.

The papers in this issue have been organized largely by chronology and geography to facilitate access for the reader. The earliest evidence for the origins of agriculture comes from Southwest Asia. Bar-Yosef (2011) writes about the role of climate change and the congruence in the chronology of agricultural origins in the Near East and China with the Younger Dryas cold episode at the end of the Pleistocene. Goring-Morris and Belfer-Cohen (2011; see also Belfer-Cohen and Goring-Morris 2011) have provided two contributions detailing the Neolithization process in the Near East as seen within the core area and from the larger region. One of the fascinating things about their contribution about the “Neolithic revolution” is that is has little to do with subsistence. Animal and plant management as well as domestication in the Near East are the focus of papers by Zeder (2011), Weiss and Zohary (2011), and Vigne et al. (2011). Zeder provides a thorough discussion of current evidence for domestication. Weiss and Zohary consider the evidence for the major founder species of plants. Vigne and colleagues provide a look at the remarkable evidence from Cyprus where Pre-Pottery Neolithic people brought plants and animals, essentially re-creating an Early Neolithic ecosystem on that rather barren Mediterranean island.

The next set of papers deals with East Asia, largely from an archaeobotanic perspective. Cohen (2011) offers an overview of the beginnings of agriculture in China in the context of interregional interaction. Zhao (2011) details the abundant new botanical data that have appeared in the past 10 years. Lee (2011) elaborates on agricultural origins in Korea. Crawford (2011) provides an overview of recent advances in our understanding of early cultivation in East Asia with a focus on Japan.

South Asia and Africa provide a very different statement on the beginnings of farming, and questions continue about the appearance of native domesticates. Fuller (2011) tracks this issue, finding plant domestication in the Indian subcon-
tinent. Animal domestication in Africa is the subject of the contribution by Marshall and Weissbrod (2011), with a focus on the donkey in particular and African pastoralism in general.

In the Pacific, two studies are presented. Bellwood (2011) provides an overview of Holocene population history of the region as a model for worldwide food-producer dispersals. Denham (2011), on the other hand, offers details of the evidence for domestication and early agriculture in New Guinea and Island Southeast Asia.

The spread of agriculture subsequent to its origins is the subject of papers dealing with the European evidence. Özdoğan (2011) provides an in-depth look at the archaeological evidence for the westward movement of early farmers from Anatolia to the Aegean and Balkans of Europe. The new evidence from European Turkey and Bulgaria is rewriting our understanding of this spread. Rowley-Conwy (2011) continues the story of westward movement from Central Europe to the Atlantic. The picture of the expansion of early farming across Europe is now one of repeated episodes of very rapid spread followed by long periods of stability. Bursts of regional expansion are not in contrast to the overarching model of continuous millennial-scale demic diffusion but provide a more detailed picture that brings the information closer to the social history of particular populations.

Turning to the New World, Piperno (2011) examines the evidence for origins of plant cultivation and domestication in the tropics of Central and South America. Abundant new evidence from starch grains and phytoliths as well as macrobotanical remains provides exciting new information and pushes back the dates for early domestication. Smith (2011) continues his documentation of an early center for domestication in Eastern North America with a consideration of the cultural context of this process, the evidence coming from archaeology.

Two papers were topical rather than areal and covered important aspects of the study of agricultural origins. Larson (2011) provides a refreshingly candid view of the role of genomics in the study of plant and animal domestication. There is great promise in this method, but serious problems remain to be solved. Jean-Pierre Bocquet-Appel (2011), proponent of the concept of the Neolithic demographic transition, describes the background and development of this model of population growth across the transition to agriculture (Bocquet-Appel and Bar-Yosef 2008).

The State of Play

In order to place the results of our symposium and some of the new ideas and information that emerged in perspective, it may be useful to briefly review the development of ideas about the origins of agriculture and some of the explanations that have been proffered. We can best understand ideas about the origins of agriculture from a historical perspective, considering the early theories first. Explanations of why domestication occurred include the oasis hypothesis, the natural-habitat hypothesis, the population-pressure hypothesis, the edge hypothesis, the social hypothesis, and more. A consideration of these ideas also reveals much about the nature of archaeology and archaeologists.

During the first half of the twentieth century, the best information on early farming villages came from riverine areas or oases in Northeast Africa and Southwest Asia—along the Nile River in Egypt and at Jericho in the Jordan Valley, for example. Early views on the origins of agriculture focused on climate change. At that time, the end of the Pleistocene was assumed to have been a period of increasing warmth and dryness in the earth’s climate. Scholars reasoned that because the ice ages were cold and wet, they should have ended with higher temperatures and less precipitation. Given that view of past climate, logic suggested that areas such as Southwest Asia, a dry region to begin with, would have witnessed significant aridity at the end of the Pleistocene when vegetation grew only around limited water sources. The oasis hypothesis suggested a circumstance in which plants, animals, and humans would have clustered in constrained zones near water. V. Gordon Childe, one proponent of this idea, argued that the only successful solution to the competition for food in these situations would be for humans to domesticate and control the animals and the plants. In this sense, domestication emerged as a symbiotic relationship for the purpose of human survival.

During the 1940s and 1950s, however, new evidence suggested that there had been no dramatic climatic changes in Southwest Asia at the close of the Pleistocene—no crisis during which life would concentrate at oases. The new information forced a reconsideration of the origins of agriculture. The late Robert Braidwood pointed out in his natural-habitat hypothesis that the earliest domesticates therefore should appear where their wild ancestors lived. That area, the “hilly flanks” of the Fertile Crescent in Southwest Asia, should be the focus of investigations. Braidwood and a large team of researchers excavated at the site of Jarmo in northern Iraq and elsewhere in the Fertile Crescent and found evidence of early agriculture, supporting his hypothesis that domestication did indeed begin in the natural habitat.

Braidwood did not offer a specific reason as to why domestication occurred other than to point out that technology and culture were ready by the end of the Pleistocene and that humans were familiar with the species that were to be domesticated. At that time, archaeologists and others generally considered that farming was a highly desirable and welcome invention providing security and leisure time for prehistoric peoples. Once human societies had recognized the possibilities of domestication, they should have immediately started farming following the perspectives of the time.

Lewis Binford (1968) challenged those ideas in the 1960s and focused on population. Binford argued that farming was backbreaking, time consuming, and labor intensive. Citing
studies of ethnographically known hunter-gatherers, he pointed out that they spend only a few hours a day obtaining food; the rest of their time is for visiting, talking, gambling, and the general pleasures of life. Even in very marginal areas, such as the Kalahari Desert of South Africa, food collecting is a successful adaptation, and people rarely starve. Binford argued, therefore, that human groups would not become farmers unless they had no other choice, that the origins of agriculture was not a fortuitous discovery but a last resort.

Binford made his point by positing an equilibrium between people and food, a balance that could be upset by either a decline in available food or an increase in the number of people. Because climatic and environmental changes appeared to be minimal in Southwest Asia, Binford thought it must have been increased population size that upset the balance. Population pressure was thus introduced as a causal agent for the origins of agriculture: more people required more food. The best solution to the problem was domestication, which provided a higher yield of food per acre of land. At the same time, however, agricultural intensification required more labor to extract the food.

Binford’s concern with population was elaborated and extended as a global explanation by Mark Cohen (1977, 2009). Cohen argued for an inherent tendency for growth in human population, a pattern responsible for the initial spread of the human species out of Africa, the colonization of Asia and Europe, and eventually colonization of the Americas as well. According to Cohen, after about 10,000 BC, all the habitable areas of the planet were occupied, and population continued to grow. At that time, there was an increase in the use of less desirable resources in many areas. Land snails, shellfish, birds, and many new plant species were added to the human diet around the end of the Pleistocene. Cohen argued that the only way for a very successful but rapidly increasing species to cope with declining resources was for them to begin to cultivate the land and domesticate its inhabitants rather than simply to collect the wild produce.

Domestication for Cohen was a solution to problems of overpopulation on a global scale. There is, however, very little evidence for population pressure in the record of agricultural origins. Population is a notoriously difficult parameter to grasp in prehistory. In the very few cases where some information is available, such as in the Levant as presented in this issue by Belfer-Cohen and Goring-Morris (2011), there may even be some population decline shortly before the first appearance of domesticates. As Bocquet-Appel (2011) points out in this issue and elsewhere, most of the evidence for growing population comes after the origins of agriculture, not before.

Others, arguing that the transition to farming and food storage and surplus cannot be understood simply in terms of environment and population, have developed social hypotheses to explain the origins of agriculture. Barbara Bender (1975) and Brian Hayden (1992, 1995), among others, have suggested that the origins of food production may lie more in the ability of certain individuals to generate a surplus of food and to transform that surplus into more valued items, such as rare and valued materials and objects. From this perspective, agriculture was the means by which social inequality emerged and egalitarian societies became hierarchical. Such a view is intriguing if difficult to document. It is very much a chicken-egg question, like the issue of population pressure, of which came first. There is subtle evidence for social inequality in the Early Neolithic of the Near East (Price and Bar-Yosef 2010), but such reorganization of social relations and wealth accumulation may be a consequence of agricultural production rather than a cause.

There are a number of other intriguing theories about why human societies began to cultivate the earth along with some not so enlightening ideas. Geographer Carl Sauer (1952) suggested that agriculture began in the hilly tropics of Southeast Asia, where sedentary groups with knowledge of the rich plant life of the forest might have domesticated plants for poisons and fibers. Botanist David Rindos (1984) has argued that domestication was a process of interaction between humans and plants evolving together into a more beneficial symbiotic relationship.

In a fascinating volume titled Naissance des divinités, naissance de l’agriculture: la révolution des symboles au Néolithique (The Birth of the Gods and the Origins of Agriculture), French archaeologist Jacques Cauvin (1994) argued that the important changes associated with the “Neolithic revolution” were more cultural than economic. He meant that the transition to farming involved concepts and ideas as much as or more than food production. Specifically, he suggested that agriculture was preceded by the emergence of new cosmologies, religious practices, and symbolic behaviors. This transformation of hunter-gatherers that allowed them to view their habitat in a different way also promoted the more active exploitation of that environment according to the views of Cauvin.

In recent years, the school of evolutionary ecology in archaeology has provided its take on the origins of agriculture in a series of papers and volumes (e.g., Bleed and Matsui 2010; Gremillion and Piperno 2009; Winterhalder and Kennett 2006, 2009). Evolutionary ecology developed out of an earlier perspective known as cultural ecology, which focused on the dynamic relationship between human society and its environment using culture as the primary mechanism of adaptation. Culture is a giant concept and hard to work with, so evolutionary ecologists have emphasized human abilities to reason and to optimize their behavior. In this view, natural selection is thought to operate on the behavior of individuals. Evolutionary ecologists assume that natural selection designed organisms to adapt to local conditions in fitness-enhancing or optimizing ways.

One of the major tenets of this perspective involves a concept known as optimal foraging theory—borrowed from biology—to explain the food-getting behavior of humans, especially hunter-gatherers. Optimal foraging theory argues that
the most efficient foraging strategies produce the greatest return in energy relative to time and effort expended. Optimal foraging assumes that humans make rational decisions based on economic efficiency. Evolutionary ecologists examine the archaeological and ethnographic record looking for things such as “optimization goals,” “currencies,” and “constraints” and applying ecological and mathematical models to explain human behavior.

Ideas about the origins of agriculture have sometimes been categorized as either push or pull models. Hunter-gatherers are either pushed, or forced, to become farmers or they are pulled, drawn by the benefits of a new lifestyle. Population-pressure models, for example, force human societies to find new ways to feed growing numbers of members. Social hypotheses usually involve pull, in which members of society are drawn into relationships of inequality in order to benefit from new arrangements that reduce risk or increase wealth.

The perspective of evolutionary ecology involves push models. Hunter-gatherers operate on the premise of efficiency to acquire sufficient food to eat. Foods are ranked by net energy value, and lower-ranked subsistence resources (such as seeds) are added only as higher-ranked foods become unavailable. Such push perspectives appear to assume that hunter-gatherers are surviving among limited resources in difficult environments. One of the most important and enlightening realizations in recent years is the fact that agricultural origins take place in relatively abundant environments, not in places where little food is available (Price and Gebauer 1995). It is in such situations of sufficient subsistence resources, where risk is limited, that experiments leading to the origins of agriculture took place. Higher-ranked food resources do not appear to have declined or become unavailable in such contexts, bringing into question the utility of such optimal foraging models.

More recently, detailed information on climate change has come from a most unlikely place, the glaciers of Greenland. Deep corings of the ice sheets there have provided a layered record of changes in temperature and other aspects of climate for the past 100,000 years and more. One of the very interesting results of this research is the documentation of a 33% increase in atmospheric CO2 at the end of the Pleistocene (Sage 1995). Higher levels of CO2 would foster the expansion of temperate species such as grasses, which include many of the ancestors of the major domesticated species. The full implications of such changes in the atmosphere are not yet clear but may play a role in the transition from hunting to farming. The evolutionary ecologists have picked up on CO2 and argue that climatic amelioration that followed in the Early Holocene and the accompanying rise in CO2 made the origins of agriculture “compulsory” (Bettinger, Richerson, and Boyd 2009).

The simple fact is that we do not yet have a good grasp on the causes for the origins of agriculture. The how and the why of the Neolithic transition remain among the more intriguing questions in human prehistory. There is as yet no single accepted theory for the origins of agriculture—rather, there is a series of ideas and suggestions that do not quite resolve the question. At the same time, of course, the evidence we have is scanty and limited. A great deal more research and discussion needs to be done. That is why we convened this symposium.

Some Observations

The focal point of the symposium was, of course, the origins of agriculture. We hoped to bring together new data and new ideas to push our understanding of this remarkable phenomenon further along. The origins of agriculture is one of the most important developments in our past. Virtually everything we as humans know and do today stems from this remarkable transition. Detailed study of this issue—the presentation of evidence and the evaluation of potential answers—has significance for students of the past, for anthropology as a whole, and for a wide range of related areas of scholarly interest.

There are both practical and theoretical implications of the study of agricultural transitions. The documentation of when and where farming began provides a powerful statement regarding the global nature of this event. Investigation of the shift from hunting and gathering to farming invokes virtually all aspects of anthropological perspectives on human behavior and cultural change. The transition to agriculture is a common human experience that has effected us all in terms of rapid population growth and aggregation and social inequality. Is it “the worst mistake in the history of the human race” (Diamond 1987) or an inevitable step in the evolution of human society?

A multitude of developments concerned with the origins and spread of agriculture have taken place in recent years. New fieldwork and new sites in new and old places, more radiocarbon dates, and new methods have documented earlier transitions to agriculture in parts of Asia, the south Pacific, and the Americas. Studies of microscopic plants remains, especially starch grains and phytoliths, have revolutionized identification of plant exploitation before the emergence of cultivation as well as the appearance of domesticated plants. Advances in the genetics of domestication, such as utilizing ancient DNA to examine the relationships among prehistoric domestics, are beginning to resolve standing questions about where and when. It is time to assemble this new information, to sift and winnow, and to summarize our current understanding of the origins and spread of agriculture.

Our symposium on the state of the art in the study of the origins of agriculture was intended to provide a baseline for continuing and future work. We wanted to learn new facts, examine a wide range of variables, and use our knowledge to evaluate current explanations and to explore new ideas for understanding what took place at the origins of agriculture.
Above all we wanted to think in new directions about this large, complex, and obstinate issue.

There is too little collaboration and interaction between the varied disciplines investigating this question (e.g., genetics, botany, zoology, archaeology, linguistics, demography). An enormous amount of research is going on today in a rather uninformed context. This symposium was intended to integrate that context and provide shared perspectives on the question of agricultural origins. This work is going on around the world, and one of our primary goals was to bring together the leading scholars concerned with this question from diverse places and origins. Such gatherings are extremely rare and often very fruitful.

We were a volatile mix of scholars, from many times and places. At the end of our time together, we did not determine why agriculture originated. We did not even agree on whether its causes were global or local. Archaeozoologists decried the difficulties involved in identifying domestication and seek complex forms of evidence for the process (Zeder 2006a, 2006b); archaeobotanists seek changes in morphology and genetic makeup as indicators of changes in plants (e.g., Smith 2006; Zohary and Hopf 2000). These differences mean distinct views on the question of agricultural origins from the two subdisciplines. Some might conclude that our symposium was not successful.

In fact, we believe this symposium was a great success. Perhaps most importantly there was a strong sense of collaboration at the meeting. There was much new in terms of both information and ideas. There was a major emphasis on the origins of agriculture in East Asia. Lesser-known regions such as Papua New Guinea, Africa, and eastern North America were included in our discussions. Lots of new data were presented from East and West Asia, Africa, and Central and South America. We were able to put together a table of the latest information on the antiquity of agriculture in various parts of the world and recognized that there are at least 10 different places with claims as original centers of domestication (fig. 1). Information on estimated dates BP cal for domestication in these areas is provided in table 1 (see also fig. 1).

The antiquity of domestication has been pushed deeper into the past in many areas. Today, an eerie synchronicity in the timing of the first domesticates around the end of the Pleistocene is emerging. Another commonality among the cradles of agriculture is the rich environments in which farming originates. Experiments in domestication do not take place in marginal areas but amid concentrations of population and resources across the globe. It also appears that in each area where several different species are involved in the transition to agriculture, there are multiple centers of domestication within the region. A number of groups appear to be manipulating their natural world.

Remarkable new studies are documenting this evidence. Microscopic studies of starch grains in South America have identified a number of early crops, and more specific information on their origin and distribution is becoming available (Piperno 2011). New work is beginning to provide data from critical regions in Mesoamerica, one of the least understood regions of early agricultural origins (Piperno et al. 2009; Ranere et al. 2009). Archaeobotany is moving forward rapidly with a variety of techniques for recording information related to domestication (Allaby, Fuller, and Brown 2008; Fuller 2011). Genetic studies of modern and ancient DNA in domesticated plants and animals are also providing remarkable data on species distribution and evolution (e.g., Dobney and Larson 2006). Genetic markers for domestication are starting to be identified. At the same time, a note of caution regarding genetic studies, especially age estimation based on mutation rate, permeated the symposium and was reiterated by our resident archaegeneticist (Ho and Larson 2006).

One of the most interesting phenomena we noted was not pattern but variation. In the one or two places where data on the transition are relatively rich, there appears to be a period of chaos, a "zone of variability" at the origins of agriculture (Weiss, Kislev, and Hartmann 2006). There seems to be a period for the auditioning of many possible new options in human adaptation. This is the beginning of a new way of life.

Three recent discoveries from the earliest Neolithic in the Near East highlight this zone of variability, change our understanding of this period in human prehistory, and raise enormous new questions. The colonization of the Mediterranean island of Cyprus by Late Pre-Pottery Neolithic A and Pre-Pottery Neolithic B people carrying domestic plants and domestic and wild animals by boat is an extraordinary story (Guilaine et al. 1998, 2000; Peltenburg and Wasse 2004; Peltenburg et al. 2000; Simmons 2007; Vigne et al. 2000). Excavations at Göbekli Tepe in southern Turkey have revealed a series of remarkable shrines or centers associated with large stone architecture and art from the same time period (Peters and Schmidt 2004; Schmidt 2001, 2003, 2006; Schmidt and Hauptman 2003). The roughly contemporary burial ground of Kafar HaHoresh in Israel documents enormous new variation in the treatment of the dead and indications of emerging social inequality at this time (Goring-Morris 2005; Goring-Morris et al. 1998).

A number of potentially important variables involved in the shift from foraging to farming were discussed at the symposium. These include sedentism, storage, population density, population pressure, resource abundance, resource availability, niche construction, processing and harvesting technologies, climate and environmental changes, ownership of produce and resource localities, potential domesticates, competition, inequality, risk reduction, nutritional requirements, choice, chance, and a receptive social/cultural context.

Some Conclusions

Farming is a way of obtaining food that involves the cultivation of plants and the controlled herding of animals. But
Figure 1. Major centers of domestication and dates for earliest plants and animals. Illustration by Marcia Bakry. A color version of this figure is available in the online edition of *Current Anthropology*. 
the beginnings of new subsistence systems were much more than cultivation, herding, or the ensuing domestication of various species. This revolution entailed major long-term changes in the structure and organization of the societies that adopted this new way of life as well as a totally new relationship with the environment. Humans truly began to harness the earth. While hunter-gatherers live off the land in an extensive fashion, generally exploiting a diversity of resources over a broad area, farmers utilize the landscape intensively and create a milieu that suits their needs.

The symposium at Temozon and the papers proffered in this issue attempt to describe some of the latest evidence and to comprehend these extraordinary developments. Here, we hope to provide some sense of the results of the symposium and our own perception of the state of knowledge concerning the origins of agriculture. We learned a great deal. Some of the major threads woven throughout the symposium included the importance of integrating the subdisciplines, the abandonment of dichotomies for the study of process and transformation, the chaos of transitions (a period of “auditioning,” as Bruce Smith termed it), the importance of attention to detail in the study of landscapes and species as well as archaeological sites, the punctuated nature of agricultural spread, the many major gaps in our knowledge, and the necessity for critically reevaluating existing information. There was also lots of terminology, much new data, some innovative ideas about causality, and many remaining questions.

It is important to separate the origins of agriculture from the process of domestication and to distinguish biology from culture in the transition from hunting to farming. The criteria for identifying domestication differ significantly for plants and animals. Plants rather quickly exhibit distinct morphological changes; animals are much slower to show such developments. Archaeozoology has introduced a number of important new concepts regarding the process. Three classes of domesticates can be identified: (1) commensals, adapted to a human niche (e.g., dogs, cats, guinea pigs); (2) prey animals sought for food (e.g., cows, sheep, pig, goats); and (3) targeted animals for draft and nonfood resources (e.g., horse, camel, donkey). Changes related to domestication may be more species specific in animals. These differences mean that nonmorphological criteria, such as changes in age profiles of herds, may be required for fauna.

Increasing site size is one of the primary archaeological indicators of changes in human subsistence and organization associated with the agricultural revolution. This increase is a reflection of population growth as well as new forms of settlement and organization. One of the more striking developments associated with the arrival of farming is the increasing visibility of a human presence in the archaeological record. Hunter-gatherers rarely leave visible traces, few bumps in the landscape. Shell middens, some ditches, and other features remain today, but even the most complex hunter-gatherer adaptations did not modify the landscape to a large extent or leave many traces that are visibly on the surface of the earth today.

The phantom of causality floated at the edge of our deliberations at Temozon, always there but not often addressed. This transition from hunting to farming poses one of the most intriguing questions about the human past and one of the most difficult to answer: why did hunters become farmers? Causality is such a thorny issue. There is no common playing field or shared rules of engagement. The evidence from different parts of the world varies in both quantity and quality. That discordance is disconcerting. Variation generates many perspectives and divergence. Consensus on fundamentals is lacking.

Are there general causes? The almost simultaneous development of agriculture in so many different places is not simple coincidence. Should we invoke climate, environment, population, subsistence intensification, brain capacity, religion, inequality, entrepreneurs? Are there specific conditions? Are there immediate and local causes distinct from global ones? Are the origins of agriculture the results of a “perfect storm” of factors that forced or encouraged human societies to domesticate plants and animals?

The division between generalists and particularists was clear at Temozon. Particularists wanted to look at each individual case of agricultural origins as unique; generalists sought a more global explanation that would encompass all of the areas where early agriculture appeared. Some in the group insist that causality is a local or regional phenomenon that varies across time and space. Zeder and Smith (2009) have argued
at some length that global views, “one-size-fits-all” approaches to the explanation of agricultural emergence and dispersal, are not feasible. Bruce Smith enlivened the symposium one morning by arguing that “causality is in the eye of the beholder”—that generalization was not possible because of the complexity of individual contexts.

Others believe that the simultaneity of the origins of agriculture in time argues for general or global causes. It is completely remarkable that the process of domesticating plants and animals appears to have taken place separately and independently in a number of areas at about the same time. Given the long prehistory of our species, why should the transition to agriculture happen within such a brief period, a few thousand years in a span of more than 6 million years of human existence? An important and dramatic shift in the trajectory of human adaptation would seem to demand general explanation. But such answers are hard to reach.

Anna Belfer-Cohen brightened the symposium room one morning with a quote from Nigel Barley (1989, p. 205): “Anthropology largely neglects the individual to deal in generalizations. Generalizations always tell a little lie in the service of greater truth.” Conclusions, of course, involve generalizations. It is important to recognize some of the limitations and constraints on such broad speculation. In spite of extraordinary advances in a variety of fields, many detailed at the symposium, we really know very little about the origins of agriculture. There is some information from Southwest Asia, a little data from East Asia and North America, and next to nothing from the rest of the world. We are still in the early stages of the process of identifying and understanding this transition from hunting to farming.

Moreover, as we learn more about a specific region, it becomes clearer how complex the past was, exhibiting much more variability than we have admitted or realized. The Near East is the prime example. There is more information from this region about the origins of agriculture than anywhere else in the world: more sites, more excavations, more analyses, more publications, and so on. Yet new discoveries in the past 20 years have completely altered our understanding of this area and revealed levels of complexity not even imagined 2 decades ago.

A number of important general factors in the origins of agriculture were recognized at the symposium. These factors can be categorized as exogenous, or natural (e.g., climate/environment, population growth), and endogenous, or cultural (e.g., social change, religion). Theories on the transition to agriculture have most often focused on external factors such as climatic change or inherent growth in population as problems solved by the cultivation of plants and animals. Exogenous factors are generally natural forces over which human groups have little control; endogenous factors reflect internal change within society and decisions that humans make.

A series of significant variables involved in the shift from foraging to farming were discussed at Temozon. The most important factors in the transition from the perspective of the authors presented here include, in order of suggested importance, available protodomesticates, human sedentism, higher population density, resource abundance, geographic and/or social constraints, processing and harvesting technology, storage, and wealth accumulation. A change from community to household levels of economic organization observed in several areas may have accompanied the transition to agriculture, including a shift from communal sharing to familial or individual accumulation. Economic intensification and competition were frequent companions of the Neolithic revolution society (Price and Bar-Yosef 2010). Wealth accumulation and status differentiation appear at the individual, household, or lineage level.

We were, however, unable to agree on the primacy of causal factors or on the major issue of general versus specific explanation. The frustrations of explanation leave us asking questions—many important questions were raised at the symposium. Beyond the specific details of local sequences, the nuances of plant and animal domestication, and concerns with the meaning of the evidence, certain larger questions arose again and again. What determines where the first farmers appeared? What makes centers of origin special places? Why do humans domesticate plants and animals? Why are some plants and animals selected for manipulation and not others? Is the domestication process determined solely by the biology of the selected species? What can we say about timing? How long does it take to domesticate plants and animals? How does the timing of this process interlace with developments such as sedentism, population growth, and social inequality? Why was agriculture such a successful adaptation? How does agriculture spread quickly to areas with different cultures, climates, and environments? Can the spread of agriculture tell us about its origins? What spreads, people or things? How do we best explain the origins of agriculture?

Questions provide the right subject to end our introduction and enter the assembled essays that follow. Questions and curiosity, of course, are inherent in the pursuit of knowledge; unanswered questions drive continuing research. Archaeology is concerned with questions about the past. The origins of agriculture is one of the most important and most obstinate. Yet we have no doubt that while it will be a long and arduous journey, our search for answers will have a successful end.

Our goal for the symposium was to develop and explore a rich and productive dialog among scholars from diverse branches of archaeology and related disciplines focused on the beginnings of farming. Through the course of the symposium there was a growing respect and a leveling of boundaries between the subdisciplines. There was lots of news—much information and inspiration. We believe that the participants in this symposium returned home with renewed optimism about the state of research—both data and ideas—on the origins of agriculture. It is our hope that enthusiasm will be conveyed through the continuing studies of the participants and will be passed to their colleagues and students.
In this way, our symposium will have a large impact on the archaeological community, and we can help to push future research along a well-lit path.

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Climatic Fluctuations and Early Farming in West and East Asia

by Ofer Bar-Yosef

This paper presents a Levantine model for the origins of cultivation of various wild plants as motivated by the vagaries of the climatic fluctuation of the Younger Dryas within the context of the mosaic ecology of the region that affected communities that were already sedentary or semisedentary. In addition to holding to their territories, these communities found ways to intensify their food procurement strategy by adopting intentional growth of previously known annuals, such as a variety of cereals. The Levantine sequence, where Terminal Pleistocene and Early Holocene Neolithic archaeology is well known, is employed as a model for speculating on the origins of millet cultivation in northern China, where both the archaeological data and the dates are yet insufficient to document the evolution of socioeconomic changes that resulted in the establishment of an agricultural system.

Opening Remarks: Observations and Statements

The Neolithic Revolution, or the Agricultural Revolution, was a major "point of no return" in human evolution. After 2.6 million years of hunting and gathering, low population densities, and a series of dispersals to the edges of Eurasia and beyond to the Americas and Australia, human societies developed a new economic system that changed the course of prehistory. Instead of survival based on foraging with partial or full-time residential and logistical mobility, the appearance and disappearance of sedentary and semisedentary communities, and episodes of genetic "bottlenecks," the first farming villages in a limited number of regions led unintentionally to a revolutionary social upheaval. Although a few Late Pleistocene hunter-gatherers developed low-level food production, the people who started cultivating the wild species of the "winning" plants—those that feed the world of today (wheat, barley, rice, and corn)—were in retrospect responsible for the rapidly increasing world population that led to the Industrial Revolution.

Before delving into the particular cases of West and East Asia (fig. 1), where I believe the earliest manifestations of this socioeconomic revolution were triggered by the impact of the Younger Dryas (YD), several issues, such as small-scale societies in core areas and their reactions to abrupt climatic changes, require some brief statements and clarifications.

Although history was not recorded during the onset of the Neolithic Revolution, the foundations laid by early farmers unexpectedly led in due course to the invention of writing systems. Indeed, in an evolutionary sense it was a set of rapid socioeconomic changes. We should therefore refer to our data sets from the first half of the Holocene as the history of "people without names," and like all historical documents they are amenable to different interpretations.

Investigations into the reasons why people became farmers are not new. Since the nineteenth century, scholars have searched for "where," "when," "how," and "why" cultivation became an attractive survival strategy. Botanists such as Alfonse de Candolle, Nikolai Vavilov, and Jack Harlan explored the natural habitats where the wild progenitors of domesticated plants were found, assuming that these were the "centers" of plant domestications. The desire to find primordial locations is still pertinent, as recent investigations in the Levant (e.g., Zohary and Hopf 2000) or the efforts to find the location of millet progenitors in East Asia (e.g., Lu et al. 2009) demonstrate.

Historically, these natural habitats or their margins were thought by archaeologists to have been the "core areas" where cultivation and domestication occurred (e.g., Binford 1968; Braidwood 1952; Flannery 1973). What seems to be a feasible research target in the Levant because of its relatively small dimensions and the large number of different schools of archaeology involved in fieldwork is more complex in East Asia, where investigations began almost half a century later and where the core area is at least two to four times as large. Hence, using the primacy of the Levant, I discuss the role of "core areas" and refer to places into which agricultural systems
Figure 1. Regions discussed in the text: the Levant and China.

were transmitted to as “secondary core areas.” For example, the Levant was the “core area” where the cultivation of wild cereals, also known as “predomestication cultivation” or “low-level food production” (e.g., Smith 2001) began and where these plants became the cultigens after more than 1,000 years of farming. These domesticated crops were introduced into Europe and the Nile Valley, both “secondary centers.”

The archaeological evidence for the initiation of cultivation, the corralling of wild herd animals, and the ensuing transmission of knowledge, techniques, plants, and animals, as well as voluntary and/or forced movements of humans among village-based societies, is characteristic of interregional connections. Short- and long-distance interactions did not always occur under stable environmental conditions. Paleoclimatic proxies from the Terminal Pleistocene and Early Holocene record numerous fluctuations. Even minor shifts in local conditions, given the available technology and social structure of human groups, could make the difference between successful biological survival and failure.

In this paper, I suggest that at the two ends of the Asian continent, a climatic change was the main trigger for the onset of cultivation (i.e., growing the progenitors of wheat, barley, rye, millet, and other grains) in a context of “low level food production” (Smith 2001). This either evolved into major food production or failed (e.g., Weiss, Kislev, and Hartmann 2006; Weiss and Zohary 2011). Hence, before delving into the climatic, social, and economic evidence acquired from archaeological investigations, we need to examine briefly the past human experience in the face of abrupt climatic change.

More than once during the Pleistocene, humans faced environmental changes that improved, worsened, or did not affect their basic ecological conditions. While we sometimes tend to see these climatic changes as the causes for the extinction of particular populations or eventual dispersals, the overall picture is too coarse-grained. History, however, has taught us different lessons. Slow or abrupt shifts of environmental conditions that resulted in social and economic disasters have been recorded (e.g., Bell 1971; Hassan 2002; Shen...
The impacts of droughts, harsh winters, flooding by rivers or the sea, failing harvests, famines, wars, spreads of disease, disturbances of the social order, and the demise of peoples are reasonably well documented. Some societies were able to cope with or to minimize disastrous effects, while others collapsed (Rolett 2008). The challenge for archaeologists is to find how humans handled a situation and either succeeded or failed in coping with the impacts of natural calamities (Rosen 2007). When biological survival is critical for individuals or a group of people—be it a band, a macroband, or a tribe (using an approximate scale of population size; see Binford 2006; Hawkes and Paine 2007; Marcus 2008; Roscoe 2008, 2009)—they will use a number of strategies within their knowledge, depending on the resilience of their social structure and cultural concepts, to insure their physical existence in the world.

The ability to minimize risk, for example, can be increased by actively intervening in the natural environment when K-selected (e.g., large-bodied mammals) and r-selected (e.g., small-bodied mammals such as hare and tortoise, as well as fruits and seeds) resources decrease or when required foray distances increase. This can be accomplished by intensifying food-acquisition techniques such as tending particular plants, using fire to enhance the growth of wild stands of herbaceous vegetation, digging simple irrigation canals, and in some cases being involved in “low-level food production” (e.g., Binford 2006; Denham et al. 2003; Kelly 1995; Lewis 1972; Lourandos 1997; Roscoe 2009; Smith 2001).

The ability to handle the complexity of the social organization through the articulation of its members and the spatial distribution of the mating system under stressful circumstances is another strategy. The increased social cohesion by increasing group size (agglomeration) or reducing (fissioning) in face of natural disasters includes the perception of home territory and its ranges, incorporation of sacred localities, and the degree of preparedness of the group to pay for costly signaling of their ownership (e.g., Roscoe 2006).

The level of preparedness of those who inhabit ecologically marginal zones—for example, those with increased frequency of droughts or prolonged cold winters—when facing natural disasters is tested when and if they are ready to change or successfully move out (Kawecki 2008). Much depends on the survival skills, ability to mitigate relations with neighbors, and socioeconomic information transmitted through the “living memory” of the social unit (e.g., Minc and Smith 1989; Rosen 2007).

The ability of the population to sustain its biological survival for future generations within a large geographic region is tested in times of stress. The intervariability of the social organization, alliances with neighboring groups, and the history of conflicts often play an important role in adaptation to new conditions, although recovering all this information from the archaeological record is difficult (e.g., Marcus 2008).

As a result, when disasters strike, the options for all foragers are (a) to increase mobility by moving to another territory or increasing the distance of forays by task groups if neighboring territories are less affected, thereby facing foes or friends (in the best situation, kin relations); (b) to stay put and defend the reliable natural resources within their immediate territory; or (c) to actively intensify the yield of available plant resources through technological improvements, new inventions, part-time cultivation, the tending of fruit trees, and even the corralling of herd animals as pets and food. The sum of all these traits, or only a few, provide the “cultural filter” through which environmental changes are mitigated by the affected society or negotiated with its neighbors, whether they belong to the same culture (and speak the same language or the same dialect) or to a different society.

Many archaeologists are reluctant to accept the notion that climatic changes expressed in environmental degradation, reflected in climatic proxies, and seemingly of the same date of an observed cultural “break” in the archaeological sequence were the cause for turnover or crisis. They are right. Chronological correlation is not causation. Employing approximate chronological correlations as the basis for proposed interpretations is merely a hypothesis to be verified or falsified. This paper relies on that approach but advocates, even if it is not yet completely feasible, that sound interpretations should be grounded on precisely dated paleoclimatic information obtained from archaeological deposits and their contents (e.g., plants and animal bones). In addition, it should be stressed that proposals by nonarchaeologists that abrupt climatic changes resulted in a socioeconomic shift should incorporate an anthropologically oriented explanation for responding to the “why” question. However, this is rarely done.

Shying away from the impacts of climatic changes has marked the archaeological literature of the last decades. Preference has been given to explanatory models that involved social changes emanating from intra- and intersociety political pressures, physical conflicts and wars, rapid population growth, and fissioning of settlements attributed to “scalar stress” (Johnson 1982) or the “Irritation Coefficient” (Rapaport 1968; cited in Bandy 2004), although New Guinean ethnography offers an alternative model (Roscoe 2009). Indeed, the main question is how did foragers and farmers minimize the risk to survival (Rosen 2007)?

In studying human responses to environmental disasters, an important source of information comes from recent international relief programs, which are forced to identify the specific interactions between populations affected by calamities such as earthquakes, droughts, or floods in their immediate environments and within given political regimes. Some reactions are common across the human spectrum, while others express the individual nature of the impaired human group. In each case, anthropologists discover that the outcome resulted from previously held beliefs, social and political organization, and historical interactions with neighboring societies (e.g., Glantz et al. 1998).

Currently, information concerning changing past climates relies on speleothems, terrestrial and marine pollen cores, and
Figure 2. Paleoclimatic changes based on Soreq Cave speleothem (after information from M. Bar-Matthews and A. Ayalon, with permission).

supporting evidence from long-distance correlations with the Greenland ice core (Greenland Ice Sheet Project 2 [GISP2]) for the following reasons. (1) Speleothems are found in many caves (whether occupied by humans or not) located in different types of environments (forest, parkland, steppe, arid). Mass spectrometers produce dates with calendar ages, and the basic isotopic information (δ18O and δ13C) traces the sources and the amounts of local precipitation (e.g., Lachniet 2009). (2) Lake and marsh pollen cores provide information concerning vegetational fluctuations in their drained basins but do not always produce precise radiocarbon dates. Correlations with marine pollen cores may refute or substantiate the terrestrial sequences. (3) Ice cores provide the most detailed information concerning climatic changes, and studies of proxies from other regions compare their results to GISP2. However, in regions farther from the Arctic, the role of local conditions increases and time correlations become more tentative and less secure, although the major trends of climatic fluctuations remain the same. (Examples of each are given below.) Taking the above comments into account, I try to demonstrate below that the conditions imposed by the YD triggered cultivation in two subregions in West and East Asia (fig. 1).

The Levantine Paleoclimatic Sequence and the Onset of Intentional Cultivation

The Levant is a region located on the edge of the eastern Mediterranean basin, geographically bordered by the Taurus Mountains on the north, the Mediterranean Sea on the west, the Syro-Arabian desert on the east, and the Sinai Desert on the south (Cauvin 2000; also see Belfer-Cohen and Goring-Morris 2011; Goring-Morris and Belfer-Cohen 2011; Vigne et al. 2011; Weiss and Zohary 2011; Zeder 2011). Its optimal habitats for exploitation are within the Mediterranean and Irano-Turanian (steppic) vegetational belts, which stretch in parallel from north to south, have variable topography, and are watered from west to east in decreasing amounts of annual precipitation. Every model of optimal foraging should take these conditions into account. Under favorable climatic conditions, the Levantine flora and fauna expand mainly to the north, along the foothills of the Taurus and the Zagros arc and beyond the Euphrates, the Balikh, the Khabur, and the Tigris rivers (an area called “Upper Mesopotamia” that bears historic connotations irrelevant to the prehistoric northern Levant).

The paleoclimatic information is derived from cave speleothems, Mediterranean marine pollen, and lake cores. The current interpretation of the terrestrial pollen cores is based on the correlations of vegetational zones within the marine cores (Rossignol-Strick 1995; van Zeist, Baruch, and Bottema 2009). Latitudinal and longitudinal shifts in several atmospheric systems dictate changing climatic patterns in this region (e.g., Enzel et al. 2008). Most of the storm tracks that transport the winter rain to the region originate in the Atlantic Ocean and cross the Mediterranean along different paths that determine their 18O content (see, e.g., Kolodny, Stein, and Machlus 2005). Subregional ecological variability is fully expressed in the Levant because precipitation, the determinant factor, decreases dramatically from west (the sea) to east (the desert) and from north (the foothills of the Taurus and mountain areas) to south (the Negev and Sinai). Thus, a paleoecological mosaic of habitats should be taken into account when sites are discussed.

The speleothems, despite disagreements concerning the precise conversion of their fluctuating δ18O and δ13C contents to the amount of annual rainfall, reflect past centennial and millennial fluctuations (e.g., Bar-Matthews and Ayalon 2003; Frumkin, Ford, and Schwarcz 2000; Vaks et al. 2003). Speleothem data from Soreq Cave, on the western flanks of the central hilly ridge, and Ma’aleh Efriam Cave, on the eastern flanks (Bar-Matthews et al. 1999; Vaks et al. 2003; fig. 2), compare well with marine and lake cores from Greece and the Aegean Sea (e.g., Rohling et al. 2002).
BP), as elsewhere, was a cold and dry period in the Levant, and its conditions are reflected in decreasing precipitation over the drainage basin of Lake Lisan, which began shrinking (Bartov et al. 2002). While this period witnessed a discernible reduction of global human populations in the higher latitudes, it affected the eastern Mediterranean less.

A rapid post-LGM rainfall increase is recorded in speleothems, marine pollen cores, and lake pollen cores in the Hula and the Ghab valleys (van Zeist, Baruch, and Bottema 2009). These sources demonstrate that the return of wetter conditions from ca. 16,500 to 14,700/14,500 cal BP facilitated a pan-Levantine distribution of foragers, bearers of the microlithic Geometric Kebaran industry in every ecological habitat from the northern Levant through the Sinai Peninsula (Goring-Morris 1995; Goring-Morris and Belfer-Cohen 2011; fig. 3). More or less at the same time, the Mushabian and Ramonian entities were competing/coexisting with the Levantine foragers (Goring-Morris and Belfer-Cohen 2011). One interpretation suggests their origins in Northeast Africa, while another proposal has them originating from local Levantine groups. It is conceivable that additional groups of hunter-gatherers were attracted by the improving ecological conditions and penetrated the eastern Levantine marginal areas through the Syro-Arabian desert and/or the Taurus foothills.

By the end of these several millennia, there were groups of mobile foragers everywhere in the Levant. Most intriguing is the question of whether a short, cold climatic episode (known in Europe as Dryas I) caused a temporary retraction of the
It is at that point in time that certain groups established the Early Natufian hamlets, although none are as yet known in the northern Levant (e.g., Bar-Yosef 2002; Bar-Yosef and Belfer-Cohen 1989; Henry 1989). This initial formation of human agglomerations, departing from the old lifeway of residential mobility by building pit houses and burying the dead on site (Belfer-Cohen 1995) and by forming sedentary or semisedentary permanent camps, is indicated by the presence of commensals such as house mice, rats, and sparrows (Tchernov 1991). Accommodating a few families or even subclans within a settlement marked territorial ownership, expressed in intrasite cemetery areas, enabling the group to achieve a sense of security and defense either by force or by symbolic acts (see Roscoe 2009 and references therein).

The success of the Natufian as a well-organized society of foragers could be related to the wetter and warmer climatic conditions of the Bølling-Allerød (ca. 14,500–13,000/12,800 cal BP). The establishment of the Early Natufian sites is what we once referred to as a “point of no return” (Bar-Yosef and Belfer-Cohen 1989; Belfer-Cohen and Bar-Yosef 2000). Their small villages and hamlets were constructed from a series of brush huts built over circular stone foundations, sometimes with wooden poles. Larger structures could have served for special uses such as rituals and were the forerunners of the Pre-Pottery Neolithic A (PPNA)—Pre-Pottery Neolithic B (PPNB) “kiva”-type subterranean buildings (e.g., house 131 in Eynan [Valla 1989]; Stordeur and Abbès 2002; Stordeur and Ibáñez 2008). The on-site burials (often of different socially explained styles; Belfer-Cohen 1995); the rich lithic, bone, and horn-core objects, including incised items; the numerous marine shells and stone beads for body decoration; animal figurines; incised slabs; and much more are among the markers of this culture. Our knowledge of Natufian economy is limited to hunted, trapped, and gathered mammals, birds, and reptiles, with evidence of fishing in some sites. It is, however, obvious from sickle blades that bear the special sheen resulting from harvesting cereals and the mortars in which cereals were processed, in addition to cup holes and rare grinding slabs, that a considerable amount of plant food was consumed. Given the wealth of literature concerning the Natufian culture and the variable social interpretations, only a few selected references are mentioned here in addition to those above (e.g., Bar-Yosef 1998, 2002; Bar-Yosef and Valla 1991 and references therein; Belfer-Cohen and Bar-Yosef 2000; Belfer-Cohen and Goring-Morris 2011; Belfer-Cohen and Hovers 2005; Byrd 2005; Cauvin 2000; Edwards 2007; Goring-Morris and Belfer-Cohen 2011; Grossman, Munro, and Belfer-Cohen 2008; Henry 1989; Munro 2004; Price and Bar-Yosef 2010; Valla 1995, 1999; Valla et al. 2007; Weinstein-Evron 2009).

Currently, the radiocarbon dates for the cultural transition from the Early to the Late Natufian indicate that it occurred before the climatic crisis of the YD, which started ca. 13,000/12,800 cal BP in the northern latitudes. The worsening conditions in the Levant probably began somewhat later, ca. 12,600/12,500 cal BP (e.g., Mayewski et al. 2004; Rohling et al. 2002; Sima, Paul, and Schultz 2004). Thus, the duration of the YD in the Levant is still unresolved, but it could have been shorter than that indicated by the ice cores and as long as that in western Europe or eastern China (Liu et al. 2008), that is, about 1,000 years.

The Ghab pollen core in the Orontes River valley demonstrates a clear decline of arboreal pollen during the YD, with a major recovery of the oak-pistachio forests during the Early Holocene (van Zeist, Baruch, and Bottema 2009; van Zeist and Bottema 1991; Yasuda 2002). The reduction in arboreal pollen is well less marked in pollen cores from Anatolian lakes located in the steppic areas or from the coast of Mount Carmel (Kadosh et al. 2004; Lev-Yadun and Weinstein-Evron 2005). Localities close to the Mediterranean Sea were generally forested, and even a reduction of ca. 30% of annual precipitation had a minimal ecological impact.

The proxy data from marine cores across the eastern Mediterranean—from the Adriatic Sea, the Aegean, and Cyprus—support the overall picture described above. The temperature cline from the Atlantic Ocean through the Mediterranean, shown by the analysis of planktonic foraminifera (Kuhlemann et al. 2008), demonstrates the general time correlations of climatic fluctuations between the two water bodies. Comparisons between the oxygen and stable carbon isotopes from cave speleothems and those from the marine cores indicate that the same sequence of climatic changes occurred in the Levant (Bar-Matthews and Ayalon 2003). Hence, in spite of probable attenuation due to local conditions, proxies from neighboring regions within the Northern Hemisphere can be employed (e.g., Enzel et al. 2008; Willcox, Buxó, and Herveux 2009). Missing from the proposed paleoclimatic interpretations are the simulated impacts of reduced precipitation on the Mediterranean forests, open parklands, and steppic environments. The overall trend was marked by diminishing yields of wild plant seeds and annual fluctuations in the production of acorns and pistachio nuts, which were intensively collected or harvested by Terminal Pleistocene foragers, as well as changes in the spatial distribution of game animals. Thus, the impact in a land “full of people” was that those who occupied the better areas probably stayed put and intensified their food acquisition. Others increased their mobility.

The Late and Final Natufian sites in the southern Levant (ca. 13,000/12,800–11,700/11,500) produced poorer remains than the Early Natufian. It probably reflects the return in many of the exploited habitats to a mobility greater than their ancestors’. Flimsy dwelling structures characterize these sites, and the dead were rarely buried with adornments, but rich lithic and bone-tool assemblages were produced (Valla et al. 2007). The Late and Final Natufians increased consumption of low-ranked resources such as bone grease, juvenile gazelles, and fast-moving small game such as hare (Munro 2004; Stiner, Munro, and Surovell 2000). Two mounds, Abu Hureyra...
(Moore, Hillman, and Legge 2000) and Tell Mureybet (Ibáñez 2008), provided the only Late Natufian archaeobotanical assemblages to be discussed below. In sum, in the face of the difficulties of the YD, the solutions triggered for risk minimization by Late Epi-Paleolithic societies were diverse and included the following:

1. Increased mobility and additional specialized adaptations to the mosaic ecology of the Levant. In the Negev and the northern Sinai, these led to the emergence of the unique Harifian culture and the invention of a typical arrowhead, the Harif Point (Goring-Morris 1991; see Belfer-Cohen and Goring-Morris 2011; Goring-Morris and Belfer-Cohen 2011).

2. Increased sedentism for security and defense from other noncultivator groups of foragers. This is demonstrated in the establishment of the village of Hallan Çemi Tepesi (11,900–10,500 cal BP) on the banks of a tributary of the Tigris River (Rosenberg and Redding 2000). No cereals were found at this site (Savad, Nesbitt, and Jones 2006), indicating that during the YD the distribution of einkorn and barley did not extend farther east from its main western habitat. Barley (Hordeum cf. spontaneum) makes its first major appearance in this region farther east (Demirköy and Qermez Dereh) only during the PPNA (after 11,700/11,500 cal BP; Savad, Nesbitt, and Jones 2006).

3. Intensified hunting and gathering and part-time cultivation. This is evident in the presence of arable weeds, reflecting increased sedentism, and it emerges in Tel Qaramel west of the Euphrates valley, Mureybet, and Jerf el-Ahmar (Willcox, Buxó, and Herveux 2009; Willcox, Fornite, and Herveux 2008). Hence, wild cereals were available only along the western wing of the Fertile Crescent, as predicted by the conditions of the YD and the plant remains from the Late Natufian at Abu Hureyra and Mureybet (Hillman et al. 2001). Exploitation of small seeds was already known from the days of Ohalo II (ca. 23,000–21,000 cal BP) and probably from earlier times as well. The decision to include the cultivation of cereals in the economy of these foragers seems to have started in the northern Levant, probably before the end of the YD (ca. 11,700/11,500 cal BP), as in Tel Qaramel (Mazurowski, Michczynska, and Padzur 2009 and references therein; Willcox, Buxó, and Herveux 2009), and the idea spread rapidly southward. It has been suggested that the first appearance of green beads among Late Natufian body decorations marked the onset of beliefs related to the practice of cultivation (Bar-Yosef Mayer and Porat 2008 and references therein). Indeed, botanical evidence indicates that within a few centuries, the climatic conditions improved and farming became successful because there were stable and sufficient amounts of winter rain (e.g., Willcox, Buxó, and Herveux 2009; Willcox, Fornite, and Herveux 2008). The ensuing millennia of the Holocene enjoyed better climatic conditions, in spite of rapid climatic changes that had variable impacts on human communities as population increased and social structure became more complex (Weninger et al. 2009).

**PPNA Communities and Early Farming**

The PPNA communities (ca. 11,700/11,500–10,700/10,500 cal BP) are considered the direct descendants of the Natufians, although we lack evidence of their contemporaries who inhabited southeast Turkey because of a paucity of research, and they invested more energy and materials than their forebears in building houses. Circular and oval stone foundations continued to be the standard shape of the domestic unit, but quarrying of clay and hand-molding of planoconvex bricks for the walls, as well as the mounting of flat roofs that required supporting posts, represent an increased investment in creating the human space (Stordeur and Willcox 2009; Watkins 2006). Private and public storage facilities were erected (Kuijt and Finlayson 2009). The villages grew up to 2.5 ha in size, with populations of at least 150–300 people practicing a mixed economy of cultivating different suites of plants, according to their local ecology, and fig trees in the Jordan Valley (Kislev, Hartmann, and Bar-Yosef 2006). Hunting the common game in the area and gathering wild plants provided a major part of the diet (Willcox, Fornite, and Herveux 2008).

Interpretations of the archaeobotanical data indicate that initiation of intentional cultivation varied. In each subregion, a different set of wild plants were cultivated and were either successful or total failures (Weiss, Kislev, and Hartmann 2006). The first experiments in cultivation could have begun during the Early Natufian, but a step forward was made during the Late Natufian (Hillman 2000; Hillman et al. 2001). Most authorities agree that during the closing centuries of the YD or the first centuries of the Holocene, bearers of the earliest PPNA tool kits, defined as the Khamian culture in the northern Levant, were the first farmers, because their carbonized plant remains contain the weeds that grow in tilled fields in addition to the cereals (Colledge 2001; Kislev, Hartmann, and Bar-Yosef 2006; Willcox, Buxó, and Herveux 2009; Willcox, Fornite, and Herveux 2008). The suite of plants grown by the first cultivators included rye (Secale cereale), einkorn (Triticum boeoticum), emmer wheat (Triticum dicoccoides), barley (Hordeum spontaneum), and oats (Avena sterilis). Several grass species, such as Aegilops and Stipa, may represent wild weeds that grew in cultivated fields or the results of gathering. Pulses such as lentils (Lens culinaris), peas (Pisum sativum), grass peas (Lathyrus), bitter vetch (Vicia ervilia), and common vetch (Vicia sativa) are well recorded, while chickpeas (Cicer arietinum) and faba beans (Vicia faba) first appeared during the PPNB (Lev-Yadun, Gopher, and Abbo 2002). Currently, the prevailing view is that systematic cultivation was carried out by several PPNA villages, including Tel Qaramel, where all the 14C dates were produced by one laboratory (Mazurowski, Michczynska, and Padzur 2009).

According to several archaeobotanists, it took some 1,000 or 2,000 years of systematic cultivation of wild cereals (Fuller 2007; Kislev 1989, 1997; Tanno and Willcox 2006) before a major portion of the plants acquired the mutation of non-shattering ears and increased their grain size. This means that...
without the continuous activities of sowing and harvesting, the domesticated plants would not have taken over in the fields. This is a process whose meaning is not fully understood by some archaeologists, for whom the terms “agriculture” and “cultivation” are interchangeable (e.g., Hodder 2007). An additional marker of intentional cultivation is the presence of typical wild weeds that grow annually in cultivated and harvested fields (Willcox, Buxó, and Herveux 2009). Therefore, the domesticated cereals that characterized the agricultural economy of PPNB villages were the result of a prolonged period of cultivation. One should refer to the historical use of terms such as “cultivation,” “domestication,” “agriculture,” and others as clearly presented by Harris (2007). If the definition of “cultivation” incorporates the entire set of activities—such as tillage, sowing, irrigation, harvesting, and storage of seeds for consumption and next year’s planting—then regardless of the genetically determined morphological traits of the plants, early cultivators were simply farmers. One may argue whether this is a fully “agricultural” subsistence system or an indication of “low-level food production” or that the definition should be retained for societies where husbandry of animals was part and parcel of annual subsistence activities (Vigne et al. 2009 and references therein). But farmers who grow tubers that are not fully domesticated are classified as “agriculturalists” and/or “horticulturalists,” because it is the practice and not the state of “domestication” of the plants that counts when the economic system is categorized.

Finally, all PPNA villages in the Levant show the same crowded clustering that a millennium later became the hallmark of several PPNB sites. Calibrated radiocarbon chronology—mostly derived from short-lived, site-by-site samples—indicates that almost every village, including those situated next to a copious spring, like Jericho, or along the river banks, as in the Euphrates valley, was abandoned within a few centuries.

Terminal Pleistocene and Early Holocene Climatic Fluctuations in China

The basic assumptions for discussing the origins of cultivation in China are the same as for the Levant, namely, that Late Pleistocene–Early Holocene climatic fluctuations in North China played a similar role as in the Levant, triggering the transition to cultivation of wild millets for the intensification of a staple food. In this argument, I follow the footsteps of others who have already suggested, either partially or fully, the relationship between the impact of the cold and dry YD conditions on the survival strategies of mobile foragers and the primacy of millet cultivation (e.g., Barton et al. 2009; Bettinger, Barton, and Morgan 2010; Bettinger et al. 2007; Lu 1999, 2006; Shelach 2000). The emergence of rice cultivation, which followed during the Early Holocene (Cohen 2011; Zhao 2010, 2011), is briefly discussed below in relation to climatic fluctuations and resources in South China.

It is important to stress that the ongoing search for the origins of millet cultivation is focused in a large area of about 500,000 km², incorporating the middle and lower Yellow River basin (Cohen 2011; Zhao 2004). The number of sites where plant remains have been carefully recovered and reported is still small, and the cultural relationships among the different subregions is debated among archaeologists (Cohen 2011). Hence, we must first consider the overall geographic features of China and the current climate and then proceed to summarize the proxies for past climatic fluctuations before delving into the particular information concerning their impact on the local hunter-gatherers.

The physiography of China (ca. 9.6 million km²) is commonly subdivided into three topographic landforms, each with its own regional variability. These are defined by elevation above sea level (a.s.l.): (1) the Tibetan Plateau, some 4,000–5,000 m a.s.l.; (2) the central mountain plateau area, ca. 1,000–2,000 m a.s.l., incorporating Inner Mongolia, the Loess Plateau, the Sichuan Basin, and the Yunnan–Guizhou Plateau; and (3) the plains and seacoast, generally below 200 m a.s.l. and crossed by numerous copious rivers. This region is strewed with hilly areas, mostly south of the Yangtze River, that can reach ca. 500 m a.s.l. (Zhao 1994).

The climate of China is characterized by the tropical and subtropical Pacific and Indian Ocean summer monsoons. The arrival of the monsoon marks the onset of the rainy season, starting in the south and advancing northward from early March to late June–July (fig. 4). Later, the rains retreat to the south, and may last from late August through September and October. During the winter, the entire landmass is dominated by Siberian–Mongolian high-pressure systems that often produce strong winds. But the winter monsoon carries some moisture from the Pacific into eastern China, and the northwest enjoys the westerlies that bring some precipitation from western Eurasia. Winter temperatures are close to or below 0°C in the north, while summer temperatures may rise to above 30°C, particularly in the south, and higher in the western deserts. Topographic variability within each of the schematically averaged levels results in a mosaic distribution of precipitation and temperature and thus of flora and fauna (Zhao 1994).

The Last Glacial in China was characterized by significant and frequent oscillations well recorded in a suite of proxies such as the Himalaya ice cores, loess sediments, pollen cores, marine cores, and cave speleothems (e.g., Cosford et al. 2008; Lin et al. 2006; Yu, Luo, and Sun 2008; Yu et al. 2000; fig. 4). Unfortunately, the distribution of caves with studied speleothems is uneven, and most are located in southeastern and central China and in Tibet, where karstic landscapes prevail (fig. 4). Hence, most of the paleoclimatic information for the western and northern regions are drawn from lake and marine pollen cores, loess sequences, and deep-sea cores in the East China Sea (e.g., Wen et al. 2010; Yi et al. 2003). The different data sets reflect the impacts of the Pacific and Indian Ocean monsoons and show some differences between the strengths of the two systems as well as the impact of the westerlies.
Figure 4. Location of Chinese caves with studied speleothems mentioned in the text.
Among the eastern sites, Hulu Cave, near Nanjing (Wang et al. 2001), produced a long paleoclimatic curve that best fits the GISP2 ice core. Other caves include Dongge (Dykoski et al. 2005), Heshang (Hu et al. 2005), Qingtian (Liu et al. 2008), Sanbao (Wang et al. 2008), Songjia (Zhou et al. 2008), and Tintin in Tibet (Sinha et al. 2005). It should be stressed that all speleothem sequences demonstrate similar trends but that not all correlate well chronologically. In addition, the transition from one climatic stage to another (e.g., from the Allerød to the YD) took 1 or 2 centuries longer than the comparable transition recorded by the Greenland ice cores (Liu et al. 2008). However, detailed discussion of these issues is beyond the scope of this paper.

LGM conditions in North China were cold and dry, and except for a few protected habitats, most of these steppic-desertic environments were desolate landscapes (Yu et al. 2000). By ca. 16,000 cal BP, climatic amelioration was witnessed in slowly rising temperatures, increasing rainfall, and a moderate return of forest habitats to the loessic areas, as judged from the evidence for the earliest Holocene (e.g., Cai et al. 2010; Ren and Beug 2002). As the monsoon system became stronger, it penetrated farther north, particularly during the Bølling-Allerød (ca. 14,500–ca. 13,000/12,800 cal BP), and facilitated the spread of foragers within this region.

Several researchers have reported information concerning the environmental conditions that facilitated the growth of human populations, producers of the microblade (microlithic) industries, before the YD (e.g., Bettinger, Barton, and Morgan 2010; Bettinger et al. 2007; Chen 2007; Madsen et al. 1998; Wünnemann et al. 2007). Most sites from this period are small and ephemeral and reflect varying degrees of mobility. Series of such occupations with microblade industries have been sampled and studied (e.g., Chen 1984, 2007; Cohen 2003; Madsen et al. 1998). Xiachuan is one of the important clusters of sites where a few radiocarbon dates indicate the presence of at least two major occupations rich in microblades (ca. 25,000 and ca. 15,000 cal BP) and a large number of grinding slabs (Lu 1999). Lu (2002) reports siliceous sheen on several flakes that resemble her experimental pieces employed in harvesting foxtail grass panicles. Another multilayer cluster of sites excavated at Shizitan, where occupational horizons were interspersed with loess accumulations several meters thick (Shizitan Archaeological Team 2002, 2010), is dated to ca. 20,000–ca. 9,000 cal BP. On the whole, microblade industries occur at several hundred sites across North China, southern Siberia, Korea, and Japan (Chen 2007; Kajiwara 2008; Kuzmin, Keates, and Shen 2007). Larger tools were often made from local raw material, such as quartz or quartzite. Grinding slabs and rubbing stones are a common component in these sites, indicating small-seed grass processing. In addition to plant resources, this vast region, dissected by the large Yellow River valley and numerous smaller ones, was frequented by several species of deer, equids, wild boar, and a few carnivores.

It seems that the penetration of the westerlies during the Bølling-Allerød increased the potential for hunter-gatherers to expand their populations into previously arid or semiarid habitats in western China. Thus, the abrupt change to the YD (e.g., Liu et al. 2008), from around 12,800/12,500 cal BP until 11,700/11,600 cal BP, was a major calamity. This natural crisis provides early testimony to the problems that North China has faced through history from fluctuations in the monsoonal system (Shen et al. 2007).

The Role of the YD in North China

Understanding the impact of the rapid climatic change of the YD on social systems is first appreciated from historical records. The absence or paucity of summer rains is not an isolated phenomenon. This can be seen in every historical review that documents droughts; droughts begin in the north, as a recent review of major droughts during the past five centuries in China indicates (Shen et al. 2007). The effects were dramatic, because anthropogenic activities had already altered the local environments. Exceptionally severe droughts occurred in AD 1586–1589 (when Taihu Lake, the third-largest freshwater lake in China, dried up), in AD 1638–1641, and in AD 1965–1966. More frequent droughts were recorded in tree rings in the Tien Shan area (Li et al. 2006). All these events were caused by a weak summer monsoon, together with the westward and northward movement of the western Pacific subtropical high.

We therefore expect a sudden increase in dryness across North China to have caused the same reactions as observed in the Levant. Unfortunately, the archaeological literature is not sufficiently detailed, and accelerator mass spectrometry (AMS) dates for localities where humans stayed during the YD are rarely available. On the other hand, we have more information concerning Early Holocene conditions, including reconstructed vegetation maps based on pollen records. These may help us speculate about what happened during the previous period (e.g., Ren and Beug 2002; Wen et al. 2010).

Hunter-gatherers retreated to more favorable habitats, including river valleys, as in Shizitan, and probably established semisedentary communities and increasingly intensified exploitation of resources arising from their reduced mobility, causing “population pressure” and increased competition for resources. Hence, during the YD and in particular during the first two millennia of the Holocene (11,500–9500 cal BP), we note the appearance of larger sites as agglomerations of families and possibly subclans reflecting the need for security and territorial defense, in view of real or imaginary enemies (Rostoker 2009). Earlier ephemeral occupations in sites such as Donghulin, Nanzhuangtou, and Zhuannian date to the YD and/or Early Holocene and are of variable sizes (Cohen 2011). These are sites of foragers who successfully survived in the region (fig. 5).

Nanzhuangtou (Hebei) contained some rare microblades, no pottery, and a rich bone and antler assemblage, including the remains of deer, dog, pig, wolf, chicken, softshell turtle,
Figure 5. Partial map of China with all the early farming sites and the locations of several of the main caves with speleothems. The list of sites is from Cohen (2011). 1, Yuchanyan; 2, Chengtoushan; 3, Pengtoushan; 4, Bashidang; 5, Xianrendong and Diaotonghuan; 6, Shangshan; 7, Kua- huqiao; 8, Xiaohuangshan; 9, Hemudu and Tianluoshan; 10, Dadiwan; 11, Shizitan; 12, Xiacuan; 13, Jiahu; 14, Peiligang; 15, Cishan; 16, Yuezhuang; 17, Xiaojingshan; 18, Houli; 19, Nanzhuangtou; 20, Yujiagou; 21, Zhuannian; 22, Xinglongwa; 23, Jiahu.
and shellfish (Cohen 2003; Underhill 1997). Only the recovery of plant remains by flotation will clarify whether the late foragers in the north were only collectors or were also part-time cultivators, growing broomcorn or foxtail millet or even both.

At the site of Donghulin, dated to ca. 10,500–9600 cal BP, the excavations and additional field research exposed a pit house, numerous stone artifacts (including microblades), pottery, grinding stones, faunal remains, and three burials, one of a woman decorated with 68 sea shells (Cohen 2011; Hao et al. 2001; Zhao et al. 2006).

In spite of a relative paucity of excavations that have provided reliable assemblages of plant remains and radiocarbon dates (some of which may represent the use of wood for building), the next phase is represented by the cultures or the cultural groups named Huoli, Cishan, and Peiligang (fig. 5; further details in Cohen 2011). The bearers of these different groups (identified by their pottery types) emerged as cultivators of millet within the middle and lower Yellow River basin (Crawford 2006, 2009; Lu et al. 2009; Zhao 2004, 2011).

It seems that they started as dryland farmers of broomcorn and foxtail millets (Zhao 2004, 2010), and they are possibly incorporated in the primary “core area” where agriculture (in terms of the set of activities as defined above) was established. The first farming communities are characterized as 1–2 ha in size with semisubterranean rounded houses; a large number of storage pits (some containing abundant millet grains); garbage pits; distinct cemetery areas; abundant pottery, stone adzes, axes, and spades; and four-legged grinding stones best known from Cishan. The architectural change to rectangular houses marks a second phase within the developing sedentary communities.

A new biomolecular study of plant remains from Cishan suggests that broomcorn millet (Panicum miliaceum) was first cultivated/domesticated by ca. 10,300–8700 cal BP (Chang 1986; Cohen 2011; Crawford 2009; Lu et al. 2009), although the earliest radiocarbon dates in this study are older than the lowermost reported layer of the village. Northward (such as to the Xinglongwa culture in Inner Mongolia) and southward to the Peiligang area, dispersals of early farming probably occurred during the second millennium of the Holocene (ca. 10,500–9500 cal BP; Cohen 2011). If this scenario is supported by new evidence, we may suggest that cultivation of wild varieties of millet possibly started during the last centuries of the YD and probably during the first millennium of the Holocene and that millet became domesticated some 1,500–2,000 years later. If such a scenario is supported by additional evidence, we may conclude that it is an interesting coincidence that the impact of the YD on populations in both North China and the northern Levant led to the onset of wild-plant cultivation (see also Shelach 2000).

Isotopic analysis of human bones from the Xiaojingshan site (ca. 8000 cal BP) suggests that millet made up only 25% of the diet of both males and females (Hu et al. 2008). Hu et al. (2008), supported by the isotope analysis from Jiahu (Hu, Ambrose, and Wang 2006), propose that only about 1,000 years later did millet become a predominant component in daily consumption. In Xinglongwa-type sites (ca. 8100–7200 cal BP), δ13C values in human bones that mark the consumption of millet (a C4 plant) reflect the presence of both species (broomcorn and foxtail), probably indicating the level of agricultural development (Barton et al. 2009). Interestingly, flotation samples from a Houli culture site—Yuezhuang (Jinan, Shandong), with one AMS date of 7900 cal BP—demonstrate the presence of 40 broomcorn seeds and one foxtail millet seed along with 26 rice seeds, indicating an unexpectedly early arrival of the latter plant in the Yellow River area (Crawford, Chen, and Wang 2006).

Animal domestication in North China is an issue raised by several authors in spite of the paucity of detailed zooarchaeological studies (Flad, Yuan, and Li 2007; Yuan and Flad 2002; Yuan, Flad, and Luo 2008). Given the relative scarcity of fish in the Yellow River (when compared with the Yangtze River) and the abundance of nondomesticated species such as deer and carnivores (including wolves), the best candidate was the wild boar. There is little doubt that pigs were the first animal to be adopted by farmers, who continued to hunt. The process, possibly similar to the one in the Levant, began with “cultural control” of individuals attracted to the garbage dumps of villages such as Cishan, at least by 8000 cal BP. By 6000 cal BP, pig meat was 60% of consumed mammal tissues (Yuan, Flad, and Luo 2008).

The two domesticated varieties of millet, P. miliaceum and Setaria italica, were identified in Xinglongwa from about 8200/8100 cal BP as well as at Dadiwan (7800–7300 cal BP) in the Laoguantai area, which is located farther west and in a higher altitude. The geographic location of both and their rectangular houses mark the later phase of the Early Neolithic (by contrast with the rounded ones that characterized the earlier phase) and indicate that they are situated within a “secondary core area.” Archaeological observations in Inner Mongolia have already led Shelach (2000) to suggest that millet cultivation must have started earlier than at the Xinglongwa site. In addition, the well-ordered rectangular-square houses oriented in the same direction, often attached or very close to one other and surrounded by a trench, hint at a social hierarchy (represented by a central house and a burial with jade earrings) that indicates further changes within farming societies. The location of the site on top of a low hill indicates that the trench was probably not to prevent water from flooding the site but rather to physically and/or symbolically deter real or imaginary enemies. Warfare among agricultural tribes is a well-known phenomenon (e.g., Keeley 1996; Roscoe 2009). If long-distance similarities are meaningful, then the arrangement of the houses at Xinglongwa resembles sites such as Asılık and Çatalhöyük in Anatolia that belong to the second phase of the Neolithic Revolution in the Levant, and cultivation had already been practiced in this region for some 2,000 years.
The Role of Paleoclimate in South China

South China stretches from south of the Qinling Mountains and the Huai River to the south and southeast coast, and although it enjoyed somewhat better climatic conditions than the North, several fluctuations are clearly recorded in cave speleothems and in the South China Sea. Not surprisingly, these are correlated with Timta Cave in Tibet. However, the origins of rice cultivation and domestication, currently debated among scholars (e.g., Fuller, Harvey, and Qin 2007; Liu et al. 2007; Zhao 2011), are sought in three geographic basins south of the Yangtze River, namely, the Lake Dongting area (Hunan), the Lake Poyang area (Jiangxi), and the lower Yangtze River. It should also be remembered that the sea rise during the post-LGM reduced the coastal belt by at least 250 km. Hence, the region we briefly examine is about 400,000–500,000 km².

The Late Upper Paleolithic sites in South China (ca. 23,000/20,000–11,500 cal BP) preserved the old tradition of cobble tools such as choppers; cores and flakes; small cup holes on cobbles; perforated cobbles; and bone, antler, and shell tools. This region produced the earliest evidence for pottery making, which dates to ca. 18,000–17,000 cal BP in Yuchanyan Cave (Boaretto et al. 2009) and probably to an earlier time in Xianrendong and Diaotonghuan (MacNeish et al. 1998); the pottery may have been used to make special liquids, to cook bones for grease extraction, or for storage and undoubtedly had special social meaning (Pearson 2005). Rice phytoliths found in these Terminal Pleistocene cave deposits are now considered evidence of gathering or of first experiments in cultivation (Zhao 2010).

Open-air sites of Late Pleistocene foragers that may represent early rice exploitation within the basin of the Yangtze River and its small tributary valleys are rare and mostly buried under the rapid Holocene alluviation. Therefore, caves are regarded as the main sources of information. The most cited are Yuchanyan Cave (Hunan), Xianrendong and Diaotonghuan (Jiangxi), and Miaoyan (Guangxi).

The recently studied deposits of Yuchanyan Cave (Boaretto et al. 2009; Prendergast, Yuan, and Bar-Yosef 2009; Yuan 2002) represent many events of building fires with wood during the early Bølling-Allerød period. Rice phytoliths identified in the first round of research (Zhang 2002) probably reflect gathering in the natural wetlands during fall. Most revealing are the animal bones, frequently of several deer species, with a few macaque, hare, small carnivores, and large rodents, particularly bamboo rat (Prendergast, Yuan, and Bar-Yosef 2009; Yuan 2002). Identified birds such as heron, tern, crane, goose, and others winter in the area, while the ducks were all wetland taxa. Fish included carp and catfish. In sum, it seems that the young age of the deer and the presence of wintering wetland birds (whose breeding grounds are in North China, Mongolia, or Siberia) indicate that Yuchanyan Cave was ephemeral occupied by a small group mainly during early fall and winter and possibly early spring.

A somewhat similar picture emerges from the reports on Xianrendong and Diaotonghuan (MacNeish et al. 1998). The caves were abandoned by the end of the Bølling-Allerød and the early YD (i.e., 13,700–12,300 cal BP), and thus direct cultural connection with the early villages of the Middle Yangtze basin is unknown. Early Holocene conditions were improved, with more stable monsoon systems that allowed foragers to carry on their gathering and hunting activities for several millennia (Cohen 2011; Zhao 2011). However, the impetus for the onset of cultivation of wild rice is unclear, and we should regard as among the potential triggers the social connections through the river network with the north, where millet was already grown. An additional option is the local “demographic pressure,” which can hardly be imagined in an area rich in plant and animal resources, and some social mechanism related to competition with other foragers. In spite of the huge areas discussed, long-distance connections in the Chinese landmass were enormously facilitated by river transport. Simple craft could be made from a bunch of bamboo tied together, and the early making of canoes is evidenced in Kuahuqiao.

Rice exploitation predates the available evidence of phytoliths and carbonized plant remains obtained in Xianrendong Cave (Jiangxi: Zhao 1998), Bashidang (Hunan, ca. 8150–7600 cal BP: Zhang 2002; H. Gu, personal communication, 2008), Kuahuqiao (ca. 7900–7300 cal BP) in the Lower Yangtze basin (Zheng, Sun, and Chen 2007; Zong et al. 2007), and Tianluoshan (by 6600/6400 cal BP; Fuller et al. 2009). Although the plant evidence is missing, quite possibly the subsistence system of Pengtoushan (Hunan, ca. 9300–8300 cal BP), an early village in the Dongting area, was partially based on rice gathering and perhaps cultivation. By ca. 8000–7000 cal BP, at least half of the rice recorded in Kuahuqiao was already of the domesticated variety (Zheng, Sun, and Chen 2007). The presence of rice in Jiahu and Yuezhuang in the Yellow River basin may indicate that there were long-distance interactions by ca. 8000 cal BP (Zhang and Wang 1998). While the overall impression may be of the simultaneous emergence of two farming systems, I believe that detailed scrutiny of the available calibrated radiocarbon dates may still raise the interpretation that the middle and lower Yangtze River basin could have been a “secondary core area” influenced by the Yellow River “primary core area” (Zhang and Hung 2008; Zhao 2010, 2011).

Concluding Remarks

When viewed from the perspective of a longue durée, subsistence strategies adopted by foragers during the Terminal Pleistocene in western and eastern Asia have much in common. In a land “full of people,” the winning option was to stay put and intensify the exploitation of plant resources—this meant starting to cultivate in suitable ecological niches. The strategy worked best within the natural habitats of the cereals in the Levant and North China. None of the early farmers aban-
doned the gathering of wild plants, hunting, trapping, fishing, or, particularly in China, collecting land snails, freshwater mollusks, and water plants. The evidence from the Japanese archipelago indicates that the mixed strategy of low-level food production with broad-spectrum exploitation of the surrounding natural environment also characterized the Jomon people (Crawford 2008). We may label these foragers as “incipient farmers” or “affluent foragers” who practiced cultivation, and we should be fully aware of their entire gamut of subsistence resources. In the Levant and North and South China, “incipient cultivation” resulted in the domestication of the harvested species and the stable, steady provisioning of staple foods under favorable climatic conditions; this led to the rapid increase of local populations and the development of full-fledged farming and herding economies.

Over the first four millennia of the Holocene (ca. 11,700/11,500–8200 cal BP), the process of annual cultivation in the Levant ended in the domestication of several species of cereals as well as a suite of other plants (e.g., legumes, flax). Corralling of selected animals (goat, sheep, cattle, and pig) caused their domestication, and together with the plants, these species provided the foundations of the agropastoral societies of later periods. The rapid population growth in Southwest Asia resulted is what is known as the “Neolithic demographic transition” (e.g., Bocquet-Appel 2011; Bocquet-Appel and Bar-Yosef 2008 and references therein). The same phenomenon is observed across other regions during the Holocene, and it makes clear that farming was a winning economic strategy and that its consequences were disastrous to hunting-and-gathering groups.

In light of the Late Pleistocene paleoclimatic and archaeological information from North and South China, it seems that the middle and lower Yellow River basin was prone to droughts much more frequently than South China, and given the reconstructed demography of mobile hunter-gatherers in this region, we should expect that the establishment of millet cultivation preceded the earliest rice cultivation by a millennium or two. There is clear evidence for the attenuated impact of the YD in South China on the local vegetation. However, Holocene conditions ranged from subtropical to tropical, with high frequencies of rainfall brought by the monsoons, and therefore the impact of the YD is not easily detectable. In both regions, there was probably a long time between the cultivation of the wild progenitors and the establishment of domesticated, nonshattering varieties as the dominant plants in the fields (e.g., Crawford, Chen, and Wang 2006; Fuller, Harvey, and Qin 2007; Fuller et al. 2009; Lee et al. 2007; Liu et al. 2007; Lu 1999, 2006; Zhao 2011; Zheng, Sun, and Chen 2007).

Attributing the incipient cereal and millet cultivation to the impacts of the YD is theoretically couched in several behavioral options that hunter-gatherers had when trying to minimize risks to their survival and create economic buffer conditions. The decision to start cultivation as a planned food-acquisition strategy had its own consequences, as much as the decision to settle down. Other options were available, and the final choice was made within the social arena. The viable option to move to other people’s territories in China could have taken place in a vast region were waterways were the prehistoric highways. Facing intergroup conflicts and minimizing mobility was a Levantine solution that would be favored where walking was the common means of crossing the landscape.

Thus, the processes in both China and the Levant were reasonably similar, and sedentism was the common group strategy. The building of domestic dwellings followed the same pattern, starting with round pit houses and shifting gradually to square and rectangular ground plans. Materials varied. In China, wood and bricks became the standard building materials, while in the Levant, undressed and dressed stones played a major role, joined by bricks. Earlier small-scale farming was additionally supplemented by gathering and hunting, a strategy that lasted longer in South China than in either North China or the Levant. While rapid climatic change served as a trigger during the closing centuries of the YD, such changes continue to punctuate the Holocene sequences of both regions, a subject beyond the scope of this paper (e.g., Berger and Guilaine 2009; Chen et al. 2008; Weninger et al. 2009).

Acknowledgments

This paper is based on several of my previous writings from the past decade concerning the impact of climatic changes in Levantine prehistory. I have added to the current version information gathered recently from Chinese Quaternary studies. I am grateful to Anna Belfer-Cohen, Nigel Goring-Morris, and Leore Grosman (Institute of Archaeology, Hebrew University) for numerous discussions in the past. Thanks to M. Bar-Matthews and A. Ayalon (Geological Survey of Israel, Jerusalem) for the information in figure 2. I thank David Cohen (Boston University) for discussions concerning Chinese archaeological issues. Thanks to David Meiggs (University of Wisconsin) for his copyediting skills. I am, however, solely responsible for any shortcomings of this paper.

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Neolithization Processes in the Levant
The Outer Envelope

by A. Nigel Goring-Morris and Anna Belfer-Cohen

The Near East is one of those unique places where the transition(s) from hunter-gatherers to farmers occurred locally, so it is possible to observe the whole sequence of these processes within the region as a whole. We discuss the archaeological evidence pertaining to those transformations within the Levant, presenting the particularistic local changes in settlement patterns and the character of the different communities juxtaposed with the landscapes and environmental background. The asynchronous developments clearly reflect the mosaic nature of the Levant in terms of specific local environmental conditions that influenced the scope and pace of Neolithization processes.

Introduction

The Levant is a distinct and limited area of the Near East characterized by its unique geographic location and the presence of a mosaic of different phytogeographic zones. There are few if any regions in the world where precipitation and vegetation zones vary so markedly over such small distances (Goring-Morris, Hovers, and Belfer-Cohen 2009 and references therein). It was against this unusual backdrop that the momentous changes from small groups of mobile foragers to large settled agricultural communities first occurred. These conditions need to be taken into account when considering Neolithization processes as a whole. Thus, in order to present as coherent a picture as possible, we here discuss and expand on the external issues pertinent to such developments. Belfer-Cohen and Goring-Morris (2011) explore the internal facets of these phenomena.

The region is also one in which relatively intensive field and laboratory research has been conducted, albeit still with significant “blank areas.” It is fascinating to observe the changes in the scientific approaches to Neolithization. These comprise early simplistic paradigms tracing the inevitable unidirectional “progress” (in a Marxist sense) from hunting-gathering to agricultural practices by means of a specific trigger such as climate change (e.g., Childe 1934). At the other end of the spectrum are complex multifactor approaches embracing demographic and social dynamics as well as quantitative and simulation studies (to name but a few, see, e.g., Bar-Yosef and Belfer-Cohen 1989; Bellwood 2005; Binford 1968; Boserup 1981; Cauvin 2000; Flannery 1969; Grosman 2004; Hayden 1990; Redman 1978; Rindos 1984; Verhoeven 2004; Watkins 2005). Yet many models suffer from a disregard of the basics, namely, that we are dealing with real people in real places and in real time. It is important to stress that developments appear to have been directional only in retrospect. The processes that took place were multifaceted, with various options available at the time; some of the choices, ultimately, were significant to future developments, but others were “sideshow” or culs-de-sac in the evolutionary sense. Accordingly, within the archaeological record, we may stumble on evidence for both categories.

As we move through the chronological sequence, increasingly detailed information is available; of course, the question arises as to whether this evidence was present earlier and simply hidden by the foggy curtain of time. We are able to identify and isolate more archaeological entities—using traditional archaeological criteria—during the earlier Epipaleolithic than previously during the Upper Paleolithic. Yet even if the archaeological cultures differed in specific settlement patterns and cultural markers, the general nature of each such entity was quite similar. This similarity most likely relates to the obvious fact that all these groups were mobile hunter-gatherers exploiting their environments by similar means and in similar modes (Bar-Yosef 1981; Byrd 1990; Goring-Morris 1995; Henry 1989). Resources during the Late Glacial Maximum (LGM) varied from one region to another, reflecting local patchiness in availability and sometimes seasonality. Diachronic changes did occur, but, in general, the overall picture remained broadly stable. Within this frame of reference, gradual demographic increase during the Early and climatically ameliorated Middle Epipaleolithic would have led to locally increased packing in some areas following previous long-lived...
Table 1. Chronology of cultural entities in the southern Levant based on available radiometric date ranges

<table>
<thead>
<tr>
<th>Dates BP Cal</th>
<th>Time stratigraphic units</th>
<th>Mediterranean zone</th>
<th>Steppe and desert zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>24,000–21,750</td>
<td>Early Epipaleolithic</td>
<td>Masraqa (Late Ahmarian)</td>
<td>Nebekian</td>
</tr>
<tr>
<td>24,200–19,250</td>
<td>Masraqa (Late Ahmarian)</td>
<td>Kebaran</td>
<td>Kebaran</td>
</tr>
<tr>
<td>21,250–17,575</td>
<td>Kebaran</td>
<td>Nizzanan</td>
<td>Nizzanan</td>
</tr>
<tr>
<td>18,000–16,250</td>
<td>Middle Epipaleolithic</td>
<td>Geometric Kebaran</td>
<td>Geometric Kebaran</td>
</tr>
<tr>
<td>17,000–15,500</td>
<td>Classic Mushabian</td>
<td>Early Ramonian</td>
<td></td>
</tr>
<tr>
<td>16,850–14,400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14,900–13,700</td>
<td>Late Epipaleolithic</td>
<td>Early Natufian</td>
<td>Terminal Ramonian Early Natufian</td>
</tr>
<tr>
<td>13,500–12,750</td>
<td>Late Natufian</td>
<td>Late Natufian</td>
<td></td>
</tr>
<tr>
<td>12,500–11,750</td>
<td>Final Natufian</td>
<td>Harifian</td>
<td></td>
</tr>
<tr>
<td>12,175–11,800</td>
<td>Early Neolithic PPNA</td>
<td>Khamian</td>
<td>(Final Harifian)</td>
</tr>
<tr>
<td>11,625–11,000</td>
<td>Sultanian</td>
<td>Early PPNB</td>
<td>Early PPNB</td>
</tr>
<tr>
<td>10,950–10,300</td>
<td>Early Neolithic PPNB</td>
<td>Middle PPNB</td>
<td>Middle PPNB</td>
</tr>
<tr>
<td>10,150–9725</td>
<td>Late PPNB</td>
<td>Late PPNB</td>
<td></td>
</tr>
<tr>
<td>9400–8900</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>9050–8450</td>
<td>Final PPNB (PPNC)</td>
<td>Final PPNB (PPNC)</td>
<td></td>
</tr>
<tr>
<td>8400–7700</td>
<td>Late Neolithic PNA</td>
<td>Yarmukian</td>
<td>Tuwailan</td>
</tr>
<tr>
<td>7750–7450</td>
<td>Jericho IX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7500–6500</td>
<td>Late Neolithic PN B</td>
<td>Wadi Raba</td>
<td>Qatifian Timnian</td>
</tr>
</tbody>
</table>

Note. There are slight discrepancies between this table and table 1 in Belfer-Cohen and Goring-Morris (2011). PNA = Pottery Neolithic A; PNB = Pottery Neolithic B; PPNA = Pre-Pottery Neolithic A; PPNB = Pre-Pottery Neolithic B; PPNC = Pre-Pottery Neolithic C.

Upper Paleolithic patterns (Goring-Morris, Hovers, and Belfer-Cohen 2009).

While, superficially, the observed changes during the earlier Epipaleolithic appear to have been incremental, gradually speeding up so that the pace of change eventually became logarithmic, common sense suggests that changes may more likely have been quite random, isolated, and independent. Obviously, we are limited by the very nature of the archaeological record. The changes would have involved technological innovations, differential social interactions, and responses to extraneous factors. Ultimately, it is the specific articulations of these various factors, internal (intra- and intergroup) and/or external (climate, carrying capacities, etc.) that are particularly relevant in terms of the nature and tempo of cultural change. This is one of the pitfalls of simulation studies, because they are based on consideration of long stretches of time and averaging out the data available. Actually, there are indications that at least at certain points in time, the course of events is more apt to be described in the mode of “punctuated equilibrium,” with periods of stasis interspersed by bursts of activity (and see below for specific examples). This pattern is reported from various parts of the world in the articles in this issue.

Another caveat concerns the very nature of the archaeological data as well as research paradigms that influence interpretations. The “rule of thumb” is that what is observed archaeologically more often than not reflects the end of the process (from invention to innovation to its wide acceptance), “solid” enough to be observed.

Considering all of the above, it transpires that the origins and incipient processes of Neolithization in the Near East should be traced all the way back to the local Late Upper Paleolithic/Early Epipaleolithic. This corresponds to a chronological span of some 15,000 years (after calibration) until the end of the Neolithic, that is, the equivalent of some 500–600 generations (table 1).

The Geographic Setting

It is vital to define the geographic boundaries in which these processes occurred. The “Near (or Middle) East” is an ambiguous term that covers Southwest Asia between the Mediterranean and Iran. The region (Western Asia) encompasses Anatolia, the Levant, Cyprus, Mesopotamia, and Transcaucasia. Here our primary focus of study is the Levant, its most distinctive feature being its ecological diversity. In addition, where pertinent, we relate briefly to adjacent regions (e.g., Cyprus and central Anatolia). The Levant is a small region enclosed between the Taurus and Zagros mountains to the north, the Mediterranean coastline to the west, the Sinai Peninsula to the south, and the Syro-Arabian desert to the east, ca. 1,000 km north to south by up to 400 km east to west (fig. 1). The topography of the Levant is characterized by a north-south longitudinal series of alternating elevated and low-lying regions: the coastal plain and western piedmont; the central hill range reaching up to 2,000 m a.s.l.; the Dead Sea Rift lying below sea level; and the Trans-Jordanian/Syrian plateau (the central-south Levant), which rises steeply to elevations between 800 and 2,000 m a.s.l., followed by a gradual descent eastward into Saudi Arabia. Today there are relatively
few perennial rivers or streams in the region, the most notable being the Tigris and the Euphrates in the north and the Orontes and the Jordan farther south along the rift valley. Almost all other drainages are seasonal and ephemeral. Changes in evapotranspiration rates were major factors in the presence and extent of Late Quaternary inland water bodies. Springs are common in the Mediterranean zone but are widely dispersed in more arid areas. Obviously, the specifics would have changed at various times, depending on the particular climatic conditions. It is important to stress that within the Levant, as indeed elsewhere, global climatic changes would have differentially affected environments at the micro- and macro-regional levels. This is especially valid in comparisons between the southern and northern Levant. For example, Terminal Pleistocene/Early Holocene geomorphological changes appear to have acted differently in the north and the south, with more extensive aggradation in the north that may have caused the burial of sites there (e.g., Ozdoğan 1997).

In this article, we use the term “southern Levant” to differentiate between the area south of an east-west line from the coast across to the Damascus Basin, as opposed to the “northern Levant,” stretching from that line north to the Taurus and the western end of the Zagros Mountains, including the Middle Euphrates and the Upper Tigris region.
(sometimes called the “Golden Triangle”). Physical and cultural interactions are documented between the south and the north during the relevant periods; developments were not always synchronous, and centers of innovation appear to have shifted from the south to the north (but see Watkins 2008, concerning the so-called primacy of the southern Levant). Whereas in the past this geographic shift of the hub of Neolithization appeared to reflect more the history of research, it is less so the case today, notwithstanding ongoing lacunae in field investigations in certain areas.

The Paleoenvironmental Background

In order to begin to comprehend developments in human adaptations, it is vital to know the physical circumstances of the landscapes that populations occupied. This is especially applicable for areas such as the Levant, which comprises a particularistic mosaic in terms of environment and ecology. Such conditions would dictate fine-tuned adaptation by local populations to specific and frequently seasonal niches. Studies have demonstrated that climatic changes during the Terminal Pleistocene and Early Holocene fluctuated markedly, and rapidly and were often of an intensity hardly encountered during much of the Quaternary. We have in mind the time span from the LGM through the Bölling/Allerød, the Younger Dryas, and then to the Preboreal and the end of the Early Holocene Optimum (e.g., Bar-Matthews and Ayalon 2003; Byrd 2005; Enzel et al. 2008; Robinson et al. 2006; Wick, Lemcke, and Sturm 2003 and references therein). Particularly relevant for human populations would have been short-term annual or decadal climatic events, which are frequently lost in paleoclimatic reconstructions that tend to average out data over longer periods (Grosman and Belfer-Cohen 2002). These climatic shifts influenced vegetation and faunal distributions and densities throughout the region. The most marked influences, for better or worse, would have been at the interfaces/ectotones between the more mesic Mediterranean regions and the semi-arid peripheries. In terms of human adaptations, these changes would have resulted in “push-pull” or “concertina” effects, alternately bringing about retreats into refugia or enabling dispersals into newly opened-up areas. Reconstructions of specific human adaptations and subsistence should take those dynamics into consideration. Additionally, late Quaternary physical changes to the landscape were more marked in some areas (e.g., lower sea level at the height of the LGM and its subsequent rise) as well as the extent of lakes—the Dead Sea Basin and inland shallow lakes farther to the east (e.g., the Azraq, Damascus, el-Kowm, and el-Jafr basins).

Epipaleolithic Settlement Patterns

In addressing the issues of the Early and Middle Epipaleolithic (ca. 23–15,000 cal BP), consideration of the scale of social networks is crucial. Here the “magic” numbers of ca. 25 individuals for many mobile-band societies and 250–500 individuals for minimal sustainable mating networks should be emphasized (e.g., Johnson 1982; Kosse 1994; Wobst 1976). Site numbers, site sizes, and their relative durations through most of the Upper Paleolithic indicate that demographic increases were slow and incremental. Relative population densities began to grow starting with the Early Epipaleolithic; this rise in density was initially somewhat artificial, inflated by local environmental deterioration with the onset of the LGM that brought about declining carrying capacities in more marginal areas. Accordingly, populations congregated in refugia, so relative packing was greater within smaller areas while other areas were, to all intents and purposes, abandoned. In regions such as the eastern Trans-Jordanian steppes, groups could congregate seasonally in winter/spring because of the presence of large herds of the seasonally migratory subspecies of gazelle Gazella subgutturosa subgutturosa (Martin 1994, 2000; Muhesen and Wada 1995 and references therein). Later, during the Middle Epipaleolithic, significant climatic amelioration relaxed previous physical and ecological constraints, providing more and different stimuli to both local and overall population increases (see Grosman 2004 for additional references; fig. 2).

It is important to stress that, indeed, general trends varied from one geographical region to another throughout the Levant, as reflected by the numbers of sites documented. We also need to take into account the sizes and the duration of sites in attempting to reconstruct actual demographic increases. There are likely to have been major jumps in relative population densities within communities that we believe correlate with a combination of increasing sedentism (likely to induce shorter birth spacing) on the one hand and technological innovations (enabling more efficient exploitation of the environment) on the other. Clearly, these tendencies are apparent within the southern Levant from the Late Epipaleolithic Natufian onward.

With regard to developments in the northern Levant and adjacent areas, we remain in the dark for much of the Epipaleolithic (until the very end of that period). The few known sites are located in or at the margins of the mountainous zones, perhaps reflecting the geomorphological burial of sites in this region (and see above). Most of these sites were excavated 50 or more years ago, when stratigraphical control and excavation techniques were much less rigorous than today. Whether the apparent absence of pre-Pre-Pottery Neolithic A sites in more open environments reflects reality or the relative lack of systematic archaeological exploration and pedestrian survey remains unresolved.

Setting the Stage: The Natufian

The Late Epipaleolithic Natufian complex lasted for some 3,000 years (ca. 100–125 generations), with the Negev/Sinai local variant of the Final Natufian, the Harifian (Goring-Morris 1991), lasting a mere 750 years (<25–30 generations; Stutz 2004). It is crucial to differentiate between the various chro-
nological phases within the Natufian while also acknowledg-
ing the high degree of variability in specific Natufian adap-
tations at the regional level (Bar-Yosef 2002; Goring-Morris
and Belfer-Cohen 1997; Valla 1999). In general, during the
Late Epipaleolithic, a greater degree of differentiation between
archaeological entities/cultures can be identified, as some
groups became increasingly sedentary, incorporating tech-
nological developments on various levels (including those
connected with food procurement and processing). This led
to the beginnings of the dichotomy between “the desert and
the sown”; thus, human groups with different economic
modes of existence interacted differently with their environ-
ments.

When discussing the subsistence mode of the Natufian, we
have to acknowledge the ranges of specific Natufian adap-
tations. While some groups were more or less sedentary in
favorable ecological settings (e.g., on the shores of lakes or
marshes), others likely practiced seasonal residential mobility,
and still others on the margins were even more mobile. In-
deed, the Natufian is not just about the sedentary logistic
collectors of the Mediterranean zone versus their (“poorer”)
foraging cousins in the periphery, because there are also in-
termediate situations and interactions. Accordingly, the geo-
graphic scale of individual territorial ranges would have varied
significantly, and a greater degree of packing of populations
would have occurred within those areas settled by more sed-
entary communities.

Natufian subsistence modes were based primarily on the
intensification of hunting and gathering and associated pro-
cessing techniques. This is reflected in the exploitation of a
particularly wide spectrum of faunal species coupled with the
intense targeting of their preferred prey, the gazelle (see
Munro 2004 and references therein). Although botanical re-
 mains are rarely preserved, the large numbers of groundstone
utensils, especially mortars and pounding tools, clearly reflect
more intensive plant-food preparation than previously (Bel-
increasing mobility later on, during the Final Natufian, would appear to result from external factors, especially the deleterious effects of the rapid onset of the Younger Dryas (Grosman and Belfer-Cohen 2002). Indeed, this is reflected most obviously in more marginal regions, such as the Negev and Sinai, with the finely tuned and short-lived Harifian entity. At the end of the day, conditions in these peripheral settings deteriorated beyond a critical threshold, and continued occupation of the area simply became untenable. There may have been no choice but to abandon the region and retreat to join communities elsewhere—whether in adjacent areas, in which the Final Natufians themselves were experiencing precarious conditions, or even farther afield.

In the northern Levant, broadly contemporary with the Late Natufian, a series of occupations have been described around the edges of the piedmont zone. This “Round-House Horizon” continues in time through the equivalent of the southern Pre-Pottery Neolithic A (PPNA; Peasnell 2000). Adoptions in the north were based primarily on hunting and gathering of nuts and fruits. There have also been claims for some degree of management of wild boar (Redding and Rosenberg 1998; Vigne et al. 2011). While there have been claims for the initial occupation of Cyprus during the Late Epipaleolithic, the available evidence for pre-Pre-Pottery Neolithic occupation of the island to date remains equivocal and open to debate (Ammerman et al. 2006, 2007; Simmons 2001, 2007 and references therein).

Archaic Villages of the PPNA

The PPNA is a short-lived phenomenon with regard to both what preceded it and what succeeded it—a mere 1,000 calendrical years (or ~40 generations). However, the scale of change for the PPNA in the southern Levant is of a lesser order of magnitude compared with the northern Levant, where there was a rapid increase in population and in the accompanying elements of social organization. The arid margins throughout the Levant were all but deserted during the course of the PPNA and were recolonized only during the Pre-Pottery Neolithic B (PPNB).

The southern PPNA displays numerous elements of continuity from the Natufian. It likely represents the amalgamation of Final Natufian populations in locally favorable settings. This includes the Harifian, which represents Final Natufian refugees from the arid margins retreating into the Mediterranean zone because of the cumulative effects of the dire events associated with the Younger Dryas (Goring-Morris 1991). During the PPNA, conditions improved but appear to have been marked by torrential episodes (e.g., at Netiv Hagdud and perhaps also at Jericho; Bar-Yosef 1986; Bar-Yosef, Goring-Morris, and Gopher 2010).

Major PPNA sites in the southern Levant display a propensity for lowland settings in a north-south alignment, especially along the edges of the rift valley (and also along the eastern edge of the coastal plain). Smaller seasonal exploitation sites are found in a gradient up the neighboring slopes.
to the west and to the east. A few sites, such as Jericho and Netiv Hagdud, are of a different order of magnitude, each encompassing areas of 1.6–2.0 ha, which may have housed up to a couple of hundred inhabitants. The scale of individually spaced oval semisubterranean residential units is indicative of nuclear family residences and reflected by the presence of grinding and pounding installations within each domestic unit (Rosenberg 2008; Wright 2000). Well-constructed external silos are found, although storage was probably also in baskets suspended from beams (e.g., Gilgal and Netiv Hagdud; Bar-Yosef and Gopher 1997; Bar-Yosef, Goring-Morris, and Gopher 2010). At Dhra, a raised silo is documented (Kuijt and Finlayson 2009), and at Jericho, what have been interpreted as larger “plastered” silos around the tower may indicate some form of community storage (Kenyon 1981).

Communal structures are few, with the exception of the enigmatic tower and wall at Jericho. Numerous interpretations have been proposed for their functions, ranging from the mundane (defenses against potential enemies or flooding) to the cultic (a ritual precinct and/or astronomical device; Barkai and Liran 2008; Bar-Yosef 1986; Crowfoot-Payne 1976; Naveh 2003; Ronen and Adler 2001).

Were these farming communities? While they probably practiced small-scale cultivation on the alluvial fans on which the settlements were located, the plant remains recovered were not always of species that were soon to be domesticated locally (e.g., oats *Avena sterilis* at Gilgal and Netiv Hagdud; Kislev 1997; Weiss, Kislev, and Hartmann 2006). There is some debate as to whether populations of medium-sized ungulates had already been depleted during the Natufian (Cope 1991 and Davis 1983, 1987 vs. Bar-Oz 2004 and Sapir-Hen et al. 2009), but there certainly appears to have been an increasing focus on smaller species, including birds (Horwitz et al. 2010; Tchernov 1994). The presence of silos may provide indirect evidence for surplus, which could have contributed to expanding exchange networks of foodstuffs. In addition, some sites appear to have served as nodes for procurement and exchange networks of valued materials (e.g., obsidian, malachite, salt, bitumen, seashells, etc.), which may have influenced their location and size. This may explain the otherwise anomalous location of the site of Wadi Faynan 16 in a marginal ecological setting at the edge of the rift valley (Finlayson and Mithen 2007) yet adjacent to abundant sources of malachite.

Coevally, in the northern Levant there was a verifiable population explosion. This trend can already be detected along the Upper Tigris (the “Round-House Horizon”) toward the end of the local equivalent of the Late Natufian before the onset of the Younger Dryas (Peasnall 2000). Farther west, a linear riparian settlement pattern of communities developed at intervals of 20–25 km along the Euphrates and its tributaries. The settlement at Jerf el-Ahmar was initially very small but rapidly increased in size (D. Stordeur, personal communication). Recently, PPNA sites have also been reported from the area between the Middle Euphrates and the coast (Abbès 2008; Mazurowski and Jamous 2001).

The northern intrasite pattern is one of dispersed small household units together with associated semisubterranean communal structures at sites such as Jerf el-Ahmar and Tell ‘Abr 3 (Stordeur 2007; Stordeur et al. 2001). The economy was presumably based on floodplain cultivation, but there is little if any solid evidence for domesticates until the end of the PPNA (Wilcoxon 2005). Similarly, there is no unequivocal confirmation for animal domestication (for an overview see Zeder 2009, 2011). Hunting often appears to have focused on herd species such as *Gazella subgutturosa subgutturosa* and *Equus hemionus*, although in some sites wild boar *Sus scrofa* is also common and may have been managed and/or culled (e.g., Vigne 2008; Vigne et al. 2011).

These developments would have necessitated changes in the scale of mating networks, which can be tied in with the foundation of various ritual-cum-aggregation sites in watershed locations (e.g., the PPNA–B hilltop ritual site of Göbekli Tepe; Schmidt 2005, 2007 and references therein). Clearly, the nature of the relationships between the various sites, as well as between the northern and southern Levant and other areas, underwent transformation. Exchange networks were widespread, as exemplified by the systematic acquisition and use of Cappadocian and Bingöl obsidian, although no PPNA sites are presently documented near those sources (Delerue 2007). Here, it is interesting to note the similarity of the “southern” Harifian projectile points to the “northern” Nemrik projectile points; are we facing the beginnings of what will be the hallmark of “convergence” (i.e., the development of a PPNA koine—a regional interaction sphere sharing focal cultural characteristics—preceding the better-known PPNB one) and/or actual population movements? While the issue of the systematic colonization of Cyprus during the Late Epipaleolithic is open to some debate, it was clearly well under way during the PPNA (McCartney et al. 2007). Various lines of material evidence indicate that the origin of the colonists was probably from the north Levantine littoral to the Cilician plain. This likely reflects major demographic increases in that region.

The demise of the PPNA in the southern Levant displays little evidence for in situ continuity; most sites were abandoned, whether from overexploitation, declining yields, climate shifts, changing geomorphology, shrinking water sources, or other causes. One should also add the possibility of contagious diseases causing havoc at the local level, because the geographical scale of local interactions was still quite limited. By contrast, in the north there is unequivocal evidence for direct continuity from the PPNA to the PPNB, which commonly (but not always) took place on-site (e.g., Muryeb; Ibáñez 2008).

**PPNB Village Society**

With the emergence of PPNB village societies, the center of innovation had already shifted to the northern Levant. In the
southern Levant, the shift from PPNA to PPNB was quite abrupt, with the Early PPNB representing but a short bridging episode. So it is only with the Middle PPNB that we find the emergence of the full-scale PPNB koine that developed through the Late and Final PPNB. The koine stretched across the entire Levant and beyond, even incorporating central Anatolia and Cyprus (Bar-Yosef and Belfer-Cohen 1989; Cauvin 2000; Esin and Harmankaya 1999; Hodder 2007; Özdoğan 2011; Simmons 2007). It is important to note that this interaction sphere encompassed a wide spectrum of specific and varied adaptations. These included large-scale permanent villages based on farming and herding or hunting and farming and fishing, as well as mobile foraging groups and, toward the end of the period, pastoral societies (fig. 3). Because of the nature of local geographic zoning, these adaptations were all in close proximity to one another. The PPNB coincides with the Early Holocene Climatic Optimum (Byrd 2005), a time of plenty as conditions improved from one year to the next.

The southern Levant settlements were initially founded in a narrow corridor along a north-south axis on the western edge of the Trans-Jordanian Plateau (and to some extent the Jordan Valley) from Aswad to southern Edom along the later “King’s Highway” adjacent to major wadi systems. These sites subsequently expanded to become the Late and Final PPNB “megasites,” reaching up to 30 acres in extent (Bienert, Gebel, and Neef 2004 and references therein). The megasites were accompanied by complementary perpendicular settlement patterns along an east-west axis with much smaller sites. The north-south axis formed the basis for the main long-range exchange (“down-the-line”) networks, the “megasites” serving as nodes for subsidiary distribution to the east and west (Goring-Morris, Hovers, and Belfer-Cohen 2009).

Still, there is little direct evidence as to the density of packing of architectural units within PPNB sites at any given point in time. This is obviously a crucial issue concerning estimations of village populations, which vary greatly. But, conservatively, communities at the top end of the scale numbered at least several hundred individuals (Campbell 2010; Kuijt 2000; Simmons 2007).

Economy displays considerable variability within the Mediterranean zone. Along the King’s Highway and down in the rift valley, communities subsisted primarily on domestic cereals. But farther west, in the Carmel and in the Galilee, the emphasis was on lentils (e.g., Garfinkel, Kislev, and Zohary 1988). So, too, there are differences in the animals exploited. At Middle PPNB ‘Ain Ghazal, a full 50% of the fauna was still hunted, a situation that changed dramatically by the Late PPNB, with 75% domesticated goats and sheep (Driesch and Wodtke 1997; Wasse 1997). But west of the rift—in the Galilee, Carmel, and Samaria—hunting continued to predominated throughout (Horwitz et al. 2000; Sapir-Hen et al. 2009).

With climatic amelioration, the desert margins of eastern Trans-Jordan as well as in the Negev and Sinai either were recolonized or relict populations increased significantly. The way of life here was one of mobile foraging supplanted during the end of the period by pastoral nomadism, which seemingly originated in the Syrian Desert and then diffused southward and later westward (Bar-Yosef and Khazanova 1992; Betts 1998; Goring-Morris 1993).

Specialized sites were located in boundary or neutral geographic settings, serving most probably as cultic centers, aggregation sites, and/or mortuary sites, as, for example, Nahal Hemar cave in the Judean Desert and Kfar HaHoresh in the Nazareth Hills of lower Galilee (Bar-Yosef and Alon 1988; Goring-Morris 2005). In the north, settlement patterns continued to be largely linear, with a focus on the Euphrates and its tributaries (e.g., the Balikh) and sites usually located at intervals of 20–25 km from one another (about a day’s walk away). The individual sites expanded significantly in size in comparison with those of the PPNA. The demise of the PPNB koine may reflect a combination of factors, including a rapid climate deterioration (the so-called 8.2-kyr event), the effects of some 2,000 years of farming without manuring (Bogaard 2005; Bogaard and Isaakidou 2010), local overexploitation of nonsustainable nearby resources (Rolleson and Kohler-Rolland 1989; but see Campbell 2010), outbreaks of contagious diseases, and increased tensions between neighboring communities (Goring-Morris and Belfer-Cohen 2010).

Discussion

Although most of the above represents a synopsis of hard-core data, there are points of debate regarding their interpretation and/or incorporation within the evolving matrix of the Levantine Neolithization process. Pertinent among them are the following.

Issues of continuity. Contrary to what was believed during earlier days of research, it transpires that there is no linear development from the Epipaleolithic to the end of the PPNB (e.g., Mellart 1975; Perrot 1968). Each major period witnessed a breakdown, being separated from the next by a short-term yet major rupture, or “bottleneck,” followed by realignment of the new system (i.e., the Early PPNA, the Early PPNB, and the Early Pottery Neolithic). However, it is important to stress that cultural complexes build on the past, sharing many common traits with their predecessors. They accordingly represent generational links within an extended family rather than a simple grandfather-son-grandson chain.

People or ideas in motion. For many years there was debate as to whether it was people or ideas that moved and dispersed from one area to the next. Currently, it is abundantly clear that both require consideration. Unequivocal examples of the former are the directed colonization of Cyprus and probably also of central Anatolia (e.g., Guilaine and Le Brun 2003; Özdoğan 2011; Peltenberg and Wasse 2004). The latter includes the diffusion of the bidirectional (naviform) chipped-stone technology from the Central Euphrates southward (Barzilai 2009; and see also Perles 2005). The situation with regard to the diffusion of animal and plant domesticates within the...
Population increase and demographic transition. Population increase and the Neolithic demographic transition (Bocquet-Appel and Bar-Yosef 2008) or, more recently, the agricultural demographic transition (ADT; Bocquet-Appel 2011) in the Near East are crucial in terms of the independence of the scale of mating networks. From the Early Epipaleolithic onward, diverse types of mating networks are likely to have operated. Variability is especially relevant as individual communities became more sedentary and increased in size. Numerical thresholds were crossed, necessitating realignments in social intercourse within and between communities because previous social mechanisms were unable to cope with novel situations (and see Belfer-Cohen and Goring-Morris 2011).

This makes it all the more difficult to predict or state when and where, precisely, the ADT occurred; should we start counting from the Natufian, the PPNA, or the PPNB?

Differences between developments in the northern and southern Levant. Was the southern Levant during the PPNB an independent center of innovation? Do developments in this
region simply reflect diffusion of novelties from the Euphrates region? Or are we witnessing combinations of both? Certainly, various facets of the material culture derive from the north, such as bidirectional naviform lithic technology. On the other hand, the evidence regarding the origins of domesticates is more equivocal.

The when, where, how, and why of plant and animal domestication. Archaeological evidence clearly demonstrates that there were more than two variants of economic existence; it was not just about farmers versus foragers. Fully fledged settled agriculturalists did coexist with hunter-gatherers during the Pre-Pottery Neolithic, but other groups, for a while at least, filled intermediate roles as forager-farmers so that there was a wide spectrum of lifeways (with the geographic distances involved being very small). Indeed, it is only toward the end of the Late Neolithic that subsistence throughout the region became based mostly on domesticated plants and animals (with the continuing dichotomy of agriculturists and pastoralists, as between “the desert and the sown”). This complexity should be acknowledged when we try to interpret the archaeological record, just as in the case of the rise of a new species. Even when we recognize the new species that will eventually replace its parent species, both the parent species and the offspring species coexist for some time, a simile to be aware of while deciphering the archaeological data at hand.

Plant and animal domestication processes. For how long was cultivation and animal herding practiced before their recognizable signatures in DNA, morphological changes, or age composition? What was the duration of plant and animal domestication processes? Domestication can be accomplished quite rapidly, but it seems more likely that initial Neolithic domestication in the Levant was a prolonged and undirected process. Not all those species that were intensively harvested and/or cultivated during the Early Neolithic were then domesticated (e.g., Avena sterilis and Secale cereale; Weiss, Kislev, and Hartmann 2006; Willcox 2005). And perhaps the same observations are valid with regard to the culling of wild animals (and see the situation in Cyprus with Dama mesopotamica; Vigne et al. 2011; Zeder 2011).

Prey stress, overhunting, and climatic changes with regard to animal domestication. Contrary to previous assertions that initial animal domestication focused on stocking the larder for meat, recently it has been claimed that the process was directed first at milk products (Vigne and Helmer 2007). Should we be looking at the central areas or the margins (and see Binford 1968, 2001; Flannery 1969)? Last but not least, we should bear in mind that domestication processes, whether of plants or animals, were intricately tied in with the non-material realms of human existence. Those promoted and encouraged the domestication venue, paced its tempo, or even arrested its progress. In short, one can be quite sure that the social realm controlled to a certain extent both the domestication processes themselves and their tempo and extent (and see Belfer-Cohen and Goring-Morris 2011).

Primary habitats and hearths of domestication. It has been taken for granted that present-day distributions of the wild precursors broadly correlate with Terminal Pleistocene/Early Holocene patterns such that advances in DNA sourcing would enable the straightforward pinpointing of domestication localities (e.g., Heun et al. 1997; Kilian et al. 2006, 2007; Naderi et al. 2007). Others have argued for a single hearth of domestication for the whole package of founder crops (Lev-Yadun, Gopher, and Abbo 2000). Notwithstanding attempts to reconstruct late Quaternary distributions (Hillman 2000), current distributions of wild plants and animals surely have been affected by almost 10 millennia of agriculture and pastoralism. Furthermore, if domestication of plants and animals was a gradual process, then there are likely to have been considerable genetic interactions between the “predomesticated” but manipulated/cultivated species and wild populations. These interactions probably continued, affecting the genetic fingerprints of both the wild progenitors and the early domesticated forms.

If we take into consideration all of the above, the concept of Neolithization involved much more than plant and animal domestication, for Neolithization processes also involved the “domestication” of fire (pyrotechnological developments leading eventually to pottery production) and water (management in the form of wells and irrigation). Additionally, and of paramount significance, is social “domestication” with new means of molding community identity and interaction, whose very essence changed; these range from bonding through kinship, exchange networks, craft specialization, feasting, and so on, to rivalry, political boundaries, and intercommunity confrontational violence. Ultimately, the “Neolithic revolution,” in the Near East at least, was a long-term, incremental, and undirected process marked by significant threshold events, the outcome of which was by no means certain.

It is important to stress the novel nature of innovations associated with Neolithization processes. This is especially relevant when considering ethnographic analogies. Observed phenomena in the archaeological record mostly reflect occurrences that had “made it in the first cut” if not later on in the sequence. But, surely, there is also evidence of phenomena and innovations that ultimately did not pass the trials of time. We thus face amalgamations of both material culture evidence of what was ultimately successful and what fell by the wayside, as we discuss in Belfer-Cohen and Goring-Morris (2011).

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Neolithization processes in the Levant differed from those in Europe. A major population growth was already occurring in the former at the onset of the Late Glacial Maximum. Population growth was not linear but rather reflected local circumstances, both external and internal. In addition to changing environmental conditions, the social implications of growth in community sizes within specific areas should be taken into account. The solutions and mechanisms that people devised during the transition to agriculture in order to counter the stresses stemming from those developments pertain to the tempo and scope of the changes as well as to endemic traditions.

Introduction

This article focuses on the internal social issues associated with the processes of “Neolithization” in the Near East, with particular emphasis on the Levant. It is intended to be read in conjunction with our other article in this volume, “Neolithization Processes in the Levant: The Outer Envelope” (Goring-Morris and Belfer-Cohen 2011).

It is vital to emphasize the marked local geographic variability within the general region of the Levant, a point frequently overlooked in sweeping treatments of Neolithization phenomena. Change was not homogenous throughout the region, with regard to either intensity or pace. Developments were affected by circumstances pertaining to the shift from mobile to increasingly sedentary lifeways, the scales of community sizes together with associated mating and social networks, the nature of interactions within and between communities, and worldviews evolving in terms of ideology and ritual.

It is important to stress the “first-time” nature of these processes all through the sequence of human prehistory, a case in point in the Near East. Moreover, the processes entailed the “domestication” of multiple elements; Neolithization was not just about subsistence. We can also observe the domestication of landscape, fire, water, social institutions, and even “the gods” (e.g., Cauvin 2000).

Ethnographic analogies are at best ambiguous even without the problems of considering recent and subrecent populations as living fossils. Facing the problem of translating material data into behavioral patterns, one should also remember that human conduct is frequently unpredictable, and hence the application of common sense and optimized models sometimes can be counterproductive. Nevertheless, some basic tenets of human behavior directly reflect the constraints of our inherent neurological wiring as Homo sapiens sapiens (e.g., Dunbar 1996; Johnson 1983; Kosse 1994; Wobst 1974).

With the rapid accumulation of archaeological data in the Near East, it seems that we have to view Neolithization from the perspective of the longue durée (Braudel 1993). These processes had already begun during the Early Epipaleolithic (ca. 23,000 years ago) and were heralded through seemingly minor but in retrospect significant changes in human behavior. Thus, we begin our overview almost 15,000 years before the emergence of the fully fledged Neolithic “package” of village farming communities.

Setting the Stage

Epipaleolithic groups in the Levant were mobile-band societies, just as in the preceding Upper Paleolithic (table 1), but the scale of individual territories in some areas shrunk as a result of increased packing, leading to relatively higher population densities at local as opposed to pan-Levantite levels (e.g., Bar-Yosef 2001). Here, the magic numbers of ca. 25 individuals for small-scale mobile-band societies with mating networks encompassing some 250–500 individuals are relevant (e.g., Wobst 1974). Virtually no data are available at this time for the northern Levant (see Goring-Morris and Belfer-Cohen 2011), and accordingly, our discourse focuses on the south.

Shifts and realignments throughout the course of the Early and Middle Epipaleolithic are documented, demonstrating that the nature of diachronic and synchronous social interac-
Table 1. Duration of the Epipaleolithic and Neolithic entities in the Levant

<table>
<thead>
<tr>
<th>Period</th>
<th>Approximate range (cal BP)</th>
<th>Duration (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Epipaleolithic</td>
<td>24,000–18,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Middle Epipaleolithic</td>
<td>18,000–15,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Late Epipaleolithic</td>
<td>15,000–11,600</td>
<td>3,500</td>
</tr>
<tr>
<td>PPNA</td>
<td>11,600–10,500</td>
<td>1,100</td>
</tr>
<tr>
<td>Early PPNB</td>
<td>10,500–10,100</td>
<td>400</td>
</tr>
<tr>
<td>Middle PPNB</td>
<td>10,100–9,500</td>
<td>600</td>
</tr>
<tr>
<td>Late PPNB</td>
<td>9,500–8,750</td>
<td>750</td>
</tr>
<tr>
<td>Final PPNB</td>
<td>8,750–8,400</td>
<td>350</td>
</tr>
<tr>
<td>Early Pottery Neolithic</td>
<td>8,400–7,600</td>
<td>800</td>
</tr>
</tbody>
</table>

Note. Discrepancies between this table and table 1 of Goring-Morris and Belfer-Cohen (2011) derive from uncertainties of 
14C dating. PPNA = Pre-Pottery Neolithic A; PPNB = Pre-Pottery Neolithic B.
* The “Round-House Horizon” in the Upper Tigris region (in two phases) is estimated at ca. 12,750–11,750–10,750 BP cal.

The Natufian

With the beginnings of sedentism during the Late Epipaleolithic Natufian in the Mediterranean “core area” at least (Goring-Morris and Belfer-Cohen 2011; fig. 1), there is clear evidence for significant increases in community sizes, with hamlets of up to 75–100 individuals (?), and perhaps no less important, for those communities lasting over extended periods of time. Calibration of 
14C dates demonstrates that the duration of the Natufian was considerably longer than previously assumed, >3,500 calendrical years as opposed to 2,000 years before (see, e.g., Bar-Yosef 1983; Stutz 2004).

Social mechanisms were necessarily of great importance to and had a great impact on enabling the Natufians in some areas to stay together in larger sedentary groups for the first time in the archaeological record. The increased community sizes apparently crossed a critical threshold in terms of social interactions. The changes indeed represent a radical “experiment” of long duration; thus, the Natufian phenomenon should not be viewed as simply intermediate between Paleolithic and Neolithic lifeways. It is important to consider the impact of the Natufian novelty in terms of the changes in social organization that occurred along its sequence. These clearly relate to a dramatic increase in the range and scope of the material culture remains (e.g., Bar-Yosef 2002). Overall, it is hardly surprising that from the very beginning of the Early Natufian there are indications of scalar stress (Johnson 1982), which is accompanied by a dramatic increase in artistic/symbolic activities (e.g., Belfer-Cohen 1988a; Belfer-Cohen and Bar-Yosef 2000; Boyd 1995; Edwards 2009; Valla 1989).

The degree of Natufian sedentism varies from one area to another. This is reflected by the combination of increased idiosyncrasy at the individual community level and regional variability (e.g., Belfer-Cohen 1988a; Stordeur 1991; Wright 1978). Social and mating networks would also likely have been diverse. Some Natufian groups may have continued to be organized along the lines of small-scale bands, the basic unit being the nuclear family. But in more favorable settings, Early Natufians probably adopted quite different patterns of domicile, whether by extended family, moieties, or the like, as reflected by the dramatic shifts in the size of architectural remains (e.g., at Wadi Hammeh 27 and el-Wad; Edwards 1991; Goring-Morris 1996; Goring-Morris and Belfer-Cohen 2008 and references therein). Another notable feature is the internal and external organization of space, with areas or whole sites designated for special activities (e.g., burial grounds and cemetery sites such as Nahal Oren, Hilazon Tachtit, and Raqefet; Grosman 2003; Grosman and Munro 2007; Lengyel and Boc-
quentin 2005; Stekelis and Yizraely 1963). One can refer also to the symbolic spatial arrangements within structures (e.g., the monoliths at Wadi Hammeh 27 and Rosh Zin; Edwards 2009; Goring-Morris and Belfer-Cohen 2003, 2008) or the various pebble arrangements, including an anthropomorphic one at Eynan (Boyd 1995; Perrot 1966; Valla 1989). Indeed, there is an exponential increase in elements pertaining to a wide range of symbolic behaviors, including changes in attitudes toward the dead and accompanying funerary practices. The overall numbers of Natufian burials within sites increase dramatically. They now represent location markers within the landscape, whether as burial grounds adjacent to living quarters, as foundation deposits (?), or as separate dedicated cemeteries (e.g., Perrot and Ladiray 1988). Indeed, it appears that

Figure 1. Reconstructed ranges of some Early Epipaleolithic groups in the southern Levant based on the technotypological and stylistic attributes of lithic assemblages. Note different scales of ranges east and west of rift valley.
we can detect the beginnings of a “dialogue with the dead” by members of the living community (and see Belfer-Cohen 1995; Stekelis and Yisraely 1963).

Another indication of communal activities above the level of individual nuclear families concerns the sizes and distributions of groundstone utensils. The presence of huge mortars as well as off-site bedrock mortar arrays provides another indication of communal activities, perhaps simply the scaling up of earlier egalitarian band principles (Belfer-Cohen and Hovers 2005). The range and quantities of raw materials and types of jewelry and other symbolic items expand considerably to include not only marine mollusks but also colored minerals, clay, animal bones and teeth, and so forth (e.g., Bar-Yosef Mayer 2005; Bar-Yosef Mayer and Porat 2008; Belfer-Cohen 1991; Marechal 1991; Weinstein-Evron and Ilani 1994). While some items were produced locally on site, others derive from considerable distances and obviously involved regional exchange networks, but usually these were internal, within the Natufian world itself (e.g., basalt groundstone tools; Weinstein-Evron, Kaufman, and Bird-David 2001); the sporadic appearance of obsidian toward the end of the period is an exception (Cauvin 1991; Delerue 2007; Valla 1999). Artistic manifestations include rare figurines of all kinds and raw materials (e.g., a female ochre figurine from Hayonim Terrace; Valla 1999).

Another interesting phenomenon is the appearance of “decorated” items that are rarely observed in earlier contexts: bone tools and groundstone utensils. Why do people decorate seemingly mundane items? Are they used on special occasions? Are they produced as goods to be exchanged or as poorer-quality imitations as grave goods (e.g., the bone tools deposited in grave XVII at Hayonim Cave), to be removed from circulation? Do the patterns denote signatures of ownership (Edwards 2007)? Concurrently, there is also a plethora of incised stone and bone plaques with abstract schematic patterns reminiscent of those observed on items from contemporary Paleolithic horizons in Europe (e.g., Bar-Yosef and Belfer-Cohen 1999; Belfer-Cohen and Bar-Yosef 2009; Svoboda 1997).

Jewelry and symbolic/artistic motifs differ in intensity and type from one base campsite and region to another, most probably denoting territories and group identities and affiliations as well as personal status (e.g., Belfer-Cohen 1991; Garrod 1936–1937; Stordeur 1981). Such items are found all through the Natufian sequence even though they largely disappear from Late Natufian grave contexts.

Many Natufian burials reflect considerable investment of time and effort. While there is significant variability in mortuary practices, some general patterns can be discerned, several of which remain ambiguous. For example, there are more primary individual burials in the Early Natufian as opposed to more secondary burials in the Later Natufian, when post-mortem skull removal is documented, a precursor of subsequent Neolithic developments (Belfer-Cohen 1988b). There are also instances of family burials (e.g., Hayonim Grave VII; Belfer-Cohen, Schepartz, and Arensburg 1991]). Although the burials are seemingly orderly and in well-defined spaces, there is great variability in the position of the interred individuals as well as in who was buried in any specific grave (whether single burial, multiple burials, burials of mixed sexes, or burials of young and old). Besides the individually decorated burials of the Early Natufian (making up ca. 10% of the total burials), there are also unique burials of the kind exposed at Late Natufian Hilazon Tachtit: the “shaman” burial (Grosman, Munro, and Belfer-Cohen 2008) or the “gazelle-horned” individuals in Grave 10 at Eynan (Perrot and Ladiray 1988). The joint human and dog burials observed at both Eynan and Hayonim Terrace represent another unique mortuary practice presaging later developments (Davis and Valla 1978; Tchernov and Valla 1997).

How does all of the above tie in with what we know about the nature of the Natufian entity? Most probably the Natufian reflects aspects of emerging social identity in the face of sharing space with distant and second-tier kin for extensive periods. At the same time, the increased packing of sites as well as other indications of territoriality (and see Goring-Morris and Belfer-Cohen 2011) brought about latent competition both within and between sites. Given postulated community sizes, some mating networks incorporated more than the individual base camp. Thus, there must have been at least two points of public social reference for each individual besides her/his private status regarding gender, age, or matrimony. It seems that Natufian lifeways, at least in the “core area,” brought forth community identity (on the level of the individual base camp), a concept that hardly existed previously; this may explain the individual styles seen in various domains in any given base camp. We do not know how the individual defined her/himself within their community or within the Natufian as a whole because currently we lack the means to isolate which attributes pertain to the personal, the community, or the broader mating-network identity. Undoubtedly there was a need for more markers of identity within these more socially complex contexts. Another factor to consider relates to the issue of possible local surpluses, whether associated with subsistence (primarily but not only vegetal, on a seasonal basis) or of an artisan-related or symbolic nature. Such surpluses would have required regulation—whether at the family, community, or some intermediate level—designating new social agendas (i.e., those individuals/families/communities with more personal goods versus those with less).

In this new world full of novelty and tension, the question arises as to whether we can detect a rise in personal or intercommunity violence? There is indeed sporadic evidence for violence during the Natufian (Bocquentin and Bar-Yosef 2004), but it should be emphasized that signs of trauma can also reflect mundane, everyday accidents. Here, as an aside, we note that although we are dealing with scientific endeavors and hard-core data, one cannot escape the feeling of changing research fashions. The mode changed from observing pre-
historic populations as “brutish and violent” in the early twenty-first century to considering them in the later 1960s/early 1970s as “flower children,” not aware that they were on the verge of becoming us (i.e., violent, greedy, impatient, etc.). Of late, the pendulum appears to have swung back, and now research focuses on potential indications for violence that tie in with the changing ways of life (e.g., Bocquentin 2003; and further afield, Solecki, Solecki, and Agelarakis 2004).

Pre-Pottery Neolithic A

The Pre-Pottery Neolithic A (PPNA) is a short-lived phenomenon both with regard to what preceded as well as what succeeded it—a mere 1,000 years (and see Goring-Morris and Belfer-Cohen 2011). However, the scale of change for the PPNA of the southern Levant is of a different order of magnitude in comparison with that of the northern Levant, where there was apparently a radical increase in population size and in the accompanying elements of social organization. In this context, the systematic colonization of Cyprus already from the PPNA (if not earlier—a matter of some debate) represents an important contribution unequivocally demonstrating the “budding off” of groups on the mainland to found settlements in new territories (Guilaine and Le Brun 2003; McCartney et al. 2007; Peltenburg et al. 2001). Undoubtedly, similar processes occurred also around the Mediterranean core area on the mainland itself (e.g., Abbès 2008).

In the south, certain sites became nodes of regional or even panregional interactions as reflected in the exchange of obsidian and its relative abundance in various sites. Such an example is Jericho, which may have functioned as a center for the distribution of various minerals—obsidian, malachite, and salt, among others. Surprises would have enabled the development of a protomarket—forces of supply and demand—and would have encouraged increasing social interaction. Nevertheless, social organization continued to be based on the concept of families, and a certain tendency toward privatization at the individual family level is observed (e.g., groundstone tool furniture within each structure; Belfer-Cohen and Hovers 2005; Rosenberg 2008). We suggest that individual domiciles would likely have been spatially organized along kinship lines, that is, as extended families within the wider community or as wards or the like (although the available data remain ambivalent on this issue).

In general the southern PPNA articulates more comfortably with the Natufian than with the following Pre-Pottery Neolithic B (PPNB). An illustration of this is the nature of PPNA burials, which often continue in the manner of the Late Natufian. Could it be that the lack of burial ornamentation and grave goods reflects an improvement through time (observed already in the Late Natufian) of social mechanisms that replaced the simple “beads and feathers” system of social nomenclature? However, for another approach invoking the promotion of egalitarian principles, see work by Kuitj (1996).

Quantities of figurines made of soft stone and burned clay are found (Hershman and Belfer-Cohen 2010) together with “decorated” stone plaques in abstract designs (Bar-Yosef and Gopher 1997; Edwards 2007). At the same time, there may have been a greater dichotomy between private and public domains as reflected in communal edifices, such as the unique tower, walls, and silos of PPNA Jericho with a concentration of burials nearby (Kenyon 1957). Do these represent endeavors to strengthen social cohesion? It seems plausible that the larger PPNA communities correspond to aggregations of residual local Natufian populations together with refugees from the periphery contracting back to refugia following the debilitating effects of the Younger Dryas.

The hierarchy of PPNA site sizes, in addition to reflecting different subsistence modes, undoubtedly had significant social implications at the local and regional levels. This would have included differentiated relationships between nuclear and extended families and larger kinship lines at community and intercommunity scales.

In the north, too, domicile was apparently also organized by nuclear families clustered into extended family compounds, each associated with a communal ritual semisubterranean structure as at Jerf el-Ahmar, Tell ’Abr 3, and Mureybet (Stordeur 2007). It is interesting to note that these “socio-cultic” structures were originally interpreted as typical residential ones (e.g., Mureybet: Stordeur et al. 2001; and Qermez Dere: Watkins 1990).

However, in the north there is an additional ritual phenomenon that emerged during the course of the PPNA and locally continued through the earlier part of the PPNB in the form of massive supraregional cult sites (e.g., Göbekli Tepe and possibly Karahan; Çelik 2000; Hauptmann and Schmidt 2007; Schmidt 2005, 2006). These huge monumental sites are found in prominent watershed locations away from the linear riparian habitation settlements in the low-lying plains. They would have required the mobilization and organization of large groups (on a quite different scale from the tower of Jericho) because their construction would have involved long-term investment to quarry and move massive pillars weighing tens of tons. The abundance of rich and intricate artistic manifestations portrays the intense investment of time and effort in the ritual sphere. The overall spiritual domain of the northern PPNA far surpasses that of the south in terms of both scale and in the motifs depicted. In particular, the iconography focuses on wild and frightening bestiary often having emphatically gendered phallocentric connotations (Hodder and Meskell, forthcoming). What remains elusive is the sociocultural background to such an explosion. It is of interest to note that the larger structures/units are the oldest, similar to phenomena observed within the Natufian sequence (Goring-Morris 1996). Furthermore, at Göbekli as elsewhere in the north, there is evidence for repeated intentional infilling and burial of structures before the construction of new ones (Ozdogan 2006).

Perhaps such sites fulfilled another function in that they portrayed the wealth and the merchandise of individual com-
munities; they would thus become active centers of social (competitive?) interaction sanctioned by “cultic” activities, with the separate units in these ritual megasites representing individual groups within the regional framework. In this they may parallel the individual ritual features in the habitation sites, which are associated with clearly defined compounds of extended families (and see above). Currently we are unable to decipher the association between particular social units and their specific symbolic vocabulary, but there is clearly evidence for the existence of such an association (e.g., some complexly incised designs at Jerf el-Ahmar approximate pictograms; Stordeur 2004).

It is quite obvious that as social circles increased in scale and scope, there was a need for more markers/symbols of identity at all levels of social interaction. Accordingly, we witness a phenomenon reminiscent of the concept of amphicytonies—leagues of neighboring communities associated with sacred locales (Belfer-Cohen and Goring-Morris 2002:144; Schmidt 2005)—known to exist in protohistoric and later periods in the Eastern Mediterranean. Indeed, these Pre-Pottery Neolithic (PPN) phenomena could find parallels in the “Chaco phenomenon” of Great Houses and associated kivas in the American Southwest (e.g., Cordell 1994; Kantner 2004; and see articles in American Antiquity 66 [2001]). Both correlates appear to provide avenues for further investigation in analyzing the scope and scale of the north Levantine PPN reality.

This complexity reflects the additional commitments of society—whether at the level of the individual, the nuclear and extended family, or the community—in order to maintain and consolidate regional cohesion at the supracommunal level. In the south, these nodes may often have been the actual settlements themselves, located in strategic settings. The differences between the southern and northern Levant are clearly perceptible; while in the south most of the ritual behaviors are more or less on a private level, in the north there are in addition large-scale interactions pertaining to the ritual domain, indicating that we are facing a multitiered system (i.e., adding yet more rings to the social “onion”).

Pre-Pottery Neolithic B

The PPNB of the south emerges after a significant break with the PPNA, albeit with various elements of continuity of earlier traditions. By contrast, the transformation in the northern Levant is relatively seamless.

The primary trends in the south regarding social organization include the later emergence, during the Late PPNB, of the “megasite” village phenomenon (e.g., ‘Ain Ghazal, es-Sifiya, and Basta; Gebel 2004; Goring-Morris, Hovers, and Belfer-Cohen 2009; Mahasneh 2004; Rollefson 2001). Whether one adopts a maximalist or minimalist approach in terms of estimating population sizes, these likely double or triple the size of the largest communities inferred for the PPNA (Kuijt 2000; Simmons 2007). This would have significantly increased the complexity of social and other interactions at the intra- and intercommunity levels. Undoubtedly, the individual now faced considerable competition, both within and between communities. On the other hand, the individuality as reflected in the stone masks and plastered skulls with modeled faces can be interpreted as personalized representatives of the community rather than actual privatization (other interpretations vary considerably, from trophies to gods; see discussions in Kuijt 2008). Apparently, as communities burgeoned, not all members could take an active part in all and every aspect of their existence, whether economic, social, and/or cultic. In consequence, the community as a whole was represented by “individuals,” perhaps personifying groups’ ancestors, who thus epitomized the group itself.

There is some evidence within settlements of the designation of separate areas for communal and cultic purposes (e.g., Beidha, ‘Ain Ghazal, and Atlit Yam; Byrd 1994; Galili 2004; Rollefson 2000). These installations display some continuity from the Natufian as reflected by monoliths and paved areas (Goring-Morris and Belfer-Cohen 2003). Further elements of continuity may also be reflected by the cult-cemetery site of Kfar HaHoresh, which is located in a prominent yet secluded neutral place (i.e., extraterritorial relative to nearby low-lying village sites; Goring-Morris 2005). The glimpses we gain of the rituals performed indicate that we are facing primarily intensifications and embellishments of past customs more than elements of a “new order” (Belfer-Cohen and Goring-Morris 2002, 2005).

By contrast, in the northern Levantine PPNB, there is a greater degree of continuity from the local PPNA that is reflected in many elements as well as further innovations. The colonization of central Anatolia as well as the continued colonization of Cyprus most probably represents the need for new territories as overall population densities increased within core areas on the mainland.

From the beginning of the PPNB, impressive “Houses of the Dead” make their appearance within habitation sites (e.g., at Djadé and at Çayönü; Coqueugniot 2006; Özdoğan 1999); whether these represent charnel houses of ancestors or of enemies remains debatable (e.g., Testart 2008). Concurrently, PPNA traditions of designated cult structures continued (e.g., at Nevali Çori and at Çayönü; Hauptmann 1999; Özdoğan 1999; for detailed discussion of some of these issues see Croucher 2006; Verhoeven 2002a, 2002b, 2002c). Interestingly, the large-scale cult sites such as Göbekli Tepe ceased to function sometime during the course of the PPNB; this may reflect a degree of social disintegration and a retreat back to the individual community.

The rise of surpluses within the PPNB koine also undoubtedly influenced the social and ritual fabric. The whole notion of organized exchange networks affected and brought about nonkin social segmentation. In this context, one should consider the emergence of incipient craft specialization involving artisans and associated merchants who would have operated not just systematically within but also between com-
munities (e.g., Barzilai 2009; Quintero 1998 with regard to lithics). Indeed, one may even speculate about the emergence of protoguilds, because we witness high levels of artisan competence executed in particular raw materials and dispersed over large geographic areas. It is not clear as to whether the products of such know-how were circulated by wandering individual specialists or whether “secrets of the trade” were disseminated among a network of a chosen few who acted in unison. Whatever the case, all of the above would have fostered further levels of communication between communities.

The end of the PPNB world likely relates to a wide array of interconnected factors, whether climatic changes, demographic pressures including diseases, and declining yields (Cohen and Crane-Kramer 2007; Goring-Morris and Belfer-Cohen 2010; Rollefson and Köhler-Rollefson 1989). This was more marked in the southern Levant than the northern Levant. Yet in terms of economy, the PPNB represents a point of no return. Human subsistence in the Levant continued thereafter to be based in one form or another on the suite of domesticates (plants and animals) initiated during the PPNB (as well as the addition of pastoralism). Breakdowns in social interactions—brought about, among other things, by the rise in contagious diseases and interpersonal violence (as perhaps reflected in more multiple burials in the Late Pre-Pottery Neolithic B [LPPNB])—heralded the demise of the PPNB koine. Vagaries in the history of research have led to an emphasis on the presence of a major break between the PPNB and Early Pottery Neolithic, but to the contrary, recent research indicates numerous elements of continuity, albeit with local trajectories rather than the previous pan-Levantine scope of the PPNB (e.g., Garfinkel and Miller 2002). What is lost is the unique character of the PPNB as reflected in its social interactions and networks and its material culture components related to the sacred and ritual, in short, the attributes considered as the hallmarks of what is traditionally referred to as a particular culture.

Discussion

The role of climate change (and especially rapid climate change) in the Neolithization process is certainly a factor to be considered at various specific points in time. Climate did change at a global scale, but the impact and effects of the changes differed in various and varied environmental settings with diverse technological and social milieus, bringing about different, particularistic responses of the human populations exposed to those climatic changes. Overall, the climatic changes caused internal “bottleneck” situations in the passage from the Natufian to PPNA, from PPNA to PPNB, and at the end of the PPNB, all of which require more detailed investigations. Sometimes these bottlenecks may have acted as tipping points or threshold events in the sense of providing catalysts for realignments of social systems. As an example, one may cite the likely presence of a refugium at low elevations in the southern Levant during the shift from the Natufian to PPNA by way of the short-lived “Khiamian” entity.

There are inherent uncertainties regarding the mode and tempo of changes in subsistence that are assumed to go hand in hand with social structures and systems and that accordingly influence our perceptions. Moreover, it seems to us that if during the course of Neolithization, changes occurred sporadically and took a long time to gel and take root and that their courses of evolution differed from one region to the next, we need to readjust the ways in which we review and evaluate the social realm.

Undoubtedly, human groups modified their attitudes to the environment in accordance with the role it played within the Neolithization process. Starting at least by the Natufian, the first orderly burial grounds functioned as location markers in the landscape. These burial customs persisted through the following Neolithic sequence, indicating the continuity and persistence of ancient traditions. Accordingly, Neolithic groups looked back and took comfort in relying on the past and its institutions rather than inventing a complete package of “new order” regulations. Changes took time and were initially of marginal impact (e.g., skull removal and skull modification). Still, it is of interest to note that there was a general consistent trajectory throughout the Levant in terms of the persistence of local traditions.

Debates have arisen regarding possible population movements as opposed to the diffusion of ideas and local continuity. For example, PPNB skull plastering originated as a southern Levantine phenomenon—the foundations of which lie in Natufian skull removal—but persisted into the Late Neolithic in the north (Ozbek 2009). It is of interest to note that some ritual phenomena, though rare, persist through the entire sequence, thousands of years apart, as exemplified by the pebble depiction at Natufian Eynan, which recalls the human bone arrangement at PPNB Kfar HaHoresh and also the stone drawings at Late Neolithic Khasm el-Tarif and Biqat Uvda (Avner 2002; Goring-Morris 2005; Perrot 1966).

Changes observed in institutionalized behavior were generally of a minor magnitude; just as decorated burials in the Early Natufian did not exceed ca. 10%, so too PPNB plastered skulls do not exceed 10% of total burials. There were changes, from an emphasis on primary to multiple secondary burials during the course of the Natufian, a situation mirrored toward the end of the PPNB. Perhaps these similarities reflect stress, with differences stemming from specific circumstances. What do the Early Natufian decorated burials represent and why did they disappear? Most of the otherwise unique burials were in the Late Natufian and thenceforth were not decorated. Still, animal themes were part and parcel of burial rituals from the Natufian through the PPNB, whether the Late Natufian Hilazon “shaman” burial (Grosman, Munro, and Belfer-Cohen 2008), the burial with a gazelle-horn headdress at Eynan (Perrot and Ladiray 1988), turtle carapaces at el-Wad, Hayonim Terrace, and Eynan, and so forth (Garrod and Bate 1937; Valla 1999). By the PPNB they include complete or partial
animal skeletons and pars pro toto (e.g., fox mandibles; Goring-Morris and Horwitz 2007; Horwitz Kolska and Goring-Morris 2004). These coassociations occur but sporadically. Do they represent professional personal achievements or some manner of status differentiation? What do animal bones as grave goods denote? Are they talismans, totemic affiliation signs, and/or remnants of ritual feasting (e.g., Twiss 2008)? Furthermore, the concept of the “House of the Dead” in the north—present in Djadı, Çayönü, Aswad, Tell Hallula, and Çatalhöyük (Düring 2009; Guerrerro et al. 2009; Stordeur and Khawam 2009 and see references therein)—could represent lineages or other social associations (and see Kuijt 2008 for a discussion of societal consolidation and the creation of communal memory).

Scalar stress began to be significant from the Natufian onward, the common explanation for the exponential rise in artistic activities and representations and accompanying stylistic variability (Belfer-Cohen and Bar-Yosef 2000 and references therein). Without delving into a detailed discussion of the social correlates of stylistic variation (e.g., Conkey and Hastorf 1990; Jochim 1987; Stark 1998; Wiessner 1989; Wobst 1977, 1999 and references therein), there was a growing need for additional markers of status/affiliation/kinship. For example, competition for potential partners would have increased both within the community as well as between communities. From the beginning of the Natufian through the entire Neolithization sequence, the thickness of the different social layers varied; there were circles of family, kinsmen, the village, nearby communities, exchange partners, and the list grew to encompass the whole PPNB koine.

There were now in the PPNB levels of segmentation that were not necessarily always based on kinship (and see, e.g., Düring 2006; Hodder 2005; Hodder and Cessford 2004). Whereas in the Earlier Epipaleolithic, contacts between external groups were more sporadic, by the PPNB the whole system involved much more intense interactions, especially with regard to the “outer rings”—“strangers” now became permanent fixtures of the everyday world, and people had to devise new codes of behavior toward new strata of social interaction.

Additionally, in many areas sedentary communities existed virtually cheek by jowl with mobile foraging communities, and this differentiation by economic mode of existence called for yet another societal differentiation (e.g., David, Sterner, and Gavua 1988; Kent 2002 for an ethnoarchaeological perspective). If, as Schmidt (2006) claims, the isolated hilltop site of Göbekli Tepe is characterized only by cultic (rather than domestic) structures, then it is possible to hypothesize that this was a sacred site serving as an aggregation locale for neighboring competitive groups within a “neutral” setting much in the manner of the later classical amphictyony (Belfer-Cohen and Goring-Morris 2002). Such a situation could have served to mitigate and facilitate intercommunity relations regarding the extended mating, exchange, and other networks that burgeoned as part of the growing complexity of the Early Neolithic Levantine koine.

Was violence an integral element to the observed social processes of Neolithization? Interpersonal violence is without doubt a human constant. And certainly at “Proto-Neolithic” Zawi Chemi Shanidar there is evidence for extensive head traumas that could correlate with violence on an intercommunity scale (Solecki, Solecki, and Agelarakis 2004). During the Natufian, the evidence for intercommunity violence is more equivocal, but later the presence of multiple burials in the LPPNB could potentially be interpreted (in addition to the possibility of poor health) as yet another mechanism for structured social intercourse. Indeed, it has even been suggested that slavery may have been a feature of PPNB lifeways (Bar-Yosef and Bar-Yosef Mayer 2002).

We believe the above represent significant issues that merit further discussion with respect to Neolithization processes in the Near East and that ultimately were not just about the “origins of agriculture” per se. Thus, we encounter societies guided by combinations of both new and old principles that had undergone profound modifications. Human societies are, by definition, conservative institutions that cling to the symbols that define them. It was the radical transformations in interpersonal and especially intercommunity relations that herald the real “revolution.”

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The Origins of Agriculture in the Near East

by Melinda A. Zeder

The emerging picture of plant and animal domestication and agricultural origins in the Near East is dramatically different from that drawn 16 years ago in a landmark article by Bar-Yosef and Meadow. While in 1995 there appeared to have been at least a 1,500-year gap between plant and animal domestication, it now seems that both occurred at roughly the same time, with initial management of morphologically wild future plant and animal domesticates reaching back to at least 11,500 cal BP, if not earlier. A focus on the southern Levant as the core area for crop domestication and diffusion has been replaced by a more pluralistic view that sees domestication of various crops and livestock occurring, sometimes multiple times in the same species, across the entire region. Morphological change can no longer be held to be a leading-edge indicator of domestication. Instead, it appears that a long period of increasingly intensive human management preceded the manifestation of archaeologically detectable morphological change in managed crops and livestock. Agriculture in the Near East arose in the context of broad-based systematic human efforts at modifying local environments and biotic communities to encourage plant and animal resources of economic interest. This process took place across the entire Fertile Crescent during a period of dramatic post-Pleistocene climate and environmental change with considerable regional variation in the scope and intensity of these activities as well as in the range of resources being manipulated.

Introduction

Eighteen years ago, a week-long seminar was held in Santa Fe, New Mexico, that, much like the Wenner-Gren Mérida conference featured in this special issue of Current Anthropology, focused on the context, timing, and possible causes of the emergence of agriculture in different world areas. Sponsored by the School of American Research, this seminar resulted in the publication of an influential edited volume, Last Hunters, First Farmers: New Perspectives on the Prehistoric Transition to Agriculture (Price and Gebauer 1995), a comprehensive global overview of agricultural origins. The contribution by Ofer Bar-Yosef and Richard Meadow, in particular, provided a richly detailed account of the transition from foraging to farming in the Near East (Bar-Yosef and Meadow 1995). The scope and breadth of the Bar-Yosef and Meadow article likely explains why it has been the most authoritative and most widely cited synthesis of Near Eastern agricultural origins. This work, then, serves as an ideal benchmark against which to measure advances in our understanding of Near Eastern plant and animal domestication and agricultural emergence in the years between the Santa Fe and Mérida conferences.


While comprehensive in its geographic scope, Bar-Yosef and Meadow (1995) had a special emphasis on the Levant, especially on the southern Levant (figs. 1, 2). Decades of survey and excavation, especially in the parts of the Levant that fell within the borders of modern Israel, had yielded a remarkably detailed and well-controlled archaeological record of the transition from foraging to farming in this part of the Near East. Similar coverage had not yet been accomplished in other parts of the Fertile Crescent. When the Bar-Yosef and Meadow article was published, documenting domestication in plants and animals required the detection of morphological modifications caused by domestication. In cereals, the marker of choice was the development of a tough rachis, a change in the plant’s dispersal mechanism thought to arise when humans sowed harvested cereal grains. In pulses, the primary domestication marker was an increase in seed size, a response to seedbed pressures that allowed sown seeds to germinate more quickly and shade out competing seedlings. In animals, archaeozoologists relied primarily on the demonstration of overall body-size reduction, held to be a rapid response to herd management.

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Based on these criteria, crop domestication was thought to have originated in the southern Levant during the Pre-Pottery Neolithic A (PPNA) period, around 11,500–11,000 cal BP (fig. 2). Animal domestication seemed to have been delayed development, with different livestock species brought under domestication in different parts of the region (from the Levant to the Zagros), beginning with goats sometime during the Middle Pre-Pottery Neolithic B (PPNB), around 10,000 cal BP, followed by sheep, with cattle and pigs domesticated later still. While livestock and some crop plants may have been domesticated in other parts of the Fertile Crescent, the southern Levant was thought to be the home of initial cultivation from which domesticates and domestic technology spread quickly into the rest of the Fertile Crescent through an “uneven series of movements affecting different areas at different times” (Bar-Yosef and Meadow 1995:41). The coalescence of disparate elements of this subsistence system into an agricultural economy was thought to have occurred over a 2,000-year period, from about 10,000 to 8000 cal BP, during which...
time it gradually became the dominant subsistence economy throughout the region.

Near Eastern Agricultural Origins: 2010

In the 16 years since publication of Bar-Yosef and Meadow (1995), there has been an exponential increase in information on this transition not only from the southern Levant but also from other parts of the Fertile Crescent that had not been as thoroughly explored in 1995. A number of new archaeological approaches to documenting domestication have been developed that are providing powerful new insights into the initial phases of domestication in both plants and animals. Also contributing to the emerging picture of Near Eastern agricultural origins are genetic analyses that have identified the progenitors of Near Eastern domestic crops and livestock species and defined the likely geographic regions of their domestication. More widespread use of small-sample accelerator mass spectrometry (AMS) radiocarbon dating has made it
possible to directly and precisely date the remains of domestic plants and animals, greatly enhancing the temporal control of our understanding of this transition. The result is a vastly changed picture of the origins of agriculture in the Near East.

**New Archaeological Insights into Plant Domestication**

*Cereals.* When Bar-Yosef and Meadow (1995) was written, the presence of a few large domestic grains of einkorn (*Triticum monococcum* cf. *monococcum*) and rye (*Secale cereale*) from Epipaleolithic levels at Abu Hureyra I had raised the possibility that initial cereal domestication occurred in the northern Levant during the Younger Dryas climatic downturn (Hillman, Colledge, and Harris 1989). Subsequent AMS dating of these grains found that, as suspected, most were intrusive from Middle PPNA levels. However, three grains of domestic-morphotype rye were found to date to between 13,000 and 12,000 cal BP, and on the basis of this early date, Hillman argued that these grains represented the earliest morphologically altered domestic cereals in the Near East (Hillman 2000; but see Nesbitt 2002:118–119). Hillman acknowledged that grains consistent in size with domestic varieties are known to occur in low numbers in wild cereals but argued that the probability of finding these rare mutant forms within archaeological assemblages of collected wild rye was essentially zero (Hillman 2000:382). If rye was domesticated at this early date, however, it does not seem to have made much of a mark on Near Eastern subsistence economies. With the onset of warmer and wetter climatic conditions in the Early Holocene, the utilization of this cool-climate cereal first declined and then ceased altogether in the Middle Euphrates (Willcox, Fortnie, and Herveux 2008). Domesticated rye is not seen again for another 2,000 years, when it is found in low numbers in central Anatolia at Can Hasan III (ca. 9400 cal BP; Hillman 1978). Never a prominent component of Near Eastern cereal crops, modern domestic rye traces its heritage to European wild rye (Weiss, Kislev, and Hartmann 2006).

Arguments advanced in 1995 for the appearance of morphologically altered domestic barley and emmer during the PPNA in the southern Levant have been largely overturned in the intervening years (Weiss and Zohary 2011). When Bar-Yosef and Meadow (1995) went to press, the handful of tough-rachis barley *Hordeum vulgare* sspp. *distichum* found among the thousands of brittle-rachis wild barley grains *H. vulgare* sspp. *spontaneum* recovered at Gigal and Netiv Hagdud in the southern Levant seemed likely candidates for the earliest domesticated cereal crop. Although this evidence was questioned at the time by Kislev (1989, 1992), who maintained that the low proportion of tough-rachis barley in the Netiv Hagdud assemblage was consistent with the representation of this morphotype in wild stands, others seemed more comfortable with the attribution of these cereal remains as domestic (i.e., Bar-Yosef and Meadow 1995:66–67; Hillman and Davies 1992; Zohary 1992). There is now a more general consensus that tough-rachis grains must constitute at least 10% of a cereal assemblage before it can be considered domestic (Tanno and Willcox 2006a; Weiss, Kislev, and Hartmann 2006). This means that the barley recovered from these early sites (where tough-rachis varieties constitute about 4% of the total barley recovered) more likely represent intensively collected and possibly cultivated morphologically wild cereals (Kislev 1997; Weiss, Kislev, and Hartmann 2006). The application of AMS dating to carbonized material recovered from new excavations at Tell Aswad has moved up the dates of the more securely identified domesticated emmer and barley from this site. Originally thought to date to the PPNA (ca. 11,500 cal BP), the levels that yielded these domestic cereals are now known to date to the end of the Early and beginning of the Middle PPNB (ca. 10,300–10,000 cal BP; Stordeur 2003; Willcox 2005).

Nesbitt’s comprehensive evaluation of the evidence for the appearance of domesticated cereals in the Near East concludes that the evidence for morphologically altered cereal domesticates before about 10,500 cal BP is either too poorly documented or too poorly dated to be accepted as marking the initial threshold of cereal domestication (Nesbitt 2002). The earliest securely identified and dated domestic emmer (*Triticum turgidum* sspp. *dicoccum*) and einkorn (*T. monococcum* sspp. *monococcum*) grains and chaff, according to Nesbitt, come from sites in the Upper Euphrates valley (Nevali Çori, Cafer Höyük, and possibly Çayönü) that date to the Early PPNB, at about 10,500–10,200 cal BP. Nesbitt contends that securely identified and dated domestic barley is not seen until the Middle PPNB, when it is found throughout the Fertile Crescent and Anatolian Plateau.

Additional evidence for the late or at least delayed appearance of morphologically domestic cereals in the Near East is provided by Tanno and Willcox (2006a), who document the gradual increase in the proportion of tough-rachis domestic morphotypes among wheat and barley recovered from sites in the Middle and Upper Euphrates valley. Domestic morphotypes constitute only 10% of the single-grained einkorn recovered from Nevali Çori (ca. 10,200 cal BP), barely meeting the threshold for demonstrating the presence of domestic cereals. Only 35% of the barley recovered from somewhat later levels at Aswad (10,200–9500 cal BP) and a little over 50% of the barley recovered from Ramad (9500–8500 cal BP) are nonshattering varieties. Even as late as 7500 cal BP, domestic morphotypes constitute only around 60% of the two-grained einkorn recovered from Kosak Shamali, a variety that Willcox postulates represents a second domestication of diploid wheats (Willcox 2005:537).

**Pulses.** Although substantial quantities of lentils had been recovered from PPNA sites in both the southern and the northern Levant by 1995, the absence of clear morphological markers of domestication (i.e., larger seed sizes) precluded Bar- Yosef and Meadow from drawing any conclusions about their domestic status. However, Weiss, Kislev, and Hartmann (2006; also Weiss and Zohary 2011) and Tanno and Willcox...
(2006b; also Willcox, Buxó, and Herveux 2009; Willcox, For- nite, and Herveux 2008) have subsequently concluded that the hundreds of lentils found in storage bins at Netiv Hagdud and Jerf el Ahmar are unlikely to represent wild, unmanaged plants. Wild lentils, they argue, are not a common component of Near Eastern plant communities, and the yield of seeds per plant, at about 10–20, is very low. Moreover, wild lentils have an exceptionally high rate of seed dormancy; only about 10% of wild lentil seeds germinate after sowing. Thus, the quantity of lentils recovered from these of PPNA sites suggests that lentils were likely being transplanted from wild patches, aggregated in new environments, and tended by humans. Weiss, Kislev, and Hartmann (2006) also argue that these early lentils had undergone a lowering in the rate of seed dormancy and an increase in the number of seeds per plant, initial steps toward domestication that would not be archaeologically detectable.

Similarly, Tanno and Willcox (2006b) maintain that the chickpeas (Cicer sp.) recovered from Tel el-Kerkh (ca. 10,200 cal BP) in northwestern Syria represent an early stage in the cultivation of this well-known Near Eastern crop plant. While these are not definitively domestic morphotypes, the high degree of morphological variability of the chickpeas from this site, together with the rarity and sparseness of wild chickpea stands (which do not grow in the region today), is again suggestive of intentional transplanting and cultivation. A similar case is made for the faba beans (Vicia faba) recovered from this site (Tanno and Willcox 2006b). Although not as large as modern faba beans, they are very similar to the faba beans recovered in large numbers from the Late PPNB (ca. 8800 cal BP) at Yiftah’el (Garfinkel, Kislev, and Zohary 1988), which are almost certainly cultivated varieties. In fact, the large-seeded modern variety of faba bean is not seen in the Near East until about AD 1000 (Tanno and Willcox 2006b).

Figs. Recently, Kislev, Hartmann, and Bar-Yosef (2006a) have argued that the earliest morphologically altered plant domesticate in the Near East was neither a cereal nor a pulse but a tree crop. The presence of parthenocarpic figs at the PPNA site of Gigal in the southern Levant (ca. 11,400–11,200 cal BP) has been interpreted as a clear indication of human selection for this mutant infertile fig variety that remains on the tree longer and develops sweeter, softer fruit. Other researchers have noted, however, that parthenocarpic is known among wild female fig trees (Denham 2007; Lev-Yadun et al. 2006) and therefore, as with the presence of tough-rachis varieties or larger cereal grains in low quantities, their occurrence in an archaeobotanical assemblage cannot be considered definitive proof of domestication. Kislev, Hartmann, and Bar-Yosef (2006b) have responded that if, as their critics contend, these figs represent the selective harvest of mutant figs from wild fig trees, at least some seeded varieties would be expected to have been collected along with these rare, naturally occurring parthenocarpic figs. Instead, all of the nine carbonized fruits and 313 single druplets recovered from Gigal represent this infertile variety. Domestication of this shrubby pioneer plant, they maintain, could be accomplished by replanting cut branches of trees that naturally produce these sweeter fruits. Such an activity underscores the degree to which people were likely modifying local environments and biotic communities as well as their willingness to invest in nurturing resources, such as slowly maturing trees, with delayed rewards.

Plant management. There is, in fact, increasing evidence that humans were actively modifying local ecosystems and manipulating biotic communities to increase the availability of certain economically important plant resources for hundreds of years before the manifestation of morphological indicators of plant domestication (Weiss, Kislev, and Hartmann 2006; Willcox, Buxó, and Herveux 2009; Willcox, Fornite, and Herveux 2008). First, the presence of distinctive complexes of weedy species characteristic of fields under human cultivation suggests that humans were actively tilling and tending wild stands of einkorn and rye at both Abu Hureyra and nearby Mureybit during the Late Epipaleolithic (ca. 13,000–12,000 cal BP; Collledge 1998, 2002; Hillman 2000: 378). Increases in this weed complex at Qaramel (ca. 11,500 cal BP) and Jerf el Ahmar (ca. 11,000 cal BP) signals an intensification of plant cultivation in the Middle Euphrates during the ensuing PPNA period (Willcox, Fornite, and Herveux 2008). Willcox, Fornite, and Herveux (2008; also Willcox, Buxó, and Herveux 2009) also interpret the increase in the quantity of wild einkorn in Early Holocene assemblages from the Middle Euphrates sites as additional evidence of human management of this plant. Wild einkorn T. monococ- cum ssp. baeticum is not well adapted to the chalky soils of the Middle Euphrates, and it would not have responded well to the rising temperatures of the Early Holocene. Today the region is too hot and arid for wild einkorn, which can be found only on basalt lava flows 100 km north of Jerf el Ahmar. The dramatic increase in the representation of wild einkorn in Middle Euphrates assemblages over the course of the PPNA to Early PPNB could happen, these authors argue, only if people were actively tending plants transplanted from preferred habitats, altering local microhabitats, removing competition, and artificially diverting water to tended plants (Willcox, Fornite, and Herveux 2008:321). A subtle increase in the thickness and breadth of barley and einkorn grains from these sites without a corresponding increase in grain length is interpreted as a plastic response to cultivation (Willcox 2004). The progressive decrease in indigenous plants of the Euphrates floodplain and the concurrent adoption of and increase in morphologically wild representatives of founder crops such as barley, emmer, lentils, chickpeas, and faba beans have also been used to argue that humans were modifying local plant communities and managing morphologically wild but cultivated cereals and pulses (Willcox, Buxó, and Herveux 2009; Willcox, Fornite, and Herveux 2008). In addition to the quantities of lentils recovered from PPNA sites such as Netiv Hag-
dud and Gigal, the large number of morphologically wild barley and wild oats (Avena sterilis) recovered from these sites (e.g., 260,000 grains of wild barley and 120,000 of wild oats from a single granary at Gigal) suggests that people in the southern Levant were also cultivating plants of economic interest (Weiss, Kislev, and Hartmann 2006).

A study of plant assemblages from the northern Fertile Crescent by Savard, Nesbitt, and Jones (2006) demonstrates that people in the more eastern parts of the Fertile Crescent were also intensively utilizing a wide variety of plant resources, with considerable regional variation in the plant species exploited. Late Epipaleolithic residents of Hallan Çemi, for example, utilized a diverse range of plant species with a special focus on valley-bottom plants such as sea club-rush (Bolboschoenus maritimus) as well as dock/knotgrass, large-seeded legumes, and, to a lesser extent, almonds (Amygdalus sp.) and pistachio (Pistacia sp.). A similar assemblage was found at Demirköy, a nearby site occupied shortly after Hallan Çemi, where a number of as yet unidentified small-seeded grasses, small-seeded barleys (Hordeum marinimum), and some wild barley (H. vulgare cf. spontaneum) were also recovered. The plant assemblages from roughly contemporary sites in steppic environments of northern Iraq (Qermez Dere and M’lefat) are dominated by large-seeded legumes, followed by small-seeded grasses, with small-seeded legumes and wild cereals (barleys and einkorn/rye) also represented.

The antiquity of this broad-spectrum plant-exploitation strategy stretches back at least to the Late Glacial Maximum (ca. 23,000 cal BP), as evidenced by the remarkably well-preserved plant assemblage recovered from the waterlogged Levantine site of Ohalo II, which contained a diverse array of large- and small-seeded grasses and legumes (Piperno et al. 2004; Weiss et al. 2004). There is some indication that the intensive exploitation of this complex of small- and large-seeded cereals, legumes, and other locally available plant resources may reach as far back as the Middle Paleolithic (Albert et al. 2003; Lev, Kislev, and Bar-Yosef 2005). It is still an open question when, over the course of this long period of increasingly intense utilization of plant resources, humans began to actively modify local ecosystems and biotic communities to encourage the availability of economically important plants. But it is clear that by at least 11,500 years ago, humans had brought a number of plant species under cultivation and that except for the manifestation of certain morphological traits seen in later-domesticated varieties, these plants might arguably be considered domesticated crops.

The delayed expression of domestication-induced morphological changes in managed plants (at 10,500–10,000 cal BP in cereals and later still in pulses) may be attributable to the frequent importation of new wild plants when cultivated crops failed (Tanno and Willcox 2006a). It is also possible that early harvesting practices may not have encouraged the morphological changes to cereal dispersal mechanisms once thought to be a first-line marker of cereal domestication. Beating ripened grain heads into baskets, for example, or harvesting shattered cereals before they were fully ripe or even gleaning shattered heads of grain from the ground might have led to the retention of the brittle rachis in cultivated cereals (Hartmann, Kislev, and Weiss 2006; Lev-Yadun, Gopher, and Abbo 2006; Tanno and Willcox 2006a; Wilcoxon and Tanno 2006). The appearance of morphological change in these founder crops is, then, most likely an artifact of a change in management or harvesting practices of cultivated crops and not a leading-edge indicator of plants being brought under human control.

New Archaeological Insights into Animal Domestication

Caprines. The utility of morphological markers as leading-edge indicators of livestock domestication is even more problematic. This is especially true of body-size reduction, the primary marker used to document animal domestication for the past 30 years. Recent analysis of modern and archaeological skeletal assemblages from the Zagros region has shown that sex and, to a lesser extent, temperature are the most important factors affecting body size in both sheep (Ovis aries) and goats (Capra hircus). Domestic status, on the other hand, has no effect on the size of female caprines and only a limited effect on males, manifested as a decrease in the degree of sexual dimorphism (Zeder 2001, 2005). This work has also shown that apparent evidence of domestication-induced body-size reduction in Near Eastern archaeological assemblages is not, as had been assumed, the result of a morphological response to human management. Instead, the apparent shift toward smaller animals is an artifact of the different culling strategies employed by hunters, whose interest in maximizing the return of the hunt often results in an archaeological assemblage dominated by large prime-age males (Stiner 1990), and herders, who seek to maximize the long-term growth of a herd by culling young males and delaying the slaughter of females until they have passed peak reproductive years (Redding 1981). Because of various taphonomic factors and methodological practices, the herder’s harvest strategy produces an archaeological assemblage dominated by smaller adult females (Zeder 2001, 2008). Comparing assemblages of hunted prey animals primarily made up of large adult males with those of harvested managed animals dominated by smaller females led to the erroneous conclusion that domestication-induced body-size reduction had taken place.

The consistent size difference between the skeletal elements of male and female caprines, however, makes it possible to compute sex-specific harvest profiles for sheep and goats that are capable of distinguishing the herding harvest signature from the hunter’s prey strategy. In the central Zagros, the herding signature of young-male harvest and delayed female slaughter is first detected within the highland natural habitat of wild goats among the goat remains from the site of Ganj Dareh, directly dated to 9900 cal BP (Zeder 1999, 2005). The same signal was also detected in the goats from the site of Ali Kosh, located outside the natural habitat of wild goats on
the lowland piedmont of southwestern Iran and first occupied at about 9500 cal BP. Progressive changes in the size and shape of goat horns has been noted over the 1,000-year occupation of this site (Hole, Flannery, and Neely 1969). These changes were a direct response to human management that arose when humans assumed control over breeding and eliminated the selective pressure for large horns used in mate competition. The unequivocal signatures of goat management documented in the central Zagros are not, however, the earliest evidence of caprine management in the Near East. As with plants, it now seems that the leading edge of animal management stretches back at least 1,000 years before the manifestation of archaeologically detectable morphological change in managed animals.

Perkins (1964) interpreted the younger age profile of the sheep from the site of Zawi Chemi Shanidar in the northwestern Zagros as evidence of sheep domestication in the Late Epipaleolithic (ca. 12,000–11,500 cal BP). A new analysis of this assemblage finds a prey profile focused on 2–3-year-old male sheep that is, as Perkins noted, a departure from the prime-adult-male strategy detected for goats in Mousterian and Upper Paleolithic levels at nearby Shanidar cave (Zeder 2008). But this demographic profile is also not consistent with the herd-management signature of young-male and delayed female harvest detected for goats at Ganj Dareh and Ali Kosh. A similar focus on 2–3-year-old males has been reported at the roughly contemporary site of Hallan Çemi, 300 km to the northwest of Zawi Chemi and part of the same Taurus/Zagros “round-house tradition” (Redding 2005; Rosenberg et al. 1998). Redding interprets this demographic pattern as a prime-male hunting strategy practiced under conditions of intensive pressure on local wild herds. The eradication of local males by sedentary hunters, he argues, created a vacuum that attracted younger males with less-established home territories from outside regions. This “male sink” effectively assured a continuous supply of preferred prey while preserving a local population of females and young. Although this strategy does not entail the same degree of intentional control over herd demographics found in managed herds, it certainly signals an attempt at increasing the availability of prey by setting a precedent for the slaughter of younger males and the preservation of female breeding stock characteristic of herd management. The demographic profile of the sheep remains from Körtik Tepe, a somewhat later (ca. 10,900 cal BP) site located 50 km to the south of Hallan Çemi, has also been interpreted as a transitional strategy between game management and herd management (Arbuckle and Özkaya 2006).

The transition from hunting to herding appears to have been complete by about 10,500 cal BP at Nevali Çori, where, using lower-resolution demographic profiling methods, Peters and collaborators have detected changes in the age and sizes of caprines consistent with the harvest of herded caprines (Peters, von den Driesch, and Helmer 2005; Peters et al. 1999). Sheep seem to have been the initial early focus of herd management here, with managed goats introduced from elsewhere at about 10,200 cal BP (Peters, von den Driesch, and Helmer 2005:111). Helmer’s (2008) recent reconsideration of the faunal remains from Cafer Höyük, (ca. 10,300–9500 cal BP), which focuses on sex ratios and harvest profiles, leads him to conclude that sheep (and likely goats) at this site, though morphologically wild, were not hunted animals, as he had originally thought (Helmer 1991). Instead, he maintains that these were “agriomorphic” herded animals, a new term he coins for “domestic animals which are morphologically close to wild ones” (Helmer 2008:169).

At Aşıklı Höyük in central Anatolia (ca. 10,200–9500 cal BP), Buitenhuis (1997; also Vigne, Buitenhuis, and Davis 1999) has detected demographic evidence for management of morphologically wild caprines, predominately sheep. Arbuckle’s (2008) analysis of faunal remains from Suberde, a site roughly contemporaneous with the latest occupation phases at Aşıklı Höyük and the initial occupation of Çatal Höyük (ca. 9500–8900 cal BP), questions the original interpretation of this site as a “hunters’ village” (Perkins and Daly 1968). Demographic patterns detected among the caprines at this site (again mostly sheep) are instead argued to represent an early and perhaps transitional form of management of morphologically unaltered animals. Management of morphologically domesticated sheep and goats is found in central Anatolia by 9500 cal BP in basin occupation levels of Çatal Höyük (Russell and Martin 2005).

Moving farther south, the first appearance of goats in the assemblage from Abu Hureyra (ca. 9600 cal BP) is accompanied by demographic data that suggest culling strategies similar to those detected at Ganj Dareh (Legge 1996; Legge and Rowley-Conwy 2000). Goats dominate the assemblage from the site after about 9300 cal BP, reversing a many-millennia emphasis on hunted gazelle. A similar replacement of a once-dominant focus on gazelles by one on goats is seen first in the Jordan Valley during the Middle PPNB (10,000–9200 cal BP), with an emphasis on gazelle still evident on the Mediterranean coastal plain until the Final PPNB/Pre-Pottery Neolithic C (ca. 8500 cal BP; Horwitz 2003; Horwitz et al. 1999; Sapir-Hen et al. 2009). Horwitz interprets demographic patterns observed in morphologically wild goats from Middle PPNB sites in the Jordan Valley (composed of immature males and adult females) as evidence of an ongoing process of independent domestication (Horwitz 1993, 2003). Other researchers have argued that these managed goats were introduced from outside the region (Bar-Yosef 2000; Peters et al. 1999). Managed sheep were a late arrival in the Levant, appearing sometime around 9200 cal BP (Horwitz and Ducos 1998). The introduction of managed sheep was also delayed in the eastern arm of the Fertile Crescent, where a shift toward adult-female-dominated assemblages appears in both highland and lowland sites in the Zagros at about 9000 cal BP (Zeder 2008).

Cattle. The outlines of cattle (Bos taurus) domestication in the Near East are still sketchy. Although cattle remains from
Early and Middle PPNB (11,000–10,000 cal BP) sites in the upper and Middle Euphrates valley fall within the size range of wild aurochs (*Bos primigenius*), Helmer finds evidence for a reduction in the degree of sexual dimorphism at several sites (especially at Halula and Dja’de, but less so at Cafer Höyük and Aswad) that he links to an ongoing process of domestication (Helmer 2008; Helmer and Gourichon 2008; Helmer et al. 2005). Cattle from contemporary sites in the same region (i.e., Mureybit III, Jer el Ahmar, and Göbekli) are still highly sexually dimorphic and are thus seen as representing wild, hunted cattle. Domestic cattle spread slowly out of this heartland of initial domestication, reaching the southernmost reaches of the Levant only during the Late PPNB (9500–9000) at the earliest (Horwitz et al. 1999) and the southern Zagros around 8500 cal BP (Hole, Flannery, and Neely 1969:303).

In the 1960s, Perkins argued for a center of cattle domestication in central Anatolia on the basis of an initial study of remains from Çatal Höyük (Perkins 1969). The analysis of a large sample of remains from the renewed excavations at the site, however, does not support this conclusion (Russell, Martin, and Buitenhuis 2005). Catal Höyük cattle show no evidence of body-size reduction, as had been claimed by Perkins, and are dominated by older male animals in earlier levels (ca. 9400–8500 cal BP). Final occupation levels at the site (ca. 8500–8300 cal BP) see a shift toward a female-dominated profile, although the continued emphasis on animals older than 4 years of age raises doubts about the domestic status of these animals.

**Pigs.** In pigs (*Sus scrofa*), a reduction in the size of molars, especially in the length of the M3, is thought to be an early marker of domestication (Flannery 1983). Changes in molar lengths in pigs have been linked to a neotomization of skull morphology, which itself is believed to be an artifact of the selection for reduced aggression in animals undergoing domestication. A similar morphological response is also seen in dogs, where juvenilization of skull morphology is thought to result in tooth crowding and size reduction. Like pigs, dogs are animals thought to have entered into domestication through a commensal route initiated when less wary individuals approached human habitations to scavenge for food (Zeder, forthcoming). It is hard to know, then, whether the initial changes in skull, jaw, and tooth morphology seen in these animals reflect the initiation of a true domestic partnership with humans or simply an adaptation to anthropogenic environments required of commensal animals. The large litter sizes of wild pigs and the demographic partitioning of wild boar herds may result in prey profiles that mimic what might be expected with management, complicating the application of demographic modeling to distinguish between hunting and herding of pigs.

Redding has reported that pigs at Hallan Cemi show some evidence of tooth-size reduction (Redding and Rosenberg 1998). He also interprets an increase in the numbers of pigs through time at the site and data on age and sex as indicative of a developing association between humans and wild boar (Redding 2005; Rosenberg et al. 1998; Rosenberg and Redding 2000). The larger data set from nearby Çayönü clearly shows gradual change in multiple indexes (tooth size, age structure, and biometry) thought to reflect a gradual process in which pigs moved from a wild to a commensal to a fully domestic status (Ervynck et al. 2001). Helmer’s (2008) recent reevaluation of the Çatal Höyük fauna leads him to conclude that on the basis of demographic patterns, domestic pigs were present at the site by 10,300 cal BP.

As with sheep and cattle, pigs seem to have spread slowly down the western and eastern arms of the Fertile Crescent. Domestic pigs are thought to have been present in Middle PPNB levels at Aswad (Helmer and Gourichon 2008), but they did not reach the southernmost end of the Levantine corridor until about 9000–8500 cal BP (Horwitz et al. 1999). Domestic pigs have been identified at Jarim in the northwestern Zagros by 9000 cal BP (Flannery 1983), but they did not reach lowland southwestern Iran until 6000 cal BP (Hole, Flannery, and Neely 1969). Swine are not evident in central Anatolia until sometime after about 8500 cal BP (Martin, Russell, and Carruthers 2002).

**New Genetic Insights into Plant and Animal Domestication.**

Plants. Heun et al.’s (1997) study of domestic einkorn, one of the first multilocus genetic analyses of Near Eastern founder crops, concluded that this crop plant had a monophyletic origin. This work traced the ancestry of all modern domestic einkorn to a single wild population growing on Karacadag volcano in southeastern Turkey, only a few kilometers from archaeological sites that have yielded the earliest evidence of single-grained einkorn domestication. A monophyletic origin of this domestic cereal is consistent with a highly localized and relatively rapid domestication process (Brown et al. 2008). A subsequent study by Kilian et al. (2007), however, contends that the wild race named by Heun et al. (1997) as the ancestor of domestic einkorn is instead a closely related sister group. This more distant relationship and the high level of genetic diversity evident in domestic einkorn, they maintain, argues against a monophyletic origin of this early cereal crop. Their study does not find support for a polyphyletic model in which multiple geographically and genetically distinct races were separately brought under domestication (see Jones 2004). Instead, they propose a “dispersed specific model” in which multiple local populations of the originally more widely distributed sister race of wild einkorn were taken under cultivation and eventually domesticated multiple times by communities across a broad area. This model is more in line with archaeological evidence indicating that multiple communities from southeastern Turkey to the Middle Euphrates were involved in a protracted process of cultivation of both local and imported wild progenitors of later crop plants (Wilcox 2005). Heun, Haldorsen, and Vollan (2008) have since defended their
initial determination of a monophyletic origin of single-grained einkorn in southeastern Turkey. They also suggest, however, that the Middle Euphrates may have been the site of the domestication of a now extinct two-grained variety of wheat from *Triticum urartu*, a more arid-adapted wheat that commonly contains two-grained spikelets.

Similarly, earlier genetic analyses of domestic emmer had concluded that this crop plant had a monophyletic origin with the closest living wild population found in the same Karacadag region identified as the home of einkorn domestication (Ozkan et al. 2002). Subsequent studies now point to at least two separate domestications of emmer (Brown et al. 2008). The geographic distance and degree of cultural independence between these events are unclear. In addition to a major domestication event at Karacadag, Ozkan et al. (2005) now think that there may have been another secondary domestication of a population near the Kartal Mountains 300 km to the west of Karacadag. They find no evidence that populations from the southern Levant were involved in emmer domestication, although there is some indication that populations in Iraq and Iran may have contributed to the gene pool of domesticated emmer (Ozkan et al. 2005:1057).

Luo et al. (2007) agree that emmer was most likely first domesticated in southeastern Turkey, but they also propose that there was subsequent hybridization and introgression into domesticated emmer from wild emmer in the southern Levant. A less likely scenario for the results of their analysis is that a population of wild emmer was independently domesticated in the southern Levant and later absorbed into the gene pool of domesticated emmer from southeastern Turkey.

Initial indications of a single domestication of barley in the Jordan Valley (Badr et al. 2000) have also recently been revised to accommodate a second domestication of this crop. Morell and Clegg’s (2007) study of wild and traditional races of cultivated barley from the Levant to western China has found evidence of the domestication of a variety of barley ancestral to landraces grown in Central and East Asia. Thought to have occurred in the Zagros, this second, geographically quite distinct domestication corresponds well to archaeological evidence that finds domesticated barley in Zagros sites at about 10,000 years ago (van Zeist et al. 1984).

There is also a concordance between archaeological and phylogeographic evidence for pulse domestication. The wild chickpea population genetically closest to domestic chickpeas was found growing at the far western end of the current distribution of this plant in southern Turkey (Sudupak, Akkaya, and Kence 2004), the closest wild samples to Tel el-Kerkh, which, as noted above, yielded early evidence for cultivation of this important Near Eastern pulse crop. Genetic evidence also points to the initial domestication of lentils somewhere in southeastern Turkey or northern Syria (Ladizinsky 1989), where there is early evidence for the initial chickpea cultivation. The appearance of quantities of cultivated lentils at contemporary sites such as Gigal suggests that this pulse crop spread quickly out of the homeland of initial domestication into the southern Levant (Weiss, Kislev, and Hartmann 2006). A separate southern Levantine domestication of a variety of lentils no longer represented among modern domestic lentils cannot, however, be ruled out.

Animals. While there are multiple genetically distinguishable lineages in all major livestock species (Bradley 2006), the degree to which these different lineages represent spatially and temporally discrete “domestication events” in which different populations were brought under domestication independently of one another is not entirely clear (Dobney and Larson 2006). In domestic goats, for example, there now appear to be as many as six highly divergent maternal lineages. These include the three lineages originally identified by Luikart et al. (2001, 2006)—a dominant A lineage and smaller B and C lineages—and three additional lineages (D, F, and G) identified in the past few years (Chen et al. 2005; Joshi et al. 2004; Naderi et al. 2007; Sultana, Mannen, and Tsuji 2003). The divergence of these lineages has considerable time depth (ca. 100,000–500,000 years), suggesting that each represents a different segment of a larger wild goat population brought under domestication (Naderi et al. 2007). A genetic analysis of a large sample of modern wild bezoar (*Capra aegargrus*) goats from Iran, Iraq, and Turkey finds all six major domestic maternal lineages represented in present-day bezoar populations (Naderi et al. 2008), patterning that, as Naderi et al. (2008) argue, traces its roots to the Early Holocene. The weak phylogeographic structure of the domestic lineages among these bezoars is seen as an artifact of human translocation of animals during the initial phases of the domestication process, before the morphological modifications that separate wild from domestic goats arose. Evidence of rapid population growth among bezoars belonging to the C lineage resembles that found in domestic goats in Iran and is not seen among bezoars that do not belong to domestic lineages. This pattern is taken as a further sign of human-mitigated demographic control and protection of bezoars before complete isolation of managed animals from wild ones. Bezoars belonging to the now-dominant A domestic matriline are concentrated in eastern Turkey, conjectured to be the most likely region of initial management of A-lineage goats. While C-lineage bezoars are most frequently found in southern and central Iran, the C-lineage bezoars most closely related to C-lineage domestic goats were found in southeastern Anatolia. These bezoars are thought to be the descendents of animals translocated from southern Iran that, along with A-lineage goats, were the first herded goats to leave the homeland of initial management, animals whose remains are found at sites such as Nevali Çori at 10,200 cal BP.

This study indicates, then, that all six modern maternal lineages of domestic goats were brought under initial human management in a region that stretches from the eastern Taurus to the southern Zagros and Iranian Plateau. Although this process apparently involved individual communities taking local populations of wild goats under control, the geographic
A New Picture of Agricultural Origins in the Near East

The emerging picture of plant and animal domestication and agricultural origins in the Near East is dramatically different from that drawn 16 years ago in the landmark Bar-Yosef and Meadow (1995) article. In 1995, there appeared to have been at least a 1,500-year gap between initial crop domestication (ca. 11,400 cal BP) and livestock domestication (ca. 10,000 cal BP). It now seems that plant and animal domestication occurred at roughly the same time, with signs of initial management of morphologically wild future plant and animal domesticates reaching back to at least 11,500 cal BP, if not earlier.

At the time this influential article was published, it appeared that the southern Levant was the core area for initial domestication, and a case could be made that all subsequent crop and livestock domestication in other parts of the Fertile Crescent followed on the precedent of the crops, domestic technology, and the Neolithic way of life introduced from this core region. Since then, the spotlight has shifted to the central Fertile Crescent, especially the upper reaches of the Tigris and Euphrates rivers, which appears to be the homeland of the initial domestication of a number of founder crops (einkorn, emmer, pulses) and three, if not four, livestock species (sheep, pigs, cattle, and possibly goats). By the late 1990s, a compelling case could be made that this region was a “cradle of agriculture” in a true Vavlovian sense (Lev-Yadun, Gopher, and Abb000). Genetic and archaeobiological evidence generated since then paints a much less focused, more diffuse picture of agricultural origins. The emergence of agriculture in the Near East now seems to have been a pluralistic process with initial domestication of various crops and livestock occurring, sometimes multiple times in the same species, across the entire region.

In 1995, morphological change in both plants and animals marked the threshold between wild and domestic. We now know that morphological change may have occurred quite late in the domestication process and can no longer be considered a leading-edge indicator of domestication. In cereals, the transition from brittle to tough rachises may actually have been the result of changes in harvest timing and technology that took place well after people began sowing harvested seed stock. In pulses, seed-size change lagged behind changes in seed dormancy and plant yield that cannot be detected in the archaeological record. In animals, the impact of human management on body size is now known to have been restricted to a decrease in the degree of sexual dimorphism; alterations in skull morphology may have resulted from a developing commensal relationship rather than a two-way domestic partnership; and changes in horn size and form may, like changes in rachis morphology, have reflected a change in management practice rather than the initiation of animal management. In fact, in both plants and animals, archaeologically detectable morphological indicators of domestication may have occurred only once managed plants and animals were isolated from free-living populations and the opportunity for introgression or restocking managed populations with wild ones was eliminated. While some may prefer not to call a plant or an animal a domesticate until this separation has occurred, concentrating solely on this late stage of the process will not help us understand how it began.

When Bar-Yosef and Meadow published their synthesis article, it seemed to have taken up to 2,000 years after initial domestication of both plants and animals for fully developed agricultural economies to coalesce across the entire Fertile Crescent. With the removal of morphological change as a leading-edge indicator of domestication, this process seems to have taken longer still. Stable and highly sustainable subsistence economies based on a mix of free-living, managed,
and fully domesticated resources now seem to have persisted for 4,000 years or more before the crystallization of agricultural economies based primarily on domestic crops and livestock in the Near East.

The exciting recent discoveries on Cyprus provide a special perspective on this long period of low-level food production (sensu Smith 2001) in the mainland Fertile Crescent. This work has produced solid evidence for the early importation of morphologically domesticated cereals (einkorn, emmer, and barley) and morphologically wild but managed animals (goats and cattle) to Cyprus by 10,500 cal BP, with managed pigs possibly brought to the island even earlier (Vigne, Carrère, and Guillaume 2003; Vigne et al. 2011; Willcox 2003). This means that at the same time that the earliest morphologically domesticated einkorn and emmer is found in the Upper Euphrates valley (and even earlier than there is solid evidence for morphologically altered domestic barley) and when we see the first indications of animal management in the mainland Fertile Crescent, people were loading these managed plants and animals into boats and carrying them, along with the knowledge of how to successfully care for them, to an island 160 km off the Levantine coast. The importation and successful exploitation of these nascent domesticates on Cyprus, where none of these plants and animals occur naturally, suggests that human control over these budding domesticates was more established than is apparent on the mainland, where the likely continued utilization of free-living populations of these species makes it hard to determine the degree of human investment in plant and animal management.

What is perhaps even more interesting about the Cyprus data is that people also imported fallow deer and foxes to the island, as well as other elements of the mainland biotic community that do not appear to have been subjected to the same degree of human control. People who colonized Cyprus in the eleventh millennium did not selectively choose to import only those plants and animals with which they had a developing domestic partnership. Instead, they seem to have transported from the mainland their entire ecological niche, made up of a wide range of economically important species exploited with a diverse array of more and less intensive strategies. It is unlikely that these early pioneers drew strict classificatory boundaries between resources collected from free-living populations, resources that required a higher degree of encouragement and protection from competition or predation, and resources that had begun to show physiological, behavioral, or morphological responses to human management. They simply took with them the world that they knew. The apparent relaxation of management strategies over time that Vigne, Carrère, and Guillaume (2003) have proposed for goats (perhaps because of the lack of major predators and a reduced threat from human poaching on this sparsely inhabited island) underscores the fluidity of exploitation strategies and the blurring of distinctions between degrees of engagement in the management of important resources that existed at that time.

This backward look at the mainland from Cyprus provides us with new insight into the initial context of plant and animal domestication in the Near East. It suggests that domestication and agriculture arose in the context of broad-based systematic human efforts at modifying local environments and biotic communities to encourage plant and animal resources of economic interest, a practice that has been characterized as human niche construction or ecosystem engineering (Smith 2007a, 2007b, 2011). The data emerging over the past 15 years clearly indicate that active human engagement in ecological niche construction was taking place across the entire Fertile Crescent during a period of dramatic post-Pleistocene climate and environmental change (Bar-Yosef 2011), with considerable regional variation in the scope and intensity of these activities as well as in the range of resources being manipulated. In certain instances, this context of human niche construction gave rise to coevolutionary relationships between humans and certain species that eventually resulted in a full-fledged domestic partnership, as it did with einkorn, emmer, and pulses in southeastern Anatolia, with barley in both the southern Levant and the Zagros, and with the four major livestock species in different parts of the broad territory between Anatolia to southern Iran. In others instances, the relationship never developed beyond the first tentative steps toward domestication. Failure to move beyond these initial stages of the domestication process may have been due to either behavioral or biological barriers on the part of the plant or animal species, as perhaps in the case of gazelle in the southern Levant that are behaviorally unsuited to domestication or with rye that could not survive conditions of increasing heat and aridity in the northern Levant. Or it might simply be due to a lack of follow-through by humans, as may have happened with wild oats that were likely cultivated in the southern Levant during the PPNA but were not domesticated until much later.

This broad middle ground between wild and domestic, foraging and farming, hunting and herding makes it hard to draw clean lines of demarcation between any of these states. Perhaps this is the greatest change in our understanding of agricultural origins since 1995. The finer-resolution picture we are now able to draw of this process in the Near East (and, as seen in the other contributions to this volume, in other world areas) not only makes it impossible to identify any threshold moments when wild became domestic or hunting and gathering became agriculture but also shows that drawing such distinctions actually impedes rather than improves our understanding of this process. Instead of continuing to try to pigeonhole these concepts into tidy definitional categories, a more productive approach would be to embrace the ambiguity of this middle ground and continue to develop tools that allow us to watch unfolding developments within this neither-nor territory.

In the Near East, this means looking more closely at the relationships between humans and plants and animals, especially within the natural habitats of future domesticates.
Continuing to develop archaeobiological and archaeological tools for examining these evolving relationships will be key, as will the development of new genetic approaches, including, one hopes, the analysis of ancient DNA of plant and animal remains from Near Eastern archaeological contexts. In 2011, we are clearly on the cusp of a new understanding of agricultural origins in the Near East and elsewhere. One can only imagine what the picture will look like in 2025.

Acknowledgments

I am very grateful to Ofer Bar-Yosef and Doug Price for including me among the participants of the Mérida conference and to the Wenner-Gren Foundation for sponsoring this wonderful meeting. Both the venue and the unique format of this meeting made it the single most enjoyable and productive one I have ever attended. The opportunity to interact with the varied group of researchers brought together in Mérida, both in formal sessions and in less-formal evening meetings on the veranda of the Hacienda Temozon, had a transformative impact on my understanding of agricultural origins—as a general process and as it played out in the many world areas where domestication arose and spread. This paper could not have been written without this intensive and most rewarding meeting. The manuscript also benefited from the comments of two anonymous reviewers and the gentle (and sometimes not so gentle) suggestions and proddings of the conference organizers/volume editors.

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The Neolithic Southwest Asian Founder Crops
Their Biology and Archaeobotany

by Ehud Weiss and Daniel Zohary

This article reviews the available information on the founder grain crops (einkorn wheat, emmer wheat, barley, lentil, pea, chickpea, and flax) that started agriculture in Southwest Asia during the Pre-Pottery Neolithic period, some 11,000–10,000 years ago. It provides a critical assessment for recognizing domestication traits by focusing on two fields of study: biology and archaeobotany. The data in these fields have increased considerably during the past decade, and new research techniques have added much to our knowledge of progenitor plants and their domesticated derivatives. This article presents the current and accumulated knowledge regarding each plant and illustrates the new picture that emerged on the origin of agriculture.

Introduction

The occasion of the Wenner-Gren conference “The Origins of Agriculture: New Data, New Ideas” raised our awareness of the importance of critical, high-quality data. We suspected that the newly obtained data sets from well-dated archaeological contexts may generate new hypotheses concerning the first steps of the agricultural revolution in Southwest Asia.

For this purpose we concentrated on two domains: the newly obtained rich archaeobotanical assemblages and the molecular analysis of present-day accessions. Some of these new data are inconclusive for pinpointing the shift from wild to domesticated plants because of bad preservation of the archaeological samples and problematic field or lab procedures. Following the fruitful discussions during the conference, we critically reassessed the available archaeobotanical data in an attempt to “separate the grain from the chaff.” In the following pages we present the data sets, both old and new, that we consider to be reliable enough to indicate the first appearances of domesticated forms in the Fertile Crescent.

Eight plants are considered to be the domesticated founder crops in the Levant (i.e., the western “arc” of the “Fertile Crescent”; table 1). This assemblage includes three cereals (einkorn wheat Triticum monococcum, emmer wheat Triticum turgidum subsp. dicoccum, and barley Hordeum vulgare), four pulses (lentil Lens culinaris, pea Pisum sativum, chickpea Cicer arietinum, and bitter vetch Vicia ervilia), and a single oil and fiber crop (flax Linum usitatissimum).

From many aspects these eight plants belong to the same group—the grain crops. All of them are annuals, self-pollinated, diploid (except emmer wheat), native to the Fertile Crescent belt, and interfertile within each crop and between the crop and its wild progenitor. Both the agronomic compensation and the dietary complementation between plants in this group have been appreciated since the early days of agriculture up until now.

The aim of this article is to review the available information on these founder crops that started agriculture in the Levant during the Pre-Pottery Neolithic (PPN) period some 11,000–10,000 years ago (table 2). We shall review the current knowledge of these plants by focusing on two fields of study: (i) biology and (ii) archaeobotany. Biological data derived from the research on living plants can indicate what the wild progenitors of the domesticated plants may have been and what the selection pressures for domesticated types were. Archaeobotanical information identifies the plants used by hunting and gathering groups, which were the plants first domesticated, and when and where these processes took place.

Large amounts of critical new data, botanical and archaeological, have been gathered in the Fertile Crescent belt in the past 40 years (fig. 1). These findings established the Levant as the critical area for understanding early domestication of both plants and animals (and see additionally Zeder 2011). (Note that we use the terms “Southwest Asia” and “Near East arc” interchangeably in this article; we also use the term “Levant” to refer to the western horn of the Fertile Crescent in the Near East.)
In this article we will adopt a critical assessment intended to recognize domestication traits in Levantine archaeobotany (Zohary, Hopf, and Weiss 2011). In some way this assessment is partially intended to follow and update Mark Nesbitt’s (2002) article. The basics of this assessment are twofold.

1. The most reliable trait for the identification of domestication is ear shattering in the cereals, pod indehiscence in the pulses, and capsule indehiscence in flax. In wild plants, ears and pods/capsules disarticulate at maturation and shatter the seed-dispersal devices or the seeds; in contrast, ears and pods/capsules stay intact in the domestic plant. This trait is the best effective diagnostic indication for recognizing grain-crop domestication (i.e., the shift from wild plants to domesticated plants), which is controlled mostly by a single major gene locus or two such loci (table 3).  

2. The second diagnostic morphological trait is seed size. In the wild progenitors the seeds are relatively small, while in domesticated plants they are frequently larger. This trait takes longer to develop, it is variable within the plant community, it is apparently a later development under domestication, and it is not as diagnostic as the first trait. This trait is controlled by various genes and other factors.

Additional markers for domesticated traits (e.g., Fuller 2007) are relevant mostly for differentiating between wild and domesticated traits in living plants. This is apparently much less so in the archaeobotanical assemblage.

During the past decade or so, molecular studies became central in research toward understanding the beginning of agriculture. Whether the mode of domestication was monophyletic or polyphyletic, these studies went in two lines (Brown et al. 2009). In the first half of this decade, molecular studies were regarded as supporting monophyletic origin of a single localized event or at least very rare events (e.g., Badr et al. 2000; Heun et al. 1997; Özkhan et al. 2002). In the second half, however, such studies were interpreted as supporting polyphyletic domestication of multiple events in more than one location, such as of einkorn wheat (Kilian et al. 2007) and barley (e.g., Molina-Cano et al. 2005; Morrell and Clegg 2007). An attempt is made to evaluate the available knowledge, crop by crop, for the above-mentioned signs of the earliest definite domesticates as well as molecular and other biological data.

From the eight founder crops, this article does not deal with bitter vetch *Vicia ervilia*. According to its large quantities in Neolithic contexts, this pulse might have been taken into domestication in Anatolia or the Levant (i.e., in the general area in which it still grows wild today). However, because currently there are no reliable diagnostic traits to morphologically discriminate between its wild and domesticated forms in archaeological remains, the early Turkish finds could be either.

The source of most dates is Radiocarbon CONTEXT database (Böhner and Schyle 2002–2006). Table 4 lists the uncalibrated and calibrated radiocarbon dates. In an attempt to simplify understanding of the domestication process, all dates in the text are representative dates only and were rounded to the nearest 50 years (please refer to table 4 for range of dates). Periods mentioned in this article, such as Pre-Pottery Neolithic A (PPNA) or Early Pre-Pottery Neolithic B (EPPNB), do not necessarily imply cultural similarities but are used for the convenience of comparing among sites that belong to the same approximate time period.

<table>
<thead>
<tr>
<th>Table 2. Cultural-historical sequence for the Southern Levantine Pre-Pottery Neolithic periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period and entity/phase</td>
</tr>
<tr>
<td>Late Epipaleolithic, Final Natufian</td>
</tr>
<tr>
<td>PPNA</td>
</tr>
<tr>
<td>PPNB: Early</td>
</tr>
<tr>
<td>PPNB: Middle</td>
</tr>
<tr>
<td>PPNB: Late</td>
</tr>
<tr>
<td>Final/PPNC</td>
</tr>
<tr>
<td>Early Pottery Neolithic, Yarmukian</td>
</tr>
<tr>
<td>Note. PPNA = Pre-Pottery Neolithic A; PPNB = Pre-Pottery Neolithic B; PPNC = Pre-Pottery Neolithic C.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1. Eight founder grain (three grass [cereal], four legume [pulse], and one oil and fiber) crops and their wild progenitors that started Neolithic agriculture in the Levant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domesticated crop</td>
</tr>
<tr>
<td>Common name</td>
</tr>
<tr>
<td>Einkorn wheat</td>
</tr>
<tr>
<td>Emmer wheat</td>
</tr>
<tr>
<td>Barley</td>
</tr>
<tr>
<td>Lentil</td>
</tr>
<tr>
<td>Pea</td>
</tr>
<tr>
<td>Chickpea</td>
</tr>
<tr>
<td>Bitter vetch</td>
</tr>
<tr>
<td>Flax</td>
</tr>
</tbody>
</table>

Note. *Linum usitatissimum* (flax), *Vicia ervilia* (bitter vetch), *Cicer arietinum* (chickpea), *Pisum sativum* (pea), *Lens culinaris* (lentil), *Hordeum vulgare* (barley), and *Triticum turgidum* (emmer) were all domesticated in the Levant. The *Triticum monococcum* (einkorn) and *Triticum dicoccon* (emmer) species were also domesticated outside of the Levant.
Cereals

Einkorn Wheat Triticum monococcum

Biology. Einkorn is a small plant, rarely more than 70 cm high, with a relatively low yield, but it survives on poor soils where other wheat types usually fail. It is a relatively uniform diploid (2n = 2x = 14 chromosomes) wheat with characteristic hulled grains and delicate ears and spikelets. Most domesticated einkorn varieties produce one grain per spikelet, hence its name, but cultivars with two grains exist as well (Harlan 1981; Schiemann 1948).

The wild ancestry of domesticated einkorn wheat is well established. Domesticated Triticum monococcum is closely related to a group of wild and weedy wheat forms spread over Southwest Asia and adjacent territories and traditionally referred to as “wild einkorn” or Triticum boeoticum. The most distinguishing trait between wild einkorn and domesticated einkorn is the mode of seed dispersal. Wild forms have brittle ears, and the individual spikelets disarticulate at maturity to disperse the seed. In domesticated einkorn the mature ear remains intact and breaks into individual spikelets only on pressure (threshing). The shape of the grain is another diagnostic character indicating domestication (van Zeist 1976).

In domesticated forms, the kernels tend to be wider compared with the wild forms.

Wild einkorn is widely distributed over Western Asia and penetrates also into the southern Balkans (Harlan and Zohary 1966; Zohary, Harlan, and Vardi 1969). Its distribution center lies in the Fertile Crescent (i.e., northern Syria, southern Turkey, northern Iraq, and adjacent Iran, as well as some parts of western Anatolia; fig. 2). In these regions, wild einkorn is massively distributed as a component of oak park-forests and steppelike formations.

Heun and colleagues (Heun, Haldorsen, and Vollan 2008; Heun et al. 1997) analyzed domesticated and wild einkorn from the Fertile Crescent and beyond for amplified fragment length polymorphism (AFLP) DNA analysis. According to their research, wild einkorn wheat was domesticated in the Karacadag range in southeast Turkey. It also supports the assumption of its monophyletic origin. These findings were recently supported by Kilian et al. (2007), who found, however, that several domesticate lines arose at the beginning of einkorn cultivation (i.e., that einkorn went through a number of independent domestication events). These lines are all part of the einkorn gene pool that grows wild in southeastern Turkey.

Archaeobotany. The earliest definite domesticated einkorn
wheat appears in two EPPNB sites, namely ca. 10,600–9900 cal BP Çayönü (van Zeist and de Roller 1991–1992, 2003) and Cafer Höyük (de Moulins 1997), southern Turkey (fig. 1). In these sites, situated within the present range of distribution of wild einkorn (fig. 2), numerous charred spikelet forks were found showing rough breakage scars.

From these localities, einkorn spreads farther south to Middle Pre-Pottery Neolithic B (MPPNB), ca. 10,200–9550 cal BP, Tell Aswad near Damascus (van Zeist and Bakker-Heeres 1982 [1985]) and Jericho (Hopf 1983), where its remains, however, are relatively few. Generally, this wheat appears to be less frequent than the emmer wheat and barley.

**Emmer and Durum-Type Wheats Triticum turgidum**

*Biology.* *Triticum turgidum* is a varied aggregate of domesticated and wild tetraploid (2n = 4x = 28 chromosomes) wheats. According to their response to threshing, the domestic *turgidum* wheats fall into two groups of cultivars that are recognizable in archaeological remains.

1. Hulled nonshattering emmer wheat, *Triticum turgidum* subsp. *dicoccum* (traditionally called *Triticum dicoccum*), in which the products of threshing are the individual spikelets. The grains remain invested by the glumes and pales. In domestic emmer, as in einkorn, threshing results in breaking the rachis of the ear in its weakest points below each spikelet. Emmer represents the primitive situation in domesticated *turgidum* wheats.

2. The more advanced free-threshing emmer, which evolved under domestication from hulled emmer. This is a group of intraspecific taxa; its common representative today is durum wheat, *T. turgidum* conv. *durum*. The glumes in all these domesticated tetraploid types are relatively thin. Threshing breaks the glumes at their bases and frees the naked grains. The rachis is usually uniformly tough. Threshing breaks it into irregular fragments.

Hulled emmer (*T. turgidum* subsp. *dicoccum*) was the principal wheat of Old World agriculture in the Neolithic and early Bronze Age.

Genetic and morphological evidence clearly indicates (for review, see Feldman, Lupton, and Miller 1995; Zohary 1969) that the domesticated tetraploid *turgidum* wheats (both hulled *dicoccum* forms and free-threshing durum-type varieties) are closely related to wild wheat native to Southwest Asia and traditionally called *Triticum dicoccoides* (wild emmer wheat). This is annual, predominantly self-pollinated wheat with characteristic large and brittle ears and big elongated grains that show a striking similarity to some domesticated emmer and durum cultivars.

In the tetraploid *turgidum* wheats, the most conspicuous diagnostic difference between wild and tame is the seed-dispersal mechanism (Zohary 1969; Zohary and Brick 1961). Wild *dicoccoides* wheats have brittle ears that shatter on maturity into individual spikelets. Each spikelet operates as an arrowlike device disseminating the seed by inserting them into the ground. The “wild-type” rachis disarticulation and the spikelet morphology reflect specialization in seed dissemination that ensures the survival of the wild forms under wild conditions. In the human-made system of reaping, threshing, and sowing, this major adaptation broke down, and selection resulted in the evolution of human-dependant nonbrittle types. Significantly, the shift from a brittle spike (in wild *dicoccoides* wheats) to a nonbrittle spike (“hulled type” in domesticated *dicoccum* wheats) is governed by a single recessive mutation in a major gene (table 3). In addition, wild and domesticated forms differ from one another in kernel morphology (van Zeist 1976). In domesticated *dicoccum* and durum forms, the grain tends to be wider and thicker as well as rounder in cross section compared with the wild *dicoccoides* counterpart.

Wild emmer, *T. turgidum* subsp. *dicoccoides*, is more restricted in its distribution and more confined in its ecology than wild einkorn. Its range covers Israel, Jordan, southwestern Syria, Lebanon, southeastern Turkey, northern Iraq, and western Iran (fig. 3).

At first, molecular studies placed a probable single origin of emmer wheat in Turkey. Özkan and colleagues (Özkan et al. 2002; Salamini et al. 2002) examined 204 AFLP loci of 99 wild emmer lines from all over the Fertile Crescent belt and

Table 3. Recessive mutations that changed wild-type trait into domestic-type trait in the Near East founder crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Wild-type trait</th>
<th>Domestication trait</th>
<th>No. recessive mutations</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einkorn wheat</td>
<td>Shattering ears</td>
<td>Nonshattering ears</td>
<td>1</td>
<td>Love and Craig 1924</td>
</tr>
<tr>
<td>Emmer wheat</td>
<td>Shattering ears</td>
<td>Nonshattering ears</td>
<td>2</td>
<td>Sharma and Waines 1980</td>
</tr>
<tr>
<td>Barley</td>
<td>Shattering ears</td>
<td>Nonshattering ears</td>
<td>2</td>
<td>Takahashi 1955; Zohary 1960:41</td>
</tr>
<tr>
<td>Lentil</td>
<td>Dehiscent pod</td>
<td>Dehiscent pod</td>
<td>1</td>
<td>Ladzinsky 1979</td>
</tr>
<tr>
<td>Pea</td>
<td>Dehiscent pod</td>
<td>Indehiscent pod</td>
<td>1</td>
<td>Waines 1975</td>
</tr>
<tr>
<td>Chickpea</td>
<td>Dehiscent pod</td>
<td>Indehiscent pod</td>
<td>1</td>
<td>Kazan et al. 1993</td>
</tr>
<tr>
<td>Bitter vetch</td>
<td>Dehiscent pod</td>
<td>Indehiscent pod</td>
<td>1</td>
<td>Diederichsen and Hammer 1995; Gill and Yermanos 1967</td>
</tr>
<tr>
<td>Flax</td>
<td>Dehiscent capsule</td>
<td>Indehiscent capsule</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Note. These mutations are responsible for the shift from wild-type seed dispersal to human-dependent crops. There is no conclusive information yet regarding the situation in bitter vetch.
several dozen different cultivars. They concluded that the most likely place of origin for emmer wheat is the Karacadag Mountains in southeastern Turkey. There is, however, still a debate regarding the validity of these results and the number of possible domestication events as attested by recent molecular studies (e.g., Brown et al. 2009; Feldman and Kislev 2007). As Feldman and Kislev (2007) pointed out recently, the data of Mori et al. (2003), Özkan et al. (2002, 2005), and Luo et al. (2007) may indicate a diphyletic or polyphyletic origin of domesticated emmer, possibly in the Karacadag area, as well as in the southern Levant.

Archaeobotany. Hullled emmer wheat. The earliest fully convincing sign to date of domesticated emmer comes from the numerous spikelet forks retrieved from EPPNB, ca. 10,600–9900 cal BP, Çayıönü (van Zeist and de Roller 1991–1992, 2003). Here, hundreds of spikelet forks were discovered, all showing rough breakage scars characteristic of domestic emmer. Numerous spikelet forks, with similar telltale rough scars, are also available from contemporary contexts at Cafer Höyük (de Moulins 1997). These finds indicate that at EPPNB, emmer domestication must have been well under way in the Fertile Crescent. We wish to have more data before being fully convinced about the domestication status of the EPPNB Cypriot find from Kissonegera-Mylouthkia and Shillourokambos (Murray 2003; Willcox 2000). Here, hundreds of spikelet forks were discovered, all showing rough breakage scars characteristic of domestic emmer. Numerous spikelet forks, with similar telltale rough scars, are also available from contemporary contexts at Cafer Höyük (de Moulins 1997). These finds indicate that at EPPNB, emmer domestication must have been well under way in the Fertile Crescent. We wish to have more data before being fully convinced about the domestication status of the EPPNB Cypriot find from Kissonegera-Mylouthkia and Shillourokambos (Murray 2003; Willcox 2000).
plump kernels start to appear in the lowest habitation level, Ia (ca. 10,500–10,200 cal BP; Willcox 2005), and also in MPPNB phases II (ca. 10,200–9550 cal BP). In these phases, however, no rachis segments have been retrieved. Significantly, no wild dicoccoides-like narrow kernels were retrieved from Tell Aswad. As van Zeist and Bakker-Heeres emphasize, the continuous presence of morphologically discernible dicoccum kernels, the total absence (from the very start) of dicoccoides-like material, and the extreme dryness (less than 200 mm annual rainfall) suggest that emmer wheat was introduced into the Damascus Basin as a domesticated cereal not later than the second half of the eleventh millennium BP. From ca. 10,100–8700 cal BP onward, charred grains that morphologically conform with dicoccum appear also at Tell Abu Hureyra, northeast Syria, again with no rachis segments (Hillman 1975, 2000; Hillman, Colledge, and Harris 1989), and in contemporary PPNB Can Hasan III and Çatalhöyük East, Konya plain, Turkey (Fairbairn, Near, and Martinoli 2005; Fairbairn et al. 2002, 2007; Helbaek 1964, 1969; Hillman 1972, 1978), Ali Kosh, Deh Luran Plain, Khuzistan (Helbaek 1969), and Jericho, Israel (Hopf 1983). From the very beginnings of agriculture in Southwest Asia, emmer is one of the principal cereals, and it prevails quantitatively over domesticated barley and domesticated einkorn.

**Free-threshing emmer wheats.** Free-threshing wheat forms, identifiable by their rachis fragments, make their appearance in Southwest Asia soon after the firm establishment of emmer wheat cultivation (for review, see Maier 1996). They are already present among the plant remains of Late Pre-Pottery Neolithic B (LPPNB), ca. 9600–8600 cal BP, Can Hasan III, Turkey (Hillman 1972), and of MPPNB, ca. 10,200–9550 cal BP, Tell Aswad (van Zeist and Bakker-Heeres 1982 [1985]) and LPPNB, ca. 9450–8600 cal BP, Tell Bouqras (van Zeist and Waterbolk-van Rooijen 1985), Syria. They also occur in the MPPNB/LPPNB, ca. 9300–9000 cal BP, Çatalhöyük, Turkey (Fairbairn, Near, and Martinoli 2005; Fairbairn et al. 2002; Helbaek 1964), and Tell Ramad, Syria (van Zeist and Bakker-Heeres 1982 [1985]).

**Barley Hordeum vulgare**

**Biology.** Domesticated barley Hordeum vulgare subsp. vulgare is one of the main cereals of the belt of Mediterranean agriculture and a founder crop of Old World Neolithic food...
production. All over this area barley is a common companion of wheat, but in comparison with the latter, it is regarded as an inferior staple. Yet barley withstands drier and warmer environments, poorer soils, and some salinity. Because of these qualities, it has been the principal grain produced in numerous areas and an important element of the human diet. Barley is also the main cereal used for beer fermentation in the Old World. The crop was and still is a most important feed supplement for domestic animals.

Barley is a diploid (2n = 2x = 14 chromosomes) and predominantly self-pollinated crop. All cultivars have nonbrittle ears, a sharp contrast with wild barleys, in which ears are always brittle. Nonbrittleness in domesticated barley is governed by a recessive mutation in either one of two tightly linked “brittle” genes (table 3).

Barley ears have a unique structure. They contain triplets of spikelets arranged alternately on the rachis. According to the morphology of the spikelets, domestic barley can be divided into two principal types.

1. Two-rowed forms, traditionally called *Hordeum distichum*, in which only the median spikelet in each triplet is fertile and usually armed with a prominent awn. The two lateral spikelets are reduced and are grainless and awnless. Each ear thus contains only two rows of fertile spikelets.

2. Six-rowed forms, traditionally called *Hordeum hexastichum*, in which the three spikelets in each triplet bear seed and usually all are awned. Ears in these varieties therefore have six rows of fertile spikelets.

Wild barley is spread over the East Mediterranean Basin and the West Asiatic countries (fig. 4), penetrating as far as Turkmenia, Afghanistan, Ladakh, and Tibet. Wild barley occupies both primary and segetal human-made habitats. Its distribution center lies in the Fertile Crescent. In this area, wild barley is continuously and massively distributed. It constitutes an important annual component of open herbaceous formations, and it is particularly common in the summer-dry deciduous oak park-forest belt east, north, and west of the Syrian Desert and the Euphrates Basin and on the slopes facing the Jordan Rift Valley. From here, it spills over the drier steppes and semideserts.

The origins of barley are still not fully understood. Early crossing experiments and chloroplast DNA (cpDNA) typing have suggested that barley is of one, two, or at most a very few major domestication events (Zohary 1999). Later, Badr...
et al. (2000) examined 400 AFLP loci in wild and domesticated lines and found that barley is probably of a monophyletic origin in the Israel-Jordan area. However, in recent studies that included sequencing of seven genetic loci, Morell and Clegg (2007; as well as other molecular studies by Molina-Cano et al. [2005], [Saisho and Puruggana 2007], and Wang, Yu, and Ding [2009]) suggested two origins: one within the Fertile Crescent and a second farther east, possibly at the eastern edge of the Iranian Plateau. Apparently, European and North African barley is largely connected to the Fertile Crescent, while much of Asian barley is connected to the eastern center.

Archaeobotany. Unmistakable remains of nonbrittle barley (i.e., forms that could survive only under domestication) came from phase II (ca. 10,200–9550 cal BP) in Tell Aswad (van Zeist and Bakker-Heeres 1982 [1985]) and from ca. 9450 to 9300 cal BP Jarmo, Iraq. In the latter site (Braidwood 1960; Helbaek 1959a, 1960, 1966), Helbaek was the first to show two-rowed barley remains still closely resembling wild spontaneum but also displaying a nonbrittle rachis. Similar finds were reported and verified by Hopf (1983) in PPN Jericho. Indicative clues come from ca. 9600–8750 cal BP Ali Kosh (Helbaek 1969), where the brittle spontaneum-like material characterized the lower layers, and in the upper strata it was replaced by nonbrittle broad-seeded barley forms. Hulled barley has been found in Cyprus from the EPPNB, ca. 10,650–9550 cal BP (Murray 2003; Willcox 2000).

Domesticated barley continued to be a principal grain crop in Southwest Asia throughout the Neolithic period. Its remains have been recovered side by side with wheats in most Neolithic sites. Shortly afterward, we are faced with more advanced forms (i.e., six-rowed hulled as well as naked cultivars of barley).

In conclusion, the archaeological finds indicate that barley is a founder crop of the Levantine Neolithic agriculture and a close companion of emmer and einkorn wheats. The archaeological remains make it also possible to trace the main developments of barley under domestication: first the fixation of nonbrittle mutations and subsequently the emergence of six-rowed hulled and naked types.

Pulses

Lentil Lens culinaris

Biology. Lentil ranks among the oldest and the most-appreciated grain legumes of the Old World (Smartt 1990; Zohary 1995). In Mediterranean agriculture it is a character-
istic companion of wheat and barley. Compared with the cereals, yields are relatively low, but lentil stands out as one of the most nutritious and tasty pulses. The protein content is about 25%, and lentil constitutes an important meat substitute in peasant communities.

The domesticated crop *Lens culinaris* (syn. *L. culinaris subsp. culinaris*, *Lens esculenta*) manifests a wide range of morphological variation in both its vegetative parts and its reproductive parts. Like many other annual grain crops, lentil is predominantly self-pollinated, diploid (2n = 2x = 14), and interfertile, or largely so.

Conventionally, lentil cultivars are grouped in two intergrading clusters of seed sizes: (a) small-seeded lentils (subsp. *microsperma*), with small pods and small 3–6-mm seeds, and (b) large-seeded lentils (subsp. *macrosperma*), with larger pods and with seeds attaining 6–9 mm in diameter. *Macrosperma* forms are to be regarded as more advanced; they start to appear rather late in archaeological sequences, only in the third millennium BP. The occurrence of pods, or their fragments, is extremely rare.

As we described in the introduction to this article, the first sign of domestication is the retention of the seed in the pod (pod’s indehiscence) and the second is the gradual increase in seed size. The pod’s indehiscence is governed by a single mutation (table 3), the nondehiscent condition being recessive to the dehiscent one.

The wild progenitor of the domesticated plant, subsp. *culinaris*, shows close morphological, cytogenetic, and molecular affinities to wild subsp. *orientalis*, native to the East Mediterranean Basin and Southwest and Central Asia (fig. 5; Ferguson et al. 1998, 2000; Ladizinsky 1993; van Oss, Aron, and Ladizinsky 1997; Zohary and Hopf 1973). In fact, subsp. *orientalis* looks like a miniaturized subsp. *culinaris* but bears pods that burst open immediately after maturation.

*Lens orientalis* grows primarily on shallow stony soils and in gravelly hillsides in open or steppelike habitats. It also enters disturbed localities such as stony patches or stone heaps bordering orchards and cereal cultivation. In most parts of its distribution, *L. orientalis* is rather inconspicuous or even rare. It usually forms small scattered colonies. However, on stony slopes of Mount Hermon, the Anti-Lebanon, the oak park-forest belt of southern Turkey, and the western escarpments of the Zagros range, *L. orientalis* is occasionally locally common at 1,200–1,600 m altitude (Ladizinsky and Abbo 1993). Frequently it grows side by side with bitter vetch (*Vicia ervilia*).
As argued by Zohary (1999), the rich chromosomal polymorphism found in the wild progenitor compared with the chromosomal uniformity in the cultivars suggests that this pulse crop was taken into domestication only once or very few times.

Ladizinska (1999) examined cpDNA restriction patterns. Using those results and additional information from crossability and chromosomal architecture led him to conclude that *Lens* originated from the territories around southern Turkey and north Syria. The same areas were also mentioned in later recombinant DNA studies conducted by Sonnante and coworkers (Sonnante, Galasso, and Pignone 2003; Sonnante, Hammer, and Pignone 2009).

Archaeobotany. Lentils seem to be closely associated with the start of wheat and barley domestication in the Levant. Very possibly this legume was introduced into domestication in this region together with emmer, einkorn, and barley; that is, it should be regarded as a founder crop of Old World Neolithic agriculture (Zohary and Hof 1973).

At the end of the tenth and in the ninth millennia BP, charred seeds of lentil appear in most of the PPNB early farming villages in Southwest Asia. The seeds are still similar in size to those of wild forms (2.5–3.0 mm in diameter) and usually do not occur in quantities. Yet they are always associated with domesticated wheat and barley. Among the richest sites are ca. 10,200–9550 cal BP Tell Aswad (van Zeist and Bakker-Heeres 1982 [1985]), ca. 10,200–8700 cal BP Tell Abu Hureyra (Hillman 1975, 2000, 2001; Hillman, Colledge, and Harris 1989), ca. 10,250–9500 cal BP Jericho (Hof 1983), ca. 10,600–9900 cal BP Çayönü (van Zeist 1972; van Zeist and de Roller 1991–1992, 2003), and ca. 9600–8800 cal BP Ali Kosh, Iran (Helbaek 1969).

A large hoard of carbonized lentils was recovered from the MPPNB, ca. 10,400–9450 cal BP, Yiftah’el, north Israel. The size of the hoard (ca. 1,400,000 seeds) and its contamination by the fruits of the weed *Galium tricornutum*, a characteristic weed in lentil cultivation, indicate that there and then lentil was already domesticated (Garfinkel, Kislev, and Zohary 1988). Large amounts of lentil seeds were discovered also in somewhat later phases of the Neolithic settlements in Southwest Asia: in ca. 9450–9300 cal BP Jarmo, Iraq (Braidwood 1960; Helbaek 1959a, 1960, 1966); in ca. 9250–9000 cal BP Tell Ramad, Syria (van Zeist and Bakker-Heeres 1982 [1985]); in ca. 8200–7800 cal BP ceramic Hacklar (Helbaek 1970); and in ca. 8350–7750 cal BP Tepe Sabz, Deh Luran Valley, Iran (Helbaek 1970). The Tepe Sabz lentils had already attained 4.2 mm in diameter. This is an obvious development under domestication. Lentils are repeatedly encountered in the early European and Southwest Asian Pottery Neolithic sites situated far outside the distribution area of *L. orientalis*, suggesting that these lentils were already domesticated.

In summary, archaeological remains do not provide us yet with direct diagnostic traits (such as indelhiscent pod remains) for a determination of the start of lentil domestication. Moreover, it is doubtful whether comparative morphology will provide us with such clues in the future. Yet once Neolithic agriculture is soundly established, cultivation of lentil is part of it. The available archaeological information on early remains of lentil comes from the Levant, the very territory over which wild *L. orientalis* is distributed.

Pea *Pisum sativum*

**Biology.** The pea ranks among the oldest grain legumes of the Old World. From its early beginnings, this crop has been a close companion of wheat and barley domestication (Zohary and Hof 1973). *Pisum sativum* is well adapted to both warm Mediterranean-type and cool temperate conditions. In peasant communities in Southwest Asia, the Mediterranean Basin, temperate Europe, Ethiopia, and northwestern India, it constitutes an important source of protein for human consumption. The protein content of the seed is about 22%. Today, pea ranks among the world’s most important pulses (Davies 1995; Smartt 1990).

Pea is a diploid (2n = 2x = 14 chromosomes) and predominantly self-pollinated crop. As a consequence of the self-pollination system, variation in pea is molded in numerous true breeding lines. Domesticated pea shows a wide range of morphological variation. As we already described, the first sign of domestication is the retention of the seed in the pod (pod’s indehiscence), and the second is the gradual increase in seed size, from 3–4 to 6–8 mm in diameter. The pod’s indehiscence is governed by a single mutation (table 3), the nonindehiscence condition being recessive to the dehiscence one. A third character here is the reduction of the relatively thick texture and rough surface of the seed coat, resulting in the breakdown of the germination inhibition of wild peas.

The crop complex of *P. sativum* contains the variable collection of pea cultivars and its closely related wild races. The wild forms of *P. sativum* fall into two main morphological types (fig. 6): (i) *Pisum sativum* subsp. *elatus*, a tall “maquis type” that thrives as a sporadic climber in maquis formations in the relatively mesic parts of the Mediterranean region and as a weed, and (ii) *Pisum sativum* var. *pumilio* (known formally as *Pisum humile*), a shorter, more xeric “steppe type” geographically restricted to southwest Asia. It occurs in the deciduous oak park-forest belt and in open steppelike herbaceous vegetation formations characteristic of the Fertile Crescent (i.e., in the same zone that harbors the wild progenitors of wheat, barley, lentil, and flax). From such primary habitats *humile* peas spill over to secondary habitats and occasionally infest cereal cultivation.

The available evidence from the living plants implicates the wild *humile* peas as the progenitor stock for pea domestication. *Humile* peas show closer morphological similarities than *elatus* peas to the domesticated aggregate and grow in steppe-like habitats (i.e., under open conditions similar to the cultivated field). Within *humile* peas, the Turkish and the south Levant forms having chromosomes identical to those present
in the cultivars should be regarded as the primary ancestral stock. This is also supported by cpDNA comparisons. Yet it is very likely that the two subspecies contributed some genes to the cultivated ensemble through occasional secondary hybridization (Ben Ze’ev and Zohary 1973; Palmer, Jorgensen, and Thompson 1985).

Nasiri and coworkers (Nasiri, Haghnazari, and Saba 2009) have examined SSR (microsatellite) markers of wild peas and cultivars. They have found that these markers effectively differentiate between the cultivars and the wild accessions. In addition, *Pisum sativum* subsp. *fulvum* was found to be the closest relative of the cultivars, but it should be noted that subsp. *humile* was not tested in this study.

Archaeobotany. Remains of peas are present in many of the PPNB farming villages that developed in the Fertile Crescent arc from 10,500 cal BP years onward. Some of the earliest finds were retrieved from ca. 10,200–9550 cal BP Tell Aswad in south Syria (van Zeist and Bakker-Heeres 1982 [1985]), ca. 10,600–9900 cal BP Çayönü in southeast Turkey (van Zeist and de Roller 1991–1992, 2003), ca. 10,250–9500 cal BP PPNB Jericho (Hopf 1983), and ’Ain Ghazal, Jordan (Rollinson et al. 1985). Much richer remains were available from somewhat later Neolithic phases in the Levant. Large quantities of carbonized seed accompany the domesticated wheats and barley in MPPNB/LPPNB Çatalhöyük (Fairbairn, Near, and Martinoli 2005; Fairbairn et al. 2002; Helbaek 1964) and Final PPNB/PPNC Erbaba (van Zeist and Buitenhuis 1983).

In contrast to those of the wheats and barley, the earliest archaeological remains of pea do not provide us with simple traits for a foolproof recognition of domestication (Zohary and Hopf 1973). In peas under domestication there is a general trend toward an increase in the size of the seed and the length of the hilum, but such changes occurred gradually in the course of domestication. In early finds there is a considerable overlapping in the dimensions of wild and domesticated forms. Perhaps the most reliable indication of domestication in peas is provided by the surface of the seed coat. Wild peas are characterized by a rough or granular surface, while domesticated varieties have smooth seed coats. However, seed coats survive only very rarely, and if they do not, it is impossible to ascertain whether the material retrieved represents wild or domesticated forms. The lower levels (ca. 10,600–9900 cal BP) of Çayönü (van Zeist and de Roller 1991–1992) retained some fragments of rough-surface wild seed
coats. Wild-type seed coats occur even much later in Pottery Neolithic Haçilar (Helbaek 1970). Significantly, the remains from MPPNB/LPPNB Çatalhöyük (Helbaek 1964) and Bouqras (van Zeist and Waterbolk-van Rooijen 1985) and those from LPPNB Çayıönu and Can Hasan I (Renfrew 1968) include a single seed with smooth seed coat characteristic of domesticated varieties. This smoothness suggests that domestication of peas in the Levant is as old, or almost as old, as the domestication of wheat and barley.

Although it is currently less definite, the archaeological evidence establishes pea as one of the founder crops of the Levantine Neolithic agriculture. Since this early start, pea seems to be a consistent and common element of food production and a common companion of wheats and barley. The evidence from the living plants complements the archaeological finds. The wild *humble* forms, with chromosomes and cpDNA identical to those prevailing in the cultivated crop, should be regarded as the closest wild relatives from which this pulse crop evolved.

*Chickpea Cicer arietinum*

*Biology:* Chickpea is a valued grain legume of the traditional agriculture in the Mediterranean Basin and Western Asia as well as India and Ethiopia. It is a member of the grain ensemble found in Levantine Neolithic and Bronze Age remains. Chickpea is adapted to a subtropical or Mediterranean-type climate; it grows almost exclusively in the postrainy season on moisture stored in the soil. Like lentil and pea, chickpea (with a seed protein content of some 20%) constitutes an important meat substitute in peasant communities.

Domesticated chickpea *Cicer arietinum*, like all other eight founder crops, is a predominantly self-pollinated annual crop with pods containing one to two seeds. The cultivars show a wide range of variation in size, color, and shape of the seed and in the size and form of leaves and flowers. All domesticated varieties are diploid (2n = 2x = 16 chromosomes) and interfertile. Chickpea landraces are grouped into two interconnected clusters (Smartt 1990; Smithson, Thompson, and Summerfield 1985). Large-seeded varieties (known as “Kabuli” type) with relatively smooth, rounded, light-colored seed coats and pale cream flowers predominate in the Mediterranean countries and Southwest Asia. Varieties producing small wrinkled seeds (“Desi” type) with dark-colored seed coats and usually purple flowers prevail in the eastern and southern parts of the distribution area of the crop (i.e., in India, Afghanistan, and Ethiopia).

As in most other seed legumes, the conspicuous features of evolution under domestication in chickpea are the retention of seeds in the pods (pod’s indehiscence) and the gradual increase in seed size, from 3.5 to 6.0 mm and more. The pod’s indehiscence is governed by a single mutation (table 3). Another change under domestication is the development of a smooth seed coat and the reduction of its thickness. Seed remains are the only material recovered to date in archaeological excavations.

The domesticated chickpea *C. arietinum* is a member of a leguminous genus comprising some 40 species centered in Central and Western Asia (Cole, Maxted, and van der Maesen 1998; van der Maesen 1972). The domesticated pulse shows close morphological affinities and an almost identical seed protein profile to two wild species of chickpea: *Cicer echinospermum* and *Cicer reticulatum*. These two wild chickpeas are diploid self-pollinated annuals known only from southeastern Turkey. The available morphological and cytogenetic evidence implicates *C. reticulatum* as the wild ancestor of the domesticated plant (Ladizinsky and Adler 1976), and it is therefore referred to as *C. arietinum* subsp. *reticulatum*. Because the distribution of the wild progenitor is restricted to southeast Turkey (fig. 7), the area of origin of the domesticated crop can be outlined there.

*Archaeobotany.* Like lentil and pea, chickpea seems to be closely associated with the start of food production in the Levant, but unlike them it is much rarer in Neolithic contexts. Earlier chickpea seeds were found in EPPNB, ca. 10,600–10,250 cal BP, Tell el-Kerik, northwest Syria (Tanno and Willcox 2006). A few of these seeds are somewhat larger and plumper than the wild progenitor, and the authors argue (Tanno and Willcox 2006:200) that this might indicate that they are an “intermediate stage” between wild and domesticated chickpeas. Some charred chickpea seeds were recovered from EPPNB, ca. 10,600–9900 cal BP, Çayıönu (van Zeist 1972; van Zeist and de Roller 1991–1992). A few more were found in the MPPNB level of Tell Abu Hureyra, northern Syria (Hillman 1975, 2000), and Asşkı Höyük (van Zeist and de Roller 1995) in Turkey. The seeds from these sites correspond in size to those of *C. reticulatum*. Because these sites are situated within (or close to) the very restricted geographic distribution area of the wild progenitor, it is difficult to be sure whether they represent wild or domestic plants. The seeds retrieved from MPPNB Jericho (Hopf 1983) and ‘Ain Ghazal (Rollefson et al. 1985) and those from LPPNB Ramad near Damascus (van Zeist and Bakker-Heeres 1982 [1985]) very probably represent domesticated forms. The latter sites lie far away from the territory of the wild progenitor, and the specimens from Jericho seem to have smooth seed coats.

The evidence from the living plants and the plant remains discovered in archaeological excavations indicate that *C. arietinum* belongs to the early Neolithic grain-crop assemblage of the Levant. Archaeological data are still limited and less definite, but in this legume, the delimitation of the place of origin is relatively simple: the wild progenitor of the domesticated chickpea is endemic to the central part of Fertile Crescent. Here, very likely, this pulse was first brought into domestication.
Fiber and Oil Plants

*Flax* Linum usitatissimum

*Biology.* Flax *Linum usitatissimum* is an annual crop with characteristic slender strong stems and rounded capsules that in domesticated forms do not dehisce but retain the oval compressed shining seed. The crop is diploid \((2n = 2x = 30\) chromosomes) and predominantly self-pollinated. Consequently, variation has been molded in the form of numerous true breeding lines and aggregates of landraces. Two specializations are apparent: (i) oil varieties, which are relatively short (30–70 cm) and branched and usually bear large seeds, and (ii) fiber varieties, which are taller and sparsely branched and usually produce small seeds. Transitional forms, cultivated for both oil and fiber, occur as well.

Flax was a principal oil and fiber source in the Old World and probably the earliest domesticated plant used for textiles. Until recently, flax was extensively cultivated in vast areas of Eurasia (Durrant 1976). In antiquity, flax fibers were the principal vegetable fiber used for weaving textiles in Europe and Western Asia. The seed contains about 40% oil, and in peasant communities linseed was used as a source for edible oil and high-grade lighting oil.

The fibers for spinning are obtained from the tall stems, which are harvested before the maturation of the seed. Traditionally, they were first dried and then immersed (wetted) in water to allow the microbial decomposition (retting) of the pectin connecting the fibers with other cells and tissues of the stem. After retting, the stems were dried, and the fibers (averaging 4 cm in length) were separated by pounding (breaking) and combing.

Domesticated flax *L. usitatissimum* is most closely related to wild *Linum bienne* (syn. *Linum angustifolium*). These two flaxes have the same chromosome number (see above), intercross readily, and are fully interfertile (Gill and Vermanos 1967). *Linum bienne*—with its characteristic strong branches, blue flowers, and dehiscent capsules—is widely distributed.
over West Europe, the Mediterranean Basin, North Africa, Southwest Asia, Iran, and Caucasia (fig. 8). Some wild forms are annual, and others are biennial or perennial; all are predominantly self-pollinated. *Linum bienne* grows mainly in wet places such as moist grassy areas, springs, seepage areas on rocky slopes, moist clay soils, and marshy lands. On the basis of its close morphological and cytogenetic affinities to the domesticated crop, *L. bienne* is identified as the wild progenitor of *L. usitatissimum* (Diederichsen and Hammer 1995). The main changes under domestication are the shift to non-splitting capsules and the increase of seed size (like in many grain crops) as well as the selection for higher oil yield or longer stems with a high amount of long fibers.

Phylogenetic evidence from modern accessions (Allaby et al. 2005; Fu and Allaby 2010) gives indications that (i) there was a single domestication event for flax and (ii) the oil-producing variety was domesticated, suggesting that domestication selected for the larger oil-rich seeds rather than its fibers.

Archaeobotany. Flax was apparently used by humans already before its domestication. Recently, twisted and dyed flax fibers were reported in Upper Paleolithic Dzudzuana Cave, Georgia (ca. 30,000 years old; Bergfjord et al. 2010; Kvavadze et al. 2009, 2010). The oldest wild linseed remains retrieved from archaeological sites in Southwest Asia come from ca. 10,900–9900 cal BP Tell Mureybit (van Zeist and Casparie 1968). Soon after, seeds of flax were found in many of the PPNB farming villages that appeared in the Fertile Crescent from 10,500 cal BP onward (fig. 1). Some of the earlier finds come from ca. 10,600–9900 cal BP Çayönü, Turkey (van Zeist 1972; van Zeist and de Roller 1991–1992, 2003); ca. 10,200–9550 cal BP Tell Aswad, near Damascus, Syria (van Zeist and Bakker-Heeres 1982 [1985]); Ali Kosh, Iran (Helbaek 1969); Jericho, Israel (Hopf 1983); and ‘Ain Ghazal, Jordan (Rollefson et al. 1985). The seeds are still small, similar in size to those of wild *bienne* forms, yet they are almost always associated with domesticated wheats and barley.

Fragments of a capsule from ca. 10,250–9500 cal BP MPPNB Jericho (Hopf 1983) is probably the earliest indication we have today of domesticated flax. Another indication of early flax domestication comes from linseed remains recovered from LPPNB, ca. 9250–9000 cal BP, levels of Tell Ramad, Syria. The calculated size of the seed from this site, corrected for charring shrinkage, ranges from 3.2 to 4.1 mm in length. This is already within the size class of the *L. usitatissimum* seed, the lower limit of which lies at 3.0 mm. It is therefore an attractive indication for flax domestication under rain-dependent conditions before ca. 8600 cal BP (van Zeist and Bakker-Heeres 1975). Such domesticated linseeds were found in Pottery Neolithic Nahal Zehora, Mount Car-
Conclusions

This article deals with current biological and archaeobotanical information from Southwest Asia (fig. 1) in an attempt to identify the earliest finds of domesticated grain crops. If we adopt the criteria suggested in the beginning of this article, we can now separate the appearance of the eight founder crops into several distinguishable groups and dates.

From the group of eight Southwest Asian founder crops, two crops seem to appear earlier at cultivated wild plants. These “pioneer crops” are (i) wild barley, found in PPNA Gilgal, and (ii) wild lentil, found in PPNA Jerf el-Ahmar and in PPNA Netiv Hagdud (Weiss, Kislev, and Hartmann 2006). Some lines of evidence suggest that cultivation of wild einkorn, wild emmer, wild barley, wild rye, and wild lentil might have been practiced at PPNA Jerf el Ahmar and Dja’de, northern Syria (Willcox, Fornite, and Herveux 2008).

From the group of founder crops, the earliest definite domesticated plants are einkorn wheat and emmer wheat from two EPPNB sites in Turkey, Cafer Höyük (de Moulins 1997) and Çayönü (van Zeist 1972; van Zeist and de Roller 1991–1992, 2003). Unfortunately, study of the third possible site in this cluster, Nevali Cori (Pasternak 1998), was published only as a preliminary publication and therefore remains uncertain.

The earliest definite domestic forms of barley and lentil first appear during the MPPNB. In this period, domesticated barley is present in Aswad (van Zeist and Bakker-Heeres 1982 [1985]) and later on (still in the MPPNB) in Jarro (Helbaek 1969). Domesticated lentil appears in MPPNB Yiftah’el (Garfinkel, Kislev, and Zohary 1988).

The earliest domesticated flax was retrieved from MPPNB Jericho (Hopf 1983) and later in LPPNB Tell Ramad (van Zeist and Bakker-Heeres 1982 [1985]) and Nahal Hemar, Israel (Schick 1988).

The evidence regarding the remaining three founder crops—chickpea, pea, and bitter vetch—is as yet inconclusive. The geographical boundaries of the first group of domesticated plants therefore focus on a rather restricted part of the Fertile Crescent (i.e., from southeastern Turkey in the north to Israel in the south).

We see now (and see Zeder 2011 for details and references) the first wave of animal domestication (all herbivores: goat, sheep, cow, and pig) more or less at the same time as early plant domestication. It is possible, therefore, that the remains of food processing for human food—stalks and inflorescences—were used for animal feed of the emerging Neolithic culture.

At present, no agreement prevails among researchers and between research disciplines regarding the mode of origin of the “first wave” of the Southwest Asian grain crops (einkorn wheat, emmer wheat, barley, lentil, pea, chickpea, bitter vetch, and flax). Was it of monophyletic origin (derived from the same ancestral taxon representing a single event of domestication) or of polyphyletic derivation (resulting from several ancestral taxa representing several independent events)?

The accumulated morphological, anatomical, and cytogenetic information seems to support monophyletic speciation as the plausible mode of origin (Zohary 1996, 1999). Important in domestication is the interaction between annaulity, reproductive biology, and self-pollination and selection; self-pollination is significant because it causes the plant community to be built of almost only pure inbred lines. The combination of selfing and selection of inbred lines further supports this notion because it causes the selection toward domestic types to be efficient and fast.

As far as the molecular research goes, however, there are currently two views based on analytical as well as methodological perspectives. Some (e.g., Badr et al. 2000; Heun et al. 1997; Özkam et al. 2002) support a monophyletic origin, while others (e.g., Kilian et al. 2007; Molina-Cano et al. 2005; Morrill and Clegg 2007) support a polyphyletic one. It seems that this major research question will get more attention in the near future. No doubt the research avenue of molecular analysis of domesticated crops and their origin is a fast-growing field that has not yet reached its climax.

Although it is beyond the scope of this article, it is important to mention the relatively new data available from Cyprus (e.g., Peltenburg et al. 2000, 2001; Vigne 2011; Vigne et al. 2000; Willcox 2000). It is apparent that already during
the EPPNB, human pioneers crossed the sea and settled the island, bringing with them the Neolithic culture. These findings hint that the beginning of agriculture on the mainland, as attested in this article, was transferred almost immediately (on an archaeological timescale) outside the core area. Cyprus, as an isolated phenomenon, teaches us the pace of the biological and cultural shifts from wild to domesticated plants and from hunter-gatherers to farmers.

Acknowledgments

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The Early Process of Mammal Domestication in the Near East
New Evidence from the Pre-Neolithic and Pre-Pottery Neolithic in Cyprus

by Jean-Denis Vigne, Isabelle Carrère, François Briois, and Jean Guilaine

Recent archaeological investigations on Cyprus have unveiled unsuspected Late Glacial and Early Holocene (twelfth–tenth millennia cal BP) pieces of the island’s human history. Based on a review of the archaeological data and of the final results of the archaeozoological analyses of Sector 1 of the prepottery site at Shillourokambos, this paper examines how Cyprus improves our understanding of the process of mammal domestication in the Near East. Early introduction of controlled wild animals and then of early domestic lineages provides information about the modalities of the domestication process on the mainland. This information emphasizes the importance of technical skills, of local opportunities and adaptations, and of long-distance and increasing exchanges in the larger Near East area. Cyprus was a recipient of wild or domestic taxa from the continent through recurrent introductions, but it was fully part of the wider area of incipient farming, as seen in local innovations such as the intensive hunting/control of wild deer and boar or local domestication of wild/feral goats. The transition to farming during the tenth millennium appears to follow an unstable and opportunistic Early and Middle Pre-Pottery Neolithic B phase of low-level food production based on rapidly changing combinations of hunting, control, and breeding.

Introduction

During recent decades, many new data have been accumulated by archaeology, archaeozoology, and genetics on the beginnings of mammal domestication in several regions of the world. This includes the Near East, where the study of early domestication began very early and has provided more evidence and models than many other regions (e.g., Davis 2005; Dobney and Larson 2006; Redding 2005; Zeder 2006, 2011). However, even in the Near East, our knowledge remains poor, as demonstrated by the fact that many recent field projects and archaeozoological studies have led to a reconsideration of the general scenarios (cf., e.g., Bar-Yosef and Meadow 1995; Ducos 1968; Helmer 1992; Legge 1996; Zeder 2005).

Since the 1990s, Cyprus has provided startling new evidence from archaeological discoveries dating to the late eleventh and the tenth millennia cal BP (Guilaine and Le Brun 2003; Peltenburg and Wasse 2004), contemporaneous with the end of the Early Pre-Pottery Neolithic B (EPPNB) and the Middle Pre-Pottery Neolithic B (MPPNB) and Late Pre-Pottery Neolithic B (LPPNB) of the mainland. Because islands are clearly defined territories, because the Mediterranean islands were massively colonized beginning only in the Neolithic (Cherry 1990), because their endemic native fauna lacked any of the wild ancestors of domesticates (Vigne 1999), and because Cyprus is the only large island in the Near East, it provides unique information. As Cyprus was necessarily dependent on influences from the continent, at least at the beginning of the Neolithic, it may be thought of as an observation post recording what occurred on the nearby mainland.

In this paper, we present a synthesis from the Cypriot Pre-
Pottery Neolithic (PPN) perspective on early mammal domestication in the Near East. This is based mainly on the recent results of the final analyses of the first sector of Parakklisha, Shillourokambos (Limassol district), the largest known Cypriot PPN site (10,400–9000 BP; Guilaine 2003; Guilaine and Briois 2007; Guilaine, Briois, and Vigne 2011).

Our approach to animal domestication lies within both the technological (Mauss 1947 [1967]) and the structuralist conceptual frameworks (Lévi-Strauss 1958): technoeconomic and symbolic uses of animals by human societies are part of their technical, social, and symbolic systems and thus a characteristic part of their cultural systems (Vigne 1998). However, as part of the ecosystem (another structural entity), the relationships between animals and humans also involve ecological approaches and should be considered within the structural framework of the “anthroposystem,” that is, a metasystem that groups together the cultural and ecological systems and their interactions and dynamics through time (Muxart et al. 2003; Pascal, Lorvelec, and Vigne 2006; Vigne 2011).

From this viewpoint, in addition to the different kinds of ecological affinities of animals to the human-made or human-modified ecosystems, including commensalisms, domestication appears as a process of intensification of animal-human relationships (Pascal, Lorvelec, and Vigne 2006) boosted by human intentionality. Consequently, we consider that control in the wild and control/protection/use of commensals are initial stages of the domestication process, although they involve animal populations that are still wild from a biological viewpoint. Such situations can be detected mostly as an increase in the frequency of the targeted species, as changes in age and sex proportions in the archaeological record (Zeder 2009, 2011), and/or as transport. We restrict the term “domestic mammals” to animal populations that show phenotypic modifications due to human breeding/herding. As some of these cannot be archaeologically detected, sometimes the domestic status cannot be determined. In the same way, we restrict the term “farming” to technoeconomic systems based mostly on animal (and plant) breeding, which appears to have started in the middle of the tenth millennium (transition between MPPNB and LPPNB) in large villages of the Near East (Vigne 2008, 2011). We distinguish farming from “low level food production” as defined by Smith (2001).

The Early Neolithization of Cyprus: A Brief Updated Review

The island of Cyprus emerged from the bottom of the Mediterranean Sea during the Miocene and has never been connected to any continent (Held 1989). As a result, the Upper Pleistocene terrestrial mammalian fauna was reduced to only four or five endemic species (Boeckxhoven and Sondaar 1972; Simmons 1999): mouse (Mus cypriacus; Cucchi et al. 2006), genet (Genetta plesictoides), dwarf elephant (Elephas cypriotes), dwarf hippopotamus (Phanourios minutus), and perhaps a shrew.

The upper layer of the rock shelter at Akrotiri Aetokremnos provides the earliest known evidence of visits to the island by humans, dated to 12,776–12,461 cal BP (nine wood charcoal dates; Simmons 1999; Simmons and Mandel 2007), corresponding to the Late Natufian in the northern Levant. Simmons (1988, 1999) has proposed that these human groups hunted elephants and hippos to extinction. This is, however, questioned by numerous authors (e.g., Ammerman and Noller 2005; Binford 2000; Bunimovitz and Barkai 1996; Davis 2003; Olsen 1999; Vigne 1999; Wasse 2007), who argue that the two native large mammals disappeared before that time for climatic (Bromage et al. 2002) or anthropic reasons (or both; Wasse 2007). The diet of the occupants of Aetokremnos shelter seems to have consisted mainly of fish, shellfish, and birds (Simmons 1999). Ammerman et al. (2006, 2008) recently found two other sites that may be more or less contemporaneous with Aetokremnos, but no radiometric data have corroborated their interpretations until now.

In addition to thousands of hippo bones, 18 suid bones were found at Aetokremnos, mainly in the upper layer (Simmons 1999). They have recently been directly dated to 11,746–11,396 cal BP (10,045 ± 69 BP [AA79923; degraded bone collagen]; δ13C, −25.1‰; Vigne et al. 2009). These suids were 9%–20% smaller than the Near Eastern Late Glacial and Holocene wild boars and were also significantly smaller than those of the PPN and Early Pottery Neolithic of the Near East. The most probable scenario (already partly suggested by Wasse 2007) is that wild boars were artificially introduced to Cyprus sometime at the end of the Late Glacial (Natufian on the mainland), rapidly decreased in size because of the isolation effect, and then were hunted by people who frequented Aetokremnos during the second quarter of the twelfth millennium (Late Khiamian on the mainland; fig. 1).

At least three recent discoveries indicate that whether permanently or not, humans continued to frequent the island in the twelfth millennium cal BP and during the first half of the eleventh. At Ayios Tychonas Throumbovounous, François Briois and collaborators (Briois, Petit-Aupert, and Péchoux 2005; Guilaine and Briois 2007) found an eroded site with large flint series similar to Mureybet II (Khiamian of the Middle Euphrates valley, late Dryas). Unfortunately, there were no associated faunal remains (F. Briois and J.-D. Vigne “Throumbovounous (Ayios Tychonas, Chypre), rapport de sondage,” unpublished report for the Department of Antiquities, Cyprus, 2003). At Agia Varvara Asprokremnos, painted stone vessels, pendants, a shaft-straightener, and unidirectional flint débitage provide strong parallels to materials dated to the late Pre-Pottery Neolithic A [PPNA]/transitional EPPNB in the northern Levant (McCartney 2010; McCartney
Figure 1. Evolution of large mammals on Cyprus during Neolithization, with particular focus on the data from Shillourokambos. The chrono-
The associated fauna is dominated by suids (*Sus scrofa*). A series of six radiocarbon dates ranging between 9525 ± 49 BP and 9432 ± 49 BP spans a likely calendar age of 10,846–10,675 cal BP (Manning et al. 2010). The last site, Ayios Tychonas-Klimonas, is also characterized by a PPN (EPPNB-type) industry (Guilaine and Briois 2007) associated with suids and dog bones (Vigne et al., forthcoming).

The subsistence of the occupants of the site should have been based on hunting of only one game species, the small autochthonous wild boar, with the help of dogs. Only one wood charcoal (*Prunus* sp.) radiocarbon date indicates the first quarter of the eleventh millennium cal BP (11,070–10,741 cal BP; Manning et al. 2010). The last site, Ayios Tychonas-Klimonas, is also characterized by a PPN (EPPNB-type) industry (Guilaine and Briois 2007) associated with suids and dog bones (Vigne et al., forthcoming).

The lithic débitage of these three sites and the radiocarbon dates of two of them clearly postdate those of Aetokremnos and predate the earliest phase (A) at Shillourokambos (Guilaine 2003; Guilaine and Briois 2007; Guilaine et al. 2000) and Kissonerga-Mylouthkia (Peltenburg 2003; Peltenburg et al. 2000, 2001a, 2001b), both of which are radiocarbon dated (fig. 1). The Early A phase of Shillourokambos, where suids are still overwhelmingly dominant (Vigne, Carrère, and Guilaine 2003), provided 12 dates (Guilaine, Briois, and Vigne 2011) ranging from 10,696 to 10,297 cal BP (mean: 10,380 cal BP). Well 116 at Mylouthkia is dated to 10,740–10,290 cal BP (9315 ± 60 BP [OxA7460]; 9235 ± 70 BP [AA33128]; 9110 ± 70 BP [1133129]; Peltenburg 2003). At Shillourokambos, the blade technology of this late eleventh-millennium phase is very well documented and shows clear relationships with Early MPPNB in the Levant (Briois 2003).

From the beginning of the tenth millennium, prepottery Cypriot sites became more numerous (Guilaine and Briois 2003; Guilaine and Le Brun 2003; Peltenburg and Wasse 2003; Wasse 2007). They show a progressive shifting of all the material culture toward a local Cypriot model, which culminated during the ninth and eighth millennia BP in the Aceramic

Khirokitia culture, contemporaneous with the pre-Halaf/Halaf phases of the northern Levant (fig. 1).

The Main Archaeological and Archaeozoological Characteristics of Shillourokambos

Shillourokambos is an open-air site located on the southern coastal plain of Cyprus, near Limassol (Guilaine 2003). From 1992 to 2004 it was excavated over more than 5,000 m² under the responsibility of Jean Guilaine. Because it is located on the top of a low hill near the confluence of two small rivers, it has been strongly eroded. No building is preserved in the upper part of the site (Sector 1, ca. 3,000 m²), which is mainly composed of large sedimentary layers and numerous pits, narrow ditches, post holes, and wells. The bases of several buildings have, however, been preserved in the less eroded lower part of the site (Sector 3, ca. 2,500 m²).

Four main phases of occupation of the site have been recognized (Early A, Early B, Middle, and Late), spanning the period from ca. 10,400–10,300 cal BP to the end of the tenth millennium (fig. 1; Guilaine 2003; Guilaine et al. 2000). Thirty-seven radiocarbon dates from Sector 1 suggest that at least this part of the site had been abandoned for several decades or centuries between the Early phases A and B, at the end of the eleventh millennium (Guilaine, Briois, and Vigne 2011). However, it was occupied continuously during the tenth millennium.

Preliminary analyses of the animal remains of Sector 1 (Vigne et al. 2000) showed that dog (*Canis familiaris*), fox (*Vulpes vulpes*), pig (*Sus scrofa*), the Mesopotamian fallow deer (*Dama mesopotamica*), goat (*Capra aegagrus hircus*), sheep (*Ovis aries*), and cattle (*Bos primigenius taurus*) were already present before or at the very beginning of the tenth millennium. Cat (*Felis silvestris lybica*) was thought to have been introduced during the middle phases and partly controlled cultural frame that is proposed by Hours et al. (1994). Radiocarbon dates are given in cal BP and calibrated at 1σ (Calib Rev 5.0; Reimer et al. 2004). For each chronological phase of Shillourokambos, a box on the right-hand side contains the following information: the total number of identified specimens [NISP], the NISP of large mammals, the material dated [Cl = bone collagen], and a reference [1, Simmons 1999 (only the nine charcoal dates); 2, Vigne et al. 2009; 3, Vigne et al., forthcoming; 4, Manning et al. 2010; 5, Peltenburg 2003; Peltenburg et al. 2001b; 6, Guilaine 2003; Guilaine, Briois, and Vigne 2011; 7, Le Brun and Daune-Le Brun 2003 [Khirokitia, earliest level, G]]. The Middle A1 and A2 phases of Shillourokambos are grouped together. Black arrows indicate the earliest evidence for the arrival of new species of fauna on Cyprus. Gray arrows indicate the probable introduction of new lineages of domestic or commensal animals to Shillourokambos and Khirokitia.
Culling profiles assemblages. They were in a good position to select the most reliable faunal and were active participants in the excavation. Consequently, Aabelle Carre`re were in charge of the archaeozoological analyses (Guilaine, Briois, and Vigne 2011). Jean-Denis Vigne and Is.

Table 1. Final archaeozoological analyses of the large mammals from Sector 1 at Shillourokambos

<table>
<thead>
<tr>
<th>Animal species</th>
<th>NISP</th>
<th>No. measurements</th>
<th>No. teeth</th>
<th>MNI</th>
<th>NISP epiphyseal</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Vulpes vulpes</em></td>
<td>56</td>
<td>214</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Canis familiaris</em></td>
<td>11</td>
<td>77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Felis silvestris lybica</em></td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sus scrofa</em></td>
<td>1,001</td>
<td>2,917</td>
<td>472</td>
<td>113</td>
<td>1,124</td>
</tr>
<tr>
<td><em>Dama dama mesopotamica</em></td>
<td>1,361</td>
<td>4,017</td>
<td>785</td>
<td>173</td>
<td>2,374</td>
</tr>
<tr>
<td><em>Capra aegagrus hircus</em></td>
<td>394</td>
<td>1,284</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ovis aries</em></td>
<td>378</td>
<td>1,318</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Capra</em></td>
<td>219</td>
<td>515</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Caprini</td>
<td>991</td>
<td>3,117</td>
<td>321</td>
<td>108</td>
<td>754</td>
</tr>
<tr>
<td><em>Bos taurus</em></td>
<td>124</td>
<td>336</td>
<td></td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>3,547</td>
<td>10,689</td>
<td>1,578</td>
<td>394</td>
<td>4,278</td>
</tr>
</tbody>
</table>

Note. Number of measured specimens, measurements, and teeth, the minimum number of individuals (MNI) used for the culling profiles, and the number of the bones used for epiphyseal profiles. NISP = number of identified specimens.

(“tamed”; Vigne et al. 2004). In the first preliminary study, all the ungulate species except the fallow deer were considered to have been introduced in the form of already-domesticated lineages, mainly because of their small size in comparison with their wild counterparts on the mainland. This interpretation has been questioned by Horwitz, Tchernov, and Hongo (2004), who suggested, though without any direct analytical data, that they were introduced as wild animals for stocking the island with meat sources.

Further investigation of the Early phase B at Shillourokambos suggested a more complex situation (Vigne, Carrère, and Guillaume 2003; Vigne and Guillaume 2004): suids, sheep, and cattle were small in size and might therefore be considered as resulting from early domestication; but morphological analyses and the slaughtering profiles suggest that (almost?) all the goats and approximately half of the suids were wild/feral and were obtained by hunting, while sheep and probably cattle were bred. These observations underlined the unstable status of the domestic ungulates during several centuries after the earliest domestication and suggested that the human societies on the mainland could also have released domestic (or even a mixture of wild and transported domesticated) ungulates into the wild and redistributed them many times during the 15 centuries of the Pre-Pottery Neolithic B (PPNB), as well as later.

At that time, the question of what happened on Cyprus before the beginning of the tenth millennium (i.e., during the Early phase A) could not, however, be answered, because this earliest phase had provided less than 100 specimens. The last season of excavation at Shillourokambos in 2004 produced many more animal bones and much more archaeological information for this phase (Guillaire et al. 2008). The final study of all the animal bones of Sector 1 could be carried out (Guillaire, Briois, and Vigne 2011). Jean-Denis Vigne and Isabelle Carrère were in charge of the archaeozoological analyses and were active participants in the excavation. Consequently, they were in a good position to select the most reliable faunal assemblages.

The first important result of this final analysis is that the proportions of the different mammal species vary significantly throughout the successive occupations of the site to such an extent and in such a well-structured way that it was possible independently to find again the four phases based on the lithics only through faunal characteristics. Correspondence analysis of the faunal spectra even allows refinement of the chronology and identification of several subphases: Early A1 and A2 (the second being more or less the initial stage of the Early phase B), Early C, and Middle A1, A2, and B phases (the last more probably being the first stage of the late phase). This new chronological framework enables a more precise approach to the succession of events on this site between 10,400 and 9000 cal BP.

The final archaeozoological results presented in this paper are based on 32,500 animal remains, of which 9,225 (the number of identified specimens [NISP]) are taxonomically determined (8,864 vertebrates and 361 invertebrates; Guillaire, Briois, and Vigne 2011). On the basis of cut marks (Vigne 2006), fragmentation, and skeletal frequencies, reconstruction of the butchery and cooking processes and estimation of the distance between the kill sites and the village for each species of ungulate were possible. Nearly 11,000 bone and tooth measurements (table 1) provided statistics and enabled multivariate analyses. For deer, goat, cattle, and to a much lesser extent sheep, mixture analyses (Monchot and Léchelle 2002) provided reliable estimates of the sex ratio of adults and the decrease in sexual dimorphism due to domestication (see Helmer 2008; Helmer et al. 2005). By this technique, the evolution of the size of the different parts of the skeleton of the dimorphic ungulates could also be studied for each sex, providing reliable approaches to morphological variations through time. The tooth and epiphyseal mortality profiles were based on large series of teeth and long bones (table 1) and processed according to Vigne and Helmer (2007). We did not use statistical comparisons (see Marom and Bar-Oz 2009), which are not adapted to these questions (Vigne 2000), but rather multivariate analyses (e.g., Helmer, Gourichon, and Vila 2007).
These final analyses led to modification and clarification of several aspects of the preliminary interpretations. Figure 1 presents the frequencies of species according to the phases. During the Early phase A1, suids, which are the same size as those at Aetokremnos, are dominant (90%). Cats, goats, and cattle are clearly present in small numbers. The presence of dog is probable, that of fox questionable. The statistical analyses indicate that the absence of fallow deer and sheep is very unlikely to be due to the size of the sample (NISP = 282). It is confirmed by the absence of both species in well 116 at Mylouthkia, which is contemporaneous with Early phase A of Shillourokambos (Peltenburg et al. 2001b). Deer appeared as the dominant species at the very beginning of Early phase B. Sheep probably arrived slightly later.

Early phase B is characterized by high frequencies of cattle (8%–12% of the total NISP of the phase), which decrease to less than 1% in the middle and late phases. The Middle A phases are characterized by an increase in suids and foxes. Sheep and goats become dominant in the Middle B and late phases.

Transport and Control: The Beginnings of Mammal Domestication before 10,300 Cal BP

Faunal Turnover on the Island

Although Mus cypriacus is attested at Mylouthkia and is present today on the island (Cucchi et al. 2006), animal bones at Asprokremnos, Klimonas, Mylouthkia, and Shillourokambos confirm that the Pleistocene endemic hippo fauna did not survive the Late Glacial–Holocene transition. According to Bunimovitz and Barkai (1996) and Ammerman and Noller (2005), this fauna would have been extinct before the human occupation of layer 2 at Aetokremnos in the first centuries of the twelfth millennium (see also Wasse 2007). The introduction of wild boar before the occupation of Aetokremnos renders it possible that people frequented the island before 12,000 BP and then caused the extinction of the hippopotamuses.

The endemic Cyprus genet (Genetta plesiictoides) is present in the Aetokremnos deposits without any direct dating (Simmons 1999). It is absent from the small-mammal fauna of Mylouthkia. It is unlikely that it became extinct at the same time as hippos because its presumed main prey, M. cypriacus, did survive. The introduction of dogs (before 11,000 cal BP) or cats (mid-eleventh millennium at the latest) may have caused the extinction of the genet sometime in the twelfth–eleventh millennium.

Suids, cats, goats, cattle, and dogs were living on Cyprus before or starting from the earliest phase at Shillourokambos (fig. 1). In addition, data from Mylouthkia provide evidence for the presence of the house mouse (Mus musculus domesticus; Cucchi et al. 2002). Because they have no Cypriot Pleistocene ancestor and because such a high rate of immigration can result only from humans (Vigne 1999), these species would have been introduced between the end of the Late Glacial and ca. 10,400 cal BP.

All the large true Mediterreanean islands have undergone a similar turnover of their mammal fauna. That on Cyprus is the earliest, beginning during the Late Glacial, because domestication in the Eastern Mediterranean was early (Vigne 1999).

Pre-Neolithic Wild Boar Management More than 11,400 Years Ago

The presence of small wild boar dated to 11,746–11,396 cal BP at Aetokremnos, the dominance of suids at Asprokremnos, Klimonas, and Shillourokambos Early A1, and the morphological similarities of suids at Aetokremnos and Shillourokambos are convergent evidence that small island suids were living on Cyprus and exploited by humans during the twelfth–eleventh millennia. This would explain why people frequented (or inhabited) Cyprus during this period.

The introduction of wild boar during the Late Natufian or Early Khiamian strengthens the hypothesis of control of wild boar in the Final Late Glacial, as proposed by Redding and Rosenberg (1998), Rosenberg and Redding (1998), and Rosenberg et al. (1998; see also Redding 2005; Starkovitch and Stiner 2009; Wasse 2007) on the basis of the Hallan Çemi site in the upper Tigris basin. The evidence from Cyprus makes a strong contribution to the picture of a long span of increasingly intensive and skilled control of wild boars. This took place over a very large area, at least in eastern Anatolia (and rapidly expanded to Cyprus), but it would have extended to western Anatolia and the Aegean, as suggested by evidence of small Mesolithic wild boar on the islands of Y oura and Kythnos during the eleventh–tenth millennia (Trantalidou 2008). Here and there, it developed into true pig breeding in the middle of the eleventh millennium, as observed in the Upper Euphrates valley at Nevalı Çori and Gürcütepe (Peters, von den Driesch, and Helmer 2005) and at Cafer Höyük (Helmer 2008). At the same time, control in the wild would have continued during a large part of the tenth millennium, as suggested at Çayönü (Ervynck et al. 2001) and in the Aegean.

Transport of Wild or Early Domestic Goats?

In our present state of knowledge, the earliest evidence of goats on Cyprus is about 40 bone specimens at Shillourokambos Early A. The final analyses for Shillourokambos confirmed that the morphology of the horn cores of the early phases was similar to that of the wild bezoar goat. But separate morphometric analyses of males and females has shown that contrary to our preliminary conclusions (Vigne, Carrère, and Guillaume 2003; Vigne et al. 2000), these animals were significantly smaller than the early domestic goat, as measured by Helmer (2008) at Cafer Höyük (Early MPPNB). Peters, von den Driesch, and Helmer (2005), Helmer (2008), and Hongo
et al. (2009) presented convincing evidence of domestic goat in the Upper Euphrates and Tigris valleys in the middle of the eleventh millennium (late EPPNB), and Helmer and Gourichon (2008) did the same for the beginning of the MPPNB of the Damascus plain (Tell Aswad), ca. 10,300–10,200 BP. It is thus likely that the earliest goats of Cyprus were introduced as already modified domesticates.

However, on the basis of convincing theoretical inferences, Redding (2005) argued for wild-goat control before the PPNB (see also Hole 1996). Genetic investigations of the Near and Middle Eastern modern bezoar goats (Capra aegagrus) have shown that the wild lineages that mothered modern domestic goats in the Zagros were subjected to a drastic demographic increase ca. 10,000 BP, whereas the other lineages showed no similar genetic signature (Naderi et al. 2008). They also suggest that wild goats might have been transferred out of the original area of the species, though still in mountain areas. Like that of wild boar, the domestication of goats seems to have begun as control in the wild in a very large area stretching from the central Iranian plateau to southeastern Anatolia. Like the pig, morphologically domestic goat would have appeared here and there, as seen in the data from Nevali Çorî, ca. 10,500 cal BP (Peters, von den Driesch, and Helmer 2005), and later (10,000–9500 cal BP) in the Zagros (Zeder 2005, 2011; Zeder and Hesse 2000).

The final analyses at Shillourokambos confirmed that (all?) goats were hunted not only during the Early phase B (Vigne, Carrère, and Guilaine 2003) but also during the Early phase C and the beginning of the middle phases. The bone sample for the Early phase A is too small for characterizing the mode of exploitation, but the low frequency in comparison with the middle phases (fig. 1) makes hunting more likely. It is therefore difficult to determine whether the introduction of goats to Cyprus in the course of the eleventh millennium resulted from the transport of controlled bezoar goats (as suggested by Horwitz, Tchernov, and Hongo 2004), which would have decreased in size because of insularity, or was a consequence of a rapid spread of early domestic goats. The ecology of the bezoar goat (which excludes its presence in the coastal plains, from which the visitors to Cyprus necessarily came), its introduction much later than the wild boar, and the absence of any evidence of goat control in the nearby mainland areas, however, make the latter scenario more likely. In any case, Cyprus provides strong evidence that the process of goat domestication in the Near East was well advanced in the middle of the eleventh millennium.

From Commensalism to Domestication: Mice, Cats, and Other Carnivores

Cucchi et al. (2002) demonstrated that the house mouse (Mus musculus domesticus), absent from Aetokremnos (Simmons 1999), was well represented in well 116 of Mylouthkia, dated to 10,740–10,290 cal BP, together with the less commensal endemic Cypriot mouse, M. cypriacus. The earliest evidence for cat at Shillourokambos is a complete fifth right metacarpus found in the bottom of the earliest stratigraphic unit, dated to 10,322–10,288 cal BP (Guilaine, Briois, and Vigne 2011). Although there are only two cat remains in Sector 1 of Shillourokambos (fig. 1), the species is frequently present on tenth to eighth millennium Cypriot sites (review in Vigne and Guilaine 2004). The house mouse and the cat were introduced to Cyprus in the middle of the eleventh millennium at the latest, and the probably unintentional transport of the former possibly led to the introduction of its predator.

Auffray, Tchernov, and Nevo (1988) showed that house mice were already commensal in the Natufian layers at Hayonim, but nothing was known about early domestication of cats in the Near East. The presence of both house mice and cats in Cyprus during the second half of the eleventh millennium not only confirms that the house mouse spread as a pest to all the territories of the PPN complex (Cucchi and Vigne 2006), including islands, but is also evidence that cat domestication had already begun. It also supports the idea, suggested by Malek (1993) in relation to Egypt, that the most likely reason for cat domestication was use of this predator against the commensal rodents and their consumption of agricultural products. Cat domestication would have followed two steps. First, “commensalization” would have occurred, that is, cats being attracted to the villages by high concentrations of mice, whose presence was due to an increase in stocked foodstuffs. Second, the villagers would merely have provided protection or simply impunity to some individuals for the commensalism to evolve toward domestication (Pascal, Lorvelec, and Vigne 2006). This would have been all the more true if the cat had a symbolic significance for those Neolithic societies, as suggested by the numerous representations of felids in the PPN (Helmer, Gourichon, and Stordeur 2004), including in Shillourokambos Early A (Guilaine et al. 1999).

Should we expect future evidence for domestic cats in the Natufian on the mainland? This is not certain, because the proposal of Auffray, Tchernov, and Nevo (1988) has to be reevaluated with modern morphometric techniques and because, although it began during the Natufian, food storage does not seem to have developed on a large scale before the PPNA–EPPNB (Kuijt 2008; Kuijt and Finlayson 2009). In addition, the abundance of foxes in the PPNA at sites such as Jericho (Clutton-Brock 1979) and their introduction to Cyprus at the beginning of the tenth millennium (fig. 1) indicate that other species of small carnivores could also have played the same role as cats throughout the PPN.

As domestic dogs are in evidence on the mainland since the Natufian (Helmer 2008; Tchernov and Valla 1997) and on Cyprus as early as the beginning of the eleventh millennium (Vigne et al., forthcoming), it would not be surprising to find them on Cyprus during the twelfth millennium. They probably played a role in autochthonous-wild-boar hunting or control at Klimonas during the first half of the eleventh millennium. At Shillourokambos, the scarceness of their re-
mains and the total absence of any gnawing mark on the other mammal bones suggest, however, that they lived away from the village, at least from the beginning in the Early phase B (Vigne and Guilaine 2004).

**Introduction of Early Domestic Cattle during the EPPNB**

Although absent at Mlyouthkia, cattle were present during the Early phase A1 of Shillourokambos, represented by a complete right pelvis found at a depth of 4 m in the Early A1 fills of well 431. Cattle were introduced to Cyprus ca. 10,300 cal BP or shortly before (fig. 1), at a time when domestic cattle had begun to appear on the mainland (Helmer et al. 2005; Hongo et al. 2009).

Cattle bones are, however, too rare in the earliest phase at Shillourokambos to provide any information on their morphology and status. Their size does not seem to differ significantly from that of Early phase B cattle bones. The latter are significantly smaller than those of the aurochs of the Natufian and PPNA layers at Mureybet (Gourichon and Helmer 2008). They are very similar to those of Dja’de (L. Gourichon and D. Helmer, unpublished data), which are mainly composed of early domestic bovids (Helmer et al. 2005). Estimated through mixture analyses of log size index, the sexual dimorphism of the bovid from the early phases of Shillourokambos appears also to be significantly less than that of the aurochs of Mureybet I–IIIA and similar to that of Dja’de. In addition, the presence on the site of all the skeletal elements of the limb extremities and all the vertebrae suggests that the animals were killed very near or in the village. The epiphysal age profile and sex ratio of the early phases indicate a well-managed breeding strategy focused on the exploitation of the meat from the young adult males.

The early Cyprus cattle bred during the Early phases at Shillourokambos thus probably resulted from the introduction of already-domestic lineages such as those at Dja’de or at less distant Tell Aswad (Damascus), where Helmer and Gourichon (2008) found evidence that cattle were used for carrying heavy loads as early as the beginning of the MPPNB.

**Tenth Millennium: Cyprus Reflects Continental Complexity and Intensive Exchanges**

Numerous archaeozoological data from the Early phase B to the Late phase of Shillourokambos are summarized in figure 2 (after Guilaine, Briois, and Vigne 2011). This provides an exceptional case study for the evolution of the status of ungulate species and of subsistence strategy through the tenth millennium, a time of emergence and consolidation of farming on the mainland (Bar-Yosef and Meadow 1995; Vigne 2008, 2011).

*The Mesopotamian Fallow Deer*

The final archaeozoological analyses provide evidence that deer were never domesticated at Shillourokambos. In all phases, age classes were slaughtered in proportion to their natural abundance without any distinction between sexes. The morphological distance between males and females remained constant, and the body size not only did not decrease but slightly and constantly increased from the tenth to the eighth millennium (Khirokitia), perhaps as a result of constant hunting pressure.

The late introduction of the Mesopotamian fallow deer to Cyprus (fig. 1) probably illustrates the persistence, several centuries after the beginning of mammal domestication, of wild-ungulate control similar to that which we have shown for wild boars during the twelfth–eleventh millennia. Even if the economic importance of the fallow deer in Cyprus appears to be unique in all the PPN and therefore specifically Cypriot, it does suggest that somewhere in the Near East, human groups were already controlling fallow deer either as a domestication experiment or as a common subsistence practice.

Who were these pioneers of deer control? The Cypriot fallow deer were noticeably smaller than their northern-Levant PPNA counterparts at Mureybet (according to Gourichon and Helmer 2008). The highest density of archaeological evidence for the Mesopotamian fallow deer is located in the southern Levant (Davis 2003). The PPNB complex of cultures reached the southern Levant only at the end of the eleventh millennium BP (Khalaily, Marder, and Barzilai 2007), several centuries later than in the northern Levant. Mammal domestication was then in a more experimental phase in the south than in the north (Conolly et al. 2011). All this may suggest that the fallow deer was introduced from the southern Levant.

*Sheep and Goats: Complementary Stories*

The large number of bone remains (table 1) of sheep and goats and morphometric, age, and sex-ratio analyses (Guilaine, Briois, and Vigne 2011; Vigne, Carrère, and Guilaine, forthcoming) enable reconstruction of the codevelopment of sheep and goat exploitation at Shillourokambos (fig. 2). Goats were hunted throughout the early phases. Beginning in the middle phases, the villagers of Shillourokambos began to exploit them more intensively, strictly culling the young males, although no additional morphological modification appeared at that time. However, they continued to hunt wild/feral goats. Size decrease and morphological modifications of the horn cores become visible only in the late phases (i.e., 2–4 centuries later). The modification of the culling profiles through time indicates that at that time, the exploitation of goats had shifted toward their milk (Vigne, Carrère, and Guilaine, forthcoming). Even though this concerns goat lineages that may have been domesticated long before on the mainland and then became feral on the island, this is the first evidence for a
domestication process on a Mediterranean island. It resulted in a “new” lineage of domestic goats ca. 9400–9000 BP, that is, more than a millennium later than in sites of the northern Levant such as Nevalı Çorî, Çayönü, Tell Halula, or Tell Aswad (Helmer and Gourichon 2008; Hongo et al. 2009; Peters, von den Driesch, and Helmer 2005; Sana Segui 1999).

Sheep were introduced up to 5 centuries later than goats (fig. 1), in the form of small, horn-modified domestic animals (Vigne, Carrère, and Guillaune 2003) similar to their contemporaneous counterparts of the MPPNB at Tell Aswad. As soon as Early phase B, they were herded in a sophisticated way for meat and milk production (“milk B,” as defined by Vigne and Helmer 2007). Just after an episode of rapid size decrease and stress increase (malnutrition marks on the horn cores) that we interpreted as a breeding failure or collapse (Middle A1), new larger-sized lineages abruptly appeared, possibly in-
Introduced from the central or southern Levant. During the late phases, herding concentrated on meat production and possibly hair production. A second rapid morphological change perhaps suggests another new lineage. Davis (1994) has demonstrated an event of very rapid and significant size change between the early and late levels at Khirikitia and interprets it as the possible introduction of a new lineage. There is no evidence for feralization or sheep hunting at Shillourokambos. The exploitation of sheep on this site was strictly limited to breeding periodically strengthened by the introduction of new lineages that probably came from the mainland.

Basically, for the villagers of early Shillourokambos, goats were game animals, while sheep were the most “domestic” of all the ungulates. This probably implies quite different symbolic values for each of them. Archaeozoology tends to mix these two species only because their bones are difficult to discriminate from one another. The evidence from Shillourokambos demonstrates once again that they are really very different animals from biocological, techno-economic, and symbolic points of view (e.g., Balasse and Ambrose 2005). Because of these differences, the two species were able to play complementary roles in the technoeconomic system. If the rapid Middle A1 size decrease of the sheep at Shillourokambos actually resulted from a herding failure, we could consider that the domestication of goats in this village, which began at approximately that time, was developed to offset it. The complementarities between the two species are again illustrated by the end of the story, when the goats take over milk production from the sheep, which are then used for meat and hair production. This scenario provides a good illustration of both a process of domestication (goat) and the early technoeconomic complementarities of sheep and goat during the tenth millennium.

Introduction of Mammals from the Mainland

In addition to the fallow deer and several waves of domestic sheep, we also found evidence for the introduction of new lineages of domestic pig and cattle in the course of the tenth millennium (figs. 1, 2; Guilaine, Briois, and Vigne 2011). Between Early phases A and B of Shillourokambos, the size variability of suids abruptly tends toward smaller values and becomes organized into two peaks. Geometric-morphometrics analyses of the outline of the molars also suggest the presence of two distinct types of shape. During the Middle and Late phases, the two different-sized peaks tend to fuse because of interbreeding between the two lineages, but the two tooth morphotypes persist. This suggests that another lineage of pig was introduced shortly before 10,000 BP and then mixed with the local lineage that had been introduced beginning with the twelfth millennium. As the former was still smaller than the latter, we concluded that it was composed of domestic types coming from the mainland, where they are attested to several centuries earlier (Hongo et al. 2009; Peters, von den Driesch and, Helmer 2005).

The cattle of the Early C, Middle, and Late phases of Shillourokambos were much larger than those of the Early phases A and B. They are approximately the same size as the domestic cattle of the Middle and Late PPNB layers of Halula (see Sana Segui 1999) and therefore significantly larger than the cattle of Dja’de (L. Gourichon and D. Helmer, unpublished data). These data suggest the introduction of a new lineage of domestic cattle between Early phases B and C.

The tooth morphometry of the modern Cypriot house mouse M. musculus domesticus does not differ from that of the mainland mouse and has not varied since the PPN (Cucchi et al. 2002). Taking into account that genetically isolated mice diverge very rapidly from their ancestor (Pergams and Ashley 2001), this morphological stability is evidence of a constant and intensive genetic flow from the mainland to Cyprus from the Neolithic up to today. Mice would have been successfully introduced into Cyprus at least several times per year (Vigne and Cucchi 2005).

The arrows in figure 1 summarize the introductions of new species (black) and new domestic (gray) lineages to Cyprus and more specifically to Shillourokambos during the twelfth–eighth millennia. Of course, introductions are possibly underestimated because lineages that did not morphologically differ from the autochthonous ones could not be detected. On the other hand, the appearance of new lineages at Shillourokambos did not necessarily result from introductions from the mainland, as some of them may have resulted only from transfers from other Cypriot sites. In any case, figure 1 clearly shows evidence of intensive movements of animals either from the mainland or from other Cypriot sites throughout this period, a phenomenon that has until now been largely unrecognized in the PPN of the Near East. As evidenced by several papers in this volume, mobility is observed in numerous regions of the world at the time of the Neolithization.

Shillourokambos: A Case Study for Incipient Farming in the Near East

Development of Meat Production: From Low Level to Farming

We estimated meat production on the basis of bone weights (Vigne 1992). For the species that were exploited through both hunting and breeding (suids, goats), we drew from the frequencies of age classes of the slaughtering profiles both minimal and maximal estimates of production. The final results are therefore given with a large range of uncertainty, but they show interesting tendencies (fig. 3). These estimates have two other weaknesses: (1) although attested to for sheep and goats at Shillourokambos (Vigne and Helmer 2007), dairying is not taken into account; and (2) the percentages of bone weights do not represent an actual value of meat weight (i.e.,...
During the Mérida conference.

and Meadow 1995) and in numerous regions, as evidenced local scenarios that led to farming in the Near East (Bar-Yosef and Helmer 2007). The latter closely corresponds to the end of curement (Conolly et al. 2011; Hongo et al. 2009; Vigne and Hongo 2007). This evolution fits the macro-regional historical tendency rather well (see Vigne 2008). Shillourokambos can be taken as an example of the numerous regional historical tendency rather well (see Vigne 2008). Shillourokambos can be taken as an example of the numerous regional historical tendency rather well (see Vigne 2008). Shillourokambos can be taken as an example of the numerous regional historical tendency rather well (see Vigne 2008). Shillourokambos can be taken as an example of the numerous regional historical tendency rather well (see Vigne 2008).

Vigne et al. Mammal Domestication in the Near East

Evolution of the Technical System: Instabilities and Opportunistic Strategies

Marine resources played only a small role in the animal supply of the Shillourokambos villagers. Fishing was represented only by some large groupers (Epinephelus sp.; Desse and Desse-Berset 2003), and most of the seashells collected were battered, worn, or naturally pierced—that is, already dead on the beach—for ornaments and pendants (Serrand, Vigne, and Guilaine 2005). Most of the protein and lipid supply came from large terrestrial mammals. Botanical data are scarce (Guilaine, Briois, and Vigne 2011; Willcox 2003).

During the Early phase A1, the meat supply came mainly from hunting the small autochthonous Cypriot wild boar. The kill-off profile is abnormally rich for the very old individuals, indicating that the suid population was subjected to low predation pressures. As humans were indeed the only large predator on the island, this suggests hunting of abundant and easy-to-catch populations or control, similar to that which entailed the introduction of wild boar to the island approximately two millennia earlier. Accessibility to wild/feral goats was probably lower because of their natural mountain behavior. Movement of humans between coastal and mountain game cannot be excluded. The apparently extreme specialization of the meat supply of the Early phase A appears, therefore, as an opportunistic adaptation to both the island faunal resources and the coastal-plain environments of the site. In addition, cattle were actually bred on the site, and although tenuous, the evidence suggests that people had already begun to domesticate some suids. Thus, these (perhaps mobile) human groups appear as mostly opportunistic hunters profiting from a favorable island situation and practicing hunting/control and breeding as well. Any attempt to classify them as strictly hunters or farmers would fail.

This image seems to agree with the data from the mainland (Goring-Morris and Belfer-Cohen 2011; Zeder 2011). There is no indication of animal breeding in the southern Levant for the middle of the eleventh millennium, and data collected for southeastern Anatolia and the northern Levant indicate that early domestic goats, sheep, pigs, and cattle actually first appeared at that time (Helmer et al. 2005; Peters, von den Driesch, and Helmer 2005) but that well-controlled hunting of hemiones, gazelles, wild boar, aurochs, and wild sheep and goats still provided the major part of the meat supply (Vigne and Helmer 2007). Only the absence of sheep at Shillourokambos Early A (and at Mylouthkia; Peltenburg et al. 2001b) is surprising, and it indicates that the processes of domestication of sheep and goats in the Near East resulted from two very different processes, as already shown by Zeder (2005) for the beginning of their domestication in Iran.

Early phase B differs highly from the previous one in terms of animal exploitation (fig. 2). The introduction of domestic pigs and sheep, immediately bred with sophisticated techniques, indicate that Cyprus then benefited from some of the late-MPPNB technical innovations of the mainland. As the

Figure 3. Evolution of meat production through the chronolog- ical phases of Shillourokambos. Bone weight percentages are not exact estimates of meat procurement. Only the relative variations between the different phases can be taken into consideration in this diagram. This is why ordinates are not graduated. EPPNB = Early Pre-Pottery Neolithic B; MPPNB = Middle Pre-Pottery Neolithic B; LPPNB = Late Pre-Pottery Neolithic B.

50% does not mean that hunting provided 50% of the meat. We can take into consideration only the relative value for each phase with reference to the others. The least unreliable reference is the Late phase, where we can reasonably consider that breeding produced all the meat for all mammal species except deer, for which the rate of production was 60%, 70%, or 76%, depending on the mode of estimation (weight of meat and offal, according to Vigne [1992], NISP, or bone weight, respectively).

Figure 3 indicates that meat production increased slowly and irregularly but constantly over time, especially starting in the Middle phases. It always remained below 60%–75% and was probably less than 50% during the Early phases. However, it was probably significant as early as the earliest phases, then represented by cattle and an unclear proportion of the suids (fig. 2). Even if milk production is added, this development implies a long stage of low-level food production (see Smith 2001) with important variations that suggest frequent modifications of the technoeconomic strategies and then a slow transition to farming. The former took place during the mainland MPPNB, when numerous sites on the mainland also show a dominance of hunting/control in their meat procurement (Conolly et al. 2011; Hongo et al. 2009; Vigne and Helmer 2007). The latter closely corresponds to the end of the MPPNB and the LPPNB. This evolution fits the macro-regional historical tendency rather well (see Vigne 2008). Shillourokambos can be taken as an example of the numerous local scenarios that led to farming in the Near East (Bar-Yosef and Meadow 1995) and in numerous regions, as evidenced during the Mérida conference.
local goats were quite abundant, the absence of goat introduction and herding reveals a selection among the potential mainland inputs that depended on local availability. Meat procurement also became more eclectic (with reference to the low taxonomic diversity) than during the Early phase A: all the species present—suids, goats, and cattle, but also newly introduced fallow deer and sheep—were exploited, and they contributed almost in the same proportion, complementing the existing subsistence system. In parallel with the Middle PPNB evolution on the mainland, animal husbandry increased in diversity and probably played an increasing buffering role in the seasonal subsistence, with a higher proportion of cattle; with the beginning of seasonal pig breeding, which very quickly mixed autochthonous and new allochthonous lineages; and in general with sophisticated sheep herding for milk and meat. The latter practice, in which lambs are kept alive but shared among the ewes for part of the time (Vigne and Helmer 2007), implies a high technical level for separate herding of young and adults, particular attention to lambs, and processing of milk and its derivatives. For the first half of the tenth millennium, this has been attested to on the mainland only for goats at Cafer Höyük, Tell Halula, and Tell Aswad (Gourichon and Helmer 2008; Helmer 2008; Vigne and Helmer 2007).

However, hunting remained the main source of meat during this Early phase B. Almost immediately after its introduction, the Mesopotamian fallow deer became the major source of meat through a very efficient strategy of exploitation, which was probably collective hunting by beating of mixed herds of males, females, and young (Vigne 2000), quick butchering of carcasses on the kill site, and selection of the most profitable joints. Wild pigs and goats were also subject to intensive hunting based on similar practices. Cooking techniques indicate this intensive exploitation (bone breakage for the consumption of marrow) with relatively standardized and refined practices (different cutting patterns for suids and ruminants, skilled cutting, roasting for some joints and boiling for others). Evidence of seasonal exploitation suggests that deer were hunted in fall and winter, suids were slaughtered in winter, and spring and early summer were devoted to lambs and milk exploitation, together with plant cultivation.

However, in that period, and again more clearly during the Early C and Middle phases, clear evidence of overexploitation of game appears mainly in the form of a demographic erosion of deer populations. This reminds us that island resources were not as diversified and abundant as those on the mainland, where MPPNB villages still practiced diversified hunting of wild equids, gazelles, and aurochs. In this context, the development of skilled breeding of cattle, pigs, and sheep in Cyprus appears not only as a counterpoint to the ongoing evolution on the mainland but also as an answer to the local necessity of dealing with both the limitation of island resources and the probably increasing population of these pioneer human communities.

This vision of the dietary history of Shillourokambos is supported by the increase in technical efforts that appear during the Early phase C. From the end of the Early phase B onward, the archaeozoological data indeed suggest an intensification of henceforth well-controlled pig breeding focused on the production of fat and meat by winter slaughtering of first- and second-year pigs. For the first time since the beginning of the tenth millennium, the NISP of pigs, which mainly result from breeding, exceeds that of deer. The presence of cattle clearly began to decline, perhaps only because cattle breeding is more difficult and less immediately profitable than pig breeding.

Until Middle phase A1, sheep herding continued at a high level. Then there was a strong and rapid decrease in the size of the sheep, together with increasing frequency of environmental stress marks on the horn cores and an extreme slenderness of the long bones. At the same time, pigs also decreased in size, and there was a significant increase in the rate of linear enamel hypoplasia, which indicates an intensification of environmental stress. New innovations and important changes in animal control seem to have emerged very rapidly to compensate for this probable breeding failure. These were based both on imports from mainland “rear bases” and on local improvements of the technical system. As mentioned above, a new, larger domestic sheep lineage arrived from the central or southern Levant as well as a new cattle lineage (which might be at the origin of the slight increase of cattle frequencies that we observed at that time). But the restoration of the system was also based on local resources, not through hunting, as the deer and then pig populations declined, but through the new domestication of the local wild goats (see above). Here again, these Cypriot populations appear to have been involved in a macroregional system of exchanges and progress, but they were also able to provide local responses to the ongoing consolidation of the new Neolithic way of life.

During the Middle phase A2, there followed a complete remodeling of the utilization of animal resources: besides deer (and secondarily goat) hunting, which persisted, seasonal pig breeding, which provided fat, is dominant; from then on, domestic goats progressively played the role of milk producers, as they usually did on the mainland (Vigne and Helmer 2007). Complementarily, the restored sheep herding tends to be devoted to meat production, then also to hair exploitation, a tendency that is also known from some pre-Halaf continental sites, such as Tell Sotto and El Kowm 2 (Helmer, Gourichon, and Vila 2007). The increase of meat production at that time is demonstrated by a 25-fold increase in the density of animal food refuse (in relation to the volume of excavated earth) in comparison with the early phases. This development appears to be a parallel to the intensification of animal breeding on the mainland at the transition between the MPPNB and LPPNB, which corresponds to the emergence of farming (Vigne 2008).

On the other hand, this emphasizes the relatively low level of animal products in the diet of the early phases at Shillourokambos. The decrease in grinding stones at the transition
between the Early and Middle phases (Perrin 2011) suggests that plant cultivation, which is well documented at Mylouthkia (Peltenburg et al. 2000, 2001a), would have played a more important role in the diet of the early phases at Shillourokambos than suggested by the relatively poor set of botanical remains (Willcox 2003). The strong development of animal husbandry in the middle of the tenth millennium may be connected to a drastic change from a mostly vegetarian diet to a more carnivorous one. It is also probably connected to a population increase in the village, as seen in Sector 3 of the site, the study of which is still ongoing.

In summary, the history of meat supply at Shillourokambos comes within the scope of the PPNB Near Eastern Neolithic transition. This is seen in the exploitation of local animals by hunting and control in local domestication as well as by breeding, which led to the slow but constant intensification of food production relative to predation, and in genetic inputs from the mainland in the form of new lineages of domestic pigs, sheep, and perhaps cattle. In comparison with the earliest known Anatolian sites with domestic animals, Shillourokambos differs in its slightly later manifestation of local domestication processes (pigs and goats), which are possibly adaptations to the local conditions, because of a low and insular biological diversity. The emergence of Cypriot animal production appears to be a local version of that seen on the mainland, driven by resource shortage and human demographic growth (Bocquet-Appel 2011). This interpretation of the subsistence strategy of Shillourokambos implies a knowledge of seafaring (Broodbank 2006; Vigne and Cucchi 2005), but this was not sufficient for sustainable development of island populations; it also required a high level of control of the sources of subsistence that could be attained only through the Neolithic way of life and strong connections to continental “rear bases.”

Conclusions

Though still poorly documented for the thirteenth–eleventh millennia, the prepottery history of the relationships between mammals and humans on Cyprus provides substantial new information about the beginnings of domestication in the Near East. In that context, the recent Cypriot data document the following: (1) a transition to farming during the tenth millennium, after an unstable and opportunistic late-EPPNB and MPPNB phase of low-level food production based on rapidly changing combinations of hunting, control, and breeding; (2) initiation of this process during the Final Late Glacial and MPPNB, which implies a knowledge of seafaring (Broodbank 2006; Vigne and Cucchi 2005), but this was not sufficient for sustainable development of island populations; it also required a high level of control of the sources of subsistence that could be attained only through the Neolithic way of life and strong connections to continental “rear bases.”

in each of the different regions or even in each site, different scenarios and rates of intensification of exploitation existed, from control of wild/feral populations to sophisticated breeding that entailed the morphological changes that characterize domestic lineages; (4) the beginnings of domestication, that is, control in a wide area extending from the Iranian Plateau to the Mediterranean shores (though ancillary to the continent through the introduction of wild or domestic taxa, Cyprus was part of this area, with special Cypriot innovations such as intensive hunting of fallow deer and local domestication of the wild/feral goat); (5) intensive and long-distance exchanges of raw materials, including not only obsidian (Briais, Gratuz, and Gualaine 1997) but also living animals across large continental and marine areas (such interaction explains the relative homogeneity of the PPN cultural sphere); and (6) social organization and technical skills in the Near Eastern Final Late Glacial and Early Holocene societies that were more sophisticated than generally believed: in addition to rapid and high-level improvements in lithic (Astruc, Binder, and Briais 2007) and construction (Schmidt 2003; Stordeur et al. 2000) technologies, these groups were able to regularly and more intensively navigate to Cyprus (probably by sailing; Vigne 2009) and to control animal populations using diversified and sophisticated techniques (for meat, milk, hair, and draft products). Illustrating a part of the socioeconomic and historical complexity involved in the beginning of the Neolithic in the Near East, Cyprus also emphasizes the multifactorial causes of the transition, including, of course, climatic and environmental conditions (Bar-Yosef 2011) but also the dominant influence of demographic (Bocquet-Appel 2011), technical, and social threshold effects.

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The Beginnings of Agriculture in China
A Multiregional View
by David Joel Cohen

Introduction
Our understanding of the origins of agriculture in China is still of low resolution, particularly during a critical time period between 12,500 and 9000 cal BP when hunter-gatherers in four distinct but interconnected geographical regions—Northeast China, the North China plains, and the Middle and Lower Yangtze River regions—establish the first sedentary villages. Although reliance on the cereals rice and millet was once thought to be a major part of this fundamental behavioral change, in recent years it has become clear that this is not the case. The advent of farming and the domestication of cereals was a slow process occurring over 4 millennia in a number of small steps, region to region, after sedentism and other social and ideological changes of “Neolithization” had begun.

Most previous work for China has focused on the archaeobotany of rice or millet or has looked at the archaeology only of single regions. The view here is purposefully broader, looking at parallel contemporaneous developments across both northern and southern China, as it is within this broad context of continuous but variable contact between Neolithic systems that we witness the gradual and interrelated development of millet (dry) and rice (wet) agriculture: there are not multiple independent “inventions” of agriculture.

The processes of Neolithization are rooted in the Late Paleolithic (Cohen 2003). Because of a gap in archaeological coverage for the last few millennia of the Pleistocene, available data begin with the earliest-known villages already established from ca. 9000 cal BP. These typically contain clusters of small round houses and storage pits, abundant and increasingly diversified pottery assemblages, edge-polished axes or adzes, bone tools, ritual features, and discreet cemetery areas, but subsistence still does not rely on domesticated plants. It is such sites that we here call “Early Neolithic.” What follows is an overview of the archaeology of the Early Neolithic in these four regions.

Recent debate has focused on the timing and pace of the domestication of cereals—rice or millet—found in the Early Neolithic and Middle Neolithic villages and how cereals are incorporated into changing modes of subsistence over a 3,000-year period (Crawford 2011; Fuller and Qin 2009; Fuller et al. 2009, 2010 and references therein; Liu, Lee, and Jiang 2007; Zhao 2011). We still do not know where cereal domestication first occurred. South China, where rice production begins, was assumed to have the earliest domestication and agriculture, but new data have given rise to a counter-argument for northern millet farming as having primacy or independent invention (Barton et al. 2009; Bar-Yosef 2011; Bettinger et al. 2007; Lu 1999, 2006; Shelach 2000). The paucity of securely dated sites leaves this an open question.
Cross-regional interactions leading to farming’s establishment and spread were facilitated by the interlacing river systems of eastern China. By 8900 cal BP, people in sedentary villages in northern and southern China lived in fundamentally different ways than their Late Pleistocene ancestors, and the socioeconomic and ideological changes of the Neolithic were well in place but still without agriculture (e.g., Cohen 1998; Crawford 2006; Lu 1999, 2005; Shelach 2000; Underhill and Habu 2006; Yasuda 2002 and references therein; Zhang and Hung 2008). The organizational and ideological changes of the Early Neolithic arise first and out of synchronization with the slower pathways leading from increasing exploitation of wild plants to their management and cultivation, to the fixing of morphological traits and domestication, and then to the spread of the domesticates (e.g., Fuller and Qin 2009; Fuller et al. 2009; Jones and Liu 2009).

The Geographical and Environmental Setting and Upper Paleolithic Precursors

The vast landmass of China consists of three major topographic “steps” (Ren, Yang, and Bao 1985). While Late Paleolithic sites are found in many regions, it is in the river drainages of the lowest “step” (sea level to 1,000 m) that hunter-gatherers first became sedentary and later domesticated plants and animals. Between 10,000 and 8900 cal BP, four Early Neolithic cultural clusters are recognized. Along the Middle and Lower Yellow River, on the North China and Central plains, we find the large village and cemetery sites of the Peiligang 裴李岗 culture and closely related neighboring cultures. These feature the intensive exploitation of millet (and some rice). The interdigitating tributaries of the Huai River system tie the Peiligang cultures to two clusters in the (and some rice). The interdigitating tributaries of the Huai River system tie the Peiligang cultures to two clusters in the

through the Terminal Pleistocene, Younger Dryas (ca. 12,800–11,600 cal BP), and onset of the Holocene (11,500 cal BP), marked variation in annual monsoon cycles and their intensities causes a shifting mosaic of localized environmental changes in China (Cohen 1998, 2002; Morrill, Overpeck, and Cole 2003; Yasuda et al. 2004; Yi and Saito 2004; Yi et al. 2003; Yuan et al. 2004). These would have been more severe and abrupt in the north and would have more greatly affected people at the margins of major phytogeographic zones (e.g., Hong and Ricklefs 2001; Yang and Ding 2008). As there is some correlation with cultural changes, the localized roles of climatic fluctuation in “Neolithization” require renewed attention (Bar-Yosef 2011).

The north-south division of Early Neolithic cultures mirrors that of their Upper Paleolithic predecessors (Cohen 2003). Terminal Pleistocene northern China features small ephemeral sites with lithics reflecting a broad range of technological strategies, including microblade production, polished bone tools, grinding stones and chipped stone axes and adzes, and body ornamentation, perhaps reflecting specialized adaptations to the more extreme and unstable environments of the region during the late Terminal Pleistocene (Elston and Brantingham 2002). Microblade sites in northern China such as Xiachuan 下川 (27,500–18,200 cal BP) and Shizitan 神子滩 (20,300–13,800 cal BP, Shanxi; fig. 1) are at the southernmost margin of an extensive Northern Asian microblade sphere (An 2000; Kuzmin, Keates, and Shen 2007; Lu 1999; Xia et al. 2002; Zhang 2002a).

Upper Paleolithic South China features stability in its typical cobble-tool industries (cores, flakes, choppers), which persist into the Early Neolithic. This has been attributed to greater environmental stability in this warmer, wetter, more resource-abundant region. It is in hunter-gatherer contexts in South China that pottery vessels—the earliest in the world—first appear, such as at Yuchanyan 玉蟾岩 (Hunan) by 18,300 cal BP (Boaretto et al. 2009; Gu and Yuan 2006; Prendergast, Yuan, and Bar-Yosef 2009; Yuan 2002) and Xianrendong 仙人洞 (Jiangxi; 21,000–14,500 cal BP; MacNeish et al. 1998; Peng and Zhou 2006; Sun and Zhan 2004; Zhang 2002b; fig. 2). While it is not clear whether sedentary villages and plant domestication emerge first in the south or north, if environmental pressure is a causal factor for either, the resource-rich Yangtze River “land of plenty” would require different modeling than the north.

In Chinese archaeology, the presence of pottery has been taken as a marker for the Neolithic, but it is now apparent that these are seasonal sites of mobile hunter-gatherers with a small amount of coarse low-fired pottery. By 16,000–14,000 cal BP, pottery is distributed as widely as South China, Japan, and the Russian Far East (Cohen 1998, 2003; Kuzmin 2006; Wu and Zhao 2003). We hypothesize that pottery making spreads through these regions via social networks and is not reinvented in each. Pearson (2005) sees the pottery as invented for feasting that reaffirmed group bonds and collective identities (but see Hayden 2009). Even if so, pottery takes on new roles in the Early Neolithic as it diversifies in form and functions.

In North China, pottery appears at larger open-air sites featuring new adaptations by foragers. At Yujiaigou 西家沟 (Hebei; TL 11,600–11,100 BP), on the cold arid grasslands northwest of the Taihang Mountains, pottery appears in a typical microblade assemblage (Guo and Li 2000, 2002). Pottery sites on the eastern warmer and wetter side of the Taihang range stand in ready contrast and can be seen as apparent precursors to the Early Neolithic. The lakesides Nanzhuangtou 南庄头 site (Hebei; 12,500–10,500 cal BP), dated to the Younger Dryas

1. Below, the lowercase terms “the north” and “northern China” are used to refer jointly to the North China and Northeast China regions.
and Early Holocene, features flake tools (no microblades), polished axes, bone and antler tools, and querns and rollers, indicating seed processing. Chiseled wooden rods give evidence of woodworking. Nanzhuangtou has activity areas for fauna processing and cooking and two natural ditches filled with midden deposits; these become typical features of Neolithic sites. The earliest domesticated dog is identified at Nanzhuangtou (Yuan 2010). Small amounts of pig and chicken—later Neolithic domesticates—are present, but deer are the primary focus. Smoke blackening on pottery may indicate cooking over fire and a new dependence on pottery in food processing (Zhu 2002:98). Decorative elaboration may indicate increased social signaling using ceramics.

Two other nearby sites, both with microblades, also show important transitional elements. Zhuannian 芝岩 (Beijing; 11,300–10,300 cal BP) features a larger site size (ca. 0.5 ha), querns and rollers, small stone axes, and fragments of stone vessels (mortars?) as well as pottery (Zhao et al. 2006). Donghulin 东湖林 (Beijing; 11,000–9300 cal BP) has small pit burials. One (M2) contained a stone axe placed at the head of a
### Pre-Neolithic / Early Neolithic / Middle Neolithic Sites

#### SOUTH CHINA EARLY POTTERY

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<th>Calibrated BP</th>
<th>Location</th>
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<tr>
<td><strong>Late Paleolithic</strong></td>
<td><strong>Xianrendong site</strong></td>
<td>21,000-14,500</td>
<td>Wannian, Jiangxi</td>
<td>Early pottery</td>
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<td><strong>Late Paleolithic</strong></td>
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<td><strong>Late Paleolithic</strong></td>
<td><strong>Yuchanyan site</strong></td>
<td>18,300-13,900</td>
<td>Danxian, Hunan</td>
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#### NORTH CHINA EARLY POTTERY

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<td><strong>Pottery Pre-Neolithic</strong></td>
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<td>Mentougou, Beijing</td>
<td>burials (9570 BP)</td>
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<td><strong>Pottery Pre-Neolithic</strong></td>
<td><strong>Yujiagou site</strong></td>
<td>11,600-11,100 BP (pottery TL)</td>
<td>Yangyuan, Hebei</td>
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<td><strong>Pottery Pre-Neolithic</strong></td>
<td><strong>Zhuanxian site</strong></td>
<td>11,300-10,300</td>
<td>Huaireu County, Beijing</td>
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<td><strong>Pottery Pre-Neolithic</strong></td>
<td><strong>Nanzhuangtou site</strong></td>
<td>12,500-10,900</td>
<td>Xushui, Henan</td>
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flexed (perhaps bundled) individual with perforated shells placed about the rest of the body. Ten pit hearths, neatly lined with cobbles, show greater pyrotechnological controls (Beijing Donghulin 2006:5).

Nanzhuangtou, Zhuannian, and Donghulin show important transitional steps toward the Early Neolithic. We find new technologies such as grinding stones, pottery, and microblade knives as part of an adoption of broad-spectrum subsistence strategies (Lu 2006), but it is still not clear if plant exploitation included millet or whether or not these are sedentary sites.

The Early Neolithic

The appearance of Early Neolithic settlements sometime after 10,100 cal BP marks increased sedentism, population agglomeration, and departures from Late Paleolithic behavioral patterns. Many sites are enclosed by ditches and have distinct
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<td>10,000-8500</td>
<td>Pujiang, Zhejiang</td>
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<td>Early/Middle Neolithic</td>
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<td>7900-7000</td>
<td>Pujiang, Zhejiang</td>
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<td>7000-5400</td>
<td>Yuyao, Zhejiang</td>
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<td>Tianhuoshan site</td>
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<td>Majiabang Culture</td>
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<td>Jiaxing, Zhejiang</td>
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<td>Songze Culture</td>
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<td>Beiyinyangying Culture</td>
<td>6000-5000</td>
<td>Nanjing, Jiangsu</td>
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<td>Late Neolithic</td>
<td>Liangzhu Culture</td>
<td>5200-4200</td>
<td>Yuhang, Zhejiang</td>
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Figure 2. (Continued)
areas for houses, for domestic activities, for storage facilities, and for the earliest planned multigenerational cemeteries, sometimes with hundreds of burials. Early houses are typically small, round, and semisubterranean. Later they shift to a rectangular plan. Houses are frequently found in clusters of several tens, and with a few exceptions, most houses in a village are similar in size. Burials are uniform in size, and grave goods tend to be few. There is little evidence for functional differentiation between households or social status differences between individuals. Within regions, there can be differences in site size.

A key issue, discussed in detail elsewhere (Crawford 2009, 2011; Fuller and Qin 2008, 2009; Fuller et al. 2009; Jones and Liu 2009; Liu 2008; Liu, Lee, and Jiang 2007; Liu et al. 2007; Lu et al. 2009; Pan 2008; Zhao 2011), is the nature of plant and animal exploitation and whether domestication occurs in this period. Since the 1970s, abundant cereal remains excavated from storage pits and also found in pottery tempering were assumed to be from domesticates. In recent years, as archaeobotanical remains become systematically recovered, as well as through stable isotope studies (e.g., Barton et al. 2009; Hu, Ambrose, and Wang 2006; Hu et al. 2008; Pechenkina et al. 2005), a more complex picture is emerging of the degree of human manipulation of plants and their environment. Early Neolithic populations continued to base their subsistence on hunting-gathering-fishing but with intensified exploitation of the plants later cultivated in agricultural systems. Pig domestication occurs perhaps at 9000 cal BP (Larson et al. 2010; Yuan 2010). Other early domesticates are dog and chicken, with cattle, water buffalo, and sheep added later, but wild animals continue to be a major meat source throughout the Neolithic, although regional patterns of reliance on domesticated animals versus wild animals vary (An 2004; Yuan 2003; Yuan, Flad, and Luo 2008).

North China: Peiligang and Related Cultures

The Early Neolithic cultures of North China date from at least ca. 9000 cal BP (or possibly 10,000 cal BP for Cishan) through
7400 cal BP. These cultures share many similarities in settlement structure, houses, burials, pottery forms and decoration, tools, grinding stones, and subsistence practices, and so we cluster them into one group here. The individual archaeological cultures within this cluster include the Peiligang (Henan) and Cishan (Hebei) cultures in the lowland plains of the eastern Middle Yellow River, the Houli culture (Shandong) on the Lower Yellow River, and, dating later, the Dadikanwan culture (Gansu and Shaanxi) in the western Middle Yellow River.

The Peiligang Culture, Jiahu, and North-South Connections

Peiligang culture sites range in size from under 1 to 20 ha. Excavated sites (all in Henan) include the typesite Peiligang, Shawoli, Egou, Shigu, and Shuiquan.
(see Li 2003), but the best understood is Jiahu (5.5 ha, 9000–8000 cal BP; Henan Jiahu 1999:515–519). The Peiligang component at the largest settlement, Tanghu, is said to cover 20 ha (Zhang and Xin 2008). Both Tanghu and Jiahu feature a ditch enclosing part of the settlement, with Jiahu’s being the oldest. As discussed by Crawford (2011) for Jōmon agriculture in Japan, human activities around these early village sites such as ditch construction and clearing would have a significant impact on plant populations and need further consideration.

Peiligang houses are semisubterranean and round in plan, ca. 2.5 m in diameter. Round houses are a common feature of the earliest sites across most regions. Interiors usually feature a hearth and a narrow sloped entryway or steps. At Jiahu (Henan Jiahu 1999), 42 of 45 structures are round and semisubterranean; most are a single room. At Tanghu, more than 60 semisubterranean round houses, some with double rooms, have been excavated along with 204 pits (Zhang and Xin 2008). Peiligang-related sites can have hundreds of these “ash-pits” for refuse disposal, storage, and ritual use (such as dog burials) found in both domestic and cemetery areas (Li 2003:40–46).

Peiligang sites feature separate cemeteries within which can be several spatial clusters of graves, and two or three cemetery areas can be located at one site. Contemporaneous cemeteries may serve separate social groups. At Jiahu, the early period has two cemeteries, and the middle and late periods have six (Yan 2006:112). Thus, we have evidence for new forms of social organization emerging with Neolithicization, with indications of both population agglomeration and social differentiation (such as clan formation) over time. Jiahu burials show some differentiation by sex and by grave-good amounts, but this differentiation in burial wealth occurs in a still egalitarian society with a continuum from poorest to richest, without clustering, and with random spatial distribution of the richest graves (Smith and Lee 2008). Unique to Jiahu are its numerous group primary burials and its many secondary burials, both group and individual.

Peiligang assemblages contain large numbers of adzes and the prototypical tongue-shaped spades, denticulate sickles, and four-footed large stone querns with rollers. Bone tools include elaborate barbed spears, points, and needles. The wide variety of pottery vessel types include mostly guan jars, hu tall-neck small-mouth jars, and bo small bowls; second most common are ding tripod vessels and wan bowls, and there are also pan platters, dou pedestal serving stands, and vessel lids (Li 2003:29–30; fig. 3).

Jiahu provides evidence for special ritual practices such as dog pits and sets of tortoise shell rattle placed in some burials. Symbolic systems become more greatly manifested in pottery decoration as well as in individual “characters” found inscribed on tortoise shells (but not related to later writing as some suggest; Li et al. 2003). Jiahu inhabitants also had a well-developed cognitive scheme of music: crane bone flutes are capable of four- and seven-tone scales like ours today (Zhang, Xiao, and Lee 2004).

Jiahu is rich in animal and plant remains. Subsistence was based primarily on hunting-gathering–fishing. Domesticated dogs are present at Jiahu, as are pigs (Yuan 2010). Jiahu storage pits contain many plant remains, including rice. Although cereals have been the focus of discussions of subsistence systems, other plant foods probably played a larger role in Early Neolithic subsistence and need more consideration. At Jiahu, these include acorns (Quercus), trapa, and wild soybean. Jiahu’s small-sized rice remains are at the center of the debate on plant domestication (Crawford 2011; Fuller and Qin 2008; Fuller, Qin, and Harvey 2008a, 2008b; Fuller et al. 2009; Liu, Lee, and Jiang 2007; Zhao 2011; Zhao and Zhang 2009). Because cereal exploitation at other Peiligang and related culture sites shares a primary focus on millet, it is extremely interesting that rice is abundant but millet is absent at Jiahu even though Jiahu maintains many defining cultural traits of the Peiligang. The exploitation of rice rather than millet had no impact on material culture at Jiahu, differentiating it from other Peiligang sites, and so it was other factors—not millet consumption—that may have maintained cultural boundaries during this period.

The Peiligang sites demonstrate evolutionary leaps in sedentism and site structure, social organization and population dynamics, technologies, and symbolic activities on first entrance into the Early Neolithic. Jiahu also supports the hypothesis that interregional contacts through social networks drive shared parallel development. For example, Jiahu mixes Peiligang material culture related to subsistence—including grinding stones, sickles, and pottery—with foods from South China cultures such as lotus, trapa, and rice (Zhao 2011). Jiahu’s location ties it into the Huai River communication channels that connect northward into the Peiligang–Yellow River system and southward into the Pengtoushan–Yangtze River system. Shared pottery vessel forms with the Pengtoushan culture—such as the double-eared, round-bellied, high-neck, small-mouth hu jugs—demonstrate this (fig. 3), as does the appearance of ding tripod vessels and three-leg cooking stands in both regions (Wu 1997). It is unlikely that all of these identical forms developed independently. Also, Pengtoushan and Jiahu (unlike other Peiligang sites) have many secondary burials (and these burials in both areas contain the double-ear hu vessels; Henan Jiahu 1999:533). They each also have the earliest examples of settlement ditches.

Cishan: Broomcorn Millet at 10,000 cal BP?

The Cishan culture is centered in Hebei, north of the Peiligang culture region (see Liu, Hunt, and Jones 2009). Excavated sites include the 8-ha Cishan type site (Hebei Cishan 1981) and Beifudi 北坡地 (Duan Beifudi 2007). Cishan’s excavations in the 1970s revealed 474 storage pits containing an estimated 50,000 kg of ashy remains of cereals, originally identified as domesticated foxtail millet Setaria italica (Zhao
Figure 3. Comparison of artifact types found in the Early Neolithic North China Peiligang and Cishan cultures and the South China Pengtoushan culture. 1, 14, and 24 are footed grinding stones of the Peiligang culture also found in Cishan later phases. 6 and 37 are cooking stands found in both North and South China. 19, 21, 32, 33, 43, and 44 are double-eared small-mouth hu jugs common at Pengtoushan and Peiligang sites. 7, 8, 17, 18, 27, and 28 are ding tripods. Objects are not to the same scale. 1–13 after Hebei Cishan 1981; 14, 15, 18, 19, 21, and 22 after Peiligang A 1978; 16, 17, and 20 after Peiligang B 1982; 23–34 after Henan Jiahu 1999; 36–44 after Hunan Pengtoushan 2006.
2005:91; 2011). Recent phytolith and biomolecular analyses of new samples from exposed sections at the site instead identify these as domesticated broomcorn (common) millet *Panicum miliaceum*, with new radiocarbon dates ranging from 10,300 to 8700 cal BP, which would mean Cishan could have the earliest domesticated cereals and dryland farming in China (Crawford 2009; Lu et al. 2009). But these radiocarbon dates, taken on samples from exposed surfaces and not from archaeological excavation, are more than a millennium earlier than those from the earlier excavations and may be problematic (Zhao 2011). Further verification is called for through systematic stratigraphic sampling and micromorphological study to assure secure contexts and associations for radiocarbon samples. Foxtail millet appears after broomcorn, at 8700 cal BP, and only in small quantities (which is the pattern at other sites, as well). Domesticated pig is present at Cishan as well (Yuan 2010). Cishan’s occupation ends at 7500 cal BP.

Cishan’s material culture shows close connections with the Peiligang regional phase. For example, grinding querns increase greatly through time. In its second phase, 52 four-footed querns are found—a unique form coming from Peiligang. Evidence for participation in wider-ranging interactions also is found. Vessel stands, ding tripods, and some ring-foot vessels are also present, and these vessel forms are distributed widely, even into South China. Flat-based ceramic jars and bowls and straight-sided wide-mouth cups (yu) may indicate ties to the northeast (below; fig. 3). Beifudi is notable for its ritual features, ceramic masks (earliest found in China), and jades (Duan Beifudi 2007). Early jades are also found in the northeast and at Dadiwan to the west.

**The Houli Culture**

Thirteen Houli 后李 sites are found at the margins of the central hills and outer floodplains of the Shandong peninsula skirting the northern edge of the highlands (Tong 2006:176). Houli sites are larger than Peiligang sites, but their chronology is poorly understood and may date later. Hu et al. (2008) date the Xiaojingshan 小京山 site to 8200–7500 cal BP. The Houli typesite is 15 ha. The Xiaojingshan site features a three-sided ditch 1,130 m in total length. The earliest houses and two cemeteries are found within its bounds. Later houses and a cemetery are added outside the ditch. There are also early pottery kilns and many ash pits. Although houses are semisubterranean, they are square with rounded corners, 35–50+ m² in size, with one to three hearths in the center and fired earthen walls. The rectangular shape may indicate a later date. Many have grinding querns installed in the floors near the hearths. Unlike Peiligang, the querns are footless and used on both sides, and they are found in domestic contexts, while Peiligang querns primarily are found in burial. Many houses also have large pottery cauldrons, sometimes half buried at the interior wall.

Houli ceramics feature more than 12 forms, but unlike Peiligang, there are few ding tripods. Instead, round-bottom fu cauldrons are the common cooking vessels. There are leg stands, as in South China and Peiligang (Tong 2006). Stable isotope studies of human bone from Xiaojingshan show C4 plants (millet) contributing 25% of dietary protein at 8000 cal BP; this increases, becoming the most significant protein source a millennium later (Hu et al. 2008). Flotation at the Yuezhuang 月庄 site (ca. 7900 cal BP) recovered 40 broomcorn and one foxtail seed but also 26 rice grains, showing *Oryza*’s arrival in the Lower Yellow River by this time (Crawford, Chen, and Wang 2006). Nuts, a significant component of Early Neolithic diets in South China, have been identified at Houli sites but in smaller quantities (Crawford 2011).

**Dadiwan and the Highlands**

After the Peiligang-related cultures developed millet production in the lower elevations, they probably expanded into higher elevations and new ecological zones. The appearance of the Dadiwan 大地湾 (or Laoguantai 老官台) culture may result from the spread of farming populations into new regions, a pattern that was to continue and accelerate through the Neolithic. The Dadiwan distribution area is centered on the Wei and Upper Hanshui Rivers and the loess plateau at ca. 1,500-m elevation, a higher and more arid region than the other Peiligang-related cultures. Sites include Dadiwan (Gansu), Lower Beishouling 北首岭, Laoguantai, Yuanjunmiao 元君廟, and Beilu 北坬 (Bai and Zhang 2001:15). At Dadiwan, 240 houses, 325 pits, 35 kilns, and 65 burials have been excavated at 10 localities. Dadiwan dates later than other Peiligang-related regions. The earliest occupation, ca. 7900–7200 cal BP, features round semisubterranean houses, pits, and burials. Ceramics share common forms with Peiligang, including tripod vessels and hu small-mouth jars, but one difference is the presence of painted pottery—bowls with a red painted band at the rim. At 6500 cal BP, the Dadiwan settlement expands from the second to the third river terrace. At this stage, a ditch is dug enclosing its 156 now rectangular semisubterranean houses positioned around a central plaza, and burial shifts to a separate cemetery zone. Ceramic forms increase, and fine wares and complex painted designs appear. Jade chisels also are found (Gansu Dadiwan 2006).

Bettinger et al. (2007, 2010) include Dadiwan in a scenario for an independent center of millet agricultural origins created by “low-level food producer” forager groups from the desert margins north of the site. Intensively specializing on broomcorn millet, they were forced to migrate to the unpopulated plains of the loess plateau when in the Early Holocene the region became more arid. In semipermanent settlements such as Dadiwan, they domesticated broomcorn millet, which is more tolerant to cold and drought than foxtail millet (Bettinger et al. 2007:91–93). In Barton et al.’s (2009) stable isotope study, they define this stage as a low-intensity domestic relationship between millet, humans, and their hunting dogs. The proposal that Dadiwan is an independent center because of its location 700 km from Peiligang, higher elevation, dif-
The Early Neolithic in Northeast China: The Xinglongwa Culture

The occupations of the few dated settlements in Northeast China’s Early Neolithic Xinglongwa 兴隆洼 culture begin 5 centuries later than the earliest in the Yellow River region. These settlements, however, parallel what is seen in contemporaneous settlements in the Yellow River region. Xinglongwa sites, in eastern Inner Mongolia, include Xinglongwa, Baiyinchanghan 白音长汗, Chahai 雕海, Nantaizi 南台子, Xinglonggou 兴隆沟, and Beichengzi 北城子 (Liu 2006a). Radiocarbon dates from Xinglongwa sites range from ca. 8300 to 7400 cal BP. The cultural sequence continues with the Fuhe 富河 culture and then the Zhaoobaogou 赵宝沟 culture ca. 7100–6700 cal BP (Liu 2006b; Shelach 2006).

Subsistence in Xinglongwa may include domesticated millets (Zhao 2011), but wild plants and animals make up the majority of the diet. Flotation at Xinglonggou recovered many carbonized seeds, most of which are wild grasses but that also include much broomcorn millet and a small amount of foxtail millet (Liu 2006b; Zhao 2005:91–92)—a pattern that is similar to North China sites. These millets, dating ca. 7650 cal BP, are morphologically domesticated (Zhao 2011).

No domesticated animals are reported for Xinglongwa sites, although domesticated pigs are already found in South and North China by this time period, but the hunting of deer and wild boar is an important part of the economy. By the Zhao-

baogou period, mortality profiles, but not morphology, of pigs suggest domestication (Shelach 2000:283). In Xinglongwa sites, early sacrificial usage of pigs and deer is found, too. Such animal sacrifice becomes a mainstay of later Neolithic and Bronze Age religious activities. In grave M118 at Xinglongwa, a 50-year-old male was interred with one male and one female pig. In house F5 at Xinglonggou, 12 pig crania and 3 deer crania—most with a hole drilled through the forehead—were placed into the house floor (Liu 2006b:9).

Xinglongwa lithics are more diverse than other regions, retaining Late Paleolithic flake tools and microblades and blades while adding polished tools. Both microblades and blades are also found at Beifu in the Cishan culture to the south. Because true blades are rare in the Chinese Late Paleolithic and Early Neolithic, this commonality may be significant. Tools include flaked and sometimes fully polished or edge-polished rectangular stone “spades” (some with waists) and polished axes/azdes (suggesting forest clearing) and awls. The percentage of polished tools increases into the Zhaoobaogou period (Liu 2006b:8–9). Bone-handle composite tools are inset with microblades. Use-wear analysis of stone “plows,” which are up to 30 cm long, suggests they were used to work soil. Stone querns and rollers are found in installations near the walls inside Xinglongwa houses and may have been used for grinding grains. Querns are relatively large, up to 40 cm across and 10–30 cm thick. These are sometimes found associated with large ceramic basins installed in the house floors (Shelach 2000:384), and this is a domestic pattern shared with North China Houli culture sites.

Xinglongwa pottery is sand tempered, coarse, and low fired. Vessel forms are few and mostly jars and bowls. Flat-based vessels predominate, with straight vessel walls angling outward to form wide vessel mouths. Vessel surfaces can be covered with rows of impressed or incised patterns, most notably the Z-shaped motif and net patterns. Zhaoobaogou culture pottery becomes elaborated with more complex decorative motifs, including geometric and net forms over the vessel surface. During the Zhaoobaogou period the first fine clay pottery appears in the region. Decorative motifs combine intertwined elements from deer, birds, boar, and other animals (see Liu 2000). The intricate designs, possibly produced by individuals with specialized skills, are early examples of iconographic or artistic motifs that blossom in the later Neolithic (Shelach 2000:389–393).

During the Xinglongwa period, early examples of carved jades are found in house floors and burials (Shelach 2000: 394), establishing the roots of the ritual jade production that becomes a hallmark of this region by the Middle Neolithic Hongshan epad culture. Jades found in the Dadiwan culture (above) date slightly later.

Xinglongwa Settlements

Unlike other regions, Xinglongwa sites are located primarily on hillsides, suggesting unique considerations for their place-
The Early Neolithic in South China: Pengtoushan and Shangshan (Middle Yangtze Region)

The Pengtoushan 彭头山 culture represents the Early Neolithic of the Middle Yangtze region. Sites are distributed in the Liyang Plain of the Lishui River in northern Hunan Province. Five sites have been excavated: Pengtoushan, Bashidang 八十垱, Fenshanbao 坎山垴, Huangjiayuan 黄家圆, and Tujiatai 涂家台 (Hunan Pengtoushan 2006; Yin 2006). The Pengtoushan culture sites have radiocarbon dates ca. 10,000–8400 cal BP but probably continued for another several centuries. Sites are probably permanent villages with subsistence still based on hunting-fishing-gathering but also with exploitation and perhaps manipulation of wild rice. Soundings at Bashidang and other sites show that an earlier but poorly understood village phase exists before the Pengtoushan culture called the “Lower Bashidang” culture.

Positioned on a slight rise above the current fields and water channels of the plain, the Pengtoushan site is ca. 2 ha in size. The later Bashidang site is ca. 3 ha in size and better preserved (Hunan Pengtoushan 2006). Bashidang is one of the largest Early Neolithic sites here, with others typically under 1 ha (Yan 2006:113). Through time, South China settlements remain smaller than northern ones, perhaps because of the watery topography of the Yangtze basin or later because of rice agriculture’s demands for available level ground for managing water flow (Yan 2006:113).

Houses at Pengtoushan are semisubterranean and comparatively small, with irregular round shapes and hearths of piled fired earth and clay. A few are rectangular and built at ground level on a low base of clay and sand. Among Bashidang’s 24 houses there are fewer semisubterranean and more surface structures, including pile dwellings. Two houses built on earthen platforms 30–50 cm high have a large central post with animal bones deposited near it, perhaps ritually. A ritual function may also hold for most of the 80 excavated pits at Bashidang. They are carefully dug, 30–50 cm in diameter, with straight walls and a flat base. Fired earth, pottery sherds, polished black stone ornamental rods, a few polished stone objects, or cobbles are cached inside many. These are similar to the sacrificial pits found in the Middle Neolithic “altar” features at the nearby Chengtoushan 城头山 settlement (Yin 2006).

Funerary treatment in Pengtoushan is simpler than in North China. The 100 graves at Bashidang and 21 at Pengtoushan are small shallow pits of rectangular, rounded, or irregular shape. Most are secondary, but some are primary and flexed. Grave goods include only one to four objects, usually a cauldron or a high-neck small-mouth jar or a stone tool (Bai and Zhang 2001:23). Bashidang burials are placed at the perimeter of the residential area but are not clustered together. Elaborate vertical pit graves with greater numbers of grave goods in larger distinct cemetery areas do not appear until the Middle Neolithic Daxi 大溪 (6400–5500 cal BP) and Qujialing 青家岭 (5500–4500 cal BP) cultures, such as at Chengtoushan (Chen 2006:210).

Archaeobotanical remains at Bashidang include 67 species of plants. Rice at Bashidang, probably a secondary food resource, has been described as a cultivated form that shows signs of human selective pressure (Hunan Pengtoushan 2006:519; Zhang and Pei 1997), but Fuller, Harvey, and Qin (2007:323), noting markedly thin rice at the site, interpret it as immature and morphologically wild. Other plants include wild soybeans, *trapa*, plum (*Prunus mume*), peach (*Prunus persica*), and wild grape. Fauna includes six species of fish, birds, *Sus sp.*, *Cervus sp.*, water deer, muntjac, and wild water buffalo (*Bubalus sp.*; Hunan Pengtoushan 2006:513).

Remarkably, although the Pengtoushan culture settlements are most likely permanent sedentary villages with a new and increasingly intensive pattern of exploitation of rice and other plants that would also become domesticates, its lithic assemblage still retains regional Paleolithic characteristics. Pengtoushan still features mostly cobbles tools, small flaked-flint tools (e.g., scrapers), and a few axes and adzes possibly used for woodworking (Hunan Pengtoushan 2006:587); this is not like later specialized assemblages associated with rice agriculture (He 1995).

Pengtoushan pottery features uneven forming of vessels, but vessel walls are thinner than Pleistocene pottery, measuring 0.6–0.8 cm. Round-bottom vessel forms predominate,
and there is much coarse cord marking (He 1995). Wares have fine sand or organic tempering, including rice husks and leaves (Pei 2002). Double-eared hu jars make up 12%–15% of the assemblages and vessel stands 4%–11% (Hunan Pengtoushan 2006:586, 622–628). As mentioned above, both are also found at Jiahu and in other Peiligang-related cultures, perhaps reflecting contact between these regions (fig. 3).

Bashidang, like Jiahu, is the earliest settlement found in the Yangtze region to feature a surrounding ditch, and it dates to the same time period, ca. 8800 cal BP. With sides of 170–200 m in length, the ditch was ca. 4 m wide, with sloping edges to a depth of 0.5–2 m. It may have in part made use of a diverted river channel, allowing drainage from the settlement into the river (Pei 2006 [2004]:280). Bashidang’s ditch building establishes a pattern of intensive landscape modification that through the Neolithic becomes increasingly used to tie together settlements and surrounding fields by water channels. As discussed by Crawford (2011), such engineering of site environments could also produce opportunities for the preferred growth of certain plant species such as wild rice. Water control, too, is central to rice agriculture, and as the water-management systems of these channels were developed following the Pengtoushan culture period, they may have been critical in the domestication process for rice (see Fuller and Qin 2009). Following Bashidang, Middle Yangtze settlements increase in size, and the ditches become moats permanently filled with water. At 7400 cal BP, Chengtoushan’s moat is 15 m wide surrounding a circular 5-ha area. At 6850 cal BP, the Chengtoushan site expands again. A new embankment wall 10 m wide by 2 m high and a 2.2-m-deep moat are constructed. Moats such as this connected the settlements to extensive waterway networks, natural and man-made, leading to fields and neighboring settlements. Oars and other wooden boat parts are found. By the Late Neolithic, Chengtoushan reaches 8 ha in size (Pei 2006 [2004]:281–283). As the Chengtoushan settlement is expanding, paddy-field rice agriculture is developing at the site as well. The earliest paddy-field systems, with long rows of raised bunding demarcating fields of 2.7 m by 20+ m, belong to the Tangjiagang 湖家港 culture, with radiocarbon dates ca. 6300–6000 cal BP (Fuller and Qin 2009:97; Hunan Chengtoushan 2007:164–167; Zhao 2010). By this period, the mode of subsistence can be called agricultural, here defined as having domesticated plants being grown in human-prepared fields.

The Lower Yangtze Early Neolithic

Shangshan and Xiaohuangshan

The Shangshan 上山 (Mao et al. 2008; Zhejiang Shangshan 2007) and Xiaohuangshan 小黄山 (Guo jia wen wu ju 2006) sites (Zhejiang) represent the earliest Early Neolithic culture found in the Lower Yangtze River region. A few radiocarbon determinations date the Shangshan site to 10,000–8500 cal BP (Zhejiang Shangshan 2007), while Xiaohuangshan’s estimated age is ca. 10,000/9000–8000/7000 cal BP (Guo jia wen wu ju 2006; Wang 2006). At Shangshan, associations and dates of its earliest features are still preliminary, and some may belong to the later Kuahuqiao and Hemudu culture phases. Both Shangshan and Xiaohuangshan have been interpreted as permanent settlements with a hunter-gatherer economy and early exploitation, perhaps cultivation, of rice (Guo jia wen wu ju 2006; Wang 2006; Zhao 2011). While the size and layout of Shangshan are not reported, within the 5-ha area of Xiaohuangshan are found three clusters of houses; it is also the largest Early Neolithic site in the south. Houses at both sites are rectangular and up to 14 m long, with some built on U-shaped foundation trenches and others, perhaps later in date, as pile dwellings (Jiang and Liu 2006). Like Pengtoushan, Xiaohuangshan burials are located about the edges of the settlement but are not clustered. Grave goods include a few pottery vessels, usually small flat-bottom basins with flared rims, ring-foot jars, or high-neck small-mouth jars. There are numerous pits within both settlements of various shapes but typically shallow—some with one or two pottery vessels or lithics—that may have been for burials or other ritual purposes. At Xiaohuangshan, there are many 1-m-diameter pits with straight walls and flat bottoms. The excavators believe they were used for stem tuber and nut storage (acorns are a common resource at later sites).

Shangshan sites have large amounts of pottery. At Xiaohuangshan, 1,000 pottery vessels could be reconstructed. The early-phase pottery can be grouped with Shangshan’s, where slab-molded or coil-made flat-bottom basins predominate (ca. 85%). As with Pengtoushan pottery, rice chaff, stalks, and leaves can be found in the sherd fabric—this tempering provides the rice evidence that is used in recent discussions of the state of rice domestication at the site (e.g., Liu, Lee, and Jiang 2007). However, the flat-bottom vessel forms at Shangshan sites are different from Early Neolithic sites in other regions and from later cultures in the Lower Yangtze, such as the Kuahuqiao and Hemudu, that instead feature round-bottom cauldrons and vessel stands (as does the Pengtoushan culture). No tripod vessels are found, either. Later-phase Shangshan pottery has more vessel forms and greater decorative elaboration, with everted-rim bowls, double-belly pedestal dishes, cordmarked egg-shaped cauldrons, and platters with a tall open-work ring foot (a new technique) all found. This formal differentiation continues into the later cultures in the region.

Shangshan and Xiaohuangshan, like Pengtoushan, retain the South China Late Paleolithic lithic assemblage, featuring mainly flakes with some retouch and cobble tools, stone balls, “digging stick weights,” and shallow “cupholes”: all are formed by percussion. Only a few adzes and chisels and a few grinding stones (up to 30–50 cm long) are found (Ren 2005; Sheng, Zheng, and Jiang 2006; Zhejiang Shangshan 2007).

Early Neolithic behavioral patterns are established in both the Pengtoushan and the Shangshan cultures, including ag-
glomerated permanent settlements, house construction, heavy use of underground storage facilities, active human manipulation of the site environment, more highly developed pottery production and functional differentiation of forms, incipient use of axes and grinding stones, and increasingly intensive exploitation of the cereal rice (and other select plants, including future domesticates and acorns). In both cultures, these early village residents maintain a primarily hunting-fishing-gathering subsistence system. Although rice, which is most likely wild but possibly managed, has entered the diet, it appears to play a secondary role in nutritional intake. Yet these earliest villages may already have crossed a certain threshold and were on a pathway toward rice cultivation, domestication, and agriculture. We still lack data for understanding seasonality and subsistence patterns at these sites as well as models for how the Early Neolithic behavioral patterns are established. When the South China hunter-gatherer annual subsistence cycle came to incorporate wild rice, even in relatively small amounts, did this effect mobility patterns or allow year-round sedentism in these early villages? And how did the construction of villages affect the landscape and wild plant populations?

Kuahuqiao

The Kuahuqiao 跨湖桥 site (Zhejiang), situated at the modern mouth of the Qiantang River, occupied 7900–7000 cal BP (Zhejiang Kuahuqiao 2004:225–227), shows the next stage in the development of the Early Neolithic in the Lower Yangtze region. The 3-ha settlement is heavily disturbed, but seven partial structures with new construction and woodworking techniques were excavated, including an oval platform 1.6 m high and 10 m wide as well as rectangular foundations up to $5.7 \times 4.7$ m (Zhejiang Kuahuqiao 2004:26–38). As in other settlements, numerous pits surround the structures, and some have their wooden covers preserved, indicating their use in storage. No burials are reported.

Kuahuqiao sat near coastal swamp marsh, and the inhabitants exploited a wide range of resources from the diverse rich environments surrounding the site. Fauna include sika deer, wild water buffalo, serow (Capricornis sumatraensis), alligator, turtle, waterfowl, various fish species, and dolphin. Deer, however, dominate the assemblage, as is typical in Neo-Lithic cultures in the Yangtze and elsewhere (Yuan, Flad, and Luo 2008). The inhabitants also were probably managing plants and animals. Domesticated dog is present, and the small numbers of pigs present show decreased mandible length, indicating domestication (Yuan 2010).

The rice remains from Kuahuqiao are central in the current debate on rice domestication (e.g., Liu et al. 2007; Pan 2008). Kuahuqiao rice grains and phytoliths have been interpreted as being in a “primitive stage of domestication,” with 41.7% of the spikelet bases identified as japonica type (domesticated) and the remaining 58.3% as wild (Zhejiang Kuahuqiao 2004:375–376; Zheng, Sun, and Chen 2007). Fuller, Harvey, and Qin (2007) and Fuller, Qin, and Harvey (2008a) observe that Kuahuqiao rice, as well as later rice at Hemudu, has significant proportions of immature harvested spikelets (as does Bashi-dang rice). A harvesting pattern involving such high numbers of immature spikelets along with the split numbers between wild and japonica implies that the rice plants at Kuahuqiao were under cultivation. Furthermore, the low relative amounts of rice present at the site as a percentage of all plants would also indicate that this cultivated rice is still a supplementary resource behind collected wild nuts and acorns (Fuller et al. 2009). Other plant remains at Kuahuqiao include trapa (water chestnut), foxnuts, peach, and apricot.

Microcharcoal and pollen studies at Kuahuqiao show humans actively manipulating the coastal swamp environment around the site by clearing the wetland scrub through fire. This could have been part of managing natural stands of rice. Kuahuqiao residents also faced regular flooding by slightly brackish water, and the site may have been abandoned because of Holocene marine transgression. If people were planting rice or managing and protecting wild stands, the rice could have needed bunding and other forms of water management (Zong et al. 2007), or inhabitants may have carefully selected areas with advantageously fluctuating water levels to promote rice plant growth and grain production (Fuller and Qin 2009).

While there is possibly stand management of rice and other plants at Kuahuqiao, the amount of human dependence on rice may still be limited. Fuller et al. (2009) suggest that domesticated rice (indicated by a higher percentage of fixed nonshattering phenotype rice present and increased representation of rice among all plant remains) appears after Kuahuqiao, during the Hemudu 河姆渡 culture period, between 6900 and 6600 cal BP, as seen at the Tianluoshan 汤湖山 site (Zhejiang; Zhao 2010; Zhejiang Tianluoshan 2007; Zheng et al. 2009). During this time period, in addition to an increasing percentage of nonshattering (domesticated) rice spikelets, rice consumption increases significantly as well, with rice remains jumping from 8% to 24% of total plant remains. Zheng et al. (2009) identify land clearing and tilling for rice fields at Tianluoshan, with many associated weeds as well.

Preserved organic remains at Kuahuqiao show a high level of development in woodworking, basketry, and other practices. A 5.6-m long-(partial) dug-out pine canoe and wooden...
oars give direct evidence of the importance of water transport in the Yangtze region. Bow and arrow are used, with a 121-cm-long mulberry bow preserved. Mortise and tenon joinery are in use to fashion timbers and to make ladders. There is also woven matting.

Pottery and lithics at Kuahuqiao show significant advancements over Shangshan’s. Iron-containing slips are used to produce red, gray, or black surfaces, and red and white patterns and abstract motifs are painted over the slip. In the Middle Yangtze, intricate geometric surface patterns occur during the same period in the Tangjiagang culture (7400–7200 cal BP), and the Daxi culture (6400–5500 cal BP) has similar painted pottery. The number of vessel forms increases over Shangshan, and the pottery is more finely made, with carefully formed rims, angled shoulders, and ring feet. There is also a considerable increase in serving vessels, such as pedestal serving stands (dou). The new decorative motifs and vessel forms represent not only technological improvements but also new roles for pottery in domestic activities (processing, cooking, serving, and storage), ritual, and social signaling. With Kuahuqiao, the majority of stone tools are now polished, including adzes, axes, chisels, arrow points, rollers, and grinding stones. There are also jade ornaments.

The Kuahuqiao cultural inventory signals the transition to the “Middle Neolithic” represented by the subsequent Hemudu culture in the Lower Yangtze region. During the Middle Neolithic, as seen at Tianluoshan after 6900 cal BP (Fuller et al. 2009), people are farming rice (i.e., they are growing domesticated plants in prepared fields). This early rice farming occurs within a broad-spectrum subsistence system based on waterside and aquatic plants, as Hemudu culture sites are found primarily in wetland catchments (Nakamura 2010; Qin, Fuller, and Hai 2010).

The subsequent development of more highly productive rice farming by means of the paddy-field system marks a major turning point in Neolithic societies. Soon after the appearance of paddy fields, we find hierarchical settlement patterns, higher population densities, increasing specialization of labor, increasingly greater internal social status differentiation, and greater accumulation of wealth and disposal of wealth in ritual (see Zhang 2003; Zhang and Hung 2008). The earliest paddy fields in the Lower Yangtze, found east of Lake Taihu in the late Majiabang 馬家浜 culture (6300–6000 cal BP) sites of Caoxieshan 草鞋山 and Chudun 绸墩, are contemporaneous with the earliest paddies in the Middle Yangtze at Chengtoushan. The Majiabang paddy fields consist of small dug-out units connected by small water channels, with water reservoir pits from which stored water could be fed into the system. This system of small paddies allows tight control of the water level in all units, which is essential to raising the productivity of the rice plants (Fuller and Qin 2009). With the advent of paddy fields and the concomitant demographic and organizational changes in societies that follow, rice farming “gains legs” and disperses quickly and widely. Rice farming reaches to southernmost China (the Shixia 石峽 site, Guangdong), over water to Taiwan and beyond in the Austronesian dispersal, and northward into the Middle and Lower Yellow River basin and possibly Korea, all by 5000 cal BP (see Bellwood 2006, 2011; Fuller and Qin 2009:101 and references therein; Lee 2011; Ruddiman et al. 2008; Zhang and Hung 2010).

Conclusions

Early Neolithic villages emerge shortly following the Younger Dryas period of climatic stress, and the role of climate change needs to be revisited (Bar-Yosef 2011). Unfortunately, we are missing critical data for the period of the establishment of these villages, and future work should focus on this. The role of pottery also needs further consideration. While pottery was already in use for over 8 millennia, once sedentary villages appear, it immediately takes on prominent new roles in food preparation, serving, storage, ritual, and social signaling. As outlined above, we have only recently come to understand that these first sedentary villages are not synonymous with the presence of full-scale farming. Village settlements emerge in China before cultivated plants make a significant contribution to diet and several millennia before agriculture systems with domesticated plants and prepared fields are in place. Instead, many of the earliest Early Neolithic villages still rely primarily on hunting-fishing-gathering. Adaptations involving the exploitation of wild resources were able to trigger and support sedentism, population growth and agglomeration, and the other cultural changes that mark the Early Neolithic, including pottery elaboration, house construction, ditch building, and new ritual activities (indicated by caches, platforms, cemeteries, etc.) that all can be related to new ideological conceptions of social grouping and territoriality. In China, the Neolithic did not require farming at its start.

During the Early Neolithic across the four cultural areas discussed above, we see the sharing of specific material culture traits and parallel developments on the road to agriculture. Information exchange is hinted at typologically in shared pottery, lithics, house forms, spatial organization of settlements, burial practices, subsistence practices, and ritual activities. I posit here that Early Neolithic cultures emerged and developed—and the farming of millet and of rice was invented and spread—within wide-ranging webs of information exchange and broad social exchange networks whose roots are in the interactions of Late Paleolithic hunter-gatherer societies (Cohen 2003). None of these regions was geographically or culturally isolated from others. Because of this, it is unlikely that there could have been multiple independent inventions of major classes of material culture such as the shared pottery vessel forms. Indeed, the long, complex developmental pathways in each of these regions for millet and for rice farming, from cultivation through domestication and agriculture, would have occurred with information exchange from other regions—regions that contemporaneously were going through parallel processes. In other words, the advent of agriculture
did not result from independent isolated processes in each region.

To accept this scenario, when looking at the origins of both millet and rice agriculture, we still need to consider how or even whether knowledge of a millet-centered dryland or a rice-centered wetland system could drive the development of the other. Could the particular steps in the development of agriculture centered on one species “jump” across to the other species, when rice and millet have biological requirements that are so different? This is a question for future consideration. To answer it, we need a better appreciation of the many steps involved. At present, we do not have enough archaeological and paleoethnobotanical data to establish the basic steps in the development of agriculture within each region or the chronological control to properly order them across regions. One possibility is that agriculture, the end product of a 3-millennia process in each region, may be an admixture of small steps coming from different regional sources over this lengthy time period: a new development in one region could be related to a previous development in another region and onward across regions. Such a possibility needs consideration because we already have good evidence for the boundaries of a material culture system—the Peiligang culture—extending across the boundary where human groups were exploiting rice on one side and millet on the other, as at Jiahu, a site whose material culture classifies well within the millet-exploiting Peiligang cultural sphere but that has no millet, only rice. The stage is set for better understanding the lengthy and likely interrelated processes leading to the development of millet- and rice-based agricultural systems in Northeast China, North China, and the Middle and Lower Yangtze regions. An interregional perspective can guide the gathering of new data to help answer the many questions we still have.

Chinese and Japanese Characters

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New Archaeobotanic Data for the Study of the Origins of Agriculture in China

by Zhijun Zhao

In the past 10 years, flotation techniques have been introduced and implemented in Chinese archaeology. As a result, a tremendous quantity of plant remains have been recovered from archaeological sites located all over China. These plant remains include crops that might have been domesticated in China—such as rice, foxtail millet, broomcorn millet, and soybean—as well as crops that were introduced into China from other parts of the world—such as wheat and barley. The new archaeobotanic data provide direct archaeological evidence for the study of the origins and development of agriculture in China. This paper attempts a synthesis of these new archaeobotanic data while presenting some new ideas about the origins and development of ancient agriculture in China, including the rice agriculture tradition that originated around the middle and lower Yangtze River areas; the dry-land agriculture tradition, with millets as major crops, centered in North China; and the ancient tropical agriculture tradition located in the tropical parts of China, where the major crops seem to be roots and tubers, such as taro.

Introduction

China is one of the major centers for the origins of agriculture. In the past, intensive study of early Chinese agriculture made it clear that there were primarily two independent subcenters of origin within China (An 1989; Cohen 2011; Crawford 1992; Ho 1977; Jones and Liu 2009; Yan 1992; Zhao 2005c): one in the middle and lower Yangtze River areas, where rice agriculture was first developed, with rice (Oryza sativa) the major cultivar; and the other in North China along the Yellow River, where the origin of dry-land agriculture is centered, with foxtail millet (Setaria italica) and broomcorn millet (Panicum miliaceum) the most representative crops. However, the origin of domesticated rice and the beginning of rice farming in China remain uncertain and highly controversial, while the study of the origin of dry-land agriculture has lagged even farther behind. Apart from these two major areas central to the origin of agriculture, a third important area that deserves thorough investigation is the southernmost part of China, centered along the Zhujiang River, where the major crops of early farming seem to have been roots and tubers, probably including taro (Colocasia sp.; Zhao 2006). This investigation should be of great importance because it may reveal a third pathway of early Chinese agricultural development in a prehistoric context. There remain many unsolved questions in the study of the origins of agriculture in China that are partly due to the lack of reliable archaeological evidence.

Ancient agriculture is generally considered to be composed of two major elements: crop farming and animal husbandry, which relied on crops or by-products of farming for fodder. Thus, plant remains, especially crop remains, are the most important evidence in the study of origins of agriculture. However, plant remains are more often than not poorly preserved, fairly small in size, and consequently difficult to identify with the naked eye in the field. Thus, without special attention to their recovery, plant remains from the past may be easily underrepresented in archaeological excavations.

Well-preserved plant remains more frequently survive at archaeological sites where fire was used by the residents. Charred plant remains are chemically stable and relatively resistant to soil and water erosion, and they can be preserved for a long time in the sediments of archaeological sites. Charred plant remains are usually lighter in specific gravity than soil particles and water. This makes it possible to separate the plant remains from the soil matrix, as the charred remains will separate from sediment and float on the surface of water. Such is the widely used and recognized flotation technique, which has been commonly accepted as an effective way of extracting plant remains from soil samples.

In recent years, flotation work has been carried out at more than 80 archaeological sites throughout China. About 7,000 soil samples have been processed, and a tremendous quantity of charred plant remains have been recovered (Zhao 2005a).
The charred plant material, especially the crop remains, obtained from the sites by flotation provide important new data for the study of the origins of agriculture. Identifiable domesticated taxa include rice, foxtail millet, broomcorn millet, wheat (Triticum aestivum), barley (Hordeum vulgare), soybean (Glycine max), adzuki bean (Vigna angularis), oats (Avena sativa), buckwheat (Fagopyrum esculentum), and so on.

The plant remains recovered by flotation in China, considered together with plant remains from previous investigations, allow us to gain a number of new insights into the origins of agriculture in China. This paper presents a brief outline of this new scenario based mainly on quantitative analysis of the crop data derived from flotation samples collected at several major archaeological sites.

The Origin of Rice Agriculture in the Yangtze River Areas

Before we go into the details of the new flotation evidence of rice agriculture, it is necessary to clearly distinguish two terms for the study of the origin of rice agriculture: “domestication” and “cultivation.” Benefiting from the discussion during the Wenner-Gren Temozon conference, I believe that there is no inevitable relationship between rice domestication and the beginning of rice cultivation.

Rice domestication was primarily an evolutionary process influenced by human activities that were by no means a deliberate effort aimed at changing the genetic or biological characteristics of plants but were simply intended to increase the yield of wild rice. People may have been unaware of the characteristics of a new species when it first appeared, and the plants were therefore not viewed as “domestic” at all. It is possible for domesticated rice to occur in a typical hunting-gathering adaptation, and the occurrence of domesticated rice might not immediately result in rice farming, which was characterized by intentional production and utilization of domesticated rice for food.

Also, the cultivation of rice might not be directly related to the domestication of rice. Cultivation is a series of intentional human activities—such as planting, protecting, and harvesting—for increasing the yield of plants that could be morphologically and genetically either wild or domesticated. Therefore, it is possible for early rice cultivation to be practiced without domesticated rice.

The flotation work at the Shangshan site has provided some clues for the study of early rice cultivation in China. The Shangshan site is an early Neolithic settlement located in the center of Zhejiang Province, which geologically belongs to the lower Yangtze River region (fig. 1). The cultural assemblage at the site can be clearly divided into two periods. The early period is named the Shangshan culture and is dated to around 8200–7000 cal BP (Zhejiang Institute of Archaeology and Xiaoshan Museum 2004:228).

Flotation work was conducted during the excavation in the Shangshan site in 2005. A diagnostic sampling strategy was employed by which soil samples were collected from each unambiguous archaeological feature found in every layer. A froth-flotation device with a 0.2-mm mesh screen was used. A total of 459 soil samples were collected and processed. Yet only a very small number of charred plant seeds were obtained from the samples. The most important result of the flotation work was the rice remains. A total of 33 charred rice grains (fig. 2) and 7 charred rice spikelet bases were found in the soil samples. However, most of these rice remains were recovered from the Kuahuqiao culture layers and only a few from the Shangshan culture layers.

Apart from flotation, other methods were also employed for obtaining rice remains. For example, heaps of rice husks were found in burnt soil blocks from the early-period layers of the site (Jiang and Li 2006, fig. 6). More significant evidence of rice used by humans was found in the temper of pottery. A large number of pottery sherds were excavated from the Shangshan site. It is possible to identify with the naked eye plant remains such as stems and leaves at the edge of these low-fired ceramic materials (Jiang and Li 2006, fig. 6). It is fairly interesting that in the two ash pits of the Shangshan culture period we examined, more than 80% of the pottery sherds were tempered with plant remains and that some rice husks were also observed in the temper. All this evidence indicates that the Shangshan people had a close relationship with rice and that rice, whether domesticated or wild, might have been one of the foods consumed by the Shangshan residents.

Some sort of rice cultivation activity might have taken place at the Shangshan site during the Shangshan period whether or not such rice remains belong to the domesticated species. Therefore, a complete study of the Shangshan site may possibly be used as a good case for the study of the beginning of rice cultivation in China. Future studies should take into account all factors, including the environmental setting of the site, the settlement pattern, pottery types, stone tools, and so forth.

As discussed at the Wenner-Gren Temozon conference, agriculture can be defined as a subsistence economy characterized by farming, although hunting and gathering continue. Therefore, the earliest archaeological site to date that clearly exhibits the characteristics of rice agriculture in China is the Jiahu site, which is located in the upper Huai River region in the center of China (fig. 1) and is dated to a period between 9000 and 7800 cal BP by 19 radiocarbon dates (Henan Institute of Archaeology 1999:515). The Jiahu site covers an area of 50,000 m², within which the living areas, manufacturing areas, and cemeteries were organized in an orderly fashion. The clear layout of the site documents a permanent village (Henan Institute of Archaeology 1999). The excavations in
the 1980s unearthed many charred grains that have been identified as domesticated rice (Zhang and Wang 1998).

Flotation work at the Jiahu site began in 2001. A diagnostic sampling strategy was employed. A simple bucket-flotation device was used, and plant remains were caught in a 0.2-mm mesh screen. A total of 125 soil samples were collected and processed. A large number of charred plant remains have been counted and identified, including about 4,100 seeds of 16 taxa (Zhao and Zhang 2009). They can be divided into two groups: edible plants and weedy grasses. The former embraces tubers (e.g., lotus roots *Nelumbo nucifera*), nuts (e.g., acorn and *trapa*), grains (e.g., rice and wild soybean *Glycine soja*), and so on. The latter includes such taxa as *Digitaria* and *Echinochloa*, among others.

More than 400 charred rice grains were found in the flotation samples (fig. 2). From analysis of the shape and size of the grains and the morphological characteristics of the embryos, and considering the fact that the Jiahu site is located far from the traditionally known distribution area of wild rice, we believe that the rice remains recovered at the Jiahu site are domesticated. Various quantitative measurements—such as absolute counts, total weight, and ubiquity—were employed to compare the plant remains recovered from the Jiahu site (Zhao and Zhang 2009). These data make it clear that wild plants derived from gathering practices accounted for the majority of food resources while domesticated rice might have played only a minor role in the subsistence of the Jiahu people.

A number of animal bones were unearthed during the excavation, and about 20 species were identified, among which dog is the only clearly domesticated animal. The identification of domestic pig from Jiahu has been controversial (Yuan 2001). A recent study suggests that the Jiahu pig was fully domesticated but was not significant for the meat supply (Luo and Zhang 2008). Nevertheless, zooarchaeological studies suggest that provisioning of animal feed was not an important part of Jiahu subsistence practices.

The abundance of fish bones and shells at the site is based not only on the absolute count but also on the fact that almost all trash pits contained fish bones. This is a strong indication that fishing played a very important role in the subsistence economy. Considering that water plants such as lotus and *trapa* are also abundant in the plant assemblage, aquatic species, both animal and plant, were a dominant food resource for the Jiahu residents.

We might conclude from the above analyses that the overall subsistence economy of the Jiahu people mainly relied on fishing, hunting, and gathering and that agricultural products produced by rice farming and animal husbandry were only supplements to their diet. Therefore, the Jiahu site is a good
Figure 2. Charred crops recovered by flotation: A, Shangshan rice; B, Jiahu rice; C, Tianluoshan rice; D, Xinglonggou broomcorn millets; E, Yuhuazhai broomcorn millets; F, Yuhuazhai foxtail millets. A color version of this figure is available in the online edition of *Current Anthropology*.
example for the study of an early stage in the transition to rice agriculture, and it thus shows that the transition from hunting and gathering to rice farming was a gradual evolutionary process rather than a revolutionary replacement.

The discovery of the Hemudu site in the 1970s resounded throughout the world. The site is located on the south bank of Hangzhou Bay, about 20 km from the present sea coast (fig. 1). Cultural assemblages have been divided into four phases dated to a period between 7000 and 5800 cal BP by 27 radiocarbon dates (Zhejiang Institute of Archaeology 2003: 411). Because of the waterlogged environment of the site, organic materials have been well preserved. Large numbers of plant remains have been recovered and identified, including rice, *Trapa* acorns, and other edible plants (Liu 2006). The most important result of the excavation was the discovery of large numbers of rice grains. Some scholars accordingly suggested that the Hemudu people might have had a very mature agricultural economy based on rice farming (Zhou 2002). Yet no quantitative analysis was carried out at that time, and it is therefore impossible to make comparisons between different plant taxa. For this reason, the importance of rice cultivation in the subsistence economy of the Hemudu society remained a question. However, the recent excavation of the Tianluoshan site, only 7 km from the Hemudu site, provides an opportunity to reexamine the unsolved questions about the Hemudu site.

The Hemudu and Tianluoshan sites are similar in size, environmental context, and the nature of the cultural deposits. Unlike at Hemudu, a systematic sampling strategy (i.e., a composite sampling strategy) was applied during the excavation of the Tianluoshan site. Both water screening and flotation techniques were employed to recover plant remains. A total of 222 soil samples were collected and processed, and a tremendous quantity of plant remains have been found by flotation as well as by water screening.

The identification and counting of plant remains are still in process because of the enormous quantities recovered by flotation. Nevertheless, abundant rice remains, including charred rice grains and rice spikelet bases, have been found in the treated samples (fig. 2). A detailed study of rice spikelet bases shows that the Tianluoshan rice consisted of a high proportion of the shattering wild type, which suggests that the process of rice domestication had not yet culminated in the Hemudu period, sometime about 6500 cal BP (Fuller et al. 2009).

Besides rice, plant remains recovered and identified from the processed samples of the Tianluoshan site include acorns, *Trapa* sp., * Diospyros* sp., *Gordon euryale*, *Ziziphus jujuba*, Chinese gooseberry seeds, bottle-gourd seeds, and seeds of various weedy grasses. The preliminary results of quantitative analysis suggest that rice farming, though important, was only part of more general subsistence activities of the Tianluoshan residents. The products of hunting and gathering, especially acorns, also made great contributions to the diet. Therefore, the importance of rice farming should not be overstated for the Hemudu culture, as seen at both the Tianluoshan site and the Hemudu site.

Thus, the above sites show that the transition to rice agriculture from hunting and gathering was not a clear-cut revolutionary change but a slow evolutionary process. During this long-term process, hunting and gathering gradually waned while rice agriculture slowly achieved a dominant position and finally became the major subsistence practice. On the basis of preliminary analysis of the flotation materials from the Tianluoshan site, the subsistence pattern of the Hemudu culture seems to be still in the transition to rice agriculture.

When was a hunting-and-gathering scenario completely replaced by rice-agriculture subsistence in the Yangtze River areas of China? We have no answer yet. More flotation work should be done in the future, especially at those sites important in the key stages of early agriculture. This is the only way that reliable evidence can be obtained.

However, on the basis of previous archaeological discoveries and studies, we believe that the overall subsistence economy of the Liangzhu culture, dated to a period between 5200 and 4300 cal BP in the lower Yangtze River region, already relied heavily on rice agriculture. Rice remains were occasionally found at some archaeological sites of the Liangzhu period in the past, but they cannot be used for a quantitative analysis because of the lack of systemic sampling strategies. In recent years, the flotation technique has been introduced, and new data has begun to emerge, but the results are not yet published. Nevertheless, some indirect evidence suggests the establishment of full rice agriculture in the Liangzhu period.

For example, a large walled town of the Liangzhu culture was unearthed near Hangzhou City recently (fig. 1), and it measures about 1,900 m in length and about 1,700 m in width, a total area of 3.23 km². The foundation of the wall is about 50 m in width and was consolidated by a layer of large pebbles (Liu 2007). It is difficult to imagine that this vast construction could be undertaken without the food support of fully developed rice agriculture.

Also, archaeological surveys indicate that the Liangzhu culture sites sharply increased in number in the lower Yangtze River region, especially in the Hangzhou Bay area, where the distribution of Liangzhu sites is even denser than that of modern villages. This clearly indicates a significant increase in human population, which is likely to have been correlated with a rapid development of rice agriculture. In other words, as late as about 5,000 years ago, rice agriculture had become the dominant food source in the lower Yangtze River region.

The development of rice agriculture in the middle Yangtze River region may have followed a pattern different from that in the lower Yangtze River region: full rice agriculture may have been established earlier. This hypothesis can be partly supported by studies of the Chengtoushan site, located in Lixian County of Hunan Province (fig. 1) in the middle Yangtze River region (Hunan Institute of Archaeology 1999). Water sieving was carried out during the excavation, and rice re-
mains were recovered. Also, a possible rice field was identified by survey as well as by the phytolith technique. The site, dated to ca. 6000 cal BP by 14 radiocarbon dates (Hunan Institute of Archaeology and International Research Center of Japan Culture 2007:186), is one of the earliest walled towns in China and was possibly constructed and used as a central settlement in response to rapid population growth. Therefore, it is likely that the subsistence of the Chengtoushan society already relied on rice agriculture.

The Origin of Dry-Land Agriculture in North China

In the past, studies on the origin of dry-land agriculture in North China have focused on the middle Yellow River region of North China because this region is believed to be the motherland of ancient Chinese civilizations, where ancient millet farming was centered, and abundant prehistoric cultural remains have been recovered there (Lu 2002). However, new archaeological data suggest that the whole Yellow River area in North China had the potential to have been the place of origin of dry-land agriculture.

Millet remains have been reported in several early Neolithic sites distributed along the Yellow River. Those from the Cishan site draw the most attention. The Cishan site is located in the middle Yellow River region (fig. 3) and is radiocarbon-dated to $6856 \pm 100$ BP (charcoal), $7141 \pm 100$ BP (charcoal), and $7024 \pm 105$ BP (charcoal). (These dates were corrected from a 5,730- to a 5,568-year half-life by dividing by 1.03.) The calibrated age is ca. 7600–8100 cal BP (Institute of Archaeology CASS 1991:21). A large number of millet remains, identified as foxtail millet, were recovered during the excavations in the 1970s (Tong 1984). However, the taxonomic identification of the remains was problematic because all the so-called millet remains had already decayed to ash when they were discovered (CPAM, Hebei Province, and Handan Relics Preservation Station 1981). The identification had to rely on the spodogrammic technique, which is the same as the present-day phytolith technique. The work was based on a direct comparison between the morphological characteristics of phytoliths extracted from modern foxtail millet and the ash remains recovered from the Cishan site, and a conclusion was drawn when similarities were identified (Huang 1982). However, it is noteworthy that using phytoliths to identify plant species is not straightforward because of the redundancy of phytolith production; that is, similar phytolith types may be produced in widely divergent plant groups (Piperno 1988).

Recently, a new study was carried out on the Cishan millet by a research team, and the results indicate that the millet remains consist of both foxtail and broomcorn millet, but the...
latter is more abundant (Lu et al. 2009a). The identification was done with the same technique (i.e., phytolith analysis), but this time it was based on a systemic comparative study with modern millets (Lu et al. 2009b), which makes the identification much more precise and believable.

New radiocarbon dates also have been obtained from Cishan, and some of them are much older than the original dates (Lu et al. 2009a). However, these new dates are highly suspect because of the ambiguous context of the materials used for the dating. For example, the term “newly excavated storage pits” in the report is misleading, because no excavation has been conducted at the Cishan site since the 1990s because of the stringent policy of the Chinese National Administration of Cultural Relics for its protection. Therefore, the samples likely had been collected from pits naturally exposed by erosion on the cliff. This is suggested from a photo shown in the report (Lu et al. 2009a, fig. 1C). The mention of materials of “millet grain crop” in the report is also confusing because the Cishan millet remains were already decayed to ashes mixed with soil when they were unearthed, according to the 1970s and 1980s reports and the materials now exhibited in the Cishan Museum. Note that it would not be necessary to use the complicated phytolith technique for the identification if actual millet grains had really been found, because it is quite straightforward and easy to identify and distinguish foxtail and broomcorn millet simply on the basis of morphological characteristics of the grains (Liu and Kong 2004). Therefore, the material used for dating likely consisted of the bulk samples rather than actual millet grains. It is interesting that one of the new dates came from sample CS-BWG, which had actually been collected during the 1970s excavation and stored in the Cishan Museum. Its date is 7671–7596 cal BP (Lu et al. 2009a; their fig. 3), which perfectly matches the original dates from the site.

An archaeological chronology relies not only on chronological dating techniques but also on the classification and seriation of the cultural assemblages. A number of archaeological sites located in North China have been classified in the same cultural phase as the Cishan site (i.e., the early Neolithic period, 9000–7000 cal BP) on the basis of comparison of their cultural assemblages, including settlement patterns, burial traditions, pottery types, stone tools, and so forth (Zhao 2008). Millet remains were reported from some of these sites, for example, the Shawoli site (Wang 1984) and the Peiligang site (Institute of Archaeology CASS 1984) in the middle Yellow River region, the Yuezhuang site (Crawford, Chen, and Wang 2006) in the lower Yellow River region, the Dadiwan site (Gansu Museum 1982) in northwestern China, and the Xinglonggou site (Zhao 2005b) in northeastern China (fig. 3). Among these, the most important new data for millets come from the systematic flotation work at the Xinglonggou site.

The Xinglonggou site is located in the upper Liao River region in northeastern China, along the eastern edge of the Mongolian Grassland. The site consists of three independent localities that were fully investigated and excavated from 2001 to 2003 (Liu 2004). Locality 1 is a large village settlement site radiocarbon-dated to 8000–7500 cal BP. More than 150 house foundations were recovered from the site. The artifacts include pottery, stone tools, and bone and jade artifacts. Large-scale flotation work with a composite sampling strategy was carried out during the excavations. A froth-flotation device with a 0.2-mm mesh screen was used. More than 1,200 soil samples were collected and processed. Abundant charred plant remains were recovered. The most important result of the flotation work was the recovery of domesticated millets identified morphologically as broomcorn and foxtail millet. The broomcorn millet is more abundant, with about 1,400 charred grains found. Only about 60 grains of foxtail millet were recovered. Other plant remains recovered by flotation include Astragalus, Chenopodium, Vitis, and so forth. Nut fragments of acorns were also identified.

Morphologically different from the wild grasses, the millet grains recovered here exhibit the distinctive characteristics of domesticated species, being more spherical in shape and larger in size (fig. 2). As crops, the millet grains are generally not as compacted inside as is usually seen in other wild grass seeds, and therefore they are more readily expanded in the embryo portion when burned, exhibiting a popcornlike appearance. Such morphological characteristics have been found in the millet remains recovered from the Xinglonggou site.

The millet remains are directly dated by accelerator mass spectrometry to ca. 7670–7610 cal BP in three independent radiocarbon laboratories (Z. Zhao, L. Zhou, G. W. Crawford, G. Liu, Y. Li, K. Liu, X. Wu, and T. Nishimoto, unpublished manuscript). Therefore, the Xinglonggou millet remains recovered by flotation, with their precise dating and clear identification, are some of the earliest domesticated millets yet found in China.

Domesticated millets account for nearly 50% of the charred seeds recovered at the Xinglonggou site. However, the ubiquity of millet remains was as low as only 5% in the soil samples processed. A number of pig skulls were unearthed, and most of them were identified as wild, while a few exceptions show some characteristics of domesticated pig. Combining the results of studies of the plant remains, animal bones, and stone tool use and wear, the subsistence of the Xinglonggou site still seems to have been dominated by hunting and gathering, although millet farming was already practiced and the pig was probably in the process of domestication. Therefore, the Xinglonggou site should be regarded as in an early stage of the transition from hunting and gathering to agriculture; that is, the Xinglonggou residents still relied on hunting and gathering for food, and agricultural products produced by millet farming and animal husbandry only supplemented their diet.

On the basis of flotation results from the Xinglonggou site and new data from other sites, we have found several significant characteristics of the early stage of the transition to millet agriculture in North China. First, morphologically, millets at this stage were already fully domesticated species. In other
words, the emergence of millet domestication should be dated as earlier than the early Neolithic period. Second, millet grains recovered by flotation from these early Neolithic sites include both broomcorn and foxtail millet, but the former is always more abundant than the latter in this time period. Third, besides the middle Yellow River region, where ancient Chinese civilization and early dry-land agriculture were centered, new data on early millet remains are widely found farther north, along the Great Wall in North China, an economic area that combines farming and herding today.

The middle Neolithic period (7000–5000 cal BP) is a very important stage of cultural development in North China. This period is represented by the well-known Yangshao culture distributed all over North China. Thousands of archaeological sites of the Yangshao culture have been found in this broad area, especially along several important branches of the Yellow River, such as the Wei, Fen, Yi, and Luo rivers. Among these sites, the best known is the Banpo site in Xi’an City.

The Banpo site is a large village settlement enclosed by a moat inside of which house foundations, kilns, and ash pits were found arranged in an orderly fashion. Outside the settlement, a complete lineage cemetery was discovered. Excavations during the 1950s found large quantities of pottery and stone tools, among which stone hoes, spades, knives, and pestles and mortars are most likely to have been used as agricultural tools in relation to farming practices such as harvesting and grinding (Institute of Archaeology CASS and Banpo Museum 1963). Pigs and dogs are both identified as domesticated. Furthermore, a few charred millet remains were found inside a pottery jar. All this evidence suggests that agriculture was a compulsory element in the subsistence practice of the Yangshao culture. Unfortunately, flotation work was not practiced at the time of excavation, and we therefore have no reliable data for quantitative analysis regarding subsistence in the Yangshao culture.

However, the recent excavation of the Yuhuazhai site, only a couple of kilometers from the Banpo site, provided an opportunity to do more-detailed analysis about subsistence in the Yangshao culture. The Yuhuazhai site is also located in Xi’an City (fig. 3) and was excavated in 2002. It is almost a copy of the Banpo site. Both sites are large village settlements enclosed by moats and dated to 7000–6000 cal BP. The cultural remains are identical in these two sites, including features such as house foundations, kilns, pits, and artifacts such as pottery and stone tools.

During the 2002 excavation season, we carried out a flotation project at the Yuhuazhai site. A diagnostic sampling strategy was employed, and a froth-flotation device with a 0.2-mm mesh screen was used. A total of 106 soil samples were collected and processed. Very abundant plant remains were recovered, including about 55,000 seeds. On the basis of taxonomic identification, the seeds belong to the families of Poaceae, Leguminosae, Cruciferae, Chenopodiaceae, Polygonaceae, and Compositae, among others. Also, some economically important plant remains were found, such as *Bras-sica*, *Papaver*, *Vitis*, and, of course, crops that included foxtail millet, broomcorn millet, and rice.

The plant remains recovered from the Yuhuazhai site are obviously dominated by the millets (fig. 2), which account for nearly 90% of the total number of unearthed plant seeds. Only four charred rice grains were found. In absolute numbers, foxtail millet (about 36,000 grains) is much more abundant than broomcorn millet (about 14,000 grains), while in terms of ubiquity, the percentage of broomcorn millet (67%) is higher than that of foxtail millet (63%). The results of flotation at the Yuhuazhai site clearly indicate that millet farming was dominant in the food production of the Yangshao people. In other words, the overall subsistence of the Yangshao culture, including the Yuhuazhai, Banpo, and other related sites, mainly relied on millet farming and animal husbandry. Hunting and gathering might still play a role in economic practices but only a secondary one in subsistence. Therefore, the transition from hunting and gathering to agriculture seems to have been faster in North China than in the Yangtze River areas. As early as the Banpo phase of the Yangshao culture (i.e., 7000–6000 cal BP), full dry-land agriculture characterized by millet farming was already established in North China.

**The Origin of Ancient Tropical Agriculture in South China**

South China here refers to the region south of the Nanling Mountains, particularly in the Zhujiang (Pearl) River areas. The study of the origin of agriculture in these areas has mainly focused on the Zengpiyan site in the last century.

Zengpiyan is a cave site located in Guilin City, Guangxi Province (fig. 4). Cultural deposits at the Zengpiyan site can be divided into five phases, with the first phase dated to 12,000–11,000 cal BP and the last to 8000–7000 cal BP. Since its excavation in the 1970s, the site has attracted much academic attention throughout the world. Because the pig bones found there have been identified as possibly from domesticated pigs, the site was believed by some scholars to be the earliest archaeological site with rice farming, and therefore it has been cited as evidence for a hypothesis stating that South China was the center for the origin of rice agriculture. However, no plant remains were ever reported from the site to support this idea. Therefore, the question of the nature of subsistence at the Zengpiyan site has been vigorously debated.

In order to solve this problem, the Zengpiyan site was reexcavated in 2001 with a multidisciplinary approach, including archaeobotanic methods such as flotation and phytolith analysis (Institute of Archaeology CASS et al. 2003). The new excavation was limited to the reserved areas between the excavated squares of the 1970s. Therefore, a complete sampling strategy was used for collecting flotation soil samples: all cultural sediments from the excavation were floated to recover plant remains. More than 8,000 L of soil samples was processed by a froth-flotation device with a 0.2-mm mesh
screen. The charred plant remains obtained included wood, seeds, nuts, roots, and tubers. The seeds were identified as belonging to more than 16 plant species, but no rice was found. Soil samples were also collected from each layer for phytolith analysis, but no phytolith type of the *Oryza* genus, such as the double-peaked glume type or rice leaf types, was observed in the samples. Therefore, both flotation results and phytolith analysis clearly indicate that the Zengpiyan site had nothing to do with the origin of rice agriculture.

Information about local subsistence after 7000 cal BP can be obtained from the Xiaojing site. The Xiaojing site is located in Ziyuan County, Guangxi Province, about 100 km north of Zengpiyan (fig. 4). Cultural deposits of the Xiaojing site can be classified into three phases based on cultural remains and radiocarbon dates. Phase I was dated to 6500–6000 cal BP, phase II to 6000–4000 cal BP, and phase III to 4000–3000 cal BP (Guangxi Archaeological Team and Ziyuan Administration of Culture Relics 2004). Water sieving was applied to recover plant remains during the excavation at the Xiaojing site. A large number of charred rice grains, numbering in the tens of thousands, were recovered from phases II and III, but not a single rice grain was found in phase I. This stark contrast suggests that a rapid change to rice farming occurred at the Xiaojing site around 6,000 years ago. This rapid change can be interpreted only as the introduction of rice farming from another place. This was further corroborated by the excavations at the Dingsishan site.

The Dingsishan site is located in Yongning County, Guangxi Province (fig. 4). The site is a well-preserved shell midden, and the cultural deposits can be divided into four phases. Phase I (early Neolithic) was dated to 10,000 cal BP. The major part of the cultural deposits of the site is in phases II and III (8000–7000 cal BP). Phase IV was dated to 6000 cal BP. No systematic flotation work was conducted during the excavations in 1997, but soil samples were collected for phytolith study at that time.

The results of phytolith analysis of the Dingsishan site indicate that no rice phytoliths are present from phase I through phase III but that large numbers of rice phytoliths are found in phase IV (Zhao, Lu, and Fu 2005). Regarding the production of phytoliths, the Poaceae is the most productive family in the plant kingdom, while *Oryza* is one of the most productive genera in the grass family. Rice phytoliths are significant not only for their abundance but also because the large size of the phytoliths enables a more definitive morphological identification. From our experience, once rice has appeared in an archaeological site, it is relatively easy to discover rice phytoliths in the cultural deposits. For these reasons, the surprising abundance of rice phytoliths in phase IV
indicates that rice was possibly introduced into this area about 6,000 years ago.

According to the above archaeobotanic studies, South China would have had nothing to do with the origin of rice agriculture. Rice agriculture was introduced into this area, probably from the middle Yangtze River region, later than 6,000 years ago, and then it rapidly became the major subsistence resource in South China. Therefore, the question becomes, what kind of subsistence pattern was present in South China before 6000 BP?

Abundant charred remains of roots and tubers recovered by flotation from the Zengpiyan site have attracted our attention. Most plants with edible roots or tubers feature vegetative propagation, and they should be easier to domesticate than seed-bearing plants. As early as the 1950s, Carl Sauer (1952) suggested that vegetative propagation should precede seed agriculture. He believed that the first domesticated plants in agricultural history were not seed plants such as wheat, rice, or corn but plants that lived in Southeast Asia, had edible tubers and roots, and reproduced asexually. Note that South China occupies the same climatic and environmental settings as, as well as sharing a similar Neolithic cultural tradition with, the northern part of Southeast Asia. Therefore, the flotation results of the Zengpiyan site remind us to reconsider Sauer’s model of the origins of agriculture. At least we know that in the tropical area of Asia, there should be a type of subsistence pattern primarily based on vegetative propagation before rice agriculture was introduced.

Conclusions

From studying new archaeobotanic data obtained by flotation over the past 10 years or so, we now have greater insight into the origins of agriculture in China. These can be summarized as follows.

Three independent agricultures have centers of origin within China: (1) dry-land agriculture, represented by the major crops of foxtail and broomcorn millet, with a center located in a wide area of loess along the Yellow River between the southern border of the Mongolian steppe to the north and the Huai River to the south; (2) rice agriculture, with a center located in an area of wetland along the middle and lower Yangtze River between the Huai River to the north and the Nanling Mountains to the south; and (3) ancient tropical agriculture, characterized by crops that propagate vegetatively, often roots and tubers and with a center located in the area along the Zhujiang River south of the Nanling Mountains.

The history of the origin of rice agriculture can be divided into three periods. (1) About 10,000 cal BP, rice cultivation began in the Yangtze River areas. Although we need more research to clarify whether the rice cultivated at this period belongs to a domesticated species in morphological and genetic terms, we believe that the purpose of the beginning of rice cultivation was only to increase the production of wild rice, not for plant domestication. (2) The time between 9000 and 6500 cal BP was a transitional period from hunting and gathering to rice agriculture. This transition features a rather slow evolutionary process. The early stage of the transition is characterized by a mixed subsistence economy in which people still relied on hunting and gathering for their major food sources but began to practice rice farming and animal husbandry as a supplement. (3) During the time from 6500 to 4500 cal BP, rice agriculture-based subsistence was gradually established; that is, people began to rely on rice agriculture more and more as their major food source. Full rice agriculture was first established in the middle Yangtze River region about 6400–5300 BP, a period known as the Daxi culture, and then in the lower Yangtze River region about 5200–4300 BP, during the Liangzhu culture period.

The history of the origin of dry-land agriculture in North China can also be divided into three periods. (1) Cultivation of millet and millet domestication might have begun as early as 10,000 years ago, but this initial stage of dry-land agriculture is still vague. It is urgent to carry out thorough investigations and get more solid and reliable archaeobotanic data in future work. (2) From 9000 to 7000 cal BP, there was a transitional period from hunting and gathering to dry-land agriculture, evidenced by new data from several early Neolithic sites. The subsistence pattern in this time period relied on hunting and gathering, with millet farming as a supplement. (3) During the time from 7000 to 6000 cal BP, millet farming-based subsistence (i.e., full dry-land agriculture) was established in North China, represented by the Yangshao culture. However, it seems that the dry-land agriculture in North China developed faster than the rice agriculture in the Yangtze River areas. The data obtained by flotation indicate that agriculture accounted for a higher proportion of the subsistence at the Xinglonggou site in the north than at the contemporaneous Jiahu site in the south at ca. 8000 cal BP. Analysis of the plant remains recovered from the Yuhuazhai site also revealed that dry-land agriculture was already established in North China by 7000–6000 cal BP, earlier than the time when rice agriculture was fully adopted in the middle and lower Yangtze River areas.

Compared with the above two subcenters, the origins and early development of ancient agriculture based on vegetative propagation in South China are not yet clear. Further investigations are needed to deepen our understanding of this process.

From the discussion during the Wenner-Gren Temozon conference, it is clear that, from a worldwide perspective, there are many similarities between China and the other major centers for agricultural origins regarding the questions of when and how agriculture emerged in these centers. For example, new studies from the Near East suggest that the beginning of agriculture was indicated by the cultivation of wild plants such as wild barley and wild lentil. The archaeological evidence for the early cultivation has been dated to the Pre-Pottery Neolithic A sometime around 11,000 cal BP. The earliest domesticated plants, such as einkorn wheat and emmer
wheat, were found from sites of the early Pre-Pottery Neolithic B, dated to about 10,000 cal BP (Weiss and Zohary 2011). Therefore, the origins of agriculture in both the Near East and China seem to follow the same pattern: they both began with plant cultivation. However, there is a slight difference in the timing between these two centers: the beginning of cultivation, as well as the occurrence of domestication, seems to be 1,000 years or so later in China than in the Near East. This might be due to inadequate archaeobotanic data in China at the moment, as flotation has been applied in the Near East for about 50 years but has been practiced in China for only 10 years.

Studies in other major centers, such as the Near East, also suggest that morphological change in crops may occur late in the domestication process not only for legumes but also for cereals (Zeder 2011). This pattern is also supported by new data from China, as can be seen in the study of rice spikelet bases from the Tianluoshan site (Fuller et al. 2009). This fact provides a challenge for the identification of domesticated plants recovered from archaeological sites because there are no generally recognized criteria to draw a line within this long, uninterrupted process in order to distinguish wild and domestic species. Also, it raises some new issues for the study of the origins of agriculture. For example, how long did it take to complete the process of plant domestication? Are there different rates in the domestication processes between different crops or between different areas? What are the factors that can affect the rate of the process of plant domestication? All of these issues need to be considered in our future research on the origins of agriculture in China as well as in the world.

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The Transition from Foraging to Farming in Prehistoric Korea

by Gyoung-Ah Lee

As a secondary setting of agricultural origins, prehistoric Korea may offer insights into the social interactions involved in crop acquisition and the human modification of local landscapes to accommodate a new agrarian way of life. Recent data may point to Korea as one of several areas where the local domestication of two crops, azuki and soybean, may have taken place. This paper explores various economic adaptations and transitions to resource production in several ecological and social settings, including the central west and southeast coasts, islands on the west coast, and the floodplains in central and southeastern Korea during the Chulmun period (7500–3400 BP). The paper reviews two popular explanations of the transition to food production, environmental impulse and migration, in the context of Korean archaeology and beyond.

Introduction

Prehistoric Korea is situated in a context of agricultural transition in which introduced crops became important in subsistence and indigenous plants may have undergone domestication. The origins of agriculture in primary regions have received more scholarly attention than that in secondary regions, where domesticated species spread later, but it was the “spread of farming” that had the major impact on human society (Price 2000b:316). For example, case studies in Europe have produced in-depth understanding of how the spread of agriculture shaped tremendous changes in social organizations, technologies, and ideologies (e.g., Ammerman and Biagi 2003; Hodder 1990; Price 2000a; Rowley-Conwy 2004). This supplement to *Current Anthropology* is also dedicated to illuminating the agricultural dispersal worldwide, including the Pacific region (Bellwood 2011), Japan (Crawford 2011), Atlantic Europe (Rowley-Conwy 2011), and the Aegean and Balkans (Özdoğan 2011). These papers not only cover the new regional data but also provide insights into the issues of population changes, social interactions, and ecological views on the transition. As a part of these efforts, this paper attempts to explore the mechanisms of agricultural spreads and the social consequences with a regional example.

The initial appearance of domesticated crops in Korea can be understood in terms of interactions with Neolithic entities in northeastern China and the maritime region of the Russian Far East. Two types of millet—foxtail (*Setaria italica* ssp. *italica*) and broomcorn (*Panicum miliaceum*)—were the first crops to appear in Korea. Shortly after their initial domestication in the Huanghe Basin (Crawford 2009; Lu et al. 2009), millets seem to have spread to the northeast, as suggested by the findings at the Xinglonggou (8000–7500 BP) and Xinle sites in Liaoning Province (Cohen 2011; Zhao 2011). Millets had dispersed farther east to the Zaisanovka Neolithic culture in the Primorie Province of maritime Russia by 6000 BP (Kang 2009). Some materials at Zaisanovka also indicate interactions with the Xinle culture and the Chulmun culture in northeastern Korea. Crops were probably one of the shared items in this interaction sphere.

Considering its proximity to early farming communities in northeastern China and Primorie, northeastern Korea may have begun millet farming earlier than current data from southern Korea suggest. In southern Korea, the earliest appearance of domesticated foxtail and broomcorn millet is dated to the Middle Chulmun period, around 5500 cal BP (table 1).

Not long after the initial adoption of millet cultivation, the

1. “Korea” is used to indicate the geography (the Korean Peninsula) rather than the term for political and ethnic distinction in this paper.
2. “Chulmun” and “Neolithic” are the terms that refer to the same time span, from the onset of pottery production and before the beginning of metallurgy. According to the new romanization of Korean issued in 2000, “Chulmun” now reads “Jeulmun.” This paper follows the new system except for commonly cited terms in previous publications (e.g., Chulmun, Tongsamdong).
3. The separation of North and South Korea has hampered our understanding of early agriculture in Korea. Neither systematic archaeobotanical study nor direct dates on domesticated crops are available in North Korea.
# Table 1. Accelerator mass spectrometry (AMS) dates

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<td>Amsandong'</td>
<td>Charred wood</td>
<td>SNU05204</td>
<td>House excavated in 1988</td>
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</tr>
<tr>
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<td>SNU455</td>
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<tr>
<td>Neunggok</td>
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<td>Beta252973</td>
<td>Floor fill, house 41</td>
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</tr>
<tr>
<td>North Chungcheong:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ilsan'</td>
<td>Peat</td>
<td>Beta48384</td>
<td>Seongjeori (zone 1)</td>
<td>4070 ± 80</td>
</tr>
<tr>
<td>Daechonri'</td>
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<td>SNU263</td>
<td>Hearth in house 2</td>
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</tr>
<tr>
<td>South Jeolla:</td>
<td></td>
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<tr>
<td>Gado'</td>
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<td>Beta2371</td>
<td>S4-W4 shell layer 6</td>
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</tr>
<tr>
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<td></td>
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</tr>
<tr>
<td>Tongsamdung'</td>
<td>Foxtail millet</td>
<td>TO8783</td>
<td>Floor fill, house 1</td>
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</tr>
<tr>
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<td>Charred wood</td>
<td>AERIK-23</td>
<td>Layer III</td>
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</tr>
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<td>AERIK-26</td>
<td>Layer III</td>
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<td>AERIK-28</td>
<td>Layer III</td>
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<tr>
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<td>H-X-VIII</td>
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</tr>
<tr>
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<td>1-V-3-5-2</td>
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<tr>
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<td>SNU00088</td>
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<td>SNU00093</td>
<td>H-X-VIII</td>
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S309
Late Chulmun:

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<th>Period, province, site</th>
<th>Material</th>
<th>Lab ID</th>
<th>Provenience</th>
<th>Uncalibrated Age (BP)</th>
<th>Calibrated Age (BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Mumun:</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
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<td>South Gyeongsang:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sangchon B°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bibongri°</td>
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<td></td>
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Middle Mumun:

<table>
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<tr>
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<th>Provenience</th>
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<th>Calibrated Age (BP)</th>
</tr>
</thead>
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<td>South Gyeongsang:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okbang°</td>
<td>Soybean</td>
<td>TO8805</td>
<td>Pit in house 658</td>
<td>2790 ± 60</td>
<td>2900 ± 70</td>
</tr>
<tr>
<td>Daumdong°</td>
<td>Adzuki</td>
<td>TO8086</td>
<td>Floor fill, house 7</td>
<td>2510 ± 70</td>
<td>2580 ± 120</td>
</tr>
<tr>
<td>Daldong°</td>
<td>Shell</td>
<td>TH1003</td>
<td>Floodplain</td>
<td>4630 ± 135</td>
<td>4660 ± 180</td>
</tr>
</tbody>
</table>

Sources. References for individual sites are in footnotes. Dates for sites not marked by source footnotes are for samples analyzed by the author. This paper uses conventions for laboratory code abbreviations provided in the journal Radiocarbon. The Carbon Dating Laboratory of the Tohoku University (TH) is not listed in Radiocarbon.

Note. All dates except for those at Daldong are calibrated with the calibration curve CalPal 2007_HULU. Dates at Daldong are calibrated with a ΔR correction from Eniwetak Atoll in the northwestern part of Pacific: ΔR = 140 ± 45 years (Stuiver and Braziunas 1993:156).

Lab IDs in boldface indicate AMS dates. a.s.l. = above sea level.

1 Kang, Choo, and Na (1993).
3 Dongguk University Museum (2006).
4 Yoon, Im, and Oh (2004).
5 Park et al. (2001).
7 Hannam University Museum (2003).
9 G.-A. Lee et al. (2011).
10 Hwang and Yoon (2002).
Chulmun culture used legumes of genera *Vigna* and *Glycine*, which may have paved the path to the domestication of azuki (*Vigna angularis* ssp. *angularis*) and soybean (*Glycine max* ssp. *max*) at least around 5000 cal BP (table 1). Recently, possible independent domestication of soybean has also been documented in the Jomon context in Japan, dating to 5300–4400 cal BP (Crawford 2011; Obata 2008). These studies emphasize the importance of research on the “evolutionary history of individual crops and regional crop associations” (Harris 1990: 15) beyond the well-known primary origins of agriculture.

Definition of the term “agriculture” often hinders understanding of the Chulmun economy. As in the Jomon case discussed by Crawford (2008), a simplistic dichotomy of hunter-gathers versus rice farmers does not illustrate the Chulmun way of life. This tendency leads to the presumption that agriculture became a primary economic activity only after the Middle Mumun period (2800–2400 BP), when irrigated rice farming was firmly established (e.g., B. Kim 2006; J. Kim 2008; Norton 2007). A simple dichotomy has further limited our understanding of the factors involved in the transition from the Chulmun to the Mumun, often described as an abrupt shift from hunting and gathering to agricultural societies.

One of the achievements of the Temozón symposium (Price and Bar-Yosef 2011) was to shape a comprehensive perspective on agriculture (or food/resource production in a broader sense) as a range of dynamic human involvements with target species. Documenting agriculture becomes the task of exploring the biology of the target species, the surrounding environments, the societies involved, and the technologies available. Domestication of species is no longer the sole criterion for determining the presence of agriculture. Well before the fully domesticated species came to be, many prehistoric societies tempered their landscapes, creating engineered niches, as seen in the Jomon (Crawford 2011) and in eastern North America (Smith 2011). Taking this holistic view on agriculture, this paper adds a refreshing perspective on the Chulmun and Mumun subsistence by focusing on two aspects.

First, the paper reviews plant manipulation in the Chulmun culture (7500–3400 BP) in central and southern regions. The archaeological sites examined are located in different landscapes, including the shoreline (Sejukri, Tongsamdong), islands (Nambukdong, Sammokdo), alluvial fans and plains (Bibongri, Pyeonggedong, Oun 1, Sangchon B), and uplands (Anganggol, Neunggok; fig. 1). Reference is also made to the Early Mumun (3400–2800 BP) period for comparative purposes. As demonstrated in many of the papers in this volume (e.g., Crawford 2011; Fuller 2011; Piperno 2011; Smith 2011; Weiss and Zohary 2011), detailed archaeobotanical study can contribute to distinguishing different types and intensities of plant use.

Second, I address the problems of the current discourse on how and why the foraging system shifted to agriculture. The popular models—emphasizing either resource-population imbalance due to decreasing marine productivity (J.-j. Lee 2001, 2006; Norton 2000, 2007) or social conflicts (J. Kim 2003, 2006)—are the two sides of one coin in terms of a shared view of agriculture as a stress response to human population increases by either internal growth or external influx. For example, it is often suggested that a population imbalance resulting from decreasing marine productivity pushed the emergence and intensification of agriculture. Agriculture naturally became a reluctant final resolution for survival when certain conditions were met, including a sea level decline, marine-resource reduction, and population increase beyond the carrying capacity of the accessible lands. What these models do is simply insert all the necessary conditions into a magic formula that itself takes care of all the explanation or necessity for explanations.

A few problematic assumptions are inherent in these approaches. It is assumed that a new intensive farming technique would have been adopted as a response to immediate crises. Because other options would have been available to humans, population growth and climatic change cannot be justified as immediate direct causes of a shift to agriculture without explaining why other options were not explored (Price and Gebauer 1995:4). Without identifying specifics in food stresses, external-stress models tend to generalize the stress as a fatal one. The food-provisioning problem can be neither defined objectively nor perceived homogenously across culture; it depends on the types and dimensions of stresses, sociopolitical organizations, existing subsistence strategies, and population densities (Minnis 1985:5–6).

### Previous Research on the Chulmun Subsistence

The Chulmun period is often subdivided into the three phases: Early (7500–5500 BP), Middle (5500–4000 BP), and Late (4000–3400 BP; fig. 2). The Middle Chulmun is distinguished from the early phase as the material culture in the southeastern region became more incorporated in the central western regions. The majority of the Chulmun sites are shell middens along the coast or on islands (Nelson 1993). Such a preference for the coasts and islands leads to the impression that the Chulmun culture was exclusively marine oriented. From the Early Chulmun, however, year-round village sites were present along the main tributaries (e.g., Amsadong and Missari along the Han River; Nelson 1993). Since the 1990s, more Chulmun settlements have been found on floodplains and hillslopes, which the Mumun people occupied later. Some...
Figure 1. Map showing the Chulmun sites mentioned in the text. 1, Amsadong, Misari; 2, Neunggok; 3, Nambukdong, Sammokdo; 4, Anganggol; 5, Daejukri; 6, Konamri; 7, Nukdo; 8, Pyeonggeodong, Nam River (Oun 1, Sangchon B); 9, Yondaedo; 10, Bibongri; 11, Tongsamdong; 12, Sejukri, Daldong; 13, Imdang.
of the sites in this study—Pyeonggeodong, Nam River, Neunggok, and Anganggol—are examples of these settlements.

The Chulmun subsistence in Korea is commonly regarded as a “broad-spectrum” system that combined fishing, hunting, and gathering (Ahn 1997; Barnes 1999; Choe and Bale 2002; Crawford and Lee 2003; Nelson 1992; Pearson 1977). A popular view in Korean archaeology is that millet farming spread diachronically from northeastern China to northwestern Korea in the Middle Chulmun and then to the south by the Late Chulmun. Crop cultivation, however, remained an insignificant strategy, and a foraging economy remained dominant throughout the Chulmun (J. Kim 2003, 2006).

Before systematic archaeobotanical research began in the late 1990s, at least 16 Chulmun sites yielded plant remains (G.-A. Lee 2003). None of these sites has been subjected to systematic recovery, and taxonomical identification of plant remains from these sites is often questionable. These data suggest that acorn (Quercus sp.) was the most important plant resource throughout the Chulmun period.

Although rice cultivation is conventionally assumed to have begun during the Early Mumun, some researchers have proposed the existence of domesticated rice in the Chulmun or even much earlier in the Late Pleistocene on the basis of on rice impressions (Son 1987), phytoliths (Kwak, Fujihara, and Yanaki 1995), and uncharred grains (Im 1997; Lee and Park 1997; Lee and Woo 2002). All the proposed data, however, are inconclusive because the context of these finds is circumstantial, and identification of rice phytoliths in this case is controversial (Ahn 2010; Crawford and Lee 2003).

Recently, foxtail millet, barley, rice, wheat, hemp, and legumes were reported from a pit house at the Middle Chulmun Daechonri site in North Chungcheong Province (Hannam University Museum 2003). Because of an incorrect identification and a lack of direct accelerator mass spectrometry (AMS) dates on these crop remains, the question of the presence of multiple crops at Daechonri remains unanswered (G.-A. Lee 2003).

Domestication of animals is one of the least-studied areas in Korean archaeology. Most reports on domesticated animals are controversial because the criteria for domestication and the context of discovery are unclear (J.-j. Lee 2009). The earliest domesticated animals found in the archaeological context are dogs, dating as early as the Middle Chulmun, from the Bibongri, Tongsamdong, and Konamri sites (J.-j. Lee 2009; table 2). Recently, cattle were reported from the Chulmun context at Bibongri (Kaneko 2008:317), but it is not clear whether the specimen represents a domesticated variety. The earliest confirmed evidence of domesticated horse, as well as domesticated cattle, came from several Late Mumun sites dating as early as 2300 BP (J.-j. Lee 2009). Cattle foot prints on the rice paddy fields at the Pyeonggeodong site indicate that cattle were well integrated into rice farming as draft animals by the Three Kingdom period (1700–1400 BP; Gyeongnam Development Institute 2007). The onset of the domesticated pig in Korea is ambiguous. Some pig remains at the Chulmun sites resemble domesticated pigs, but clear evidence comes from the much later Unified Shilla period (1400–1100 BP; J.-j. Lee 2009). Overall, domesticated animals may have played a small role in subsistence throughout the prehistoric period in Korea.

It is difficult to assess how much domesticated resources contributed to human diet, because dietary reconstruction based on human remains has been rare in Korea. Recent attempts indicate dietary patterns mainly based on plant resources from the Mumun (table 3). The importance of C₄ plants in the Early-Middle Mumun at Konamri is contrasted to the dominance of C₃ plants in the Late Mumun and historical periods, as seen in the Konamri, Neukdo, and Imdang sites (An 2006b; Choy and Richards 2009; Shin and Lee 2009). The results of these cases, although limited, are correlated with an increase of large cereals (rice, wheat, barley) from the Late Mumun onward (G.-A. Lee 2003).

On the basis of one human remain, Choy and Richards (2010) suggest that the Chulmun people at Tongsamdong were largely dependent on marine protein resources. Other analyses, however, reflect a more diverse, complex picture. Recent trace-element analysis at the Yonndaedo shell midden suggests a plant-based diet with a sizable supplementary portion of shellfish and fish during the Early Chulmun (An 2009:20). Two Chulmun shell middens in similar environments and cultural settings on the southwestern coast show differences in diet: a mixed consumption of C₃ plants and terrestrial and marine proteins at Konamri and a plant-dominant diet at Daejukri (An 2006a, 2006b; table 3).

Again, limited numbers of cases cannot represent the dietary pattern of the entire Chulmun population. An intriguing theme in these studies is that Chulmun diets cannot be summarized as one homogenous pattern. Tongsamdong and Yonndaedo (also Konamri and Daejukri) accentuate a possible differentiation of resource uses even in close proximity in similar environmental and cultural settings.

Case Studies

A decade of effort in recovering plant remains through flotation has increased the database and yielded promising results that help us to understand the transition to agriculture.

6. In most cases, identification was made without microscopic aids, and the resolution of seed images in the reports is not high enough to identify their taxa. Finds at a few sites in North Korea have been recurrently cited as evidence of millet farming in the Middle Chulmun, although the initial site report cast doubt on the identification of plant remains from these sites (Do and Hwang 1961:52).

7. Although Choy and Richards (2010:9) realized the limitation caused by the small sample size in their analysis, their conclusion, interpreting a single sample (one human metacarpal of unknown gender and age) as representative of the Tongsamdong people in the Middle Chulmun period, is a far reach by any standard. The analyzed sample size of human remains is 1, not “a small number of individuals” (emphasis added).
Figure 2. Chulmun chronology. This graph illustrates 36 dates from the 12 Early Chulmun sites, 57 dates from the 12 Middle Chulmun sites, and 10 dates from the seven Late Chulmun sites. Dates with standard errors of more than 100 years are not illustrated here. The bars of the date ranges are arranged in reverse order of the Chulmun samples listed in
in Korea. The following case studies provide good examples because the archaeobotanical materials were collected and analyzed systematically.

*Early Chulmun (ca. 7500–5500 BP)*

Because of waterlogged conditions, two Early Chulmun shell middens, Sejukri and Bibongri, yielded well-preserved organic remains (table 2). Sejukri (35°27′N, 129°21′E) is located in the northeast corner of a small bay along the east coast of Korea (fig. 1). Remains of both terrestrial and marine mammals are abundant, along with fish and shellfish.

I identified at least 16 taxa of seeds, along with nut remains (G.-A. Lee 2003). A few pits are filled with remains of several *Quercus* species (table 2). The AMS dates of charred acorn encrustations on vessels are associated with the Early Chulmun (table 1). A high proportion (80%) of the weeds in seed counts were found in several pits and a hearth, but no crop remains were found. The absence of domesticates does not necessarily mean that plant resources at Sejukri were less important. Besides nut remains, edible seeds/fruits of annual herbaceous plants and shrubs are abundant. Early Chulmun inhabitants may have familiarized themselves with these plants by observing or even making use of them. In particular, *chenopod*, abundant in most samples at Sejukri, may have had economic value to the inhabitants as a source of greens or as grains. *Chenopodium album*, a common Asian *chenopod*, occurs frequently in the archaeological record in Asia where millet farming was practiced (Crawford 2006; Weber 1998). A relevant ethnographic example is found among the Central Mountain aborigines in Taiwan, who mix foxtail millet with *C. album* and sow them together as crops (Fogg 1983:100). This annual weed is still used as greens in Korea (Pemberton and Lee 1996:62).

Like millet, *chenopod* may have been valued for its wide adaptability to short growing seasons and deficient soils as well as for its large, compact heads with many small seeds that were easy to collect and process (Weber 1998:267). The abundance of *chenopod* seeds suggests that it may have been a protected garden plant, if not intentionally propagated, during the Early Chulmun. In addition to *chenopod*, the presence of knotweed, panic grass, and grass of Hordeae (*Elymus* or *Agropyron* sp.) document other annuals at Sejukri that thrive in disturbed areas. They seem to take advantage of human-induced disturbance that often leads to generating open canopies and an increase in soil nutrients by waste. These plants, often called “anthropogenic flora,” were important in subsistence from the Initial Jomon (8000 BP) onward in Tohoku and Hokkaido, northern Japan (Crawford 1983). An anthropogenic community is often evident before the emergence of food production in archaeological records worldwide.

The Bibongri shell midden (35°24′N, 128°37′E) is located on a foothill in a steep valley along a subsidiary channel of the Nakdong River. Tools made of perishable materials are exceptionally well preserved, including dugout canoe planks, wooden posts, and fiber mats (Gimhae National Museum 2008). Faunal diversity here is high, consisting of terrestrial (e.g., wild boar, deer), marine (e.g., shark, rays), and riverine (e.g., carp) species. Moreover, cranial bones, femurs, and humeri of domesticated dogs were found in the Middle Chulmun context (Kaneko 2008:311–312). One maxillary second molar of cattle was also recovered, and it is reported to be similar to those of wild cattle *Bos taurus* that are distributed in Japan (Kaneko 2008:317).

I found 19 taxa of flora at Bibongri (G.-A. Lee 2008b). Nutmeat and shells of *Quercus* and *Juglans* are dominant. Possible dietary sources other than nuts are several taxa of edible fruits and wild green onion (*Allium* sp.) that were encrusted on pottery. Possibly useful resources for medicinal purposes are spicebush, dogwood, and Japanese snowbell (table 1). Like Sejukri, Bibongri indicates use of anthropogenic flora from both disturbed upland and lowland zones. A few charred grains of foxtail millet were found at Bibongri, but it is not clear whether they belong to the early or the middle phase.

Bibongri and Sejukri data suggest the possibility of early management of wild/weedy species that had economic value, including edible nuts, annual herbaceous greens and seeds, and fruit-bearing shrubs. Wild green onion at Sejukri is the only evidence for tuber use. Nuts were stored intensively. Further research is required to know whether intentional planting of wild plants took place in the Early Chulmun period.

*Middle and Late Chulmun (ca. 5500–4000 BP)*

The distinction between the Middle and Late Chulmun is mainly based on ceramic typology. Most sites that I have examined were occupied in both phases (table 1). Three sites are on islands along the southeast (Tongsamdong: 35°05′N, 37°04′E) and central west coasts (Nambukdong: 37°27′N, 126°24′E; Sammokdo: 37°29′N, 126°28′E), while five sites occur in inland settings; three are situated in the alluvial flats along the Nam River (Oun 1: 35°14′N, 127°58′E; Sangchon B: 35°13′N, 127°58′E; Pyeonggeodong: 35°13′N, 128°07′E), and two are located on the hillslopes of the central west (Neung-
Table 2. Taxa identified in the Chulmun sites

<table>
<thead>
<tr>
<th>Category, family, common name</th>
<th>Scientific name</th>
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<th>Middle–Late</th>
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<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broomcorn millet</td>
<td>Pennisetum miliaceum</td>
<td>X?</td>
<td>X</td>
</tr>
<tr>
<td>Foxtail millet</td>
<td><em>Setaria italica</em></td>
<td>X?</td>
<td>X</td>
</tr>
<tr>
<td>Wheat</td>
<td><em>Triticum aestivum</em></td>
<td>X?</td>
<td>X</td>
</tr>
<tr>
<td>Rice</td>
<td><em>Oryza sativa</em></td>
<td>X?</td>
<td>X</td>
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<td><strong>Fabaceae:</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Azuki bean</td>
<td><em>Vigna angularis</em></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Soybean</td>
<td><em>Glycine max</em></td>
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<td>X</td>
</tr>
<tr>
<td><strong>Weeds:</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Aliaceae:</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Wild onion</td>
<td><em>Allium</em></td>
<td>X</td>
<td></td>
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<tr>
<td><strong>Asteraceae:</strong></td>
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<td></td>
</tr>
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<td>Dandelion?</td>
<td><em>Taraxacum</em></td>
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<td><strong>Cannabaceae:</strong></td>
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<td><em>Humulus</em></td>
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<tr>
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<tr>
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<tr>
<td>Honey weed</td>
<td><em>Leonurus sibiricus</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Beefsteak plant</td>
<td><em>Perilla frutescens</em></td>
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<td>X</td>
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<tr>
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</tr>
<tr>
<td>Spicebush</td>
<td><em>Lindera</em></td>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td><em>Lespedeza</em></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Poaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barnyard grass?</td>
<td><em>Echinochloa crusgalli</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Green foxtail</td>
<td><em>Setaria italica viridis</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Panic grass</td>
<td><em>Panicum</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Panicoïd grass</td>
<td><em>Paniceae</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Wheatgrass/wild rye</td>
<td><em>Agropyron/Elymus</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Polygonaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knotweed</td>
<td><em>Polygonum</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dock</td>
<td><em>Rumex</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solonaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nightshade</td>
<td><em>Solanum cf. nigrum</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Rubiaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedstraw</td>
<td><em>Galium</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Cyperaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulrush</td>
<td><em>Scirpus juncoides/Scirpus fluviatilis</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Alismataceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrowwood</td>
<td><em>Sagittaria latifolia</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Actinidiaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild kiwi</td>
<td><em>Actinidia</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Rosaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plum</td>
<td><em>Prunus</em></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Rosaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bramble</td>
<td><em>Rubus</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Vitaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild grape</td>
<td><em>Vitis</em></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Ramanaceae:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese jujube</td>
<td><em>Ziziphus jujuba</em></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 (Continued)

<table>
<thead>
<tr>
<th>Category, family, common name</th>
<th>Scientific name</th>
<th>Early</th>
<th>Middle–Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solanaceae: Ground cherry</td>
<td>Physalis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Styracaceae: Japanese snowbell</td>
<td>Styrax japonicus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuts: Fagaceae: Oak</td>
<td>Quercus aliena, Quercus serrata, Quercus variata</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pinaceae: Pine</td>
<td>Pinus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juglandaceae: Manchurian walnut</td>
<td>Juglans mandshurica</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cornaceae: Dogwood</td>
<td>Cornus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domesticated animals: Canidae: Dog</td>
<td>Canis familiaris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bovidae: Cattle</td>
<td>Bos cl. taurus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Bbr = Bibongri; Sjr = Sejukri; Ng = Neunggok; Nbd = Nambukdong; Smd = Sammokdo; Ang = Anganggol; Tsd = Tongsamdong; Nam = Nam River; Pgd = Pyeonggedong. The Oun 1 and Sangchon B sites are collectively called the Nam River sites because they share the same cultural traits in close proximity. Faunal remains at Bibongri were recovered from the Middle Chulmun context.

gok: 36°22′N, 126°48′E) and southwest regions (Anganggol: 36°47′N, 127°06′E).

The Tongsamdong site is located on an islet in Busan Harbor on the southeast coast (fig. 1). A shallow embayment adjacent to the site probably provided rich marine resources. The numbers of terrestrial and marine mammal bones and various fish and shellfish remains are enormous. House floor fill at Tongsamdong yielded two domesticated taxa—foxtail and broomcorn millet—and several herbaceous annuals, including bedstraw, chenopod, knotweed, green foxtail, and diverse panicoid weeds (table 1). Domesticated taxa made up more than half of all seeds. As in the Sejukri samples, chenopod was the most abundant weed and is almost as common as foxtail millet.

Two island sites along the central west coast, Nambukdong and Sammokdo, show different patterns of plant use. Sammokdo was a dwelling site, while Nambukdong was probably a seasonal task camp for gathering shellfish (J.-j. Lee 2006). Both sites show a similarity in material culture. At Sammokdo, one charred seed each of chenopod and wild legume was recovered, along with possible tuber fragments from 75 L of floor fills (G.-A. Lee 2009). Plant remains were also rare at Nambukdong: a total of 184 L of hearth fill revealed one dogwood seed (G.-A. Lee 2006).

Neunggok and Anganggol are dwelling sites on a gentle hillslope dating to the Middle–Late Chulmun (fig. 1). Both sites yield domesticated foxtail and broomcorn millets (fig. 3). In addition, beefsteak plant from house floor fills at Neunggok may also represent a domesticated variety. At Neunggok, acorn remains of several oak species are abundant, similar to those from Bibongri and Sejukri. Chenopod and panicoid weeds are dominant at Anganggol and Neunggok, similar to the evidence at the Tongsamdong site (G.-A. Lee 2008a).

The Oun 1, Sangchon B, and Pyeonggedong sites are located within a 100-km reach of the Nam River channel (fig. 1), sharing similarity in surrounding landscapes and cultural remains. A total of 400 L of soil were collected from outdoor hearths and pits from Oun 1 and Sangchon B (G.-A. Lee 2003). Domesticated species include foxtail and broomcorn millets, which are dominant in the samples. Two legume seeds at the Oun 1 site seem to belong to the genus Vigna, which is the genus of domesticated azuki bean (table 1). Weed taxa are similar to those found at other Middle-Late Chulmun samples, but the presence of chenopod is negligible. Instead, panicoids account for 80% of all the weedy seeds. Panicoid-dominant weed composition continued until the Mumun period. Panicoid weeds probably flourished in gardens and fields and were included with harvested crops and left in activity or dumping areas after threshing. Nuts, both acorn and Manchurian walnut, are present at Sangchon B. Although one of the AMS dates for charred rice grains at Oun 1 raises a ques-
Table 3. Human dietary reconstruction based on isotope and trace-element analyses

<table>
<thead>
<tr>
<th>Period, site, province</th>
<th>Sample</th>
<th>Results</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Mumun: Nukdo, South Gyeongsang&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48 human remains: skull, limb, rib, femur, vertebra</td>
<td>δ&lt;sup&gt;13&lt;/sup&gt;C = −18.3‰ ± 0.4‰, δ&lt;sup&gt;15&lt;/sup&gt;N = 11.2‰ ± 0.7‰ for adult (n = 15); δ&lt;sup&gt;13&lt;/sup&gt;C = −18.7‰ ± 0.7‰, δ&lt;sup&gt;15&lt;/sup&gt;N = 12.5‰ ± 1.1‰ for juveniles (n = 33)</td>
<td>Diet based on C&lt;sub&gt;3&lt;/sub&gt; plants and terrestrial protein with a supplementary marine protein</td>
</tr>
<tr>
<td>Middle Chulmun: Tongsamdong, South Gyeongsang&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1 human metacarpal</td>
<td>δ&lt;sup&gt;13&lt;/sup&gt;C = −14.8‰; δ&lt;sup&gt;15&lt;/sup&gt;N = 18.1‰</td>
<td>Diet based on marine protein</td>
</tr>
<tr>
<td>Late Chulmun: Konamri, South Chungcheong&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1 human femur</td>
<td>Sr = 309 ppm; Ba = 73 ppm; Zn = 54.2 ppm</td>
<td>Mixed diet of plants, low terrestrial protein</td>
</tr>
<tr>
<td>Daejukri, South Chungcheong&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1 human femoral diaphysis</td>
<td>Sr = 435 ppm; Ba = 280 ppm; Zn = 66.3 ppm</td>
<td>Diet based on plants</td>
</tr>
<tr>
<td>Konamri, South Chungcheong&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1 human bone</td>
<td>δ&lt;sup&gt;13&lt;/sup&gt;C = −17.83‰; δ&lt;sup&gt;15&lt;/sup&gt;N = 9.12‰</td>
<td>Diet based on C&lt;sub&gt;3&lt;/sub&gt; plants with a supplementary animal protein</td>
</tr>
<tr>
<td>Mumun: Konamri, South Chungcheong&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1 human bone</td>
<td>δ&lt;sup&gt;13&lt;/sup&gt;C = −12.2‰; δ&lt;sup&gt;15&lt;/sup&gt;N = 10.1‰</td>
<td>Diet based on C&lt;sub&gt;3&lt;/sub&gt; plants</td>
</tr>
<tr>
<td>Early Chulmun: Yondaedo, South Gyeongsang&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2 human male and 1 female</td>
<td>Ba/Sr = 0.408, 0.416, 0.442; Zn = 203, 195, 280 ppm</td>
<td>Diet based on plants with supplementary fish and shellfish</td>
</tr>
<tr>
<td>United Shilla: Imdang, North Gyeongsang&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2 human males and 1 female; possibly 3 human males, and 3 females; 8 unidentified</td>
<td>δ&lt;sup&gt;13&lt;/sup&gt;C = −17.5‰ ± 0.7‰; δ&lt;sup&gt;15&lt;/sup&gt;N = 10.3‰ ± 1.3‰</td>
<td>Diet based on C&lt;sub&gt;3&lt;/sub&gt; plants</td>
</tr>
</tbody>
</table>

<sup>a</sup> Choy and Richards (2009).
<sup>b</sup> Choy and Richards (2010).
<sup>c</sup> An (2006b).
<sup>d</sup> An (2006a).
<sup>e</sup> An (2009).
<sup>f</sup> Shin and Lee (2009).

8. Rice grains from an Early Mumun context are dated to the Late Chulmun, although four other AMS dates from the same context all fall into the Early Mumun (table 1). Postdepositional disturbance may have occurred, considering the proximity of the Chulmun and Mumun features at Oun 1 (G.-A. Lee 2003). Although Norton (2007:141) quotes the earliest accepted evidence of rice from Oun 1 in the Late Chulmun from Crawford and Lee (2003), the original lines read that “no rice has been recovered from unequivocal Chulmun contexts at Oun 1,” and that “rice as well as millet was grown during the Late Chulmun, but the evidence needs strengthening” (92–94). A recent publication by Ahn (2010:91) also misread Crawford and Lee’s interpretation on this find.

9. Legumes of genus <i>Vigna</i> were identified at Oun 1, but the quantity is small. This reveals a large quantity of legumes of two genera, <i>Vigna</i> and <i>Glycine</i>. The pumule-hypocotyl (embryonic leaves and stem) shape and size relative to the cotyledon appear to distinguish East Asian azuki (<i>Vigna angularis</i>) from the South Asian mung bean (<i>Vigna radiata</i>; Yoshizaki 1992). The morphology of <i>Vigna</i> cotyledons resembles that of azuki rather than that of mung bean (fig. 5).

Anthropogenic vegetation is well documented at Pyeonggeodong, including panicoid grass, chenopod, knotweed, chickweed, honey grass, nightshade, wild legume, and plum (table 2). The AMS dates for broomcorn millet, azuki, and soybean (4950–4660 cal BP) here fit the Middle Chulmun chronology (table 1). Soybean seeds at Pyeonggeodong (fig. 6) are about half the size of seeds of the domesticated soybean from the Mumun component at the Nam River and Daundong sites (Crawford and Lee 2003; fig. 7). Pyeonggeodong soybean specimens fall into the size ranges of Late Longshan (ca. 4500–4000 BP) soybeans in China (Lee et al. 2007). Soy-bean...
beans from the Middle Jomon sites in Kyushu (ca. 5300–4400 cal BP) were interpreted as belonging to a domesticated variety on the basis of their morphology and size (Obata 2008). Size, however, should not be the sole distinguishing trait of domestication in earlier archaeological contexts (Crawford et al. 2005). Small legumes could be from purposefully managed populations that resulted in initial domestication even though they still retained the morphology of wild species. Even if they were wild, the dense concentration of soybeans at Pyeonggeodong indicates their important economic value to the settlers. The seed morphology and size of azuki beans at Pyeonggeodong match those of the domesticated specimens found at the Mumun sites as well as those found in the Middle and Late Jomon sites (Obata 2008). The Pyeonggeodong data support phylogenetic studies that propose multiple origins of soybean (Abe et al. 2003; Xu et al. 2002). The Korean Peninsula is probably a part of the large area in which azuki and soybean were domesticated.

Chulmun Resource Production

Recent archaeobotanical study confirms Chulmun as a resource-producing economy by the middle phase. Several sites confirm foxtail and broomcorn millet cultivation throughout the Middle–Late Chulmun, beginning by 5500 cal BP. Recent discovery of azuki and soybean at Pyeonggeodong and beefsteak plant at Neunggok and Angangol indicates the earlier appearance of upland cultivation of multiple crops in Korea by the Middle Chulmun.10 As supported by three AMS dates (Obata 2008, 159, Table 3), the seeds found here resemble those of the modern domesticated beefsteak plant (*Perilla frutescens*), although their full domestication status has yet to be confirmed.

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10. The seeds found here resemble those of the modern domesticated beefsteak plant (*Perilla frutescens*), although their full domestication status has yet to be confirmed.
dates on soybean and azuki at Pyeonggeodong (table 1), use of both legumes around 5000 cal BP is clear, regardless of their domestication status. They were probably managed anthropogenic plants, and the domestication process was certainly under way even if they were not fully domesticated.

Millet farming in the Chulmun and Jomon is often considered a transitory phenomenon that was a prelude to intensive (rice) agriculture in the Mumun and Yayoi (Crawford and Takamiya 1990:891). The gap between foraging and intensive agricultural systems, exemplified by Chulmun and Jomon food production, is often seen as a temporary, unstable stage or a developmental transition that was both radical and rapid. In other words, this unidirectional view assumes that a foraging economy shifted to agriculture rapidly without carefully considering any possible risk embedded in such a rapid shift. Could foragers adjust promptly to new sets of domesticates that required cultivation techniques and affected scheduling rhythms? I view the Chulmun economy from a different perspective. Upland dry farming of millet and legumes per se was a well-adapted sustainable strategy for a prolonged time during the Chulmun.

Weedy plants at Chulmun sites tell another interesting story. The diversity of taxa and morphology of weeds are comparable with those found in Yangshao-Longshan sites (5500–4000 BP) in the Yiluo region of China (Lee et al. 2007) and Jomon sites in northeastern Japan (Crawford 2011). Most weedy remains represent millet-tribe annuals and other arable species common in upland cultivation. The composition may
represent a viable “garden” for Chulmun people as sources of both domesticated and useful wild plants. The Chulmun may be another example of the earlier efforts of humans to actively engineer their niche for food and other vital resources, as documented in Jomon sites and in Late Archaic eastern North America (Smith 2001).

Confining the Chulmun economy to a narrowly defined concept of either specialized hunting and gathering or broad-spectrum subsistence does not seem to be the right direction. The large number of Chulmun shell midden sites is often used as evidence of a specialized economy focusing on marine resources. A substantial number of residential shell midden sites (e.g., Tongsamdong, Sejukri, Bibongri), however, reveal richness of both marine and terrestrial fauna as well as plant resources (J.-j. Lee 2001). Moreover, more sites in inland settings (e.g., floodplains, hillslopes) have been found throughout Korea where diverse terrestrial resources of both plants and game were exploited. One of the common biases in Chulmun subsistence studies is selective use of evidence for certain edible resources. The visibility of sizable remains gives further weight to the importance of shellfish and edible nuts, whereas mostly smaller, invisible seed/fruit and tuber remains are simply overlooked unless systematic recovery efforts are applied. Fortunately, a recent increase in archaeobotanical and faunal-archaeological efforts illustrates the Chulmun as a complex economy beyond a specialized subsistence based on shellfish and nuts. For instance, several coastal and offshore sites in central western Korea demonstrate a variety of faunal remains, including 36 species of terrestrial mammals, birds, fish, and shellfish (E.-y. Kim 2007; J.-j. Lee 2006; Shin 2007). Dominant species are different across locations, but a complete picture does not support the idea of a specialized economy based...
mostly on shellfish and fish. Isotope and trace-element analyses, although limited, show different dietary patterns, depending on the location (table 3). Overall, the Chulmun people seem to have diversified the subsistence strategies into procuring seasonally available niche-specific marine and terrestrial resources, possibly managing wild/weed plants, and tending domesticates (millet, legumes, beefsteak plant, and dog), from at least the middle phase.

Assumptions Revealed

Most hypotheses about the origins of agriculture in Korea offer a direct cause-and-effect explanation, whether the cause is population increase or climate change. This paper aims to test the plausibility of these arguments against available archaeobotanical and paleoenvironmental data, radiocarbon dates, and cultural conditions. In this attempt, it is crucial to distinguish two transitions in agriculture in Korea: the emergence of resource production and the shift to intensive farming of both wet and dry crops.

Quantitative analyses of marine resources have been used to examine subsistence changes in the Chulmun-to-Mumun transition (e.g., J.-j. Lee 2001, 2006; Norton 2000, 2007). J.-j. Lee (2001:317) regards the use of crops as a risk-reduction strategy against sea level decline on the east and south coasts and as population–marine resource imbalance on the west coast from 4000 BP onward.

Norton (2000) emphasizes population increase as a key condition for the adoption of rice farming along the west coast. Based on the overrepresentation of cranial bones of large-sized fish at the Konamri shell midden in South Jeolla Province, Norton suggests the differential processing of large fish as evidence of residential stability (fig. 1). Residential stability increased human population throughout the Chulmun, causing a decrease in fish sizes and favorable taxa and subsequently pushing the Chulmun hunter-gatherers to adopt rice farming.

On the other hand, J. Kim (2003, 2006) suggests the combination of environmental deterioration and subsequent southward migration as a major cause of the agricultural transition in Korea. Because of a cooling climate around 4000–3000 BP, the farmers in the Jilin-Duman regions along the current border with China migrated to the south, which was better suited for farming.11 Kim assumes constrained logistical

mobility for indigenous hunters-gatherers when immigrant agriculturalists blocked the way to resource patches. The inaccessibility of foraging territories prompted the conversion of hunter-gatherers to farmers.

The Beginning of Resource Production as a Stress Response

As reviewed above, the Middle Chulmun data indicate that cultivation of millet and legume was practiced by 5500 cal BP and around 5000 cal BP, respectively, before the proposed period of sea level decline and subsequent resource reduction around 3000 BP (table 2). It is not clear whether the appearance of crops in Korea was concurrent with the climatic amelioration. A recent palynological study suggests that a cooling episode between 6000 and 4500 cal BP caused a switch from oak-dominated forests to mixed conifer-deciduous broad-leaved forests in the central west coast (Jun, Yi, and Lee 2010). Deprivation of resources because of a cooling condition, however, is not evident in the Middle Chulmun records (5500–4000 BP). For example, my ongoing research shows an abundance of acorn at Neunggok in the central western region. Faunal and plant data from Bibongri, Sejukri, and Tongsamdong in the south indicate that their inhabitants managed complicated scheduling of diverse marine and terrestrial resources. A change to a mixed forest probably diversified resources rather than impoverishing the choices for the Middle Chulmun people. In most cases of primary origins, agriculture appeared in complex foraging economies in affluent environments where risk was affordable (Price and Geibauer 1995:8). Chulmun does not seem to be an exception. Resource stress due to environmental degradation probably was not a direct cause of the appearance of millet and legumes. Furthermore, evidence of resource stress due to high population density in the Chulmun period is lacking (Lim 2009). Current research on paleoclimate in Korea is too preliminary to address any environmental impact on emerging food production conclusively.

Another problem with previous research is the assumption of incompatibility between agricultural and foraging strategies. For example, some claim that Jomon inhabitants in northeastern Japan maintained their foraging economy because of the conflicts in resource scheduling that farming might have brought (e.g., Akazawa 1986; Matsui and Kane-
A misunderstanding of Chulmun scheduling practices is similar to the case of Jomon. Was the complex scheduling of exploiting marine/terrestrial resources seriously compromised by the demands of agriculture? It depends on what kind of cultivation and crops were adopted. Ethnographic data from Korea indicate that oysters and other common shellfish are mostly exploited between late fall and early spring (J.-j. Lee 2001:300). Shellfish harvesting is rarely pursued in summer because spawning makes shell meat less palatable and more susceptible to pest infection. In contrast, June and July are the best sowing months for the autumn varieties of millet, azuki, and soybean, the early crops that appeared in the Middle Chulmun, and these crops can be harvested by early fall, just before fishing and acorn-harvesting season (Jo 1995). Moreover, none of these crops require demanding soil conditions. Millet, in particular, is a low-maintenance, quick-growing, drought-resistant crop. Even nomads often cultivated broomcorn millet because of its ability to mature quickly, sometimes within 6 weeks (Purseglove 1972:199). It is, therefore, unlikely that coastal inhabitants were prevented from millet (and legume) cultivation because of the scheduling conflicts or the unsuitable landscape along the coast.

Why did foragers invest their efforts in cultivation when no immediate external stress existed during the Middle Chulmun, supposedly during the time of a climatic optimum? Sedentary conditions may give a hint to the answer. Sedentism existed in many areas where agriculture originated and spread (Price and Gebauer 1995:8).

Evidence of winter occupation and abundance of pottery for storage can be found in most Chulmun sites (Nelson 1992:180). House structures and faunal seasonality at Tongsamdong indicate that inhabitants may have lived there year-round (J.-j. Lee 2001). A prerequisite for sedentism is a sufficiently reliable food source to sustain a group without having to move around (Higham 1995:151). Complex foragers sometimes use storage to guard against seasonal or annual fluctuations of resources. Food-storing foragers must be able to exploit diverse species so that fluctuations in the availability of any one of them are not catastrophic (Rowley-Conwy, comment on Testart 1982:533). Adoption of domesticates may have provided an opportunity to expand storable food and thus to increase a stability in food supply. Testart (1982:535) even suggests that once foragers are practicing intensive storage and living a sedentary life, they can, without any immediate major changes in their way of life, adopt a new crop. I suggest that this depends on the required level of investment in crops adopted. As the Bibongri, Tongsamdong, and Sejukri data indicate, Chulmun inhabitants along the coast managed a complex seasonal foraging schedule with labor-intensive techniques and a storing strategy in an affluent environment (Kaneko and Nakayama 1994; Sample 1974). If a new resource can be acquired with minimum energy and time and is storable for an extended period, that resource can be highly desirable to settlers. Certainly millet and legumes fit the profile. In brief, the resource production in the Chulmun is comparable with one argued for the Archaic period of eastern North America (Smith 2011). As in eastern North America, the Chulmun does not provide much support for general models that incorporate environmental downturn, external environmental stress, population growth, landscape packing, constricted resource zones, and carrying-capacity imbalance in explaining the initial domestication (or adoption) process.

Sea-Level Changes as the Cause of Rice Farming

As reviewed above, the population-resource-imbalance model depends on an assumption of an abrupt sea level decrease at the transitional period around 4000–3000 BP. Information on sea level fluctuations around the Korean Peninsula is, however, inconclusive. Before the hypotheses of cultural changes related to the oscillating sea level can be scrutinized, a brief summary of different estimations of sea level changes around the peninsula during the Holocene is necessary.

According to a popularly quoted hypothesis on sea level fluctuations, the sea level rose almost to the present level around 6000 BP (Early Chulmun), decreased slightly around 4000 BP (Late Chulmun), increased to a maximum at 3200 BP, and decreased again between 3000 and 2300 BP (Early–Late Mumun), with a fluctuation gradient of 1–2 m (Hwang and Yoon 1999, 2002). On the contrary, Kim et al. (1999) and Jang and Park (2002) suggest a gradual sea level rise on the west coast until the mid-Holocene and stability thereafter.

Models of sea level fluctuation in Japan are often cited in Korean archaeology. Several studies in Japan present a maximum sea level around 6000 BP and a decrease afterward, but the timing and magnitude of oscillations are estimated differently according to the locations and methods applied. For example, Toizumi (1999) explains the changing frequency of Jomon shell middens in Tokyo Bay as a result of fluctuations in shellfish availability corresponding to an abrupt sea level fall (3500–2000 BP) below the current sea level. In contrast, Sato’s (2008) reconstruction in the Seto Inland Sea does not suggest any downfall below the current level during the Late Holocene.

Unlike the common assumption of the synchronicity between the maximum sea level and shoreline transgression, Shimoyma and Nishida (1999) reveal that the highest sea level and the Jomon Transgression were not concurrent. Diatom and marine clay deposition from the Saga Plain in northern Kyushu suggests that the transgression had already turned to a regression at 7000 BP, at least 1,000 years earlier than the maximum sea level span. Considering the proximity

12. The forward movement of shorelines from 15,000 BP is commonly called the “Jomon Transgression” because the transgression became remarkable in the Jomon period (10,000–2500 BP).
of Kyushu to Korea, this study also provides a cautionary tale for Chulmun studies. Shoreline retreats and marine-resource fluctuations may not have occurred concurrently with the sea level decline. The local topography of coasts and channel systems probably affected shorelines differently. Direct triangulation of the sea level fall, shoreline regression, and marine-resource decrease as explanations for the onset of agriculture should be reconsidered.

Another archaeological concern regarding sea level history is a simplistic correlation between uncalibrated dates on marine samples and archaeological events without a proper calibration based on marine reservoir effects. One of the examples is the two dates for cored shell fragments from Daldong, Ulsan, along the east coast (table 1). Simply adding error ranges seems to confirm that the sea level decreased during the Chulmun-to-Mumun transition, around 3200 BP (TH-1005: 3090 ± 110 uncal BP) and 3000 BP (TH-1004: 2910 ± 125 uncal BP; Hwang and Yoon 2002). After being calibrated,13 however, the two dates correspond not to the beginning of the Mumun (and the emergence of agriculture) but to the Middle Mumun phase, 2860–2340 cal BP. In other words, a sea level decrease was coincident with neither the Early Mumun nor the transition to intensive agriculture. In conclusion, the hypothesis that sea level decline facilitated the emergence of agriculture between 3000 and 2300 BP is unsupported. Accordingly, external-stress models rarely have the strength to explain the transition as clearly and simply as they may seem to.

An assumption implicit in this correlation is that marine resources were the most important food source. Terrestrial taxa, particularly plants, were considered a minor resource for foragers in coastal regions. Accordingly, a decline in marine resources was considered devastating to subsistence, which must have led to the adoption of new strategies. Although the Jomon culture in northeastern Japan is commonly regarded as marine oriented, wild and domesticated plants played a substantial role (D’Andrea 1999). The data from settlements on the shoreline (Bibongri, Sejukri, and Tong-samdong) prove that plants, either crops or nuts, were a crucial part of Chulmun subsistence. Moreover, as seen at Neunggok and Pyeonggeodong, domesticated crops and wild plants were important food sources for the Chulmun inhabitants in the inland and riparian habitat, where both freshwater and terrestrial resources were plentiful.

Migration as a Force for Intensive Agriculture

Like the stress models, some of the social models also emphasize a single factor—migration—as a strong impulse for the agricultural shift (J. Kim 2003, 2006). Populations moved to Korea across the Duman River when the climate began to deteriorate in northeastern China. Palynological records from the Huanghe Delta plain at the mouth of the Bohai Sea show an abrupt cooling period (4500–2700 cal BP) at the end of the Holocene hypsithermal climatic conditions from 9800 to 4500 cal BP (Yi et al. 2003:624). However, the effects of the cooling trend on the landscape and agricultural productivity in the Jilin-Duman regions have not been studied in detail. It is premature to conclude that migration resulted from a reduction in agricultural productivity because of the cooling trend.

Let us review the claim that the transition from the Late Chulmun to the Early Mumun in central western Korea was one of the most rapid transitions from foraging to agricultural economies in the world (J. Kim 2003, 2006). The rapidity of the transition should be put to the test in light of the chronometric dates. Radiocarbon dates have often been used to explain cultural changes without a distinction between the terrestrial and marine calibrations. If only the dates of terrestrial samples are considered, most Late Chulmun dates overlap with either the Middle Chulmun or the Early Mumun (fig. 2) and do not support Kim’s claim of little overlap of dates between the Late Chulmun and Early Mumun sites (J. Kim 2003:304). In contrast, a recent study by Kim and Bae (2010) suggests a prolonged transition from the Neolithic (Chulmun) to the Bronze Age (Mumun). Based on limited numbers of dates from Late Chulmun sites, it is inconclusive whether and how long the Chulmun may have overlapped with the Mumun or whether the boundary between the two is different from the one suggested. Simplistic explanations of a rapid transition, therefore, should be reconsidered.

The mechanism of the agricultural transition is explained as the conflicts over land use between farmers (newcomers) and foragers (indigenes) and a subsequent reduction in the logistical mobility of foragers (J. Kim 2003, 2006). J. Kim (2003) claims that no cultivated millet was found in the central west “despite recent effort to find cultigens by archaeobotanists” (298).14 In reality, the irregular presence of domesticates in Korea reflects a research paucity rather than a real picture, at least at the inland sites. Sizable Chulmun settlements have rarely been examined for evidence of plant use. Consequently, these Chulmun people were regarded as foragers emphasizing riverine food sources and nuts. Whenever rigorous archaeobotanical work is applied, however, the Middle–Late Chulmun sites in the central west also reveal evidence of crop cultivation. For example, the Neunggok and Angangol sites (G.-A. Lee 2008a) confirm that millet cultivation was well established at least as early as in the other regions from the Middle Chulmun (table 1). Contrary to the view that any findings of domesticated taxa in the Chulmun are rare and irrelevant exceptions in the overall Chulmun economy (J. Kim 2006:170), it is more likely that Chulmun settlement sites would yield evidence of farming and its importance if efforts were made to recover plant remains. The

13. Because there is no correction data on marine reservoirs around Korea, I used ΔR from the North Pacific for calibration (see table 1).

14. No systematic archaeobotanical study, however, had been conducted or reported in the Chulmun sites in the central west before 2003.
Chulmun people were not pure foragers but resource producers who acknowledged the importance of crops.

According to J. Kim (2003:311), the Late Chulmun foragers were forced to adopt agriculture because they could not afford the increasing mobility costs of resource exploitation when the colonist Early Mumun farmers blocked the traffic. This hypothesis is based on the general fact that Korea is predominantly mountainous terrain and that the routes of movement are limited in number. Kim does not provide any geographical information on the distribution of resource patches and the location of the high-traffic nodes. This hypothesis, therefore, remains highly conjectural.

Discussion and Conclusion

Focus on only one causal factor is not a proper approach to understanding the complicated issue of food production. Instead, the transition to agriculture must be seen as a complex process resulting from several forces operating simultaneously on different chronological and spatial scales of resolution (Zvelebil 1986:167). Foragers adopted farming selectively to fit local needs, which varied from region to region. There is no single ultimate cause that would fit all situations. As reviewed above, models heavily based on sea level changes and resource-population imbalance do not provide a plausible explanation in the Chulmun-Mumun case.

Europe, a well-studied secondary region of agriculture, can give a comparative perspective to prehistoric Korea. As Rowley-Conwy (2011) summarizes succinctly, the spread of farming in Europe is explained best by rapid but lurching migrations of Neolithic farmers with a package of southwest-Asian domesticates. The argument is supported by multiple lines of evidence, including a gap in radiocarbon dates between Mesolithic and Neolithic sites, absence of evidence for local domestication, and differences in ancient DNA between the Mesolithic and Neolithic populations. Detailed debate over rapid large-scale migration in the Chulmun-Mumun transition is beyond the scope of this paper, but key evidence for the debate is lacking, unlike the case in Europe. Although small in number, radiocarbon dates do not well establish the disjunction between the Late Chulmun and the Early Mumun. Ancient human genes are simply not available in numbers sufficient to document migration. Most of all, in Korea, adoption of several domesticated animals and plants did not occur all together, unlike the European case. Clearly, millet, azuki, and soybean were available as early as 5500–5000 cal BP, while wheat, barley, and rice arrived later. However, the dates for the initial adoption of the three large cereals are controversial. Were they incorporated into millet farming individually over a number of generations during the transitional period? Or were all these crops incorporated as a package at once? Some Middle–Late Chulmun sites raise the question of the early availability of rice and wheat, as seen in the case of the Nam River sites, but such a claim has yet to be confirmed.15 Unfortunately, systematic archaeobotanical data are lacking for the critical transitional period from the Chulmun to the Mumun between 4000 and 3400 cal BP. Because of a lack of data from several hundred years during the transition, the question of the rate of changes to intensive agriculture cannot be resolved.

Recently, some researchers have cast doubt on the abrupt replacement of the Chulmun by the Mumun. Shin (2007:11) argues that cultural continuity in pottery making and site selection indicates a gradual transition. The longevity of the Chulmun culture (over 4,000 years) may have been based on developing economic, technological, and social complexities. We must review carefully how cultural continuity and external influence were integrated into the Chulmun-Mumun transition rather than simplify the transition as a sudden entire demise of the Chulmun and a wholesale replacement by the Mumun.

What most studies in Korea overlook is the distinction between the first adoption of crops and the later establishment of intensive agriculture. We should consider these as two separate contexts of crop adoption during the Middle Chulmun and the Chulmun-Mumun transition, respectively. The Early Chulmun people had already begun to manage useful wild plants, including small-seeded annual grass, fruit-bearing shrubs, and nuts. Evidence from the Early Chulmun Bibongri site indicates that tuberlike wild onion was used early on. Because of a lack of preservation, it remains unanswered whether other starchy tubers were utilized, as in the Early Neolithic in the Yangtze Basin of South China (Cohen 2011; Zhao 2011) and the Initial and Early Jomon (Crawford 2011). From at least 5500 cal BP, Chulmun culture developed specific subsistence solutions to floodplains, hilly regions, and coastal areas that involved distinctive combinations of wild (e.g., acorn, Manchurian walnut), possibly managed (e.g., chenopod, panicoid grass), and domesticated (e.g., foxtail and broomcorn millets, possibly soybean, azuki, and beefsteak plant) species. Changes in plant use seem to have gone through similar phases in the Chulmun and Jomon periods. Early Chulmun subsistence resembles that of the Initial Jomon (9500–7000 BP), which is characterized by low densities of herbaceous annual plants while shrubs and nuts predominate (Crawford 2011). The increasing importance of annual herbaceous species and shrubs is well documented in the Middle-Late Chulmun, similar to the case of the Early to Late Jomon periods (7000–3000 BP). Chulmun and Jomon are good examples of attempts at ecological engineering well before intensive agriculture was established.

The clearest archaeological evidence for intensive agriculture in Korea is found in the Early Mumun by 3400 cal BP. Mumun people devoted multiple seasons, almost year-round, to tending various domesticated plants, as evidenced by a series of new crops that required labor-intensive care and the construction of massive raised dry fields and irrigated rice

15. The argument on the beginning of rice farming in Korea is well summarized in Ahn (2010). See also footnote 6.
paddy fields (G.-A. Lee 2003). An overly simplified focus on rice farming often blurs the real complexity of Mumun agriculture. For example, rice farming has been viewed as a cure-all remedy that solved the marine-resource reduction (Norton 2007). Also, according to B. Kim (2006), the Early Mumun agricultural economy, based heavily on rice cultivation, spread suddenly and swiftly into the Late Chulmun foraging contexts with little evidence of a transitional period. Rice farmers seem to be portrayed as a highly able group that could have eradicated the Chulmun foragers. According to the available archaeobotanical evidence, a heavy reliance on rice probably occurred much later than the Early Mumun period (G.-A. Lee 2003). Newcomers, if there were any, probably needed time to adjust to local environmental conditions, particularly for rice, which required irrigation techniques. Already available crops from the Middle Chulmun, such as millet and legumes, would have been the first choice. Detailed archaeobotanical study shows that millet and legumes were the most dominant and frequently used crops throughout the Mumun period (Crawford and Lee 2003). Rice alone seems to have played no more than a minor role in mitigating resource stress, if there was any stress, and it did not serve as a prime impetus for sociocultural changes.

Contrary to the common view of millet cultivation in the Chulmun as a transient, minor strategy, resource production was in fact a foundation for the long-lasting adaptation of the Chulmun culture. Chulmun subsistence represents a rich and diverse array of comparatively stable and successful sociopolitical and economic solutions that should be recognized and studied in their own right.

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Kim, J. 2003. Land-use conflicts and the rate of the transition to agricultural economy: a comparative study of southern Scandi-


Advances in Understanding Early Agriculture in Japan

by Gary W. Crawford

Six episodes—the Jomon, Yayoi, Tohoku Yayoi, Satsumon and Ainu, Okhotsk, and Gusuku—of agricultural development are examined. These events involve both indigenous adaptations as well as migration and diffusion to and within the Japanese archipelago. All but Jomon subsistence adaptations began as a result of migration and diffusion. Jomon populations engaged in niche construction/anthropogenesis that ranged from annual plant encouragement and probably management, lacquer tree (Toxicodendron verniciflua) and nut tree (Castanea crenata and Aesculus turbinata) management, and probable domestication of barnyard millet and soybean as well as cultivation of bottle gourd and hemp and possible cultivation of Perilla and adzuki. These characteristics place the Jomon in a middle ground that is neither hunting and gathering nor traditionally conceptualized agriculture. A brief comparison with China shows late Upper Paleolithic and Early Neolithic/Early Jomon similarities that can inform discussions about agricultural origins. The Okhotsk raised pigs, grew a few crops, hunted and gathered; this culture also does not fit traditional definitions of an agricultural economy.

Japan is not normally considered a region of independent or primary agricultural origins. Yet evidence for domestication, cultigens, plant management, and anthropogenesis indicate that a unique form of resource production had developed in Middle Holocene Japan. Furthermore, developments during the Pleistocene-Holocene transition in Japan have parallels with developments in China where indigenous agriculture quickly developed. The issue of primary origins is masked by the apparent contrasts between the economic systems of the Jomon and the apparent obliteration of indigenous systems by agricultural practices introduced from China and Korea. This paper explores the Jomon issue as well as subsequent developments in Japan. The complex processes I outlined almost two decades ago still have validity today (Crawford 1992). At the time, I felt it constructive to approach the topic from the perspective of four transitions. The first involves small-scale Jomon practices (what I called “plant husbandry”). The second transition is tied to the development of the Yayoi culture beginning shortly after 3000 cal BP (revised chronology) in southwestern Japan. Yayoi influence spread to northeastern Honshu (fig. 1) during a third phase that resulted in a production system dominated by dry crops. The fourth step resulted in the ancestors of the Ainu (the Satsumon) establishing food production in a significant portion of Hokkaido beginning between 1400 and 1200 cal BP. These transitions are reassessed in this paper, and two additional transitions are considered: the expansion of agriculture to the central Ryukyu Islands (Okinawa) from the north and to the northern coast of Hokkaido (the Okhotsk culture) from mainland East Asia.

Conceptualizing Agriculture

My perspective does not adhere to an overly constricted definition of agriculture. I acknowledge that the widely held perspective of what constitutes agriculture is Eurocentric, and excellent discussions of this perspective can be found in Deur and Turner (2005) and Vrydaghs and Denham (2007). I also reject the hunter-gatherer/farmer or hunting-gathering agriculture dichotomy, as do many others (Smith 2001, 2005). The existence of a broad continuum or “middle ground” (Smith 2001) informs this paper. Smith, acknowledging the difficulty identifying this middle ground, calls it “low-level food production” (Smith 2001). For the Middle Holocene in Japan, the term “resource production” may be more appropriate because, as will be seen later in this paper, food was not the only resource produced, and distinguishing “low” from higher levels of production, particularly in Japan, is difficult if it involves, for example, woodland management (Crawford 2008). Nevertheless, this refocusing removes constraints on the discourse. The focus is on a broad range of...
human activities that may include cultivation, other management techniques, and anthropogenesis. Domestication is an important issue, and it may help distinguish agriculture, but one cannot assume that phenotypic characteristics associated with domestication will be visible in the archaeobotanical record (see, e.g., Smith 2005). Some domesticated plants (e.g., barnyard millet *Echinochloa esculenta*) probably originated in Japan, so domestication is important to investigate there. Adherence to a dogmatic categorical reliance on physical markers of domestication may mask the presence of management, cultivation, or even domestication (see, e.g., Zeder 2011). As such, this paper reviews evidence for indigenous domestication in Japan as well as the introduction of domesticated plants and animals, but it does not rely on domestication as the key signal that a form of agriculture is present. In Zeder’s words, I embrace the ambiguity and reject pigeonholing the Jomon (in particular). This paper is not concerned with whether the Jomon were hunter-gatherers or agriculturalists.

Humans are early-succession organisms. That is, humans flourish in nonmature or disrupted ecosystems. Early stages of succession in terrestrial systems have, among other characteristics, high production and reproduction rates and organisms with short life spans (annual and biennial rather than perennial; Odum 1969). Resource production (and agriculture) is a specialized early-successional stage. Creation of such
Jomon

The existence of Jomon agriculture is still debated (Crawford 2008; Matsu and Kanehara 2006). The lack of a clear outcome of the debate is linked to theoretical stances, ethnographic analogies, a tightly constrained definition of agriculture, and popular conceptions of the past and its role in defining Japanese culture (Crawford 2008; see also Mizoguchi 2002). I have also argued that these conceptualizations unnecessarily constrain Jomon research (Crawford 2008). Concerns have overemphasized the classification of the Jomon to the extent that many scholars reference “Jomon hunter-gatherers.” In the Japanese-language literature, the Jomon is usually referred to as the “Jomon culture” (Jomon bunka) or the “Jomon period” (Jomon jidai). The emphasis on the name “Jomon hunter-gatherers” began in the 1980s when the concept of affluent foragers seemed to provide a better characterization of the Jomon subsistence economy (Aikens, Ames, and Sanger 1986; Koyama and Thomas 1981). This conceptualization was based on analogies with a narrow range of cultures in western North America as well as with the Ainu of northern Japan. Agriculture to many Japanese archaeologists is synonymous with “wet rice agriculture.” The view that agriculture in Japan is fundamentally wet rice production is a reductionist argument that ignores the fact that rice was only one of a wide range of crops there. The hunter-gatherer conceptualization is also rooted in outdated and partially romanticized narratives of the ancient human condition in Japan. The Ainu have become part of the folklore of this ancient condition. The Ainu, however, have a complex history, with agriculture being part of that history (Crawford 2008). The major ethnography by Watanabe (Watanabe 1968, 1972) cited by many archaeologists has a partially romantic foundation. Unfortunately, the Ainu still play a role in hunter-gatherer studies and are one of the three ethnographic examples of hunter-gatherers from Northeast Asia cited by Binford (2001). I do not argue that the Jomon had food production or agriculture in the way that the Chinese Middle Neolithic did, but the Jomon should not be isolated from discussions of food production or agriculture (Crawford 2008). Fortunately, many Japanese archaeologists feel the same way (Matsu and Kanehara 2006). A fresh evaluation is long overdue.

Some archaeological projects in Japan involve the regular use of flotation, while most still do not. The bulk of the recently reported plant-specific subsistence-ecological data are from wet sites such as Shimoyakebe, Awazu, and Matsugatake (fig. 1). Most reports of small numbers of exotic domesticates from Jomon sites are not reliable (Nishimoto 2007), so the development of a mainland style agricultural system during the Jomon as a result of external influences is not a viable hypothesis. Nevertheless, evidence indicates that the Japanese archipelago was not particularly isolated. Pottery from both the Korean Chulmun and Chinese Neolithic has been reported from a few Jomon contexts. Significant interaction between the Korean Peninsula and Kyushu is evidenced at sites such as Tongsamdong in Pusan, South Korea (Sample 1974). Peach Prunus persica (not native to Japan) pits (not AMS dated) from the Ikiriki site on the coast of Kyushu suggest early contact with the mainland (Minaki et al. 1986). I am not aware of any other reports of peach from the Jomon period.

The plant that is consistently recovered from northeastern Japanese sites by flotation is the annual disturbance-affiliated barnyard grass Echinochloa crus-galli (Crawford 1983, 1997; D’Andrea 1995b; Yoshizaki 1997; H. Yamaguchi, unpublished report). The oldest site from which carvories of these plants have been recovered dates to roughly 9000–8700 cal BP at the Nakano B locality at Hakodate Airport (Crawford 1983; Yoshizaki 1996). So far, populations of Echinochloa carvories have been recovered in Hokkaido from 16 Jomon sites (every Jomon site from which flotation samples have been obtained), 17 Satsumon sites, and 15 Medieval and Ainu sites. On Honshu (Tohoku), they are reported from two Jomon sites, one Yayoi site, and 11 sites dating from the ninth century and later (H. Yamaguchi, unpublished report). It is also reported from wet contexts at Shimoyakebe in Tokyo. In one study of collections from Jomon sites in the Kameda Peninsula, we were able to document that the seeds increased in size by about 20% over several millennia, indicating that selection was taking place (Crawford 1983, 1987). One specimen was recovered from residue adhering to the inside of the base of a Middle Jomon pot that was set into the floor of a house at Usuiji B. The specimen is a fruit with the carvory and portions of the pallea, lemma, and rachis. It is indistinguishable from the cultigen Echinochloa esculenta (fig. 2). Clusters of about 100 seeds are reported from single contexts at the late Early Jomon Hamanasuno and Middle Jomon Usuiji B sites, while smaller clusters are reported from the Yagi site (early Early Jomon). Other Panicoide grasses have been recovered from the Kameda Peninsula sites. They represent a minimum of three types that range from Digitaria-like to Setaria sp. Hordeae (possibly Agropyron or Elymus). A Digitaria-type grass cluster numbered nearly 900 specimens at Yagi.
Jomon people in the Kameda Peninsula were also exploiting herbaceous annuals such as chenopods (*Chenopodium* sp.), dock (*Rumex* sp.), knotweeds (*Polygonum* sp.), and other anthropogenic plants including biennials (e.g., *Rubus*) and early successional species such as silvervine (*Actinidia*), elderberry (*Polygonum* sp.), grape (*Vitis*), and lacquer tree *Toxicodendron verniciflua* and trees such as walnut (*Juglans ailanthifolia*) and Amur cork tree *Phelodendron amurense* (Crawford 1983, 1997; Crawford, Hurley, and Yoshizaki 1976).

The presence of the lacquer tree (*T. verniciflua*) raises questions. The species has been considered an introduction from China. However, the oldest lacquer products in the world are documented in the Kameda Peninsula of Hokkaido. Lacquer-painted pottery has been AMS dated to approximately 9000 cal BP at Kakinoshima B (Minamikayabe Buried Cultural Properties Research Team 2002). Lacquer is commonly associated with Jomon burials, but it is not limited to such contexts. The lacquer tree is classified as *Toxicodendron* (not *Rhus*) *verniciflua* because recent genetic studies indicate a clear separation of the two genera. Only one species of *Rhus* (*Rhus javanica*), following this reclassification, is present in Japan (Suzuki, Yonekura, and Noshiro 2007:59). The seeds of the two genera are quite similar but can be distinguished on the basis of pericarp structure (Yoshikawa and Ito 2004). A significant number of *Rhus/Toxicodendron* seeds have been recovered from Jomon sites in Minamikayabe. A preliminary examination of a few specimens indicates that at least two species are in the Kameda Peninsula samples. The cross section of the pericarp of some conforms to the structure of *T. verniciflua* (fig. 3). Botanists believe that the lacquer tree was introduced to Japan from China based on its growth in forests that are not considered to be “natural,” in other words, early successional or secondary forests. However, it grows almost exclusively in secondary forests in China, too (Suzuki, Yonekura, and Noshiro 2007). This species is likely indigenous to Japan, China, and probably Korea as well. Methods to distinguish wood charcoal and pollen of the lacquer tree have been developed, and both lines of data indicate that it was this species that grew around sites and was utilized (Suzuki, Yonekura, and Noshiro 2007). Both wood charcoal and pollen have been identified from Early Jomon contexts and later. Tools for extracting lacquer as well as a pot with remnants of lacquer collection have been recovered from the Shimo-yakebe site. Not only was the resin used for the production
of lacquer, but the wood was used as a construction material. The domesticated status of this tree is not clear. At present in China, people collect sap from both tended and untended trees. Apparently untended trees produce more sap (Suzuki, Yonekura, and Noshiro 2007:60).

Just over 100 km south of the Kameda Peninsula in the city of Aomori is the Sannai-Maruyama site. Bottle gourd *Lagenaria siceraria* and burdock *Arctium lappa* (a cultigen form, *gobo*, is apparently native to Japan) are reported (Habu 2004). Many beans (Fabaceae) have been recovered from the Early Jomon component of Sannai-Maruyama (ca. 6000 BP), but their specific identification based on seed morphology has been difficult to ascertain. Ancient DNA research has so far identified only *Glycine* sp. (soybean) in the assemblage (Sakamoto et al. 2006). The DNA is so far similar to both wild (*Glycine soja*; revised taxonomy: *Glycine max* subsp. *formosana*) and domesticated soybean (*G. max*; Sakamoto et al. 2006:3). Barnyard grass phytoliths have been identified in the clay matrix of pottery. Other plant remains similar to those recovered from the Kameda Jomon sites (herbaceous plants such as sedges [Cyperaceae] and knotweeds, shrubs such as elderberry and bramble [*Rubus*], and vines such as grape [*Vitis* sp.]) and silvervine indicate the presence of anthropogenic habitats similar to those in and around the Kameda Peninsula Jomon occupations.

A number of potential domesticates/tended plants have been recovered from Torihama, Fukui prefecture. The reports cite bottle gourd, hemp *Cannabis sativa*, beefsteak plant (*Perilla*), paper mulberry *Broussonetia papyrifera*, burdock, and mustard family (Brassicaceae) as well as weedy annuals and shrub fruits and nuts (Matsui and Kanehara 2006; Morikawa and Hashimoto 1994:87). *Perilla* is reported from several other Jomon sites such as Matsugasaki (ca. 5800 BP; Matsui and Kanehara 2006) and Shimoyakebe (Sasaki, Kudo, and Momohara 2007). Hemp is also reported in substantial quantities (clusters of charred, fused seeds) from the Late–Final Jomon occupation dating to ca. 3400 cal BP at Shimoyakebe (Sasaki, Kudo, and Momohara 2007). Japanese yam *Dioscorea japonica*, foxnut (*Euryale*), and prickly ash (*Zanthoxylum* sp.) are also evidenced at the Matsugasaki site (Matsui and Kanehara 2006). The oldest reports of bottle gourd (AMS dated to 11,700–10,900 cal BP), *Perilla*, beans (*Vigna* sp.?), burdock, and goosefoot (*Chenopodium* sp.) date to the Initial Jomon at the Awazu site on L. Biwa (Tsuboi 1994). Seeds “similar to” foxtail millet as well as barnyard millet are added to the list by the Middle Jomon at Awazu (Matsui and Kanehara 2006:264). Quite possibly this is reference to the wild forms: green foxtail and barnyard grass. Bottle gourd and *Perilla* are reported from the Middle Jomon at Shimoyakebe. Other plant remains from the site include leek/onion (*Allium* sp.), elderberry, and mulberry *Morus australis* (Sasaki, Kudo, and Momohara 2007). Legumes, totaling about 80 specimens, are reported from most periods at Shimoyakebe, where the oldest association is with the 5300–4800 cal BP walnut midden. The original report distinguishes two types of *Vigna* based on size (Sasaki, Kudo, and Momohara 2007:41). The larger seeds, ranging from about 5.8–8.3 mm long by 4.0–5.8 mm wide, have been reclassified as *Glycine* sp. A sample of these *Glycine* is AMS dated to about 5000 cal BP (table 1; Kudo and Sasaki 2010). The measurements are significantly larger than those of wild soybean, suggesting that selection for larger soybeans was taking place by the Middle Jomon. The relationship of soybean seed size to its domestication is a complex issue (Lee et al. 2011). The Middle Jomon Shimoyakebe soybean is considered domesticated based on its size. Japanese researchers have also been examining impressions on pottery recovered mainly in...
Kyushu. Flotation has not been conducted, so attention has turned to the scanning electron microscope examination of seed impressions on pottery using peels or casts. About 20 impressions have been identified as soybean. Five are impressions of the beans themselves, while 15 examples are soybean hilar areas. The oldest is from the Middle Jomon Sakanomiba site. The beans are significantly larger (over 10 mm long) than wild soybean (Obata, Sasaki, and Senba 2007). Obata, Sasaki, and Senba (2007) hypothesize that there was an independent domestication of one land race of soybean in Japan by at least 4,000 years ago. Genetic diversity among 120 cultivars indicates that the Japanese and Korean soybeans are distinct from those of China (Li and Nelson 2001:1346). Interpretation of this pattern has been informed by an assumption that soybean was domesticated once and in China, but this assumption no longer appears viable (Lee et al. 2011).

More than 100 examples of beans have been recovered from archaeological sites in Japan. Primarily two types are found: adzuki or red bean (Vigna), and soybean (Glycine). Wild species of both genera are distributed widely in East Asia. Wild adzuki bean (Vigna angularis subsp. nipponensis) is found throughout East Asia, and forms intermediate between wild and domesticated are generally confined to the Korean Peninsula and Japan (Yano, Yasuda, and Yamaguchi 2004:S136). Yayoi, Satsumon, and later historic beans have been confirmed to be adzuki (V. angularis) through DNA studies (Yano, Yasuda, and Yamaguchi 2004). The same study unsuccessfully attempted to confirm the suspicion that the Sannai-Maruyama beans were also Vigna, but subsequent research has shown that they are Glycine (Sakamoto et al. 2006). Adzuki, on the other hand, is not easily distinguished from the mung bean. Nevertheless, because adzuki is native to Japan, archaeobotanists refer to these specimens as “adzuki type.” Yoshizaki and Tsubakisaka (2001) outline a method to determine the difference between the two, but in order to do so one requires specimens in which the embryo is well preserved. Well-preserved specimens have been classified as adzuki. The oldest examples are from contexts dating to about 8000 cal BP. According to Obata, Sasaki, and Senba (2007), the number of adzuki reports increases through the Late Jomon.

The extent to which Jomon populations utilized root foods/crops such as yams and burdock (gobo) is an open question. Dental caries among selected Jomon populations range from 3.7% to 10.1%, the higher rates being associated with the Late–Final Jomon (Temple 2006). These rates are not consistent with agricultural dependence. Temple suggests that root and tuber consumption were the cariogenic foods responsible. The role of yams and burdock may be underestimated in the Jomon diet.

One of the more important Jomon resources is the wild boar or pig (Sus scrofa). They were exploited so extensively during the Early Jomon that a mutualistic relationship may well have existed at the time (Anezaki 2007:306). The overall size of pigs appears to have increased from the Early to the Middle Jomon and subsequently decreased. By AD 400, their size increased substantially. Middle Jomon pig burials have been found, and some of these burials are newborn pigs accompanying human infants, suggesting that there was a complex relationship between pigs and people at the time (Anezaki 2007:306). Furthermore, pigs were moved to islands as early as 9000 BP, with the farthest offshore transport by Jomon people being about 200 km (to Hachijo Island; Kobayashi, Kaner, and Nakamura 2004:88). Age and sex distributions are not those of a managed population; furthermore, populations of domesticated pigs in East Asia do not evidence any genetic contribution from the Japanese wild boar (Larson et al. 2010:7687).

The orthodox view that the Jomon developed and sustained itself for millennia relatively passively in a naturally rich environment is an oversimplification if not incorrect (Crawford 2008; Kobayashi, Kaner, and Nakamura 2004; Nishida 1981, 1983). Humans as ecological engineers and niche constructors generally do not inform discourse on the longevity of the Jomon. Furthermore, critical assessments of what “natural” means for Japan during the Holocene are lacking (Crawford 2008). Jomon populations were quite large in some areas, particularly northeastern Japan, where 80% of Jomon sites are located (Koyama 1992). In all likelihood, Jomon populations were ecologically dominant in this region, and their impact on both local and regional scales was probably significant. If domestication as well as resource production arose during the Jomon, then Holocene human ecology of the Japanese archipelago becomes relevant to the discourse on early agriculture. This appears to be the case.

Plant remains from Jomon sites in the Kameda Peninsula evidence a wide variety of annual herbaceous small-seeded plants as well as a number of perennial shrubs and vines.
These plants would have thrived in and around Jomon communities. Dwellings during the Early Jomon were semisubterranean houses often more than 1 m deep and 10 m in diameter. Initial Jomon dwellings such as those at Nakano B were not as large, but they were certainly numerous. The fill excavated during construction of these structures would have provided rich habitats for plants as would have the abandoned dwellings. These occupations are normally quite large and lasted for centuries and in some cases millennia. At other sites, such as Kakinoshima A situated on a coastal terrace of the Kameda Peninsula, the land was leveled, and the extracted earth was heaped around the coastal side of the terrace, resulting in a three-sided embankment about 450 m long and 35 m wide with an elevation of about 3 m (Minamikayabe Burial Cultural Properties Research Team 2003). This is probably not unique. Some Late Jomon populations in Hokkaido also invested considerable labor in the creation of cemeteries surrounded by earthworks.

Plant remains distinguish at least four episodes in the Kameda Peninsula Jomon record (Crawford 1983). The Initial Jomon is characterized by low densities of herbaceous annual plants, while shrubs and nuts predominate. The Early through Late Jomon is characterized by annual plants as well as tree (but not nuts) and shrub fruit. This period was the setting in which barnyard grass appears to have gone through a selection process that appears to be domestication. Nut remains become slightly more common later in this sequence. Chestnut (Castanea) makes its first Kameda Peninsula appearance in the Late Jomon at the Seizan site. This tree appears to have been introduced to southwestern Hokkaido by Jomon people (Yamada and Shibauchi 1997).

Chestnut, horse chestnut (Aesculus), and walnut consumption is a theme that runs through Jomon archaeology (e.g., Kobayashi, Kaner, and Nakamura 2004). This is not the case for Hokkaido, but it is for other parts of Japan. Extensive use of nuts is considered to have been so prevalent that nut-tree management is generally accepted. Nishida (1983) pointed out that these tree species along with other plants flourish in open sunlit areas. He also pointed out that plant management and plant use in the contemporary village of Mukasa beyond what we traditionally consider agriculture is extensive. Some nuts were harvested from the only relatively undisturbed forest in the area, but the closer to the village center, the more intensive plant management and plant use becomes (Nishida 1983). In the spaces among houses and gardens are chestnut, persimmon Diospyrus kaki, apricot Prunus armeniaca, fig (Ficus), prickly ash (Zanthoxylum), Perilla, and ginger (Zingiber), and a number of other plants were established (Nishida 1983: 309). Some of these plants were purposefully planted while others were not. Nishida noticed that people selectively cleared and retained certain plants. He also proposed that chestnuts and walnuts, being sun-loving plants, were managed in groves during the Jomon and that Jomon plant use likely followed the pattern similar to the one he observed in and around Mukasa.

Since Nishida wrote his paper, substantial pollen analyses have been conducted to test the idea that Jomon people managed nut trees (Kitagawa and Yasuda 2004, 2008). Comparisons of expected pollen percentages of the species with the pollen recovered from cores near archaeological sites has resulted in a number of examples where pollen of chestnuts and horse chestnuts far exceeds expectations, particularly because both are insect pollinated. Wood remains from Jomon sites indicate a marked preference for chestnut as a construction material (Noshiro and Sasaki 2007; Noshiro, Suzuki, and Yamada 1992; Sasaki and Noshiro 2004). The general conclusion is that in some places and times, chestnuts and horse chestnuts were indeed managed. Nut-tree management was not simply for the purpose of increasing the quantity of nuts but to provide construction material as well.

Yayoi

During the first millennium BP, significant socioeconomic changes began to sweep southwestern Japan. This period, the Yayoi, sees the development of clearly ranked society, metallurgy, and significant interaction with regions outside Japan. This is also the period when intensive agriculture, usually described as wet rice production, became established in Japan. The agricultural system was, of course, not strictly based on wet rice production. A broad suite of plants including barley, wheat, millet, and other dry crops was also a significant component of the new agricultural system. When and under what circumstances this significant change developed is actively being investigated. In the last few years the chronology has significantly changed (Shoda 2007). The Yayoi chronology was originally based (uncritically) on cross-dating with the mainland. A project that radiocarbon-dated residue on pottery has established that the chronology was in serious need of revision. Instead of beginning about 2400 BP and comprising Early, Middle, and Late phases, the Yayoi began ca. 2800 BP (Harunaru and Imamura 2004). It begins now with an Initial period. This is significant because the Yayoi involves an intrusion from outside. In terms of food production, there is little difference between what was transpiring on the mainland 2800 cal BP as opposed to 2400 cal BP. Nevertheless, the new chronology is an exceptional development in Yayoi archaeology.

Although the Yayoi culture has many characteristics of cultures that are its contemporaries in China and Korea, the Yayoi became uniquely Japanese. Once the Yayoi was established in the Japanese archipelago, it developed along its own historical trajectory. Its history involved considerable interaction with the indigenous Jomon cultures (Kobayashi 2001). Although 80% of the Jomon population resided in northeastern Japan, the Yayoi still encountered significant Jomon populations. Questions surround the nature of the relationship between Yayoi and Jomon peoples. Both material culture studies and genetics indicate that the Jomon were not strictly replaced. The development of distinct Yayoi pottery com-
plexes was not a simple matter and involved interaction with neighboring Jomon peoples, and the Yayoi was a fusion of cultures (Kobayashi 2001). Genetic studies indicate that Jomon genes survive "at high frequencies" in modern Japanese populations (Hammer et al. 2006).

Since the 1980s, a substantial number of archaeobotanical studies have been conducted on sites dating to roughly 3000-700 cal BP in northern Tōhoku and Hokkaido. These sites belong to five cultures: Tōhoku Yayoi, Epi-Jomon (Zoku Jomon), Satsumon, Okhotsk, and Ainu. To briefly summarize, the emergence of the Tōhoku Yayoi was a result of a complex set of processes involving the interaction of Late and Final Jomon cultures with the Yayoi cultures of southwestern Japan (Crawford and Takamiya 1990). The Tōhoku Yayoi in turn interacted with their contemporaries in northernmost Honshu as well as in Hokkaido. The Epi-Jomon developed in this context. While the Tōhoku Yayoi culture established an intensified dry farming system, its contemporaries in Hokkaido did not develop such a system until much later. Epi-Jomon sites are, with a few rare exceptions, a mixture of burials and short-term occupations (Crawford and Takamiya 1990; Nomura and Utagawa 2003). These types of settlements are not known for the preceding Jomon. The short-term occupations are evidenced by artifact, bone, and plant-remains concentrations (Crawford 1987; Crawford and Takamiya 1990; Sapporo-shi Kyoiku Inkan 1987). Often these concentrations are in shallow, burned deposits. Epi-Jomon pit houses are occasionally reported but are rare. For the first time an obvious record of sacred art flourishes in Hokkaido. Such art is concentrated in two cave sites. Ritual offerings such as pottery sherds placed on deer scapulae have also been reported. The explanation for the Final Jomon to change in so many ways has yet to be examined in any detail, but it likely relates to circumstances of its contacts with the Tōhoku Yayoi. Under such circumstances, disease, intergroup hostilities, revitalization movement(s), among others, may be in play.

Plant remains from Epi-Jomon sites primarily represent nuts, shrub and vine fruits, and anthropogenic annual plants (Crawford 1987; D’Andrea 1992, 1995a). A few cultigens such as rice are reported, but they are not found in significant quantities. These plants were likely exchanged for other products. Not only were crops exchanged but Yayoi pottery and glass beads are a minor component of Epi-Jomon assemblages. Epi-Jomon pottery is found on Tōhoku Yayoi sites. Extensive flotation at K135 and Mochiyazawa indicate that Epi-Jomon resource use is characterized by significant variation and is distinct from the preceding Jomon periods (Crawford 1987; D’Andrea 1995a; Yoshizaki 1990). Plant remains from K135 suggest short-term processing events. Large concentrations of single species of nuts indicate that they were processed and consumed over a short period of time. Similar patterns are noted for annual weedy plants such as knotweeds. At the moment there is no clear evidence of local food production during the Epi-Jomon. At least two occupations are separated by alluvial deposits. The earlier and later occupations do not suggest increasing anthropogenic influences. This pattern contrasts significantly from exploitation and settlement patterns of the preceding Jomon and the later Satsumon.

Satsumon and Ainu

The subsequent Satsumon culture represents a significant technological, subsistence, and settlement change (Yokoyama 1984; Yoshizaki 1984). We have hypothesized that the Satsumon culture arose from the Tōhoku Yayoi culture that was interacting with cultures of southwestern Japan. Significant sociopolitical developments in southwestern Japan resulted in the formation of the first Japanese state. As the state developed, so did its interests in northeastern Japan. Through a complex process of warfare, exchange, colonization, and the establishment of political and economic affiliations, sociopolitical and cultural developments in the northeast were not static. The circumstances in the northeast were ultimately so hostile that the Emishi (the name applied to all non-Japanese in the region at the time) left Honshu for Hokkaido. This event marks the beginning of the Hokkaido Satsumon period. To what extent the Satsumon merged with or eliminated the Epi-Jomon is not known. No one questions that the Satsumon is ancestral to the Ainu. Many archaeologists still prefer a unilineal model, with the Jomon leading directly to the Ainu. Elsewhere I have reviewed the arguments against this model (Crawford 2008; Crawford and Takamiya 1990); however, most archaeologists agree that the underlying factor that distinguishes the Satsumon from its predecessors on Hokkaido is food production.

Although sporadic and fortuitous reports of crop remains had been reported over the years from Hokkaido Satsumon sites, it was not until systematic flotation at the Sakushu-Kotoni River site on the Hokkaido University campus that crop remains were clearly associated with day-to-day activities of this culture (Crawford 1987; Sapporo-shi Kyoiku Inkan 1987; Yoshizaki 1990). We recovered tens of thousands of charred specimens of crops, weeds, and other plants. The crops at the site included barley, wheat, foxtail millet, broomcorn millet, melon Cucumis melo, flax Linum usitatissimum, Perilla, soybean, Japanese red bean, and hemp.

The twelfth century in Hokkaido saw significant technological changes. Indigenous technology is replaced to a large extent by technology from the southwest. Significantly, local manufacturing of pottery ceases. The technology of Hokkaido comes to look very much like that of the rest of Japan. Other aspects of the material culture, including agriculture, remained unchanged. This new period of intensified influence from the rest of Japan is what separates the Satsumon from the Ainu. Plant remains have been recovered by flotation from eight Ainu sites. The collections are primarily rice, but the general assumption is that the rice was obtained by trade. Other crops, including barnyard millet, were grown. Otherwise, the crop assemblage is similar to that of the preceding
Satsumon (Yamada 2002). Iron agricultural tools as well as ridged fields have been found in the archaeological record dating to the seventeenth century AD (Yamada 1999).

**Okhotsk Culture**

The Okhotsk culture is commonly characterized as a maritime culture that migrated from Sakhalin to the north coast of Hokkaido ca. 1500–1400 cal BP. DNA research points to their close relationships to people of the lower Amur and Sakhalin as well as to the Ainu (Sato et al. 2007). The Okhotsk culture disappeared a little over 1,000 years ago, presumably absorbed by the Satsumon culture. Flotation samples have been collected from five sites, and it is now clear that they brought crops and domesticated pigs with them. Crops include barley, foxtail, and broomcorn millet. Weedy plants include Chenopod, silvervine, grape, and elderberry; some nuts (walnut) are usually also part of the plant assemblage (Yamada and Tsukakisaka 1995). The earliest Okhotsk barley is distinct from the type grown by the Satsumon, being wider and thicker. Crops eventually grown by the Ainu likely included varieties introduced directly from the mainland, not only from the south.

**Central Ryukyu Islands: Okinawa**

Agriculture was a relatively late and sudden development in the central Ryukyu Islands that lie between Kyushu and Taiwan (Takamiya 2001, 2005). Significant research has been accomplished in this region since 1985. Flotation samples from sites dating from the Jomon to the beginning of the Gusuku period indicate that only wild foods were collected. The plant remains are mainly nuts and seeds of fruits such as grape and sildiverne (Takamiya 2005). Results of flotation at the Yayoi-Heian period Nazakibaru site have clarified that between the eighth and tenth centuries AD, wheat, barley, rice, and foxtail millet were the principal crops and that weeds such as knotweeds and sedges indicate that the crops were grown locally; potential fields have been identified (Takamiya 2005). However, Takamiya suggests that because a rapid population increase is not associated with the Yayoi-Heian period, this initial experiment with crops failed. Not until the tenth to the twelfth centuries AD (Gusuku period) did agriculture become permanently established. Apparently the shift to food production at the beginning of the Gusuku period was rapid, likely the result of a migration from Kyushu (Takamiya 2005). Preliminary DNA studies indicate that the modern Ryukyu population originated in Kyushu (Shinoda 2007). Furthermore, the Japanese dialects of the Ryukyu Islands are believed to have separated from the Japanese dialect of Kyushu some time in the middle of the first millennium AD (Hokama 1977).

**Japan and China**

The Jomon, although exhibiting considerable regional and chronological variability, represents relatively stable and similar adaptations with few if any rivals at this degree of complexity and longevity during the Holocene. This is particularly evident when compared with North China and the Yangzi basin where cultures evolved after the Upper Paleolithic from low-level food production emphasizing millets or rice as well as other resources to intensive farming that supported centralized polities and urban centers by 5000 to 4000 cal BP (Lee et al. 2007). The divergence of Japanese and Chinese subsistence-economic systems after the Upper Paleolithic is the orthodox view; Chinese populations embarked on one or more agricultural trajectories while Korean and Japanese populations settled into hunting-and-gathering modes of varying affluence and complexity that never became centralized, hierarchical, or heterarchical (see Pearson 2007). One problem is that flotation and the recovery of other plant evidence (when the plant remains are not obvious, such as at wet sites) in Japan (with some notable exceptions) is favored only when investigating questions related to agriculture. In contrast, flotation has been rapidly adopted in China over the last decade and has become standard practice there for the most part. At sites in Japan presumed to be hunter-gatherer occupations, plant-related data are not a high priority, so plant-related issues are normally not empirically investigated, thereby reinforcing preconceptions; that is, comparisons are hampered by the dearth of research explicitly designed to answer subsistence-ecological questions. As a result, this discussion is more in the realm of hypothesis building rather than testing and is meant to be exploratory. Despite the limitations of the data, table 2 compares the earliest evidence of settlement and technological innovations as well as ecological indicators of anthropogenesis/ecological engineering/ niche construction in Japan and China. Table 2 is not meant to be comprehensive but provides key or best-available examples of the evidence.

The Upper Paleolithic throughout Northeast Asia is far less regionally variable than the subsequent Early and Middle Holocene cultures. Cultures dating from the Late Glacial Maximum to 13,500–10,000 cal BP in Japan and parts of China and the Russian Far East developed the oldest pottery vessels in the world, beginning 17,800–16,000 cal BP (Boaretto et al. 2009; Kuzmin 2006; see also Cohen 2011) in contexts that are otherwise Paleolithic. By 13,500 cal BP, differences in developmental trajectories arise, but they are not what one might anticipate if populations in China were developing material and ecological precursors to the Neolithic (in the Western sense that includes food production), and those in Japan were not. Houses, villages/hamlets, and nut exploitation are all possibly two to three millennia earlier in Japan than in China (table 1). Gridding technology and evidence of storage may not be much later in China, although this depends on the interpretation and dating of remains from Nanzhuangtou (see Cohen 2011). Grass (millets and rice) exploitation and pro-
Table 2. Japan-China earliest evidence comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Japan</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pottery</td>
<td>17,000–16,000 cal BP (Boaretto et al. 2009; Kuzmin 2006)</td>
<td>17,800–17,000 cal BP (Boaretto et al. 2009)</td>
</tr>
<tr>
<td>Houses</td>
<td>Pit houses 14,000–12,800 cal BP</td>
<td>Houses cluster ca. 8000 cal BP but possibly 2 millennia earlier (Jiang and Liu 2006; Lu et al. 2009)</td>
</tr>
<tr>
<td>Hamlets/villages</td>
<td>12,800–9500 cal BP in Kyushu (Uenobara 4) and Hokkaido (Nakano B; for detailed summary see Pearson 2006)</td>
<td>Certainly by ca. 8000–7700 cal BP and probably by 10,500–9000 cal BP (Crawford, Chen, and Wang 2006; Jiang and Liu 2006; Lu et al. 2009)</td>
</tr>
<tr>
<td>Storage pits</td>
<td>13,400–13,100 cal BP in Kyushu (Habu 2004;64)</td>
<td>10,500–10,200 cal BP (Lu et al. 2009); ash pits at Nanzhuangtou, 12,700–11,000 cal BP (Cohen 2011)</td>
</tr>
<tr>
<td>Landscape modification (beyond village construction)</td>
<td>Kanjodori earthworks at Kiusu, Kakinoshima-A site preparation; these are Late Jomon</td>
<td>Ditches at Xinglonggou ca. 7700 cal BP; possible wetland management at Kuahuqiao ca. 7700–7600 cal BP (Shelach 2000; Zong et al. 2007)</td>
</tr>
<tr>
<td>Metates/querns</td>
<td>13,500 BP (see Pearson 2006)</td>
<td>11,200–8700 cal BP (Jiang and Liu 2006); Nanzhuangtou (Cohen 2011)</td>
</tr>
<tr>
<td>Nut collection</td>
<td>Large quantity in single pit 13,400–13,100 cal BP at Higashi-Kurostu-chida (see Habu 2004;64)</td>
<td>Contrast between North and South China; large quantities of acorn in Yangzi Valley wet sites; small amounts of charred walnut at Xinglongwa and acorn at Yuezhuang, all ca. 8100–7700 cal BP (Crawford, Chen, and Wang 2006; Shelach 2000; Zong et al. 2007)</td>
</tr>
<tr>
<td>Fleshy fruits (from vines, shrubs, or trees)</td>
<td>Small quantities recovered in Initial Jomon, extensive use by Early Jomon (Crawford 1983)</td>
<td>Good evidence from Pengtoushan/Bashidang 9500–8600 cal BP (or to 7500 cal BP), Kuahuqiao ca. 7700–7600 cal BP, etc. (Yan 1991; Zhejiang Provincial Institute of Cultural Relics and Archaeology Xiaoshan Museum 2004)</td>
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<tr>
<td>Annual plants:</td>
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<tr>
<td>Chenopodium</td>
<td>Initial and Early Jomon (Crawford 1983; Matsui and Kanehara 2006)</td>
<td>Xinglonggou, Yuezhuang ca. 8100–7700 cal BP (Crawford, Chen, and Wang 2006; Zhao 2005)</td>
</tr>
<tr>
<td>Polygonum</td>
<td>Early Jomon (Crawford 1983)</td>
<td>Yuezhuang ca. 8000–7700 cal BP (Crawford, Chen, and Wang 2006)</td>
</tr>
<tr>
<td>Rumex</td>
<td>Middle Jomon (Crawford 1983)</td>
<td>Pengtoushan/Bashidang ca. 9500–8600 cal BP (Hunan Provincial Institute of Archaeology 2006); rare in later sites, all are wild phenotype</td>
</tr>
<tr>
<td>Echinochloa</td>
<td>Initial Jomon (Nakano B, Hokkaido); potentially domesticated by Middle Jomon (Crawford 1983); 6700–6300 cal BP at Awazu (unclear status; Matsui and Kanehara 2006)</td>
<td>By 8100–7700 cal BP at Cishan, Xinglonggou, and Yuezhuang</td>
</tr>
<tr>
<td>Setaria</td>
<td>Genus in Early Jomon Hokkaido flotation sample and Awazu; non-AMS-dated domesticate at Usujiri B, Hokkaido; cultigen associated with AMS-dated rice at Kazahari (Crawford 1983; D’Andrea et al. 1995; Matsui and Kanehara 2006)</td>
<td>Gishan millet ca. 10,500–10,000 cal BP; common at sites after 8000 cal BP (e.g., Xinglonggou, Yuezhuang)</td>
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<tr>
<td>Panicum</td>
<td>Rare; domesticate at Late Jomon, Kazahari (D’Andrea et al. 1995)</td>
<td></td>
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<tr>
<td><strong>Other grasses (Poaceae)</strong></td>
<td>Quantities of at least two species (Hordeae and probable <em>Digitaria</em> at Yagi [early Early Jomon]; Crawford 1983)</td>
<td>Variety of Paniceae usually associated with millets</td>
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<tr>
<td><strong>Glycine</strong></td>
<td>Sannai-Maruyama (ca. 6000 cal BP); large by Middle Jomon at Sakanomiba and Shimoyakebe</td>
<td>By 8000–7700 cal BP; small through Chinese Neolithic</td>
</tr>
<tr>
<td><strong>Vigna</strong></td>
<td>Initial Jomon (Awazu; Matsui and Kanehara 2006)</td>
<td>Present in Late Neolithic</td>
</tr>
<tr>
<td><strong>Perilla</strong></td>
<td>Awazu 6700–6300 cal BP (Matsui and Kanehara 2006); Torihama</td>
<td>Houli Period, Yuezhuang site (8000 cal BP; G. W. Crawford, X. Chen, and J. Wang, unpublished manuscript)</td>
</tr>
<tr>
<td><strong>Bottle gourd</strong></td>
<td>11,700–10,900 cal BP at Awazu (Matsui and Kanehara 2006)</td>
<td>Hemudu (7000–6000 cal BP)</td>
</tr>
<tr>
<td><strong>Hemp</strong></td>
<td>Torihama (Initial-Early Jomon), Shimoyakebe (Late Jomon)</td>
<td>Gansu Province 5600–4600 cal BP (Teacher’s College of Northwest China, Institute for Plant Research, and the Gansu Provincial Museum 1984)</td>
</tr>
<tr>
<td><strong>Lacquer tree</strong></td>
<td>Lacquer at Kakinoshima-B (Initial Jomon) ca. 9000 cal BP; lacquer, wood, and seeds throughout Jomon</td>
<td>Hemudu</td>
</tr>
<tr>
<td><strong>Roots/tubers:</strong></td>
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<td></td>
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<tr>
<td><strong>Burdock</strong></td>
<td>Early Jomon (Awazu ) 6700–6300 cal BP (Matsui and Kanehara 2006)</td>
<td></td>
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<tr>
<td><strong>Dioscorea</strong></td>
<td>Early Jomon (Matsugasaki; Matsui and Kanehara 2006)</td>
<td></td>
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<tr>
<td><strong>Animals:</strong></td>
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</tr>
<tr>
<td><strong>Pig or wild boar</strong></td>
<td>Boar transported offshore ca. 9000 BP</td>
<td>8000 cal BP (probably domesticated); wild (?) at Nanzhuangtou (Cohen 2011)</td>
</tr>
<tr>
<td><strong>Dog</strong></td>
<td>Initial Jomon (e.g., Natsushima site; see Imamura 1996:61)</td>
<td>Nanzhuangtou (Cohen 2011); by 8000–7200 BP at Cishan and Dadiwan if not earlier; chicken also reported from Cishan (Barton et al. 2009; Zhou 1981)</td>
</tr>
</tbody>
</table>
duction becomes prevalent in both North and South China between 10,400 and 8000 cal BP but not in Japan. Nut exploitation in China before 8000 cal BP is not yet clearly documented. Nut remains are reported in low densities from Early Neolithic sites in the north (e.g., Xinglonggou and Yuezhuang) and in much higher densities in the Yangzi Valley (e.g., Kuahuqiao). The history of nut use in China is probably much longer than these data suggest, but these reports are all we have for now. With only 1,000 years separating the earliest evidence of Late Pleistocene–Early Holocene settlement changes in China and Japan, cultures in both areas were beginning to develop along similar trajectories, although details of the timing suggest that some changes were occurring earlier in Japan (houses, grinding technology, storage pits, and nut use) while others may be earlier in China (pottery).

Houses in the form of hamlets or villages do not simply represent increased sedentism. They also represent a form of habitat modification. Significant earthmoving is later in Japan (Late and Final Jomon) than in China (Early Neolithic). In China, ditches around and within communities are known during the Early Neolithic. These would produce specific forms of anthropogenic habitat modification. How these habitats may relate to food production is not known. The extent to which anthropogenic habitats were exploited in this initial stage is not clear either. If the Cishan millet data are an indication, grass exploitation and possibly cultivation predate 10,400 cal BP given the level of development shortly thereafter. A low-density representation of annual plants including at least one grass, the wild ancestor of barnyard millet, is evident during the Initial Jomon in Hokkaido. Grass exploitation is potentially present at a low level in Early Holocene Japan in contrast to at least some locations in China. Not until the Early Jomon do anthropogenic plants become commonly exploited. Elsewhere in Japan are the earliest records of hemp, bottle gourd, Perilla, and the lacquer tree as well as lacquer production. In fact, they are represented in the archaeological record much earlier than in China. Chenopodium on the other hand is present in the Chinese Early Neolithic as well as in the Initial and Early Jomon. Legumes were being exploited during the Initial Jomon, too. Vigna and Glycine have been recovered from several sites. The latter is well represented in the archaeological record of China and Korea, but for now, Vigna is rare in the Chinese Neolithic record. Domesticated soybean, adzuki, and barnyard millet may be present in the Middle Jomon along with a variety of managed/cultivated resources. The plant correlates of anthropogenesis, cultivation, and selection leading to domestication are evident in both China and Japan by 7000 cal BP, but the level of production appears to be much higher in China by 8000–7000 cal BP. However, the diversity of cultivated plants appears to be higher in Japan where the focus is not on grain production, although one grain seems to have emerged as a cultigen by ca. 4500–4000 cal BP. Pigs, too, were important to the Jomon just as they were in China, but they appear not to be domesticated in Jomon Japan, whereas they were domesticated early in China. Another significant difference may be the extent to which ecological succession was engineered in Jomon Japan to produce nuts and lacquer rather than cereals. The former represents a young successional stage while cereal production represents an initial stage.

I have tried to make it clear that the distinctions between Jomon and Chinese Neolithic subsistence developments are significantly different from the orthodox view. Plants were being cultivated, and productive habitats such as nut-tree orchards appear to have been created. Domestication appears to have occurred at least by the Middle Jomon. Criteria for assessing the domesticated status of plants such as Perilla have not been established, so much work remains. However, a Chinese-style agriculture is relatively late in Japan and results from extensive interaction with the mainland. These developments occurred during the Yayoi, Satsumon, Okhotsk, and Gusuku periods. Environment change after the Late Glacial Maximum and concomitant rearrangement of vegetation, large mammal extinctions, and changes in animal species distributions likely influenced Early Holocene developments, but the precise nature of the relationship to subsistence and settlement developments have not been adequately examined. We know little (empirically) about Upper Paleolithic subsistence in Japan or China. The level of production and intensification during the Jomon compared with China is difficult to assess given the eventual focus on grass seeds in China and not in Japan, although the Jomon did not ignore grasses.

The parallels in subsistence-settlement systems and technology, at least from a qualitative perspective, in Early Holocene China and Japan raise an important question: why did the cultural trajectories differ so substantially by 8000–6000 cal BP? In particular, why did resource use in China rapidly involve many domestication events and the subsequently significant economic contribution of these resources and agrarian lifeways while the Jomon did not, instead developing a somewhat agrarian lifestyle based on a few domesticates that apparently did not significantly displace other resources? I do not intend to answer the question here, but I hope that raising it will stimulate discussion.

Part of the problem involves understanding that people were not only adjusting to late and post-Pleistocene environmental changes but that they were also actively changing the environment in which they were living: that is, they were ecological engineers who made significant anthropogenic impact on their habitats. A food crisis or population pressure on resources is not apparent in either region. If anything, packing would be more influential in Japan than in China given that sea-level changes cut the archipelago from the mainland. These developments occurred during the Yayoi, Satsumon, Okhotsk, and Gusuku periods. Environment change after the Late Glacial Maximum and concomitant rearrangement of vegetation, large mammal extinctions, and changes in animal species distributions likely influenced Early Holocene developments, but the precise nature of the relationship to subsistence and settlement developments have not been adequately examined. We know little (empirically) about Upper Paleolithic subsistence in Japan or China. The level of production and intensification during the Jomon compared with China is difficult to assess given the eventual focus on grass seeds in China and not in Japan, although the Jomon did not ignore grasses.

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zone where grasses and other annuals such as Chenopodium thrived and forested river valleys (Chen 2004). Such an ecotone is minimally evident in Japan and absent at the beginning of the Holocene. Nevertheless, a different balance of managed resources, crops not strictly for food, food crops, and fish, hunted, and gathered resources proved to be sustainable for thousands of years.

Discussion

The six episodes outlined in this paper document a complexity seen in few other places. Developments during the Jomon have parallels to eastern North America (Smith 2011), Papua New Guinea (Denham 2011), and even China (Cohen 2011; Zhao 2011). Post-Jomon developments that involve diffusion and migration (Yayoi, Tohoku Yayoi, Satsumon, Okhotsk, Gusuku) also have parallels with parts of North America (including the northwest coast) and with Europe (Rowley-Conwy 2011) and Oceania as well. The Jomon is the most ambiguous of the six episodes, with evidence of niche construction/anthropogenesis that included domestication, cultivation, and tree management and potentially wild-pig management. Late Upper Paleolithic and Early Holocene developments parallel, or are identical to, some aspects of these developments in China at the same time. Yet the Jomon did not evolve along the same trajectory of domestication and intensification of agroecology as did China. Jomon subsistence adaptations were extremely successful, lasting more than 10,000 years. Viewed in these terms, early post-Pleistocene adaptations in China could be considered maladaptive initially, and they led to domestication and agrarian lifeways being adaptive over the same 10 millennia. The differences would be easily, if not overly simplistically, explained environmentally, Japan having significantly less habitat variation with no xeric to mesic ecotones, potentially fewer domesticable resources, and differences in seasonality and associated risks. However, environmental differences are not particularly satisfying explanations at this point. Agricultural-origins research in China is still relatively poorly documented, so comparing China and Japan in any substantial way is premature. Cultures in Japan did not have an agricultural system resembling that of parts of China until the development of the Yayoi that had both wet and dry agriculture. The similarities mainly are due to the ancestry of these cropping systems in mainland East Asia. By Satsumon, Okhotsk, and Gusuku times, locally suited systems of relatively productive agriculture had developed. Each of these systems—including hunting, gathering, and/or fishing—and determining the contribution agriculture made to society (nutrition, trade, symbolism, etc.) are difficult to assess. The Jomon will remain a special problem until more research is directed to understanding the roles of legumes, grasses, and other small-seeded plants in local economies and to the chronological and spatial variation in tree (nut, other fruit, and lacquer) management.

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Finding Plant Domestication in the Indian Subcontinent

by Dorian Q Fuller

Recent research indicates that cultivation may have begun in as many as five regions of India before the introduction of exogenous crops and cultivation systems: South India, Orissa, the Middle Ganges, Saurashtra, and the Himalayan foothills of the Punjab region. These potential centers of crop origin have been triangulated from data on the biogeography of wild progenitors and a growing archaeobotanical database. Nevertheless, none of these centers provide unambiguous evidence for local domestication or evidence that domestication occurred entirely in the absence of introduced crops and food-production systems. One of the major lacunae is archaeobotanical evidence from hunter-gatherer sites or evidence of the transition to initial cultivation. In addition, documentation of the morphological changes accompanying domestication is available for only a few species. This paper reviews the arguments for local domestication in each of these five regions, paying particular attention to data that might document domestication processes. But an alternative hypothesis for several regions also can be considered in which agriculture arose as a result of secondary domestica
tions of local species after an initial introduction of farming from outside. On the basis of these alternative working hypotheses, research priorities are identified for resolving these issues.

Introduction: Multiple and Overlooked South Asian Centers of Origin

Almost everywhere on earth, hunter-gatherers of prehistory have at some time given way to farmers or given up their bows for ploughs. In archaeological research, however, greater efforts have been expended on investigating the origins of agriculture in those few world regions that have long been accepted as having been likely “centers of origin” (see Harlan 1971; Harris 1990). However, as research into agricultural origins has tended to focus on accepted centers of origin with a shortage of research on other regions, this has meant that it is difficult to assess local origins of agriculture whether by introduction or local evolution. Such blanks on the map of research in turn help to reinforce the sense that there were very few widely spaced centers of origin. One of these areas that has long been a blank on maps of early agriculture is the Indian Subcontinent, and this paper reviews recent empirical research that indicates local domestication processes.

In the past few years there have been arguments in favor of independent agricultural origins in India (Fuller 2002, 2006, 2008a; Saraswat 2005; Tewari et al. 2006, 2008). This has arisen in part from increased attention to identifying the wild progenitors for many crops that are poorly known in the mainstream Western agricultural literature and that are underdocumented relative to crops from the Near East, West Africa, or the Americas. It is only the past few years that Southern Neolithic sites have joined the growing body of archaeobotanical evidence from South Asia (Fuller et al. 2004). The Middle Ganges plain has also seen rapid growth in new archaeobotanical information (Saraswat 2005; Tewari et al. 2008). This paper reviews the archaeological and botanical evidence for agricultural origins in six regions of South Asia (fig. 1; for additional details for each region, see CA+ online supplement A).

The past 25 years have seen the steady increase in archaeobotanical evidence in South Asia (fig. A1 in CA+ online supplement A), especially by flotation, which now accounts for more than half of the reported evidence. Of particular note is the recent addition of a rich database from Southern India. It should be stressed that we still lack evidence in South Asia for most of the transitions, for initial cultivation, and for shifts toward morphological domestication and agricultural dependence. Instead, our evidence is clearest for the
emergence of sedentary village societies that are invariably already dependent on cultivation and usually have domesticated crops and livestock.

A Terminological Note on “Independent Origins”

As the archaeology of agricultural origins draws on natural and social sciences, it is important to be aware of potential differences of emphasis in how origins are defined. Whether origins are “independent” or not is ambiguous without specifying whether one’s emphasis is on the genetic derivation of a cultigen or the cultural tradition of cultivation. Table 1 provides a clarification by defining secondary and primary origins as they are used in this paper. Primary and secondary origins of crops in a given geographic region are differentiated on the basis of whether the plant species are introduced as cultigens, in which case they are secondary, or are derived from local populations of wild progenitors, in which case they are primary. Within both primary and secondary origins we can make further divisions in terms of the social processes of agricultural origins. In cultural terms we can ask whether local domestications might be inspired by contacts with other farmers or whether the impetus to begin cultivation was truly pristine and an innovation in the cultural sense. Cases of “additive primary origins” are those that botanists have traditionally called “secondary domestica
tions” (e.g., Vavilov 1992 [1927]:151), such as poppies in the Western Mediterranean or European rye and oats, where local wild/weedy species were added to the repertoire of existing farmers.

In this paper, and for me, independence is considered first on the botanical side of the matrix. In this sense, several parts of South Asia can be defined as centers of primary crop origins. In the discussion that follows, consideration of whether the social process was pristine or inspired or whether agriculture arrived by migration or adoption will also be considered. But the inference of such social processes from the archaeological evidence remains less certain and more debatable than biological domestication.

The agrobiodiversity in South Asia is high by comparative standards, especially in terms of cereals and grain legumes. The modern agriculture of India boasts 12 domesticated millet crop species in addition to rice, wheat, barley, and Job’s tears; these are augmented by a dozen pulse species. In a series of previous publications, I have summarized evidence for native millet and pulse domesticates of India and their likely geographical and ecological contexts of origin (e.g., Asouti and Fuller 2008, chap. 3; Fuller 2002, 2006; Fuller and Harvey 2006). Tables A2, A4, and A5 (in CA+ online supplement A) and tables A1, A3, and A6 (available as Excel files in the online edition) summarize current details for the key domesticates, while the sections below provide a synthetic interpretation of the evidence. See figure A1 for a cumulative total of sites with published archaeobotanical reports from 1960 to 2005.

The South Deccan Center

The South Deccan has recently emerged as a potential center of a distinctive indigenous early agriculture (Boivin et al. 2008; Fuller, Korisettar, and Venkatasubbaiah 2001; Fuller et al. 2004). The crops that recur and dominate Southern Deccan Neolithic archaeobotanical samples (fig. 2; table A1, available as an Excel file in the online edition; table A2) have wild ancestors to be found in the hills of scrub woodlands of the region (Asouti and Fuller 2008; Fuller 2006). While these are likely to have come together from local domestications in the Southern Deccan, these origins themselves remain elusive. Archaeobotanical evidence from sites of the Southern Neolithic consistently indicates the predominance of mungbean (Vigna radiata), horsegram (Macrotyloma uniflorum), and two millets (Brachiaria ramosa and Setaria verticillata; Fuller, Korisettar, and Venkatasubbaiah 2001; Fuller et al. 2004). These crops occur on virtually all sites (that have been well sampled) and dominate samples on sites across the region (fig. 3; table A1). The millets of the Southern Neolithic, in particular, had been previously overlooked. In recent times, browntop millet B. ramosa is restricted to small plots of cultivation in a few isolated areas of the eastern Ghats zone in Eastern Karnataka and Andhra Pradesh (Kimata, Ashok, and Seetharam 2000). I have no unambiguous evidence that S. verticillata is cultivated anywhere today, although one secondary source indicates cultivation somewhere in Tamil Nadu (Maheshwari and Singh 1965). It is clear that a century ago, it was a wild-gathered resource in Maharashtra (Gammie 1911), while the sister species Setaria pumila (syn. Setaria glauca of many authors) was and still is cultivated (Kimata, Ashok, and Seetharam 2000; Kobayashi and Kimata 1989; Prasada Rao et al. 1987).

Unfortunately, at present our earliest systematic archaeobotanical samples date only from ca. 2000 BC with some earlier incompletely published evidence from Watgal (M. D. Kajale, personal communication; cf. Deveraj et al. 1995) and Budihal (Kajale and Eksambekar 1997). Thus, while we have good evidence for this package once it was fully formed and established in its region, we lack a clear sequence for its origin: this must become a priority of future research (table A2).

Most members of this crop package, the two millets and horsegram, could have been more widely available in the drier savannah zones of peninsular India. These are not species that form extensive stands in the way that wild wheats, barley, or wild rice do, but rather these species are likely to have formed local dense patches in favorable microenvironments such as springs and slope bases for the millets and perhaps less disturbed scrub patches for the wild horsegram. Thus foragers exploiting these species may have seen advantages in concentrating them together and expanding these stands through clearance of other plants. At present we lack clear morphological indicators on preserved remains for domestication, and thus cultivation has only been inferred based on dominance of samples, recurrence across sites, and association with
Mungbean differs from the other crops in its particular region of origin, and the core region of the Southern Neolithic was, and is, too dry (Asouti and Fuller 2008; Fuller and Korisettar 2004; cf. Tomooka et al. 2003). Thus the zone in which domestication occurred must have been toward the sides of the peninsula where the dry savannahs intergrade into deciduous forests, and my current suggestion is the eastern Ghats north of the Krishna River, along the Northeast Karnataka/Andhra/Maharashtra borders, where $V.\ radiata$ occurs without $V.\ mungo$ (Asouti and Fuller 2008; Fuller and
Harvey 2006). It might have occurred somewhat more widely wild under slightly wetter mid-Holocene conditions. We (Boivin et al. 2008; Fuller, Boivin, and Korisettar 2007) suggest north of the Krishna River because Neolithic sites in the Kur- nool district are only from the later Neolithic, mainly after 1700 BC. This candidate region is, however, poorly explored for the Neolithic or Mesolithic, and thus a key gap in archaeo- logical research can be highlighted (fig. 3).

The mungbeans that have been found from Southern Neolithic sites, however, are decidedly small seeded, like modern wild populations, indicating that the seed enlargement associated with modern domesticates had not yet evolved (Fuller 2007a; Fuller and Harvey 2006). Domestication, by which is meant a presumed reduction in germination inhibition, is inferred based on mung’s occurrence in quantity in regions such as Bellary beyond the wild-progenitor range. When a regional data set is considered, seed-size increase in mungbeans took place from the end of the Southern Neolithic, after the mid-second millennium BC and through Iron Age times (fig. 4; cf. Fuller and Harvey 2006). Evidence from the Ganges, where this species was introduced, suggests a parallel but somewhat earlier evolution of large-seeded forms. Even earlier large-seed specimens are reported from the eastern Harappan zone, suggesting that small-seed mungbean was introduced to the Ganges from the south. The South Indian increase in mungbean size, beginning from ca. 1500 BC, correlates with a period of probable agricultural intensification and diversification, the same period when African crops became established in South India (Fuller, Boivin, and Korisettar 2007), and there is evidence from Hallur for little millet (Panicum sumatrense), a probable domesticate of Gujarat (see below; Fuller et al. 2004).

Other crops were introduced into the Southern Neolithic, such as wheat and barley, by 1900 BC (table A2). They are not widespread or dominant crops, and this suggests that they were adopted through processes of cultural diffusion (Boivin et al. 2008; Fuller 2005) rather than the immigration of northwestern winter cereal growers. The near absence of other members of the winter crop package (pea, chickpea, and lentil) that are present in the Harappan area and in Chalcolithic Maharashtra is also worth noting. Nevertheless, wheat and barley do occur at the earliest well-sampled levels at Sangan-

<table>
<thead>
<tr>
<th>Social process</th>
<th>Plant origins</th>
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<tr>
<td>Pristine: cultivation initiated by hunter-gatherers only in contact with hunter-gatherers</td>
<td>Primary: cultivation started from wild progenitors local to region</td>
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<tr>
<td>Inspired: cultivation initiated by hunter-gatherers in contact with food producers (i.e., “stimulus diffusion”)</td>
<td>Secondary: crops introduced, not evolved from local wild progenitors</td>
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<tr>
<td>Additive: cultivation initiated by farmers possessing other crops</td>
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<tr>
<td>Migration: immigrant farmers carry crops and/or livestock (i.e., “demic diffusion,” moving frontier of agriculture)</td>
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<tr>
<td>Adoption: crops or livestock from another area obtained by trade with minimal immigration (i.e., “cultural diffusion,” static frontier of agriculture)</td>
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</table>
ern peninsula (Southworth 2005). We can propose then that there was a secondary dispersal, perhaps partly by adoption but also by migration of Proto-Dravidian speakers, focused on the savannah zone between the Thar Desert margins and the South Deccan between 3500 and 2500 BC. The recent report of primitive pre-Chalcolithic(? ) pottery from Sakshal Pipri, although inadequately dated, could relate to this (Mishra et al. 2006). This pastoralist-collector way of life can be suggested to have inspired the local primary domestica
tions of indigenous pulse and millet crops on the peninsula.

Based on current dating evidence, the early settlements in the South Deccan predate 2500 BC while those in the North Deccan start from 2500 to 2300 BC. Where data are available (e.g., Utner, Piklihal, Banahalli), South Deccan ceramic sites include domesticated caprines and cattle, and the early phase of the Deccan ashmounds (composed largely of burnt cattle dung at penning sites: Alchin 1963; Johansen 2004; Korisettar, Venkatasubbaiah, and Fuller 2001) date to this period (Fuller, Boivin, and Korisettar 2007). Subsequently in both South and North Deccan, this savanna corridor becomes increasingly

Figure 2. Southern Neolithic crop package. Line drawings of horsegram, mungbean, browntop millet, and bristly foxtail panicles showing overall plants and seeds. (Seed drawings and millet panicles by the author; horsegram and mungbean plants from Church [1886].)
Figure 3. Map of sites with archaeobotanical evidence from peninsular India, indicating those with Neolithic/Chalcolithic evidence and those with Iron Age/Early Historic evidence. Indicated are putative centers of plant domestication in region A and region C (from fig. 1), both gaps in archaeological survey and sampling. 1, Kayatha; 2, Dangwada; 3, Ujjain; 4, Nagda; 5, Navdatoli; 6, Kaothe; 7, Tuljapur Garhi; 8, Kaundinyapur; 9, Kharwada; 10, Bhagimohari; 11, Bhatkuli; 12, Naikund; 13, Paunar; 14, Adam Cave; 15, Bhokardan; 16, Daimabad; 17, Nevasa; 18, Paithan; 19, Walaki; 20, Inamgaon; 21, Terr (Thair); 22, Gopalpur; 23, Golbai Sassan; 24, Kolhapur; 25, Budhihal; 26, Pilkhal; 27, Veerapuram; 28, Tekkalakota; 29, Kurugodu; 30, Sanganakallu; 31, Hiregudda; 32, Hattibelagallu; 33, Velpumudugu; 34, Sanyasula; 35, Ramapuram; 36, Singanapalle; 37, Rupanagudi; 38, Injedu; 39, Peddamudi; 40, Hanumantaraopeta; 41, Hallur; 42, Koppa; 43, Kunnatur; 44, Arikamedu; 45, Adichannalur; 46, Perur; 47, Kodumanal; 48, Mangudi.
.populated by sedentary farmers, especially after 2200–2000 BC, and the role of a climatic aridification around this time bears some consideration in the emergence of sedentism. On these sedentary sites, integrated agropastoralism is evident, including the indigenous crop package of South India but also on sites of the northern peninsula, having a strong emphasis on Harappan/Near Eastern winter crops (wheat, barley, lentil, pea, grasspea), which must have spread by secondary adoption to the northern peninsula, perhaps from the Ahar/Balathal culture zone of Rajasthan.

The Ganges Center

On the great floodplain system of the Ganges and its tributaries, the origins of rice takes center stage. Rice is ubiquitous on all archaeobotanically sampled sites of Mesolithic, Neolithic, or Chalcolithic age (fig. 6; table A3). The balance of evidence suggests a distinct origin of cultivation of ancestral indica rice in this region but that full domestication in the morphological sense was not completed until domesticated japonica varieties were introduced to North India from China, allowing for hybridization (Fuller and Qin 2009; Fuller et al. 2010). The necessity of hybridization was first postulated by Sato (1996, 2002) and more recently numerous other authors (e.g., Sang 2009; Vaughan, Lu, and Tomooka 2008). A key to unraveling this complex story is to recognize that “domestication” as used in phylogenetic studies refers to the subsampling process of wild populations with the beginnings of cultivation, whereas archaeobotanical or morphological “domestication” refers to the fixation of genotypes adapted to cultivation and dependent on humans. The protracted transition between cultivation and domestication makes it difficult to pinpoint how many starts of cultivation there were, and genetic data can offer only a bare minimum (Allaby, Fuller, and Brown 2008).

Numerous data sets and studies indicate wide genetic divergence between modern indica and japonica cultivars (e.g., Bautista et al. 2001; Caicedo et al. 2007; Cheng et al. 2003; Garris et al. 2005; Londo et al. 2006; Takahashi, Sato, and Nakamura 2008; Tang et al. 2004; Vitte et al. 2004). There is plausibly more than one origin within each of these as well as a distinct aus-type origin in the Bangladeshi region. Nevertheless, completely separate Indian and Chinese origins are complicated by recent data indicating that a few key domestication genes, including one that controls panicle shattering (sh4) and one that causes grains to be white (rc), are shared across indica and japonica (Kovach, Sweeney, and McCouch 2007; Sang 2009; Sweeney and McCouch 2007). In addition, one key mutation that affects plant growth—prog1, making crops tall and erect as opposed to short and spreading the stature of wild rices—is also shared (Tan et al. 2008). In other words, phylogenetic evidence from across the nuclear and chloroplast genomes suggests separate origins of cultivation (wild-population subsampling), but the evidence of functional genes indicates partly shared domestication through...
Figure 5. Distribution of Neolithic/Chalcolithic sites on the Indian Peninsula showing their correlation with the "savanna corridor" (generalized from vegetation zones and rainfall data, 40–80 cm/year; see Asouti and Fuller 2008). The geographic division is indicated between a South Indian Neolithic, reliant on a package of indigenous crops, and North Deccan Chalcolithic, where introduced winter cereals were more important than indigenous millets. Selected early/representative sites are labeled. Note the lack of sites in the North/East, which may reflect a lack of systematic investigation and excavation including in the hypothesized domestication center.
hybridization. Vaughan, Lu, and Tomooka (2008) maintain a single-origin model in which introgression from wild population into the crop as it spread south from China accounts for the genetic divergence. But this hypothesis ignores the archaeobotanical evidence from India, the archaeological evidence for early contacts between northwestern South Asia (not the northeast) and China, and the archaeobotanical evidence in China that increasingly suggests a slow and late domestication process for rice (Fuller, Harvey, and Qin 2007; Fuller, Qin, and Harvey 2008; Fuller et al. 2009, 2010). It is also not clear how the “snowball model” of Vaughan and colleagues (Vaughan, Lu, and Tomooka 2008) can account for divergence in the chloroplast genome (e.g., Chen et al. 1993; Takahashi, Sato, and Nakamura 2008; Tang et al. 2004), which is not transmitted in pollen.

The distinct origins of indica and japonica cultivars is associated with different wild ecologies and differing economic systems of exploitation (Fuller and Qin 2009). Essentially, the process in the Lower and/or Middle Yangtze of China focused on a perennial wetland species (Oryza rufipogon sensu stricto), in which manipulation of water levels and selection for annual high-grain-yielding plants was central (see also Cohen 2011; Zhao 2011). By contrast, the monsoon-adapted wild annual (Oryza nivara) was already high yielding and could be readily collected from extensive wild stands (much as is postulated for wild sorghum, wheats, or barley). Oryza nivara probably could be effectively exploited without agriculture but through simple management such as burning off competing vegetation during the dry season. Recent palynological studies in the Ganges plain indicate significant microcharcoal levels from the terminal Pleistocene warm period, ca. 14,500–13,000 BP through the early and mid-Holocene, at Sannai Tal with similar evidence from the end of the Pleistocene at Lahuradewa (Singh 2005). These charcoal levels from the terminal Pleistocene are accompanied by the presence of Oryza bulliform phytoliths from ca. 8000 BC, which show increased levels and morphological diversity (suggesting mosaics with nivara, rufipogon, and perhaps other wild Oryza) from ca. 7000 BC (Saxena et al. 2006). Whether some of these bulliforms represent cultivated rice (as argued by Saxena et

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Figure 6. Map of northern South Asia showing representative archaeological sites that track the spread of rice (after Fuller and Qin 2009) but indicating likely foci of early Gangetic cultivation. 1, Harappa; 2, Kunal; 3, Ojiyana; 4, Mahagara; 5, Koldihwa; 6, Tokwa; 7, Malhar; 8, Senuwar; 9, Lahuradewa; 10, Narhan; 11, Imilidh-Khurd; 12, Manji; 13, Charda; 14, Hulashkhera; 15, Gopalpur; 16, Golbai Sassan; 17, Sannai Tal lake (pollen core); 18, Balathal; 19, Shikarpur; 20, Surkotada; 21, Kanmer; 22, Bagasra (Gholo-daro); 23, Kuntasi; 24, Rojdi; 25, Oriyo Timbo; 26, Babor Kot; 27, Rangpur. Sites of the greater Indo-Gangetic divide region, with mixed indigenous(?)-introduced agriculture: E1, Kalibangan; E2, Banawali; E3, Rohira; E4, Sanghol; E5, Rupar; E6, Mahorana; E7, Balu; E8, Mitathal; E9, Daulatpur; E10, Burthana/Tigrana; E11, Laduwala.
Grain size and shape evolution in Indian rice does not appear to be early or precede full domestication as postulated for Chinese rice (Fuller 2007a). The available morphometric evidence for Neolithic Gangetic rice (collected in Fuller et al. 2010) indicates that grains are on the small side, congruent with morphologically wild rice and perhaps immature grains being present. Indeed, the measured grains from Koldihwa and Mahagara are consistent with those from Lahuradewa about 4,000 years earlier, all of which are smaller than later domesticated rice grains from Iron Age or Early Historic India (Fuller et al. 2010). Re-sorting of samples has recently confirmed that rice spikelet bases, previously overlooked, are present in the fine fraction of flotation samples from Mahagara (1700–1600 BC) and that these are predominantly of domesticated morphology (for earlier preliminary archaeobotanical results, see Harvey and Fuller 2005; Harvey et al. 2006). Interestingly, this implies that spikelet bases were non-shattering by this time, perhaps based on an introgressed mutation from introduced japonica cultivars, but grains at this period had not yet undergone clear size increase, which occurs instead by the end of the second millennium BC into the Iron Age (Fuller et al. 2010). This size increase appears to occur faster than that documented for the Lower Yangtze domestication of japonica rice, although the latter began much earlier when wild-type shattering still predominated (Fuller et al. 2010). The period of grain-size increase in Indian rice parallels an apparent delay in size increase in Gangetic mungbeans (Fuller and Harvey 2006) and may imply a connected cause such as the advent of more intensive cultivation and tillage. The available weed data from the Ganges suggest that early rice cultivation was essentially dry cropping based on monsoon rains and seasonal flood recession but that plausible wet-field irrigated rice may have been grown by the end of the second millennium BC and certainly by the Iron Age (Fuller and Qin 2009). Thus two key factors, the development of irrigated cultivation techniques and the introduction of some japonica rice genes, may in turn be linked to the evolution of larger-grained indica rices and the more extensive spread of rice (cf. Fuller and Qin 2009). Agricultural intensification is indicated also by the adoption of cash crops such as cotton and flax and may be linked to the emergence of social hierarchy (cf. Fuller 2008b).

From as early as 2400 BC, secondary cultivars were introduced including free-threshing wheat and barley (Saraswat 2004, 2005), and these were widespread by ca. 1700 BC (Fuller 2006; Harvey 2006). Goats, sheep, and probably domestic cattle also arrived in this horizon, certainly by 2000 BC. These presumably came from the Indus region to the west, which also shows some ceramics links. After 2000 BC, peninsular Indian cultivars were adopted, such as mungbean and horsegram (Fuller and Harvey 2006). Cash craft crops such as flax and cotton are found from Ganges Chalcolithic sites from ca. 1400 BC (Fuller 2008b). It can be suggested that ard tillage was adopted in this period too. The evidence for local continuity within the Middle Ganges suggests that this was mainly
a sequence of episodes of secondary adoption from the west (the Indo-Gangetic divide) and sometimes the south (down tributaries such as the Betawa and Chambal) into a regime of primary rice cultivation. The evidence seems to favor primary pristine origins for rice cultivation, but dependence on cultivation and the emergence of sedentism occurred with the secondary adoptions of additional domesticates, including fully domesticated rice \((japonica)\) hybrids. Interestingly, the emergence of sedentism occurs between 2400 and 1800 BC, with a plausible focus on 2200–2000 BC (i.e., synchronous with that in South India).

**The Greater Orissa Center**

The plains of the Mahanadi River and the surrounding hills constitute a plausible region for rice origins based on the widespread and diverse wild-progenitor populations. In the early 1980s it was established by Van der Maesen (1980) that the wild progenitor of the pigeon pea—the second most important pulse, behind chickpea, in Indian production today—was native to South Orissa and the adjacent Bastar area (table A4). However, this region remained off the map of early agriculture for the lack of archaeology. Attempts to retrieve archaeobotanical evidence from four upland sites of central and northern Orissa were unsuccessful apart from phytolith “background” noise (Harvey 2006; Harvey et al. 2006). Other archaeobotanical sampling in 2003/2004 was successful (at Gopalpur and Golbai Sassan; table A4) and provides an archaeobotanical corpus for the established village societies on the coastal plains around Chilka Lake dating to the Late Neolithic/Chalcolithic (i.e., 1500–1000 BC; Harvey 2006; Harvey et al. 2006).

Rice appears to be the dominant find. In addition, native Indian pulses are present, including the local domesticate \(Cajanus cajan\) and introduced \(Macrotyloma uniflorum\) and both \(Vigna radiata\) and \(Vigna mungo\) (Fuller and Harvey 2006). The \(Vigna\) grains are still largely in the small “wild” size range but presumably domesticated in terms of germination and dehiscence congruent with a dispersal from the South before the \(Vigna\) seed-size increase of 1400–1100 BC. Millets appear to have been insignificant in this region. A couple of grains of \(Panicum sumatrense\) from Gopalpur could indicate use, or cultivation, of this species as a cereal, but the sample size is too small to inspire confidence, and the wild progenitor is available in the region. These and other small millets (\(Echinocloa, Paspalum, Setaria\ sp.) are all plausible weeds of rice.

The sum of the evidence is that agriculture and sedentism were established by the mid-second millennium BC. These sites also appear already to have domesticated fauna (at least cattle and buffalo, but sample size is very small; Kar, Basa, and Joglekar 1998). This established agriculture certainly includes some secondary crops from the south and west and adopted livestock. In terms of ceramics, stone-axe forms, and bone tools, this region is distinct from the peninsula region (although probably continuous with the Neolithic of north-eastern Andhra, such as Korisettar, Venkatasubbaiah, and Fuller 2001, fig. 9), and as such this is most likely a case of adoption. However, the persistence of pockets of North Dravidian– and South-Central Dravidian–speaking tribes in the hills of Jharkhand, western Orissa, and Chattisgarh may be indicative of some early migration processes into parts of the region. Some apparently shared loan words between the Munda languages and Dravidian also support this (Fuller 2003b, 2007a). The earlier establishment of rice agriculture remains unknown, and while wild populations make primary domestication possible, secondary spread from the Ganges is at least equally plausible. However, as indicated in figure 4, the postulated center for crop origins in the upper Mahanadi River basin and the surrounding foothills remains largely unexplored: the region can boast no published excavations, although the river courses are rich in Neolithic/Chalcolithic settlement mounds (Dorian Q Fuller, personal observation, 2004; Dorian Q Fuller, personal communication from Sadasiba Prabhan, Utkal University). Domestication of \(Cajanus\) is primary but presumably inspired or additive. It is not yet clear whether this precedes the introduction of peninsular pulses such as horsegram that could have served as a model. With the sparse data at present, no causal model can be proposed.

**The Saurashtra Center**

Archaeobotanical research on the Saurashtra Peninsula of Gujarat (fig. 6; table A5 and table A6) has been mainly carried as part of excavations of sites related to the Harappan civilization (2500–2000 BC) and to the local Late/Post-Harappan cultural phase (e.g., Chanchala 1995; Kajale 1996a; Pokharia 2007; Reddy 2003; Weber 1991). My only firsthand experience with material is from a small flotation assemblage from recent Maharaja Sayajirao University of Baroda excavations at Harappan Gholo-daro (Bagasra; Luddy 2008; S. Luddy and Dorian Q Fuller, unpublished data). The case for a potential primary domestication center has been made on the basis of the contrasts between archaeobotany in this region and that of the Harappan Indus (Fuller and Madella 2001) and the biogeographic evidence of potential wild progenitors. I have serious concerns over the reliability of some reported identifications of small millet grains in previous work (which have been detailed in Fuller 2002, 2003a; see also Hilu, De Wet, and Harlan 1979), and these concerns have not yet been addressed through adequate illustrated publication of identification criteria. At issue is first, the presence and antiquity of finger millet \(Eleusine coracana\) of African origin, and second, the presence/antiquity of \(Setaria italica\) of Chinese origin, which is extremely difficult to separate from endemic \(Brachiaria ramosa\). In the case of finger millet, it is clear from photographs that reports from some sites were misidentifications of \(Setaria/Brachiaria\) grains (see Fuller 2003a). Recent work on samples from Gholo-daro recovered only native Indian millets \(Panicum sumatrense\) (the cereal that all workers
agreed was important), B. ramosa, and other wild Indian Setaria spp., but no S. italica or E. coracana.

Despite these problems, the quantitative picture of the region is archaeobotany dominated by small millets including P. sumatrense and native small Setaria spp. (plus at least some B. ramosa) during the Mature Harappan period, 2500–2000 BC. The agriculture is thus completely different from that of the Harappan-period Lower Indus and Baluchistan (see Fuller and Madella 2001; Tengberg 1999). The winter crops that were staples of the Harappan civilization and the Indus region are present but extremely rare. For example, a few fragmentary wheat and barley grains could be identified at Bagasra (Liddy 2008), while a few wheat were reported from Kuntasi, and 10 grains of barley (compared with thousands of millets) were found at Rojdi (Weber 1991). Lentils were also a rare find at Rojdi. Pulses in general are rare, but Vigna mungo, potentially native to the region, is present in the third millennium, while Vigna radiata and Macrotyloma are introduced in the early second millennium. Introduced at the start of the second millennium BC were crops of African origin, perhaps the first acceptably identified and dated in South Asia, including pearl millet, sorghum, and Lablab purpureus (Fuller 2003a).

The evidence is suggestive of a primary pre-Harappan agricultural tradition based on native monsoon-adapted crops (small millets, including P. sumatrense and V. mungo). As with South India, however, there is no archaeobotanical evidence for the earlier stages of this tradition or for the transition from collecting to farming these species (table A5). The evidence for introduced domesticated fauna with early ceramics from northern Gujarat (the southern fringes of the Thar Desert) by ca. 3500–3000 BC, for example, at Loteswar (Patel 2008) would fit with a model in which primary local plant domestications were inspired either by the advent of intrusive pastoralism or by contacts with the Indus and regions to the west. Saurashtra may have been the first link in a chain of inspiration with the spread of pastoralism that culminated in Northwest India. Additional support for a local derivation comes from the enlarged size of Harappan-period Vigna seeds from Kunal and Balu, as these appear to have undergone size increase ahead of those elsewhere in India (Fuller and Harvey 2006).

Given the limited Early Harappan evidence and the lack of Neolithic precursors, the origins in this region are obscure. It seems plausible to see domestications in this region as initially secondary, based on introduced Near Eastern crops, after which local plants were added to the repertoire as “primary additive” domesticates.

Assessing Early Near Eastern Influence: Some Notes on Baluchistan

Most accounts of the Neolithic of South Asia start in the northwest with the site of Mehrgarh, where I have chosen to end. This is an important and informative site (Jarrige 1982, 2008; Jarrige, Jarrige, and Quivron 2006; Possehl 1999:450–473), but it remains without good comparisons, neither local early Holocene precursors nor well-sampled contemporaneous sites dated 7000–4000 BC; instead, most archaeobotanical data come from the third millennium BC (table A6; fig. A3). This region clearly had early agriculture based in large part of nonindigenous crops (glume wheat[s], bread wheat, barley varieties; Costantini 2008) and probably nonindigenous livestock (at least the goat; Meadow 1996). Other Near Eastern crop domesticates also came to the Indus, although whether this happened at the initial dispersal or only later remains unclear (table A6). Also, it should be noted that the barley on South Asia probably had its origins all or at least in part
from a separate domestication in the Eastern Fertile Crescent (Iran), which appears to be the source of most Central, South, and East Asian barleys (Morrell and Clegg 2007; Saisho and Purugganan 2007). Nevertheless, the domesticates were not a single package entirely from one area of origin but were shuffled together along the trajectory to Baluchistan. While this region is a secondary center in terms of agricultural origins, it is nevertheless an important area for indigenous developments in terms of adding new domesticates to the economy: zebu cattle, quantitatively the most important domestic animal for all of the previously discussed regional Neolithics (when quantified bone reports are available); cotton, certainly used for threads in the Late Neolithic/Early Chalcolithic (Mouilherat et al. 2002); and probably somewhat later and domesticated in the Indus alluvial plains, sesame (Fuller 2003a) and water buffalo (Meadow and Patel 2003; Patel and Meadow 1998). While all of these are primary additive domesticates, their importance to economic developments within the Indus valley, which ultimately supported the Harappan civilization, and to the spread of crops and livestock to other Neolithic traditions elsewhere in India deserves emphasis. Nevertheless, the early Holocene village farming Neolithic represented by Mehrgarh and its successors in the Indus valley and its western borderlands is more typically Neolithic in the Near Eastern sense but quite different from the early food-producing communities to the east in the subcontinent.

Comparative Comments: Trajectories and Causation

The accumulation of archaeobotanical data makes it clear that a number of tropical crops were domesticated in South Asia in prehistory, and we are now able to propose the regions and general periods in which this occurred and whether this represents additive, inspired, or pristine origins of cultivation. It is now clear that different trajectories into the Neolithic took place in different parts of the subcontinent, and this suggests that different world regions may provide the most useful comparisons for assessing convergent processes in the various Indian regions. What is striking is that there is no evidence in South Asia for the emergence of sedentary, densely populated hunter-gatherer societies comparable to the Epi-palaeolithic Levant (see Goring-Morris and Belfer-Cohen 2011; Zeder 2011) or parts of East Asia (e.g., the early to mid-Holocene Lower Yangtze, parts of Jomon Japan; see Cohen 2011; Crawford 2011; Zhao 2011). Rather, it appears that food production began among more mobile and perhaps sparser populations. This must surely call into question the relevance of demographic prime movers often considered for explaining the beginnings of agriculture in the Near East (see, e.g., Bar-Yosef 2011; Bocquet-Appel 2011). In addition, this leaves us with the challenge that the archaeological record is largely silent before sedentism; presedentary sites have been harder to identify, rarely excavated, and present difficulties for archaeobotanical recovery. What we have at present is clear evidence for the nature of regional agricultural economies from the period when sedentary villages emerged. Intriguingly, this seems to have occurred across most of India between the later third millennium BC and the early second millennium BC (Fuller 2006). If climatic pressures are to be considered, it is the 2200 BC “event” and the establishment of sedentary agropastoralists that might be linked rather than the beginnings of pastoralism or cultivation per se.

Only in the Middle Ganges region is there evidence for a pristine start of cultivation before animal domestication, whereas elsewhere the spread of domestic livestock herding and potting appears to have occurred among hunter-gatherers. In some Indian centers, cultivation began later among potting pastoralists. This was especially true around the southern margins of the Thar Desert and through the peninsular savannah corridor. Useful comparisons can be drawn with the Sahelian-Sudanic pastoralists of the middle Holocene in Africa (see Marshall and Weissbrod 2011). The hypothesis of a “scheduled availability” model (sensu Marshall and Hillbrand 2002) for motivating groups of pastoralist-collectors to plant and tend key species seems plausible; such a model may be useful for considering motivations behind the initial uptake of small domestic herds among grain-gathering hunters. Also, it may be that as domestic herds (and/or herders) increased in population, territoriality emerged, which increased competition for or denied access to limited seasonal seed-food resources located in the forests and hills. Such hill forests—although rich in plant resources, including wild progenitors of several Indian domesticates—were peripheral to the savannahs, which were attractive for herding, and motivation for cultivation may lie in this spatial disjunction of resources. These earliest stages of food production are better considered in terms of a “primary pastoral community” with its comparisons to the early Nile region and Sudan (e.g., Wengrow 2006:26–31) rather than a classic Neolithic (of the Levantine, European, or Chinese sort). As in this period in Egypt, occupation sites were ephemeral and characterized by dung deposits and thin middens of ash and other waste. Such sites have preservational problems and have been difficult to recognize until when in the Southern Deccan some of them became monumentalized through burning, creating the Deccan ashmounds (see Boivin 2004; Johansen 2004; Korisettar, Venkatasubbaiah, and Fuller 2001)—which itself may relate to increasing territoriality and associated social and ritual transformations. In such early pastoral communities, herds and especially cattle were central to systems of wealth and ritual rather than land and its plant produce. Thus it need not be surprising that at the third millennium town of Balathal in Rajasthan, the center of the settlement appears to have been a fortified pen with a deep stratigraphy of dung (Misra 2005). One challenge is to better understand the processes of sedentarization and the role that local plant domestication may have played in this, while another even greater challenge is to find and document the evidence for the latest hunter-
gatherers and their interactions with or transformations into early pastoralists.

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Holocene Population History in the Pacific Region as a Model for Worldwide Food Producer Dispersals

by Peter Bellwood

Pacific prehistory (excluding Australia) since 3000 BC reflects the impacts of two source regions for food production: China from the Yangzi southward (including Taiwan) and the western Pacific (especially the New Guinea Highlands). The linguistic (Austronesian, Trans–New Guinea), bioanthropological/human genetic, and Neolithic archaeological records each carry signals of expansion from these two source regions. A combined consideration of the multiregional results within all three disciplines (archaeology, linguistics, and biology) offers a historical perspective that will never be obtained from one discipline or one region alone. The fundamental process of human behavior involved in such expansion—population dispersal linked to increases in human population size—is significant for explaining the early spreads of food production and language families in many parts of the world. This article is concerned mainly with the archaeological record for the expansion of early food producers, Austronesian languages, and Neolithic technologies through Taiwan into the northern Philippines as an early stage in what was to become the greatest dispersal of an ethnolinguistic population in world history before AD 1500.

Introduction

The organizers of the Wenner-Gren conference “The Origins of Agriculture: New Data, New Ideas” asked me to examine the dispersal of agricultural systems in the Pacific and the relationships among language, culture, and farming in the area and also to discuss to what extent I think this model provides for a more general understanding of the dispersal of languages and farming in other parts of the world. At the outset, I wish to make my fundamental perspective clear. The dispersal of the Austronesian language family and its speakers commenced after 4000 BC among increasing populations of Neolithic food producers in southern China and Taiwan, in a cultural situation of increasing population density, advancing technology (including boat construction and carpentry), and increasing dependence on agriculture and animal domestication, also a portable food production repertoire that allowed long-distance dispersal to take place. Food production and the remarkable lithic and lignic technology behind it thus underpinned the expansion, and without them it is unlikely that populations would have migrated when they did into the remote reaches of Oceania. No stage in Austronesian dispersal involved populations who permanently abandoned all commitment to food production unless forced to do so by environmental circumstances, no matter how significant the contributions of fishing, bird and sea-mammal hunting, and wild-plant consumption were in initial colonizing situations of natural plenty. No claim is made that farming drove the expansion via overpopulation or a desperate search for new territory, but the systematic development of food production stands forward as the fundamental cultural basis for the expansion.

My topic thus focuses on dispersals of agriculture, languages, and attached human populations, and not specifically on the ultimate origins of food production systems in China or New Guinea or gradients in their development through stages such as predominestication cultivation or low-level food production. We start with populations in southern China and Taiwan before 3000 BC who manifested already an identifiable level of dependence on food production.

Initially, I offer several introductory observations presented in more detail elsewhere (Bellwood 2001, 2005, 2008, 2009a, 2009b; Bellwood and Oxenham 2008). (a) Spreads of food production and human migration in general are phenomena

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1. All dates are expressed as BC/AD and based on calibrated C14 determinations.
that have always involved demographic growth—declining populations cannot create successful colonists. Birth rates must exceed death rates over the long term. (b) Archaeology and comparative linguistics attest to coherent movements of food-producing populations from several large homeland regions in different parts of the world. (c) Food production in general spread with existing food producers even when previous hunter-gatherer populations existed, the more so as dependence on morphologically domesticated plants and animals increased within the food producers' diet. (d) Migration and interaction have played different roles in creating cultural and biological patterns within humanity (Bellwood 1996; see Hunley et al. 2008 for western Oceania). Migration, as a sporadic rather than continuous occurrence on any large scale, has laid down successive foundations of biological phylogeny and cultural/linguistic genealogy. Interaction has continually and productively modified these foundations, normally reorganizing rather than suddenly replacing previous patterns. (e) In general, major movements of languages in prehistoric societies occurred with major movements of native speakers, not through language shift or the expansion of "trade languages." Ostler (2005) and Ross (2008) have discussed these matters in detail, the latter for Austronesian, and those who believe in trade languages as the source of any extensive ancient language landscape should consider Melanesia—home for some of the most famous exchange systems in world ethnography yet also one of the most diverse linguistic regions in the world in terms of its high number of mutually unintelligible precocial languages. Exchange in Melanesia did not homogenize languages. Indeed, it probably had the opposite effect through its role in underpinning group identity. Communication relied on multilingualism, not language shift. This is one reason why the recent linguistic arguments by Donohue and Denham (2010) for the spread of Austronesian languages by elite dominance, as lexical replacements within existing non-Austronesian languages, are unconvincing. (f) Comparative linguistics is also of absolutely fundamental importance in offering hypotheses about language-family homelands, directions, and relative chronologies of subgroup dispersal as well as protolanguage reconstructions of meanings relevant for archaeological inference. Linguistic reconstructions can be deeply meaningful for historical understanding given the importance of language as the most significant vehicle of human expression and interaction.

My operational model for early agriculturalist dispersal is that of "demic diffusion" involving a food producer "wave of advance" extending or leapfrogging, as the case may be, and mixing with forager populations as proposed originally for Europe by Ammerman and Cavalli-Sforza (1973). This is a logical mechanism for population expansion, involving continuous population growth in frontier regions, fissioning, and intermarriage with other communities. It is not necessarily a mechanism for population replacement. The "early farming dispersal" hypothesis (Bellwood 2005, 2009a, 2009b; see also Renfrew 2002) does not demand extermination of foragers by early farmers; indeed, the latter would probably have welcomed new members from foraging communities before the development of sufficient population density to promote resource competition. Well-studied farming dispersals in Europe, the Andes (Heggerty and Beresford-Jones 2010), South Asia, and China required more than 3,000 years for completion, and homeland genetic configurations could not possibly have spread intact and hermetically sealed through such long time spans.

The validity of the demic diffusion model is strengthened by analyses of early food-producing cemetery populations that indicate marked increases in birth rate following the regional appearances of agriculture and animal husbandry. These increases occurred before the later increases in mortality that resulted from the crowded and insanitary lifestyles associated with increasingly sedentary life (Bocquet-Appel 2011). Increasing populations must either seek fresh land or intensify production in order to survive, and the former option would often have been inviting in situations surrounded by lower-density forager populations. The historical validity of such a model is also revealed for us by a small number of ethnographical small-scale and kinship-based tribal populations who managed to avoid the main hazards of the colonial era. One such group were the Iban of Sarawak (Borneo), swidden rice farmers with long fallow land requirements who were colonizing along rivers starting perhaps in the late eighteenth century and continuing into the early decades of the twentieth century (Freeman 1970). The movements spanned an already-populated territory stretching more than 850 km from western Kalimantan through Sarawak to Brunei Bay. According to Freeman,

The main incentive behind the remarkable migrations of the Iban has been a desire to exploit new tracts of primeval forest, and the tendency has been for communities to abandon their land as soon as a few lucrative harvests have been reaped, and move on to fresh precincts. (Freeman 1970:76)

The Iban expansion, with its consequent assimilation of intervening populations, can be compared with that of the ethnographic Yanomami of the upper Orinoco as described by Chagnon (1992) and the Nuer of Sudan as described by Kelly (1985). All represent demic spreads of food producers into terrain inhabited either by foragers or by other less aggressive food producers. Interestingly, recent genetic research in Bali (Lansing et al. 2008) has revealed that modern subak irrigation associations have low genetic diversity and so probably formed by internal demographic growth through fissioning from founder populations into adjacent drainage systems, rather than by state-enforced population movement. Although not directly related to Neolithic issues, there is an interesting model here for the gradual spread of earlier farming populations through demographic growth.
Agricultural Origins in East Asia and the Pacific

What is the central question? I suppose it has to be why at the beginning of the colonial era (AD 1500 for argument’s sake) were the majority of populations in Southeast Asia and Oceania subsisting from the proceeds of food production? Continuations of foraging, hunting, and fishing from the wild are irrelevant for the question posed because they have always existed and always will, global warming permitting. Likewise, all ethnographically recorded foragers manage resources in one way or another. Predomestication cultivation and low-level food production (Smith 2001, 2011) are useful concepts for the beginnings of food production, and the latter will always exist among ecologically marginal communities, but the focus here is on the conscious production of food from combinations of wild and domesticated species in nonmarginal environments sufficiently productive to support outward population expansion.

Within the Asia-Pacific region, the inceptions of food production occurred independently in the New Guinea Highlands and central China (the Yangzi and Yellow river basins). In both regions, some populations were reasonably dependent on food production by 4000 BC (Cohen 2011; Denham 2011; Fuller, Harvey, and Qin 2007; Zhao 2011). China witnessed the development of cereal (rice, foxtail, and common millet), legume (soybean), and pig production. Whether the Yellow and Yangzi river basins formed one or two “centers” is not relevant for present purposes—I suspect only one on the evidence of cultural connections, but animal domestication appeared slightly later in the south than in the north (Yuan, Flad, and Luo 2008). The New Guinea Highlands, a unique high-altitude and equatorial-cordilleran environment without geomorphic parallel anywhere in the volcanic arcs of Island Southeast Asia, witnessed the development of tuber and fruit cultivation without cereals or domestic animals.

Chinese material culture was quintessentially “Neolithic,” with pottery, sawn and ground stone, weaving, advanced carpentry, and boats and paddles, whereas New Guinea Highland material culture was less modified from its Pleistocene lithic and aceramic roots, except for the addition of fully polished stone axes during the Holocene. New Guinea Highland archaeology reveals no signs of direct contact with contemporary Neolithic societies in Island Southeast Asia, although the situation was different with respect to the islands of Melanesia and lowland New Guinea. Movements of useful plants such as sugarcane, bananas, and taro from New Guinea into Indonesia in the mid-Holocene are perfectly possible, as claimed by Donohue and Denham (2010), but are so far underdemonstrated. So, too, are pre-Neolithic movements the other way, from Indonesia into New Guinea.

Following the development of food production in central China, outward migrations of farming populations with their genes, material cultures, and languages occurred widely between 3000 and 1000 BC, when populations moved via southern China to reach ultimately as far as the Ganges Basin, Sumatra, and Samoa. These movements sometimes involved migration into uninhabited terrain, but more common were processes of demic diffusion into regions already occupied by indigenous populations. However, the New Guinea Highland populations restricted their biological and cultural influences to the western Pacific, and while some degree of migration might have occurred, particularly from Trans–New Guinea genetic and linguistic perspectives (Mona et al. 2007; Pawley 2007), it was evidently not dramatic. This situation reflects the differing capacities of the food production systems in China and New Guinea to support internal population growth via increased birth rates. Cereals, legumes, and pigs fueled expansion from China, particularly during the period of high-density population represented by the Qujialing, Liangzhu, and so-called Longshan cultures of the Yangzi and Yellow river basins (third millennium BC; Jing and Campbell 2009; Zhang and Hung 2008, 2010). Without cereals and domesticated animals (pigs and dogs probably arrived less than 3,000 years ago on the New Guinea mainland), the early New Guinea systems of food production were less expansive.

In terms of agricultural dispersals and human prehistory in general, Island Southeast Asia and Oceania have had different historical trajectories. East of the Solomons, in the scattered archipelagos of “Remote Oceania,” human settlement has occurred only within the past 3,100 years (fig. 1). Nowhere within Remote Oceania is there evidence to suggest complete population replacement—whether genetic, linguistic, or cultural—except to a minor degree in cases such as those of the Polynesian outliers. All scholars agree that the first settlers in these islands were the direct ancestors of the populations there today, allowing for some obvious situations of later interisland migration, contact, and intermarriage (e.g., Addison and Matisoo-Smith 2010). All of these populations, without exception, speak Malayo-Polynesian languages, and all practiced noncereal food production focused on fruit/nut and tuber cultivation in one form or another at European contact, with the exception of the southern Maoris of New Zealand, who lived beyond the growing-season limits of the sweet potato, their only significant cultivated plant.

The area termed “Near Oceania” (New Guinea and western Island Melanesia), together with the much vaster extent of Island Southeast Asia to the west, is rather more complex. Modern humans presumably first reached these islands within the past 50 kyr, and their descendants in New Guinea and Melanesia were also mainly food producers at European contact. But it is in the region west of New Guinea that the contentious debates occur. Today, no one suggests that the islands of Remote Oceania underwent totally independent transitions to agriculture, but most accept that the island of New Guinea, particularly its cordilleran central highlands, supported indigenous systems of fruit and tuber food production early in the Holocene (Denham 2011). The issues involve the Southeast Asian islands—Taiwan, the Philippines, Indonesia, and East Malaysia (northern Borneo). These is-
Figure 1. Southeast Asia and Oceania, showing geographical divisions and the main chronological trends in Neolithic and Austronesian settlement.
lands, except for a few immediately west of New Guinea (Timor, Halmahera, Alor, Pantar), are occupied entirely by speakers of Austronesian languages who are biologically clinal, with a dramatic and steep change from Asian to Melanesian genetic ancestry within a relatively narrow geographical window in the eastern Lesser Sunda islands and the Moluccas (Cox 2008; Cox et al. 2010; Mona et al. 2009).

At present, there is no archaeological evidence that Island Southeast Asia witnessed any independent development of agriculture, even at a very low level. We have yet to learn whether early Holocene foragers here were involved in moving around plants such as bananas, breadfruit, and sugarcane (but presumably not cereals), perhaps even selecting and planting some varieties. Yet even if people made such transfers, especially from New Guinea, well before the appearance of the Asian-derived ceramic Neolithic, it could be entirely irrelevant for understanding events since that time. The botanical origins of translocated plant species are not the issue under debate; rather, it is food production and human migration.

The Austronesian-Speaking Peoples and Their Significance

My aim here is to examine the data enshrined within the different disciplines that support the inference of a migration of ancestral populations speaking Austronesian languages, especially those within the major Malayo-Polynesian subgroup, as outlined in figure 1. I make no apology for beginning with the linguistic evidence because the Austronesian-speaking populations have a well-studied linguistic history and formed the most widespread ethnolinguistic group in the world before AD 1500. The Austronesian language family is a clearly defined taxon, and all current homeland theories for it focus on Taiwan (Donohue and Denham 2010; Ross 2008). As linguist Malcolm Ross notes,

Of the disciplines represented . . . linguistics is probably the closest to unanimity about Austronesian origins. All Austronesian languages spoken outside Taiwan belong to a single subgroup, dubbed Malayo-Polynesian by Blust (1977), whilst the thirteen Austronesian languages still spoken in Taiwan belong to several primary subgroups (Blust 1999 proposes nine, on phonological grounds). The logical inference is that proto-Austronesian (Pan) was spoken in Taiwan, that it split initially into dialects, and that these dialects eventually diversified into separate languages. Speakers of just one of the dialects, proto-Malayo-Polynesian (PMP), left Taiwan and settled initially either on Lanyu (Orchid) Island, or somewhere in the Batanes Islands, or on the north coast of Luzon. It is speakers of languages descended from PMP who have settled the huge expanse of the Austronesian-speaking region beyond Taiwan. (cited in Bellwood et al., forthcoming)

Ross (2008) also comments that "the main reason why Austronesian languages cover the vast territory which they occupy . . . is quite simply that their speakers dispersed, taking their languages with them" (165).

Comparative lexical reconstructions for Pan and its daughters PMP and proto-Oceanic (POc) indicate major changes in material culture through time and space (Blust 2009; Pawley 2002; Ross, Pawley, and Osmond 2007). For Pan itself, they reveal an economy focused on rice cultivation, with a large vocabulary for rice in many forms and stages of growth as well as a processing and cultivating vocabulary with words for millet, sugarcane, and possibly aroids. PMP added many fruits and tubers to this vocabulary as befitted its probable location in the tropical Philippines (Taiwan is mostly temperate in latitude). POc witnessed the ultimate loss of rice under equatorial climatic and day-length conditions (Paz 2002:280). Other reconstructions apply to words for pigs and dogs (but not chickens until PMP), pottery, boats and sails, fishing, and a wild placental (not marsupial) mammal fauna. The morphological and semantic integrity of these many reconstructions, as Pawley (2002:266) points out, implies continuous linguistic transmission through time, not late borrowing. In other words, Austronesians did not start as farmers, revert to foraging and lose all their farming vocabulary, and then readopt farming much later. Even the few centuries of naive faunal exploitation on Remote Oceanic islands did not reduce the food-producing vocabulary of Polynesians. Furthermore, the rakelike phylogeny of the main MP subgroups implies rapid migrational spread at least from the Philippines to as far east as western Polynesia (Gray, Drummond, and Greenhill 2009; Pawley 1999).

The recent claim by Donohue and Denham (2010) that differing geographical distributions of Malayo-Polynesian grammatical features in Island Southeast Asia imply only a spread of Austronesian vocabulary, not whole languages, hence without significant population movement, is not convincing. No recorded non-Austronesian languages survive for comparative purposes west of Halmahera and Timor, and the described grammatical variations could also be due to contact-induced change operating subsequently to the period of initial Malayo-Polynesian settlement. Furthermore, their claim does not explain why Malayo-Polynesian languages are spoken across the entirety of the Philippines and Indonesia, west of Timor and Halmahera, yet not spoken at all in most of the interior of New Guinea. Why was New Guinea different if, as Donohue and Denham claim, food production existed across the whole area in pre-Austronesian times? How could Austronesian languages possibly have spread by processes that involved almost no population movement? Naturally, pre-Austronesian languages once occurred in Island Southeast Asia; the disagreement concerns not their existence but their role in the formation of the modern languages of the region.

Despite the clarity of their shared ancestry in a linguistic sense, Austronesian biological origins are expectancy more diverse. Not all Austronesians share a recent genetic origin, and the prehistories of some regions in eastern Indonesia and the western Pacific have involved a high degree of genetic
indigenization and localized instances of full language shift (Mona et al. 2009). Nevertheless, while Donohue and Denham (2010) rely on somewhat outdated molecular-clock–based mitochondrial DNA analyses to support their claimed refutation of any significant Austronesian population expansion, the reality from current genetic research—haploid, autosomal, and increasingly at a whole-genome level—is that Holocene population movement from mainland Asia via Taiwan into Island Southeast Asia and Oceania is very strongly supported (Cox 2008; Cox et al. 2010; Friedlaender et al. 2008; Kayser 2010; Kayser et al. 2008a, 2008b; Kimura et al. 2008; Tabbada et al. 2010). The genetics of human stomach bacterial parasites (Moodley et al. 2009) provide additional confirmation.

Current Archaeological Perspectives: New Research in Taiwan and the Philippines

Understanding of prehistory in Taiwan and the northern Philippines has recently developed very rapidly. The main breakthroughs have come with the established presence by at least 2800 BC of an agricultural (rice and foxtail millet) economy for the Dabenkeng Neolithic culture of southwestern coastal Taiwan (Tsang 2005; Tsang, Li, and Chu 2006), with the documentation of a sixfold or greater increase in site numbers during the course of the third millennium BC in eastern Taiwan (Hung 2005:126) and also with the recovery of fine-grained ceramic evidence for the spread at about 2200 BC of Neolithic material culture from Taiwan to the Batanes Islands (previously uninhabited) and northern Luzon (Bellwood and Dizon 2005, 2008; Hung 2005, 2008). This Neolithic spread carried (not necessarily all together) red-slipped pottery with specific rim forms and body shapes, pottery spindle whorls, stone bark cloth beaters, tanged or grooved stone adzes, Fengtian (eastern Taiwan) nephrite, Taiwan slate knives and stone shanks and bone points had also developed by at least 2000 BC (Hung et al., forthcoming).

In the case of the Batanes, excavations in five caves and rock shelters with plentiful ceramic period occupation leave no doubt that humans had not previously reached these wind-swept islands, protected by relatively rough sea and sometimes strong ocean currents, until the Neolithic. There is absolutely no trace in caves or surface finds of prior hunter-gatherer preceramic occupation or flaked lithic tool manufacture. Luzon, to the contrary, had Paleolithic hunters and gatherers in occupation since at least 24,000 and possibly 67,000 years ago, so the first Neolithic arrivals must have interacted with these groups, as Mijares has shown for the Peñablanca Caves near Tuguegarao (Mijares 2006; Mijares et al. 2010).

The Spread of Neolithic Pottery from Taiwan into the Philippines and Indonesia

Newly excavated ceramic data establish the development of a tradition of red-slipped plain ware pottery manufacture in southern and eastern Taiwan, emergent by at least 2200 BC from a prior “Middle Neolithic” tradition with both cord marking and red slip (Bellwood and Dizon 2008; Hung 2008; table 1; fig. 3). A key site here is Chaolaiqiao, on Shanyuan Bay, accurately dated by AMS C14 to 2200 BC and with red-slipped pottery forming almost 100% of the assemblage, with virtually no cord marking or other type of decoration. By 2000 BC, this red-slipped plain ware tradition had spread to previously uninhabited Batanes as documented in Reranum and Torongan Caves on Itbayat. Pottery vessels in this phase commonly had pedestal bases and tall everted rims and lacked body decoration apart from the red slip (fig. 2U, 2V). Reranum and Chaolaiqiao still have some residual cord marking (fig. 2R), and the close similarities in red-slipped pottery between these two sites raise the possibility that a direct migration from sites such as An Son in southeastern Taiwan to Itbayat could have occurred between 2200 and 2000 BC.

For northern Luzon (Philippines), current research on the lowest deposits beneath the late Neolithic shell mound at Nagsabaran (Hung 2008; Hung et al., forthcoming) suggests that both red-slipped plain ware and stamped pottery appeared together around 2000 BC (see also Ogawa 2005). A closely related tradition of red-slipped and punctate/circle-stamped pottery decoration is also reported from early sites such as Achugao and Unai Bapot on Saipan in the Mariana Islands, western Micronesia, where initial settlement across 2,300 km of open sea (the first truly long-distance sea voyage in human history) occurred from the northern Philippines at about 1500 BC (Butler 1995; Carson 2008; Clark et al. 2010; Hung et al., forthcoming). A similar co-occurrence of red-slipped plain ware with small amounts of stamped and incised decoration also commenced at ca. 1300 BC at Bukit Tengkorak in Sabah, here with bark cloth beaters and trapezoidal cross-sectioned adzes paralleled in Batanes, Taiwan, and Fujian (Chia 2003; Jiao 2007). Bukit Tengkorak also has Talasea (Kutau/Bao) obsidian from the Bismarck Archipelago in Near Oceania, thus illuminating two-way human movement on a remarkable scale (Bellwood 1989; Chia 2003).

In other parts of central and eastern Indonesia, the decorated pottery appears later than the red-slipped plain ware,
similar to the situation in southeastern Taiwan and Batanes. Red-slipped plain ware is dated from ca. 1500 BC at Kamassi and Minanga Sipakko in West Sulawesi (Simanjuntak et al. 2008; incised pottery and obsidian from these sites is younger), and other sites in central and eastern Indonesia with early red-slipped plain ware include Kendeng Lembu in eastern Java, Uattamdi in Maluku, Leang Tuwo Mane’e in Talaud, possibly Paso in northern Sulawesi, and Madai Cave in Sabah (Bellwood 1997; fig. 3).

The above evidence comes together (table 1) to suggest that a red-slipped plain ware tradition of clear Taiwan origin was joined after 2000 BC by a very significant tradition of zoned incision with incising by punctate or circle stamping, the punctate made by a multiple-toothed tool such as a tattooing chisel. Some sites have both plain and stamped pottery from the start; others appear to have an earlier horizon of plain ware only, but the picture is still obscure because so many assemblages are very small and come from caves and rock shelters. Perhaps the punctate and circle-stamping tradition was introduced from mainland southern China or Hainan (Rispoli 2008; H.-C. Hung, unpublished data), although it is not possible to rule out Taiwan as the immediate source on present evidence because examples occur there from Yuan-shan and Yingpu contexts dating to ca. 1500–500 BC (e.g., Chang 1969, pls. 82D, 84D).

Similar punctate and dentate stamping is a very typical feature of Lapita pottery in western Melanesia (1350–750 BC; Green 2003) and occurs here with white lime or clay infilling of the designs, as in Luzon and the Marianas, where the greatest similarities occur (fig. 3). Punctate stamping with Lapita affinities is rare to absent in eastern Indonesia. In the Lapita sites in Oceania, the stamping apparently commenced everywhere at the base of the local Neolithic sequence, as in Luzon and possibly the Marianas, and it is likely that movement through the latter islands into the Bismarck Archipelago introduced some of the Lapita decorative repertoire into Oceania. No claim is made that Lapita origins occurred only via the Marianas, because multidirectional movements through Indonesia are also implied by the Bukit Tengkorak obsidian and could have involved populations speaking relatively undifferentiated languages still very close to PMP.

Different developments appear to have taken place in Sarawak, where rice husks in pottery dating from about 2200 BC onward in the cave of Gua Sireh (Beavitt, Kurui, and Thompson 1996; Ipoi 1993) are associated with paddle- or comb-impressed pottery with only rare red slip and no stamping. The Gua Sireh impression is paralleled in rim forms and decoration in Middle Neolithic assemblages in southern Taiwan (e.g., Li 1983) and Hong Kong (Meacham 1978: Sham Wan assemblages F and C). I have also raised the possibility that the Gua Sireh assemblage could indicate a former Austroasiatic linguistic presence in Borneo (Bellwood 1997:117, 236–238), and current research on the Neolithic in southern Vietnam leaves this option open, especially for certain parallels with rice chaff-tempered pottery from sites such as An Son in southern Vietnam (P. Bellwood, M. Oxenham, C. H. Bui, et al., unpublished manuscript). However, this is still an area of uncertainty that requires further research.

The above pottery data thus point to a secure ceramic sequence for much of Island Southeast Asia (except for Sarawak and perhaps Sumatra), within which combinations of red-slipped and stamped pottery spread from Taiwan and possibly other adjacent regions of the Asian mainland into Indonesia and western Oceania via the Philippines, with linguistically close populations moving in different directions at the same time. Influences from this tradition reached the Marianas and Lapita regions of Island Melanesia between 1500 and 1000 BC (fig. 3; table 1).

Debate has recently been expressed over whether the Neolithic assemblages carried from Taiwan into Island Southeast Asia and western Oceania constituted a “package” of coherently related material items (Donohue and Denham 2010). If there was such an Austronesian package, it was clearly polythetic in the sense of David Clarke (1968). Rice cultivation, domesticated pigs and dogs (see below), red-slipped pottery, earthenware spindle whorls, sown and ground stone adzes with tanged or grooved butts and quadrangular to triangular cross sections, Taiwan slate and nephrite, notched pebble sinkers, stone bark cloth beaters, and a variety of shell, stone, or bone artifacts including bracelets, beads, and fishhooks can all be argued to have been carried from Taiwan into at least the Philippines and in many cases beyond (Bellwood and Dizon 2008; Hung 2008; fig. 2). Eventually, the domestic animals, pottery, stone adzes, bark cloth beaters, woodworking technology, canoe construction, and fishing gear, and perhaps even the working of nephrite (e.g., in Maori New Zealand), extended deep into Remote Oceania, although pottery making did not survive after about 2,000 years ago in Polynesia or much of Micronesia. Other items remained restricted in distribution—artifacts of Taiwan slate, for instance, are so far reported only from Batanes, and pottery spindle whorls apparently did not travel beyond Luzon.

My view is that no “package” concept can afford to be exclusive, and there will always be a danger that people will read far more into the concept than is necessary. Allowance must always be made for indigenous contributions to the suite of moving concepts and items, if and when they are required. The problem is that such contributions are often difficult to establish, especially from pre-Austronesian Island Southeast Asia and Oceania. Hard archaeological evidence as opposed to supposition does not support the claims for pre-Austronesian interaction networks made by Donohue and Denham (2010), for instance, or Bulbeck (2008), or in the form of Terrell’s (2010) “ancient lagoons” hypothesis for early Holocene New Guinea. Ancient lagoons formed by high mid-Holocene sea levels were certainly not unique to New Guinea. Populations in southeastern coastal China experienced them as well.
How Significant Were Rice and Pigs?

It has been suggested that the failure of rice cultivation to spread widely in perhumid equatorial eastern Indonesia or into prehistoric Oceania renders invalid any suggestion of Neolithic movements out of Taiwan (Oppenheimer and Richards 2002:289). But these authors fail to note that remains of rice and millet were universally absent from sites of the Dabenkeng phase in Taiwan (3500–2500 BC) until both were found in unprecedented carbonized quantities in hitherto unique waterlogged conditions dating to ca. 2800 BC in the Nanguanli sites in the Tainan Science-Based Industrial Park (Tsang 2005; Tsang, Li, and Chu 2006). In fact, the list of sites in Island Southeast Asia in which evidence for rice has been found, particularly as a result of careful analysis of pottery or phytoliths, is rapidly increasing, especially in circumstances where carbonized macroremains are absent. For example, rice remains are present in pottery at Andarayan in the Cagayan Valley before 1400 BC (Snow et al. 1986). Rice phytoliths have been identified in the site of Kamassi in the Karama valley in western Sulawesi, but it is unclear whether they relate to food production (Anggraeni, personal communication). In Malaysian Borneo, rice remains including phytoliths have been reported dating variously between 2200 BC and AD 1 from Gua Sireh and Lubang Angin (see above) in Sarawak and Madai and Bukit Tengkorak in Sabah. For Sarawak, Doherty, Beavitt, and Kurui (2000) report the discovery of rice in pottery from a total of 35 sites. Strangely, however, Victor Paz (2002:279) identified charred remains of Dioscorea alata and possibly Colocasia esculenta, but no rice, in a large quantity of late prehistoric charcoal from Madai Cave 1 in Sabah, even though one hearth sample from the same site dating to ca. 2000 years ago, submitted to phytolith specialist Geoff Parr, yielded rice phytoliths in quantity. Situations such as this are puzzling and suggest that failure of rice remains to survive macroscopically need not imply a total absence. New excavations at Eluanbi in southern Taiwan have also yielded rice phytoliths in a situation where charcoal is absent (T. Cheng and L. Tsuo-Ting, personal communication, February 2009). As Pearsall (2003:274) notes for sites in Ecuador, and as I have noted many times in Southeast Asian field conditions, charcoal can disintegrate rapidly in seasonal tropical environments with strong cycles of wetting and drying.

Put simply, archaeologists working in Island Southeast Asia have probably failed to recognize cereal remains because of poor preservation conditions and lack of observational tech-
Table 1. Archaeological Phases of the Neolithic in Taiwan and the Northern Philippines from before 3500 BC to 500 BC

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (before 3500 BC)</td>
<td>Flaked lithics and shell tools, no evidence for Neolithic technology (such as stone sawing, grinding, use of nephrite, or pottery)</td>
</tr>
<tr>
<td>2 (3500–2200 BC)</td>
<td>Dabenkeng and “fine-cord-marked” phases in Taiwan: appearance of Neolithic technology with use of nephrite and slate, rice and foxtail millet cultivation, and transition from cord-marked to red-slipped plain ware pottery. No known expansion south of Taiwan occurred at this time, but Sumnerhayes and Anderson (2009) raise the possibility of movement into the nearby Ryukyu Islands, southern Japan</td>
</tr>
<tr>
<td>3 (2200–1000 BC)</td>
<td>First human settlement of Batanes and Luzon from southern Taiwan, about 2200 BC, followed by a considerable flow of material culture, especially red-slipped plain ware pottery, from Taiwan into the Philippines and onward into Island Southeast Asia. Associated with this was a spread of stamped pottery decoration from ultimate mainland Asian sources, which traveled with the red-slipped plain ware into the Philippines and onward to the Mariana Islands in western Micronesia and the Lapita zone of Island Melanesia and western Polynesia. This spread appears to have had only limited impact in Taiwan but a major impact in the northern Philippines</td>
</tr>
<tr>
<td>4 (first millennium BC)</td>
<td>Increasing evidence for frequent Taiwan-Batanes-Philippines and across-the-South-China-Sea contacts in both directions, particularly involving Taiwan nephrite (Hung and Bellwood 2010; Hung et al. 2007)</td>
</tr>
</tbody>
</table>

The failure of rice cultivation to spread into Oceania is not hard to explain. Dewar (2003) discusses reasons of climatic variability for a relative absence (or nonsignificance) of rice in many parts of northern and eastern Island Southeast Asia, suggesting that El Niño–Southern Oscillation (ENSO)-related rainfall unreliability was a major reason for its failure to spread into Oceania. Paz (2002), as noted above, refers to day-length considerations. Island Southeast Asia encompasses 30° of latitude, from subtropical regions with strong seasonality of rainfall distribution into equatorial regions that were uniformly hot and humid all year round. We can hardly expect that people would always have continued to grow rice when more suitable fruits and tubers were available, just as farming populations moving from the Indus into the Ganga Valley at about 3000 BC eventually adopted rice and other monsoon crops and allowed their West Asian winter crops to decrease in significance (Bellwood 2005:87; Fuller 2011). So far, our attempts to identify rice in phytolith samples from Batanes have not been successful, but because rice was apparently not grown at European contact on Batan (Dampier 1687, in Blair and Robertson 1903–1909, vol. 38:98), we would not necessarily expect to find it, even though it is grown today as a minor monsoon crop in upland fields. The Batanes Islands have no flat alluvial land and no high-level water sources that could support terrace farming in the manner of the famous Ifugao terraces at Banaue in northern Luzon. My suspicion is that the Batanes formed a filter against a spread of rice in the early years of Austronesian expansion and that it became significant only when settlers reached the broad alluvial landscapes of the Cagayan Valley and other parts of Luzon. Within much of the Philippines and Indonesia, Neolithic populations in mid-Holocene-drowned coastal landscapes (Bellwood et al. 2008) that lacked good alluvial rice soils moved expectably toward fruits and tubers for subsistence and doubtless encountered these species when they were already under exploitation by indigenous food gatherers.

The domestication of the pig in Island Southeast Asia is currently a topic of considerable debate (Larson et al. 2007, 2010) rendered complex by the wide distribution of native suids in mainland Asia, western Indonesia (Sundaland), and Sulawesi. Pig bones are widespread in Neolithic sites in Taiwan and are common in the lower Neolithic layer at Nagasbaran in the Cagayan Valley, where Piper has identified teeth of domesticated Sus scrofa directly AMS dated before 2000 BC (Piper et al. 2009). These pigs predate, perhaps by many centuries, the introduction of the so-called Pacific clade of pigs of southern China or northern Indochina origin into Lapita Melanesia. Unfortunately, the oldest Batanes sites, Reranum and Torongan Caves, contain no animal bone, but pig was present by 1200 BC in Sunget on Batan.

At this stage, it is not clear to what degree pigs traveled with Neolithic migrants in Island Southeast Asia or how many separate domestications of local species occurred (Larson 2011). It seems that pigs were not carried from Luzon to the Marianas in prehistoric times, so they did not enter the Lapita
zone by this route. It is also quite possible that pre-Neolithic populations translocated indigenous wild pig species to resource-poor islands such as Flores in eastern Indonesia (Dobney et al. 2008), just as they might have translocated marsupials out of New Guinea (Flannery et al. 1998).

The Nephrite Trail

In Taiwan, nephrite (jade) tools and ornaments have been identified from more than 100 sites dating between 3000 BC and AD 500 (Hung et al. 2007). Taiwan nephrite is generally green in color and was exploited from deposits at Fengtian, located at the northern end of the eastern rift valley of Taiwan inland from the city of Hualian. This appears to have been the only nephrite source utilized in prehistoric Taiwan. Fengtian nephrite has recently been subjected to a detailed sourcing program by Yoshiyuki Iizuka at the Institute of Earth Sciences, Academia Sinica, Taipei, using a low-vacuum scanning electron microscope equipped with an energy-dispersive x-ray spectrometer (Iizuka and Hung 2005; Iizuka et al. 2005). It can be identified with confidence in terms of the chemistry of its matrix and its zinc-chromite inclusion minerals. All green jade artifacts tested from Taiwan and the Philippines are from the Fengtian source (but Luzon also has at least one separate white nephrite source).

Jade working was most probably introduced into Taiwan from southern China, where it was present in the Yangzi Basin as early as 5000 BC. In Taiwan, sawn nephrite adzes appear in the Dabenkeng phase (ca. 3000 BC; Hung 2004), and the long-lasting tradition of grooving, snapping, drilling, and polishing nephrite later developed into the remarkable funerary assemblages of Beinan in southeastern Taiwan (ca. 1500–500 BC), with pendants (some anthropomorphic), penannular...
Out of Taiwan into the Philippines: A Summary

Four factors render a southward movement of Neolithic material culture from Taiwan into the northern Philippines at about 2000 BC a virtual certainty. (1) Strong parallels in material culture between 2200 and 1500 BC link southern Taiwan and the northern Philippines, reinforced by the movement of artifacts of Taiwan slate and positively sourced Taiwan nephrite. The synchronous changes in pottery decoration that link southeast Taiwan, the Batanes Islands, and Luzon, from a predominance of cord marking in Taiwan only, through a dominance of red-slipped pottery and into a slightly later phase of red-slipped and stamped pottery are especially important. (2) Taiwan has chronological priority of the artifact types concerned involving an unbroken continuity since at least 3000 BC in cord-marked and red-slipped pottery, and many of the items are illustrated in figure 2. To these can be added the oldest radiocarbon dates for rice and millet, domesticated dogs, and probably pigs in Southeast Asia. (3) There is an absence of closely related Neolithic material culture before 1500 BC in Indonesia, and there are deep and significant differences in most aspects of Neolithic (pre–Sa Huynh) material culture between Vietnam and the Philippines before 1000 BC. (4) The absence of an earlier population in the Batanes Islands implies a movement of people to establish colonization, not an adoption of Neolithic material culture by an indigenous hunter-gatherer population (as probably happened to a degree in the Peñablanca Caves in Luzon; Mijares 2006).

From an archaeological perspective, the progression of Neolithic material culture assemblages of ultimate East Asian/Taiwan origin through the regions settled by ancestral Austronesian speakers required about 4,000 years to unfold from Taiwan to New Zealand, perhaps 6,000 years if commencing in southern China (fig. 3). Populations already resident in Island Southeast Asia and Melanesia contributed cultural capital in the form of some shell-artifact technologies (especially flaked-shell tools), tuber and fruit crops of western Pacific (especially New Guinea) origin, flaked lithic traditions (found commonly mixed with Neolithic assemblages in Indonesian caves), and even translocated species of marsupials in some islands close to New Guinea. As to the origins of the economic and technological complexes that fueled Austronesian dispersal in the first instance, we must look to southern coastal China (Fuller, Harvey, and Qin 2007; Hung 2008; Jiao 2007; Rispoli 2008; Zhang and Hung 2008, 2010). Food production, maritime knowledge, and perhaps even domino effects from the movements of Yangzi Basin rice farmers all played roles here. What is clear is that the Neolithic complex that spread through Island Southeast Asia and into the Pacific emanated from southern China via Taiwan and then presumably via the Philippines and Borneo. It manifestly did not originate from the south.

In conclusion, it is possible to focus on Taiwan and the Philippines at the end of the third millennium BC in order to identify the start of a migration, by both land and sea, of speakers of Malayo-Polynesian languages and of the carriers of a broad range of Neolithic material culture with food production. Both of these spreads are likely to have been two sides of one “event” involving a single ethnolinguistic and genetic population in the final resort, albeit one that was constantly adapting and interacting, as all humans do. The migration originated more deeply in southern China and eventually encompassed warm temperate through equatorial latitudes in the Northern Hemisphere, out again into temperate latitudes (New Zealand) in the Southern Hemisphere, thus passing through some major zones of environmental and resource difference as well as through preexisting populations with their own long-established cultures and languages, particularly in western Oceania. One of the results of this equa-
torial transition appears to have been an abandonment of cereal (rice and millet) cultivation in Indonesia in favor of the fruit-and-tuber-based plant economy that characterized the Pacific Islands.

Why did the Austronesian dispersal occur? Within eastern Taiwan, the archaeological record indicates a marked increase in the number of archaeological sites after 2500 BC (Hung 2008), so population growth and a need for new cultivation land come to mind, given that southeastern Taiwan is a rugged area with low agricultural potential. But early Austronesians moved on to settle new islands very rapidly in terms of both archaeology and comparative linguistics (Pawley 1999). For instance, colonists spread 8,000 km from the Batanes Islands to Samoa in less than 1,000 years, beyond which a slowdown occurred, perhaps due in part to the nonemergence of Pacific atolls until much later in time (Dickinson 2003). This rapid movement to western Polynesia surely reflected a reliance on both maritime and lowland agricultural resources, the latter greatly reduced in extent by the drowning of the most fertile alluvial and coastal soils as the sea attained its maximum mid-Holocene sea level (Bellwood et al. 2008). This would have rendered good coastal and alluvial farmland scarce in the early centuries of Austronesian migration, creating deep estuaries and steep coastlines against rugged island interiors, at least until forest clearance caused soil aggregation to build up fertile lowlands. Advancing maritime technology also fueled the Austronesian spread, with the earliest evidence for canoes and paddles in this region coming from coastal central China during the early Holocene.

Can the Austronesian Dispersal Inform Us about Dispersals of Languages and Farming in Other Parts of the World?

The reality of Austronesian dispersal via Taiwan and the Philippines is powerfully reinforced by evidence from three independent research areas: linguistics, archaeology, and human biology. This dispersal did not involve an autonomous origin of food production on present evidence, which admittedly is slight; rather, it was a peripheral result of the developments of food production farther north in mainland East Asia and farther east in New Guinea. There is much uncertainty here, and little mileage would be gained by debating whether Austronesian languages or peoples can be traced directly into the Yangzi Basin. Domino effects could have occurred, even localized language shift (because language shift was surely always localized under Neolithic social conditions), as well as direct transmission.

What is clear, however, is that the Austronesian dispersal to Taiwan and beyond between 3000 and 1000 BC occurred at the same time that agricultural populations in China and Taiwan attained very high demographic densities, especially during the Longshan and Shang periods in China itself. Austronesian dispersal did not originate as an independent product of forager activity in the archipelagoes of Island Southeast Asia during the early Holocene millennia of sea-level rise. Neither could it have been caused only by maritime knowledge or unusual concatenations of ENSO events (Anderson et al. 2006). Such factors no doubt helped, and of course without their rafts or canoes, Austronesians would presumably not have traveled far. But without the demographic impetus and technological advancement provided by East Asian food production, this dispersal could never have occurred, at least not through the inhabited portions of Island Southeast Asia. The previously empty islands in the Pacific would in many cases have been too small, isolated, and impoverished in terrestrial resources for long-term low-technology forager settlement. Early Jomon people in Japan and early Australians had rudimentary sea craft in some regions at least, but as far as we know, their forager economies did not lead to maritime population dispersal over large distances. Neither of these populations attempted to colonize the Pacific.

In conclusion, the Austronesian dispersal was little different in a demographic and causative sense from other early farming dispersals across the Eurasian, African, and American continents. The maritime setting is unusual, but we have no data to suggest that Austronesians ever entirely gave up food production, except in equatorial rainforests in Borneo and frosty southern New Zealand. Doubtless, Austronesian food production varied in intensity—many Austronesians are low-level food producers in Bruce Smith’s (2001, 2011) terms today—but this need not be a universally ancestral condition. Inability to find prolific evidence for cultivated crops in archaeological sites does not mean that we must throw out all the comparative linguistic reconstructions of an early Austronesian agricultural vocabulary. Naive birds, fishing, and westerly winds doubtless assisted many individual episodes of colonization but alone did not lead to Pacific colonization beyond Near Oceania.

Acknowledgments

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Early Agriculture and Plant Domestication in New Guinea and Island Southeast Asia

by Tim Denham

A multidimensional conceptual framework is advanced that characterizes early agriculture as a subset of human-environment interactions. Three cross-articulating dimensions of human-environment interaction are considered that accommodate the varied expressions of early agriculture in different parts of the world: spatial scales, transformative mechanisms, and temporalities of associated phenomena. These ideas are applied and exemplified at two different scales of resolution—contextual and comparative—in terms of early agricultural development in the highlands of New Guinea and the dispersal of domesticates from New Guinea into Island Southeast Asia.

Recent conceptual debates on early agriculture have shifted from definitions based on domestication—namely, phenotypic and genotypic transformations in plants and animals or degree of dependence on domesticates (e.g., Harris 2007; Smith 2001)—to broader understandings of the environmental and social contexts within which early agriculture was practiced (e.g., Cauvin 2000; Ingold 2000; Marshall 2007; Pearsall 2007). Currently, there is neither agreement on nor universal application of a standard definition for identifying early agriculture in the past, with considerable geographical variation (e.g., Barker 2006; Bellwood 2005; Denham, Iriarte, and Vrydaghs 2007).

In this article, a multifaceted framework is proposed that characterizes early agriculture as a subset of broader human-environment relations, thereby incorporating both the biophysical and social realms. The intensive, discursive nature of the Temozon conference contributed greatly to the emergence of these ideas and to my understanding of research into early agriculture across the globe. I am indebted to both the organizers for inviting me and to other participants for their stimulating company.

My intention here is to develop a conceptual framework that can incorporate different emphases in our understanding of early agriculture for different regions of the world rather than to propose a prescriptive definition designed for universal conformity. The purpose is to characterize rather than to define. The multidimensional model is exemplified at two different scales of resolution. The emergence of agriculture in the Upper Wahgi Valley of New Guinea is discussed contextually at the landscape scale. The spread of domesticates from New Guinea to Island Southeast Asia is discussed comparatively at broader spatial and temporal scales. The multidimensional framework potentially has broader application to elicit commonalities and differences for the various regions across the world in which agriculture has emerged, although there is insufficient space for elaboration here.

Early Agriculture: A Subset of Human-Environment Relationships

Animal and plant exploitation, including pastoralism and agriculture, are among the most important subsets of human-environment relations both in terms of human dependence and environmental change. The interpretation of agriculture in the past should consider the multiplicity of factors that converge in any given human-environment interaction, including those of the biophysical realm—such as climate, environment, and the biology of cultivated plants and tended livestock—as well as the social realm—namely, people and various facets of their practices, including cultures, societies, and technologies. Consequently, and inherently, agriculture has multiple socioenvironmental dimensions that are mutually transformative; namely, they are historical, and each acts on and changes the other through time (e.g., from Time\(_1\) to Time\(_2\) in fig. 1). It is proposed and demonstrated here that the totality of these dimensions is essential to characterize the emergence of agriculture in any given historicogeographical context.

An inclusive conception of agriculture as a subset of human-environment interactions sheds critical light on the nature of attempts to elicit a singular definition or an ultimate "cause" of agricultural development in the past. Any singular definition of agriculture prioritizes one epiphenomenon...
Figure 1. Schematic representation of the multiple dimensions of early agriculture, hereby described as a subset of human-environment interactions. Each dimension (a to c) is characterized in figure 2.

above others. For example, definitions focused on the identification of domesticated animals or plants in the archaeobotanical record or on inferences regarding dependence of people on domesticates fail to fully acknowledge that the morphogenetic transformation of species are not uniform in the past or the present. Numerous factors affect the relative propensity of a species to accumulate anthropically selected traits through time; some are biological (Ladizinsky 1998), while others are environmental (e.g., Pearsall 2007) and social, technical, or practical (e.g., Denham 2007; Marshall 2007). Multiple dimensions of domesticatory relationships influence their archaeological visibility.

The recursivity of human-environment interactions hinders the interpretation of a singular or ultimate cause of early agriculture. The positing of any biophysical or social phenomenon as a primary cause is arbitrary because any explanation inevitably folds back into the duality of human-environment relations (drawing on Giddens 1984). It is effectively impossible to determine causation within a recursive spiral; transformation in human-environment interactions is continuous, multifaceted, and multicausal. To exemplify, if climatic amelioration and stabilization at the beginning of the Holocene are posited as the ultimate cause for the emergence of agriculture across the globe (e.g., Richerson, Boyd, and Bettinger 2001), this explanation fails to account for the restricted number of locations in which this actually occurred. Why did agriculture emerge in some places and not in others, and why is there so much temporal variation?

Any account of ultimate causation is soon beset by qualifiers, such as resource availability and species’ susceptibility to domestication. Although there are geographical variations in the availability and susceptibility of animal and plant resources to domestication, these do not solely account for why agriculture emerged in some places and not in others during the early Holocene. For instance, indigenous plants were evidently domesticated in other regions much later (e.g., India [Fuller et al. 2004], parts of Africa [Kahlheber and Neumann 2007], and North America [Asch and Hart 2004]). Any climatic explanation soon shifts sideways from the biophysical realm to the social realm in order to account for the observed spatiotemporal variations. The social realm necessitates a much broader consideration of how people in different locales engaged with their environments such that some developed agriculture and others did not. In logical terms, what may initially be characterized as a cause—whether climatic amelioration, environmental degradation, or social transformation—soon becomes a relatively widespread precondition, which in turn then becomes a relatively benign context.

Three cross-articulating dimensions of human-environment interaction are relevant to the characterization of early agriculture in any historicogeographical context (fig. 2): (a) spatial scales of analysis, type of method, and lines of evidence; (b) transformative mechanisms and archaeological expressions of agriculture; and (c) temporalities of associated phenomena. Each dimension is briefly discussed below.

Articulating Space and Place

There are considerable variations in the spatial scale of analysis through which early agriculture is inferred. The scale of analysis adopted has implications for the ways in which evidence is used—whether conflated, low resolution, or in particular, high resolution—and tends to be associated with a specific methodology—either comparative or contextual, respectively (fig. 2a). Characterizations of early agriculture at the continental and subcontinental scales often conflate data from different locales and of slightly different ages to draw a general comparative picture of agricultural development (e.g., Bellwood 2005; Renfrew 2002). Others draw on locally generated,
heavily contextualized evidence to characterize early agricultural development within given landscapes or places (e.g., Denham and Haberle 2008; Pearsall 2007) and emphasize intraregional variability.

Although there are some conceptual tensions between comparative and contextual approaches (cf. Renfrew 1973, 2002; Thomas 1996), they are not necessarily incompatible. A key aim of archaeological research is “to use archaeological data to gain an understanding of the indeterminate relations between large-scale processes and individual lives” (Hodder 1999:175). For those seeking an understanding of early agriculture, reconstructions at the local level need to be situated...
within broader regional, interregional, and continental processes. Highly specific and contextual information can be cautiously situated within broader historical and geographical processes, although the converse is more problematic because of the lack of resolution and specificity in conflated data sets.

**Transformative Mechanisms and Archaeological Expression**

Agriculture is based on the management of plants and animals for human exploitation. Agriculture is predicated on varying degrees of human intervention in the life cycle of plants, which in turn yield intended and unintended consequences in terms of plant biology and the utility of managed plants for people. The nature of the mutually transformative interaction between animals/plants and people is differentially expressed in given historicogeographical contexts; it is not restricted to the biological domain even though issues of domestication have been the focus of most debate.

Four domains have a bearing on the character of agriculture, namely, how agriculture is expressed archaeologically in any historicogeographical context (fig. 2b; cf. Sayer 1984): (1) biology: degrees of domestication (phenotypic and genotypic change), gene expression, and phenotypic elasticity; (2) social world: demography, dependence, Neolithic traits, orientation to resources, sedentism, and sociopolitical change; (3) environment: human and natural influences, transformation, rate of change, sensitivity to change; and (4) technology: translocation, propagation, cultivation, harvesting, processing, and storage.

Academic discourses draw variably on different domains and lines of evidence to construct arguments for or against early agriculture in different parts of the globe. In part, these positions reflect the definitions of agriculture adopted, which are usually either inherited from research in Eurasia or developed to suit the available evidence within a region. These domains are variably expressed, articulated, and aligned in different instances of early agriculture. Particular factors seem to be important and correspond in some regions whereas in others they do not; however, they are all relevant.

**Temporality of Associated Phenomena**

Debates concerning early agriculture tend to project unilinear or multilinear trajectories from the past to the present; namely, they are teleological. Time is viewed as continuous; processes are viewed as cumulative (e.g., Richerson, Boyd, and Bettinger 2001), as if they lead somewhere significant other than solely toward the present. Three aspects of time, and the temporality of things (namely the temporal extension of something, or its being in time; Thomas 1996), are significant. Although time and temporality are implicit to any discussion of early agriculture and subsequent transformations, they are rarely made explicit (fig. 2c).

First, the temporality of things is usually assumed to be continuous, or semicontinuous. In part this reflects the punctuated nature of archaeological finds and the need to place fragmentary finds into chronological-geographic sequences (e.g., Scarre 1988). Interpretations adopt various lines of reasoning—from uniformitarian to Occam’s razor to historical materialist to postprocessualist—to place archaeological finds in time, namely, to temporalize them, inferring their temporal extension and position in a sequence. Although discontinuities can be recognized in prehistory, such as the abandonment of a crop or technology, these can be hard to determine with confidence because of the absence of evidence, which is not evidence of absence.

Second, rates of change are rarely considered, which in part can be a function of the records and partly a function of perspective. For example, domestication is a process that operates at variable rates for different species and subspecies in different historicogeographic contexts. Some species—perhaps those with annual life cycles subject to intensive human selection and a high degree of genetic isolation—would be anticipated to accumulate traits resulting from human management at a relatively rapid rate. Conversely, these same species not subject to the same degrees of human selection and genetic isolation, as well as other species with longer life cycles (such as trees and some animals), would be anticipated to accumulate traits at a slower rate. The rate of accumulation of domestication traits within an organism is a function of the human-environment context, namely, a function of the multiple domains associated with a domestica- tory relationship. Thus, experimental farming can yield high rates of change in cereals within decades (Hillman and Davies 1990), perhaps because of the high degrees of human selection and genetic isolation, whereas archaeobotany suggests the accumulation of these traits actually occurred over thousands of years in Southwest Asia (Tanno and Willcox 2006), perhaps because of continual genetic interaction between wild and cultivated stock as much as to selection through management practices (see Jones and Brown 2007). It follows that the accumulation of domestication traits in trees can be anticipated to occur over centuries or millennia (Yen 1996).

Genotypic and phenotypic changes are a continuum of change along which measures of domesticity, as opposed to wildness, are determined. Variations in the rate of domestication, whether measured genetically or phenotypically (as is customary in archaeobotany), can be anticipated to vary depending on whether a plant is propagated sexually or clonally; the accumulation of selected somatic mutations in the latter is a qualitatively different type of process to the accumulation of selected mutations through sexual reproduction (Yen 2003). Additionally, genotypic and phenotypic traits resulting from human management should not be anticipated to accumulate at the same rate within a species, or between species, especially given latent issues of gene expression and phenotypic elasticity for some plants under cultivation (Gremillion and Piperno 2009). The generation of phenotypic varieties in some plants, such as bananas and yams, need not correspond to genotypic change but may solely represent a phenotypic...
response or the differential expression of a gene due to the environment of cultivation and growth.

Third, the archaeology of early agriculture has tended to view time in the abstract, namely, chronologically, and not from the perspective of lived experience or experiential time. Issues of plant domestication are generally considered from the perspective of how many years before traits $x$ and $y$ become apparent in the archaeobotanical record; they are rarely considered from the perspective of how these traits accumulated through the day-to-day activities of people and were passed on from generation to generation. The time of lived experience is a precondition for the constitution of chronological time (Heidegger 1962) and processes thereby inferred.

Existential aspects of time are glossed or avoided because they can be considered to be attempts to get inside the minds of people in the past. Although partly true, this is always the case, because discussion of domestication often considers whether traits were intentionally or unintentionally accumulated, namely, to understand the intent, or mindset, of the people involved. The intentionality of the domesticatory process requires a consideration of experiential time whether to understand the deliberate selection of a taro corm or cereal grain or the qualitatively different temporal perspective of planting a tree. The former yields within a year, whereas the latter may take decades before yielding and requires an intergenerational perspective (Ingold 2000; Terrell 2002).

Contextual: Early Agriculture in the Highlands of New Guinea

Landscape Scale of Analysis

In New Guinea, as elsewhere, there are high degrees of regional variability in the nature of plant exploitation practices across the island (e.g., in major crop plants; Bourke and Harwood 2009; Kennedy and Clarke 2004), the nature of cultivation practices (Bourke 2001), and the degree of reliance on cultivation (Roscoe 2002; Terrell 2002), with similar variability likely to have characterized the recent and more distant pasts (see fig. 3; Denham 2005b). Consequently, it may not be meaningful to conflate evidence over broad sociospatial scales—from across the highlands or lowlands, for the island of New Guinea, or for Near Oceania—together into a single macrochronology or macrointerpretation of plant exploitation in the past. By so doing, plant exploitation practices and suites of domesticates that never co-occurred may be erroneously brought together into a single historical narrative; namely, the whole can be misleadingly coherent and much greater than the sum of the parts.

The interpretation of the emergence and transformation of agriculture in Highland New Guinea has sought to avoid teleological interpretations by focusing on the expanding repertoire of plant exploitation practices (including various forms of cultivation) toward the present and the spatial manifestation of each within the Upper Wahgi Valley (Denham 2009; Denham and Haberle 2008). In this landscape, a teleological unfolding is at one level unavoidable because agriculture did emerge from previous foraging practices at some point in the early Holocene. However, if the island of New Guinea is taken as a whole, a unilinear or multilinear characterization does not hold, because multiple types, including ambiguous types of plant exploitation, were being practiced up to the modern era.

The multidisciplinary evidence from a relatively restricted region or landscape can be relied on as the primary context for interpreting the emergence and transformation of agriculture (Denham 2008; Denham, Fullagar, and Head 2009; Denham and Haberle 2008). The multisite records from the Upper Wahgi Valley are the most detailed in New Guinea for eliciting plant exploitation and associated landscape changes in the past, primarily because of numerous archaeological and paleoecological investigations at wetlands bearing evidence of past manipulation for plant exploitation, including early agriculture (figs. 4, 5; table 1; reviewed in Denham and Haberle 2008 and supplemented by Coulter et al. 2009; Denham, Haberle, and Pierret 2009; Denham et al. 2009; Sniderman, Finn, and Denham 2009). The evidence from these sites of food production will eventually be complemented by the multidisciplinary results (once complete) from the excavations of proximal occupation sites along an altitudinal gradient on the valley wall (Christensen 1975; Donoghue 1989).

Transformative Mechanisms and Domestication Histories

The phenotypic or genotypic (application of ancient DNA) transformation of plants from wild to domestic forms has not been clearly charted through time and across space for any plant in the New Guinea region despite variable claims (Denham 2004b; Donoghue 1989; Golson introduction in Christensen 1975; Haberle 1995; Lentfer 2009; Yen 1996). As a result, the case for early agricultural development in New Guinea has leaned heavily on archaeological evidence of technologies and past practices (Denham 2005a, 2006, 2007, 2009; Denham and Haberle 2008; Golson 1982) and environmental transformation (geomorphology and paleoecology: Denham, Golson, and Hughes 2004; Denham et al. 2003; Golson and Hughes 1980; Haberle 1994, 2003, 2007; Hope and Haberle 2005). There is limited understanding of the social world inhabited by early agriculturalists (Golson and Gardner 1990; Haberle and Chepstow-Lusty 2000) largely because few occupation sites dating to the early Holocene have been excavated in the highlands, and most of these have not been published in full (except White 1972).

Types of archaeological information often considered to accompany early agricultural development in other parts of the world are equivocal or absent in the New Guinea record (e.g., Diamond 2002; Piggott 1954). In the absence of cemeteries or ossuaries, demographic signatures of early agriculture have been inferred using crude proxies, such as number
of archaeological traits (Haberle and Chepstow-Lusty 2000). Several Neolithic traits often associated with early agriculture (e.g., pottery and domesticated animals) are absent. The relationship between sedentism and early agriculture is equivocal; there are questionable claims for Pleistocene-aged settlements in the highlands at NFX (Watson and Cole 1977) and Wanelek (Bulmer 1977), but most settlements postdate 4000 cal BP. Archaeobotanical investigations at occupation sites are few (excepting Christensen 1975) and incomplete, and consequently shed little light on plant-food consumption preferences and practices. In a similar vein, sociopolitical transformations are poorly known, although the rise of putatively patrilineal, highly territorial descent groups and the big-man form of leadership have been inferred from agricultural history (Denham and Haberle 2008; Golson and Gardner 1990).

Given the limited knowledge of the biological and social domains in the early and mid-Holocene, the following discussions of the transformation of plant exploitation through time focuses on people’s orientation to plants within the Upper Wahgi Valley as inferred from the cross-articulation of archaeological (plants), archaeological (technology/practice), and paleoecological (environment) evidence.

Archaeobotanical and paleoecological research provides information on food plants that were available locally at Kuk and in the Upper Wahgi Valley as well as for the processing and inferred cultivation of some staples (Denham 2005b, table 2). Evidence for the presence of a food plant does not indicate that it was exploited in the past even if its use has been documented ethnographically (Powell 1982). However, on-site evidence of food plants in association with archaeological features representing either foraging or a form of agriculture is more suggestive of potential exploitation, even if adventitious. By contrast, archaeobotanical evidence for processing or cultivation enables more direct comparison with, and the direct integration of plants into, the plant exploitation chronology for the region (e.g., Denham 2009; Denham and Haberle 2008). At present, significant archaeobotanical evidence is limited to bananas (*Musa* spp.), *karuka* Pandanus (*Pandanus julianettii*/iwen/brosimos), taro (*Colocasia esculenta*), and a yam (*Dioscorea* sp.; Denham, Haberle, and Lentfer 2004; Denham et al. 2003; Donoghue 1989; Fullagar et al. 2006, 2008).

Because of evidential deficiencies, the domestication histories of significant crop plants can only be hypothesized in terms of current understandings of how plant exploitation practices changed through time. For the Upper Wahgi Valley, these hypotheses can be formulated with respect to bananas, taro, and a yam (e.g., Denham 2009). Each crop plant had been considered to be of lowland derivation and brought to the highlands by people (Hope and Golson 1995; Yen 1995), although they potentially grew naturally in the highlands during the early Holocene (Denham, Haberle, and Lentfer 2004; Haberle 1993). Only two early steps in the domestication process can be hypothesized from the archaeological and archaeobotanical evidence: planting and cultivation.

First, planting of these three plants from wild stock is hypothesized to have occurred in the early Holocene before mound cultivation dating to 7000–6500 cal BP on the wetland margin at Kuk (radiocarbon dating for Kuk is presented in Denham et al. 2003). Some form of swidden cultivation is likely to have preceded more intensive forms of cultivation (Denham and Haberle 2008). It is still unclear whether initial planting was through seed or vegetative propagation, although the latter is the dominant characteristic of highlands agriculture and some other forms of plant exploitation in New Guinea. Indeed, domestication has led to the development of numerous cultivars that are no longer able to reproduce sexually under normal growing conditions. Consequently, vegetative propagation is generally considered to have always been the dominant mode of plant reproduction under cultivation in New Guinea (Denham 2005b), although some plants are grown from seed. Planting encouraged the development of “cultiwild” populations, namely, cultivated or managed populations of effectively wild plants, which may still interbreed with any wild populations growing in the vicinity (following De Langhe et al. 2009).

Second, an increased reliance on vegetative propagation and the systematization of agricultural practices in the highlands, exhibited with the development of mound cultivation by at least 7000–6500 cal BP and of ditched field systems by ca. 4000 cal BP, led to increasing degrees of domestication (Gabella 2004) in managed stands and the creation of an array of cultivars through anthropic selection and increasing genetic isolation of favored plants. Genetic isolation prevented inbreeding between cultivated and wild stock and was achieved through a combination of intentional and unintentional practices, including plant translocation, environmental degradation, and vegetative propagation of cultivated stock. Translocation brought managed plants from lower altitudes to the

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Figure 3. Maps depicting the variability in plant exploitation across Papua New Guinea. *Top,* contour map of Papua New Guinea; *middle,* geographical distribution of major crop plants today (from Bourke and Harwood 2009); *bottom,* interpretation of the geographical distribution of major crop plants following the exclusion of recently introduced crops. Crop plants likely to have been introduced within the last 500 years comprise sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), and taro *kongkong* (*Xanthosoma sagittifolium*).
floor of the Upper Wahgi Valley, in which wild stands of the same species were rare or absent. The degradation of forest to grasslands on the floor of the Wahgi Valley in the vicinity of Kuk by ca. 7000 cal BP would have removed the habitats of wild stands of banana, taro, and yam, if present, thereby further isolating cultivated stock. The focus on vegetative propagation isolated cultivars genetically through clonal reproduction, albeit with somatic mutation, thereby partially selecting against sexually reproduced plants and increasing the isolation of cultivated stands from wild gene pools. Some cultivars in New Guinea are still interfertile with wild populations, especially some diploid banana cultivars, and interbreeding is encouraged in some areas (Kennedy and Clarke 2004); however, this would be dependent on the survival of local pollen sources and pollinators in heavily altered environments.

These domestication scenarios are currently hypotheses; the purpose is heuristic and not intended to suggest that these processes were restricted to the Upper Wahgi Valley region. Rather, similar types of process were probably widespread, if variable, across New Guinea and plausibly in adjacent regions. The net effects of these domesticatory relationships are visible in the phylogenies that shed light on the natural distributions, geodomestication pathways, and anthropic spread of major crop plants in New Guinea and Island Southeast Asia.

Comparative: Dispersal of Domesticates and Plant Management in Island Southeast Asia

At present, there are no multidisciplinary records of plant exploitation elsewhere in New Guinea comparable to those from the Upper Wahgi Valley. Tentative comparisons can be made with similar types of records from locales within neighboring regions of northern Australia (Denham, Fullagar, and Head 2009) and Island Southeast Asia (Barton and Denham, forthcoming). These comparisons suggest that the plant exploitation mosaics characteristic of New Guinea may have extended possibly into northern Australia before European arrival (Denham, Donohue, and Booth 2009; Jones and Meeman 1989) and into Island Southeast Asia before the advent of Austronesian speakers (Barker 2006; Barton and Denham, forthcoming). At present these mosaics are largely invisible, although the dispersal of plants considered to be domesticated in the New Guinea vicinity sheds a clearer light on plant exploitation practices, effectively the orientation of people to plant resources, within these regions (Denham 2010; Donohue and Denham 2010). Currently, knowledge of the social and technological domains of early plant exploitation through Island Southeast Asia is limited; they can only be implied through broadscale and low-resolution (both spatially and chronologically) comparisons of the dispersal and nondispersal of crop plants from New Guinea.

Traditionally, the suite of domesticates considered indigenous to New Guinea included a range of highland and lowland plants, most of which were insignificant or absent outside the region. Highland domesticates included the karaka Pandanus complex (Pandanus juliannetii/iwen/brosimos complex), edible pitpit (Setaria palmifolia), and Runjia (Runjia klossii), whereas lowland domesticates included species of marita Pandanus (Pandanus conoides), Canarium spp., and Terminalia spp., as well as sago (Metroxylon sagu; Barrau 1955:46). Species with broad altitudinal ranges included sugarcane (Saccharum officinarum; Simmonds 1976a:104–108) and Australimusa bananas (Musa spp.; Simmonds 1976c:211–215). The domestication locus of Pueraria lobata (Watson 1964), a tuberous plant formerly cultivated in the highlands, is questionable. Interpretations of origin and domestication have largely been based on centers of greatest genetic diversity and the presence of ancestral wild forms from which domesticated forms arose (Yen 1985, 1991). Domestication processes in New Guinea, as elsewhere, focused on decreasing toxicity (e.g., taro), decreasing seed size in some fruits (e.g., some breadfruit, bananas), and increasing the edible portions of most root crops, fruits, and nuts.

The application of genetic tools to modern-day plant populations has been revolutionary and suggests that a whole range of important pantropical food plants underwent initial or separate domestication in the New Guinea region (table 2; Kennedy and Clarke 2004; Lebot 1999). Many of these food plants were previously thought to have been domesticated in Southeast Asia, and potentially the locus of domestication may change again as additional cultivated and wild populations are included within the analysis. Of particular significance for understanding the history of agriculture in New Guinea, Island Southeast Asia, and beyond are four globally significant starch-rich plants (elaborated in Denham 2010).

Figure 4. Depictions of (a) significant archaeological and paleoecological sites on the island of New Guinea; (b) significant archaeological and paleoecological sites in the western highlands of Papua New Guinea (shaded box in a); (c) the locations of Ambra, Kuk, Warrawau, and Wurup sites in the Upper Wahgi Valley (box in b); and (d) the relative locations of Kuk, Warrawau, and Wurup sites along an altitudinal transect from the floor to the upper walls of the Upper Wahgi Valley (reproduction of Denham and Haberle 2008, fig. 1).
Bananas (Musa spp.)

Bananas (Musa spp.) are an important cash and subsistence crop in the tropics and subtropics (De Langhe et al. 2009). The most significant fruiting bananas are derived from species of Eumusa section, principally Musa acuminata (genome A) and Musa balbisiana (genome B). Formerly, Eumusa bananas were presumed to be Southeast Asian domesticates, whereas bananas of sections Australimusa and Ingentimusa were considered indigenous to the New Guinea region (Simmonds 1976a; Stover and Simmonds 1987; Yen 1973).

According to recent research, the initial stages of the domestication of most Eumusa cultivars can be traced to Musa acuminata ssp. banksii populations, which are indigenous to the New Guinea region; parthenocarpy is inferred to have arisen in this species first (Perrier et al. 2009). Musa acuminata ssp. banksii contributes to the genome of several different groups of banana cultivars, including some of the Pacific plantains (AAB), Western and Central African plantains (AAB), East African cultivars (AAA), as well as the yellow Cavendish banana (AAA), which is the most widely grown and consumed plantation cultivar today (e.g., Kennedy 2008). The enormous diversity of modern Eumusa-derived banana cultivars represents complex geodomestication pathways, including multiple subspecific and specific domestications, progressive parthenocarpy and seed suppression, the creation of diploids and triploids, interspecific and intersubspecific hybridization, and somatic mutation (Perrier et al. 2009).

Interpretations suggesting early domestication of Musa spp. in the New Guinea region have received some archaeobotanical corroboration. Phytoliths of Eumusa type date to ca. 10,000 years at Kuk Swamp in the highlands, with subsequent banana cultivation inferred from high Musaceae phytolith frequencies, including those of Eumusa type, in association with archaeological features from 7,000 to 6,500 years ago (Denham et al. 2003; Lentfer 2009). Multidisciplinary evidence suggests the dispersal of bananas westward from New Guinea is uncertain (Denham, Golson, and Hughes 2004).
Table 1. Summary of wetland archaeological excavations and evidence for prehistoric agriculture in the interior of New Guinea

<table>
<thead>
<tr>
<th>Site name</th>
<th>Altitude (m)</th>
<th>Location</th>
<th>Main field seasons</th>
<th>Principal publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambra Crater</td>
<td>1,760</td>
<td>Upper Wahgi Valley</td>
<td>1999</td>
<td>Sniderman et al. 2009</td>
</tr>
<tr>
<td>Kindeng⁵</td>
<td>1,600</td>
<td>Upper Wahgi Valley</td>
<td>1968</td>
<td>Unpublished</td>
</tr>
<tr>
<td>Mugumamp</td>
<td>1,560</td>
<td>Upper Wahgi Valley</td>
<td>1977</td>
<td>Harris and Hughes 1978</td>
</tr>
<tr>
<td>Kana</td>
<td>1,480</td>
<td>Middle Wahgi Valley</td>
<td>1993–1994</td>
<td>Muke and Mandui 2003</td>
</tr>
</tbody>
</table>

Note. This table is an updated version of Denham 2007, table 5.1.

⁵ Other wetland sites have been inspected by archaeologists, although none was investigated in detail. For example, the site at Kotna (1,580 m) in the Upper Wahgi Valley was village land under drainage for coffee. The site was visited by Jack Golson and John Muke in 1988, at which time they sought permission to record features exposed in drain walls. Permission was refused, but while waiting they were able to look at some stretches of drain wall, in which ditches comparable to those of Phase 5 at Kuk were exposed (Jack Golson, personal communication, 2002).

⁶ The archaeological finds at Kindeng have not been cross-correlated with those at other wetland sites (Jack Golson, personal communication, 2001).

Guinea occurred within a pre-Austronesian time frame (Denham and Donohue 2009; Donohue and Denham 2009, 2010). Musa acuminata ssp. banksii-derived cultivars spread westward into eastern Island Southeast Asia, where they hybridized with other species and subspecies to produce more robust triploid cultivars that subsequently became widely dispersed throughout Southeast Asia and Africa, potentially to Kot Diji in Pakistan by ca. 4000 cal BP (Fuller and Madella 2009) and to Cameroon by ca. 2500 cal BP (Mbida Mindzie et al. 2001; cf. Neumann and Hildebrand 2009). These processes are suggestive of cultivation of bananas in parts of Island Southeast Asia before the advent of Austronesian language speakers from ca. 4000 cal BP.

Sugarcane (Saccharum officinarum)

Although widely perceived to be a snack food, sugarcane has been documented as a staple in parts of the eastern highlands of New Guinea (Daniels and Daniels 1993), and its importance in other regions in the past should be considered, especially as fodder. Sugarcane is an interspecific cultivar predominantly derived from the hybridization of Saccharum robustum and Saccharum spontaneum. The scenarios of sugarcane domestication are in some respects similar to that for Eumusa bananas, namely, initial domestication in New Guinea with subsequent westward dispersal and interspecific hybridization in Southeast Asia (Grivet et al. 2004). Although the origin and domestication of sugarcane has long been presumed to have occurred in New Guinea, alternative origins in East Asia have been proposed (Daniels and Daniels 1993) and are yet to be fully investigated.

The initial stages of sugarcane domestication were proposed to comprise the anthropic selection and domestication of a wild ancestor of Saccharum robustum in New Guinea (Simmonds 1976:104–108). Lebot advanced this scenario in his evaluation of the molecular evidence to suggest that S. robustum is the most likely precursor of sugarcane and was domesticated in New Guinea where human selection of chewing plants with sweet juice and low fibre produced the S. officinarum clones. Cultivars were subsequently differentiated in numerous distinct morphotypes via vegetative propagation and selection of somatic mutants. (Lebot 1999:622–623)

Lebot (1999) concludes that “S. officinarum cultivars are derived from introgressions between wild forms of S. robustum and S. spontaneum in Melanesia” (623). Lebot envisages a similar domestication scenario for Saccharum edule, a plant cultivated in New Guinea for its aborted inflorescences. While agreeing that initial domestication of S. robustum occurred in New Guinea, Grivet et al. (2004) consider that the resultant cultivar dispersed westward to Southeast Asia, where it hybridized primarily with wild populations of S. spontaneum to produce S. officinarum as well as with other species to produce other cultivars.

Archaeobotanical evidence of any antiquity for sugarcane
interbreeding and intermixing of diploid taro populations in diversity (Lebot et al. 2004). Based on current evidence, the clearly distinguishable, and each exhibits relatively low genetic of diploid cultivars in Southeast Asia and New Guinea are Guinea (Irwin et al. 1998; Lebot et al. 2004). The gene pools independent domestications of taro in Southeast Asia and New (Lebot and Aradhya 1991). Recent research suggests inde- eastern India (Kurvilla and Singh 1981) to eastern Indonesia beyond that involving human management. Matthews 2003) and potentially species-specific pollinators research). The only approximate chronological information for the origin of sugarcane is linguistic and tenuous; a term for sugarcane, “*CebuS,*” reconstructs to proto-Austronesian, namely, the languages on Taiwan before the subsequent differentia- tion of Austronesian languages on Taiwan ca. 5,500 years ago (Blust 1984–1985; Pawley 2007). If the linguis- tical reconstructions are sufficiently specific, both botanically and chronologically, which is doubtful, then several stages in the domestication of sugarcane occurred before Austronesian lan- guage dispersal from Taiwan (Donohue and Denham 2010), including initial domestication of *S. robustum* in New Guinea, westward movement of the derived cultivar to Island Southeast Asia, and subsequent hybridization with *S. spontaneum.*

**Taro (Colocasia esculenta)**

Wild-type taro (*Colocasia esculenta var. aquatilis*), the pre- cursor to cultivated taro (*C. esculenta*), has a pantropical dis- tribution extending from northeastern India to mainland Southeast Asia, Indonesia, New Guinea, and northern Aus- tralia (Matthews 1995:108–114). The biogeographic and hu- man processes that created this wild-type distribution are un- known (Matthews 1991). Some regions, however, such as New Guinea, have endemic species-specific pests (*Tarophagus* spp., Matthews 2003) and potentially species-specific pollinators (Matthews 1995), suggesting a long antiquity for the plant beyond that involving human management.

The locus of taro domestication has been variably deter- mined based on different types of analysis, that is, from north- eastern India (Kurvilla and Singh 1981) to eastern Indonesia (Lebot and Aradhya 1991). Recent research suggests inde- pendent domestinations of taro in Southeast Asia and New Guinea (Irwin et al. 1998; Lebot et al. 2004). The gene pools of diploid cultivars in Southeast Asia and New Guinea are clearly distinguishable, and each exhibits relatively low genetic diversity (Lebot et al. 2004). Based on current evidence, the interbreeding and intermixing of diploid taro populations in Southeast Asia and New Guinea were prevented through re- productive isolation, whether geographically or culturally de- termined (Lebot 1999:624).

Archaeobotanical and paleoecological research indicates that taro was potentially exploited during the Pleistocene in Island Melanesia (Loy, Spriggs, and Wickler 1992) and on Borneo (Barton and Paz 2007). At ca. 10,000 cal BP, taro was exploited at Kuk Swamp in the highlands of New Guinea (Fullagar et al. 2006), and taro pollen was present in northern Australia (Haberle 2005) and lowland New Guinea (Haberle 1995). Despite the relative ubiquity of the plant, the potential exploitation of taro during the Pleistocene and early Holocene is significant because of the processing required to remove acridity and increase the edibility of wild types.

**Greater Yam (Dioscorea alata)**

The natural distribution and locus of domestication for greater yam (*Dioscorea alata*) are unknown. Current pantropical distributions of *D. alata* cultivars are generally ac- cepted to result from human agency, namely, vegetative prop- agation of clones, even though the plant can become a persistent weed once established in a region. Morphological, enzymatic, and physicochemical characteristics are not solely due to somatic mutation and asexual reproduction; some sexual reproduction is represented (Lebot et al. 1998).

Limited intraspecific differentiation of *D. alata* cultivars reflects geography, morphology, isozymes, and physicochemical characteristics, but there are few correlations among att- ributes (Lebot 1999:624–625; Lebot et al. 1998; Malapa et al. 2005). For example, the high degree of morphological vari- ation within *D. alata* represents phenotypic elasticity and not genotypic variation (Malapa et al. 2005). Effectively, widely dispersed cultivars are clones with a narrow genetic base (Le- bot 1999:625).

Several authors consider the New Guinea region to be the locus of initial *D. alata* domestication because it exhibits the greatest morphological variation and genetic diversity (Cour- sery 1972, 1976; Lebot 1999; Martin and Rhodes 1977). As De Candolle noted (1884:13), however, the determination of or- 

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alocasia macrorrhiza</em></td>
<td>Giant taro</td>
<td>Lebot 1999</td>
</tr>
<tr>
<td><em>Artocarpus alitif</em></td>
<td>Breadfruit</td>
<td>Zerega, Ragone, and Motley 2004</td>
</tr>
<tr>
<td><em>Musa</em> spp. (<em>Australimusa</em> section)</td>
<td>Feʻi bananas</td>
<td>Sharrock 2001</td>
</tr>
<tr>
<td><em>Colocasia esculenta</em></td>
<td>Taro</td>
<td>Lebot et al. 2004</td>
</tr>
<tr>
<td><em>Cyrtosperma chamissonis</em></td>
<td>Giant swamp taro</td>
<td>Lebot 1999</td>
</tr>
<tr>
<td><em>Dioscorea alata</em></td>
<td>Greater yam</td>
<td>Malapa et al. 2005</td>
</tr>
<tr>
<td><em>Musa</em> spp. (<em>Eumusa</em> section)</td>
<td>Bananas and plantains</td>
<td>Perrier et al. 2009</td>
</tr>
<tr>
<td><em>Metroxylon sagu</em></td>
<td>Sago</td>
<td>Kjær et al. 2004</td>
</tr>
<tr>
<td><em>Saccharum officinarum</em></td>
<td>Sugarcane</td>
<td>Grivet et al. 2004</td>
</tr>
</tbody>
</table>

Note. Some plants have undergone independent domestication events elsewhere (e.g., taro and aerial yam).
forms (namely cultivars) and not on the diversity of cultivars. Perhaps the most compelling evidence for Wallacea and Sahul being the locus of origin of *D. alata* is the genetic proximity of this species to two other yam species derived from the same regions, *Dioscorea nummularia* and *Dioscorea transversa* (Malapa et al. 2005:928). Although circumstantial, the New Guinea region seems to be the place of *D. alata* origin and domestication from which cultivars were dispersed clonally across the globe.

There is no definitive archaeobotanical evidence for *D. alata* predating ca. 3500 cal BP (Paz 2005). Nonspecific yam residues dating to the early Holocene have been identified on stone tools in Island Melanesia (Barton and White 1993) and at Kuk Swamp (Fullagar et al. 2006). The reporting of “*Dioscorea* sp., possibly *D. alata*” (Barton 2005:66) at Niah cave in Borneo should be treated as provisional. Despite the ambiguities of archaeological, botanical, and genetic evidence, the proposed domestication of *D. alata* in the New Guinea region is currently the most plausible interpretation. Clones were subsequently dispersed over a wide geographical area, including Island Southeast Asia, Southeast Asia, and Africa as well as eastward into the Pacific.

**Implications for Understanding Plant Domestication Mosaics in Island Southeast Asia**

There is no doubt that the New Guinea region was a major center of plant domestication (Lebot 1999). It is also important to note that the crop domestication histories and dispersals outlined above do not follow similar historicogeographical pathways. These plants are unlikely to have spread westward from New Guinea as part of a coherent (horti)cultural package, although dispersal of crop associations may have potentially occurred from Island Southeast Asia to other regions, such as to parts of mainland Southeast Asia, South Asia, and Africa. Bananas and sugarcane are suggestive of westward dispersal from New Guinea with subsequent hybridizations in Southeast Asia. Taro is suggestive of independent domestications in New Guinea and Southeast Asia with geographical and cultural isolation between cultivar gene pools. Greater yam is suggestive of domestication in New Guinea with subsequent widespread dispersal of clonally reproduced cultivars. Presumably some plants did not move, such as taro and some yams (*e.g.*, *Dioscorea bulbifera*; Lebot 1999), because they were relatively ubiquitous resources across New Guinea and Island Southeast Asia, were subject to varying local forms of management and domestication, or were less significant than alternatives and can therefore be assumed not to have been highly prized trade items (Denham 2010).

In the absence of archaeobotanical verification, there seems to have been a westward movement of bananas and sugarcane precursor from New Guinea before the arrival of Austronesian language speakers from Taiwan after 4000 cal BP. These dispersals were facilitated by intersland interaction within Island Southeast Asia (Bulbeck 2008; Donohue and Denham 2010); localized exchange networks between islands resulted in the net transfer of ideas and things over vast regions. The plants would have been moved and planted rather than solely being tradable commodities exchanged via long-distance voyaging. At present, it is not clear whether crop plants spread together with practices of cultivation and processing or whether cultivars were introduced and adopted into preexisting plant exploitation mosaics across Island Southeast Asia. The time depth of these practices and dispersals across Island Southeast Asia is similarly enigmatic, although they seemingly predate 4000 cal BP.

In sum, it is proposed that people in parts of Island Southeast Asia practiced forms of cultivation before Austronesian language dispersal. At present the history of these presumably nascent agricultural practices is unknown, and it is unclear whether they were in situ developments or were introduced from Asia or New Guinea. Arguably, people inhabiting parts of Island Southeast Asia had comparable orientations to plant resources to those documented for parts of New Guinea, including plant management, vegetative propagation, and cultivation.

**Conclusions**

In this article, a multidimensional model of early agriculture has been applied at two different scales of analysis: a contextual application at the landscape scale and a comparative application at the regional scale. The emergence and transformation of agriculture in the highlands of New Guinea is discussed with respect to multidisciplinary evidence from the Upper Wahgi Valley. In contrast to previous publications, which have emphasized environmental and technological transformations, the focus here has been on the changing nature of domesticatory relationships through time. A similar theme was applied to understanding the dispersal and non-dispersal of crop plants from New Guinea to Island Southeast Asia; the focus was on crop-plant domestication and dispersal with a view to eliciting an impression of plant exploitation mosaics that are, in the main, currently invisible to archaeological and paleoecological research.

The variability in plant exploitation practices and crop plants witnessed for New Guinea in the recent past and reconstructed for the distant past are likely to apply to parts of Island Southeast Asia before any Austronesian influence on the region. Plant exploitation mosaics are likely to have included parts of Island Southeast Asia and New Guinea for much of the Holocene as well as other parts of Near Oceania and potentially northern Australia. Food plants (and plants used for other purposes) were incorporated in varying degrees of domestication into these plant exploitation mosaics as evidenced by the westward dispersal of *Musa* bananas and a domesticated form of *Saccharum robustum* (sugarcane precursor), which indicates that the region’s inhabitants had an orientation to plant resources that plausibly included forms of cultivation.
The framing of early agriculture within a broader set of human-environment relationships is intended to free discussion from conceptually restrictive debates regarding definitions and causation. The multidimensional perspective outlined here is designed to be an enabling framework for interpretation rather than to be prescriptive. Viewing early agriculture through the multidimensional lens of human-environment interactions provides an integrated perspective to understand how agriculture emerged and transformed in the past. Instead of prioritizing one epiphenomenon of agriculture, most often domestication, the generic framework encompasses biological, environmental, social, and technical domains. Although illustrated with respect to the evidence from New Guinea and Island Southeast Asia, the concepts have broader applicability. The comparative application of this generic framework would enable commonalities and differences, both of kind and emphasis, to be determined from the diverse multifaceted expressions of early agriculture in different regions of the world.

Acknowledgments

Many thanks to Ofer Bar-Yosef and Doug Price, as well as to the Wenner-Gren Foundation, for the invitation to “The Origins of Agriculture: New Data, New Ideas” symposium. The ideas in this article were stimulated by participants at the symposium and derive from several significant collaborations, most especially with Huw Barton, Mark Donohue, Jack Golson, and Simon Haberle. I would like to acknowledge their profound contributions to my thinking and research. I also thank Mike Bourke, Edmond De Langhe, Carol Lentfer, Karina Neumann, and Xavier Perrier for giving me permission to cite what was at the time unpublished research. Thanks to Uri Gilad for assistance with figure 3 and Kara Rasmanis for the production of the other figures.

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Domestication Processes and Morphological Change
Through the Lens of the Donkey and African Pastoralism

by Fiona Marshall and Lior Weissbrod

Little is known about the beginnings and spread of food production in the tropics, but recent research suggests that definitions that depend on morphological change may hamper recognition of early farming in these regions. The earliest form of food production in Africa developed in arid tropical grasslands. Animals were the earliest domesticates, and the mobility of early herders shaped the development of social and economic systems. Genetic data indicate that cattle were domesticated in North Africa and suggest domestication of two different African wild asses, in the Sahara and in the Horn. Cowpeas and pearl millet were domesticated several thousand years later, but some intensively used African plants have never undergone morphological change. Morphological, genetic, ethnoarchaeological, and behavioral research reveals relationships between management, animal behavior, selection, and domestication of the donkey. Donkeys eventually showed phenotypic and morphological changes distinctive of domestication, but the process was slow. This African research on domestication of the donkey and the development of pastoralism raises questions regarding how we conceptualize hunter-gatherer versus food-producer land use. It also suggests that we should focus more intently on the methods used to recognize management, agropastoral systems, and domestication events.

The question of whether understanding of the beginnings of food production is being constrained by definitions and methods of detection that focus on morphological change rather than management is becoming a major theme in studies of the origins of agriculture. Recent research in the humid tropics of southeastern Asia and the Pacific suggests that definitions that depend on morphological change hamper recognition of early farming in these areas (Bayliss-Smith 2007; Denham 2007, 2011). This perspective has so far centered on plants of the humid tropics that have a history of long-term cultivation in agricultural systems but lack morphological change (Denham 2007; Kahlheber and Neumann 2007; Yen 1989).

Another feature of both humid and arid tropical agricultural practices that has strained conceptions of early agricultural systems is the variety of economic activities—including fishing, gathering, hunting, cultivation, and herding—that may be combined in complex and diverse subsistence systems. In their approach to definitions and the question of whether morphological change is an effective marker of domestication, Jones and Brown (2007) focus on selection processes and timing rather than on region. They contend that under certain circumstances, practices of cultivation and protective tending could have resulted in stable long-term systems of food production that depended on plants and animals lacking distinctively domestic morphological and genetic characteristics. Reproductive isolation and morphological change, Jones and Brown (2007) go on to suggest, are linked with later stages of agricultural development, when human populations expanded and people removed plants and animals from their wild ranges.

There is a growing appreciation, however, of differences among species in time elapsed before domestication processes are readily detectable and of variability in the sensitivity of methods that can be brought to bear on any given taxon. In a detailed study of the domestication of goats in western Asia, Zeder (Zeder 2008; Zeder and Hesse 2000) used regional and age- and sex-based variability in animal size to document early herd management, which was followed by diminution in size. In the absence of clear morphological indicators, evidence for management—culling, corralling, and milking—has also been

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key to a better understanding of early phases of domestication of the horse (Outram et al. 2009). The discovery by Rossel et al. (2008) that donkeys used by Egyptian pharaohs for transport at approximately 5000 cal BP (historic date 3000 BC; table 1) remained morphologically wild 1,000 years after they were thought to have been first domesticated further emphasizes possibilities for underestimating the timing of domestication of large mammals and draws attention to species-specific pathways to domestication (see also Zeder 2011).

In the light of these different emphases on global, regional, and taxon-specific impacts of late morphological change on general understanding of early food production, we evaluate current perspectives on the beginnings of food production in Africa, a continent that represents the world’s largest tropical landmass. We reexamine evidence of early animal and plant domesticates and employ ethnoarchaeological data on donkey management and breeding behavior to examine species-specific domesticatory practices that influenced selection and the likelihood of morphological change. These analyses allow us to return to the larger question of Africa’s contribution to understanding variability in early agricultural systems worldwide. In most of Africa, pastoralism is considered the earliest form of agriculture, followed by plant cultivation and adoption of mixed herding-cultivation systems.

### Early Food Production in Africa

Africanists have built up a picture of the beginnings of food production in which early dependence on domestic animals and increasing reliance on mobility guided the development of social and economic systems of the Early Holocene and resulted in late domestication of African plants. Specific themes that have emerged include locally and socially contingent responses to large-scale climatic change, domestication of cattle for food and donkeys for transport, intensive hunting and possible management of Barbary sheep, long-

<table>
<thead>
<tr>
<th>Taxon, region</th>
<th>Site, period (cal BP)</th>
<th>Argument for management/domestication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbary sheep:</td>
<td>Uan Afuda Uan Tabu; tenth to ninth millennium</td>
<td>Caprine dung in shelter suggests penning; plant remains suggest foddering</td>
</tr>
<tr>
<td>Cattle:</td>
<td>Nabta Playa; eleventh to tenth millennium</td>
<td>Cattle out of wild range; provisioning of water from well</td>
</tr>
<tr>
<td>Modern African cattle</td>
<td>Sheko, Ethiopia; Ndama, Mali</td>
<td>Modern cattle genetics: mitochondrial, microsatellite, Y-chromosome, Y2 data distinctive of Africa; geographic patterning</td>
</tr>
<tr>
<td>Donkeys:</td>
<td>Maadi, Merimde, Hierakonpolis; mid-seventh millennium Abydos; ∼5000 cal BP</td>
<td>Donkey bones, some smaller than wild ancestor’s</td>
</tr>
<tr>
<td>Nubian/Somali wild ass, donkeys</td>
<td>Sahara, Horn</td>
<td>Modern donkey and wild ass genetics: mitochondrial, genetic variability, ancient DNA</td>
</tr>
<tr>
<td>Sorghum:</td>
<td>Um Direiwa; seventh millennium</td>
<td>Intensive use of grains, no morphological change, 20,000 grindstone fragments</td>
</tr>
<tr>
<td>Sahel</td>
<td>Qasr Ibrim; early second millennium</td>
<td>Morphological change</td>
</tr>
<tr>
<td>Cow pea: West Africa savanna, forest B-sites, Birimi</td>
<td>Early fourth millennium</td>
<td>Morphological change</td>
</tr>
<tr>
<td>Tef: Ethiopia, high altitude</td>
<td>Aksum, Ona Nagast; early second millennium</td>
<td>Morphological change, no size decrease</td>
</tr>
<tr>
<td>Roselle, baobab, shea butter: West African park savanna</td>
<td>Early second millennium</td>
<td>Common in sites; heavily used today, but no morphological change</td>
</tr>
<tr>
<td>Oil palm, canarium, yams: West African tropical forests</td>
<td>Early second millennium</td>
<td>Common in sites, heavily used, no morphological change; yams: no preservation, morphological change?</td>
</tr>
</tbody>
</table>
term reliance on a broad range of wild plants and animals, and late domestication of African plants.

In this review of the African evidence, we see domestication as a microevolutionary process that transformed animal and plant communities and human societies (see Clutton-Brock 1992), but we examine rather than assume relationships between domestication and long-term genetic and morphological change (see also Vigne et al. 2011). We follow Zeder (2009, 2011; Rindos 1984) in emphasizing long-term coevolutionary relations between people, animals, and plants, but unlike Rindos (1984), we also highlight the intentional role that individuals played in selection (Hildebrand 2003b; Marshall and Hildebrand 2002). Pastoralism is also an important concept for discussions of the beginnings of food production in Africa, and this, we argue, differs from herding or simple keeping of animals because pastoralists rely on moving livestock to pasture and emphasize the social and symbolic role of domestic animals (Dyson-Hudson and Dyson-Hudson 1980; Smith 2005; Spear and Waller 1993). This does not necessarily imply, however, a diet heavily based on domestic animals. Historically, African pastoralists prioritized the needs of their herds in scheduling activities and locating settlements (McCabe 2004; Western and Dunne 1979), but they usually relied on a broad range of complementary subsistence strategies ranging from seasonal cultivation, fishing, hunting, and gathering to food exchange or trade (Dyson-Hudson and Dyson-Hudson 1980; Evans-Pritchard 1940; Schneider 1979). As a result, it is overly simplistic to rely on high proportions of domestic animal bones to differentiate pastoral from hunter-gatherer or farming sites. Multiple lines of evidence are necessary, including households oriented to mobility— with slope, soil, and vegetation characteristics organized around the needs of domestic herds (Western and Dunne 1979)—animal pens, dung deposits (Shahack-Gross, Marshall, and Weiner 2003; Shahack-Gross, Simons, and Ambrose 2008), milk residues (see Evershed et al. 2008), livestock-focused rock art, and ritual livestock burials (di Lernia 2006).

Domesticatory Settings: Climatic and Social Variability and Subsistence Intensification

Large-scale climate change forms the backdrop to the beginnings of food production in northeastern Africa (Kröpelin et al. 2008). Hunter-gatherer communities deserted most of the northern interior of the continent during the arid glacial maximum and took refuge along the North African coast, the Nile Valley, and the southern fringes of the Sahara (Barich and Garcea 2008; Garcea 2006; Kuper and Kröpelin 2006). During the subsequent Early Holocene African humid phase, from the mid-eleventh to the early ninth millennium cal BP, ceramic-using hunter-gatherers took advantage of more favorable savanna conditions to resettle much of northeastern Africa (Holl 2005; Kuper and Kröpelin 2006). Evidence of domestic animals first appeared in sites in the Western Desert of Egypt, the Khartoum region of the Nile, northern Niger, the Acacus Mountains of Libya, and Wadi Howar (Garcea 2004, 2006; Pollath and Peters 2007; fig. 1).

During the Early and mid-Holocene, diverse hunter-gatherer groups lived close to permanent water in widely separated regions of northeastern Africa, from the Acacus to Lake Victoria (Caneva 1988; Garcea 2006; Holl 2005; Prendergast and Lane 2010). Ethnoarchaeological research suggests that this social and economic variability played a significant role in pathways to food production in Africa. Recent hunter-gatherers with long-term investment in hive and trap construction and delayed-return social systems and limited sharing have historically been able to accommodate more easily property-rights issues arising out of time investment in agriculture than have those with highly egalitarian norms (Brooks, Gelburd, and Yellen 1984; Dale, Marshall, and Pilgram 2004; Marshall 2000; Smith 1998; Woodburn 1982). Moreover, cattle herding requires significantly greater commitment than cultivation because foragers can tend crops intermittently and accommodate them into flexible hunter-gatherer schedules, whereas animal herds require protection against predators and constant attention (Dale, Marshall, and Pilgram 2004; Marshall 2000). As a result, Africanists have hypothesized that domestication of cattle is more likely to have been undertaken and pastoralism adopted in regions of northeastern Africa that were occupied by complex rather than highly mobile egalitarian hunter-gatherers (Marshall and Hildebrand 2002).

Arguments that complex or delayed-return systems of social organization existed in the Acacus, the Sudanese Nile Valley, and some other regions of the African Early to mid-Holocene are based on elaboration of material culture, including manufacture of ceramics and storage facilities in these areas and highly patterned use of rock-shelter sites and local landscapes (Barich 1987; di Lernia 1999, 2001; Garcea 2004; McDonald 2008). Significant investment in living spaces and limited movement are indicated by hut construction at Nabta Playa in the Acacus Mountains and the northern Sudanese Nile Valley and by isotopic analyses at Gobero in Niger and Acacus sites (Barich 1987; Garcea 2006; Sereno et al. 2008; Tafuri et al. 2006). In the central Sahara, the Sudanese Nile Valley, and the Acacus, human burials are common (Caneva 1988; Honegger 2004; Sereno et al. 2008). Garcea (2004) and di Lernia (1999, 2001) argue that their presence in the Late Acacus phase (ca. 10,250–9600 to 9890–9440 cal BP) may relate to group identities and rights to land.

North African hunter-gatherers of the Early and mid-Holocene employed highly diverse subsistence as well as social systems. Wild cattle (Bos primigenius) were hunted along the Mediterranean coast and the Nile Valley, and small numbers of wild ass (Equus africanus) were also present in many sites (Alhaïque and Marshall 2009; Gautier 1987a; Marshall 2007). Barbary sheep (Ammotragus lervia) were the most common animal hunted across North Africa at this time (di Lernia 2001; Gautier 1987a; Saxon et al. 1974). In the Late Acacus sites of Ti-n-Torah, Uan Tabu, and Uan Afuda, intensive exploitation of wild cereals (e.g., Echinochloa, Panicum, Setaria, Digitaria,
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Figure 1. Map of North Africa showing the location of sites mentioned in the text.

and *Pennisetum* is associated with heavy grindstone use (di Lernia 1999; Garcea 2001; Mercuri 2001; fig. 1). A similar set of wild grass seeds were harvested, processed, and stored in the eastern Sahara during the late tenth and early ninth millennia at Nubta Playa, site E-75-6 (Wasylikowa et al. 1993; Wendorf and Schild 1998; for radiocarbon dates, see table 2). Along the Sudanese Nile, a variety of wild mammals were hunted in conjunction with fishing for large deepwater fish and intensive grindstone use (Caneva 1988; Haaland 1987).

Taming of Barbary sheep. There has been a recurrent suggestion that some North Africans penned and culled Barbary sheep herds during early phases of the Holocene (di Lernia 1998, 2001; Garcea 2006; Saxon et al. 1974; table 1). Earlier arguments for management without morphological change were based on young male–dominated culling profiles from the sites of Tamar Hat and Haua Fteah on the Mediterranean coast (Saxon et al. 1974; Smith 2008; fig. 1). More recent evidence is based on the presence of dung accumulations in the rear of rock-shelter sites occupied by complex hunter-gatherers during the tenth and early ninth millennia cal BP in the Libyan Acacus at Uan Afuda, Uan Tabu, and Fozzigiaren (Cremaschi and Trombino 2001; di Lernia 2001; Garcea 2006). Di Lernia (2001) argues that dense dung deposits in these rock shelters differ from natural dung accumulations characterized by loose and scattered pellet matrices and result instead from use of shelters for coralling animals. Micromorphological analyses of the “dung layer” sediments suggest trampling and indicate the presence of spherulites common in caprine dung, and studies of the plant remains indicate a selected range of plant species suggestive of foddering (Castelletti et al. 1999; di Lernia 2001; Mercuri 1999). Interestingly, Livingstone Smith (2001) notes that hunter-gatherer pottery of Late Acacus levels at Uan Afuda is dung tempered, a characteristic of later pastoral ceramics. The number of Barbary sheep remains declines in later sites, however, and there are no dung deposits that suggest subsequent emphasis on Barbary sheep (di Lernia 1999; Garcea 2001, 2004). Taken together, the micromorphological and archaeological evidence for dung accumulation resulting from penning of Barbary sheep in the Late Acacus rock shelters is suggestive, but additional faunal data and dung deposits are needed from open-air sites.

Domestication of African cattle? The evidence for taming of wild cattle during the Early Holocene provides an interesting
parallel to that for management of Barbary sheep. Wendorf and colleagues (Gautier 1987b; Wendorf and Krölik 2001; Wendorf and Schild 1998; Wendorf, Schild, and Close 1984) have argued that seasonally settled hunter-gatherers of the Nabta Playa region (fig. 1) domesticated African cattle in the Western Desert of Egypt during the eleventh to tenth millennium cal BP (reviews of arguments in Gilford-Gonzalez 2005; table 2). Domestic sheep and goats, on the other hand, were introduced to Africa from southwestern Asia during the early eighth millennium cal BP and postdate the appearance of cattle at all sites except Uan Muhaggiag (Gautier 2001; Linseele 2010; Linseele et al. 2010). The independent domestication of African cattle has been tied to arid episodes, the desire of hunter-gatherers for increased short-term predictability in food resources, and the difficulty of intensifying plant foods under these conditions (Marshall and Hildebrand 2002). Bos remains are ubiquitous in sites of the Nabta and Bir Kiseiba regions (fig. 1) from the eleventh to the tenth millennium cal BP (table 2) but in very small numbers, precluding detailed analyses of morphometric change or reconstruction of culling profiles (Gautier 2001). Linseele (2004) has demonstrated, however, that size decrease is not a useful indicator of domestication in northeastern Africa because the size of African Bos primigenius varied regionally and temporally and because ancient Egyptian longhorn cattle overlapped in size with some wild cattle populations.

Close and Wendorf (1992) and Gautier (1984b, 1987b) also argued, largely on the basis of a well and a watering basin at site E-75-6, that the repeated presence of water-dependent North African B. primigenius in Western Desert sites during the tenth and ninth millennia cal BP (table 2) reflected range extension facilitated by management and watering of cattle (table 1). Bos cranial remains in a human grave at El Barga could not be ruled out (Bradley and Magee 2006; but see Bradley et al. 1996). These findings are consistent with an independent African domestication, although the possibility of a demographic expansion of Near Eastern cattle in Africa could not be ruled out (Bradley and Magee 2006; but see Achilli et al. 2008). Recent analysis of single-nucleotide poly-

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Table 2. Radiocarbon dates for key African sites with evidence relating to management and domestication

<table>
<thead>
<tr>
<th>Taxon, site</th>
<th>Uncalibrated Age (BP)</th>
<th>Calibrated Age (BP)</th>
<th>Calendrical date (BC)</th>
<th>Material</th>
<th>Lab ID</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbary sheep:</td>
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<td>T-4045</td>
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<tr>
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<td>B-sites</td>
<td>3410 ± 60</td>
<td>3814–3574</td>
<td>1865–1625</td>
<td>Cotyledon</td>
<td>TO 11883</td>
<td>D’Andrea et al. 2007:689</td>
</tr>
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<td>Oil palm, morphologically wild:</td>
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<tr>
<td>Karkarichinkat</td>
<td>4011 ± 33</td>
<td>4519–4433</td>
<td>2570–2484</td>
<td>Seed</td>
<td>OxA16919</td>
<td>Manning et al. 2011:317</td>
</tr>
<tr>
<td>Dhar Tichitt</td>
<td>3500 ± 100</td>
<td>3898–3640</td>
<td>1949–1691</td>
<td>Grain</td>
<td>Pa-1157</td>
<td>Summarized in Neumann 2003:75</td>
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<tr>
<td>Birimi</td>
<td>3460 ± 200</td>
<td>3977–3475</td>
<td>2028–1526</td>
<td>Grain</td>
<td>TO-8172</td>
<td>D’Andrea, Klee, and Casey 2001:343</td>
</tr>
</tbody>
</table>

Note. All calibrated BP ages and calendrical dates were calculated with IntCal 09, OxCal v4.1 (Bronk Ramsey 2009), with 68.2% confidence (1-σ range). Note that only the earliest and latest dates from each site are reported here.
It has long been suggested that ancient Egyptians domesticated the donkey (Equus asinus), although the Near East has also been considered a possible area of origin. Egyptian Predynastic sites have yielded the earliest potential domestic donkeys, which date to the mid-seventh millennium cal BP (historic date 4600–4400 BC; Boessneck and von den Driesch 1990; table 1). Some faunal elements from these sites, zooarchaeologists argue, exhibit size decreasement relative to the wild ass (Boessneck and von den Driesch 1990), but widespread morphological change was slow to develop in ancient Egypt. Evidence of bone pathologies from early dynastic donkey burials at Abydos (fig. 1) demonstrates that by approximately 5000 cal BP (historic date 4600–4400 BC), First Dynasty Egyptian kings were using donkeys to carry heavy loads (Rossel et al. 2008). Rossel et al. (2008) show, however, that these animals were not yet morphologically distinguishable from the African wild ass.

Recent studies of genetic variability in modern donkeys suggest that prehistoric pastoralists may have domesticated donkeys on the fringes of the Sahara. Beja-Pereira and colleagues (2004; also Vilá, Leonard, and Beja-Pereira 2006) documented the existence of two different haplogroups or clades of domestic donkeys. Their genetic-diversity data suggest two domestication events, both in northeastern Africa. Kimura et al.’s (2010) recent analysis of ancient DNA from the Nubian donkey (Equus africanus africanus) and the Somali wild ass (Equus africanus somaliensis) demonstrates that the Nubian wild ass was the ancestor of modern donkey Clade I but that the ancestor of donkeys of Clade II is currently unknown. This research also documents the ancient distribution of the Nubian wild ass and Clade I donkeys from the Atbara River and Red Sea Hills in Sudan and northern Eritrea across the Sahara to Libya, a geographic distribution that suggests that prehistoric pastoralists domesticated Clade I donkeys (Kimura et al. 2010). However, domestication by pastoralists or farmers of the northern Nile Valley during late prehistoric/early Predynastic times is also a possibility.

The Herding-Hunting Mosaic and the Spread of Pastoralism

In the central Sahara, cattle became common in the eighth to sixth millennium cal BP at sites such as Ti-n-Torha, Uan Muhaggiag, Uan Telocat, Adrar Bous, Gobero, Enneri Bardagué, and Wadi Howar (Clark et al. 2008; di Lernia 2006; Jesse et al. 2007; Roset 1987). Interestingly, recent research has documented lactase persistence among some contemporary African hunter-gatherers, a practice that archaeologists have tended to assume was adopted after herding for blood and meat and with some difficulty (but see Linseele 2010).

Different genetic bases for lactase persistence in Europe and Africa show coevolution between people and cattle and the strong selective advantage conferred by drinking milk (Tishkoff et al. 2006). Interestingly, recent research has documented lactase persistence among some contemporary African hunter-gatherers. Tishkoff et al. (2006, supplementary information) note that lactase persistence could be selected for by delaying weaning of infants and, moreover, that the trait is also adaptive for digestion of certain roots and barks. This suggests several pathways to lactase persistence among hunter-gatherers and raises the question of whether African herd...
milked their cattle earlier and incorporated dairy products into their diets with fewer digestive difficulties than previously thought. However, milking scenes depicted in prehistoric African rock art and in Saharan ceramics have so far not produced dates or residues that bear on the antiquity of milking in Africa (Jesse et al. 2007; Marshall 2000).

Oscillating periods of aridity and humidity resulted in periods of increased mobility and occasional depopulation of the Sahara (di Lernia 2002; Garcea 2004; Kröpelin et al. 2008). In the eighth to seventh millennia cal BP, herders combined livestock keeping with hunting and collection of wild grain in regions such as the Acacus Mountains (Gautier 1987b). At Adrar Bous and other sites near lowland lakes, herders also fished and collected shellfish (Gifford-Gonzalez 2005; Smith 1992; fig. 1). Cattle-focused rock art attests to the symbolic importance of cattle for Saharan herders (Holl 2004; Smith 1992, 2005). Hunter-gatherers also flourished during this period at sites such as Dakleh Oasis (McDonald 2008) and Amejni (Camps 1969; fig. 1), creating a mosaic of hunters and herders across northeastern Africa (fig. 1).

Through the mid-Holocene, grasslands became more arid, precipitation became increasingly unpredictable, and desert regions of the Sahara expanded. Northeastern Africans responded to these pressures by heightening mobility, relying on introduced sheep and goats, and decreasing use of wild cereals (Barich 2002; di Lernia 2002; Garcea 2004; Gautier 1987a). It was during this period that the domestication of cattle was documented (Rossel et al. 2008). Their use would have made increased residential mobility and dispersal of settlements from water possible and would have facilitated long-distance migrations (Marshall 2007).

Significant expansion of the geographic distribution of the dotted-wavy-line ceramic motif and distinct human mortuary practices in the early seventh millennium cal BP reflect the southward movement of pastoralists, long-distance contacts among Saharan groups, and elaboration of pastoralist ideologies (Jesse et al. 2007; Keding, Lenssen-Erz, and Pastoors 2007; Smith 1992; Wendorf and Krölik 2001). Just as in the Mediterranean and western Europe, however, the trajectories of small immigrant groups may have varied greatly (Özdoğan 2011; Rowley-Conwy 2011). Domestic stock appear to the south in the Sudanese Sahel by the early seventh millennium cal BP at Esh Shaheinab and Kadero (Gautier 1984a, 1984b) and by the mid-fifth millennium cal BP in Kenya (Marshall and Hildebrand 2002). Similarly, Saharan lithics and other traces of Saharan herders are first found in the West African Sahel by approximately 4500 cal BP (Jousse et al. 2008; Linseele 2010; Smith 1992). Di Lernia (2006) argues that the widespread ritual burial of cattle across the Sahara at the end of the seventh millennium BP represents a social response to rapid aridification. Cattle burials and associated ritual activity are a prominent feature of site E-96-1 at Nabta (Wendorf and Krölik 2001). At Djabarana 84/13, in the middle of Wadi Howar at the beginning of the sixth millennium cal BP, more than a thousand pits are filled with cattle bones and relatively complete ceramic pots (Jesse et al. 2007; fig. 1). As far south as Kenya by the middle of the fifth millennium cal BP, large stone circles such as those at Jarijole were constructed as centers for human burial rituals by southward-migrating herders (Marshall, Grillo, and Arco 2011; Nelson 1995). Hunter-gatherers, however, continued to flourish after the movement of herders into these regions (Lane et al. 2007; Lesur, Vigne, and Guthertz 2007).

**Domestication of African Plants**

The earliest evidence for domestication of indigenous African plants with morphological change dates only to the beginnings of the fourth millennium cal BP (table 1). Although many Holocene hunter-gatherers of northeastern Africa relied heavily on wild Saharan cereals, high mobility and repeated abandonment of the region seem to have impeded long-term directional selection and morphological and genetic change. Instead, selection processes culminated in morphological change once Saharan herders settled in the southern reaches of the Sahara and more humid Sahelian regions and established more permanent settlements in areas that were still within or close to the edge of the wild range of Saharan species.

Sahelian herders—who also hunted, gathered, and fished—integrated cultivation of domestic pearl millet *Pennisetum glaucum* into their subsistence economies in one or two domestication events documented at or after 3898–3640 cal BP at sites west of Lake Chad, including Karkarichinkat Nord (KN05), Dhar Tichitt, Birimi, and Gajiganna (D’Andrea, Klee, and Casey 2001; Fuller 2007; Kahlheber and Neumann 2007; Manning et al. 2011; fig. 1, table 1). Morphologically, this is evidenced by changes in seed shedding and shape, although increases in seed size were delayed (D’Andrea, Klee, and Casey 2001). Fuller (2007) argues that the appearance of domestic pearl millet in India in the mid-fourth millennium cal BP indicates a somewhat earlier African domestication and rapid dispersal. Recent research has also shown that the cow pea *Vigna unguiculata* was also an early-fourth-millennium morphological domesticate, dating to ca. 3898–3475 cal BP at the Kintampo B-sites in the grasslands of central Ghana (D’Andrea et al. 2007; table 2). By contrast, African rice *Oryza glaberrima* was domesticated in the inland Niger delta of the Niger bend region by the early second millennium cal BP. On the eastern side of the continent, domestic teff *Eragrostis tef* and finger millet *Eleusine coracana* were cultivated by Aksumite populations in the Ethiopian highlands by the beginnings of the second millennium cal BP (historic date AD 150–350; D’Andrea 2008). The oil-seed noog *Guizotia abyssinica* is also present in Late Aksumite contexts (D’Andrea 2008). D’Andrea (2008) points out, however, that morphological change is difficult to identify in the small-seeded cereal teff, which was selected for reliable production under arid conditions rather than for increased seed size. In humid forested southwestern Ethiopia, Hildebrand (2003a, 2003b, 2007) has documented...
varied selection processes leading to domestication of yams *Dioscorea cayenensis* and ensete *Ensete ventricosum*. In these and other areas of Africa, domestic plants are thought to have been advantageous to pastoral hunter-fishers for risk minimization and greater predictability (D’Andrea et al. 2007; Kahlheber and Neumann 2007; Marshall and Hildebrand 2002).

Although morphological change occurred in a range of domesticated African plant taxa, it has been suggested that a number of African savanna plants were cultivated or intensively managed over the long term in ways that did not lead to morphological domestication (reviews in Marshall and Hildebrand 2002; Neumann 2005). Haaland (1999) and Abdel-Magid (1989) argued, largely on the basis of the ~30,000 grindstones that were unearthed at the site of Um Direiwa, for cultivation of sorghum *Sorghum bicolor* in Sudanese sites dating to the seventh millennium cal BP (table 1). Mechanisms that they suggested for late morphological change include continued outcrossing between cultivated and wild populations and harvesting through beating into baskets or uprooting. This has led to arguments that sorghum was not morphologically domesticated until it was removed from its wild African range (Haaland 1999; but see Fuller 2003). Although mechanisms exist that may have caused late morphological change in African cereals and harvesting of wild grains was at times intensive, there is no macrobotanical evidence or indication of landscape modification that supports claims for cultivation of African grains before the early fourth millennium cal BP.

In the wetter tropical regions, there is evidence of long-term use of a number of forest taxa without morphological change. Long-term use of oil palm *Elaeis guineensis* and incense trees *Canarium schweinfurthii* has been documented across the humid tropics of Africa (D’Andrea, Logan, and Watson 2006; Mercader et al. 2006). This pattern is not confined to forests, however. D’Andrea, Logan, and Watson (2006:216–217) argue that Kintampo people living in the grasslands of central Ghana employed a system of arboriculture that did not rely on management strategies that would result in morphological change. Kahlheber and Neumann (2007) also note that a number of west African park savanna species, such as baobab *Adsonia digita* and the shea-butter tree *Vitellaria paradoxa*, were protected and encouraged but never domesticated. Other wild plants that are still protected and sometimes actively sown in many different African environments include weedy green species ranging in status from crops to semidomesticated or wild (Kahlheber and Neumann 2007; Marshall 2001). Kahlheber and Neumann (2007:333) point out that in the West Africa Sahel, reliance on morphologically wild park savanna species became more evident when economies diversified and populations concentrated close to water 2,000 years ago. In many regions of Africa, Iron Age agriculturalists relied on a particularly broad range of resources, and farmers incorporated diverse domestic crops and managed plants, cattle, sheep, goats, dogs, and donkeys into their agricultural systems and fished and hunted a wide range of wild-animal foods (Casey 2005; Neumann 2005; Plug and Voigt 1985; van Neer 2000).

This brings to the fore the question raised at the outset of whether such diverse subsistence strategies fit current conceptions of agricultural systems. Kahlheber and Neumann (2007:339) are doubtful whether “farming” is an appropriate term for some of these ways of life. Smith’s (2001, 2011) term “low-level food production” has been used in the region, but it does not fully capture the complexities of African settings. The question of whether the Kintampo should be considered “foragers,” “farmers,” or something else has also been reviewed by Casey (2005) and by D’Andrea and colleagues (D’Andrea, Logan, and Watson 2006:216–218; D’Andrea et al. 2007), who argue that although there are clear-cut cases of foragers or farmers in Africa, there are many others that defy simple categorization. Hildebrand’s (2003) ethnographic research among the Sheko of southwestern Ethiopia and the literature on use of weedy greens in Africa (Etkin 1994; Fleuret 1979; Marshall 2001 and references therein) provide ample evidence that such subsistence strategies have long-term trajectories in many parts of Africa and cannot be dismissed as transitory.

Ethnoarchaeological Insight into Management, Selection Processes, and Domestication of the Donkey

One approach to better addressing conceptual problems presented by questions of late morphological change and the diversity of economic systems in Africa is to consider pathways to domestication for particular species in light of the potential for morphological change, or lack thereof, in specific social and environmental contexts. The question that we address here is how the behavior of the African wild ass and management of donkeys by herders and small-scale farmers in Africa contribute to selection processes and the likelihood of development of archaeological signatures of domestication in the donkey. This analysis focuses on aspects of the biology and behavior of the donkey and its use as a transport animal that influence management practices in extensive pastoral and agricultural systems and are relevant (sensu Wylie 2002) to ancient settings for domestication. It is often argued, for instance, that sociability and the presence of a dominance hierarchy are desirable characteristics for potential domesticatability (Clutton-Brock 1992; Diamond 1997). African wild ass do not, however, fit this profile. The extant Somali wild ass, or *dibokali*, is solitary or forms groups with weak short-term associations. It also lacks a pronounced dominance hierarchy (Klingel 1974; Moehlman 2002). This social system profoundly influences donkey behavior under human management.

Recent ethnoarchaeological research on donkey use and management among Maasai households in Kajiado District
of southern Kenya provides the first detailed information on selection processes in a pastoral social and economic context. During 2006, Lior Weissbrod lived in Maasai communities in the study area and collected interview and participant observation data from 26 women from eight households spread among six different pastoral settlements (table 3). The study focused on use and daily management, herd composition, mortality, and breeding behavior. After a 2-year period of severe drought (2004–2006), the donkey holdings of households participating in the study were reduced but still totaled 65.

Donkeys were not regarded as food. They were considered women’s animals, important for transport but without the symbolic status of cattle. Women were the caretakers of donkeys and used them to carry household goods during residential moves, to collect water, and to take intermittent trips to trading centers. Donkeys also carried meat, firewood, and water for large ceremonies. During the dry season, women went long distances for water every other day, returning with a typical load of 50 L per donkey. Children herded household donkeys with the calves, but during the wet season, donkeys were free ranging. Many families penned donkeys within the settlement thorn fence or in calf enclosures at night for protection against predators.

Our data show that the use of donkeys in Kajiado enhanced the flexibility and stability of local herding systems (see also Marshall 2007; Marshall and Weissbrod 2009). Families in the study area who did not own donkeys could not move as a whole away from permanent sources of water and were unable to make optimum use of available grazing. Donkeys were, nevertheless, managed less than other livestock. Marshall (2007) previously noted that the ability of donkeys to dig for water and to protect themselves from predators more successfully than other livestock was associated with low levels of management, which might result in low levels of selection. Our data show that behavior was a factor but that the level of use of donkeys in the study area ultimately determined the degree to which donkeys were herded and penned.

In addition to management practices, we also collected information on reproduction and desired characteristics of donkeys that might be selected for through strategic breeding. Women that we talked to particularly valued strength and calmness in a donkey. Some also mentioned the importance of disease and drought resistance, although they noted that donkeys were less vulnerable to these hazards than other livestock. We found, however, that participants in the study made no attempt at all to influence mate choice among donkeys or to breed for particular characteristics. The ancestry of a particular donkey was unknown except for the female parent. By contrast, research on cattle genealogies shows that Maasai herders memorize these in great detail for several generations (Ryan et al. 2000). The lack of strategic breeding of donkeys is influenced by donkey behavior and herd compositions but is also related, at least in part, to the fact that Maasai herders do not use donkeys as symbols of social transactions in the same way that they do cattle or value color distinctions ideologically.

The dynamics of wild ass mating systems, based on short-lived associations that occur when females move through male territories, influence donkey breeding in the domesticated environment. Maasai women stressed their concern with the aggressive behavior of jacks during mating. Even when they wanted to keep a female from breeding with an especially aggressive jack, women said that they found it impossible to keep the male away. They also noted that estrus jennies might go astray without warning in search of males. They are often lost this way, and we documented a number of cases in which wandering females, as well as males, were cared over a long term by women in distant settlements. Lack of selection because of the difficulty of controlling donkey breeding is, therefore, likely wherever a premium is placed on “wild” characteristics of the donkey, such as strength, rather than on docility and productivity for food. The relatively high proportion of males in herds (one male : two females) is another factor that makes control over breeding logistically difficult. Because donkey owners kept small herds specifically for transport, they

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<tr>
<th>Settlement, women</th>
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Table 3. Donkey holdings of eight Maasai households organized according to settlements and individual caretakers.
weighed the breeding advantages of females against the superior transport potential of males. The strength of males was greatly favored, and so was their consistent availability for transport use.

Herd growth and mortality patterns also contributed to patterns of selection in domestic donkey herds. Pastoral Maasai donkeys had, on average, a foal every 2 years. Mortality resulted from predation by hyenas, disease, and drought. Herds grew relatively slowly, and additional animals were recruited to herds through gifts, loans, and purchase. Socially based loans or exchanges of cattle are deeply woven into the fabric of Maasai society (Ryan et al. 2000). To a lesser extent, this system is also used for donkeys, and social exchange is a mechanism of selection and gene flow. Animals entering or leaving a herd through loans were carefully selected and predominantly female. In some cases, however, exchanges were involuntary, resulting from donkeys running away.

In the wet season, herds of donkeys made up of animals from different settlements in the same neighborhoods range freely. This practice and the system of intentional and unintentional loans maintain gene flow among settlements. Purchases were rarer than loans also but recruited animals to slow-growing herds and maintained intentional selection on an interregional scale. Men purchased animals when visiting markets, and the strength and price of the donkey were major considerations affecting purchases. Young male donkeys were cheaper than others, and purchases were one male : two females. There was no intentional culling of donkeys, and donkeys were not eaten, but small, slow-growing, or aggressive males were removed from the breeding pool through castration. We recorded six castrated males (40% of the males studied), and castration of male donkeys was a more important factor affecting the direction of intentional selection than culling or selective breeding.

Very few studies of donkey management and selection have been conducted in settled agricultural villages. Mohammed’s (1991) and Wilson’s (1991) Ethiopian research can, however, be used for comparison with the Maasai pastoral study. They focused on Ethiopian farmers of the central and southern highlands who used donkeys to transport grain to market and for hauling household firewood and water. Most families in the study areas kept one to two donkeys, usually female (Mohammed 1991; Wilson 1991). Donkeys were also loaned to family and friends. In the Awassa region, males were rare (100 females : 1 male); in other regions the number of males was higher (73 females : 27 males). Where males were more common, they were usually less than 4 years old. Mohammed (1991) notes that male donkeys were not castrated. We infer that low proportions of males in herds indicated male culling, although donkey eating was not discussed. People in Awassa did not supervise donkeys when they were not using them, and Mohammed (1991) documents minimal donkey management and poor animal nutrition in this area. Because of the danger presented by hyenas, however, people often brought donkeys inside their houses at night. There was no intentional control over breeding, however. Mohammed mentions that copulation might occur anywhere and was actively discouraged in the market center (Mohammed 1991).

Overview of management and selection. In order to consider patterns of directional selection, it is useful to examine factors that affect the likelihood of genetic drift, intentional selection, and reproductive isolation in donkeys managed by pastoralists and small-scale farmers. Culling of male donkeys by Ethiopian villagers and castration of male donkeys by Maasai pastoralists were important factors affecting selection. These practices ensured that males with desired traits, such as strength or size, remained in the breeding pool. Females, on the other hand, were never culled, and management of donkeys was minimal. None of the donkey owners that we studied tried to ensure a diverse set of breeding males, to breed select females or males, or to keep records of parentage. We argue that these management practices are influenced by wild ass and donkey courtship and breeding behavior and have significant consequences for long-term directional selection and domesticatory processes. The data also indicate that different sets of functional and symbolic considerations affect Maasai practices of cattle and donkey management and are associated with differing levels of selective pressure and control of gene flow. In our study area, people also bred or obtained cattle for ideal coat colors and conformation, and it is possible that without this additional symbolic motivation, functional reasons for breeding donkeys were not enough to overcome significant practical difficulties. As research on mammals such as the fur fox (Belyaev 1979; Trut 1999) and the guinea pig (Künzl et al. 2003) has shown, without selective breeding, retention of individual animals with desired traits and culling of others, directional selection may be very slow or fail to occur even in the absence of gene flow from wild populations.

From a wider perspective, there are related issues that work against genetic drift as a major factor driving genetic and morphological change in donkeys. In both the Maasai and Ethiopian Arsi cases, donkeys from numerous households grazed unsupervised in mixed herds, allowing uncontrolled genetic exchange among neighborhood populations. Donkeys were loaned among broad social networks in both regions, and the frequency with which donkeys were taken to market in Ethiopia also provided a wider setting for interbreeding among donkeys from different areas. We argue, however, that in both the pastoral Maasai and Arsi farmer cases, low levels of formal management and lack of intentional selective breeding are linked to donkey biology and behavior, the use of donkeys for transport, and the fact that donkeys are not often eaten. Male culling plays a significantly greater role in animals that are primarily managed for meat—including cattle, sheep, and goat—than it does in donkeys. Although culling and castration affect donkey selection, they are outweighed by lack of directional selection in breeding and consistent gene flow among donkeys over significant distances.

The data for Maasai pastoralists and Ethiopian Arsi farmers
also suggest that the potential for gene flow from the wild is likely in both settings but marginally less so in agricultural villages. The Maasai villages studied lie outside the historic range of the wild ass. But it is easy to see that had they not, the runaway tendencies of estrus females would have made the prevention of introgression difficult. Like contemporary herders valuing strength and endurance in their donkeys, historic Beja pastoralists of Sudan and Eritrea intentionally encouraged interbreeding among donkeys from domesticated and wild settings (Baker 1867; Murray 1935). During the 1950s, Nicolaisen (1963) also recorded capture and taming of wild or feral animals by Tuareg pastoralists of the central Sahara.

It is possible, therefore, to begin to identify separate contexts for the domestication process of donkeys in Africa. We predict that ancient Saharan pastoralists reduced the number of breeding males in herds through culling and castration in order to cope with practical difficulties resulting from courtship and breeding behavior in donkeys. Isolation from wild ancestors would have been possible in some pastoral settings as a result of mid-to-Late Holocene climate change, range fragmentation, and pastoral settlement in island or marginal ecosystems. Wild asses may also have been removed from their wild range by pastoral dispersals into the high-altitude Ethiopian highlands and other regions, such as southern Sudan and northern Kenya, outside the historic range of the wild ass.

Selection for morphological change would have been slow until donkeys were removed from close proximity to the wild ass and interbreeding between local donkey populations was restricted. It would appear that reproductive isolation of captive wild asses from free-living populations is somewhat more likely to have occurred in ancient urban settings such as the Predynastic and Dynastic Egyptian towns of the Nile Valley, with permanent walls and high densities of protected agricultural land. Gene flow would still have been possible, however, given the narrowness of the Nile agricultural belt and the mobility of pack donkeys. An appreciation for the advantages of strong animals may also have made interbreeding between captive and wild asses desirable for both villagers and pastoralists.

The lack of morphological change evident in the Abydos donkeys as late as 5000 cal BP (3000 BC; Rossel et al. 2008) demonstrates that size decrease was not generally established until well after this period. It is also conceivable that morphological change did not occur until donkeys were taken across the Red Sea to Yemen or other regions of Asia. However, the case, donkeys are a classic example of a species that was used to carry loads for millennia as a domesticate but with late morphological change. We conclude that slow morphological change in domesticated donkeys can be explained by low levels of selection, high potential for interbreeding between founder populations, and potential for introgression with the wild.

Do Holocene Pastoralists in Africa Fit Conceptions of Early Agricultural Systems in Other Regions?

After examining evidence for the beginnings and spread of food production in Africa and analysis of the way that management and behavioral factors affect the likelihood of morphological change in one large mammal—the donkey—we return to consideration of whether African pastoralism fits current conceptions of early agricultural systems developed for other regions. We start by considering the question of whether recognition of early food production in tropical regions of Africa has been hampered by concepts of domestication that rely on morphological change by focusing on donkeys, cattle, Barbary sheep, African cereals, and West African tropical tree crops.

Some evidence suggests that complex hunter-gathers may have attempted to manage cattle in the northeastern Sahara and, for a time, Barbary sheep in the Libyan Acacus. There is no doubt that short-term participation in domesticatory relations are difficult to recognize archaeologically, but nevertheless evidence for management of Barbary sheep is suggestive rather than conclusive. In contrast, genetic data offer a measure of support for the hypothesis of cattle domestication in Africa. The sociality of wild Bovini, however, and the expectation that wild cattle were used mainly for food suggests strong selection and a pathway to domestication—characterized by a postmanagement lag rather than late morphological change and fewer problems with identification of early domesticates—different from that discussed for the donkey.

Ethnoarchaeological data on the donkey reveal relations among selection processes and slow genetic and morphological change and illuminate conditions under which biology and human management influenced domestication and the likelihood of late morphological change. The biological and behavioral reality of donkeys in current domesticatory settings in Africa is that females actively seek out mates, territorial males are reproductively aggressive, and high proportions of males are advantageous for transport use. These factors interact to make reproduction difficult to control and gene flow likely among donkeys of different households and villages, along trade routes, and between tame animals and wild asses.

Archaeological and genetic data suggest that pastoral societies of the Sahara or the Horn of Africa played an important role in the early development of stable and long-term systems of management of morphologically wild donkeys. Morphological change was late, and mechanisms for this probably included creation of built environments of the Nile Valley, late agriculturally modified landscapes, the high mobility of Saharan pastoralists, and ecological fragmentation created by climatic changes of the mid-Holocene.

Although an appreciation of the likelihood of delayed morphological change and biases against identification of domestic donkeys is novel, Africanists have long discussed the
question of whether the lack of morphological change resulted in bias against recognition of cultivation of early cereal crops. There is mounting evidence for long periods of intensive use of wild cereal grasses by Early Holocene hunter-gatherers and early herders of the Sahara without evidence of domestic traits. This has been related to a lack of continuous directional selection as a result of increased aridity and pastoral mobility. Morphological changes in well-known African cereals such as pearl millet and pulses such as cowpeas occur relatively late and in conjunction with pastoral sedentization in better-watered locales within the semi-arid Sahel and in the more humid West African woodlands after the fourth millennium cal BP. Recent research in more humid regions of West Africa has revealed, however, a number of tended and managed tree crops, such as incense, baobab, and the shea-butter tree, that were heavily used during the Holocene but remain morphologically wild to this day. This is typical of tropical tree crops worldwide and common in weedy greens.

It is worth reiterating at this point that identification of management of plants and animals before genetic or morphological change is inherently problematic, and the longer the period before morphological change occurs in a particular plant, animal, or setting, the greater the difficulties that arise. It is clear that there are at least three axes of variability in morphological responses of plants and animals to selection during coevolutionary relations with humans. We have found it useful here to conceive of this temporal and spatial variation in terms of a “post-management lag” before morphological change, as opposed to “late morphological change” or “regionally clustered variability.”

Our review suggests that all these forms of variability exist in Africa. The available data appear to accord with Jones and Brown’s (2007) suggestion that a long, stable period of management without morphological change or a normal “morphological lag” is common to many domesticates worldwide. In Africa, however, it is not clear that their corollary—that population expansion leads to removal of plants and animals from their wild range and morphological change—holds true. Instead, heightened mobility related to climatic changes and increased aridity ultimately led to the movement of some species out of their wild ranges. Furthermore, early African cereals appear to have been domesticated within their wild ranges and intensified on the edge of these regions. Increasingly settled pastoral communities and management practices that maintained directional selection seem to have been more important factors affecting domestication of these crops than reproductive isolation.

We focused above on the possibility of biases against the recognition of early agriculture in tropical regions. We do not, however, see a cluster of taxa subject to late morphological change in the arid or high-altitude subtropics of Africa; here, species-specific analyses of the likelihood of late morphological change are crucial. We agree with Denham (2007), however, that the biology of many species of the African humid tropics increases the likelihood of a lack or significant delay of morphological change and the potential for interpretive bias. These data are strongest with regard to African tree crops. Despite this, however, there is little evidence that archaeologists have ignored early agriculture in the humid tropics of Africa. There is, in fact, no archaeological evidence that the humid tropical forests were heavily populated by African hunter-gatherers during the Early Holocene, and there are few traces of intensification in these regions until after they were settled by food producers (see D’Andrea, Logan, and Watson 2006; D’Andrea et al. 2007; Mercader et al. 2006 and references therein). Nevertheless, as Africanist paleoethnobotanists have pointed out, much work remains to be done on the nature of agricultural systems dating to the past several thousand years in the humid tropics (D’Andrea, Logan, and Watson 2006; Hildebrand 2007; Kahlheber and Neumann 2007).

We conclude that there is no indication of significant regional-scale biases that would have affected current interpretations of the sequence of plant and animal domestication in Africa or geographic patterns of the timing and spread of food production. The larger patterns, as we see them, are that some complex hunter-gatherers of the Early Holocene in North Africa successfully managed cattle, developed pastoral social and subsistence systems, and spread over vast areas of the Sahara. Other such groups in North Africa may have experimented with management of Barbary sheep, but this was short-lived. Later, during the mid-Holocene, there is evidence that donkeys were domesticated by African pastoralists in the Sahara and the Horn of Africa and possibly by Predynastic Egyptians in towns along the Nile. These animals remained morphologically wild for long periods. The earliest plant domesticates in Africa are associated with decreased mobility as pastoralists moved into better-watered locales within the semi-arid Sahel and into West Africa. It can also be shown, however, that in some humid tropical regions of Africa, clusters of species existed with a long history of cultivation or tending by established agricultural communities and with biological traits amenable to management but no traces of morphological domestication.

African patterns of food production were distinctive. Animals were domesticated before plants, herding populations became more mobile than their forager ancestors, the subsistence system was characterized by a few morphologically wild domesticates (e.g., the donkey), a wide range of wild resources in ecodiverse combinations continued in use, and mosaics of hunter-gatherers and herdiers occupied varied regions. Pastoralism developed early in the arid topics, whereas the beginning of farming based on domesticated plants was late.

These African data are informed by and provide perspectives on pathways to food production in other regions. In discussions at the Wenner-Gren conference in Temozon in 2009, Meadow (2009) and Fuller (2009; also see Fuller 2006) argued that South Indian patterns of early pastoralism and subsequent domestication of local millets and pulses are rem-
niscent of Africa. Similarly, pastoralism has long been considered an early phenomenon in the Andes (Aldeenderfer 2003; Browman 1974; Mengoni-Gotalons and Yacobaccio 2006) and the Zagros (Abdi 2003; Hole 1996). Mobile pastoralism is also a major theme in data emerging on the beginnings of food production in central Asia (Frachetti and Benecke 2009; Outram et al. 2009). In addition, Belfer-Cohen and Goring-Morris (2011) and Goring-Morris and Belfer-Cohen (2011) document African-like mosaics of hunter-gatherer and early-food-producer settlement in the Levant during the Early Holocene. Evidence is also mounting that shows continued reliance on wild resources and ecodiverse strategies pursued by small-scale food producers or low-level farmers of the Americas and subtropical and tropical regions (Denham 2011; Fritz 2007; Piperno and Pearsall 1998; Smith 2001, 2011) and perhaps even temperate regions of Asia (Crawford 2011; Lee 2011; Zhao 2011). Understanding ways in which specific strands such as these contribute to larger similarities and differences in the warp and weft of data on the beginnings of agriculture requires attention to methods of detection of early phases of domestication, information on specific social contexts, and regionally focused and temporarily expansive research. These kinds of data are only just beginning to emerge from Africa, which, as this summary demonstrates, has much to contribute to unravelling patterns of variability in global pathways to food production.

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Archaeological Evidence on the Westward Expansion of Farming Communities from Eastern Anatolia to the Aegean and the Balkans

by Mehmet Özdoğan

The beginnings of the Neolithic way of life in Europe and the role played by the Anatolian Peninsula in this process are much-debated issues that involve a number of distinct topics. In this debate, it should not be overlooked that distinct from Europe, at least a portion of the Anatolian plateau had been part of the “Neolithic world” for at least 4,000 years before the appearance of the earliest claimed Neolithic culture in Europe. Accordingly, in viewing the interaction between southeastern Europe and the Aegean with the Anatolian Peninsula, the core area of primary Neolithization has to be considered.

The Neolithic way of life, after stabilizing in the region of its origin for several millennia, was rather suddenly dispersed to other regions by the beginning of the seventh millennium BC. The mode and the pace of this expansion have been much debated. The problem has been unresolved because of the lack of research in the peripheral areas of primary Neolithization and in particular in the contact zone between Anatolia and southeastern Europe. During the last 2 decades, there have been a number of new excavations in this critical zone that for the first time have provided concrete evidence regarding the expansion of the Neolithic way of life. Until recently, the Neolithic period of western Anatolia was known, aside from excavations such as at Hacılar, largely from sherds collected from the surface. Thus, all comparisons between Anatolia and the Balkans had to have their focus on stylistic features of the pottery assemblage. Now, though data collection is still in a preliminary stage, there is a wide range of available data covering settlement organizations, architectural features, subsistence patterns, lithic technologies, and burial customs. Many of these sites are still being excavated, and thus, the results are available mainly in the form of preliminary reports. However, even a preliminary assessment of what has been published is enough to give insight into a newly appearing picture. A brief survey of recent literature indicates that these new data have been either overlooked (Anthony and Chi 2010) or considered in the view of conventional hypothetical frameworks, which has led to a rather chaotic admixture of conventional models with a random selection of new data. It is necessary to begin with a conspectus questioning the history of the problem.

Preamble: A Prelude to the Problem

The question of how farming began in Europe has been much debated since the first half of the last century (Tringham 1971). Because the question pertains to both understanding the foundations of European civilization in addition and scientific concerns, it has been a stimulus to politics as well (Özdoğan 2004, 2007a). It seemed evident in the early years of research that the area key to the resolution of this problem was southeastern Europe—the Aegean and the Balkans. As can be seen in Rowley-Conwy (2011), defining the process of Neolithization in western parts of Europe is less problematic, because there the discussions are based solely on solid evidence. In the southeastern parts of Europe, however, archaeological biases bear not only on political concerns but even the origin of agriculture. Accordingly, before presenting the recent evidence from western Turkey, for the sake of clarity it is necessary to include an overview of changing trends pertaining to the origin of Early Neolithic cultures.

There has been so much controversy regarding the beginning of the Neolithic way of life in southeastern Europe that the question has occasionally been distorted. In the midst of ongoing discussions, it is worth keeping in mind that the initial concern is to understand how and when the Neolithic
way of life began in southeastern Europe. The quest to answer these questions has followed two distinct trajectories, considering Neolithization either as the result of a local development or as being introduced from the East. Uncompromising confrontation between these two approaches remains an enduring dilemma. Nevertheless, it is now evident that the emergence of the Neolithic way of life in southeastern Europe was very complex and did not develop along a single line but from different types of simultaneous occurrences.

As noted, the resolution of Neolithic origins in southeastern Europe is embedded in the Neolithic culture’s interaction with the Near East, where an uneven distribution of excavated sites due to research strategies has been the primary agent to hamper reaching a consensus. The excitement triggered by the transformation of the meaning of the term “Neolithic” from technology to imply a new way of living based on food production had a significant impact in designing field projects, both in the Near East and in southeastern Europe, considerably increasing the number of Neolithic excavations. In the initial stages, Neolithic research was focused mainly on two geographic regions, one in the semiarid regions of the Near East, mainly along the so-called Fertile Crescent, and the other in southeastern Europe. The former was considered to be the core area or the main formative zone of sedentary farming communities, and the latter was considered to be where the European Neolithic originated.

The geographic locations of the research projects in the Near East were selected based on the following considerations: (a) regions where environmental restrictions would necessitate consuming cereals; (b) zones of the natural habitat of the primary components of the Neolithic package, mainly the regions where wild cereals and wild forms of domestic animals were present; and (c) areas where the political context did not hamper archaeological research. Given such considerations, research on the Neolithic Period was concentrated in the Levant and, to a lesser degree, along the eastern arm of the Fertile Crescent. The work in the Near East was research oriented, focused on understanding various aspects of the Neolithic process. In southeastern Europe, however, excavating a Neolithic site was considered somewhat more prestigious then working on other periods. By the second half of the twentieth century, the number of excavated Neolithic sites in southeastern Europe had reached 200. By the third quarter of the twentieth century, there had been considerable knowledge accumulated on both ends of the Anatolian Peninsula, which until then had been largely outside the sphere of interest of Neolithic research. On a general level, Anatolia was discussed mainly as the connection between the Near Eastern Neolithic cultures and the Balkans, but even in this context, the question was whether Anatolia was a barrier or a cultural bridge (French 1986; Tringham 2000).

In this respect, it should not be forgotten that before the implementation of $^{14}$C dating, the beginning of the Neolithic Period in southeastern Europe, including that of mainland Greece, was believed to be rather late, sometime around 3400 to 3200 BC. At the same time, it seemed evident that the Neolithic communities of southeastern Europe had been derived from the Near East. As the presence of Neolithic cultures in Anatolia was beyond consideration, various models were envisaged to connect littoral areas of the eastern Mediterranean with the Balkans—bypassing Anatolia. In this context, Childe noted in 1957 that “no recognizable archaeological milestones mark an ancient route across Anatolia from the Orient to Europe” (Childe 1964 [1957]:36) and “Sakçaköy (Çoba Hoyuk) further north seem[s] to prove that Mesopotamian farmers with slings and gaily painted pots colonized the Orontes valley; indeed they penetrated right to the Mediterranean coasts at least at Ugarit (Ras Shamra)” (Childe 1964 [1957]:217). Some years later, Seton Lloyd also commented that “the region more correctly described as Anatolia shows no sign whatever of habitation during the Neolithic period” (Lloyd 1956:53–54) and “various phases were later found, first in north Syria and then at Taurus and Mersin beyond the Turkish frontier . . . testifying to the westward and northward extension of the great Chalcolithic province . . . barrier still existed and beyond it Anatolia remained unpopulated” (Lloyd 1956:58–61).

While culture historians were trying to define routes between the Levant and the Aegean, others working in southeastern Europe were more engaged in searching for parallels with the Neolithic sequence of the Near East. In this respect, one of the active discussions of the time was the one triggered by V. Milojčić, a prominent archaeologist on the prehistory of the Balkans who argued for the presence of an “Acemistic Neolithic” horizon in Thessaly (Milojčić 1960) that was almost identical to the cultural stage that had just been identified in the Near East. Needless to say, this was a highly paradoxical model, because Milojčić believed in both the Near Eastern origins of the Balkan Neolithic and the very young dates ascribed to it. Nevertheless, given the dates for the Balkan and the Anatolian cultures, numerous parallels were put forth between these two regions, the most notable being the association of Troy I with the Vinča culture. As narratives of changing perceptions regarding the Neolithization model of Europe have been published extensively (Bogucki 1996; Özdoğan 1995; Renfrew 2002; Sherratt 2004), here I shall note only a few relevant stages.

The implementation of $^{14}$C dating, in particular for the early cultures of southeastern Europe, led to the creation of a “mental fault line” between the early Balkan and Anatolian cultures. The $^{14}$C revolution came at a time when numerous Neolithic sites were being excavated in southeastern Europe, revealing that the Balkan cultures were 2,000 to 3,000 years older than assumed. While the cultural sequence in the Balkans was going through revolutionary changes, almost no prehistoric excavations were taking place on the Anatolian plateau, and the conventional dates established before the $^{14}$C revolution, particularly from sites such as Alişar with a long sequence, were not questioned for decades (Mellaart 1960; Özdoğan 1996). The discrepancy among the dates of the early
cultures of these regions, now spanning almost 3,000 years, coupled with the uneven geographic distribution of excavations, eliminated Anatolia as the source area of Balkan cultures. This, along with contemporary political concerns, led to a new way of thinking based on disregarding endemic movements between regions, conveniently known as the "antidiffusionist" approach. Through some decades, the discussion of the origin of the European Neolithic developed along this line. It was hypothesized that there was an autochthonous development in the Balkans devoid of any impact from the East. Thus, the concept of a "source area" for the European Neolithic cultures became firmly attached to the Balkans. Mention of possible diffusion from the East was considered an embarrassment. Concerning this interim stage, the question of how staple crops such as wheat, which do not have wild ancestors in southeastern Europe, appeared in the early Neolithic sites remained a subject of unresolved debate. In spite of the prevailing tendencies, a few scholars continued to consider the Eastern origins of European civilization. Among them, Garasănin, with her "Balkano-Anatolian cultural complex" (Garasănin 1981, 1997), and Theocharis, inconsistent on Anatolia as the source of the Aegean Neolithic (Theocharis 1973), need to be acknowledged.

The recovery of early sites—Hacılar first, followed by Çatalhöyük, Can Hasan, Süberde, and Erbaba on the Anatolian plateau—initiated a number of discussions questioning both the place of Anatolia in the process of Neolithic formation in the Near East and its role as the source of the European Neolithic. In this debate the insight and intuition of James Mellaart (1975) and David French (1986) stand as landmarks in noting the significant importance of the Anatolian Peninsula in the process of Neolithization at such an early date and with such little evidence. In this respect, Fritz Schachermeyr should also be acknowledged as one of the few scholars of his time to perceive the connections between Aegean, Anatolian, and Near Eastern assemblages (Schachermeyr 1976). However, it is interesting to note that in spite of the flambouyant finds from Çatalhöyük and elsewhere, Anatolia for a long time was still not included in theoretical discussions of the emergence of Neolithic cultures.

As new excavations commenced in Anatolia, the antidiffusionist views went through a gradual stage of transformation (Harris 2003; Özdögan 1995, 2007b; Runnels 2003). In this respect, excavations at Çatalhöyük and Hacılar caused considerable excitement with their colorful artifactual finds; however, the main impetus in bringing Anatolia into the theoretical framework of the Neolithic studies was the data on the natural environment provided by the natural scientists taking part in the Cayönü excavations. Nevertheless, until the commencement of excavations at Nevalı Cori, Hallan Çemi, and Asikli, the conventional view of disregarding Anatolia from the primary zone of neolithization endured. At first the presence of early Neolithic settlements on the plateau was taken as a late reflection of the Levantine Neolithic, connoted as an "area of secondary Neolithization." Later still, Anatolia began once more to be considered as the source area of European Neolithic cultures. It is of interest to note that arguments based on ethnolinguistic and/or biogenetic studies were more instrumental than conventional comparisons based on artifact assemblages in silencing antidiffusionistic approaches (Renfrew 2002).

During the last decade or so, the picture has almost completely changed; what we now see is a revival of the old Balkano-Anatolian cultural complex based on more concrete evidence. All of the previous explanations, whether diffusionist or antidiffusionist, are now regarded as overly simplistic. Even if there are still considerable lacunae in our knowledge, it is evident that the real picture was far more complex than ever envisaged.

Defining the Problem

The Neolithic of southeastern Europe has been rather well studied through hundreds of excavations evenly distributed in the Balkans and in the Aegean. Even though considerable amounts of data have been accumulated—in addition to biases that are deeply rooted in the history of research, as noted above—the development of a clear vision of the Neolithization process has also been obscured by working with misconceived definitions. Among them, overlooking the difference between the appearance of the "Neolithic way of life" and "Neolithic elements" has considerably obstructed answering the question "how" Neolithic dispersal happened. A Neolithic way of life implies a village life with all of its social network and regulations; it can hardly be imitated unless the settlers were village dwellers previously. On the other hand, commodities can travel and technologies can be learned. In this respect, for example, Neolithic culture appears in the Balkans or in Cyprus as a way of living in villages, regardless of their size. However, farther to the west, in the Mediterranean littoral where certain commodities or technologies occur, there is hardly any evidence of village life in the sense of Anatolia or the Balkans.

The next question to be asked is "when"; the answer, in spite of all the available ¹⁴C dates, is still far from being resolved. The main bias of this line of thought is considering the Neolithization of southeastern Europe as an instantaneous event. We now realize that it was an extended process that took place in installments and that lasted for more than a thousand years. Compressing the events that had such a long history into one arbitrary horizon has seriously jeopardized any ability to make sense out of the absolute dates.

One other obstacle that deserves to be noted here is the "conceptual" border between the East and the West (Özdögan 2007a). Archaeology as a science, in Anatolia and in the Balkans, has developed in different directions. Different and at the same time opposing political regimes in these regions have created a barrier to sharing knowledge. For decades, scholarly contacts and the flow of data between Anatolia and southeastern Europe was minimal if any did pass through. More-
However, these regions have developed distinct schools of social science. Anatolian archaeology has traditionally been Mesopotamia centric, almost totally uninterested in Europe, including the Turkish part of Thrace. On the other hand, most of the archaeology in southeastern Europe concentrated on a local scale. Thus, even simple concepts such as the definition of culture or of a site differed considerably between these regions. This, coupled with the problems of following the outcomes of recent archaeological work in the other region, made any reasonable dialogue almost impossible between Anatolia and southeastern Europe.

Constraints on drawing a comprehensive picture between the Neolithic cultures of Near East Anatolia and southeastern Europe Aegean are not limited to what I have noted above. If paucity of Neolithic research is the prime obstacle in Anatolia, the picture in the Balkans is blurred by an abundance of data in which the information either remains as a chaotic bulk or is of questionable context. It is rather regrettable that a great number of excavations in southeastern Europe have been conducted as small soundings with no clearly defined stratigraphy or architectural features. Even with extensive excavations, publication of the data has been extremely selective and not always presented in an objective manner. Likewise, the bulk of 14C dates are from unclear contexts or processed in unreliable labs. However, in spite of all these obstacles, with an unbiased approach, the recent evidence provides grounds
to develop a new perspective and allows reformulation of questions. It is too early to draw a conclusive picture, but at least now with the new information pouring in from the western parts of Turkey, it is possible to redefine the problem and to ask proper questions. Accordingly, the following are essential questions that need to be asked before any general statements on how and when the Neolithic way of life began in southeastern Europe can be made.

**Defining the Western Border of the Primary Zone of Neolithization**

The area of primary Neolithization, or the core area of Neolithic formation, which long was considered to be restricted to the regions in and around the Fertile Crescent, is now firmly extended to cover southeastern sections of the central Anatolian basin. Along with the excavations at Pınarbaşı, Aşıklı Höyük, and Kaletepe (Özdoğan and Başgelen 2007), a number of surveys conducted in the southeastern section of inner Anatolia have pushed its beginning to considerably earlier dates, implying that here the process of Neolithization was more or less parallel to that of the Fertile Crescent (fig. 1). Even though it is not possible to define the western and northern boundaries of the primary Neolithic formation zone, it is clear that it did not extend too much in western and northern directions. What was there in those times is far from clear; even in the most intensively surveyed areas, material indicative of the presence of a Mesolithic/Epipaleolithic horizon, as is the case in Greece and southern Bulgaria, is restricted to the coastal areas, suggesting that the inner parts might be devoid of population (Özdoğan 2005, 2008). As revealed by excavated coastal sites such as Öküzini or Franchthi, the Mesolithic assemblages bear no indication of contact with the contemporary Neolithic cultures nor any element that could be taken as a forerunner of the Neolithic cultures that appeared later in those areas. This strongly implies that up to a certain period, Neolithic cultures remained within the formation zone without expanding their area.

**Defining the Contact Zone**

This is an issue that until recently has been largely overlooked. Most of the literature dealing with the Neolithization process in Europe has focused either on the northern and western sections of the Balkan peninsula or central Europe, where there existed a strong Mesolithic/Epipaleolithic substratum (Bogucki 1996; Pinhasi 2003; Zvelebil and Lilie 2000). What happened in these areas with the advent of Neolithic cultures is apt to be different from regions that were either devoid of habitation or very sparsely inhabited, such as the western parts of Anatolia, mainland Greece, and southern Bulgaria (Gatsov and Özdoğan 1994; Özdoğan 2007b, 2008). Evidently, western parts of the Anatolian Peninsula, the immediate periphery of the primary zone of Neolithization, formed the main “contact zone” during the initial stage of expansion. Later, after the Neolithic reached southeastern Europe, this became a new core area for the expanding zones. Components of initial expansion, whether an endemic movement or the movement of ideas and commodities, can clearly be observed only in this region not only because of its immediate proximity to the core area but also because there is no need to sort out the impact of local assemblages, as is the case in much of Europe.

**Defining “Neolithic Packages” and Trajectories**

For a long time the concept of the “Neolithic package” was limited to cultivated plants, domesticated animals, groundstone artifacts, and pottery, and it ignored not only other elements such as prestige or cult objects but also more specifically architecture, the arrangement of settlements, and the way of life. It now seems evident that there were different types of Neolithic packages—though almost all contained cultivated plants, domesticated animals, groundstone artifacts, and pottery—that reflect different social structures and ways of living. Thus, to define patterns, it is necessary to make a more detailed analysis of the assemblages and to work out trajectories of Neolithic expansion (Özdoğan 2010).

**The Evidence**

Regrettfully, there is very little new data from Greece and from the Balkans in the last 2 decades on the initial stages of the Neolithic period. There are numerous publications, though each with a distinct view on the Aegean (Runnels 2001), Greece (Perles 2001), and Bulgaria (Nikolov 2003, 2004; Nikolov, Bacvarov, and Kalchev 2004; Todorova 1995). On the other hand, there is now an unprecedented inflow of new information from the western and northwestern parts of Turkey (fig. 1). The geographic distribution and the status of research of sites relevant to the subject matter of this article are listed below as a gazetteer. The primary information on these sites, with extensive illustrations and references, are to be found in Özdoğan and Başgelen (2007). Here I note only the most recent publications.

**Eastern Thrace**

Hoca Çeşme: small mound (Bertram and Karul 2005); Aşağı Pınar: mound, excavations continuing (Karul et al. 2003); Yarumbleduz Cave and İstanbul Yenikapı: submerged site and necropolis excavations continuing (Kızıltan 2003); İstanbul Çekmece survey (Aydıngün 2009).

**Eastern and Southern Marmara**

Fikirtepe: flat site; Pendik: flat site and necropolis; Ilıpar: mound and necropolis (Roodenberg and Alpaslan-Roodenberg 2008); Menteşe: mound; Barçın: small mound, excavations continuing (Roodenberg, van As, and Alpaslan-Roodenberg...
Coastal Aegean

Ulucak: mound, excavations continuing (Abay 2005; Çilin-giroğlu and Abay 2005); Yeşilova: mound, excavations con-
tinuing; Ege Gürbey: mound, excavations continuing; Çukurçiçi Höyük: mound, excavations continuing (Horejs 2008); Çine-Tepecik: mound, excavations continuing (Günel 2003); Beş-
parmak Latmos: cave site, excavations continuing (Peschlow-
Bindokat 2003); Uğurlu-Zeytinlik: small mound, excavations con-
tinuing (Harmankaya and Erdoğ 2003); Coşkuntepe: small mound, excavations continuing (Seeher 1990; Takaoglu 2005).

Coastal Mediterranean

Peynirciçeği: cave site, excavations continuing (S. Yaylah, un-
published manuscript, 2007); Suluin: cave site, excavations con-
tinuing (Taşkiran 2008).

Inner West Anatolia

Kuruçay: mound; Höyük: mound (Duru 2008); Badema-
ğaç: mound, excavations continuing (Duru 2008); Keçitçayırı: 
flat hilltop site, excavations continuing (Efe 2005); Demirci Höyük: mound; Dedek-Heybelitepe: small mound, exca-
vations continuing.

As the above list documents, over the last 2 decades a total 
of 26 Neolithic sites have been excavated in the western parts 
of Turkey. Thirteen of these are currently being excavated. The increased number of excavated sites is certainly of sig-
nificance; however, what is more important is the fact that 
most of these sites are multilayered mounds with Neolithic 
deposits 4–8 m thick, and they are being extensively excavated; 
most of the excavations are conducted by competent multi-
disciplinary teams. Along with the increase in the number of 
excavations, there are now numerous surface surveys in vari-
ous parts of the region providing not only new evidence but 
also making it possible to define distribution patterns. Here 
I will restrict myself to presenting a conspectus on certain 
selected issues that contribute to developing a new insight on 
the dispersal of a Neolithic way of life.

A Dilemma: The Aceramic Horizon

The beginnings of a Neolithic way of life in the western parts 
of Anatolia, as in the Balkans, are far from clear; the evidence 
for this incipient stage is very scanty and at the same time 
open to controversy. At the root of this problem lies the 
question of whether a Pre-Pottery or Aceramic Neolithic 
phase was present. Even though the question had its origins 
in parallels with the Near East, it is deeply embedded in 
Milojić’s claims for an Aceramic horizon in Thessaly (Mi-
lojić 1960). Similar claims were later put forward for Le-
penski Vir and Vlassac in the Iron Gates of the Danube. 
However, for each of these cases there have been others claim-
ing that neither of these sites were Aceramic and that some 
pottery was always present, including whole pots in photo-
graphs from Lepenski Vir (Garasanin and Radovanović 2001; 
Reingruber 2005). A similar case can be seen at Hacilar in 
western Anatolia. Mellaart claimed to find an Aceramic 
mound below the alluvial plain on the outskirts of the pottery 
mound of Hacilar (Mellaart 1970:3–7). Much later at Catal-
höyük, Mellaart noted that an Aceramic layer was recovered 
at the bottom of the deep sounding (Mellaart 1989:316). Duru 
(1989), reexcavating Mellaart’s Aceramic mound at Hacilar, 
found some coarse sherds in situ, and at Catalhöyük the pres-
ence of a Pre-Pottery horizon has not been confirmed, al-
though pottery is reported to be extremely rare both at basal 
Hacilar and in the deep layers of Çatalhöyük. A similar claim 
has been made at Ulucak following the 2009 season, reaching 
a Pre-Pottery level, phase VI, with red-coated floors and walls 
(Cevik 2010); the available dates of the overlaying phase are 
as early as the end of the eighth millennium BC.

There have been other suggestions regarding the presence 
of Pre-Pottery Neolithic sites in various surveys conducted in 
western Anatolia, including Keçiçayıırı, located on the Phry-
gian highlands in the eastern part (Efe 1997, 2005), and Calca 
(Özdoğan and Gatsov 1998), based on lithic typology, but 
some pottery is also present at both sites. For the other claims 
for Pre-Pottery sites, mainly from the littoral areas of both 
Turkey and Greece, there is so little lichit material available 
that it is not possible to say with any confidence whether they 
represent a Mesolithic or a younger horizon.

Even though the evidence does not support the existence of an 
Aceramic horizon in the regions west of the central 
Anatolian basin, it still should not be excluded as a possibility. 
As noted above, pottery is extremely rare in the basal layers 
of all known early Neolithic sites, including those such as 
Çatalhöyük and Bademagac, which contain a long sequence 
of development. The fact that the earliest horizons with pot-
ttery have dates as early as the eighth millennium implies that 
the first detectable expansion of the Neolithic culture took 
place either at the beginning of the Pottery Neolithic period, 
when pottery vessels were rare, or just before it, more or less 
between 7400 and 7100 cal BC. Nevertheless, it would not be 
at all surprising if there were some sporadic movements to 
the west at a slightly earlier date.

Multiple Trajectories and Maritime 
Expansion

The second controversy involves the route of this initial dis-
persal. Given the recent information from the Anatolian pla-
ateau, we have always considered a land route rather than the 
maritime route suggested by Childe in earlier years. Recently, 
however, Perles (2003, 2005), after analysis of early Neolithic 
assemblages in Greece, suggested that there are some elements 
in the Aegean that seems to have arrived directly from the
eastern Mediterranean, bypassing Anatolia. The recovery of Early Neolithic sites in Cyprus and in some of the Aegean islands (Sampson 2005; Vigne et al. 2011) strongly supports the interpretation of Perlès. In this discussion, the recent excavations at Ege Gûbre in İzmir, located on the coastal plain adjacent to the Aegean, presents an interesting case. The earliest Neolithic occupation, with dates around 6250 cal BC, in addition to typical central Anatolian elements has round stone buildings and quantities of impresso pottery that are alien to inland Anatolian assemblages. Likewise, the basal layers of Hoça Çeşme, dated to 7637 BP (Bln 4639; i.e., roughly to 6400 cal BC), is also located on the coastal plain by the Aegean. This layer contains both monochrome pottery almost identical to that from central Anatolia and round architecture not found in central Turkey. A naviform core and related blades were recovered in 2007 in a surface survey conducted along the northern coast of the Sea of Marmara (Aydungün 2009). The total absence of these cores—so common in the Levant—anywhere in the Anatolian plateau also seems to support long-distance maritime connections in the Neolithic.

Discussion of what parts of the Neolithic package came west by which route is a rather tricky issue, full of traps, particularly if the discussion is based on single items that are uncommon in an assemblage. Accordingly, here again the general picture should be more helpful in developing insight even though there will always be some contradictions because of the presence or absence of certain diagnostic elements. Here at least it is certain that the sea was intensively used since the earliest stages of Neolithization, as evidenced by the presence of early sites in Cyprus and now also in Crete by the inflow of central Anatolian obsidian (Şevketoğlu 2008) and the early distribution of Melos obsidian. Accordingly, it is no surprise that there was considerable interaction between the eastern Mediterranean and the Aegean along a coastal maritime route (van Andel 2005). In this respect, round-plan buildings, as best known from Cypriot sites, and the so-called impresso pottery stand as clear indicators of a maritime package, and both are conspicuously lacking at inland sites. Thus, it seems possible to surmise that both the land route over the Anatolian plateau and the maritime route following the Anatolian coasts were operating simultaneously and that coastal sites along the Aegean incorporated a mixture of both assemblages. The geographic location of some sites such as Keçiçayırı or Çalca on high plateaus suggests that some early Neolithic groups were following the plateaus or mountains and not the alluvial plains as conventionally considered. At our current level of knowledge, it is not possible to define the trajectories of endemic movements with any precision; however, patterning the distribution of Neolithic elements indicates that there was more than one movement, each following a different route.

**The First Congregate Movement of Neolithic Communities**

Following what I have described as the initial stage of expansion, there is a succession of rapid and rather massive movements of the Neolithic way of life extending to temperate Europe. Now it is evident that this process, at least in the western parts of Turkey and in the adjacent areas of the Balkans, was not an instantaneous happening. There are at least two definable stages bringing with them different assemblages and following different trajectories. What is being normally referred to in the literature as the Early Neolithic occupation of Europe is related to the second stage. Consideration of these two distinct movements as a single process has been the source of considerable bias in assessments of the beginning of the Neolithic in Europe. Here I consider them under different headings.

As noted above, the evidence for the initial expansion of the Neolithic communities, whether by land or by sea, seems to be rather sparse and sporadic. This first stage appears to have continued up to the second half of the seventh millennium, around 6500–6400 BC, just to the time of Çatalhöyük layer 6.

Immediately afterward, there are the first indications of a more substantial expansion indicated by the numerous sites in the lakes district and in the inner parts of western Anatolia. What triggered this movement is beyond the scope of this article, although some sort of a social turbulence in the main core area (Özdoğan 1997, 2005) coupled with the unstable environmental conditions seemingly related to the 8.2 kyr BP climatic event (Alley and Ágústdóttir 2005; Berger and Galil 2008; Roberts and Rosen 2009) seem to be the main agencies in this movement. In parts of Anatolia in close proximity to the central Anatolian basin, this era is much better documented than in the coastal regions of the Aegean, although current work in the earlier levels of the sites such as Çukuriçi Höyük, Uluçak, and Yeşilova are now yielding ample evidence of the presence of this second stage in the littoral areas of the Aegean.

This horizon is best represented by monochrome pottery with well-finished and burnished surfaces very much akin to the so-called dark-faced burnished wares of the Near East. Similarly, the vessel forms range from variations of hole-mouth jars to semiglobular cups, some having ledge or crescent lugs, with small knobs not being uncommon. Decoration is rather rare; very seldom are there vessels with red bands, incised patterns, or relief bands. Even though most of the pottery is dark brown, reddish brown, or black, occasionally there are also pieces with a fine burnished whitish or light creamy slip. The Anatolian origin of this pottery is indisputable. It is possible to find analogous material from a large geographic zone extending from southeastern Anatolia to the Central Plateau. The assemblage, besides pottery, is rather limited; the chipped stone industry is characterized by the extensive presence of pressure flaking, microbladelets, prismatic and/or bullet cores, round scrapers, backed bladelets, and chipped discs. Bone polishers, spoons, and hooks are among the few definable prestige objects. Architectural details as well as the layout and the organization of the settlements...
also reflect what is known from farther east in Anatolia. Sub-
sistence, unlike most early Neolithic areas in central and east-
ern Anatolia, was mainly dependant on farming, with little
evidence of hunting. Sheep and goat were more common than
cattle.

Comparing the assemblages from both regions, it is evident
that every component found in the newly settled areas has a
counterpart in the primary zone of Neolithization, though in
varying degrees of intensity. However, there is much that re-
mained in the core area that did not move along with the
expansion, indicating some sort of a selection. Resorting the
assemblage indicates that only certain categories in the orig-
inal package were carried by the farmers, and these were
mainly the utilitarian components of the culture (Özdoğan
2010). The expansion model includes all variations of do-
mesticated animals and cultivated plants—not only cereals
but in particular legumes and lentils—groundstone artifacts
including celts and building techniques but without most of
the cult and prestige objects. This strongly implies that the
groups that were on the move did not include the ruling elite
or the clergy, and it was more as a segregated movement of
simple farmers or herdsman (Özdoğan 2008). Going into
detailed analyses of the sites, the picture is far more complex
than what I have presented here as a generalization; some
components such as painted lime floors, reminiscent of the
terrazzo technique (Hauptmann and Yalçın 2000) of the east,
 occur in some sites, mainly at Bademążaci and Hoca Çeşme,
seemingly as “social memory.” On the other hand, during this
stage some specific tools that require special craftsmanship,
such as flint arrow points, disappear in both regions, sug-
gesting that the skilled craftsman had also joined moving
groups (Özdoğan 2002). All of a sudden, with the disap-
pearance of arrow points, clay sling missiles become a major
component of the assemblage in both regions.

This stage is best documented in northwestern Turkey,
mainly along the southern and eastern parts of the Marmara
region, as the Archaic and Classic phases (Özdoğan 1997,
2005) of the Fikirtepe culture. This cultural stage is known
from over 25 sites. İlpinar (Roodenberg, van As, and Alpas-
lan-Roodenberg 2008) and Aktopraklık (Karul 2007) have
securely solved the chronological position of the Fikirtepe
culture, placing it between 6450 and 6100 cal BC.

As the details of the Fikirtepe culture and its development
have been extensively published (Özdoğan 1997; Özdoğan and
Başgelen 2007), these will not be repeated here. However, the
differences between the inland and coastal sites of this culture
are important for this discussion. As noted above, there is an
extensive presence of Mesolithic or Epipaleolithic sites in the
coastal areas of eastern Marmara and along the Black Sea
littoral (Gatsov and Özdoğan 1994). On the other hand, far-
ther inland on the Anatolian plateau, this stage is conspicuously absent. There was always an argument that this might be the result of survey biases. However, the difference in the composition of Fikirtepe assemblages between the areas where a Mesolithic substratum is known and other areas where it is not found strongly implies that the survey results were more or less correct. In both areas, most of the assemblage and in particular the pottery—in ware, shape, decoration, and in sequential development—is identical. On the other hand, those sites located inland, such as Ilıpınar or Mentes¸e, have rectangular buildings arranged like the Anatolian settlements, while those along the coastal areas have round or oval wattle-and-daub huts with semisunken floors. This latter form is best known from Fikirtepe, Pendik, Istanbul Yenikapi, and Aktopraklik (Ozdoğan and Başgelen 2007). Another striking difference between the two areas is seen in burial customs. Inland sites such as Ilıpınar and Aktopraklik have extramural cemeteries (Alpaslan-Roodenberg 2008), while coastal sites such as Pendik and Fikirtepe have intramural burials beneath the floors of the huts. Even more interesting are the recently found cremation burials at Yenikapi in Istanbul (Kızıltan 2010), in the Fikirtepe and Yarimbusgaz 4 horizons, a custom completely alien to Early Neolithic Anatolia. Likewise, subsistence at sites such as Ilıpınar is primarily dependent on farming, with almost no evidence of hunting or fishing (Buitenhuys 1995). Fikirtepe, Pendik, and Istanbul Yenikapi display a mixed pattern of hunting, fishing, mollusk collecting, and farming (Boessneck and von der Driesch 1979). Accordingly, it is possible to assume that while inland sites represent an endemic movement, those in the coastal areas merged with indigenous groups without signs of hostility.

How far west in the Balkans these groups penetrated is difficult to say at present. In the western parts of the Marmara region and in eastern Thrace, the presence of this stage is firmly attested at Aşağı Pınar in layer 8, well stratified below a Karanovo I–related level. In our surveys in eastern Thrace,
this type of material has been recorded from Kaynarca (Özdoğan 1986) at Gelibolu and Uğurlu-Zeytinlik Mevkii on Göktepeada Island (Harmankaya and Erdogu 2003), indicating its presence in northwestern Turkey. Farther west, in the Aegean, at least some of the material from Agios Petros (Evstratiiou 1985) and from mainland Greece, Pre- and Proto-Sesklo stage, can be considered to be related, though with notable differences. Farther into the Balkans, the picture is much less clear, especially in light of the controversy regarding the so-called Proto-Starčevo and/or Koros cultures. It is not possible to present a brief comment within the spectrum of this article.

In Bulgaria, the presence of an monochrome horizon preceding the Karanovo I painted-pottery horizon has been much argued (Stefanova 1996; Todorova 2003). It seems very likely that the dark-burnished pottery at sites such as Koprivets and Krainitsi represent the rapid but rather thin expansion of the prepainted-pottery stages all the way up to the Danube. The presence of similar dark-burnished pottery found stratified below Karanovo I horizon at Aşağı Pınar supports this view.

This stage of Neolithic expansion, which with some reservation we have been calling the “monochrome phase,” is of critical importance even if it is not as notable as the next phase because it sets the foundation of the Neolithization process in Europe. With the exception of northwestern parts of Turkey, this phase is still poorly understood. We can anticipate that ongoing excavations in the Aegean parts of Turkey will contribute to defining this stage.

Subsistence patterns during this stage are of crucial importance not only for this local region but also for defining the beginning of agriculture and domestication in Europe. Even though natural scientists have been participating in almost every excavation conducted during the last 2 decades, at present only lists of species—plants, animals, fishes, or mollusks—and general overviews are published, with few specific details. What can be noted at this stage is that even the first migrant groups arrived with the full range of domesticated farm animals, cultivated cereals, and legumes. The recent evidence indicating that not only fully domesticated sheep and goat but also cattle and pigs arrived in the Marmara region presents a new problem regarding how these groups were able to move such long distances together with those animals through Anatolia. In this context, the recovery of dairy product remnants in Fikirtepe pottery is challenging expectations (Evershed et al. 2008). The preliminary assessment of Fikirtepe that documents a mode of subsistence seems rather similar to what has been described as a “low-level food production” model (Smith 2001, 2011). In this respect, the extensive presence of various fruits and nuts (mostly almonds and seeds of wild pear) in many of the sites is worth considering, particularly in light of the evidence for planted trees at Yenikapi, suggesting that tree cultivation might have been
more important and had an earlier beginning than previously assumed (see also Weiss and Zohary 2011).

The Second and More Rapid Massive Expansion of the Neolithic Way of Life

It is not possible to comment on the intensity of the initial wave of the Neolithic that I described above. It seems to have been mainly oriented toward the eastern parts of the Marmara region, as indicated by the numbers of settlements recorded in that area. Farther to the west, the evidence is more sparse and difficult to trace. The second impulse, on the contrary, is easier to observe because it must have been a more massive and a rapid movement. Questions such as exactly when it began or whether it was an uninterrupted continuum of the earlier wave are difficult to answer. But at the end of the seventh millennium BC, numerous Neolithic settlements, big and small, appeared almost instantly over almost all of western Turkey and in most of the Balkan Peninsula, sharing more or less similar assemblages (fig. 2). Most of the areas now occupied have no trace of earlier occupation; even in previously settled regions, with some exceptions, the site location preferences of the newcomers were different. This new wave is at best characterized by red-slipped and burnished pottery displaying mostly S-curved profiles, tubular lugs, plastic decoration in relief, anthropomorphic or zoomorphic vessels, steatopygic figurines, pintaderas, and so forth (figs. 3–5). Recent excavations at sites in the eastern parts of central Anatolia, such as Tepecik-Çiftlik and Köşk Höyük (Özdoğan and Başgelen 2007), strongly imply that this assemblage must originate in that region.

Even if this wave was much more massive than the earlier one, it is also evident that there was a preference for alluvial valleys and large and well-watered intermountain plains as well as for avoiding high plateaus. The lake district and the alluvial valleys extending from central Anatolia to the Aegean coastline are among the most intensively settled regions, where recent surveys have revealed over a hundred sites of this horizon (Ozsait 1991). On the other hand, the eastern sections of the Marmara region, most densely inhabited by the pre-
vius group, seems to have remained beyond the reach of this new wave.

Excavations at sites such as Kuruçağ, Höyücek, Bademağaç, Ulucak, Yeşilova, and Hoca Çeşmeler have revealed information on the sequential development of this stage, indicating that painted decoration was extremely rare or even absent at the very beginning. As the issue of painted decoration surfaces in most of the discussions in the Balkans (Nikolov 1987, 2002, 2003; Schubert 1999), it is worth presenting some details. In the older layers of all the sites mentioned above, the pottery assemblage is dominated by very fine lustrously burnished red or jet black vessels. When painted decoration first appears, it is extremely rare and displays thick bands in red that are mostly made not by paint but by using different colored slips. This earlier stage, being rather common along the Aegean coast of Turkey, is either absent in Bulgaria or it has not been reported in the publications. The final stage of painted decoration with a vast range of geometric designs is found all over the Balkans under different cultural denominations such as Karanovo I–II, Kremikovci, Gradesnitsa, Starcevo, and so forth. Nevertheless, differences among these groups are not as significant as suggested in the literature.

During the rapid expansion of red-slipped pottery—with or without painting—in the eastern Marmara, regions previously occupied by the Fikirtepe culture remained outside of this wave. There, all over the eastern Marmara and around the Bosphorus, Yarımburgaz 4 culture, possibly developing from the Classical Fikirtepe, became established. Yarımburgaz 4 culture (Özdögan, Miyake, and Özbașaran-Dede 1991) still produced pottery in dark colors, although there are some red-slipped wares, but the decoration is either deeply incised or excised, or occasionally it is executed in the so-called furchenstich technique. Yarımburgaz culture seems to continue developing locally into what is known as Yarımburgaz 3, displaying very fine black-burnished pottery with incised spiral and notenkopf-like motifs. Major sites of this culture, besides Yarımburgaz, include İlipınar layer 8, Aktopraklı, and İstanbul Yenikapi (fig. 6). The pottery of Yarımburgaz culture, along with some of its other elements, is highly reminiscent of the early Linear cultures in the Danubian area (Özdögan 1989). Whether these similarities are accidental or imply some genetic relationship remains a controversy. During the rescue excavations carried out in İstanbul Yenikapi in 2008, a number of burials of Yarımburgaz 4 culture were recovered. The presence of a vessel with deeply incised spiral designs in the graves conspicuously points to connections with the Danubian area. As no pottery of Yarımburgaz type has been found either in eastern Thrace or in Bulgaria, any connection with the north-
ern Balkans must have been along the Black Sea coastline through the Danube River valley.

The border between the red-slipped and painted cultural groups and the Yarimburgaz distribution is more or less clear. In eastern Thrace, Aşağı Pınar is the easternmost excavated site of this culture, and the surveys have revealed some other sites 50 km farther to the east. Because the contemporaneity of Aşağı Pınar and Yarimburgaz is firmly attested by $^{14}$C dates, the border must lie immediately to the west of Istanbul, implying that the second wave entered Thrace not through the Bosporus but from the western parts of the Sea of Marmara, probably following the coastal plains along the Aegean.

Concluding Remarks

Recent archaeological evidence from the western parts of Turkey strongly implies that the arrival of a Neolithic way of life was not a single instantaneous event and on the contrary was a multifarious process that lasted for more than 1,000 years. It is now possible to speak of separate waves of Neolithization—each with its own mode, pace, and trajectory—yet some may have taken place simultaneously. With this article I tried to present a conspectus of the recent evidence from the western and northwestern parts of Turkey and its implications for our understanding of the initial stages of Neolithization in southeastern Europe, including the Aegean. One other point needs to be emphasized. In the earlier stages of the Neolithic expansion, the western parts of Turkey were the frontier, developing as a periphery. However, as the Neolithic culture expanded its coverage to southeastern Europe, those parts became the core or the primary zone of the European Neolithic. For that reason, understanding both historical roles is essential to understanding what and how Neolithization developed in Europe.

I could have written this article using same evidence in another way by defining the distinct compositions of different Neolithic packages. Then the picture would have been slightly different. As an example, there are some Neolithic packages that do not include the “way of village life.” Only commodities seem to have been transferred—most probably by some sort of an exchange. There are others where all sorts of status or prestige objects are either absent or present in minimal amounts, possibly indicating that these groups represent simple farmers on the move. It all leads to the conclusion that the latter half of the eighth millennium and lasting up to the sixth millennium witnessed a very dynamic succession of events that cannot be explained by a single model. Throughout the article, I intentionally avoided going into the discussion of absolute chronology; as noted above, with the available dates regularly published by the Central Anatolian Neolithic E-Workshop, especially from the Balkans, working out a precise chronology that is not problematic is still not possible (Biagi, Shennan, and Spataro 2005). Thus, I confined extrapolations to a general level.

After an overview of previous discussions on the nature of this expansion, it now seems clear that all arguments, no matter how contradictory, were correct. There was endemic movement, migration, and colonization by both land and sea; there were “frontiers” merging with local communities, expansion by exchange of knowledge and/or commodities, and to a degree, local development. Of the latter, transformation of the mud-brick architecture of the Anatolian plateau to wooden posts or wattle-and-daub structures in the wooded areas of Marmara should be considered as a fine example of adaptation to local environment. Some of the mobile groups were strictly farmers and others had a mixed economy with intensive hunting, but there were others who were highly dependent on marine resources. What is clear is the fact that it was a dynamic era, and there was motivation to move or to migrate that was not common in other periods. What is also clear at this stage is the sustained relationship between the newly settled areas and the original homeland.

I find this continuing connection to be extremely significant in understanding the mode of Neolithic expansion. If it had taken place as a rapid and organized movement, then sooner or later the developments in the new areas would have been different from those of the homeland. On the contrary, from the earliest stage of the Pottery Neolithic up to the so-called Vinca period in the Balkans, there is an apparent parallelism in the primary cultural traits between Anatolia and the Balkans that is defined by Garasınan as the "Balkano-Anatolian culture complex" (Garasınan 2000). This implies that moving groups somehow sustained contact to keep track of what was happening in their original homeland, a pattern described as “chain migration” by Anthony (1997:24).

As I have noted, the evidence is still very fragmentary, and the data are very recent and need time to develop. Here I have offered some generalizations, and they should be understood on that level. Every excavated site has various pieces of evidence that do not fit with the general statements in this article. Perhaps the Neolithic era can best be described as a complex mosaic with a strong social motivation to migrate.

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Westward Ho!
The Spread of Agriculture from Central Europe to the Atlantic

by Peter Rowley-Conwy

Recent work on the four major areas of the spread of agriculture in Neolithic western Europe has revealed that they are both chronologically and economically much more abrupt than has hitherto been envisaged. Most claims of a little agriculture in Late Mesolithic communities are shown to be incorrect. In most places, full sedentary agriculture was introduced very rapidly at the start of the Neolithic. “Transitional” economies are virtually absent. Consequently, the long-term processes of internal development from forager to farmer, so often discussed in Mesolithic-Neolithic Europe, are increasingly hard to sustain. The spread of agriculture by immigration is thus an increasingly viable explanation. The crucial role of boats for transport and of dairying for the survival of new farming settlements are both highlighted. Farming migrations were punctuated and sporadic, not a single wave of advance. Consequently, there was much genetic mixing as farming spread, so that agricultural immigrants into any region carried a majority of native European Mesolithic genes, not Near Eastern ones.

Westward ho!
(This was the Thames watermen’s cry, indicating direction of travel to prospective passengers. By Shakespeare’s time, it was a more general expression of intent to travel westward, often by boat. [Twelfth Night, act 3, scene 1, line 134])

Introduction: Event and Process

In this article I will consider the spread of agriculture from central Europe to the Atlantic (fig. 1). This involves four major “spread events”: the Cardial of the western Mediterranean, the Linienbandkeramik (LBK) of the interior, the Trægtbægerkultur (TRB) of southern Scandinavia, and the Neolithic of Britain and Ireland.

Archaeologists often regard the appearance of agriculture in any region as a slow process of transition: the Later Mesolithic may have had a few domestic animals or plants, while the Neolithic may still have involved nomadic foraging. In this article I will, however, argue that recent work has demolished the basis for thinking that these were slow transitions. Instead, full sedentary agriculture appeared rapidly in most places. The evidence for these four spread events has been “sharpened up,” rendering them chronologically more abrupt. They thus appear more as archaeological events than as processes.

“Process” implies continuity within the local group. “Event” raises the possibility of immigration. In this article I will argue that agriculture was introduced by immigration more often than is currently believed: the four spread events considered here were all probably migrations. This position is remarkably similar to that adopted by Özdoğan (2011) in his consideration of Anatolia and the Balkans; at the Wenner-Gren conference from which these articles stem, “The Origins of Agriculture: New Data, New Ideas,” it seemed almost that they were two halves of the same article.

On a broader scale, the conference threw two things into sharp relief for me. The first is the contrast between the lengthy and complex origins of the Near Eastern agricultural system—as discussed by Goring-Morris and Belfer-Cohen (2011) and Zeder (2011)—and the rapid subsequent spread of that system across Europe. It seems that “origins” and “dispersals” are becoming ever more sharply differentiated as archaeological work proceeds. The second is the fact that the origin and spread of the Chinese agricultural system shows some similarity to the Near Eastern system, the complex origins (Cohen 2011; Zhao 2011) contrasting with its spread through Korea (Lee 2011) and Japan (Crawford 2011). Similar explanations may thus be emerging for the spread of agriculture at both ends of Eurasia: in temperate zones away from the centers of agricultural origins. At a still wider level, the conference served (for me, at least) to emphasize the difference between the mode and speed of the spread of the East.
Figure 1. Map showing the major farming "spread events" discussed in this article. Dates are in calibrated years BP. A color version of this figure is available in the online edition of Current Anthropology.
and West Asian cereal/pulse/domestic-animal farming systems on the one hand and the Southeast Asian root/fruit system (Denham 2011) on the other: the former appears on current evidence to spread much faster than the latter.

The Debate: Immigrants or Indigenes

This debate has a long and complex history in Europe. Most scholars of course argue for a combination of the two but nevertheless tend to favor one over the other. In the middle twentieth century, immigration was the standard view (Childe 1957). In the wake of the radiocarbon revolution, British scholars began suggesting indigenous developments even though radiocarbon dating had not altered the relative dating of early agriculture in Europe: in Britain it was still later than in the near continent, and it remained earliest in the Balkans. Indigenism, however, appeared an attractive new idea forming part of a broader research agenda seeking indigenous origins for megalithic tombs and Bronze Age chieftoms. British researchers applied indigenist arguments to early agriculture in wide areas of Europe (Barker 1985; Dennell 1983), and recent postprocessualists have followed this pattern (Thomas 1999; Whittle 1996). Continental reactions have been mixed. South Scandinavians have mainly concurred (Jensen 1982) as more recently have many Iberians (Arias 1999); but most German archaeologists mistrust Anglophone overviews and espouse migrationism (Gronenborn 1999, 2007).

Indigenism

Wild einkorn is present in the Balkans; aurochs and wild boar were widespread in Europe; some have suggested that the wild species of sheep, barley, and lentils were present as well. Various arguments for local domestication have been put forward (Barker 1985:252–253; Dennell 1983:159–163; Whittle 1996:67; Zvelebil 1995, 2008:31). The latest reiteration is by Barker (2006:336), who adds wild goat.

Current research is unkind to these suggestions. The genetics of einkorn, barley, and lentils all indicate a Near Eastern origin (Badr et al. 2000; Heun et al. 1997; Ladizinsky 1999). Modern “wild” sheep on Mediterranean islands are in fact feral (Poplin 1979), and recent DNA studies support a Near Eastern origin (Meadows et al. 2007). The “goats” mentioned by Barker (2006:336) are actually ibex (Capra ibex), which have never been domesticated and have nothing to do with the origin of domestic goats. Capra aegagrus was domesticated in the Near East (Naderi et al. 2008). Metrical evidence is against the European domestication of aurochs (Rowley-Conwy 2003a); the genetic evidence agrees, demonstrating Near Eastern origins for the domestication of cattle (Bollongino and Burger 2007; Edwards et al. 2007; Troy et al. 2001). Attempts to make Europe part of a vastly expanded Near Eastern “agricultural hearth” (cf. Barker 2006:384) have thus failed. Some secondary domestications did occur: wild boar were domesticated in Europe but only after the arrival of domestic pigs of Near Eastern origin (Larson et al. 2007), and rye and oats were domesticated in the Iron Age.

Indigenism, however, receives support from human genetics. Early work used modern human blood groups in Europe to argue for large-scale immigration in the Neolithic, the famous “wave of advance” hypothesis (Ammerman and Cavalli-Sforza 1984). Recent work on mitochondrial DNA (mtDNA) indicates the opposite, that most Europeans are descended from pre-Neolithic hunter-gatherers. This is because mtDNA lineages began to diverge before the Neolithic. The most recent studies have involved the complete mitochondrial genome and indicate that this divergence started ~15,000 years ago (Soares et al. 2009, 2010).

Indigenism has therefore largely become “adoptionism.” Local hunter-gatherers provided the bulk of the human genes in Neolithic and later cultures but acquired the elements of farming from neighbors who had already “gone agricultural.”

Migrationism

Migrationism has received support from linguistics. However, Renfrew’s (1987) argument that agriculture was carried into Europe by Indo-European speakers has met with considerable opposition. Mallory (1989:121, 126–127) pointed out that words associated with wheels, carts, and traction are related in most Indo-European languages, and because such technology did not exist before ca. 5500 BP, this suggested an Indo-European dispersal after that date. Anthony (2007) argues that if Proto-Indo-European was spoken by Europe’s earliest farmers around 8500 BP, the common terminology for wagons would mean that it remained a single language spread across most of Europe for 3,000 years, diversifying only after 5500 BP, a most unlikely scenario. A more recent suggestion is that Basque, normally regarded as unrelated to any other language, may in fact have connections with other linguistic isolates, including some languages spoken in the mountains of the Caucasus, and with Burushaski, spoken in northern Pakistan. Some of the suggested connections refer to domestic cattle, sheep, and goats, to cultivated cereals, and to milking and tillage. This could imply that Basque is Europe’s sole remnant of a pre-Indo-European language family that spread with the first agriculturalists (Bengtson 2009). Most European Neolithic archaeologists do not involve themselves in the linguistic debate, probably feeling that it can contribute little to the elucidation of the archaeological record.

Genetics also provides some support for immigration. The divergence dates for most European mtDNA lineages (as mentioned above) fall in the Late Paleolithic. But these studies allow perhaps 15% of modern European mtDNA to derive from Neolithic immigrants (Soares et al. 2010), so the initial introduction of agriculture was probably by immigration. The Y chromosome provides a complication. Chikhi et al. (2002) suggest that as much as 50%–65% of modern European Y chromosomes descend from Near Eastern ancestors. This does
not mean that such a proportion of males immigrated in the Neolithic, however, because the movements cannot be dated (Chikhi et al. 2002:11012–11013). A recent estimate for the immigrant Neolithic Y chromosome proportion is that it might have been similar to that for mtDNA (Soares et al. 2010).

Y chromosome patterns are particularly difficult to disentangle. Zvelebil (2000:70) aptly describes the modern pattern as an “incremental palimpsest.” Migrations of all kinds have occurred in the past. Armies have high Y chromosome counts and are highly mobile. Roman and Ottoman armies, to mention but two, penetrated huge areas of Europe and involved diverse males—auxiliaries and janissaries recruited soldiers not of Roman or Turkish ethnicity. The difficulties of establishing what may be Neolithic are shown by the attempt by King and Underhill (2002) to correlate immigrant Y chromosomes and Neolithic anthropomorphic figurines. Where the correlation is positive (e.g., northern Italy, southern France), Neolithic immigration is proposed, but where figurines are absent (e.g., eastern Spain), the authors resort to historically recorded Greek or Phoenician migrations 5,000 years later to account for the immigrant Y chromosomes now present in eastern Spain. This seemingly random invocation of such disparate migrations does not inspire confidence—why not Napoleon’s invasion army of 1808? It ignores the archaeological unity of the Cardial phenomenon (see below), and the notion that “Y chromosome lineages = figurines” is remarkably reminiscent of the “pots = people” archaeological theories of half a century ago.

Genetics will no doubt be taken much further by the addition of ancient DNA to the discussion. This is problematic because of the possibility of contamination, but it is beginning to occur. It is likely that there will be surprises. One study of 24 LBK skeletons revealed that six of them (25%) carried an mtDNA type that is now present in just 0.2% of modern Europeans. If this tiny sample is representative, modern Europeans cannot therefore be descended from this farming population (Haak et al. 2005).

Integrationism

Our explanations must now rest on two major foundations: most Neolithic genes were native, but the major domesticates were exotic. Small-scale rather than continent-wide migrations are the best way to integrate these into one model. Agriculture in a region may have been introduced by immigrants, but that does not mean that the immigrants carried mainly Near Eastern genes (Richards 2003; Rowley-Conwy 2004b; Zvelebil 2000). The LBK, for example, originated in the Carpathian Basin; the population that moved westward emerged there carrying a complex mix of European and Near Eastern mtDNA and no doubt picking up more as it moved. The same is potentially true of all the spreads shown in figure 1.

One integrationist scenario is therefore migration by agriculturalists, but agriculturalists who carried largely “Mesolithic” genes from elsewhere in Europe. Small-scale alternatives to the wave of advance are envisaged as “infiltration,” “trickle,” or “creep” migrations. Perhaps more applicable to larger movements is “leapfrog colonization” moving beyond the farming frontier into available space (Rowley-Conwy 2004b; Zvelebil 2000). Several likely instances will be mentioned below.

Sharpening the Agricultural Spreads

Improved excavation and dating everywhere in Europe has put migrationism firmly back on the agenda. The following sections show how this has happened with regard to the four spread events plotted in figure 1.

The Cardial of the West Mediterranean

Twenty years ago, the northern Italian Neolithic was thought to start around 7000 BP (uncalibrated), its subsistence based largely on wild foods. The adoption of agriculture from the south was slow, sheep and cereals becoming predominant only later in the period (Barker et al. 1987). The Neolithic farther west (fig. 2) was, however, much earlier, with dates of 7520 ± 240 BP (uncalibrated) at Châteauneuf-les-Martigues and 7970 ± 150 BP (uncalibrated) at Verdelpino (Guilaine 1979). Furthermore, sheep were reported in Mesolithic contexts at several sites: at Châteauneuf, preceding the early 13C date just quoted (Ducos 1977), Gazel and Dourgne (Geddes 1980, 1985), and Nerja (Boessneck and von den Driesch 1980). The role of cereal cultivation was unclear, some emmer wheat perhaps appearing at the start of the Neolithic (Lewthwaite 1986a). This appeared to be a classic case of agricultural adoption by hunter-gatherers. The “filter model” suggested that agriculture moved along preexisting Mesolithic interconnections. Foragers in northwest Italy adopted only certain agricultural elements—initially only sheep—so the other items were “filtered out” and not available for transmission to the west. These transitional economies developed into full agriculture later in the Neolithic (Lewthwaite 1986a, 1986b).

Recent work has transformed this. Early Neolithic agriculture in northern Italy is now known to comprise four cereals—emmer, einkorn, free-threshing wheat, and barley—and five pulses—lentil, pea, broad bean, bitter vetch, and grass pea—from the start, indicating a rapid transmission of full agriculture from the south (Rottoli and Castiglione 2009). The earliest Neolithic in northwest Italy at Arene Candide is dated to ~7700 cal BP (Maggi and Nisbet 2000), and the fauna is dominated by domestic animals from the start (Rowley-Conwy 1997). In Portugal, Cisterna dates to ~7400 cal BP (Zilha 2009, forthcoming), Caldeirão to ~7300 cal BP (Zilha 1992). The claimed earlier Neolithic dates in between have been discounted: Zilha (1993:47) has pointed out that the sites were not excavated to modern standards.
and were disturbed by burrowing animals. “Mesolithic” sheep are no longer accepted because of these problems (Guilaine and Manen 2007:25–26) and the difficulty of distinguishing the bones of domestic sheep and goat from wild ibex (*Capra ibex*) and chamois (*Rupicapra rupicapra*), especially when juvenile (Rowley-Conwy 2004a).

Continuity from the Mesolithic is now regarded as minimal. Long considered a “cave Neolithic,” the Early Cardial has recently produced major open-air settlements at La Draga (Bosch, Chinchilla, and Tarrús 2000) and Mas d’Is (Bernabeu et al. 2003), each with several structures. Farther southwest, the earliest houses so far known are at Castelo Belinho, dating to the later Early Neolithic, after ∼6900 cal BP (Gomes 2008). São Pedro de Canaferim has produced a substantial open-air settlement dating to before 7000 cal BP (Simões 1999), so earlier houses are likely to be found. Faunal assemblages contain a majority of domestic species from the start—La Draga has >90% domestic animals (Palomo et al. 2005). Cultigens predominate among the plants: the eastern Spanish Cardial economy comprises the same four cereals and five pulses as in northern Italy (Zapata et al. 2004, table 2); La Draga produced a huge sample of over half a million wheat grains (Buxó, Rovira, and Saúch 2000, fig. 103). Margineda has both Mesolithic and Neolithic layers (Guilaine and Martzloff 1995). Domestic animals first appear at the start of the Neolithic (Geddes 1995); significantly, four cereal grains in Mesolithic contexts are discounted as intrusive (Marinval 1995:72). Nothing remains of “transitional” economies.

The Epicardial of the Iberian interior has only been studied very recently. Major rivers such as the Ebro and Tagus were likely routes for colonization, though mating with local Mesolithic people may also have occurred (Arias 1999:414; Guilaine and Manen 2007:43). Very early Neolithic dates have been claimed: 8000 cal BP at Mendandia (Alday 2007) and 7800 cal BP at La Lámpara (Rojo et al. 2006:53, 60). They have, however, been criticized by Zilhão (forthcoming): pottery was present at Mendandia, but all the animals were wild (Alday 2007), while at La Lámpara the dated bone was not identified as to species. Directly dated cereal grains at La Lámpara start at ∼7200 cal BP (Rojo et al. 2006; Stika 2005), the same as at Los Barruecos on the Tagus (Cerillo and González 2006). There was a delay of several centuries before agriculture spread to the northern coast, perhaps because the region was more densely settled with hunter-gatherers (Arias 2007:62). Cattle appear at Arenaza at ∼6900 cal BP (Arias 2007:60) and emmer at El Mirón at ∼6400 cal BP (Peña-Chocarro et al. 2005). Cultivation seems to have become restricted to the cereals as it spread northwest: just three peas were found at Margineda (Marinval 1995), and no legumes at all were found at La

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**Figure 2.** Map of the western Mediterranean, showing the location of sites mentioned in the text. A color version of this figure is available in the online edition of *Current Anthropology.*
Lámpara (Stika 2005) or El Mirón (Peña-Chocarro et al. 2005).

Cardial Colonists and Colonization

Most researchers now regard the Cardial phenomenon as a rapid colonization by boat (see the influential article by Zilhão 2001). This has been reinforced by the recent definition of the earliest Cardial phase, the “Impressa,” at Pendimoun and Arene Candide (Binder and Maggi 2001). This has subsequently turned up also at Pont de Roque-Haute and Peiro Signado along the coast in France (Guilaine, Manen, and Vigne 2007). These two sites are only 3 km apart, but the Peiro Signado ceramics resemble those at Arene Candide, while Pont de Roque-Haute is more similar to Giglio farther around the Italian coast (Manen 2007:160–163). Pendimoun resembles sites in eastern peninsular Italy (Binder et al. 1993: 227–228). This suggests multiple leapfrog colonizations, and the recent discovery of an Impressa site at El Barranquet in Spain extends this apparent Ligurian colonization to 900 km from Arene Candide (Bernabeu et al. 2009). Even this early, the fauna is dominated by domestic animals (Vigne and Carrère 2007).

In most areas there is a radiocarbon gap between Mesolithic and Neolithic (Guilaine and Manen 2007, their fig. 2; Skates 2003). In southern Portugal there was considerable Mesolithic occupation that, bypassed by the Cardial colonization, continued until after 7000 cal BP (Zilhão 2003, forthcoming). The Mesolithic diet was largely coastal, that of the Neolithic terrestrial (Lubell et al. 1994). DNA from the two populations differs, although neither carry the Near Eastern lineage implicated in carrying agriculture into Europe (Chandler, Sykes, and Zilhão 2005). This is consistent with Cardial immigration involving farmers of indigenous Mesolithic ancestry (cf. the “integrationist” model suggested above).

The practicalities of maritime colonization must be considered. Broodbank and Strasser (1991) discuss the Early Neolithic colonization of Crete. Forty colonizing humans would need 5–10 breeding pairs of each animal species and 250 kg of grain, weighing in total some 15–20 tons, to establish an agricultural economy. Such a cargo might be carried in 10–15 boats each carrying 1–2 tons (Broodbank and Strasser 1991:241) or fewer boats each making several voyages. A >10-m log boat comes from the Cardial lake settlement of La Marmotta near Rome (Fugazza, Delpino, and Mineo 1995). A reconstruction was routinely able to sail 30 km in a day with a crew of 10 and plenty of space for cargo (Tichy 1999). Boats made of animal hides stretched over a frame would have been an even better option: they have greater cargo capacity but are light enough to be carried by their own crew (Case 1969). The efficacy of such boats for transport is shown by the Irish curragh (fig. 3). Whatever kind of boat they used, Cardial people took cattle, sheep, goat, and pig to Sardinia (e.g., Filiestru: Levine 1983) and also (but without the cattle) to Corsica (e.g., Basí: Vigne 1988:153). The optimal time for colonizing voyages would be late summer, after the harvest was gathered and before winter-sown crops were planted (Broodbank and Strasser 1991:241; Case 1969:178). The feasibility of such colonizing voyages is underlined by the spectacularly early evidence of Neolithic colonizers on Cyprus presented at the conference (Vigne 2011).

Survival for the first year, until the newly established cereal fields begin producing, is a further critical variable. Along the Mediterranean coasts hunting would presumably have been particularly important, but this would have been chancy, and any food supplies that could be carried with the colonists would have been extremely valuable. Cereals are heavy. Recent work suggests an alternative: dairy products. The milking of sheep and goat by Cardial people has been suggested on zoo-archaeological grounds (Rowley-Conwy 1997:168, 2000). Analysis of lipids in ceramics has recently demonstrated the use of dairy products in Anatolia back to the ninth millennium cal BP (Evershed et al. 2008). Because this was the source area of the Cardial agricultural regime, it is likely that dairying spread with the other items and practices. Dairying might be critical in one particular way, because pregnant or lactating animals can be driven (Case 1969:177). Such animals could therefore presumably be carried by boat without ill effects. The presence of some lactating animals in a newly established settlement would be invaluable, providing food each day for several months, thus bridging the gap until other aspects of the economy “kicked in.”

In conclusion, the Cardial phenomenon is an immeasurably sharper event than was understood 20 years ago. In its new guise it conforms with what we would expect from a migration: cultural derivation from northwest Italy, not the local Mesolithic; a very rapid spread, with the transplantation of the entire agricultural system; and the means in place to assure its spread and survival.

The LBK of Central Europe

The LBK was accepted as appearing relatively abruptly much earlier than the Cardial, so recent developments have been less revolutionary. In a landmark article, Quitt (1960:163–164, fig. 3) argued that the cultural uniformity of the LBK indicated a rapid immigration along two routes: the Elbe and the Danube/Upper Rhine. Subsequent workers mostly accept migration (e.g., Bogucki 2003; Lüning 1989; Scarre 2002), though some advocate indigenism (e.g., Price 2000a; Whittle 1996). Gronenborn (2003:81) argues for a migration covering 800 km in 100 years and involving a “multi-faceted combination of migrations, adaptations and acculturations” (2007: 73). Faunal assemblages usually comprise >60%–80% domestic animals, with cattle and pigs being predominant (Döhle 1997). Botanical assemblages testify to the overwhelming importance of cultigens (Bogaard 2004; Lüning et al. 1997).

The logistics of rapid migration must be considered. Early discussions envisaged shifting cultivation and temporary fields
moving across Europe on a broad front (Childe 1929:46; Clark 1952:92–93). Shifting cultivation has subsequently come under heavy criticism (e.g., Lüning 1980, 2000; Rowley-Conwy 1981, 2003b; Sherratt 1980), though some still espouse it (Whittle 1996:160–162, 1997:22). Bogaard (2004) has convincingly shown on the basis of weed floras that LBK crops were intensively cultivated in small autumn-sown fixed plots. Distribution is patchy, which is not suggestive of a broad-front migration: settlement largely follows loess soils, forming discrete siedlungskammer, or “settlement cells” (Lüning 1989), sometimes widely dispersed (fig. 4). These siedlungskammer start with a few houses close to rivers; later, the houses multiply, and settlement spreads away from the rivers (Kruk 1980; Lüning 1989; Stehli 1989).

The forest facing the LBK immigrants was thick, with much understory and undergrowth (Kreuz 2008). Heading off to found a new siedlungskammer with the entire agricultural package would be a challenging enterprise. We must dispense
Figure 4. West central Europe at the time of agricultural colonization. The northern part of the map is based on Verhart (2000, fig. 1.15). Loess areas and settlement cells to the southeast are from the more general map in Clark (1952, fig. 45). Where these disagree I have followed Verhart. La Hoguette and Limburg pottery sites from Lüning, Kloos, and Albert (1989, fig. 2), van Berg (1990), and Lefranc (2008, fig. 5). Several Limburg findspots in the Hesbaye cluster are omitted for clarity. A color version of this figure is available in the online edition of *Current Anthropology*. 
with preconceptions derived from the managed woodlands and regulated rivers of our own times. Choked underground and sprawling waterways and mires would face anyone attempting to move through the landscape. In the open, cattle and pigs cluster into manageable herds, but in woodland they disperse and rapidly become uncontrollable. How then could an 800-km migration be achieved in 100 years?

The clue may lie in Quitta's (1960:165) stressing of the importance of the Elbe and Danube as routes. The siedlungskammer germinate near rivers (see above). Perhaps the rivers themselves were the highways along which Neolithic colonists moved. If maritime colonization was feasible for the Cardial (see above), riverine colonization is a viable hypothesis for the LBK. Many central European rivers form a nexus that would facilitate this (fig. 4). From the Elbe, travel to the Weser would be difficult. But from there, short overland moves provided access to the Ruhr and Rhine and from there to the Meuse and subsequently to the Marne and Seine. The Danube similarly runs close to the Rhine and Neckar. Considerable sections of these river systems must have been navigable in the Neolithic.

A 10-m hide boat could carry several people, a couple of dogs, two cows, two calves, and their bedding (Case 1969). After a day or so, the animals would become restive because of thirst, but on a river, with overnight stops, this would not be a problem. Recent Irish curraughs are smaller (up to ca. 6 m), but they can effectively move cattle and pigs, which can be carried inside the boat for longer moves or towed behind for shorter hops (fig. 3). Early autumn, between harvesting and autumn sowing, was an agricultural “down time” and would be the optimal time for movement. As with the Cardial, the first year in a new settlement would be critical. Hunting would no doubt be important, but once again dairy products may have played a key role. A cow that had given birth in late spring would be lactating in early autumn and might also be again in calf. This could be a way of transporting a continuously productive food supply. Bogucki (1984) has argued that the ceramic sieves found in LBK contexts were used in dairying.

LBK contacts with local foragers took a variety of forms. In much of its area, the LBK is at the head of a sequence of later cultures derived from it. This is not the case for the Villeneuve-Saint-Germain (VSG) of northwestern France (fig. 1). Scarre (2002:401) regards the VSG as the ultimate westward extension of colonizing farmers. But the VSG did not give rise to later cultures descended from it. After a couple of centuries it disappeared, replaced by a more widespread local Neolithic. Agriculturalized foragers appear to have absorbed the immigrants (Scarre 2002). The picture near the mouth of the Vistula is different. The recent discovery of several post-LBK Stroke Ornamented Pottery (stichbandkeramik) settlements indicates agriculture here around 7000 cal BP (Czerniak 2007). But this colonization failed, and the economy of the area reverted to hunting and gathering after this apparently brief and abortive penetration.

Elsewhere, the immigrants absorbed hunter-gatherers. Strontium isotopes in human skeletons suggest that more females than males were of nonlocal origin in the LBK cemeteries at Schwetzingen and Dillingen (Price et al. 2001). This may indicate hunter-gatherer women marrying into farming communities (Bentley et al. 2002). This pattern is not repeated everywhere, and farming practices such as long-range pastoralism are complicating factors (Bentley et al. 2003; Bickle and Hofmann 2007). However, the loss of only a few women could destabilize low-density foraging populations and might prompt the remainder to adopt farming if the unmarried males developed “cattle envy.” If this suggests peaceful interaction, the same was not true farther north: in the Hesbaye region, several LBK sites were fortified, apparently against Mesolithic attack (Keeley and Cahen 1989).

“La Hoguette” and “Limburg” ceramics are problematic. La Hoguette sherds appear on the earliest LBK sites and also farther west, beyond the LBK distribution, with Mesolithic flints (fig. 4). Limburg ceramics are later, with an analogous distribution on and beyond the earliest farming settlements farther west (Lefranc 2008; Lüning, Kloos, and Albert 1989; van Berg 1990). These groups may be partially acculturated hunter-gatherers, so their ceramics on LBK sites would indicate contact (Gronenborn 1990:178; Zvelebil 2005). Economic evidence is very limited; the La Hoguette site of Bad Cannstatt has provided nine deer bones (and 39 antler fragments) and two caprine teeth (von den Driesch, in Kâlis et al. 2001, table 3). Dating also is imprecise: there is no clear evidence that La Hoguette pottery predates the LBK. The suggestion that La Hoguette represents “local Mesolithic peoples who had begun to practice horticulture and herding several hundred years before the arrival of LBK” (Price et al. 2001:595) goes further than the evidence currently allows. An added complexity is that La Hoguette ceramics are derived from the Epicardial of southern France. Lefranc (2008) and van Berg (1990) argue that Limburg has a similar origin, though Lüning, Kloos, and Albert (1989) disagree. Both ceramic styles have turned up in Cardial contexts at Gazel (Guilaine and Manen 2007:46). The Rhône-Saône system is part of the river nexus mentioned above (fig. 4), thus providing a potential route to the north. Could the La Hoguette people be “Epi-epi-cardial” farming immigrants?

**Beyond the Northern Frontier**

The northern edge of the LBK was the longest-lived forager-farmer boundary in Neolithic Europe, lasting from ~7500 cal BP to ~6000 cal BP. To the north were hunter-gatherers: Swifterbant in the Low Countries and Ertebølle in southern Scandinavia and the Baltic. Artifactual signs of contact occur soon after the arrival of adjacent Neolithic groups. LBK arrowheads occur in the Swifterbant region from 7500 cal BP (Louwe Kooijmans 2003). Adzes also spread north (see fig. 4) into the same area (Verhart 2000, fig. 1.15) and through Poland (Bogucki 2008), reaching the Baltic by 6700 cal BP.
(Hartz, Lübke, and Terberger 2007). The Swifterbant regions began making pottery around 7000 cal BP (Louwe Kooijmans 2007), the Ertebølle following around 6700 cal BP (Andersen 2007; Hartz, Lübke, and Terberger 2007), although the ceramic style owed more to northeastern Baltic types (Hallgren 2004). Things were not all one-way: Bogucki (2008) argues that T-axes of antler in the LBK derive from Ertebølle prototypes.

These artifactual contacts did not, however, lead to the diffusion of agriculture. A few domestic animals are sporadically claimed, but they rarely stand up to scrutiny. Mesolithic caprines were claimed at Deby in Poland (Domanska 1989). Objections were soon raised (Kozlowski 1990), and these claims are no longer accepted (Domanska 2003:590). Some domestic cattle and pigs were claimed at the Ertebølle site of Dabki on the Baltic (Ilkiewicz 1989). No criteria demonstrating domestication were ever put forward, but the specimens are still sometimes mentioned (Zvelebil 2004). A recent re-examination has, however, demolished these claims: domestic cattle appear at \( \sim 6200 \) cal BP (Kabacinski, Heinrich, and Terberger 2009). A few cattle bones at Rosenhof at \( \sim 6700 \) cal BP were claimed to be domestic (Nobis 1975). On metrical grounds these are probably aurochs (Rowley-Conwy 1985, 2003a), but they are still often cited as domestic (Hartz 2005; Hartz, Heinrich, and Lübke 2000, 2002; Schmökel 2005; Zvelebil 2004). Strong support for their identification as aurochs has come from two recent studies. Isotopes show that these animals’ diet was like that of contemporary aurochs, not later domestic cattle (Noe-Nygaard, Price, and Hede 2005). Their DNA matches the European aurochs lineage, not the imported domestic Near Eastern lineage (Scheu et al. 2008). There can be little doubt that these animals were wild. The earliest domestic cattle from this area are those from Wangels, dating to after \( \sim 6100 \) cal BP, when caprines and cereals also occur (Hartz, Lübke, and Terberger 2007:586; Price and Noe-Nygaard 2009).

In the Netherlands, a few bones of domestic animals are claimed at \( \sim 6700 \) cal BP: 20 sheep/goat at Brandwijk L30 (Raemaekers 1999, table 3.49), and 15 more, with three domestic pigs and 15 domestic cows, at Hardinxveld De Bruin (Oversteegen et al. 2001). The criteria for separating the cattle and pigs into wild and domestic have not been published, but the sheep/goat (if contemporary with the rest of the materials) are clearly domestic. Louwe Kooijmans (2003:621) regards these as likely imports of joints of meat, not as locally reared animals. Cereal grains have not been found, but one barley grain comes from Doel in Belgium in a context dated to 6600 cal BP (Crombé and Vanmontfort 2007:269); there is, however, later occupation at this site (Crombé, Perdaen, and Sergant 2005:55), and the grain itself has not been directly dated (Philippe Crombé, e-mail, February 2009). Cereal agriculture is first well attested after 6100 cal BP at Swifterbant S3 (Cappers and Raemaekers 2008).

There is thus a disparity between artifacts and agriculture: 1,500 years of artifact exchange led to no economic Neolithization. As archaeologists, we like imported artifacts because they are (a) identifiable and (b) considered important. But how important were they to their Mesolithic recipients? Large quantities are known, many getting as far as Denmark (fig. 5). It is often assumed that they were sought after merely because they were exotic, engendering competition and destabilization in hunter-gatherer societies (e.g., Fischer 2002; Thomas 1996; Zvelebil 1996, 1998). But virtually all are stray finds (Klassen 2002:308–309; Verhart 2000:33); there is no archaeological reason to assume that they were regarded as in any way special by their Mesolithic users.

The LBK remains a sharp archaeological event, still best interpreted as a migration. The speed of the westward migration contrasts spectacularly with the 1,500-year pause before agriculture spread north into the Swifterbant/Ertebølle sphere. The huge lag between the spread of artifacts and agriculture suggests that the artifacts did not have any significant catalyzing effect. The way to destabilize and Neolithize hunter-gatherers is not to sell them axes but to encroach on their territory and steal their women.

Southern Scandinavia

Southern Scandinavia is characterized by the Late Mesolithic Ertebølle shell middens. The hunter-gatherer population may have been as high as about 1 individual per 2 km\(^2\); this is similar to that of recent sedentary groups in California and the Northwest Coast and much greater than typical densities elsewhere (Rowley-Conwy 1983). For this reason alone, a substantial degree of indigenism is espoused by virtually all who consider the appearance of agriculture (e.g., Andersen 1973, 2007; Fischer 2002; Larsson 2007; Price 2000b; Rowley-Conwy 1999; Zvelebil 2008).

Yet even here the case can be made for some migration. Chronological sharpness is the crucial issue: if the change to agriculture is gradual, it can be portrayed as an indigenous development, merely acquiring the domestic crops and animals from elsewhere; but if it is rapid, migration becomes more likely. Numerous axes of continental Neolithic origin are found in Mesolithic Denmark (fig. 5). It is sometimes argued that these caused social developments toward Neolithization, such as the sedentary occupation of large coastal base camps (Fischer 2002). The counterargument (see above) is that the exotic artifacts had little impact: increasing population density, base camps, and territoriality as indicated by the appearance of cemeteries are better explained as a Mesolithic response to increasingly maritime conditions (Rowley-Conwy 1998, 1999). These developments in fact all took place much earlier than the arrival of agriculture in central Europe (Larsson 2007; Rowley-Conwy 1999). Coexistence between foragers and farmers and a gradual transition to agriculture are suggested at Lødødesborg (Jennbert 1984). This site, however, has major stratigraphic problems and is written off by Scandinavian scholars (see Rowley-Conwy 2004b:87), although it is still occasionally cited (Zvelebil 2004, fig. 4.2).
Figure 5. Late Mesolithic and Early Neolithic southern Scandinavia. Shoe-last axes of Late Mesolithic date imported from farmers to the south from Klassen (2002, fig. 20.1). Trægtbægerkultur and other pottery in Norway from Østmo (2007, fig. 1); Early Neolithic thin-butted axes imported from Denmark or southern Sweden from Hinsch (1955, fig. 7). A color version of this figure is available in the online edition of Current Anthropology.
The appearance of agriculture was quite abrupt. In Denmark there was a rapid change in settlement pattern. Some sites did continue to be occupied, but these were seasonal special-purpose camps (Rowley-Conwy 1983; Skaarup 1973). Mesolithic base camps such as Ertebølle (Andersen and Johansen 1986) or Bjørnsholm (Andersen 1991) show reduced levels of Neolithic occupation and may have become special-purpose fishing camps. Neolithic “base camps” were in inland agricultural areas. The shift to interior settlement at the start of the Neolithic was abrupt (Larsson 1986; Nielsen 1985). A classic example is the island of Bornholm, where even the earliest Neolithic occupation has a markedly inland distribution (Nielsen 2009, fig. 6). The same happens on Gotland (Osterholm 1989). The pointed butted axe, characteristic of the earliest phase of the Early Neolithic, has a markedly inland distribution both in eastern Denmark (Nielsen 1977, fig. 7) and southern Sweden (Hernek 1988, figs. 4–7).

The available economic evidence also suggests an abrupt change. There is no evidence for domestic animals in Mesolithic contexts, contra Thomas (1996:314) and Zvelebil (1996:334). One domestic cow, directly dated to ~6900–6600 cal BP, is claimed from Lollikhuse (Sorensen 2009, but the identification of the tooth remains is in doubt (S. Sorensen, e-mail, March 2009). The earliest domestic cattle in Denmark are 3 specimens from Åkonge; this site is dated to after 5900 cal BP and is transitional to the Neolithic (Gotfredsen 1998). Neolithic economies are dominated by domestic species. Isotopic analysis of human bones shows an abrupt transition from a Late Mesolithic marine diet to a terrestrial Neolithic one (Tauber 1981); even farmers living close to the coast ate few marine foods (Richards and Koch 2001).

This sharp change suggests that some migration occurred even if most Neolithic mtDNA was local. The TRB in fact spreads a long way north very rapidly (Knutsson and Knutsson 2003), Skogsmossen (Hallgren et al. 1997) being near the northern limits of cultivation (fig. 5). Farming here seems to “overreach” itself, and subsequently it retreated, being replaced by the Pitted Ware culture, termed “Middle Neolithic” even though they were hunter-gatherers (Erikkson 2004). Farming probably reached southeastern Norway as well, marked by the TRB pottery in figure 5, though organic preservation is poor (Ostmo 2007; Ostmo and Skogstrand 2006).

This farming spread must have been by boat. There were no native aurochs on Zealand (Aaris-Sorensen 1980), so the early cattle at Åkonge were definitely imported. Farther north, agriculture was probably carried by boat up the coasts, an easier method of travel than overland (see above). Baltic crossings would require longer open-water voyages than in the Cardial or LBK. Irish curraghs can, however, make substantial voyages and weather considerable seas (Hornell 1938, sec. 5: 17–21), and a large one has even crossed the Atlantic (Severin 1978). The role of dairy products in such moves has been stressed above. If fresh milk (rather than yogurt, cheese, etc.) was to be consumed, the consumers must have the lactose-tolerant gene present in some modern peoples. Swedish researcher have recently located this gene in 13 archaeological skeletons, the oldest being Middle Neolithic (directly dated to 5308–4980 cal BP; Malmbrom et al. 2008). If this gene was present earlier (and elsewhere in Europe), this would have made the daily food production from a lactating animal even more valuable to migrants.

This agricultural spread apparently stopped just as abruptly as it started and did not extend west of Oslo Fjord. Atypical ceramics and Early Neolithic thin-butted flint axes imported from the farmers do occur across southern Norway (fig. 5), and in earlier times these were assumed to indicate farming (Hinsch 1955). Cereal pollen has been claimed at Kotedalen, dated to ~5800–5000 cal BP (Hjelle 1992). No charred grains were present (Soltvedt 1992), however, and domestic animals were completely absent (Hufthammer 1992, 1995). The pollen record has been strongly criticized (Prescott 1995, 1996; Rowley-Conwy 1999) because of the discrepancy between pollen and zooarchaeological evidence: the first domestic-animal bones appear at Skips Shelleren and Srivarshelleren after ~4200 cal BP (Prescott 1995).

The agricultural arrival in southern Scandinavia thus appears sharp. Gradualist views of Late Mesolithic developments can be discounted despite the spread of shoe-last axes beyond the farming frontier. Western Norway presents a similar pattern: axes and ceramics were in circulation for over a millennium beyond the farming boundary. Southern Scandinavia had dense hunter-gatherer populations, which made a high genetic contribution to later agricultural populations. I suggested long ago that ecological events might have destabilized the hunter-gatherer economy around 6000 cal BP (Rowley-Conwy 1984). This idea has not found much favor, but Bonnall et al. (2002) have argued that other ecological factors may have been active at the same time. If this is so, these ecological factors achieved in a generation what 1,500 years of trading axes from farmers failed to do.

Ireland and Britain

Since the later 1960s, Britain has been the homeland of gradualist perspectives on agricultural origins. This is one of the few models that has successfully crossed from “processual” to “postprocessual” archaeology and has indeed been taken further by the latter. The currently dominant model argues that for much of the Neolithic, Britain and Ireland remained effectively “Mesolithic,” based on nomadic hunting and gathering. Cultivated cereals and domestic animals were “special” foods that were hardly utilized on a daily basis but kept in unoccupied stores for occasional consumption (Richmond 1999; Thomas 1996, 2008).

Against this, some have argued that the transition was abrupt. Unoccupied cereal stores are an unlikely notion: burnt houses full of charred cereal remains, as for example at Balbridie, are most simply interpreted as normal domestic structures, more and more of which are turning up (Rowley-Conwy 2004b). Cereal agriculture has long been written down,
but a very large amount of evidence is now available (Jones and Rowley-Conwy 2007) that is fully comparable to the evidence for LBK cultivation (Bogaard and Jones 2007). Neolithic faunas with a predominance of wild species persistently refuse to make themselves known (Rowley-Conwy 2003). Hambledon Hill, with Britain’s largest Neolithic fauna dated to \( \sim 5500 \) cal BP, has just been published—and it is dominated by domestic animals (Legge 2008). Dairying could again be very important (contra Thomas 2008:70–71); it has long been argued for on zootechnical grounds by Legge (1981) and is supported by lipid analysis of Neolithic ceramics (Copley et al. 2003), notably at the recently excavated Early Neolithic timber hall at Crathes (Soberl and Evershed 2009).

Stable isotope analysis supports an abrupt transition to terrestrial (i.e., agricultural) foods at the start of the Neolithic even in such agriculturally unpromising areas as western Scotland (Schulting and Richards 2002). The Céide Fields, a 12-km² agricultural field system in the west of Ireland, are Early Neolithic (Caulfield, O’Donnell, and Mitchell 1998). An “abruptist” view is thus a viable alternative to the gradualist orthodoxy.

In keeping with this, migrations are being suggested. Pride of place among migrants goes to the Orkney vole, a subspecies (Microtus arvalis orcadensis) quite different than the voles of the rest of Britain. Orkney voles have inhabited Orkney since some time during the Early Neolithic, as a directly dated specimen from Links of Noltland shows; it is not clear whether they arrived at the start of the Neolithic or somewhat later. The mtDNA of modern voles shows that they are probably derived from voles in the Bay of Biscay region (Thaw et al. 2004). One or more pairs of voles must have been stowaways on an Early Neolithic voyage from Biscay to Orkney—perhaps in animal bedding. This is the longest individual voyage proposed here for a curragh-type boat (fig. 6). A new study suggests that while such a voyage would be difficult in a sailing boat, a paddled boat could make the trip from Brittany around the west of Ireland to Orkney in less than 2 weeks (Callaghan and Scarr 2009).

Sheridan (2010) proposes that the Early Neolithic was introduced by several different migrations (fig. 6): the Carinated Bowl tradition may have derived from northern France, reaching Scotland around 5900 cal BP; simple megaliths and their associated ceramics suggest connections from southern Brittany to western Scotland and Ireland as early as 6000 cal BP (Sheridan 2003); and northwest France and southwest England show similarities in ceramics and funerary monuments, the “Trans-Manche West” connection (Sheridan 2007; Sheridan et al. 2008). Tresset (2003) argues that the animal economy of southern England is so similar to that of northern France that direct import is likely. Sheridan (2010) states that no areas of Britain or Ireland are perfect cultural analogues of any area of Europe, so complete cultural transplantations are not proposed. The mixings and blending inherent in piece-meal leapfrog migration are the likely causes of this pattern.

A special place may be reserved for Ireland. The earliest dated cow bones from anywhere in Britain and Ireland are among two specimens from Late Mesolithic Ferriter’s Cove dating to \( \sim 6300 \) cal BP; a slightly younger one comes from Kilcreany Cave (Woodman, Anderson, and Finlay 1999; Woodman and McCarthy 2003). These may have been imported as joints of meat rather than as live cattle (Tresset 2003:26), but at all events they indicate connections with the continent in the Late Mesolithic, a time when no such connections can be seen in Britain (Sheridan 2007:466). Dates for the conventional Neolithic in the west of Ireland are somewhat curious. The Carrowmore megalithic cemetery has produced very early radiocarbon dates, some before 6000 cal BP (Burenhult 2001). The early dates have been criticized (Bergh 1995:98–110). Sheridan (2003:12) nevertheless accepts that construction started at \( \sim 6000 \) cal BP; if correct, that makes them among the earliest megalithic tombs in Britain and Ireland. And the causewayed enclosure at Magheraboy, just 2 km from the Carrowmore cemetery, has been dated to \( \sim 6000 \) cal BP, also among the earliest in Britain and Ireland (Danaher 2007:104).

The evidence discussed here suggests that the appearance of agriculture in Britain and Ireland was about as abrupt as radiocarbon dating is currently capable of demonstrating. Because both are islands, a degree of migration is not just a viable but an inevitable explanation. Further, we must face the surprising possibility that Ireland “went agricultural” before Britain; if true, it would be the biggest leapfrog migration in Europe and the ultimate testimony to the importance of the hide boat. Thomas argues that the rapidity of the process indicates either “a massive, coordinated seaborne invasion” or local adoption by hunter-gatherers, because leapfrog migration could not achieve the same result so fast (Thomas 2008:65). But this is a false dichotomy: leapfrog migration most closely accounts for the visible patterns (see above). The couple of centuries spanned by the dates is entirely compatible with this and is similar to that documented in the other spreads discussed above.

**Conclusion: Lurches of Advance**

The four major spreads of agriculture (fig. 1) are all compatible with the immigration of at least a considerable proportion of farmers. The proposed scenario differs from the “wave of advance” in two important ways: first, each involved farmers carrying many genes of European Mesolithic origin, and second, the movement is sporadic and punctuated, not continuous. We must replace the monolithic “wave of advance” concept with a series of local and disparate “lurches of advance.” A similar scenario may also be appropriate for southeastern Europe (see Özdoğan 2011).

The incoming farmers interacted with local foragers in a wide variety of ways. Sometimes the foragers were rapidly overwhelmed and disappeared as a separate group. All the four major spreads can be interpreted in this way, though with differing proportions of “local” and “incoming” genes.
Figure 6. Map of Britain, Ireland, and the adjacent continent showing sites mentioned in the text and the connections described. A color version of this figure is available in the online edition of *Current Anthropology*. 
being present in the subsequent Neolithic cultures. In some cases—for example the VSG—the incomers overreached themselves and were subsumed into a Neolithic largely "local" in character. And in two cases—the lower Vistula and eastern Sweden—farming did not root itself after its first arrival, failed initially, and was displaced temporarily by renewed hunting and gathering.

If the scenarios put forward here have any merit, various lines of inquiry need following up with more energy than hitherto. Boats and dairying are two themes I have championed; the latter is now being more generally examined, and more thought should perhaps be given to the former. Finally, the rapidity of the spreads in each area raise the long-discredited specter of environmental contexts for some of the "lurches of advance," as Bonsall et al. (2002) have suggested for Scandinavia and Britain.

Above all, the migrationist scenarios suggested here may account for one thing: why we so rarely see long-term "transitional" stages between foraging and farming. Now we see foragers, now we see farmers; but in Europe we have singularly failed to catch foragers in the act of becoming farmers. The long-term developmental processes we have expected for decades have not materialized. Farmers can evidently trade axes with foragers for centuries or longer without destabilizing them or leading them to adopt farming. "Processes" there undoubtedly are, but we need to look inside the standard deviation of a radiocarbon date to see them in action.

Acknowledgments

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The Origins of Plant Cultivation and Domestication in the New World Tropics

Patterns, Process, and New Developments

by Dolores R. Piperno

Introduction

It has long been recognized that numerous New World plant domesticates—more than half, in fact, of all American crops and many of the staples that supported indigenous peoples when Europeans arrived—originated in Neotropical forests (e.g., Harris 1972; Sauer 1950). In the past few decades, a large corpus of archaeobotanical, paleoecological, and molecular/genetic information has become available from Central and South America that has led to a significantly increased understanding of the geography and chronology of tropical food production. This information has established the lowland Neotropical forest as an early and independent cradle of agricultural origins. In a volume published in 1998, Deborah Pearsall and I reviewed and synthesized the known archaeological, paleoecological, ethnographic, and molecular/genetic evidence bearing on the prehistory of Neotropical agriculture (Piperno and Pearsall 1998).

Since then, much more evidence has been generated from all the contributing disciplines. New archaeological sites have been discovered, excavated, and analyzed using the full complement of now-available archaeobotanical techniques. Important early sites that were first identified and studied more than 30 years ago and for which little to no botanical information was available have seen reexcavation and applications of microfossil research. Phytoliths and in some cases macrofossils from other early human occupations have been revisited during the past 10 years with the use of expanded and improved modern reference collections, and some of these remains have been directly dated. Starch grain data from stone tools and human teeth are becoming available from a growing number of sites, and construction of large modern reference collections has allowed identification of some domesticated root and seed crops. Major collecting efforts of important economic taxa such as the Cucurbitaceae have been undertaken, adding significant knowledge about modern landrace diversity in Cucurbita and Lagenaria, along with distributional ranges of wild species. Last but not least, newer molecular and other information has refined and in some cases revised the geography of plant domestication and also caused us to reconsider how we should view and come to an understanding.
of the domestication process. In this paper, I review the presently available information and assess current views of how and why plant food production and domestication arose.¹

The Geography of Domestication

Agriculture may originate in discrete centers or evolve over vast areas without definable centers.

(Jack R. Harlan 1971:468)

It is useful to begin by assessing what is currently known about the geography of Neotropical plant domestication (for a summary, see fig. 1). Scholars such as David Harris, Carl Sauer, Jack Harlan, and others of their generations knew that tropical forest probably developed relatively independently long before European arrival, and they for the most part understood whether Central America (largely Mesoamerica) or South America was the original home of the major crops. More precise area origins for New World crops, and whether single or multiple domesticaions or even hybrid origins occurred in some, was often less clear for a number of reasons. Wild congenerics that potentially could be progenitor species on the basis of shared morphological attributes or apparent lack of hybridization barriers were often broadly distributed, and they sometimes occurred in both Central America and South America (e.g., *Manihot* [manioc]; *Cucurbita* [squashes and gourds]; *Zea* [teosinte], the ancestor of maize; *Ipomoea* [sweet potato]; *Xanthosoma* [malanga or cocoyam, New World representatives of the taro family]; *Dioscorea* [yams]; *Phaseolus lunatus* [sieva beans]; *Gossypium* [cotton]; many tree crops; Piperno and Pearsall 1998).

The analysis of protein and DNA-based molecular markers has significantly elucidated these issues, most recently for some major root, seed, and tree crops such as manioc, various species of *Cucurbita*, chayote (*Sechium edule*), *P. lunatus* (sieva beans), *Leucaena* spp. (guaje), *Spondias purpurea* (pejibaye or peach palm), *Bactris gasipaes* (jocote or Mexican plum), *Bactris gastapsea* (pejibaye or peach palm), peanuts (*Arachis hypogaea*), South American cotton, and others (e.g., Bertoti de Cunha et al. 2008; Cross, Saade, and Motley 2006; Hughes et al. 2007; Léotard et al., forthcoming; Milla, Islesib, and Stalker 2005; Miller and Schaal 2005; Motta-Aldana et al., forthcoming; Olsen 2002; Olsen and Schaal 1999; Robledo, Lavía, and Seijo 2009; Rodrigues, Filho, and Clement 2004; Sanjur et al. 2002; Westengen, Huamán, and Heun 2005; fig. 1). Furthermore, it has been conclusively shown that the wild ancestor of maize is not native to the semiarid Mexican highlands but rather to lower, warmer, and moister habitats of Guerrero and Michoacán states, where seasonal tropical forest is the native vegetation (e.g., Doebley 2004; Matsuoka et al. 2002; van Heerwaarden et al. 2011).

In many cases studied where multiple domesticaions were discussed, single domesticaions are now indicated (e.g., manioc, maize, the important pejibaye palm; Léotard et al., forthcoming; Matsuoka et al. 2002; Olsen 2002; Olsen and Schaal 1999; Rodrigues, Filho, and Clement 2004). On the other hand, a double domestication of the lima bean, one event in the southern Ecuador/northern Peru Andes leading to the large-seeded lima and another in the humid tropical lowlands leading to the small-seeded sieva bean, is again indicated by the newest molecular data (Motta-Aldana et al., forthcoming). Furthermore, lowland western Mexico is definitively revealed as an origin area for the sieva, and it is possible that another independent domestication event occurred in the lowlands of Central or South America (Motta-Aldana et al., forthcoming). More than one domestication of an important Central American tree crop, *S. purpurea*, also appears likely (Miller and Schaal 2005).

An Old World plant, the bottle gourd, was transported to and well used throughout tropical America during the pre-Columbian era. Erickson et al. (2005), working with modern and ancient DNA, established conclusively that prehistoric plants originated in Asia, not Africa, as was previously assumed. The archaeological rinds they studied bore the mark of domesticaioned plants. The investigators concluded that humans, not ocean currents, probably carried the domesticaioned plant from Asia during the initial colonization of the New World.

Importantly, molecular data have also elucidated in more detail some of the different processes involved in the domesticaion of plants (see also “The How of Plant Domestication”). For example, interesting cases of hybrid origins of Mesoamerican polyploid tree crops were confirmed in the important genus *Leucaena*, whereby human-mediated sympatry in “backyard gardens” of previously separated wild taxa, extensive domesticaion cultivation, and subsequent spontaaneous hybridization led to the emergence of different domesticaioned species in the genus (Hughes et al. 2007). The most widely cultivated Mesoamerican cactus, *Opuntia ficus-indica*, probably arose by the same means (Griffith 2004; Hughes et al. 2007). The importance of these processes and backyard, also called “dooryard,” cultivation in contributing to the stock of plants domesticaioned prehistorically was proposed long ago by Edgar Anderson (1954). We should remember that other major American crops, such as peanuts, are products of the hybridization of two different species and the how, when, and where of the domesticaion hybridization events that led to their initial emergence are not well understood.

Figure 1 shows known or postulated geographic zones of domesticaion for some Neotropical crops on the basis of current molecular, archaeological, and ecological evidence (for a more complete list of crops native to the Neotropics, see Harlan 1992). In some cases, designations of the circled and

1. The following definitions are used in this paper. “Cultivation” and “farming” refer to the preparation of plots specified for plant propagation and repeated planting and harvesting in such plots. A “cultivated plant” or “cultivar” refers to those that are planted and harvested, regardless of their domesticaioned status. “Domesticated species” are those that have been genetically altered through artificial selection such that phenotypic characteristics distinguish them from wild progenitors.
other localities on the maps as origin areas for particular crops should be treated as hypotheses that require testing with additional molecular and archaeological data. For example, more precise domestication localities for yam Dioscorea trifida, leren Calathea alloia, cocoyam Xanthosoma sagittifolium, and achira Canna edulis within their likely origin areas of northern South America may be forthcoming once relevant molecular studies have been undertaken. There is a major root crop for which neither Central American nor South American origins have been conclusively demonstrated. Sweet potato’s presumed wild ancestor is Ipomoea trifida, a poorly demarcated taxon naturally distributed from Mexico to northern South America (Piperno and Pearsall 1998). Some molecular work based on amounts of diversity in modern landraces suggests that it may be Central American in origin (Zhang et al. 2000), although the oldest archaeological evidence for its far derives from western South America (Piperno and Pearsall 1998; Shady, Haas, and Creamer 2001). Centers of present diversity do not always accurately pinpoint a center of origin, and additional molecular work focusing on the construction of a rigorous phylogeny of wild and domesticated sweet potato is needed to resolve the issue.

Even with the existing uncertainties, it is clear that crop origins were spatially diffuse. Using the conventional definition of a center—a circumscribed region where agriculture began and out of which it spread—Mesoamerica, more precisely Mexico, may still qualify, although it is clear now that maize, the common bean (Kwak, Kami, and Gepts 2009) and other Phaseolus species (the tepary bean), various tree crops, chile peppers, cotton, chayote, and others were domesticated in different and sometimes ecologically dissimilar regions of the country (see also Piperno, forthcoming). In South America, an attempt to designate a single circumscribed center or core area of agriculture would clearly not be supported. The origins of major and now minor crops are spread from the northern parts to the southern parts of the continent, west and east of the Andes, mostly in seasonal types of lowland tropical forest for major root and seed crops but also in lowland wet forests and midelevation moist forest habitats.

Patterns indicating multiple areas of domestication become even more accentuated when highland crops such as Phaseolus, Amaranthus spp., Chenopodium spp., and the various Andean tubers are added to the picture (the Andean complex also includes additional species of Cucurbita and Capsicum; Piperno, forthcoming; Piperno and Dillehay, forthcoming). Crops that would eventually become major staple foods or condiments and that were commonly grown together after food production was established—such as maize, manioc, various squashes, chile peppers, sweet potato, and Phaseolus and Canavalia beans—had spatially disparate areas of origin and did not at first spread together. In fact, some of the earliest and most widespread anchors of lowland food production are now minor, even disappearing, foods (below). Early patterns of dispersals probably did not involve significant population movements or diffusion of crops in packages.

Of course, knowing that crop plant origins were geographically widespread does not necessarily lead to a conclusion that food production was independently developed wherever a particular crop originated. Rather, the spread of a crop or crops into new regions may have inspired receiving cultures to grow their own native plants. This issue is further complicated by the fact that we do not know when some of the crops displayed in figure 1 were initially brought under cultivation. How many truly independent developments of lowland food production were there? Given that lowland northern and southern South American domestication zones are separated by large distances and that a number of plants native to these areas were taken under cultivation and domesticated by the middle of the eighth millennium BP, it is difficult to see how the northern and southern lowland regions do not form at least two to three independent areas of food production (e.g., D1, D3, and D4 in fig. 1B). These questions will be further illuminated in the near future as more data are accumulated.

In sum, Harlan’s (1971) idea that peoples over a wide geographic area were simultaneously engaging in early cultivation and domestioratoy relationships with plants and considerably influenced the early development of some domesticates after the plants left their native areas seems particularly relevant in the light of current data. Opportunities for such kinds of processes to occur would have been even greater if, as in the Old World (e.g., Fuller 2007; Jones and Brown 2007; Weiss, Kislev, and Hartmann 2006; Willcox, Fortniten, and Herveux 2008), protracted periods of predomestication cultivation and/or spread of predomesticated crops occurred in the Neotropics. This issue is discussed in more detail below.

Finally, molecular and botanical studies together with an increasing amount of archaeobotanical data, summarized below, tell us that the wild ancestors of many important crop plants are native to the seasonal tropical forest, those formations that receive a 4–7-month-long period every year during which little to no rain falls. Annual precipitation in these areas averages about 1,200–1,800 mm a year, soils are less weathered and thus more highly fertile than in ever-wet (aseasonal) forest, and the prolonged dry season enabled early farmers to efficiently clear vegetation and prepare plots for planting with the simple use of fire. Seasonally dry tropical forests do not carry the distinction of their rain forest relatives, but their prominent position in Neotropical agricultural origins is clear.

Early Food Production and Its Cultural and Ecological Contexts

The New World was colonized before 15,000 BP, by which time human populations had traversed most of the Western South American landmass, probably by moving along the Pacific Coast, and found themselves in what is now southern Chile (Dillehay et al. 2008). (All dates given in the text are in calibrated 14C years; uncalibrated and calibrated determi-
nations for specific dates from sites discussed are found in table 1.) The earliest indisputable evidence of human occupation in what is now the lowland Neotropical forest comes from sites distributed from Belize to eastern Brazil that were first occupied at about 13,000 BP (Piperno and Pearsall 1998; Piperno 2006a; see also Cross, Saade, and Motley 2006; Hughes et al. 2007; Matsuoka et al. 2002; Miller and Schaal 2005; Motta-Aldana et al. forthcoming; Olsen and Schaal 1999; Plowman 1984; Rodrigues, Filho, and Clement 2004; Sanjur et al. 2002; Wessel-Beaver 2000; Westengen, Huamán, and Heun 2005). Modern vegetation zone guides are (a) 1, tropical evergreen forest; 2, tropical semievergreen forest; 3, tropical deciduous forest; 4, savanna; 5, low scrub/grass/desert; 6, mostly cactus scrub and desert; and (b) 1, tropical evergreen forest (TEF); 2, tropical semievergreen forest (TSEF); 3, tropical deciduous forest (TDF); 4, mixtures of TEF, TSEF, and TDF; 5, mainly semievergreen forest and drier types of evergreen forest; 6, savanna; 7, thorn scrub; 8, caatinga; 9, cerrado; 10, desert.

ended at about 11,400 BP, human settlement of the Neotropics began to change from these sparsely distributed and short-term occupations. People "settled into" their landscapes, staying for longer and/or more frequently returning to specific locations, and they frequently manipulated and altered their environments by creating clearings in forests and/or burning
them. They developed tool kits indicating that for the first time the exploitation of plants was as important an economic strategy as hunting had been (e.g., Gnecco and Aceituno 2006; Mora 2003; Ranere and Cooke 2003; Ranere et al. 2009). Archaeobotanical information indicates that food production began in a number of localities in tropical Central and South America during the early Holocene (between 11,000 and 7600 BP), not long after the Neotropical climate and vegetation underwent profound changes associated with the end of the Pleistocene (discussed in more detail below).

The best evidence currently comes from the Central Balsas Valley of southwestern Mexico (Piperno et al. 2009; Ranere et al. 2009), central Pacific and western Panama (Dickau 2010; Dickau, Ranere, and Cooke 2007; Piperno 2006c, 2009; Piperno et al. 2000), the sub-Andean and premontane zones (elevation between 1,000 and 1,600 m) of the Cauca and Porce valleys in Colombia (e.g., Aceituno and Castillo 2005; Bray et al. 1987; Gnecco and Aceituno 2006), the Colombian Amazon (Cavelier et al. 1995; Mora 2003; Piperno and Pearsall 1998), southwestern Ecuador (Pearsall 2003; Pearsall, Chandler-Ezell, and Zeidler 2004; Piperno 2009; Piperno and Stothert 2003; Zarillo et al. 2008), and the Zaña Valley of northern Peru (Dillehay et al. 2007; Piperno and Dillehay 2008). The vegetation of all of these areas was humid tropical forest with the exception of the Vegas, Ecuador, sites located at an ecotone between forest and scrub vegetation. Table 1 contains detailed information on crop plant occurrence and chronology. Associated published references and other information about the sites involved can be found in CA+ online supplement A. Figure 2 displays site locations. The reader should refer to the citations given above and in CA+ supplement A in discussions that follow below.

The relevant archaeobotanical data are in the main part from microfossils, namely, starch grains recovered from numerous securely dated stone tools and human teeth and phytoliths retrieved from the same stone tools and/or closely associated sediments. In several cases, phytoliths and starch grains have been directly dated. Macrobotanical information is available from Colombia and northern Peru, and paleoecological efforts allied with archaeological work provide pollen, phytolith, and charcoal data indicating crop presence and/or substantial human vegetational modification near sites. Table 1 also includes early macrobotanical data from the arid coast of Peru, where crops grown were largely from elsewhere...
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<td><strong>Mexico:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tabasco State: San Andrés</td>
<td>6208 ± 47 BP (7204–6904 cal BP)</td>
<td>Maize (Phy, Po)</td>
</tr>
<tr>
<td><strong>Panama:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Central Pacific Panama: Aguadulce Rock Shelter | By ca. 8600 cal BP | *
| Cueva de los Ladrones | 6860 ± 90 BP (7804–7631 cal BP) | Maize (SG-GS) |
| Cerro Mangote | 6810 ± 110 (7779–7584 cal BP) | Maize (SG-GS) |
| Western Panama: Chiriqui Rock Shelters | 7590 ± 90 BP (8493–8313 cal BP) | Cucurbita (Phy) |
| | Between ca. 7000 and 5000 BP (ca. 8000–6000 cal BP) | *
| Hornito | 6270 ± 270 BP (7779–7584 cal BP) | Maize (SG-GS) |
| **Colombia:** | | |
| Middle Porce Valley: Hacienda Lusitania | Between 6280 ± 120 and 5880 ± 80 BP (between 7321–7032 and 6799–6597 cal BP) | Maize (SG, Phy-GS; Po) |
| Hacienda El Dorado | 5600 cal BP | |
| **Middle Cauca Valley:** El Jazmin | 7980 ± 120 and 7830 ± 140 BP | *
| | 9901–8674 and 8903–8508 cal BP | *
| Hacienda El Dorado | 6680 ± 230 BP (7771–7349 cal BP) | Maize (Po) |
| **Middle Cauca Valley, Calima Region:** El Recreo | 7980 ± 120 and 7830 ± 140 BP | C. *moschata* (Phy); *Persea americana* (M, [Cu?]) | *
| Hacienda Lusitania | >5150 ± 180 BP (>6138–5721 cal BP) | Cucurbitaceae (M) | *
| Hacienda El Dorado | 6680 ± 230 BP (7771–7349 cal BP) | Maize (Po) | *
| **Upper Cauca Valley:** San Isidro | 9530 ± 100 BP (11,058–10,706 cal BP) | Bottle gourd (M, Phy), *Cucurbita* (Phy [Cu?]), *P. americana* (M), *Maranta* cf. *arundinacea* (SG-GS [Cu?]) | *
| **Colombian Amazon:** Middle Caquetá Region: Peña Roja | 8090 ± 60 BP (9107–8884 cal BP) | *Cucurbita*, leren, bottle gourd (Phy) | *
| Abeja | >4695 ± 40 BP (>5539–5551 cal BP) | Maize, manioc (Po) | *
| **Southwestern Ecuador:** Las Vegas Sites: OGSE-80 and OGSE-67 | Between 10,130 ± 40 and 9320 ± 250 BP (11,750–10,220 cal BP) | *Cucurbita ecuadorensis* (Phy) | *
| | 9320 ± 250 BP (11,060–10,950, 10,780–10,220 cal BP) | Leren, bottle Gourd (Phy) | *
| | 7170 ± 60 BP (8015–7945 cal BP) | Maize (Phy) | *
| | >5820 ± 180 BP (6850–6810 cal BP) | Maize (Phy) | *
| **Valdivia Sites:** Real Alto | Ca. 4300 BP (ca. 5000 cal BP) | Leren, achira, arrowroot, maize, manioc (SG, Phy-GS; Phy), jack bean, cotton (M) | *
| **Ecuadorian Amazon:** Ayauachi | Ca. 5300 BP (ca. 6500–5200 cal BP) | Arrowroot, maize, manioc, jack bean, *Capsicum* (SG-Cer) | *
| **Eastern Amazon:** Geral, Brazil | Ca. 5760 ± 90 BP (6662–6464 cal BP) | Maize (Po, Phy-Lake sediments) | *
| | Ca. 3350 BP (ca. 3800 BP) | Slash-and-burn cultivation (?) | *
and their first appearance provides a minimum date for their domestication. The earliest crops were Calathea allouia (leren) and Maranta arundinacea (arrowroot), both grown for their tubers; Cucurbita moschata, Cucurbita ecuadorensis, and possibly C. argyrosperma squash; bottle gourd; maize; manioc; peanuts; avocado; and pacay (Inga feuillei), another tree crop. The first three—leren, arrowroot, and C. moschata squash—along with the bottle gourd are persistently present in northern South America and Panama between 10,200 and 7600 BP, underlining their probable northern South American origins. In many cases, different kinds of archaeobotanical remains provide mutually supporting evidence for the same crop species from the same site and specific context (table 1). It is obvious now that the earliest crop complexes were neither seed, tree, nor root crop based but rather mixtures of these different elements.

During the middle eighth millennium BP, the first signs of major crop movements northward from their area(s) of origin in southern South America can be seen. Macrofossil and starch grain data show that peanuts moved into the Zaña Valley of northern Peru by 8500 BP. Macrofossils of manioc (identification confirmed by starch grains isolated directly from root remains) also occur there by about 8500 BP, and starch grains from the plant are present in central Panama at 7600 BP. Pollen evidence from the Colombian Amazon indicates that manioc arrived there before 5800 BP. It is possible that peanuts and manioc moved north together from a common area of origin (fig. 1B). Chile peppers were well dispersed in southern Central America and South America by 6000–5000 BP (Perry et al. 2007). A large corpus of data indicates that it was dispersed into lower Central America by 7600 BP and had moved into the inter-Andean valleys of Colombia between 7000 and 6000 BP. Given the number of Cauca Valley, Colombia, sites that demonstrate early maize, it is likely that the inter-Andean valleys were a major dispersal route for the crop after it entered South America (table 1; fig. 2). Furthermore, directly dated starch grains from food residues in early Valdivia ceramics once again affirm maize and other crop presence in domestic contexts in these Early Formative (6000–5000 BP) occupations (Zarillo et al. 2008; see table 1 for other Valdivia crop plant occurrences).

An abundance of artifactual evidence also speaks to early traditions of dedicated plant exploitation and cultivation. Stone implements used for plant processing ("edge-ground

### Table 1. (Continued)

<table>
<thead>
<tr>
<th>Site</th>
<th>Age</th>
<th>Crop plants</th>
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<tbody>
<tr>
<td><strong>Northern Peru:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zaña Valley</td>
<td>9240 ± 50 BP (10402–10253 cal BP)</td>
<td>C. moschata (M)</td>
</tr>
<tr>
<td></td>
<td>7840 ± 40 BP (8630–8580 cal BP)</td>
<td>Arachis sp. (M)</td>
</tr>
<tr>
<td></td>
<td>5490 ± 60 BP (6301–6133 cal BP)</td>
<td>Cotton (M)</td>
</tr>
<tr>
<td></td>
<td>Ca. 7500 BP (ca. 8500 cal BP)</td>
<td>Manioc (M)</td>
</tr>
<tr>
<td></td>
<td>8210 ± 180 BP (9403–8784 cal BP)</td>
<td>C. moschata, Arachis, Phaseolus, Inga feuillei (SG-HT)</td>
</tr>
<tr>
<td></td>
<td>7120 ± 50 BP (7950 cal BP)</td>
<td>Coca (Erythroxylum novogranatense var truxillense; M)</td>
</tr>
<tr>
<td>Siches</td>
<td>9533 ± 65 BP (11015–10885 cal BP; BGS 2426) and 9222 ± 60 BP (10243–10306 cal BP; BGS 2475)</td>
<td>Cucurbita (Phy)</td>
</tr>
<tr>
<td><strong>Southern Coastal Peru:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paloma</td>
<td>Ca. 7800 BP (ca. 8800 cal BP)</td>
<td>Bottle gourd (M)</td>
</tr>
<tr>
<td></td>
<td>5070 ± 40 BP (5900–5740 cal BP)</td>
<td>Cucurbita ficifolia (M)</td>
</tr>
<tr>
<td></td>
<td>By 5300–4700 BP (6500–5700 cal BP)</td>
<td>Phaseolus lunatus, Cucurbita spp., guava (Psidium guajava; M)</td>
</tr>
<tr>
<td>Chilca 1</td>
<td>5616 ± 57 BP (6440–6310 cal BP)</td>
<td>Cacahuita, Achira, Jacama (Pachyrhizus ahipa), jack bean</td>
</tr>
<tr>
<td>Quebrada Jaguay</td>
<td>7660 ± 50 BP (8445–8395 cal BP)</td>
<td>Bottle gourd (M)</td>
</tr>
<tr>
<td>Los Ajos</td>
<td>4190 ± 40 BP (4800–4540 cal BP)</td>
<td>Maize, Phaseolus (SG-GS); maize, Cucurbita (Phy)</td>
</tr>
</tbody>
</table>

Note. Dates indicate the first appearance of crops in the different contexts from each site studied. GS = recovered from grinding stones; HT = recovered from human teeth; Cer = recovered from food residues in ceramic pots; if none of these context designations is listed, the botanical remains were recovered from sediments. M = macrobotanical; Phy = phytoliths; SG = starch grains; Po = pollen. Bold printed 14C dates indicate that the determinations were made directly on the botanical material. Other 14C dates are on other materials (usually wood charcoal, sometimes shell and human bone) from closely associated contexts. Laboratory numbers are listed for previously unpublished radiocarbon dates. Cul? = uncertainty as to whether remains are from wild or cultivated/domesticated plants.
Figure 2. Location of sites with early food production in Central and South America discussed in the text. The sites are shown with open circles. Sites with an open triangle are important examples of pre-6000 BP crop diffusion into southern coastal Peru (Chilca 1, Paloma, and Quebrada Jaugay) and regions of South America where agriculture as a whole had been poorly documented (e.g., Geral, located in the interior of the Amazon, and possibly Los Ajos, Uruguay, by ca. 4000 BP). They are not discussed in the text but are listed in table 1.

cobbles,” quern stone bases, hand milling stones) are common in sites with early food-producing activities, and they are often present from the earliest Holocene onward in sites that were occupied at that time. Residues studied from these tools have commonly produced starch grains and phytoliths from a variety of cultigens (table 1). In the Porce and Middle Cauca valleys of Colombia, the Colombian Amazon, and the Zaña Valley in Peru, finely made stone hoes firmly dated to from 9500–7300, 8000, and 7000 BP, respectively, occur in sites with evidence of early food production (table 1) and in others for which botanical data are not available (Aceituno and Castillo 2005; Gnecco and Aceituno 2006; Herrera et al. 1992; Mora 2003; Salgado 1995). The Cauca region Colombian examples, which by 7300 BP are beautifully polished, are among the most typical implements documented in early preceramic occupations there. Stone axes presumably used for creating openings in the forest are also found in the Cauca, Porce Valley, and Colombian Amazon occupations at the same time.

In the way of other economic remains documented, a number of wild plant taxa, including a variety of palms and other tree fruits (e.g., Spondias, Erythrina, Byrsonima), yams other than Dioscorea trifida, Calathea species other than C. allouia, and Zamia have been identified. It is possible that some of them, particularly a few of the palm genera, were cultivated, but this cannot be empirically demonstrated with either the macrobotanical data or the microbotanical data. Current in-
formation similarly cannot be employed to adequately quantify changes in the proportions of wild and cultivated plant foods as early periods of cultivation ensued. Bone often does not survive in the humid tropics, but in the few sites with faunal records (e.g., Las Vegas and the Zaña Valley), both large and small animals were hunted. The totality of evidence indicates broad-spectrum subsistence orientations shortly before and at the beginning of food production.

With evidence accumulating rapidly now, other questions such as how early cultivated and domesticated plants moved (through movements of people, objects, or cultural knowledge) will take on increasing importance. This issue cannot be discussed in any detail here, but considering the present evidence, simple down-the-line forms of exchange that did not involve significant population shifts or movements of material culture may best account for early crop plant diffusion. It should be stressed that different scenarios may have been true for later cases of crop diffusion through the Neotropics not discussed here, when Formative-period societies were established and population numbers were much higher than they were during the early and early middle Holocene.

It is clear that unlike in the Near East and China (see papers this issue), Neotropical food production did not originate and take hold in the context of large or fairly large permanent and nucleated villages situated in major river valleys. Rather, intensive foot surveys and excavations in the Balsas region of southwestern Mexico, central and western Panama, southern Ecuador, the Cauca and Porce regions, Colombia, and northern Peru show that between 11,000 and 7000 BP, sites are typically rock shelters and/or limited clusters of small open-air occupations that were located beside secondary watercourses and seasonal streams whose small stretches of alluvium likely were used for planting gardens. Settlements were typically less than 1 ha in size, and many may have been occupied seasonally. Settlement organization was similar to modern tropical hamlets and hamlet clusters, where one to a few nuclear families composed the residential community.

Early expressions of permanent settlements and nucleated communities are found in the Zaña Valley, Peru, where occupations between 10,000 and 7600 BP are small circular houses located 200–400 m apart with stone foundations and stone-lined storage pits. The deep and dense Las Vegas, Ecuador, midden, situated near the Pacific coast, where a wide variety of marine and estuary resources (e.g., mollusks, fish, and crabs) as well as plants and terrestrial animals were exploited, may also have been occupied on a permanent basis.

It was not until substantially later in time that settlements in these and other regions were positioned to exploit the rich bottomland of significant river courses. The earliest such evidence comes from the Valdivia culture of southwest Ecuador and dates to 5500 BP (e.g., Pearsall, Chandler-Ezell, and Chandler-Ezell 2003; Raymond 2008). In other regions, this development took place at about 4000–3400 BP. Another related and often-discussed facet of early farming is the view that it should originate in zones of plentiful wild food resources (see papers this issue). For a number of reasons, the high biodiversity of tropical forests does not translate into habitats with abundant and stable wild resources for hunters and gatherers. Useful calorie-rich plant species occur in low number and are widely dispersed in space, and animal protein is similarly far from plentiful, with the effect that natural resources would generally be expected to support small groups of mobile foragers (Piperno and Pearsall 1998:52–78). Resource abundance would have been better, at least seasonally, in localities of early food production where permanent lakes occurred, such as in an area of the Central Balsas, Mexico, studied recently (Piperno et al. 2007, 2009; Ranere et al. 2009). However, most early food producers did not have access to lakes. Piperno and Pearsall (1998:323) concluded that in the Neotropics, early farming occurred “in the most optimal zones of the most optimal types of forests and, in this sense, they represent resource abundance,” adding that “nonetheless, as long as people are not starving or otherwise experiencing frequent and severe shortfalls of food, food abundance per se may have little relevance.” There is no reason to alter this view.

When Did Neotropical Farming Become a Significant Subsistence Practice?

The evidence increasingly indicates that it would be a mistake to assume that Neotropical food production during the entire 11,000–7000-BP period was a casual undertaking practiced by people who are better called foragers than farmers (see also Iriarte 2007, 2009 for discussions of this issue). Multifaceted archaeobotanical data—now including starch grain and phytolith evidence from the calculus of human teeth—along with settlement pattern, landscape modification (in some cases resulting from slash-and-burn cultivation), and artifactual information indicate that by 8800–7600 BP in the Zaña Valley, Peru; central Panama; probably the Central Balsas, Mexico; Tabasco, Mexico; and possibly other regions, a significant number of dietary calories and nutrients came from crop plants. For example, more than 70% of the starch grains recovered from the teeth of nine different Zaña Valley individuals dated from 8800–7700 BP were from four crops: Phaseolus, Cucurbita moschata, peanuts, and Inga feuillea, a tree (Piperno and Dillehay 2008). In Panama, the Colombian Amazon, and southwestern Ecuador, root crops such as leren and arrowroot that were significant and reliable sources of carbohydrates are ubiquitous components of early crop plant assemblages. Cucurbita, another ubiquitous early plant, provided high-quality proteins and fats. Furthermore, the starch, phytolith, and macrobotanical evidence from a number of regions makes it clear that squashes (including the fruit flesh in the Zaña Valley) were routinely consumed, had undergone artificial selection for different traits related to fruit edibility, and thus were not primarily used as little-modified nondietary plants.

In the Central Balsas and San Andrés regions of Mexico
and in central Panama, forest clearance from slash-and-burn cultivation is documented by pollen, phytolith, and charcoal records from lake sediment cores beginning at 7600–7200 BP (Piperno et al. 2007; Pohl et al. 2007; Pope et al. 2001). Small irrigation canals are present in the Zaña Valley beginning at 7700 BP (Dillehay, Eling, and Rossen 2005). In a number of regions, then, agricultural intensification began before 7000 BP. In central Panama, the Zaña Valley, Peru; and the Cauca and Porce regions, Colombia, it is also evident that site number and artifact density significantly increased around 7600–7000 BP. These trends are likely the result of an increase in human carrying capacity made possible by effective systematic food production.

In summary, these people appear to have been committed horticulturists and slash-and-burn cultivators who, while still integrating planting with collecting and hunting, were taking important steps along the pathway to full-scale agriculture. The appearance of large sedentary and nucleated villages, which postdates 6000 BP throughout the Americas, should no longer be considered a necessary backdrop for the occurrence or recognition of effective and productive agriculture in the Americas. This is all the more true when it is considered that indigenous Neotropical farmers still live in—and more commonly did so in the recent past—small seminucleated and shifting communities. The idea that the appearance of sedentary village life and all of its trappings should be the measure of when farming began in the Americas emerged from faulty comparisons with Near Eastern pre- and postagricultural trajectories, which were a product of ecological and demographic circumstances very different from those associated with the beginnings of Neotropical food production (Piperno and Pearsall 1998). As also stressed by Iriarte (2007), Vrydaghs and Denham (2007), and Denham (2011), agricultural origins in different parts of the world should be studied using the totality of evidence relevant to the region being investigated.

The How of Plant Domestication

Phenotypic innovation depends on developmental innovation, and developmental innovation spans a broader field of possibilities than does mutation alone.

(Mary Jane West-Eberhard 2003:144)

Allowing for cryptic variants and novel phenotypes from new epistatic combinations to arise during domestication, it is easy to imagine that maize was domesticated from teosinte.

(John Doebley 2004:56)

Evolutionary Development, Gene Expression, and Developmental Plasticity

Recent developments in evolutionary biology and archaeobotanical data gathering and interpretation indicate the need to reassess how plant domestication occurred. Fundamental new insights about the origin of novel traits and adaptive evolution are arising from the fields of evolutionary developmental biology (evo-devo), molecular biology, and developmental plasticity. In addition, a constant stream of detailed archaeobotanical investigations has altered our views about the trajectory of plant domestication following the advent of systematic cultivation (defined here as the cycle of planting and harvesting in plots prepared for this purpose). I start first with new insights from the nonarchaeological spheres of research.

Gene regulation/expression acting during an organism’s development and phenotypic (developmental) plasticity are now widely viewed as significant forces, indeed by some investigators as the primary forces, in evolutionary diversification and the origin of novel traits (e.g., Carroll 2005; Kruglyak and Stern 2007; Pigliucci 2005; West Eberhard 2003). There is good reason to believe that these research foci should become standard elements of domestication studies (Gremillion and Piperno 2009a). Regulatory genes are not protein-coding or functional genes but rather act to switch other genes on or off or change when and where in an organism they are active or increase/decrease their effects, usually during early ontogeny. This is the process of gene expression (e.g., Kruglyak and Stern 2007). Novel phenotypes may then often result from reorganizations of existing genomes, not by the spread or appearance of mutations, and new phenotypic variation can rapidly arise in populations without a corresponding genetic change.

Developmental plasticity, recently given a complete treatment in a major book (West-Eberhard 2003), refers to the inherent capacity of organisms to rapidly produce novel heritable phenotypes through one of several available developmental pathways in direct response to changes in their environments. This capacity should be particularly important in plants, which cannot simply get up and move to places more to their liking when physical and biotic conditions change and become less favorable. Gene expression during plant development orchestrates this process, resulting in different phenotypic pathways to adulthood. The new phenotypes have the potential to become fixed (stabilized) by genetic assimilation/accommodation if the new ecological conditions are maintained over multiple generations (West-Eberhard 2003). An important source of genetic variation that may enable the creation of novelties through developmental-mediated mechanisms is “cryptic genetic variation,” so named because it is unexpressed in the phenotype of standing populations and thus normally hidden from selection (e.g., Gibson and Dworkin 2004; Lauter and Doebley 2002). However, it may be set in motion or “released” by interactions between genes (epistasis) or by perturbations from the external environment, rapidly resulting in new phenotypes. Lauter and Doebley (2002) have shown that maize’s wild ancestor possesses a significant degree of cryptic variation that is associated with important traits such as polystichous (many-rowed) cobs.
and nonshattering ears. Studies of this kind are needed in many other crop plants.

Crop evolution has usually been characterized using the assumption that phenotypic change is driven by selection for rare mutants that are deleterious in wild plants or by selection for new random mutations that appeared after cultivation began. Associated single trait–single gene models are also deeply rooted in domestication studies. However, it is increasingly recognized that (1) inheritance of domesticated traits is often complex (simple Mendelian segregation is not indicated) and does not involve straightforward human selection on mutations that occurred as rare variants in wild ancestral or early cultivated populations; (2) some “domestication genes” controlling crucial phenotypic attributes are in fact regulatory genes, for example, in maize (tbp and gai), controlling plant architecture and the formation of naked grains, respectively), rice (sh4 and qSH1, controlling shattering), and tomato (fw2.2, underwriting fruit size increase); (3) these and other identified genes control developmental pathways in specific immature tissues and organs that lead to adult phenotypic variability; (4) phenotypic outcomes are significantly influenced by the external environment as well as by regulatory and other gene–gene interactions; and (5) considerable cryptic variation occurs in at least one crop progenitor, teosinte, that provides preexisting genetic material that can translate into multiple developmental trajectories (e.g., Doebley 2004, 2006; Jones and Brown 2007; Lauter and Doebley 2002).

Doebley (2004) describes what happens in crosses between teosinte and maize as a result of gene actions that alter the trajectories of plant development: “The dichotomies of single versus paired spikelets, shattering versus nonshattering ears, soft versus hard glumes, and two- versus multiranked ears are striking when one compares maize and teosinte. However, in F1 families, these discrete classes blur into a continuum of phenotypes, and novel phenotypes and interactions appear” (54). All of this means that the domestication process involved simple unconscious/conscious selection targeted at specific mutations controlling discrete (single) traits and more complex plant-people-genetic-environmental interactions that often played out during plant ontogeny and involved humans “reconfiguring” (Lauter and Doebley 2002:341) the preexisting pool of variability into new combinations. Present evidence suggests that in some crops, the latter may have been more important than the former. Gene expression appears to have been very important, and it probably gave early cultivators a great deal of phenotypic variation to work with in some crops and traits, especially as hybridization between crops and wild ancestors was initially common. This may have either slowed down or speeded up the domestication process. Furthermore, preexisting variation for plasticity would have enabled crops to more quickly adapt to new ecological circumstances as they were brought from their natural habitats into cultivated fields and dispersed out of their areas of origin, and it likely in part determined the amount of landrace diversification that was possible after domestication. Maize is a classic example of a domesticated species that was capable of adapting successfully to many different environmental circumstances, and prehistoric peoples across the New World created many different races from it, neither surprising in light of how much variation and plasticity are present in its wild ancestor.

Additional research will provide more detailed information about how gene expression and multiple possible developmental trajectories influenced the creation of domesticated phenotypes, and this type of work will be important for animal domestication as well (e.g., Dobney and Larson 2006). What has so far been largely neglected in domestication studies and should be an important part of future investigations is the role of what West-Eberhard (2003) calls “environmental induction” in creating new phenotypes from ancestral populations (Gremillion and Piperno 2009a). This is a crux of the phenotypic plasticity argument as developed by West-Eberhard—that alternative phenotypes can be induced directly by environmental change and subsequently genetically assimilated/accommodated (genetically stabilized) under the proper conditions. It is known, for example, that maize-like phenotypes in plant architecture can be induced in teosinte by environmental stresses such as lowered temperatures and light intensity (West-Eberhard 2003). Given that crop domestication first occurred shortly after the environmental perturbations that marked the end of the Pleistocene, human environmental modification was significant starting during the early Holocene, and human care for/selection of novel phenotypes in secure ecological niches—cultivated fields—would lead to the genetic assimilation necessary to stabilize the new phenotypes, the role of natural- and human-induced environmental induction as a substitute for and/or complement to artificial selection in engineering some of the major phenotypic steps in crop evolution should be investigated (see Gremillion and Piperno 2009a for possible examples relating to Chenopodium seed attributes and maize branching and inflorescence architecture).

Predomestication and Nondomestication Cultivation

Newer and more highly detailed archeobotanical information indicates that rather than a rapid appearance of domesticated plants shortly after cultivation began, protracted periods of predomestication cultivation (PDC) and even instances of nondomestication cultivation (NDC) of cereals and pulses occurred in the Old World. PDC goes hand in hand with what appears to have been a nonsimultaneous development of the suite of traits that make up the domestication syndrome (e.g., Cohen 2011; Dillehay et al. 2007; Fuller 2007; Piperno and Dillehay 2008; Weiss, Kislev, and Hartmann 2006; Weiss and Zohary 2011; Willcox, Fortnite, and Herveux 2008; Zeder 2011). Some important implications from the accumulated data are obvious. Domestication took longer after cultivation was initiated and was a more complex process than was
thought, involving different kinds and thresholds of (often competing) natural and artificial selection pressures from region to region and cultivar to cultivar. The cultivation of major crop species may have arisen independently more than once. Productive and stable food production could be based on morphologically wild plants. And if, as seems likely, PDC plants spread, defining a single geographically localized area as the cradle of origin for the domesticated plant would prove difficult because multiregional processes involving gene flow were at work (Allaby, Fuller, and Brown 2008; Brown et al. 2009; Jones and Brown 2007).

I previously suggested that the commonplace focus on domestication as the preeminent event in human/plant relationships is perhaps misplaced and that the crucial shift we may want to understand is the origins of plant cultivation, when people began to repeatedly sow and harvest plants in plots prepared for this purpose (see Piperno 2006a for a more detailed discussion). Given the evidence brought to light more recently, I see no reason to change this view. Less attention has been paid to PDC and NDC issues in the New World, but some highland and lowland data already suggest that they were components of early food production. At Guílã Naquitz Cave, highland Mexico, a type of morphologically wild runner bean (*Phaseolus* spp.) was present between ca. 10,600 and 8500 BP in quantities that suggested to the investigators that people were artificially increasing their density by cultivating them (Flannery 1986). The plant was never domesticated. In the Zaña Valley, Peru, hulls of peanuts (the nuts themselves did not survive) dated to 8500 BP do not exhibit some features of modern domesticated plants, nor do they conform to a known wild species (Dillehay et al. 2007). Predomestication cultivation of this plant and its transport out of its area of origin in southern South America before it acquired the full package of domesticated characteristics is thus indicated. Peanut nut starch grains recovered from human teeth, on the other hand, are identical to those from modern varieties of *Arachis hypogaea* and are unlike starch in modern wild peanuts closely related to *A. hypogaea* analyzed so far (Piperno and Dillehay 2008). More work is needed on wild peanut starch, but the suite of phenotypic traits that characterize domesticated peanuts may not have developed all at once.

In fact, as discussed in detail elsewhere (Piperno 2006a: 162–163; Piperno and Pearsall 1998), PDC and NDC scenarios for agriculture, even if they were not called that, have long seemed to a number of investigators to be particularly well suited to the Neotropics (e.g., Harlan 1992; Harris 1989). Even today, many horticultural plots still contain morphologically wild plants that do not change their phenotypic characteristics even after many years of persistent cultivation. Crops grown for their belowground organs (e.g., *Calathea* and *Dioscorea* spp.) and many palms and other fruit trees are among the most stubborn taxa. Instances of PDC and NDC should be sought for more widely in the New World by using multifaceted archaeobotanical data sets and allied paleoecological evidence whenever possible.

Coming full circle back to the discussion that initiated this section, the complex inheritance of and multifactorial influences on domestication traits may have played roles in slowing domestication. Furthermore, the effects of gene expression and possible environment-on-phenotype influences at the onset of plant cultivation and after may have led to pools of interesting phenotypic diversity in early crops that people picked through and discouraged or encouraged over a protracted period before the domesticated examples that we identify archaeologically emerged.

The Why of Food Production

*Human Behavioral Ecology and Agricultural Origins*

Piperno and Pearsall (1998) and Piperno (2006a) offered an account of why and when Neotropical agricultural origins occurred that is rooted in human behavioral ecology (HBE), especially optimal foraging theory, and they suggested that HBE models had potential relevance in other regions of the world. Explanations such as population pressure and changing social relationships (e.g., competitive feasting) used by some investigators to account for agricultural beginnings elsewhere (Piperno and Pearsall 1998:10–18) did not and still do not appear to be important in the Neotropics. Before discussing the relationships between agricultural origins, HBE, and other explanations for the transition to food production, I should reiterate my belief that the near synchronicity of food production origins in at least seven widely dispersed and ecologically disparate regions of the world when or shortly after the world’s fauna and flora were experiencing profound shifts driven by the end-Pleistocene ecological perturbations should cause us to look for common underlying processes that may have been influential in the transition wherever it occurred. Put at its simplest, it is difficult to believe that near-synchronous origins of such a major economic transformation were a coincidence, an accidental convergence of disparate regionally specific underlying factors in widely dispersed and different social systems. This is not to say that identifying specific aspects of Neolithic developments on a region-by-region basis is not important, only that we should in a deliberate way look for underlying commonalities rather than immediately emphasizing putatively unique, supposedly causal local or regional variables that may turn out to be more apparent than real.

The basic concepts and uses of HBE in archaeology are by now well known and discussed and will not be reviewed here in any detail (for recent literature reviews, see Bird and O’Connell 2006; Lupo 2007). In brief, HBE is concerned with the adaptive plasticity of the human phenotype in response to variation in its particular ecological and social environment. It assumes that behavior is shaped by evolutionary forces and asks “why certain patterns of behavior have emerged and continue to persist” (Bird and O’Connell 2006:...
The emphasis on a flexible phenotype means that HBE’s engine for change resides in human decision making. HBE is embedded in archaeological theory and empirical testing to a degree such that it is viewed along with dual inheritance theory as a primary and distinct research tradition in evolutionary archaeology (e.g., Shennen 2008). As such, it has been and will continue to be a focus of discussions, both incisive and off the mark. Examples of the latter (Smith 2009; Zeder and Smith 2009) make faulty claims that explanations derived from HBE are analogous to covering law models or that HBE ignores the active roles of foragers in altering environments (see Gremillion and Piperno 2009b for additional comments). Investigators in fact are drawn to HBE by its focused, hypothesis-driven, problem-solving approaches that, as mentioned, incorporate human agency and dynamic human/environmental relationships. These elements constitute good science and are productive means for “eliminating problematic answers and identifying and pursuing more promising ones” (Bird and O’Connell 2006:171).

Although HBE has been used to study a broad array of economic and social issues, “foraging theory” applications that address subsistence decisions are most common to this point. At the heart of foraging theory is the assumption that, all things being equal, more efficient food procurement strategies should be favored by natural selection over those less efficient, a largely unquestioned premise in nonhuman animal studies. The simplest version of foraging models is called the “optimal diet” model, or the “diet breadth” model (DBM). It employs a straightforward currency—energy—to measure the costs and benefits of alternative resource sets and assumes that humans will have a goal of optimizing the energetic returns of their subsistence labor. Recent research indicating that spatial memory in women is preferentially engaged and most accurately expressed for calorie-rich foods further buttresses the likelihood that natural selection shaped a human proclivity for efficient plant foraging (New et al. 2007). As reviewed in detail elsewhere (Piperno 2006a; Piperno and Pearsall 1998:15–18), there are a number of good reasons why the DBM can productively be applied to agricultural origins and dispersals. For one thing, its sometimes counterintuitive predictions regarding resource choice bring new insight to issues such as the onset of “broad-spectrum” subsistence strategies and the links between diet breadth, technology, and resource intensification. Another strength of the model is its ability to elucidate from patterns in the archaeological record important processual questions relating to human economic decision making and its determinants vis-à-vis the focal point of energetic constraints. Importantly, in this regard, paleoecological data can serve as objective informants on past shifts in the availability of different subsistence resources and as proxies of changing returns to labor from foraging, adding valuable information that can be used in conjunction with or in the absence of archaeological subsistence records.

A range of ethnoarchaeological information indicates that in the Neotropical forest, as elsewhere, energetic efficiency is a major influence on food procurement decisions (reviewed in Piperno and Pearsall 1998). The following lines of evidence were used to argue that optimal foraging and the relative energetic efficiency of resource sets available to foragers during the late Pleistocene and early Holocene played a major role in Neotropical agricultural origins (details in Piperno 2006a; Piperno and Pearsall 1998). First, a large set of paleoecological data ranging now from the Central Balsas region of southwest Mexico to Bolivia (e.g., Burbridge, Mayle, and Killeen 2004; Piperno et al. 2007) indicates that the shift from foraging to food production began within contexts of rapid and significant changes of climate, vegetation, and fauna occurring at the close of the Pleistocene. Large increases in temperature, precipitation, and atmospheric CO2 levels resulted in vegetational transitions from savanna-like/thorny scrub growth to seasonal types of tropical forest across the Neotropics. Many now-extinct megafauna were replaced by the smaller, fewer, and more dispersed tropical forest fauna found in modern environments.

Second, on the basis of robust sets of ethnographic and ecological data, these environmental perturbations would have significantly lowered the overall efficiency of food procurement for hunters and gatherers in those zones where open-land types of vegetation gave way to forest when the Pleistocene ended. For example, the big game and open-land plants that disappeared were almost certainly higher-ranked resources compared with those offered by the tropical forest, in which animals were far fewer and smaller, carbohydrates were limited and spatially dispersed, and many plants were toxic and required extensive processing before they were consumed. Decreasing foraging efficiency as dietary breadth expanded to incorporate these low-ranked resources was probably an important selection pressure acting on human food procurement strategies during the early Holocene.

Third, on the basis of these factors, along with the costs of plant cultivation estimated from modern small-scale tropical farming, it appears that early Neotropical food-producing strategies probably were more energetically efficient, not more costly, than full-time foraging (see Piperno 2006a for a detailed discussion of this issue for the tropical forest). Finally, following the DBM, people would have initiated the cultivation of some plants when the net return from this strategy exceeded the return from full-time hunting and gathering. In light of shifts in vegetational formations and available resources indicated by paleoecological records, the ca. 11,000–9000-BP time period should have been highly relevant for the initiation of food production. It should be noted that all of the above points are especially relevant to areas that today support or would support in the absence of human disturbance highly seasonal types of tropical forest, where the end-Pleistocene environmental perturbations would have impacted foraging return rates most strongly.

Comparing these points with archaeological data (see above; Piperno and Pearsall 1998), it appears that predictions of optimal foraging and the DBM are well supported and
effectively account for when and where food production emerged in the lowland Neotropics. As has been discussed in detail elsewhere, other issues such as why some plants and not others out of the many available were singled out for human manipulation can be elucidated using HBE (Piperno 2006a; see below). The point made above about early farmers’ energetic efficiency should be stressed. Although many investigators assume that early farmers everywhere experienced diminishing returns to their labor, studies in the southwestern and eastern United States and the Near East have also failed to support that notion when it was properly tested using appropriate measures of resource costs and benefits (e.g., Barlow 2002; Gremillion 2004; Simms and Russell 1997). The energetic efficiency of early farming compared with the last hunting and gathering should be reevaluated in other regions of the world. Especially in the cases where foraging theory appears to effectively account for the initiation of food production, it would not be surprising to see a revision of previously assumed cost/benefit equations for foraging versus farming.

The DBM or combinations of DBM and other HBE theories have recently been productively applied to predict under what circumstances and how intensively foragers should become farmers in a number of world regions (for other examples, see, e.g., Barlow 2002; Bird and O’Connell 2006; Gremillion 2004; Kennett and Winterhalder 2006). In the eastern United States (Gremillion 2004), it was found that some of the predictions of the DBM (e.g., that immediate resource returns provide the best measure of their utility) did not fit the archaeological data. In this case, the research led to a better grasp of the variables most important in agricultural transitions (e.g., risk reduction, energetic considerations of processing certain key resources with regard to the seasonal availability of others), and refinements in how HBE models should be applied in this regional circumstance. Students of HBE see this as one of its strongest features. If a good fit between theory and data is not evident, then one moves on to find a better-supported theoretical approach.

**HBE and Risk**

HBE is a highly flexible research program by no means limited to simple energetic efficiency models and currencies. For example, risk sensitivity, an often-used explanation for why foragers turned to farming, is increasingly being incorporated into HBE research (see papers in Kennett and Winterhalder 2006). It is evident that under a number of circumstances, energetically efficient diets are also risk-minimizing diets and that attention to risk avoidance does not necessarily override attention to energetic efficiency. It is worth repeating here that there is also considerable ethnographic evidence that among tropical foragers and horticulturists, food sharing in the context of extensive household exchange is the most important strategy for mitigating risk (see Piperno and Pearsall 1998:239–241 for a detailed discussion of these issues).

**HBE and Coevolution**

There is little disagreement that coevolutionary forces and food production origins were entwined. As the general process unfolded, dependency of humans on certain plants increased and vice versa, and both the plants and people involved experienced fitness increases. However, when coevolution is operationalized at more detailed levels of analysis, discordance between the model and empirical archaeobotanical data becomes evident. This was initially discussed by Piperno (2006a), and more examples can now be added.

The Cucurbitaceae and Marantaceae, each with important examples of early domesticated plants, are large families with many edible species that respond to a human presence by quickly colonizing disturbed areas near living places. This makes them particularly suitable for testing the most complete and prominent explication of how agricultural transitions exemplify coevolution, that of Rindos (1984). The fruit rinds of most Cucurbitaceae genera produce high numbers of recognizable phytoliths, and Marantaceae seeds and tubers are similarly rich in diagnostic phytoliths. These durable microfossils provide a record of exploitation unbiased by the preservation factor. Marantaceae tubers also produce many diagnostic starch grains, which would be expected to occur on stone tools that were used to process them. The sites of Xihuaxtla, Mexico; San Isidro, El Recreo, and Peña Roja, Colombia; Siches, Ecuador; and Zahta Valley, Peru, can be added to those from central Panama and Vegas, Ecuador, as examples of where only *Cucurbita* (often along with bottle gourd) is recorded among plants from this family. In the sequences from Tehuacán and Guila Naquitz, Mexico, where macrobotanical preservation was excellent, one additional genus of the Cucurbitaceae, *Apodanthera*, occurred with *Cucurbita* and bottle gourd, but rarely, and it was considered a possible modern intrusive. Students of foraging theory would immediately notice that the fruits and seeds of wild *Cucurbita* are among the largest in the family and therefore would likely provide higher return rates relative to other cucurbits.

A similar example of highly selective exploitation is found with regard to the Marantaceae. *Maranta arundinacea* and a few species of *Calathea*, usually solely *Calathea allonii*, are the only Marantaceae taxa represented in the tropical sites. There are numerous plants from a variety of other families with edible seeds and underground organs that should be visible in phytolith and starch grain records had they been exploited early on with any persistency, but they are not recorded. Moreover, just a few species of wild grasses out of the hundreds that were available to human foragers were manipulated in pre-Columbian Mexico: two species of *Setaria* (Austin 2006) and *Zea mays ssp. parviglumis* (Balsas teosinte). Only the latter was demonstrably domesticated. A correlation between grass domestication and seed size is also evident, as teosinte has the largest grains of any annual Mexican grass.

Therefore, Neotropical archaeobotanical data better support predictions from foraging theory that stress the impor-
tance of deliberate directed human choice rather than the slowly unwinding reciprocal plant/human interactions involving experimentation with numerous different taxa that would be characteristic of coevolution. Efficiently procuring food, especially in the tropical forest, would necessarily entail paying serious attention to and deriving the most plant calories, proteins, and fats from a relatively small set of the available wild species. Long periods of experimentation and mutualistic relationships with a high diversity of species do not appear to have been associated with squash, Marantaceae, and grass domestication in part because energetic efficiency was probably a major determinant of subsistence decisions.

Conclusions

Discussions regarding the origins and dispersals of agriculture are increasingly based on robust empirical information as new and more precise data from all the contributing disciplines of study become available. With gene expression, phenotypic plasticity, and HBE among the important additions to the how and why of food production, the level of analysis has been raised to incorporate the phenotype of both the plants and humans involved. Given the immense importance that gene expression and developmental plasticity are finding in evolutionary biology, it is likely that they will contribute much to our understanding of how people domesticated plants. Human behavioral ecology similarly is likely to have growing importance in agricultural origin studies. Microfossil data have been shown to be essential lines of evidence in documenting the transition from foraging to farming in the Neotropics. As new sites are discovered and older ones reexamined, much more information can be expected on early agriculture in the New World’s tropical regions.

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The Cultural Context of Plant Domestication in Eastern North America

by Bruce D. Smith

The timing and sequence of the independent domestication of indigenous eastern North American seed plants (Cucurbita pepo, Helianthus annuus, Iva annua, Chenopodium berlandieri) and the subsequent development of a crop complex are discussed within a broader environmental and cultural context. The settlements that have yielded the earliest record of eastern domesticates are all small and situated in resource-rich lower-order river valley corridors within oak-savannah and oak-hickory forest regions. Well-preserved floral and faunal assemblages indicate continued substantial reliance on a wide range of wild species with no evidence of resource depletion. Similarly, there is no indication of landscape packing in terms of high site density in these resource-rich river valleys, calling into question developmental models of domestication and agricultural origins that rely on population pressure or resource imbalance as causal factors.

Our archaeology is that of hunting and gathering groups, no more complex than a simple band or bands . . . that late in the Archaic period began to experiment with simple gardening.

(Kay 1983:64)

Introduction

Over the past 2 decades, geneticists and archaeologists have made impressive advances worldwide in documenting the temporal and spatial context of domestication of a growing variety of different species of plants and animals, as well as identifying their wild progenitors (Zeder et al. 2006). When combined at regional scales of analysis, these species-level initiatives have in turn significantly increased our understanding of the pace and sequence of domestication of different species within the world’s independent centers of domestication and agricultural origin, including eastern North America (Smith 2006a).

Even though eastern North America temporally lags behind many of the world’s other centers of agricultural origin and only witnessed the domestication of a few species that remain important in today’s world economies (e.g., sunflower and Cucurbita pepo squash), it nonetheless provides an important comparative case study situation in a number of respects, primary among these being that the spatial and temporal parameters of two developmental milestones are reasonably well established: first, the initial domestication of the region’s four domesticated seed plants and, second, the formation of a distinctive crop complex based on these indigenous domesticates. This well-defined temporal and spatial framework for initial plant domestication and the formation of a distinctive crop complex provides a good foundation for a regional-scale consideration of the general environmental and cultural context within which domestication and the initial transition to food production occurred. In this article I briefly outline the temporal and spatial parameters of initial plant domestication and the subsequent establishment of a distinctive crop complex in eastern North America and then employ this spatial-temporal framework to focus on a consideration of the general environmental setting and socio-cultural characteristics of the societies that made the initial transition from hunting and gathering to food production in the region by looking at their levels of technology, settlements and subsistence economies, and regional-scale networks of interaction.

The Temporal and Spatial Context of Plant Domestication in Eastern North America

Based on several morphological changes (e.g., seed size increase, reduction in seed coat thickness) that are associated with the “adaptive syndrome of domestication” and that have been documented in well-preserved seed specimens recovered from a number of archaeological sites in eastern North Amer-
Chenopod (Chenopodium berlandieri), at least four indigenous seed-bearing plants were brought under domestication in the region over a span of about 1,300 years, from 5000 to 3700 BP (table 1; fig. 1). Maize (Zea mays), the first Mesoamerican domesticate to reach eastern North America, did not arrive for another 1,200 years, at ca. 200 BC (Riley et al. 1994). In addition to these four seed plants that exhibit morphological changes, three other species that lack such changes have also been identified as probably having been the subject of deliberate planting and harvesting of stored seed stock based on their relative abundance in seed assemblages of this time period: erect knotweed (Polygonum erectum), little barley (Hordeum pusillum), and maygrass (Phalaris caroliniana; Smith 2006a; Yarnell 2004).

The genetic and archaeological evidence for the domestication of these eastern seed plants has been discussed at length by a number of researchers over the past several decades (Reisberg and Harter 2006; Smith 2006a, 2006b; Yarnell 2004), but in comparison, relatively little attention has been given to what the societies were like that brought these plants under domestication. The general temporal and spatial parameters of initial domestication and the emergence of early low-level food production economies in the region, as indicated in table 1 and figure 1, provide a good starting point for such a consideration.

As shown in table 1, morphological changes indicating the initial domestication of three of the four eastern crop plants are first documented in assemblages dated to between 5000 and 4400 BP, with the earliest evidence for domestication of the fourth species (Chenopodium) not appearing for another 6 centuries, at 3800 BP. Earlier evidence for chenopod domestication will quite likely be recovered in the future, however, and I expect that initial domestication of the four eastern domesticates identified so far in terms of morphological changes as well as perhaps others will fall into the 5-century span between 5000 and 4500 BP. Rather than restricting this discussion to the societies and settlements of this 500-year period, however, it is worthwhile to expand the time span of consideration another 11 centuries, from 5000 to 3400 calibrated calendar years BP, in order to both increase the number of archaeological sites that have yielded domesticates and include several sites that provide substantial information. This time span also correlates closely with the cultural period often termed the “Late Archaic” (Emerson, McElrath, and Fortier 2009; Sassaman and Anderson 1996; Smith 1986).

The currently available evidence of indigenous domesticated plants for the 5000–3400 BP time period has been recovered from a total of seven archaeological sites, all of which are located within the resource-rich oak-savannah and oak-hickory forest regions of eastern North America (Delcourt and Delcourt 1981; fig. 1). These small settlements, which are scattered across five states and are separated by up to 1,000 km, represent the primary data sets for considering the early history of low-level food production in the region. Information regarding these seven sites, however, is relatively limited, and an expanded consideration of a larger sample of

Table 1. Earliest occurrence of indigenous domesticated seed crops in eastern North America

<table>
<thead>
<tr>
<th>Domesticated plant species</th>
<th>Age (AMS-calibrated calendar years BP)</th>
<th>Age (radiocarbon years BP)</th>
<th>Laboratory sample no.</th>
<th>Archaeological site and provenience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucurbita pepo ssp. ovifera</td>
<td>5025 ± 75</td>
<td>4440 ± 75</td>
<td>δ47295</td>
<td>Phillips Spring (unit K2)</td>
</tr>
<tr>
<td>Helianthus annuus ssp. ovifera</td>
<td>4480 ± 75</td>
<td>4265 ± 60</td>
<td>δ54050</td>
<td>Hayes (unit 14)</td>
</tr>
<tr>
<td>Iva annua ssp. ovifera</td>
<td>4400 ± 75</td>
<td>3920 ± 40</td>
<td>δ216463</td>
<td>Napoleon Hollow (feature 20)</td>
</tr>
<tr>
<td>Chenopodium berlandieri: “Naked”</td>
<td>3800 ± 40</td>
<td>3490 ± 40</td>
<td>δ253114</td>
<td>Riverton (feature 1)</td>
</tr>
<tr>
<td>Thin testa</td>
<td>3700 ± 150</td>
<td>3450 ± 150</td>
<td>δ11348</td>
<td>Cloudsplitter (F. S. 1361)</td>
</tr>
<tr>
<td>Thin testa</td>
<td>3690 ± 40</td>
<td>3440 ± 40</td>
<td>δ253117</td>
<td>Riverton (feature 8A)</td>
</tr>
<tr>
<td>Thin testa</td>
<td>3640 ± 40</td>
<td>3400 ± 150</td>
<td>δ11347</td>
<td>Newt Kash (El 1114)</td>
</tr>
</tbody>
</table>

1. Discussions of the independent domestication of plants in different regions of the New World rarely consider the bottle gourd (Lagenaria siceraria) because it was a “utilitarian” domesticate rather than a food plant. Highly prized for its strong, lightweight fruits that made excellent containers and vessels of various shapes and sizes, the bottle gourd was carried from Asia to the Americas either by ocean currents or more likely by Paleolindian colonists (along with another utilitarian domesticate, Canis familiaris), reaching the New World by 10,000 BP (Erickson et al. 2005). It reached eastern North America by 7300 BP (Doran, Dickel, and Newsom 1990) and is frequently recovered in association with eastern North American domesticates, particularly before the development of ceramic vessels in the region.

2. Of the seven archaeological sites in eastern North America that have provided early evidence of domesticated plants, only six are profiled here in detail. Newt Kash Hollow is not discussed, given the limited amount of information that is currently available regarding the site. The domesticated Chenopodium berlandieri documented for Newt Kash (table 1) consisted of thin-testa fruits extracted from an unprovenienced but directly dated human coprolite from the site (Smith and Cowan 1987). A number of other sites that date to this time period and that have been identified as having produced domesticates (Yarnell 2004)—for example, Jernigan II, Peter Cave, and Iddens—are not included in this discussion either because the species in question was the bottle gourd, a utilitarian domesticate with deep time depth, or because the specimens recovered did not exhibit morphological markers of domesticated status (e.g., thin-rind wild Cucurbita gourd rind fragments and maygrass, sunflower, and chenopod seeds that fall into the wild size range).
Late Archaic period sites from the oak-savannah and oak-hickory forest zones will provide a broader and clearer general profile of the societies that initially domesticated plants in eastern North America. The numerous small-scale societies that populated the blank portions of figure 1 were similar in many respects to those represented by the seven sites shown, and while excavations at many of these other sites have not yielded domesticates, they have produced considerable material cultural evidence of technology, subsistence and settlement patterns, and likely mechanisms and networks of broadscale regional interaction (Jefferies 1996).

The Late Archaic Settlements That Have Yielded the Earliest Evidence of Domesticates

Scattered across the interior riverine midlatitudes of the oak-savannah and oak-hickory forest zones between 5000 and 3400 BP, the seven sites shown in figure 1 are often thought of as comprising two distinct groups based on their environmental setting and the factors that contributed to the preservation of archaeobotanical specimens. Marble Bluff at the western end of this distribution of sites and Cloudsplitter and Newt Kash at the eastern end are dry rockshelters situated in rugged upland settings in proximity to small streams. Preservation of plant remains in these sites is excellent because of an absence of soil moisture in the archaeological deposits. Between them, Phillips Spring, Napoleon Hollow, Riverton, and Hayes are all located in river valley settings, with preservation of early domesticates resulting from either carbonization or, in the case of Phillips Spring, wet rather than dry soil conditions.

The recovery of early domesticates from both riverine and more upland settings has engendered a very interesting and ongoing discussion regarding the specific habitat setting of initial plant domestication in eastern North America: is the presence of early domesticates in more upland sites largely a function of good preservation of plant remains in dry rockshelters, or does it indicate in fact that the initial domestication of *Cucurbita* gourds, marshelder, and chenopod—all early successional floodplain colonizers (see discussion below)—occurred outside of their natural riverine habitats? At the present time the available archaeological evidence best supports a river valley context of initial domestication, with the earliest evidence for all four eastern domesticates recovered from sites in stream valley settings. Rather than being situated along the main trunk of the Mississippi Valley, however, or any of its major tributaries (e.g., the Missouri, Ohio, and White rivers, etc.), all seven of the sites discussed here are instead situated in proximity to smaller primary (Illinois),

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Figure 1. Oak-savannah and oak-hickory forest regions of eastern North America at ca. 5000 BP (after Delcourt and Delcourt 1981). The Late Archaic settlements that have provided the earliest evidence of domesticated plants in eastern North America are shown.
secondary (Wabash, Buffalo), and tertiary (Pomme de Terre, Duck, Red) tributaries of the Mississippi. In addition, although the seven sites that have produced the earliest domesticates all share a generally similar river valley setting, they are dispersed across a broad area of the interior midlatitudes.

While acknowledging the challenges inherent in determining the geographical range of wild progenitor populations at 5000 BP, genetic profiling of modern wild populations of both Cucurbita pepo var. ovifera squash and sunflower indicate that initial domestication of these two species probably occurred along the western end of the oak-savannah and oak-hickory forest zone (Reisberg and Harter 2006; Smith 2006). Because neither of the other two eastern domesticates—*Iva annua* and Chenopodium berlandieri—is cultivated today in the region, any effort through genetic analysis to determine more specifically where they were brought under domestication will necessitate comparison of modern wild populations with domesticated specimens from archaeological contexts.

While future genetic and archaeological research may establish with greater spatial resolution those geographical locations where marshelder, chenopod, and other eastern crop plants were most likely initially domesticated, it is possible now to identify with considerable confidence the specific habitats within which domestication occurred. Four and perhaps more local seed-bearing plants—all aggressive river valley colonizers of disturbed soil settings—were initially domesticated and were being cultivated in stream valley and upland settings across a broad area of the Mississippi drainage catchment (midlatitude oak- and hickory-dominated forest zones) by 5,000–3,500 years ago. At the same time, it is surprising that if you look past the dating and documentation of the early domesticates from these seven sites, there is relatively little additional published information that is currently available regarding the actual settlements or their inhabitants. This relative absence of information regarding the seven sites in question is the result of a number of factors, including the limited nature of excavations, complex stratigraphy, substantial disturbance and mixing of habitation layers in multicomponent sites (see Cowan 1984:323; Fritz 1986), and lack of published site reports. Drawing from available primary references, brief cameo descriptions of each of the Late Archaic settlements that have yielded early domesticates are provided below.

**Marble Bluff (3SE1)**

Excavated by a University of Arkansas crew in 1934, Marble Bluff is a 7-m-wide habitation zone that extends for about 120 m along a west- to southwest-facing overhanging bluff located just above Mill Creek, a tributary of the Buffalo River, which in turn flows into the White River, in Searcy County, Arkansas (Fritz 1986:11, 24, 27; 1997). A large alluvial terrace is located less than 0.5 km from Marble Bluff, and an estimated 30 ha of arable land was available within 2 km of the settlement (Fritz 1986:30, 36).

Although cultural deposits at Marble Bluff are described as reaching 47 inches in depth and producing a “full range” of artifact types and 405 catalog numbers (Fritz 1986:27, 1997), the long time span of likely occupation of the site, the low frequency of temporally diagnostic material culture, and the often disturbed nature of Ozark rockshelter deposits in general have made it difficult to either distinguish Archaic materials and features from those of subsequent occupational episodes or to accurately characterize the nature of the Late Archaic occupation of the settlement. In addition, most of the domesticated sunflower, chenopod, marshelder, and *C. pepo* squash specimens recovered from Marble Bluff came from an isolated charred storage deposit located in a crevice against the back wall of the shelter and could not be easily associated with other cultural features or artifact assemblages. In general, Late Archaic small-scale societies in the Ozarks have been characterized as being largely autonomous, with settlement systems centered on multiseasonal multiple-activity base camps that are situated on the terraces of major streams and smaller short-term seasonally occupied rockshelters in smaller tributary drainages and upland settings (Fritz 1986:39; Sabo, Waddell, and House 1982:64). Subsistence economies centered on white-tailed deer (*Odocoileus virginianus*) and smaller species (raccoon, turkey, squirrels), as well as on hickory nuts and acorns.

**Phillips Spring (23Hi16)**

Located in Hickory County, Missouri, the Phillips Spring site centers on a small artesian spring situated on the 1b terrace of the Pomme de Terre River, a tributary of the Osage, which in turn flows into the Missouri River. Excavation units in the water-saturated anaerobic sediments adjacent to the spring exposed a “squash and gourd zone” (unit K2) that contained abundant plant remains (hickory, walnut, abundant acorns, grape, elderberry, ragweed), including bottle gourd rind fragments and 125 uncarbonized *C. pepo* seeds and seed fragments (Kay 1983, 1986; Kay, King, and Robinson 1980). Based on their size and a direct date of 5025 calibrated calendar years BP on one of the seeds (table 1), this large assemblage provides the earliest evidence for the domestication of this species in eastern North America.

This unit K squash and gourd zone, which is the oldest of the six stratified living surfaces documented at Phillips Spring, was exposed to only a very limited horizontal extent during excavation, and little information is available regarding architectural features and patterns of artifact distribution. The subsequent six Sedalia-phase occupational episodes at Phillips Spring, which occurred over a period of about 500 years (Kay 1983:54–55), however, yielded abundant artifacts, pit features, hearths, and discrete residential-area midden scatters, which Kay (1983:61) considers to represent a series of warm-season (spring to fall, and perhaps through the winter) base encampments that centered around the artesian spring. Along with more or less sedentary river valley settlements like Phillips Spring, smaller family groups occupied outlying sites,
including caves and rockshelters, on an intermittent seasonal basis. Although squash and bottle gourd were grown, oak mast and hickory nuts played a major dietary role, with white-tailed deer, mussels, and fish being the most important prey species.

**Napoleon Hollow**

Located where a small tributary valley known as Napoleon Hollow joins the Illinois River, which in turn flows into the Mississippi, this large, deeply stratified site is known primarily for its extensive and well-documented middle woodland occupations (Wiant and McGimsey 1986). A block excavation into the colluvial fan emanating from the bluff on the north side of the hollow where it joins the Illinois Valley, however, also exposed a series of stratified Middle and Late Archaic period occupations (Wiant, Farnsworth, and Hajic 2009).

One of the pit features associated with a Late Archaic Titterington phase (feature 20) contained abundant artifacts and plant remains, including *Cucurbita* rind fragments and *Chenopodium berlandieri*, sunflower, and ragweed seeds, along with 44 carbonized marshelder achenes. Based on their large size and a direct date of 4400 calibrated calendar years BP, this substantial assemblage of *Iva annua* achenes provides the earliest evidence for the domestication of this species (Asch and Asch 1985:161; table 1).

Given the number and variety of stone tools and the amount of debris recovered during excavation, the Titterington component at Napoleon Hollow is considered to have been a seasonally occupied river valley base camp (Wiant, Farnsworth, and Hajic 2009). In a broad regional consideration of the Titterington phase and other neighboring and generally contemporaneous Late Archaic societies, Cook (1986:175) characterizes their subsistence system as having a heavy reliance on white-tailed deer, shellfish, fish, waterfowl, small mammals, hickory, walnut, and oaks, with seed plants—including chenopod, ragweed, sunflower, marshelder, and *Cucurbita*—playing only a minor role. Their annual cycle involved seasonal multigroup nucleated base camps and smaller single-group settlements dispersed across a range of environments:

many Titterington-phase sites with preserved feature populations have a recurrent pattern: either there is a single cluster of nonoverlapping shallow-basin hearths, or large roasting pits or there are linear clusters of such features. I assume that the single-cluster sites are occupied by one or more extended families while the multiple-cluster sites represent simultaneous use by several extended families. (Cook 1986:184)

**Riverton (Cw-170)**

In his landmark study of the Late Archaic Riverton culture, Howard Winters (1969) excavated three large shell-midden sites (Robeson Hills, Swan Island, and Riverton) located along a 20-mi stretch of the Wabash River, a tributary of the Ohio River, in Crawford and Lawrence counties, Illinois. One of these, the Riverton site, yielded evidence of four domesticated plants: sunflower, chenopod, *C. pepo* squash, and bottle gourd.

The Riverton site is a large, deeply stratified midden that extends over an area of about 2 acres (ca. 470 ft × 220 ft) on a T-0 terrace of the Wabash River. In 1961, five 5 × 5-ft excavation units in three separate locations exposed 44 inches of cultural deposits, including abundant features and well-preserved material culture assemblages. In 1963, a large block excavation unit (unit X) exposed, just below the plow zone, a group of 10 clay floors, along with associated pit and hearth features, artifacts, and extensive midden lenses (fig. 2). Roughly rectangular in shape, the Riverton clay floors ranged in size from about 100 to 200 ft² and from 4 to 6 inches in depth, and they are thought to have been built within a short time of each other. Like the numerous similar features documented in Late Archaic contexts across the eastern woodlands (Sassaman and Ledbetter 1996; Smith 1986:27), these clay floors are thought to be prepared house floors even though associated post holes are not always observed.

A series of eight radiocarbon dates from unit X indicate a relatively short-term occupation dating to ca. 3800–3700 calibrated calendar years BP (Smith and Yarnell 2009; Winters 1969). The Riverton material culture assemblage included a wide range of chipped and groundstone lithic tools (projectile...
points, knives, side and end scrapers, hammerstones, manos, metates, axes, etc.), along with a variety of well-preserved bone tools (antler projectile points, awls, gravers, fleshing tools, etc.; Winters 1969).

Soil samples taken from features associated with the clay floors at Riverton by Richard Yarnell subsequently yielded domesticated sunflower, C. _pepo_ squash, bottle gourd, and two distinct cultigen varieties of domesticated chenopod (Smith and Yarnell 2009; Yarnell 2004). Although seeds of a small number of wild species were also recovered (e.g., persimmon, elderberry, _Polygonum_), the archaeobotanical assemblage primarily consisted of carbonized fragments of black walnut and hickory nuts and acorns (Yarnell 2004). A diverse faunal assemblage was dominated by white-tail deer, with significant representation of raccoon, beaver, and turkey, along with waterfowl and other birds, 13 species of fish, and 37 species of freshwater mussels (Parmalee 1969).

Given the floodplain location of Swan Island and Riverton, along with seasonality indicators, Winters (1969:137) identified them as spring-fall and summer occupations, respectively, while Robeson Hills, with its higher elevation above the Wabash Valley, was characterized as a winter settlement. Alternatively, all three sites could be considered as generally comparable in terms of representing larger river valley multisessional macroband base camps linked to numerous outlying shorter-term, more limited activity sites (Smith 1986).

_Hayes (40ML139)_

Situated on a T-1 terrace at the confluence of Caney Creek and the Duck River, a tributary of the Tennessee River, in Marshall County, Tennessee, the Hayes site is a large (ca. 900–m²) stratified multicomponent midden with up to a 1.7-m-thick Middle Archaic stratum of freshwater gastropod shells (stratum III) overlaid by more than 1 m of Late Holocene alluvial deposits, including a Late Archaic shell-free habitation layer (stratum II; Crites 1987; Klippel and Morey 1986). A flotation sample recovered from square 98N920E, level 14 (130–140 cm below ground surface), in a small block excavation unit located on the T-1 terrace (Crites 1987:16), contained six complete domesticate-size sunflower seeds, one of which yielded an AMS radiocarbon date of 4840 calibrated calendar years BP (Crites 1993; table 1). Although both Benton and Ledbetter projectile point/knives were also recovered from the same natural stratum as the sunflower seeds (Crites 1993:146), a fuller description or characterization of the Late Archaic occupation of the Hayes site is not available.

_Cloudsplitter (15Mf-36)_

Situated about 100 m upslope from a semipermanent stream that flows 250 m southward to join the Red River in Menifee County, Kentucky, the Cloudsplitter rockshelter extends 55 m along a westerly facing overhang that protects an area of about 15 m in width (Cowan 1984:315; Cowan et al. 1981). Although relatively few intact Late Archaic deposits were uncovered during the site’s excavation in 1978 because of disturbance both by subsequent Early Woodland period occupations and modern vandalism, a 35-m² area along the back wall of the shelter yielded evidence of a number of intermittent occupational episodes between 4500 and 3000 BP. A surface hearth, a basin-shaped pit, and a few ash lenses were uncovered, along with three post molds that suggested a small enclosed area near the rear wall of the overhang.

The archaeobotanical assemblage from Late Archaic contexts at Cloudsplitter is dominated by nuts, with various hickory species and black walnut accounting for 90% of the nuts recovered (Cowan 1984:338). In addition to the seeds of a range of wild plant species, five domesticates are represented in low numbers: bottle gourd, _C. _pepo_ squash, marshelder, sunflower, and chenopod. Several uncarbonized and well-preserved thin-testa fruits of domesticated chenopod recovered during excavation yielded a direct AMS calibrated intercept of 3700 BP (Smith and Cowan 1987; table 1). White-tailed deer dominated the faunal assemblage, followed by turtles, small to medium mammals (e.g., raccoon, squirrel, opossum), and turkey. With lithic debris reflecting retouch of tools rather than manufacture, a relative lack of formal tools, a limited number of features, and the absence of any evidence of forest clearance, Cloudsplitter was identified as reflecting a pattern of repeated short-term seasonal (likely fall) occupational episodes during the Late Archaic as part of a seasonal round that involved larger and longer-occupied river valley settlements (Cowan 1984:359–364).

Setting the Stage: Middle Holocene Environmental Change and River Valley Stabilization

The Late Archaic sites briefly described above span more than 1,500 years and are scattered across a large geographical area of eastern North America. In addition, with the exception of Riverton, they have yielded only limited information regarding the way of life of their inhabitants. At the same time, however, they all do reflect a range of shared characteristics and fit a general overarching profile that comes into clearer focus when viewed within a broader environmental and cultural context.

To a considerable extent, the answer to why plant domestication in eastern North America lagged behind a number of the other centers of domestication worldwide by 4,000 years or more can be found in the “prerequisite” Mid-Holocene climatic and environmental changes that reshaped the interior river valley landscapes of the region. By about 6500–6000 BP, many of the river systems across the interior midlatitudes had shifted from an Early Holocene pattern of episodic pulses of sediment removal and river incision to a sustained phase of aggradation and stabilization (Knox 1983; Schuldenrein 1996: 3, 9–10; Smith 1986:22–23; Styles 1986), resulting in the for-
mation of river valley meander belt topography with associated oxbow lakes and backswamps along some stream courses and shallow-water and shoal habitats in others. This shift in seasonal stream flow patterns and the stabilization of river valley landscapes in turn resulted in a significant increase in the abundance and diversity of floodplain plant and animal resources available for human exploitation, while at the same time an apparent decrease in effective precipitation resulted in a deterioration of upland resources (Schuldenrein 1996; Smith 1986:24). Not surprisingly, these changes in river valley and upland environments were accompanied by a broadscale intensification of human occupation of river and stream valley corridors (Brown 1985). As Joseph Schuldenrein (1996:3) notes, the Mid-Holocene was the “window of adjustment” during which postglacial environments stabilized, stream channels adjusted to renascent floodplains, hill and slope sedimentation rates diminished, and critical resource zones emerged,” and human societies “mapped onto” these favorable resource and subsistence zones.

The stabilization and resource enrichment of river valley corridors was not uniform across the eastern woodlands, however, and outside of this interior midlatitude riverine zone, Mid-Holocene climatic and environmental changes were quite different (Schuldenrein 1996; Smith 1986). While meander belt systems were established in many of the tributaries of the Mississippi River by 6000 BP, for example, such is not the case in the lower alluvial valley of the Mississippi, where open swamps emerge on the margins of prograded deltas (Schuldenrein 1996:9). In addition, within the interior midlatitude riverine zone, substantial and sustained “mapping” onto river valley corridors does not appear to have been universal, nor does it reflect any filling in or “packing” of these enriched resource zones (Claassen 1996:240–242; Smith 1986:22).

The Geographical Range and Floodplain Niche of Eastern Domesticated Seed Plants

Just as the Mid-Holocene emergence of stable and enriched river valley landscapes within the Mississippi River catchment plays a significant prerequisite role in the timing of the initial domestication of seed plants in eastern North America, the geographical range and habitat of their wild ancestors is also of obvious importance in delineating the region where initial domestication took place. In general, the present-day geographical range of the wild species from which the eastern domesticates were derived is fairly well established. Using modern distribution data to estimate the ca. 5000-BP geographical range of the wild ancestors of the eastern lineage of *Cucurbita pepo* squash, sunflower, marshelder, and *Chenopodium berlandieri* is complicated, however, by a range of factors. Principal among these is the extent to which natural river valley habitats and plant communities have been altered because of post-Columbian human impacts and introductions of exotics on the one hand and the well-documented propensity of the species in question to both hitch a ride on human transport and to invade and colonize both natural and anthropogenic disturbed soil situations (Smith 2006b) on the other. In addition, the taxonomies of *Chenopodium*, *Iva*, and *C. pepo* in eastern North America remain challenging at the species level, making the use of modern distribution studies sometimes problematic.

Surveys carried out in the 1980s document the present-day distribution of *C. berlandieri* and *Iva annua* in riverine habitats across much of the oak-savannah and oak-hickory forest regions shown in figure 1 (Smith 2006b), and neither species grows today with any frequency south of the fall line onto the Atlantic coastal plain, west into the plains, east into the Appalachians, or very far north into the Northeast or Great Lakes. Similarly, free-living populations of *C. pepo* var. *ovifera* have been located growing in riverine settings in many areas of the oak-savannah and oak-hickory forest regions, as well as down onto the coastal plain (Smith 2006b), and the extent to which the distribution of this wild cucurbit extended into the Northeast remains a topic of considerable interest (Fritz 1999). Although the sunflower has a geographical range that encompasses a broad area of North America, present-day wild populations along the western edge of the oak-savannah forest zone in figure 1 have been identified as the specific and sole source of all modern domesticated sunflowers (Rieseberg and Harter 2006).

At the same time that Mid-Holocene river valley stabilization and enrichment were important in determining when plant domestication occurred in eastern North America and the geographical distribution of wild progenitors within the resource-rich river valley corridors of the oak-savannah and oak-hickory forest regions played a role in determining where domestication occurred, the answer to why some plants were domesticated and not others can be found, to a considerable degree, in the functional ecological profile of the wild progenitors (Bogaard et al. 1999; Charles, Jones, and Hodgson 1997). Three of the four species brought under domestication in eastern North America—marshelder, chenopodium, and *C. pepo* gourds—are floodplain “weeds,” aggressive pioneers of the disturbed and exposed soil situations created on an annual basis by spring floods (Smith 2006b). Their abundant seeds (a single *C. berlandieri* plant can produce 50,000 seeds; a single *C. pepo* plant can produce 5,000) are dispersed by floodwaters, and they colonize the sandy banks and backwater margins that are exposed each year by receding floodwaters within the constantly shifting landscape of river floodplains. Early successional species, they cannot compete with other plants for long in undisturbed locations, but frequently they can be found in recently disturbed floodplain soil situations, both natural and man-made (e.g., construction sites, backyard gardens, dumps, fields lacking herbicides, etc.). As a result, all three are preadapted in a number of respects to both flourish in garden plots created for them and provide a sub-
ostal return at minimal cost if humans play the role of dispersal agent and scatter their seeds in areas naturally exposed by receding floodwaters (Smith 2009b). The substantial expansion of “natural” stands by casual scattering of seeds of all three of these floodplain weeds into appropriate exposed soil settings, described up into the 1700s in Louisiana (Smith 2006b, 2009b), may have considerable time depth in the region, along with a number of other niche construction efforts by human societies in eastern North America (Smith 2011), and may have paved the way to the establishment of more permanent and stable garden plots.

In contrast, while the sunflower frequently grows in disturbed soil settings in valley landscapes and generally conforms to the floodplain weed profile of the other three eastern domesticates in that it is also an early successional species favoring open disturbed soil settings, it can be found thriving in many locations where the other three would not grow. Like marshelder, chenopod, and C. pepo, however, sunflower was well adapted to take full advantage of the new growing opportunities that humans would offer.

The Societies That Domesticated and Cultivated Eastern Seed Plants between 5000 and 3400 BP and Developed a Crop Complex by 3800 BP

Briefly described above, the seven archaeological sites that have yielded all of the archaeobotanical evidence for the domestication and cultivation of seed-bearing plants in eastern North America before 3400 BP extend over a considerable span of time and a sizable geographical area. They also vary considerably in terms of the amount of information each has provided regarding the way of life of the societies that occupied them. In spite of these challenges of space and time and variable archaeological information, however, it is possible to develop a general profile of these Late Archaic period societies.

In large part, this is possible because of the broadscale patterns of continuity in material culture assemblages, settlement types, and subsistence patterns that characterize the Late Archaic societies that occupied the midlatitude riverine environments of the oak-savannah and oak-hickory forest regions (Emerson, McElrath, and Fortier 2009). These societies are often partitioned in space and time by phase designations (e.g., the Riverton phase, the Titterington phase), which group together sites that are geographically and temporally close to each other and that have similar material culture assemblages. As more sites are excavated and larger material culture inventories become available for comparative analysis, phase designations often become more tightly bounded in terms of the geographical areas and the time spans they encompass. In the oak-savannah and oak-hickory forest regions during the Late Archaic, phase designations at the present time are rather large in scale, and opinions differ regarding how and where to draw phase boundaries in both space and time (McElrath 1993:150). To some extent, the relatively large size of these Late Archaic phases and the different opinions regarding where to draw phase boundaries is a reflection of limited available archaeological information. But it also indicates that while exhibiting geographical variation in diagnostic artifact categories (primarily projectile points), these societies were also generally quite similar in terms of their stable long-term adaptation to eastern deciduous forest ecosystems: their technology, their economies, their annual cycle, and their settlements all follow the same general pattern.

Technology

With the exception of the Mount Nebo phase of northwestern Missouri and adjacent states at the western edge of the oak-savannah forest zone, which has yielded small sherds of fiber-tempered ceramics of uncertain vessel forms (Reid 1983:29–32), none of the Late Archaic (5000–3400 BP) societies of the oak-savannah and oak-hickory forest regions had pottery vessels. Cooking was done over open fires or in pits using heated stones (as reflected by abundant fire-cracked rock and basin-shaped features). Artifact assemblages are dominated by chipped-stone tools and debitage, with chert and quartzite raw material used to manufacture a wide range of formal and expedient hunting and processing tools, including bifacially flaked knives, drills, and spear points (the bow and arrow was not present in the east during the Late Archaic), along with unifacial end scrapers and side scrapers. Groundstone tools include heavy-duty three-quarter-grooved axes; manos; and hammer, grinding, and nutting stones. Bone-tool assemblages, when preserved, are dominated by white-tailed deer skeletal elements, including ulna awls, metatarsal and humerus fleshing tools, antler projectile points and flakers, and bone pins. Of the seven sites briefly described above, Riverton provides one of the largest and most comprehensively described artifact assemblages; Howard Winters’s (1969) landmark functional analysis of both lithic and bone-tool categories offers an excellent general profile of Late Archaic technology. Numerous other more recent comprehensive analyses of assemblages from Late Archaic sites have also been published (e.g., Cook 1976; Emerson, McElrath, and Fortier 2009; Fortier 1984). Other material culture categories, including basketry and cordage, are preserved only occasionally in dry rockshelters and caves (Fritz 1986; Scholtz 1975).

Settlements

Riverton also provides one of the best windows on what the settlements of the societies that cultivated seed plants in eastern North America between 5000 and 3400 BP looked like. The unit X block excavation exposed a grouping of 10 roughly rectangular clay floors ranging in size from 100 to 200 ft² that are thought to have supported small house structures (fig. 2).
Numerous shallow-basin-shaped pit features, a few hearths, and sheet-midden deposits were associated with the Riverton clay floors, along with abundant artifact assemblages. Clay floors of similar size and suspected function have been described at Middle and Late Archaic period sites across the eastern United States, and, along with more infrequently documented post mold patterns, they provide evidence of habitation structures that were relatively small and that did not reflect a substantial investment of labor (Sassaman and Ledbetter 1996).

In the far more frequent absence of any evidence at all of house structures in Late Archaic contexts, the spatial signature of basic domestic units (likely extended families) usually consists of a cluster of pit and hearth features (Fortier 1983). Determining the number of such family units that made up a settlement is complicated by a number of factors. Frequently, as was the case at Phillips Spring, Napoleon Hollow, Riverton, and Hayes, excavation does not expose the full extent of the occupation. In addition, even when there is little overlap or superposition of feature clusters, it is difficult to determine which features (and family units) were present contemporaneously as opposed to reflecting sequential habitation episodes over a number of years. At the same time, the overall areal extent of Late Archaic settlements can be misleading in that river valley topography can play an important role in determining site boundaries. The overall size of the Riverton site, for example, may in large part be dictated by the areal extent of Groundhog Hill, on which the settlement was located. In contrast, the Go Kart North site, just east of St. Louis, dating to 4000 BP and like Napoleon Hollow, assigned to the Titterington phase, was situated on a topographically unconstrained bank of what was an active stream channel and extends linearly for more than 175 m, leading Thomas Emerson to suggest that, floodplain topography permitting, Late Archaic groups moving through an annual cycle may return not to specific points on the landscape but to more general "locales" (Emerson 1984:343–344; Emerson and McElrath 1983).

Go Kart North, which is the only fully exposed Late Archaic settlement in the interior Riverine midlatitudes, also provides clear evidence of Late Archaic settlement structure (Fortier 1983). Even though it extended for more than 175 m along the edge of the Hill Lake Meander and included 131 discrete hearth and pit features and lithic activity areas organized into four discrete and "socially segmented" clusters, it is characterized not as a large settlement of any duration but rather as a short-term seasonal occupation involving a relatively limited range of activities, including animal butchering, food preparation, and lithic manufacture.

To add to the difficulties often inherent in establishing the number of basic domestic units that make up a Late Archaic settlement at any one point in time, it is also difficult to establish whether settlements were occupied year round on a permanent basis or annually during certain seasons of the year. There are a wide variety of different seasonality indicators that can be employed to establish what part of the year a site was occupied, but other than substantial evidence of cold-season house structures (which are lacking at Late Archaic sites), there are no good indicators of a settlement being occupied during the winter.

Taking into consideration all of these potential complications in describing any individual Late Archaic settlement in detail (including the seven sites that have provided the earliest evidence of domesticated plants in the region), a number of generally similar settlement pattern models have been proposed over the past 4 decades that, while relatively low in resolution, are still of considerable interpretive value and are reasonably applicable to many of the Late Archaic phases of the oak-savannah and oak-hickory forest regions (Smith 1986:24–25). These settlement systems encompass two different settlement types, the larger of which can be labeled the "river valley base camp." Situated on lower terraces of river and stream valleys, base camp settlements are sometimes characterized as permanent year-round settlements or more frequently as semipermanent to permanent, summer-fall, low-water seasonal occupations reoccupied on an annual basis over long periods of time by a number of related extended families. Phillips Spring, Napoleon Hollow, Riverton, and Hayes could be placed in this general settlement category based on their river valley location and occupational history.

During the season of the year when the lower terrace location of these base camps was subject to flooding or isolation by rising waters, groups are thought to have moved into the uplands, either to nearby functionally distinct valley-edge wet-season residential base camps (e.g., Robeson Hills; Winters 1969) or smaller dispersed short-term occupation sites occupied by a single extended-family unit. Marble Bluff, Cloudsplitter, and Newt Kash fit this settlement profile. Short-term limited activity settlements could also, of course, be located in river valley locations (e.g., Go Kart North), and both base camps and shorter-term sites could vary considerably in duration, range of activity sets, and number of domestic units from year to year.

One of the most interesting aspects of the larger semipermanent to permanent multifamily river valley base camp settlements is the lack of any internal organizational structure above the level of extended-family domestic units. Artifact assemblages, feature clusters, and structural evidence (clay floors, post mold patterns, when present) all show little differentiation across settlements, and while some linearity and adjacency can be discerned in the patterning of domestic unit placement, there is no evidence of centrality (e.g., integration around a central shared or corporate open area), nor is there any indication of storage above the extended-family level. This picture of associated but largely autonomous extended-family units is also reflected in corporate mortuary sites (Charles and Buikstra 1983:121–122), which when present both indicate sustained long-term shared "ownership" of a society's resource catchment area and the absence of any within-group ascribed status differentiation.
This is a rather homogeneous picture of generally similar technology, societal organization, settlements, and seasonal rounds over a broad geographical area and with phase boundaries defined largely in terms of variation in the shape of projectile points and the presence or absence of other distinctive tool types. It is also evident in the subsistence economies of Late Archaic societies within the oak-savannah and oak-hickory forest regions.

**Subsistence Economies**

The Late Archaic societies that first domesticated and cultivated eastern seed-bearing plants in the interior midlatitudes of eastern North America between 5000 and 3700 BP shared what was in many respects a very similar basic subsistence economy. White-tailed deer was the single most important prey species, and it invariably dominates faunal assemblages from Late Archaic sites. This is not surprising in that this species combines large body size with a very high reproductive potential (Smith 2009b), and it is the primary prey species in faunal assemblages in the region throughout the Holocene. In sites with good bone preservation, smaller mammals—including raccoons, opossums, rabbits, and squirrels—are also frequently present in Late Archaic faunal assemblages, as well as turkey. Not surprisingly, river valley settlements with good preservation also contain abundant evidence of fish and freshwater bivalves, as well as waterfowl. In situations where preservation and recovery are good, this basic pattern of faunal utilization can be expanded, and the finer-grain differences between Late Archaic economies in different parts of the oak-savannah and oak-hickory forest zones come into clearer focus (Phillips and Brown 1983; Styles and McMillian 2009).

In a similar manner, Late Archaic sites throughout these oak- and hickory-forest regions have archaeobotanical assemblages invariably dominated by carbonized acorns and nut fragments of hickory and black walnut (Simon 2009). Representing an abundant and highly nutritious food source that can be stored for a year or more, hickory and black walnuts and acorns occur in varying frequency in plant assemblages across the region, with acorns more abundant at Phillips Spring, for example, in the oak-savannah forest zone and black walnut predominating at Riverton, with Yarnell (2004) discussing the excellent habitat the Wabash River Valley represented for this species. As Munson (1986) suggested more than 3 decades ago, it is possible that human niche construction efforts involving the selective culling of forest trees to encourage nut- and mast-bearing species, which is well documented in the early historic period (Foster, Black, and Abrams 2004), may have deep time depth in eastern North America (Smith 2009b, 2011) and may extend into the Late Archaic.

Although seeds of a wide variety of different species have been recovered from Late Archaic contexts—particularly of fruits, including grape, persimmon, hackberry, and plum—overall seed counts are invariably low. Differential preservation likely plays a role to some extent in the low seed-to-nut ratios documented in Late Archaic archaeobotanical assemblages across the interior midlatitudes (Johannessen 1984), but it is also clear that human utilization of plant resources was relatively narrowly focused, with a concentration on hickory and walnuts, along with acorns, which could be gathered, processed, and stored over long periods with a minimum of effort (Ash, Ford, and Asch 1972:27–28).

**Regional Interaction**

Given the relatively limited importance of seeds generally in the diet of Late Archaic societies in the interior midlatitudes and the substantial distances that separated the settlements that have yielded early evidence of domesticated plants, it would be reasonable to wonder how, exactly, the seeds of domesticates were moved from society to society. There is no clear answer to this question beyond the simple suggestion that the exchange networks that moved information, innovations, various raw materials, and finished artifacts around the Southeast [and adjacent areas] during the 5000–2500-BP time period apparently consisted of innumerable multidirectional, reciprocal, down-the-line exchanges between trading partners (often lineage leaders) of both nearby and distant communities. (Smith 1986:30)

The extent to which settlements within the oak-savannah and oak-hickory forest regions were linked by these complex webs of interaction is reflected in the broad geographical distribution of a range of different artifact forms, most notably projectile points but also including a number of other categories of objects. By mapping the geographical distribution of distinctively carved and engraved bone pins, for example, Richard Jefferies (1996:228) has recently outlined a “lower Ohio–central Mississippi Valley interaction network” that he argues “defines a socially bounded area extending over several hundred kilometers of the midcontinent, within which groups of increasingly sedentary hunter-gatherers interacted and exchanged information that facilitated their survival.” While the area outlined by Jefferies includes both the Riverton and Napoleon Hollow sites (fig. 3), a similarly regionally scaled discussion by Cook (1986) outlines an area of interaction based on shared hafted biface types that in turn encompasses three archaeological phases (Titterington, Sedalia, and Nebo Hill; fig. 3) and includes the Napoleon Hollow and Phillips Spring sites. Dale McElrath (1993:150) concludes that “it seems likely that the Titterington-Sedalia-Nebo Hill cultural entities interacted to a significant degree and can be viewed as representing a culture (TSN culture).” McElrath (1993:150) also notes the occurrence of the distinctive Benton projectile point at the Titterington phase Go Kart North site in the American Bottom, indicating a clear link to other Late Middle Archaic and Late Archaic sites across the Southeast that have yielded Benton points, including the Hayes site.
Although linked by a number of artifact forms (and archaeologists), Phillips Spring, Napoleon Hollow, Riverton, and the Hayes site span a considerable period of time and space, and such linkages are meant not to suggest either direct or contemporaneous interaction between these settlements but rather to indicate that the societies in question were all involved in broadscale networks of simple down-the-line interaction and exchange that existed over long periods of time. People and ideas, as well as seeds and other lightweight commodities, moved along these networks in ways that are as yet not very well understood. But it does seem clear that between 5000 and 3500 BP, the oak-savannah and oak-hickory forest regions were inhabited by a large number of small autonomous societies, some if not all of which were experimenting to various degrees with the cultivation of local seed plants and sharing their success and failure, as well as their seed stores, along well-established networks of interaction.

Summary Discussion

Eastern North America provides a rare opportunity to view the very earliest stages of a transition from hunting and gathering to food production, to look at the societies involved in the initial efforts to domesticate local species and the subsequent emergence of a coherent crop complex (Smith and Yarnell 2009), and to consider the general cultural and environmental contexts of this major shift in human history. As this period of initial experimentation with domestication comes into clearer focus in the other independent centers of agricultural origin worldwide, it will certainly be interesting to compare these as yet less well-documented developmental trajectories with what is known about the societies that domesticated seed plants in eastern North America.

In the oak-savannah and oak-hickory forest regions of the East, the initial domestication and early cultivation of indigenous seed plants (ca. 5000–3400 BP) were carried out by small-scale societies, each consisting of perhaps a half dozen or more related extended-family units. Situated along and tethered to the second- and third-order tributary river valley corridors of the Mississippi River catchment, these societies followed an annual cycle that linked multiple-family-unit
semipermanent to permanent settlements in river valley locations with a range of other short-term multiple-family and single-family river valley and upland occupations.

Clay floors and post mold patterns, along with spatially discrete feature clusters, provide occasional glimpses of the spatial structure and size of these settlements, which lack any indication of ascribed status differentiation or corporate organization above the level of extended-family domestic units. The relative frequency and within-site distribution of a range of different chipped-stone, groundstone, and bone tools allows for the identification of different activity sets, from lithic and bone-tool manufacture and maintenance to food processing.

Although a large range of different species of plants and animals have been identified in the archaeobotanical assemblages of these settlements, their subsistence economies were generally comparable over a broad area of the interior riverine midlatitudes in terms of centering on a limited number of plant resources (e.g., hickory, walnut, oaks) and a consistent list of terrestrial animal species and species groups, including the white-tailed deer, several smaller terrestrial species (e.g., turkeys, raccoons, rabbits, squirrels), and aquatic resources (bivalves, snails, and fish). Although seeds of a variety of different species played a small role in the economy of these groups, based on consistently low seed/nut ratios, the initial domestication and early cultivation of local species did take place within their river corridor natural habitat zones rather than in upland settings based on the earliest recovery of all four eastern domesticates from river valley settlements (table 1). Subsistence economies remained stable over long periods of time, reflecting general long-term successful adaptations to the resource-rich river valley corridors of the oak-savannah and oak-hickory forest regions. These societies may have been modifying their environments in a range of different ways, from differential culling of trees to expanding natural stands of floodplain seed plants and establishing “orchards” of fruit- and berry-producing species, and initial domestication of eastern seed plants could well have taken place within a broader behavioral context of human niche construction (Smith 2007, 2009b, 2011).

There has been considerable discussion over the past several decades about the extent to which population growth during the Late Archaic period resulted in the filling up or “packing” of eastern North American landscapes. This, it is argued, resulted in a reduction in resource catchment zones and increased territoriality and competition over resources, which in turn resulted in a range of adaptive responses, including, perhaps, the domestication of plants (Brown 1985; Jeffries 1996; Smith 1986). Alternatively, I would argue that even though site density certainly increases in the Late Archaic and corporate cemeteries and deep-midden deposits reflect the establishment of long-term human utilization and “ownership” of sections of river valley corridors and adjacent uplands, the case for landscape packing and resource competition playing a causal role in plant domestication has yet to be made. Claassen (1996) makes a major point in this regard, observing that there are many resource-rich river and stream valley settings in the region that did not witness substantial human occupation during the Late Archaic period. If human population growth led to an increase in human occupation of river valleys and greater competition over resources, why do some valley segments remain empty? Similarly, why do subsistence economies remain stable and generally comparable over long time spans and across geographical areas? In addition, in a number of areas where extensive surveys have documented the size and spacing of Late Archaic river valley settlements having a long history of occupation, resource catchment zones turn out to be quite substantial. The three large river valley settlements identified by Winters in the Wabash Valley that make up the Riverton culture, for example (Riverton, Swan Island, Robeson Hills), are spaced at 10-mi intervals, and he estimates that the resource catchment area on one side of the river for all three settlements was 500 mi² (Winters 1969:110).

The debate about the role of population growth, landscape packing, and resource in the initial domestication of plants and animals worldwide will no doubt continue for a substantial period of time. I would argue, however, that eastern North America, arguably the best-documented regional case study currently available, does not provide much support for general models, including those of human behavioral ecology (Smith 2009a) that incorporate environmental downturn, external environmental stress, population growth, landscape packing, constricted resource zones, and carrying-capacity imbalance or resource scarcity in explaining the initial domestication process. Based on the archaeological information now available, small societies in eastern North America first domesticated local seed plants and developed initial crop complexes in resource-rich river valley environments within a larger context of stable long-term adaptations and broad-scale niche construction efforts that were carried out in the absence of any carrying-capacity challenges or seriously compressed and compromised resource catchment areas. It is interesting in this regard to reconsider the discussions of the role resource-rich environments and initial domestication made more than 15 years ago by Price and Gebauer (1995).

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Genetics and Domestication
Important Questions for New Answers

by Greger Larson

The recent ability to extract genetic data from archaeological remains of wild and domestic animals has opened up a new window onto the history and process of domestication. This article summarizes the impact of that new perspective derived from both modern and ancient DNA and presents a discussion of the validity of both the methods and conclusions. In general I address the use of post hoc conclusions and the lack of starting hypotheses to inform what we know about domestication from a genetics perspective. I use three case examples (dogs, goats, and pigs) to exemplify fundamental aspects of the genetic data we still do not understand before specifically commenting on the use of molecular clocks to date domestication and the necessity of thinking about domestication as a process. I conclude on a positive note with a brief discussion about the future relationship between genetics and domestication.

Introduction

The hullabaloo really began in 1997. That year, an article appeared in Science with the title: “Multiple and Ancient Origins of the Domestic Dog” (Vila et al. 1997). The use of population-level DNA sequence data to reveal insights into animal domestication was not entirely novel. The year before, Bradley et al. (1996) explored the dynamics of African and European cows, but the high-profile nature of the dog article definitively consummated the marriage between genetics and domestication. The article created a stir for two reasons. First, it demonstrated the power of population genetic analysis to reveal details that were previously beyond the scope of an analysis based on either morphology or DNA restriction patterns. Sequences of As, Ts, Cs, and Gs possessed a degree of resolution that could not be matched by bones or differing molecular fragment lengths.

Second, the primary conclusion of the article, that dogs were domesticated 135,000 years ago, simultaneously sparked the imaginations of science journalists and in equal measure infuriated zooarchaeologists who knew that the oldest bones that could be safely ascribed to fully domestic dogs were no more than 10,000–12,000 years old (Clutton-Brock 1995). The estimated age of 135,000 years was nonsense. Archaeologists knew the dates were wrong, but a lack of familiarity with genetic methods meant they could not say why. The sexy conclusions and the high impact that have often been generated from these kinds of studies (Vila et al. 1997 has been cited more than 300 times in 13 years) combined with the power to begin sentences with the words “in direct contrast to long-held beliefs” have led to a flood of domestication genetics papers.

In this essay I will review not only the conclusions of a number of publications in this vein but also the more general paradigms that geneticists have operated under in order to guide their research. I will then apply a thought experiment to demonstrate how little is known regarding the fundamentals of genetic data before addressing specific questions related to molecular clocks, the process of domestication, and the ramifications that domestication studies can have on other fields. First, however, in order to critique the validity of genetics-based assertions, it is worth discussing briefly the methods such studies employ and the strengths and weaknesses therein.

A Genetics Primer

The basic modus operandi of these studies is as follows. Hundreds if not thousands of (typically modern) samples of a given species are collected from as many different geographic locations, breeds, or populations as possible. These samples are usually derived from tissue, hair, or feathers, and each sample is bathed in a series of chemicals in order to isolate the DNA.

The extracted DNA possesses millions of copies of the entire genome of the organism as well as many more copies of the mitochondrial genome housed within the mitochondria.

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organisms found in virtually every cell. Domestication geneticists have historically ignored the multibillion base pair nuclear genomes of their samples and instead focused on the 16,000 base pair mitochondrial genome. As sequencing technology becomes cheaper and faster, however, the nuclear genome is becoming increasingly accessible. Still, the mitochondrial genome remains attractive for several reasons.

First, it does not recombine. That is, the only changes that occur in the sequence of a mitochondrial genome are the result of mutations. Thus, modeling its linear evolution is far simpler than having to think about and account for diploid genomes that hybridize and swap genes every generation. Second, although most of the 16,000 base pairs that make up the mitochondrial genome code for genes crucial to an organism’s basic survival, there is a small region, typically less than 2,000 base pairs, between these protein-coding genes where replication begins when a new mitochondrial genome is being built. This region, known as either the control region or the d-loop, is not part of the translation or transcription process and is thus not under the same restrictive selective regime to which the rest of the genome is subjected.

Mutations, or errors that occur during replication, occur all the time. It is the fate of those mutations that differ. If a mutation occurs in a protein-coding gene that negatively influences the functional properties of that gene, then the mitochondria carrying that mutation will not be replicated as often (if at all), and the mutation will disappear. This means that although mistakes during replication happen all the time and in an unbiased fashion across the genome, rates of substitution, or rather the potential of that mutation to survive, are distinctly nonrandom. Because the control region does not code for a protein and thus there are no ramifications (good or bad) for a new mutation, far more of those mutations become incorporated into the sequence. Evolution is simply change through time, and because mutations in this region generally do not affect the organism, the control region evolves at a faster rate than the rest of the genome, where most mutations are deleterious and are selected out before they can become incorporated and sequenced by researchers. This relatively speedier evolution allows for differences between populations and species to build up over short periods of time, thus enabling geneticists to differentiate between conspecific individuals and to draw inferences from the sequences regarding the demographic history of the species. Though mitochondrial DNA (mtDNA) data almost always distinguish between species and can often distinguish populations below the species level, some populations, such as dog breeds, do not possess diagnostic mtDNA signatures.

Once the DNA has been extracted, geneticists select and amplify a fragment rich in variability, typically a few hundred base pairs of the control region of the mitochondrial genome, from every individual. As stated above, this region evolves quickly, and as a result, geneticists expect to find differences (substitutions) at numerous positions along the sequenced fragment, the patterns of which differentiate the individual samples. Not every individual, however, will possess a unique sequence. Numerous samples will often carry the identical sequence of base pairs along the entire fragment. The set of samples that share such identical sequences are said to possess the same haplotype. Although the word “haplotype” has different meanings depending on the type of genetic marker amplified by geneticists, in the studies discussed below, a “haplotype” simply refers to a unique combination of base pairs across the amplified fragment. It is with the haplotypes that the next stage of analysis begins.

A set of haplotypes can be used as raw material to build either a phylogenetic tree or a haplotype network. Both kinds of diagrams visually depict the relationships between the haplotypes. Of the two, networks are the easiest to understand. They typically consist of circles and lines in which each circle represents a haplotype, and the size of the circle corresponds to the number of individuals in the data set that possess that haplotype. Larger circles result when more individuals are all identical across the sequenced region, and the smallest circles represent those individuals that possess haplotypes not shared by any other individual. Two circles connected by a line differ by a single substitution no matter where in the sequence that substitution sits, and hash marks are often placed across the line to indicate additional substitutions. These kinds of figures are often simple enough to be drawn by hand, but software programs also exist to first identify the haplotypes in a data set and to draw the corresponding network depicting how closely or distantly related all the haplotypes are from one another (fig. 1).

Phylogenetic trees are generally more complex than networks because they employ models of evolution to infer the evolutionary relatedness of the haplotypes. The evolutionary models place differing weights on the kinds of substitutions encoded in the sequence, and these weights alter the mathematical distances between the haplotypes. Because trees are depictions based on those distances, different models can produce differently shaped trees or trees with the same shape but with differing levels of statistical support for the branches. Adding additional individuals from previously unsampled populations that possess novel haplotypes can also alter the shape of the networks and trees.

Once networks and trees have been generated, two additional terms are often used to discuss their shapes. A “haplogroup” on a network is a cluster of closely related haplotypes that together create an easily recognizable group that is more or less (it is hoped more) differentiated from other haplotypes and haplogroups. A “clade” on a tree is more or less the same thing, although its technical definition is a group of haplotypes that are more closely related to each other than any one is to any other haplotype. In human-relationship terms, this would be called a family. Because a single tree is just one of many that could possibly be drawn from the data, phylogeneticists prefer to generate numerous trees to see how frequently the same patterns of clades and haplogroups appear. The more often they appear, and the more robust they are
to different parameter values within separate models of evolution, the more confidence phylogeneticists have that the relationships are "real" and not just artifacts of the data (fig. 1).

At this stage—armed with a network, a tree, or both—geneticists are ready to begin the process of interpreting the images and gleaning the implications for our understanding of how, when, where, and how many times domestication of a particular species has occurred. Having laid out the basic methods of these studies, what follows is a short critique of the ways in which inferences and conclusions have been drawn.

The Appeal of the Post Hoc Narrative

The majority of studies of the ilk I describe above do not contrast their observed data with an expected result. For the most part, there are no expectations regarding the shapes of networks, the number of haplotypes or haplogroups, or the structure of trees derived from the data. These studies do not follow the textbook scientific method that begins with a falsifiable assumption and dichotomous easily defined expectations and ends with a comparison between the generated data and the expected result. This is not necessarily a bad thing. Scientific enquiry, especially at the early stages of data gathering using a newly available technique, is often investigative and explorative. Newly derived categories of data cannot be expected to be acquired or interpreted within the confines of explicitly stated hypotheses. Given the relatively short period of time that population-level sequence data have been available, it is perhaps no surprise that within the field of domestication genetics, there has been little explicit hypothesis testing. My own work on pigs is no exception.

Though many domestication studies strive to interpret the data within the context of what is already known about their study animals, many of them are content to report only descriptive accounts of the generated data. Not every study has
done this, of course, but the general trend was recently exemplified by a 2007 article, the title of which was “Large-Scale Mitochondrial DNA Analysis of the Domestic Goat Reveals Six Haplogroups with High Diversity” (Naderi et al. 2007). This particular article does, in fact, present insights regarding goat domestication, but the plainly descriptive title hints at the nature of many of these studies that generate data in theoretical vacuums.

In order to elucidate this trend, I present three case studies that focus on dogs, goats, and pigs. All three employed the general methodology discussed above, and taken together they demonstrate the potential and limits of genetic domestication studies. I have chosen these three because populations of the respective wild ancestors—wolves, bezoars, and wild boar—remain extant, thus allowing for a comparative analysis of the genetic patterns found in both wild and domestic animals. For studies of animals whose wild ancestors are either extinct (e.g., cows and camels) or uncertain (e.g., sheep), the genetic differences between the wild and domestic forms can only be revealed by generating DNA sequences from archeological material. A large number of studies have attempted to do just that with respect to cows (Edwards et al. 2007), but the first ancient sheep and camel DNA article are still forthcoming.

Because wolves, bezoars, and wild boar are still around, geneticists are able to sample them and place both wild and domestic variants into the same network or tree. Though more recent studies have been published, a 2002 study of dogs (Savolainen et al. 2002) is instructive. This study typed more than 600 domestic dogs and nearly 40 wolves, numbers that in 2002 were relatively large. Two articles focused on goats were published in 2007 and 2008 (Naderi et al. 2007, 2008), but in the intervening 5 years, the acceptable standard for sample numbers had increased, and these studies analyzed 2,430 domestic goats and 473 wild bezoars.

The first statistic normally generated in these articles is the number of haplotypes found among all the samples. In these cases, the authors identified 110 unique haplotypes in dogs and 17 in wolves. The goat studies, based on fourfold more domestic samples and tenfold more wild samples, identified a total of 1,783 unique haplotypes in both populations. The issue of what those numbers mean and whether they are significant is difficult to answer for the simple reason that no one knows how many haplotypes to expect from a given number of populations or individuals.

Even without this understanding, a comparative approach can be used across species to ask new questions that will form the basis of future studies. The first question worth asking is how many haplotypes are found in both the wild and domestic samples. In canines, out of a total of 127 haplotypes, only one was identified in both dogs and wolves. In caprines, of 1,783 unique haplotypes, only three were shared by both wild and domestic goats, and those three were found only on the island of Sicily, where the status of the goats and the timing of their arrival is uncertain. According to the authors, the domestic goats found on this island could be ancestors of wild animals only recently transported there (Naderi et al. 2007). If true, the number of shared haplotypes between truly wild and truly domestic would be 0.

This observation has not gone unnoticed, and the near universal lack of shared haplotypes between dogs and wolves has been exploited as a means to identify recent hybrids by observing stereotypically dog haplotypes in modern wolves (Randi and Lucchini 2002). Still, beyond the use of this observation as a conservation tool, no one has yet questioned why wild and domestic animals of these species share so few haplotypes.

A Thought Experiment Involving Haplotypes

We know that dogs and goats are derived exclusively from wolves and bezoars, respectively. Thus, the earliest domestic populations must have shared 100% of their mitochondrial haplotypes with their wild counterparts. Given this, the question must be why and how has the shared proportion dropped to virtually 0%. One explanation could be that the original wild populations that gave rise to domestic stocks are now extinct and the sampled extant wild populations in these studies were not involved in the domestication process. This could be especially true for wolves, which have suffered a long history of persecution. Under this scenario, however, the expected networks and trees would generate haplogroups that consist of either wild or domestic animals. In the dog study, the tree did in fact demonstrate that some clades consisted only of wolves or dogs consistent with the extirpation scenario, but the majority of clades contained haplotypes of both dogs and wolves even if that was because some of the haplotypes were shared (Savolainen et al. 2002). In goats, though several bezoar-only clades are evident, every single domestic goat sample is found within a cluster of bezoars, though again, none of the haplotypes are shared (Naderi et al. 2008). These patterns do not fit any simple scenario of domestication that focuses on demographic patterns of limited sampling from wild populations and periodic bottlenecks for both wild and domestic animals.

The explanation above rests on an assumption that though the control region of mtDNA does evolve quickly relative to both other genes in the mitochondrial genome and the nuclear genome of the organism, it is traditionally not thought to be fast enough for mutations to accumulate over the relatively short time frame of domestication (10,000 years). If true, this would mean that haplotypes found in modern wild and domestic animals have not changed since the beginning of the Holocene and that the observed substitutions not only occurred long before domestication but also reflect population structuring that resulted from a long-term lack of gene flow between geographically partitioned groups. This assumption may not always hold, however, and a series of articles has suggested that substitution rates are not fixed (Ho and Larson 2006; Ho et al. 2005).
These authors demonstrated that the evolutionary rate derived from a data set is dependent on the time depth of the most recent common ancestor of the studied sample set. A data set consisting of a group of humans known to have had a common ancestor on the order of hundreds or thousands of years will possess a great deal more variation than what would be expected using standard evolutionary rates. When the data set is increased to include chimpanzees and other primates, the date of the most recent common ancestor is pushed back to a scale of millions of years, and the evolutionary rate tumbles. This so-called time dependency of evolutionary rates could result from the retention of slightly deleterious mutations over a sufficient time frame to be included in population-level data sets. Over longer time frames, those mutations are eliminated, which would then reduce the observed variability in the data set and give the appearance of a slower evolutionary rate. Additional studies of different species have thus far confirmed the phenomenon (Burridge et al. 2008) even if a fully satisfactory explanation remains elusive.

What this might mean is that we should not necessarily expect wild and domestic haplotypes to be identical. Instead, wild and domestic individuals that shared a common ancestor around the time of the origins of domestication would possess substitutions that have accumulated since they split. So long as this pattern was generalizable across different animal domesticates, this would explain why wild and domestic dog and goats fail to share any common haplotypes.

Pigs, however, are different. The pig data contradict the dog and goat data in at least two key ways. First, wild boar and domestic pigs share at least 17 haplotypes (Larson et al. 2005, 2007a, 2007b, 2010). This could easily result if the pig data were based on shorter sequences than dogs or goats, thus reducing the chances of finding substitutions that differentiate individuals, which would lead to a reduction in the number of overall haplotypes. The number of base pairs amplified for dogs, goats, and pigs, however, is 582, 469, and 662, respectively. All else being equal, pigs should therefore possess more total haplotypes and fewer shared haplotypes between wild and domestic animals. This is not the case.

Not only are the two most frequent domestic haplotypes found in Europe also found in European wild boar, more than 15 haplotypes are found in both East Asian wild boar and Chinese domestic breeds, an additional haplotype was shared by Indian wild boar and domestic pigs, and another was shared by wild boar from Vietnam and domestic and feral pigs found in Island Southeast Asia (Larson et al. 2007b, 2010). The most obvious explanation for this pattern is that it results not from distinct instances of domestication but that the haplotype as an indigenous wild boar that was never part of a domestication process, male domestic pigs would have to mate with female wild boar, and the piglets would have to be incorporated into the domestic stock. The opposite scenario is common practice in many cultures, especially in New Guinea, where females are often left tied to a stick at the edge of a village overnight and are subsequently impregnated by feral males from the forest. In this case the resulting piglets retain their mother’s domestic mitochondrial signature.

Second, an argument that assumes a high degree of hybridization must explain why so many populations of indigenous wild boar—including those in India and on islands such as Japan, the Ryukyu chain, and Taiwan—retain their genetic distinctiveness (Larson et al. 2005) and why domestic pigs introduced to these areas have not acquired the local DNA haplotypes. Neither the model that associates shared haplotypes with independent domestication nor the model that assumes all instances of shared haplotypes are the result of recent hybridizations explains the data. The truth, of course, probably lies somewhere in the middle, although observing and describing DNA evidence is only the first step to uncovering it.

This issue touches on a second key difference between the wild boar and wolf and bezoar data sets, and for this discussion it is worth explaining another common term. “Phylogeography” is the study of the association of phylogenetic signals with the geographical provenance of the samples. A strong phylogeographic signal is the result of a high degree of reciprocal correlation between a geographic region and a specific haplogroup or clade. If an analysis of a wild population demonstrates that hypothetically, highly differentiated haplogroups are found in Spain, Italy, and Greece but that animals carrying all three types are present in northern Europe, geneticists would be tempted to suggest that the strong phylogeographic pattern in southern Europe suggests a genetic differentiation that took place in refugial regions during ice ages and a mixing of haplotypes when those populations migrated north after a climactic amelioration. By assigning colors to specific haplogroups or clades and by pinning the colors onto a map, geneticists are able to ascertain the relative strength of the phylogeographic signal.

A strong signal is desirable because it allows authors to pinpoint hypothetical centers of domestication. Unfortunately, most wild animals involved with domestication lack strong signals, at least when the data sets consist only of mtDNA. (As sequencing techniques become cheaper, data sets studies that interrogate and analyze nuclear genomes [e.g., vonHeldt et al. 2010] may reveal more geographically proscribed and genetically distinct populations of wild and domestic populations.) Three wolves, for example, sampled from China, Mongolia, and Saudi Arabia all possessed the same mitochondrial haplotype, as did individual wolves from Turkey, Sweden, and Portugal (Vila et al. 1997). Thus, assigning an origin to dogs who possessed haplotypes closely related to the maternal line. Thus, in order for domestic pigs to share...
these wolves is problematic or at least lacking in precision. Modern bezoars are significantly more geographically circumscribed than modern wolves, and though some haplotypes seem to be found only in small regional pockets, almost all of the full complement of haplotypes were identified in bezoars sampled exclusively between Turkey and Iran (Naderi et al. 2008).

In many ways this makes sense. Wolves migrate long distances during their lifetimes, and thus different haplotypes are expected to be present at many locations across the Old and New Worlds. Humans, too, have been responsible for the movement of both wild and domestic animals, thus smearing and blurring any phylogeographic pattern that may have existed in the Pleistocene. In addition, the history of the ice ages, as described in the hypothetical above, has also played a role by forcing populations apart where they begin to diversify before reuniting them. This has been shown to play a role in yaks, herds of which often contain individuals with highly variable and differentiated haplotypes (Ho et al. 2008).

The overall effect of these homogenizing forces should lead to a modern-day situation in which no wild population retains a strong phylogeographic signal. Yet unlike virtually every other wild animal involved in domestication and in defiance of both their natural migratory ability and a long history of human-assisted transport and reproductive meddling, wild boar do. This strong phylogeographic signal allows for a relatively straightforward identification of centers of origin. For instance, a handful of wild boar collected in India are all positioned in a haplogroup that is significantly different than all other groups. These haplotypes are only present in South Asia, and thus when an Indian pig identified as domestic also possessed the same signature, the most parsimonious explanation was that these wild boar were likely involved in domestication (Larson et al. 2005). Of course, it is possible that domestic pigs derived from a separate population in a different place were transported to India and then mated with an indigenous female wild boar, thus producing a litter that was retained by humans. The data cannot differentiate between these two scenarios, but the strength of the phylogeography at least allows the suggestion of an independent Indian domestication to be made, which can then be further investigated and corroborated by archaeological or historical sources.

When phylogeographic signals are weak, suggestions regarding the geography of domestication rest on more subtle arguments. The most popular one is based on a determination of the genetic variability present in domestic animals in different regions. The more variation a region possesses relative to the total diversity evident in an entire data set, the more likely that region was a center of origin because, as the argument goes, only a subset of the total diversity is generally transported by people away from the center. This is certainly true of human diversity, which is far higher on the African continent than it is in Australia, or at least it was until the fifteenth century, when large numbers of genetically diverse people began migrating to Australia, the Americas, and other parts of the world. A modern analysis of this kind that did not take into account the historical migrations of people to the New World would conclude that the United States of America was the origin of all humans. That is to say, highly diverse regions can result not just from a legacy of origination but also from migration into the region by genetically diverse populations. Thus, demonstrating that a region is particularly diverse without also offering nongenetic evidence suggesting the region was in fact a center of domestication is problematic at best. All of the data related to cows is used in this argument (Troy et al. 2001) as well as in the argument that dogs were first domesticated in China (Savolainen et al. 2002). In the former case, archaeological evidence also supports a Near Eastern origin of cattle domestication and a subsequent Neolithic migration into Europe, suggesting that the genetic interpretation is correct. In the latter case, however, a supporting narrative based on archaeology remains elusive, and a recent publication using genetic data from a large number of geographically isolated wolves and domestic breeds concluded that because Near Eastern wolves also played a large role in the domestication of dogs (vonHoldt et al. 2010), China was likely not the sole center of dog domestication.

Confidence-Free Molecular Clocks

Numerous attempts have also been made to place an independent time frame on the history of domestication using genetic data sets. In many cases, the authors of these articles have concluded or at least implied that animal domestication began hundreds of thousands of years ago (Ho and Larson 2006). Perhaps the most famous of these attempts was the Vila et al. (1997) publication that pushed dog domestication back more than 100,000 years. The authors were able to conclude this by first determining that the average mitochondrial genetic difference between wolves and coyotes was 7%. By borrowing a date of one million years for the last shared common ancestor between the two species, they established a rate of 1% per 135,000 years. As discussed above, because most of the clades on their tree contained both wolves and dogs, the authors estimated the divergence between wolves and the one clade that only contained dogs. The figure, 1%, meant that dogs and wolves last shared a common ancestor 135,000 years ago (Vila et al. 1997).

There were a number of assumptions made during this exercise, and the decision to not bracket the estimate with error bars gave an unwarranted impression of precision. The conclusion proved intriguing, however, and for several years all genetic animal domestication articles included highly suspect molecular clock analyses (Ho and Larson 2006). Very few (if any) efforts have been made to combine all the possible sources of error associated with these kinds of analyses in an effort to confidently ascertain the precision of the estimates.

More recently, another source of error, the time dependency of molecular clocks discussed above, has only added to the
error, although the variable-rate issue does go some way toward explaining the discrepancy between the dates derived from molecules and from archaeology. In most cases, geneticists applied evolutionary rates derived from data sets whose most recent common ancestor existed millions of years ago to data sets of populations whose common ancestor was far more recent. By applying a slow clock to a data set that possessed substantial variation, they significantly overestimated the time it would take to produce that variation, thus pushing the timing of domestication deep into the past. Taking this effect into account only removes a single source of error, however, and the combination of all the others suggests that the error bars almost certainly encompass the present day. Thus, molecular clock efforts so far simply lack the precision to date Holocene phenomena. And this is true even after putting aside the issue of what a domestication date actually means.

The production of large mtDNA data sets to glean insights into domestication is no longer novel, and the number of species left to investigate in this manner is dwindling. The general approach has a great deal of merit, and this first stage of sequence generation is necessary to understanding how a genetics-based approach can help us to understand domestication. But it is just the first stage. If sequence data have thus far failed to revolutionize our understanding of the patterns and processes of domestication, I suspect this is because we may have hoped that the data themselves would be easily interpretable and provide robust conclusions. Without starting hypotheses about what the data sets would generate, however, easy interpretations were only possible if the trees and networks revealed something immediate and obvious. When they did not, we have been left to either simply describe what we see or tell post hoc stories sometimes using shaky assumptions.

I am confident, however, that the next stage will achieve a great deal more. Far from asking how many times was species X domesticated, we should be asking why are so few haplotype shared between wild and domestic animals? What climatic conditions or landscape contexts are necessary to produce x number of clades or haplogroups? What exactly constitutes a high level of diversity? Is it appropriate to compare levels of diversity between species? By focusing not on how to interpret the data but instead on how many ways the data set can be generated and under what conditions and parameters, we can begin to replace post hoc explanations with a hypothesis-testing framework. Again, this is not to say that post hoc narratives are inferior; they are a vital prerequisite to further understanding, but they are limited in the degree to which they can ultimately inform the history of domestication.

Hypothesis-driven research in this vein is already yielding fascinating new conclusions. An article published by Allaby, Fuller, and Brown (2008) employed simulations to reveal that post hoc narratives used to support a rapid transition from wild to domestic crops were based on a false assumption regarding how the data were derived. They demonstrated that counterintuitively, multiple origin scenarios of crop evolution are more likely to give the superficial impression of a single origin than a single origin scenario. This result demonstrates that our intuitions are not always valid and that we should therefore simulate data sets based on our assumptions of what is supposed to happen to see what other mistakes we might be making when divining the “obvious” story from the shapes of networks and trees.

A Note on the Process

The Allaby, Fuller, and Brown (2008) article is also noteworthy because it does not ignore the long history of domestication. Domestication, like speciation, is not an event. Geneticists know this as well as archaeologists, but for a multitude of reasons including convenience, we often use the word “event” and describe wild and domestic as complementaries, that is, opposites that possess no intermediate form (Dobney and Larson 2006). This fallacy is maintained largely because processes are messier than events, and an event mind frame is a necessary fudge that must be assumed before analyses such as molecular clocks can be applied. None of the attempts to place a molecular time frame on the history of domestication differentiates between the beginning and the end of the process. Instead, a single date estimate is gleaned that is intended to be interpreted as the year in which wild became domestic.

If we are to embrace the process (see Denham 2011; Marshall and Weissbrod 2011; Piperno 2011; Vigne 2011; and Zeder 2011), we have to think differently about both the questions and the data sets. As the Allaby, Fuller, and Brown (2008) study demonstrated, an approach that replaces or at least supplements the mitochondrial genome with the full nuclear genome has enormous benefits. By looking at the genome of the organism, which contains the genes that code for the differences between wild and domestic individuals, it becomes possible not just to understand what genes are changing but precisely how those changes affect the total animal. Using these kinds of data sets, we can start asking deeper questions that focus not on the where and when but on the how. In other words, it may soon be possible to identify the genetic alterations that took place between the first steps of domestication (fig. 2) and today.

The Belyaev fox-farm experiments that began in Siberia in 1959 revealed that by selecting solely for tameness, it was possible to produce, in relatively few generations, a population of foxes that looked and acted like domestic dogs (Trut 1999). That much is well known. Two other aspects of these experiments have been less well publicized. First, the farm experimented not just with foxes but also with populations of rats, beavers, and other animals. Second, the goals were to produce both extremely tame animals and extremely aggressive ones as well. An anecdote from these later revelations stated that the Soviet army was ready to deploy large numbers of the
most aggressive beavers on the Soviet borders in the event the U.S. military ever dared a land invasion.

The two colonies of tame and aggressive rats are now in residence in Leipzig, Germany. By first crossing individuals from both groups and then measuring 45 separate physiological and behavioral traits, a recent study (Albert et al. 2009) was able to identify two specific quantitative trait loci associated with tameness. This kind of study represents an important first step in revealing links between genetics and behavior and begins to test the hypothesis that a small number of genes are ultimately responsible for the large behavioral and phenotypic differences that divide wild and domestic animals (Dobney and Larson 2006; Stricklin 2001).

Despite a lack of access to parallel populations bred explicitly for this purpose, a number of geneticists have already developed a long history of insights into the genetic architecture underlying domestic phenotypic traits. These kinds of studies have generally been focused on single traits, many of which are commercially important. Geneticists first type a large number of known variable positions across the genome in two populations of animals, one that possesses one variant of a trait, such as a white coat, and one population that has a different coat color. A comparison of the regions of difference and similarity across the genome allows the geneticists to focus their search, and from there they use similar methods to isolate the fragment of DNA that possesses the causative mutation(s) underlying the trait. Actually identifying the mutation is often more difficult, although on occasion, such as in traits for muscle growth in pigs, a single mutation was pinpointed (Van Laere et al. 2003).

Occasionally these types of studies reveal insights into the history of domestication. After identifying the gene responsible for yellow legs in chickens, geneticists then sequenced the region in a variety of wild jungle fowl. An alignment of four different wild species revealed that although the majority of the domestic genome was identical to the wild red jungle fowl, the gene responsible for producing yellow legs showed a far greater identity to the same region found in gray jungle fowl. This result resolved the paradox of how yellow legs, a trait never seen in red jungle fowl, could be so prevalent in domestic chickens, but in so doing it also revealed a somewhat unexpected conclusion that chickens are not derived from a single ancestor (Eriksson et al. 2008). This revelation opens up an entirely new set of questions related to the process of domestication, the frequency of hybridization and the creation of hybrid domestic animals, and the debate over the degree of human intentionality in selecting for specific traits at various stages.

Perhaps the best bet we have for using genetics to unravel the big questions surrounding domestication is to look for the newly identified changes that underlie key traits in the bones of domestic animals found in archaeological contexts. A recent study on coat colors in pigs demonstrated that the pattern of mutations that cause coat colors—including red, black, and white spotted—are the result of a strong selection pressure away from the camouflage coat colors selected for in the wild (Fang et al. 2009). The suggestion is that coat color variation has been a feature of domestication from the very beginning of the phenomenon. Armed with the causative mutations, this hypothesis can be tested by screening ancient bones for the genetic variants that underlie the specific coat colors. This method has already been used on both ancient mammoth (Rompler et al. 2006) and horse (Ludwig et al. 2009) remains, the latter of which revealed an explosion in the number of coat colors in horses around the fifth millennium BP.
Proxies for Domestication’s Ramifications

Ancient DNA techniques will no doubt be employed in future studies to type phenotypic traits in subfossil material. As discussed above, uncovering a strong phylogeographic signal in domestic animals using an alignment of neutrally evolving DNA (the control region of the mitochondrial genome) has been rare, though wild boar possess an inexplicably strong relationship between the phylogenetic placement and their geographic provenance.

In his book Guns, Germs, and Steel (Diamond 1997), Diamond discusses the universal tendency for populations that have acquired agriculture and domestic animals to first develop a large population and then to move (see also Bellwood 2011). Diamond recounts migrations of people armed with a suite of domestic crops overtaking indigenous hunter-gatherers in, among other places, Europe, East Asia, sub-Saharan Africa, and New Zealand. The routes and timings of these migrations are often contentious, but given the fact that domestic animals were always a key part of the migratory package, the genetic signals derived from their remains can act as a proxy for human migration.

Because wild boar indigenous to Europe possess such a divergent haplotype from those native to the Near East, a short fragment (less than 85 base pairs) of DNA was enough to ascertain the genetic legacy of an ancient pig bone. The wild or domestic status of pig bones was determined using a morphological analysis (though of course many remains could not be confidently assigned to either category) after which the diagnostic fragment was amplified. Not surprisingly, the bones identified as wild in European Mesolithic and Neolithic contexts were European in origin. The domestic bones from a number of sites stretching from Romania through Germany to France, however, displayed a Near Eastern signature. Although this pattern conformed to expectations based on the known history of the Neolithic migrations into Europe, what was a surprise was the speed with which the Near Eastern lineages were replaced by domestic pigs of European origin, first in Europe itself and then in the Near East (Larson et al. 2007a). European wild boar are now the primary (if not sole) progenitors of European domestic pigs, although whether this process was initiated independently of the Near Eastern pig domestication or whether it was kick-started by the introduction of Near Eastern pigs remains an open question.

Beyond demonstrating the use of genetics to reveal the patterns of movement among a key domestic animal and hence the movement of their human herders, the study by Larson et al. (2007a) also underlined the dangers of inferring historical patterns based on modern data alone. All modern continental pigs in Europe possess European-specific mitochondrial haplotypes. But they only do so today because the Near Eastern-specific pigs originally brought into Europe have been completely replaced, leaving no descendants in modern pig populations. Given the number of human migrations and instances of animal transport that have taken place since the Neolithic, it is a certainty that domestic animal populations originally introduced into a new region have subsequently been replaced, perhaps several times over. A temporal perspective is thus a necessity for any study that pretends to a robust conclusion regarding the long-term history of population movements.

Conclusion

Given the relatively short period of time over which genetic methodologies have been applied to domestication questions, it is perhaps no surprise that the initial claims are now being tempered. This is the nature of youth. Practitioners of a new technique with the promise of novel data sets have the benefit of knowing that every result is potentially revolutionary. Journalists and academic journals alike are delighted to publish the rapidly generated conclusions of the new method, and the more often the new studies overturn conventional wisdom or directly contradict decades of findings based on more traditional methodologies, the better.

As the field eases beyond its teenage brashness, my position is that there is now time to take stock and to begin questioning the assumptions on which many of our early studies were based. The massive data sets that will be generated as part of the high throughput sequencing revolution will reveal fine-scale structure at the population level and new genes important in the domestication process. I suspect the new technologies will also generate insights not just into DNA sequences but RNA sequences as well. Insights at this level of organization will facilitate an understanding of not only what genes were key but in which tissues and when they are active. These kinds of studies will have significant ramifications not just for domestication but also for the nature of evolutionary change. In addition, a focus on simulation and modeling will reveal how demographic changes affect the patterns in population genetic data, which will better allow us to choose which of several competing scenarios best explains the early history and process of domestication. Finally, improved sequencing techniques will allow for an essential temporal component to be layered onto the data, and thus with any luck a complete understanding of the hows, whens, wheres, and maybe even the whys of domestication will be within our grasp.

The discussions that took place at the “The Beginnings of Agriculture: New Data, New Ideas” Wenner-Gren Foundation Symposium in March 2009 in Mexico went a long way toward solidifying my impression that the big questions are increasingly knowable. First, highly precise data regarding the specific temporal, geographic, and ecological circumstances in which domestic plants and animals became integrated into human settlements are accumulating at an unprecedented pace. This level of detail is allowing researchers to piece together the specific order of events (on a region-by-region basis) that first set the stage and then allowed for domestication to take place.
(e.g., Zeder 2011). Second and equally impressive, the theoretical framework for understanding the process of domestication at the macrolevel is becoming ever more refined. These structures (see Denham 2011) will allow us to place the new data into a scaffold that will facilitate a genuine comprehension of the bigger themes of global domestication on top of their specific regional narratives. These are exciting times.

References Cited


Diamond, J. 1997. The origins of plant cultivation and domestication at the macrolevel is becoming ever more refined. These structures (see Denham 2011) will allow us to place the new data into a scaffold that will facilitate a genuine comprehension of the bigger themes of global domestication on top of their specific regional narratives. These are exciting times.

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The Agricultural Demographic Transition During and After the Agriculture Inventions

by Jean-Pierre Bocquet-Appel

An abrupt increase in fertility has been recorded in data from 200 cemeteries and ethnographic data ranging from the Meso-Neolithic Eurasian center in the Levant to the arctic circle in the North American continent in the twentieth century AD. This shift has been called, synonymously, the Neolithic demographic transition or the agricultural demographic transition (ADT). It is interpreted as the effect on fertility of an abrupt change in maternal energetics that occurs during the transition from a mobile forager economy to a farming economy in any period, whether prehistoric or historical. The primeval prehistoric ADT was a loop of retroactions capable of rapidly raising the rate of population growth and in which the population was both the cause and the effect of the demographic shift. During the eighteenth century AD, new areas of demographic change appeared across this agricultural population area that were characterized by a drop in mortality and then in fertility and were determined by the introduction of new rules of hygiene along with medical and contraceptive techniques. This shift represents the contemporary demographic transition (CDT). The CDT occurred in reverse symmetry with the ADT. A unique phenomenon occurred at the margins of the residual area of the forager system with a quasi coincidence of the effects of both the ADT and the CDT.

During the transition from forager to food-producer economies, the signal of a relatively abrupt shift has been detected in paleoanthropological data from about 200 cemeteries in Europe and North Africa, the Levant, and North America, as well as in archaeological data from Europe and South America (Bandy 2005, 2008; Bocquet-Appel 2002; Bocquet-Appel and Dubouloz 2004; Bocquet-Appel and Naji 2006; Bocquet-Appel and Paz de Miguel Ibanez 2002; Buikstra, Konigsberg, and Bullington 1986; Guerrero, Naji, and Bocquet-Appel 2008; Kohler and Claude 2008). In the cemetery data, this signal is characterized by a relatively abrupt increase in the proportion of immature skeletons, which, as is now well known, mainly expresses an increase in the birthrate (and beyond this in fertility) among populations and not an increase in mortality (Johansson and Horowitz 1986; McCaa 2002; Sattenspiel and Harpending 1983). This transition is an indication of a demographic explosion relative to the preceding forager period. In the archaeological data, the signal of demographic change shows that the rate of increase in archaeological remains diminishes as their density increases. This, known as a two-stage pattern (Bandy 2008), is interpreted as expressing a density-dependent demographic pattern in which when the population density increases, its growth rate, although still positive, decreases asymptotically.

The coincidence of this demographic signal with the economic transition from foragers to food producers has led us to consider the signal as the signature of a major demographic phenomenon initially named the Neolithic demographic transition (NDT). The idea of the NDT, either named as such or under another name, has also been expressed independently by other researchers (Binford and Chasko 1976; Livi-Bacci 1992; Simoni et al. 2000). As we will see below, through a return to certain neglected historical data, the NDT occurred not only during the prehistoric period but also during historical times that saw a transition from a nomadic forager economy to a farming economy (or to the modern Western economy). What has been called the NDT up to now can therefore be generalized as the agricultural demographic transition (ADT), a term that will be employed synonymously with NDT in this article. In the first part of this article, four signals of the ADT produced at different periods and in different regions from prehistoric times to the twentieth century AD and obtained from archaeological and ethnographic sources are juxtaposed in order to highlight the unique pattern of the ADT and to understand the causes of its variation. In the second part, the metabolic load model of maternal energetics developed by Valeggia and Ellison (2004) is put forward to explain the rapid increase in fertility during the ADT. The third part addresses various questions such as the impact...
of mortality, which is not directly observable, and the self-catalyzing nature of the ADT process. In the final part, the contradictory impacts of the ADT and of the recent contemporary demographic transition are brought into perspective through a projection involving ethnographic populations living on the fringes of the world economy.

Signatures of the ADT in Archaeological and Ethnographic Data

Different signals of the ADT have occasionally been obtained, from prehistoric cemeteries for the oldest examples and from demographic surveys of ethnographic groups for the more recent. But these signals were not understood as representing different expressions of the unique demographic phenomenon of the ADT occurring at different times and in different places. While the signal of the ADT is easily visible in the ethnographic demographic data—expressed by a steep increase in the fertility index over a relatively short period of a few decades—this is not the case in cemeteries, where, in general, the signal is not directly visible to the archaeologist. To bring it out, an archaeometric procedure to detect demographic change in the space-time cemetery data has to be used. This provides the underlying trend of an unconventional demographic indicator expressing how the age pyramid in a living population expands with the rate of the transition from a forager economy to a horticulture-farming economy. As repeatedly stated, this indicator is represented by the proportion of 5- to 19-year-old skeletons in a cemetery (named $d_{p_{5}}$ to conform with demographic notation) relative to individuals aged 5 years plus, because skeletons under 5 years of age are notoriously underrepresented in cemeteries. When the proportion is high, the age pyramid forms the obtuse angle of a young population; when it is low, it forms the acute angle of a relatively older population. Beyond the opening of the age pyramid, this indicator expresses the birthrate, the growth rate, and the fertility rate in a stable population model (Bocquet-Appel 2002; Bocquet-Appel and Naji 2006, fig. 6).

In order to extract a demographic pattern that is common among the space-time data scattered across the map, a tempo of the economic transition in relative chronology—relative to the economic transition locally—is used, symbolized by $dt$, instead of an absolute (historical) chronology. When the introduction of the farming system is positioned in a locality at $dt = 0$, the effect of the relative chronology is to arrange the values of the demographic indicator $d_{p_{5}}$ in a new reference frame in such a way that when $dt < 0$, the indicator informs on forager demography, while $dt \geq 0$ informs on horticulturist-farmer demography. As we shall see below, the signal of the ADT is characterized by a relatively abrupt increase in the paleodemographic indicator $d_{p_{5}}$ over the tempo of the relative chronology $dt$ during the economic transition, which can be represented graphically by a profile. This profile expresses the kinetics of the opening of the age pyramid and, beyond, of an increase in birth and fertility rates.

When this increase in the birth/fertility rate levels off, during the agricultural period, the plateau indicates the stabilization of the fertility “phase” of the ADT in the geographical area of the sampled cemeteries. The degree of change in fertility during the ADT can then be summarized by two figures: the value of $d_{p_{5}}$—the relative youth of the population—at the plateau and time $dt$ taken to reach it. In most cases, using an absolute chronology would make it difficult to detect the ADT and its phenomenological unity because of the distance between cemeteries in space and time, which a relative chronology does allow (for a discussion, see Bocquet-Appel 2002, 2008a; Bocquet-Appel and Naji 2006). The use of relative chronology makes it possible to bring all the data together whatever their absolute chronology. ADT images are technically less difficult to obtain from ethnographic data directly, however scarce such information may be.

Four signals of the ADT are shown in figures 1 and 2. The first three were obtained from paleoanthropological cemetery data and the fourth from ethnographic data. These images range geographically from the Meso-Neolithic Eurasian center in the Levant to the arctic circle in the North American continent in the twentieth century AD.

The first signal represents the ADT in the Levant (fig. 1A). Its profile shows, during the forager period, first of all, a high value for the demographic indicator $d_{p_{5}}$, during a period that corresponds in absolute chronology to the Natufian forager system (with $d_{p_{5}} = 0.30$ toward $dt = 2,600$ years). The profile then slopes continuously downward until it falls below the floor value of a demographically stationary population (fig. 1A, horizontal dotted line) when the profile is interpreted in terms of growth rate. The profile then curves back upward, once more crossing the stationary value at $dt = 0$, which corresponds to the beginning of the Pre-Pottery Neolithic A cultural horizon in absolute chronology. At $dt = 2,600$ years—the limit of the available data—the expected plateau of $d_{p_{5}}$, with the high value $=0.400$, is still not reached. The ADT in the Levant corresponds to a relatively slow but continuous increase in birthrate and fertility. During these 2,600 years, the estimated total fertility rate (TFR; Bocquet-Appel and Naji 2006, fig. 6) increases from 4.5 to 10 children per woman at the end of her reproductive life, that is to say an increase of 2.1 additional children per millennium.

The second signal shows the ADT in the North American Southwest (NASW; fig. 1B; Kohler and Glade 2008), which corresponds in absolute chronology to the middle of the first millennium AD. In that region, the ADT starts at $dt = 250$ years after the introduction of the intensive farming system until the profile reaches a plateau value $d_{p_{5}} = 0.30$ at $dt = 850$ years.

The third signal shows the ADT at the intercontinental geographical scale of the Northern Hemisphere (North America, North Africa, and Western Europe; fig. 1C) obtained from 133 cemeteries, five being already included in the NASW pro-
Figure 1. Three archaeological signals of the agricultural demographic transition obtained from the paleodemographic indicator for cemetery data ($15P_5$, vertical axis) plotted on the relative chronology ($dt$, horizontal axis). A, The Levant epicenter ($N = 16$; Guerrero, Naji, and Bocquet-Appel 2008); B, the North American Southwest ($N = 49$; Kohler and Glaude 2008, with permission); C, the Northern Hemisphere, covering America, Europe, and North Africa ($N = 133$, Bocquet-Appel 2008a).

In this figure the data are not redundant except for five sites that are common to the last two graphs. The horizontal axis ($dt$) represents the tempo of the economic transition from foragers to horticulturist-farmers (top) or to intensive farming (bottom). The line indicating the trend is obtained with the Loess local linear fit procedure. Up to a constant, the trend represents the variation of the birthrate in a stable population model. If the trend is interpreted in terms of the growth rate $r$, the horizontal dotted line indicates the expected value of $15P_5$ for a stationary population $r = 0$.

file but not including the Levant. This profile is roughly flat during the forager period ($dt < 0$), with $15P_5 = 0.22$, until $dt = 1,000$. It then dips slightly for approximately 600 years during the period preceding the ADT. With the introduction of the agricultural system at $dt = 0$, the demographic indicator $15P_5$ in the profile rises relatively abruptly, reaching a plateau $15P_5 = 0.28$ at $dt = 800$ years.

Before moving on to the signal of the ADT in the ethnographic data, the question may arise of the relative importance of data-point dispersion in the paleodemographic indicator $15P_5$ in the three first graphs of figure 1. There are at least three reasons: (i) an effect of binomial sampling of the frequencies $15P_5$ because of the cemetery sample size, even though this effect has been limited by keeping only cemeteries with at least 50 skeletons (5+ years old); (ii) an archaeological sampling bias determined by the excavated areas in the cem-
eteries, which are seldom excavated in their entirety; and (iii) extreme and pathological local situations affecting \( \frac{p}{p_0} \) because of sudden events (massacres, epidemics, accidents), which add to the ADT effect. Finally, the dispersion of demographic phenomena and their indicators in space and time is a normal situation; it is rather the reverse that is less common, that in spite of the wide dispersion, the force and visibility of an a priori unpredictable trend in the data reflects an exceptional demographic phenomenon.

The fourth signal shows the ADT in the ethnographic data from Alaska and Canada (fig. 2; Nunamiut Eskimo: Binford and Chasko 1976; Canadian Indian and James Bay Indian: Romaniuk 1981), with the actual birthrate during the transition as a variable, not the proportion of immature, as used in the cemetery data. Unlike the three preceding archaeological signals reconstituted in relative chronology, this profile can be directly represented in absolute time, for the data reflect a succession of demographic states at the same locality—like a time-lapse film being shot in the same place—and not spatially and temporally scattered localities like the cemeteries. From 1900 to 1950, the birthrate remains at 40 per 1,000. It then rises steeply to 48 per 1,000 within 10 years before collapsing during the contemporary demographic transition (CDT) that follows, with its widespread use of contraception. As will be seen below, the demographic information from the ethnographic literature does not distinguish between the impact of the ADT and the CDT on populations, which are grouped together as "transitional populations" (except in Binford and Chasko 1976).

Some comments are in order here concerning the variability of the ADT signature in prehistoric cemeteries. This variability provides information regarding the potential causes of the ADT and its tempo and mode of expansion relative to agricultural epicenters. It should be noted that both the Levantine and Northern Hemisphere profiles dip during the last forager period preceding the ADT for about \( \Delta t = 600–800 \) years (fig. 1). In the Levantine profile, this period corresponds to the final Natufian. Compared with the previous period, it
is characterized by “smaller social units,” “increasing mobility” (Goring-Morris and Belfer-Cohen 2011), and biological hardship (Belfer-Cohen, Schepartz, and Ahrensburg 1991; Smith and Horwitz 2007), all of these being attributed to the impact of the rapid onset of the Younger Dryas (Goring-Morris and Belfer-Cohen 2011). The profile shows the population’s response in terms of fertility to this environmental change. In light of the metabolic load model (see below Valleggia and Ellison 2004), an increase in mobility must be expected to induce an increase in the energy expenditure of mothers. This increasing mobility perhaps also reveals a reduction in the high-calorie food items—wild cereals and other leguminous plants in the diet, relative to the low-calorie food items obtained by hunting. In any case, as will be seen below, even with no change of food, the increase in energy expenditure induced by an increase in mobility has the effect of decreasing fertility in mothers, evidence also noted 40 years ago by Sussman (1972). There is a noticeably high degree of coincidence between the interpretation of the archaeological data and the observed demographic profile in the Levant.

All four images show the same signal of a relatively abrupt increase in the demographic indicator. In comparison with the others, the Levantine pattern confirms the prediction of a much slower ADT tempo in the zones of primary invention of the Neolithic tool kit (technical, social, and political) compared with the secondary expansion zones (Bocquet-Appel 2002). The ADT in the NASW and the Northern Hemisphere shows a relatively abrupt demographic shift, suggesting the effect of a regional intrusion that could be either populational, bringing with it a new economic system (with its technical and cultural tool kit) and demographic regime, or only cultural (technical tool kit only). In the overall image of the Northern Hemisphere, the onset of the ADT coincides with the introduction of the new farming system at $dt = 0$, but this is not the case in the NASW, where it occurs at $dt = 250$ years. Finally, it is noticeable that in the archaeological data, if the profiles are interpreted in terms of growth rate via paleodemographic estimators (Bocquet-Appel 2002), they all show a positive rate except during the short Natufian pre-ADT period in the Levant, as indicated above.

Two criticisms have occasionally been made against the $^{15}P_{5}$ values, one taphonomic/cultural and the other statistical. The taphonomic/cultural criticism is that the low $^{15}P_{5}$ values observed in the forager cemeteries could be a data artifact resulting from the mobility of foragers, who may have failed to bury immature skeletons systematically in their cemeteries. For that criticism to be valid for any time and place, it would be necessary to provide an explicit link between selective burials omitting 5–19-year-olds—and not other age classes—and mobility, which has never been produced up to now to the best of my knowledge. This assertion is therefore unproven.

1. However, an increase in the frequency of 5–19-year-olds inversely proportional to the cemetery sizes and producing a systematically higher $^{15}P_{5}$ value in small cemeteries than in large ones has been observed in a sample of 68 European and North African cemeteries extracted from the
The statistical criticism is that the size of the \(1_{SP} \) sample, which is appreciably smaller for the forager group than for the farmers, casts doubt on the equal representativeness of the two groups and therefore on the quality of the profile estimation in the forager zone. To remove this doubt, the \(1_{SP} \) sampling points must be understood as having been determined by the corresponding demographic densities of the ADT with a pre-ADT period at low forager density and therefore a low density of sampled points followed by an ADT period with a high farmer density and therefore a higher density of sampled points. The unequal sampling of \(1_{SP} \) points for the two periods reflects the corresponding demographic densities in the profiles from which the sampling comes, which are themselves unequal. There is nothing that can be done about this.

Explaining the Agricultural Demographic Transition: The Metabolic Load Model

What is called the ADT here is in fact the positive effect on fertility of a relatively abrupt change in maternal energetics that occurs mainly during the transition from a mobile forager economy to a farming economy in any period, whether prehistoric or historical (Bocquet-Appel 2008a). Let us recall that for a fixed reproductive duration of roughly 35 years, the fertility level can be expressed by the duration of the birth interval. During the fertile life of a mother, when the duration of the birth interval increases, the number of children born decreases. The duration of the birth interval is inversely proportional to fertility. This duration is a function of the energy balance (energy status and energy balance). The energy balance is determined by energy expenditure (on necessary milk production and physical activity) and postpartum energy intake (mother’s diet). The relationship between energy balance and fertility can be explained by the relative metabolic load model, in which the relative energy change in the energy balance during gestation is the determinant variable (Dufour and Sauther 2002; Ellison 1991; Ellison et al. 1993; Huffman et al. 1987; Lunn et al. 1984; Valeyegia and Ellison 2004; see also Hurtado and Hill 1990). The nursing frequency is a necessary but not sufficient signal determining the duration of postpartum amenorrhea.

Figure 2. Signal of the agricultural demographic transition with the demographic data (birthrate) for Canadian Indians (Romanin 1981) and Nunamuit Eskimo (Binford and Chasko 1976). The line indicating the trend is obtained with the Loess local linear fit procedure.

In the context of a transition from a mobile forager economy to a farming economy with (i) a reduction in energy intake in the proportion of low-calorie and null-carbohydrate food items (tissues from hunted animals, <150 kcal; carbohydrate, 0) relative to high-calorie and carbohydrate food items (>300 kcal; carbohydrate, >0; see table 1; in Eurasia: lentils, millet, peas, rice, wheat; in America: beans, chenopodium, hickory nuts, sunflower, maize; for a summary, see Pickersgill 2007) and (ii) a reduction in energy expenditure in the physical activity involved in mobility and in the maternal stress of child transportation (Bleek 1928; Burton Jones 1986, 1987, 1989, 1994; Lee 1972, 1979), an increase is to be expected in what might be called the fertility energetics, represented by the (inverse) duration of postpartum amenorrhea and vice versa. This suggests that there is a function connecting natural fertility to the energy balance in all primates and even in mammals. Another effect of fertility energetics must be noted: its impact on the onset of menstruation, which is influenced by body fat (Baker 1985; Biro et al. 2003). The consequence of this impact is to decrease the age of the onset of reproductive life and, probably, to extend its duration. For the same reasons of fertility energetics given above, it can be inferred that during the ADT, menstruation in teenagers in farming economies began earlier than in mobile foragers, which, together with the smaller birth interval, would tend to increase fertility (see also Cohen 2008). The birth interval is equal to the duration of postpartum amenorrhea and the possible duration of the postpartum sex taboo, the latter being significantly longer, on average, among ethnographic farmers than foragers (Bocquet-Appel 2008a; Saucier 1972). A minimal estimate of the postpartum taboo from the semiquantitative data in Murdock’s ethnographic atlas (Gray 1999) gives 7.2 months for the former and 11.4 months for the latter (Bocquet-Appel 2008b). From the be-
Table 1. Nutrients database for selected game animals and domesticated plants in Eurasia

<table>
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<tr>
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<th>kcal/g</th>
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<th>Carbohydrate (g)</th>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
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<td>22</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>Mesoamerica and North America:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antelope (Americana)</td>
<td>114</td>
<td>22</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Beaver</td>
<td>146</td>
<td>24</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Raccoon, roasted</td>
<td>255</td>
<td>29</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Squirrel</td>
<td>120</td>
<td>21</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>Plants:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Eurasia:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lentils</td>
<td>338</td>
<td>24</td>
<td>56</td>
<td>2</td>
</tr>
<tr>
<td>Millet</td>
<td>378</td>
<td>11</td>
<td>73</td>
<td>4</td>
</tr>
<tr>
<td>Peas (seeds)</td>
<td>341</td>
<td>25</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>Rice (short grain)</td>
<td>358</td>
<td>6</td>
<td>79</td>
<td>1</td>
</tr>
<tr>
<td>Wheat (seeds)</td>
<td>342</td>
<td>13</td>
<td>67</td>
<td>3</td>
</tr>
<tr>
<td><strong>Mesoamerica and North America:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bean common (Phaseolus vulgaris)</td>
<td>339</td>
<td>22</td>
<td>61</td>
<td>1</td>
</tr>
<tr>
<td>Chenopodium berlandieri</td>
<td>347</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cucurbita pepo ssp. (summer)</td>
<td>16</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Hickory (dried)</td>
<td>657</td>
<td>13</td>
<td>18</td>
<td>64</td>
</tr>
<tr>
<td>Maize (corn flour, yellow)</td>
<td>375</td>
<td>6</td>
<td>83</td>
<td>1</td>
</tr>
<tr>
<td>Maranta (arrowroot)</td>
<td>65</td>
<td>4</td>
<td>13.3</td>
<td>2</td>
</tr>
<tr>
<td>Sunflower (seeds)</td>
<td>595</td>
<td>24</td>
<td>19</td>
<td>47</td>
</tr>
</tbody>
</table>

Sources. Unless otherwise noted, the data are from http://www.tabledescalories.com/aliments-boissons-o-p1.html.

Note. All nutrient quantities are in grams per 100 g of food.


** Gremillion 2006.

171 populations of Jorgensen’s western North American Indians (WNAI; Bocquet-Appel 2008a; Jorgensen 1980, 1999). When the usual constraints of ethnographic data are taken into account, WNAI data have produced reasonably satisfactory semiquantitative information on mobility and food but not on fertility. The only available demographic variable is density. These data show that the variation in demographic density is not correlated with the variation of venison or fishery product consumption (low-calorie food) but is correlated with variation in the consumption of agricultural products (high-calorie food) and/or with mobility (energy expenditure). On the whole, demographic density in WNAI data, taken as a proxy for fertility, is distributed as expected with the metabolic load model. Nevertheless, to link demographic density to fertility, the following conditions must be met: the population is subdivided into subpopulations (with same date of origin for the subdivisions), migrations are marginal, the subpopulations have the same age distributions, and mortality is constant. The whole is similar to the Island Model in population genetics. Under that Island Model, the within-subdivision demographic density is determined by the input to the subpopulation (i.e., by fertility). But these stringent
The ADT: An Inevitable Transitional Stage?

More than 20 years ago, authors seeking to measure the fertility differential between foragers, horticulturists, and farmers in natural-fertility populations from ethnographic data (Campbell and Wood 1988) observed an absence of significant differences in average fertility between these three groups. A critical analysis of the data (Bentley, Goldberg, and Jasienska 1993; Bentley, Jasienska, and Goldberg 1993) has shown that they were frequently approximate. After their audit, Bentley, Jasienska, and Goldberg (1993) reached the conclusion that the average number of children of postmenopausal mothers (also called TFR) among intensive farmers is higher than among nonfarmers but with wide within-group variance, making it impossible to predict the fertility level for a known subsistence group. Bentley and colleagues' study (Bentley, Goldberg, and Jasienska 1993; Bentley, Jasienska, and Goldberg 1993) was relatively influential in demographic anthropology and, coupled with the extreme scarcity of ethnographic data on natural fertility, brought matters to a conclusion of a sort that was apparently final. When projected onto the impact of farming on forager fertility, Bentley et al.'s conclusion could be interpreted, wrongly, as showing the farming impact as negligible at best and dubious at worst.

However, besides the arguable grouping of populations, the actual data of Bentley and colleagues are not without minor errors. Specifically, the impact of the ADT cannot be deduced by comparing averages of fertility indexes for ethnographic forager/farmer groups who are alien to each other. The ADT is a within-population shift. To detect the impact of the ADT, what needs to be compared are not the absolute values of the averages of fertility indexes between subsistence groups but the rates of change within those same populations when they are experiencing an economic transition. The question that should be raised is, among the transitional populations (Bentley, Jasienska, and Goldberg 1993, table 4), how many experienced a shift in fertility that (i) was positive, indicating the ADT; (ii) was negative, indicating the CDT; or (iii) was both positive and negative in succession? It is to be expected that all the transitional populations experienced i or ii? But the transitional data gathered by Bentley, Jasienska, and Goldberg (1993) are heterogeneous and cannot be exploited directly.

In ethnographic surveys, when demographic quantitative data exist, the shift can be evaluated simply by the within-population ratio of the fertility index before and during (or after) the economic shift. When this ratio (which is a rate) is greater than 1, the ADT has occurred. But such data at two points in time for the same group are rare. The authors of ethnographic surveys have generally given impressionistic ac-

2. Because of the usual scarcity of forager data, Bentley, Jasienska, and Goldberg (1993) mention the creation of the "forager-horticulturists" group "partly to increase the sample size for the foraging category" (272, n. 19). If we consider only the "foragers" in this group (and not the "forager/horticulturalist" aggregate), where the number of mothers is ≥30, average fertility among foragers is curiously closer to that of farmers than that of horticulturists.

3. Lapps, Sápmi, Sweden, population reported as foragers instead of herd or herders (P. Sköld, "Aspects on the demographic development in life and death in Sápmi: demographic aspects on the history of the Sami in northern Sweden," unpublished manuscript, p. 2), which shows the difficulties involved in gathering reliable information, often from ill-defined sources in the ethnographic literature.
counts (i.e., qualitative accounts of demographic shifts using descriptions of populations growing or decreasing since contact). These demographic shifts proceed along with the usual associated economic changes, notably sedentism (or semi-sedentism), together with food support provided by a governmental or religious agency and the keeping of registers on individuals. It is therefore legitimate to take this information into account. In order to work only with populations in which changes are due to their fertility and not to their mortality, immunized populations were excluded. Finally, if we consider as minor a possible migratory effect on individuals of neighboring populations because of the attraction/repulsion of the point of contact with the world economy (places surveyed), then the demographic change in a population, described in an apparently impressionistic way, can be reasonably attributed to a variation due to fertility.

By using the quantitative and qualitative criteria described above, the nature of the demographic changes experienced by Bentley, Jasienska, and Goldberg’s (1993, table 4) transitional populations can reasonably be inferred: ADT, CDT, or unknown (see table 2). Among the 15 so-called transitional populations for which the information was present, seven populations out of seven experienced the ADT (Nunamiut, Asmat, Tiwi, Hall Beach Eskimos, Wainwright Eskimos, Northern Territory Aborigines, Athapascan), six out of seven experienced the CDT (Nunamiut, Asmat, Tiwi, Wainwright Eskimos, Chipibo-Conibo, Athapascan; uncertain: Navajo), and five out of six successively experienced both the ADT and CDT transitions (Nunamiut, Asmat, Tiwi, Wainwright Eskimos, Athapascan; uncertain: Navajo), and five out of six successively experienced both the ADT and CDT transitions (Nunamiut, Asmat, Tiwi, Wainwright Eskimos, Athapascan; uncertain: Navajo), and five out of six successively experienced both the ADT and CDT transitions (Nunamiut, Asmat, Tiwi, Wainwright Eskimos, Athapascan; uncertain: Navajo). The ADT is thus indeed a necessary stage in the transition from nomadic foragers to sedentary farmers. Fertility among nomadic foragers always increases with the impact of the agricultural (or world) system, whatever its absolute values, which can be higher or lower from regional population to regional population for uncontrolled reasons, the first two candidates being the postpartum taboo and, perhaps, the maternal energetics determined by the regional economic system in its ecological setting.

If the metabolic load explanatory model is true, then variation in maternal energetics was the cause of the ADT in the initial transition zones from foragers to producers in ancient (pre)historic periods and also, repeatedly, throughout history and up to the present, whenever populations have been absorbed at the frontiers of expansion of what is currently the world economy. This recent effect was detected and detailed by Bentley, Goldberg, and Jasienska (1993, table 4), and the Calusa of southern Florida (Widner 1988). With aquatic resources, there is no qualitative change in energy intake for the caloric density compared with hunter-gatherers. But in becoming sedentary or semisedentary (i.e., in reducing their relative energy expenditure), these foragers partially affected their maternal energetics and their influence on fertility, prompting an upward trend. Such was the biological cause of demographic growth among sedentary shellmidden foragers relative to mobile foragers.

Postpartum abstinence is a historical creation that has certainly not always existed. The great apes do not abstain from sex. During the ADT, with the rise in fertility (energetics), the birth interval decreased considerably at the same time. This leads us to assume that during the first phase of rapid population growth, the inhibiting mechanism of postpartum abstinence did not yet exist and that it was invented during or after the primeval ADT. It was incorporated among the positive checks of the Malthusian model as a new density-dependence mechanism along with those that must have appeared consecutively to the new demographic situation. I currently do not see which data would make it possible to test this assumption. Future bioanthropological indicators on skeletons will perhaps make it possible to estimate, from the cemeteries, the ages at which a mother was pregnant and therefore to open the door to comparisons of variations between populations in prehistoric economic systems.

Expressing Mortality

The glaring data gap in the ADT signal is the invisible impact of mortality in cemetery data. It is masked by the well-known confusing effect of the birthrate in cemetery data (Johansson

4. See also other cases in Bentley, Goldberg, and Jasienska (1993, n. 10).
5. Bentley, Goldberg, and Jasienska (1993) indicate that they did not retain populations where the postpartum taboo lasts longer than 6 months (n. 16). But in the reference publication on the 15 transitional nonagricultural societies (table 4), these data are missing.
6. The Tiwi (Australia) were also affected by the impacts in rapid succession of the ADT and CDT during the years from 1929 to 1996 (Peterson and Taylor 1998).
and Horowitz 1986; Sattenspiel and Harpending 1983). In the
ethnohistorical demographic data, the impact of mortality is
either extremely high, corresponding to the introduction of
new pathogens during contact, or artificially low, with the
introduction of medical services in contemporary times.
There is no natural reference for ADT mortality other than
the epidemic crisis by contact or its eradication. Therefore,
on this point, we have to rely on indirect data and theory.

Mobility spares foragers from a lot of problems that arise
from sedentary village life and the growth in local population
density and determined permanent promiscuity (with small
commensal rodents, feces and the absence of latrines, lack of
clean drinking water, contamination from humans and ani-
mals living in close proximity in enclosed spaces). The mor-
tality rates inherited from foragers eventually rise, particularly
in children under 5 years of age, with reduced breast-feeding.
Candidate germs by “epidemiological inference” from current
preindustrialized areas and those with poor health facilities
can be inferred (see Bocquet-Appel 2008a). The underlying
trend toward a decline in health during the shift to agriculture
(Bocquet-Appel, Naji, and Bandy 2008, fig. 4; Cohen and
Armelagos 1984; Cohen and Crane-Kramer 2007) is an in-
dication that tends to support this assumption. The assump-
tion of a rapid return to a rising mortality rate is also sup-
ported by the density-dependent demographic model (Blum,
Bonneuil, and Blanchet 1992; Lee 1987; Reher and Ortega
Osona 2000; for a discussion, see Wilson and Airey 1999; for
mammalians, see Sibly and Hone 2003). As I said above, a
density-dependent pattern has been detected in the archae-
ological data representing the increase in site density in Peru
(Bandy 2005, 2008). Finally, unless we assume an exponential
population increase over a relatively long duration, eventually
reaching a cosmic number, we have to postulate that a rising
death rate soon—within a few generations—followed the rise
in birthrate, producing the historical growth rate typical of
agricultural populations (1–2 per 1,000).

Table 2. Identification of impacts of the agricultural demographic transition (ADT) and the contemporary demographic transition (CDT) in transitional populations

<table>
<thead>
<tr>
<th>Population</th>
<th>Source</th>
<th>Remarks</th>
<th>ADT</th>
<th>CDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navajo, Ramah</td>
<td>Morgan 1973</td>
<td>Agriculturist</td>
<td>. . .</td>
<td>?</td>
</tr>
<tr>
<td>Lapps, Sweden</td>
<td>Fraccaro 1959</td>
<td>Reindeer herders (P. Skold, unpublished manuscript, p. 2)</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Sioux-Ojibwa, Great Plains</td>
<td>Boas 1894</td>
<td>Poor data</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Asmat, Irian Jaya</td>
<td>Van Arsdale 1978</td>
<td>Semisedentary (Van Arsdale 1978:435, 437)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Aborigines, Australia</td>
<td>Kirk 1981</td>
<td>Sedentary (McAlpine and Simpson 1976:115); very small sample of 15 postmenopausal mothers in 1971</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Eskimos, Waimwright</td>
<td>Milan 1970</td>
<td>. . .</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Eskimos, Kuskokwim</td>
<td>Hrdlicka 1936</td>
<td>No comparative data locally</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Shipibo-Conibo, Ucayali River</td>
<td>Hern 1977:356</td>
<td>Swidden agriculture</td>
<td>. . .</td>
<td>Yes</td>
</tr>
<tr>
<td>Aborigines, Northern Territory, Australia</td>
<td>Jones 1965, 1972</td>
<td>Duplicate information on Aborigines, Australia</td>
<td>. . .</td>
<td>. . .</td>
</tr>
</tbody>
</table>

Note. TFR = total fertility rate.

* From the list made by Bentley, Jasienska, and Goldberg (1993:783).
Maternal Energetics and the Emergence of the ADT

The scenario of the ADT at its onset might have begun with a steady trend toward demographic densification of the forager’s world (Cohen 1977; in North America, see Doran 2007: 40, table 3.1), which was at quite a low population density (Bocquet-Appel et al. 2005) because of the demographic fragility of ungulate herds (Stiner et al. 2008), producing pockets of sedentary (or semisedentary) foragers (Bar-Yosef and Belfer-Cohen 1989). These are located in zones that were ecologically favorable to a broadening of the food spectrum, including cultigens (Flannery 1969; Stiner 2004), in Eurasia at the end of the Pleistocene (Belfer-Cohen and Bar-Yosef 2000; Weiss et al. 2004) in Mesoamerica during the early Holocene (between 10,000 and 7000 BP; see Piperno 2011). A brief calculation shows that wild megafauna could not continue to fuel continuous human demographic growth. This sociocultural configuration has the effect of raising maternal energetics and fertility soon followed by a mortality transition toward these same high values for the reasons of density dependence indicated above.

The population was thus both the cause and the effect of the demographic shift: the cause—because as it increased the pressure on the carrying capacity of the hunter-gatherer production system, the population also increased the probability of a systemic transition—and the consequence—because as soon as the new economic system appeared, the population tended to expand toward the limits of the new carrying capacity (Wood 1998) of the horticulturist-farming system. The pri-meval prehistoric ADT was a positive feedback loop capable of rapidly raising the growth rate locally or regionally (Bocquet-Appel 2008a; Bocquet-Appel and Naji 2006). This certainly explains why the tempo of the ADT signatures in the peripheral zones of expansion in Europe and North Africa are three to four times faster (400–800 years $d_t$) than in the original Levantine epicenter ($>2,800$ years $d_t$). These primary centers were the sources of expansions proceeding according to different patterns (continuous geographic front, discontinuous, leaps by individual families or individuals as in Amazonia today). In the Levant, the doubling of fertility over 3,000 years was initially determined by the transgression by sedentary Natufian foragers of the evolutionary demographic regulation of mobile foragers to the local carrying capacity, producing unprecedented demographic growth. In certain groups, this demographic growth produced not one of the innumerable Malthusian crashes that occurred during prehistory but what became the ADT because the resources of Natufian foragers in the process of becoming farmers were able to support this growth.

The initial colonization of North America, perhaps over a few hundred years, by mobile hunter-gatherers who “must have had high reproductive rates while maintaining a very mobile lifestyle” (Surovell 2000: 494) might seem to contradict this energetics-based fertility model. Surovell’s simulations show that annual total mobility (residential + logistic) is substantially lower, with higher rather than lower residential mobility producing the relatively lower energy expenditure that is compatible with high fertility (Surovell 2000).

Concluding Remarks

Starting in the continental epicenters of prehistoric agricultural invention, in the 12–5-ka BP window, the ADT expanded populations geographically up to the marginal and peripheral limits of the forager system of the twentieth century AD. At an evolutionary scale, as determined by maternal energetics, the ADT has produced an increase in the human metapopulation that results from a (very high) fertility gain over (high) mortality as well as a massive cultural complexity, the whole being unprecedented. The ADT generated the demographic regime of the agricultural population, also called traditional or preindustrial populations.

During the eighteenth century AD, nearly 12 ka after the onset of the ADT, new areas of demographic change appeared across this agricultural population area that were considerably more abrupt than at the time of the previous demographic transition, located in France and Massachusetts (Smith 1972; Temkin-Greener and Swedlund 1978). In these zones, the new shift is initially characterized by a drop in mortality and in fertility, in rapid succession or actually merging, determined by the introduction of new rules of hygiene and medical and contraceptive techniques correlated with but with no direct link to the Industrial Revolution that was then primarily located in England (Dupâquier 1998:13, fig. 3). This shift represents the CDT. Whether in the order of variation of demographic variables ($[a]$ mortality shift, followed by or simultaneously with $[b]$ fertility shift) or in the direction of the shift (decreasing and not increasing), the CDT occurred in reverse symmetry with the ADT. In the latter, as it was caught up by the extremely rapid expansion of the CDT, a unique phenomenon occurred at the margins of the residual area of the forager system with the quasi coincidence of the effects of the ADT and CDT, the latter canceling the effects of the former.

Acknowledgments

Thanks to Bryan Hayden (Simon Fraser University), Claude Masset and Lyliane Rosetta (Centre National de la Recherche

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7. A simple example shows how the size of a bison metapopulation has to increase when the size of the human predatory population is increasing. Meriwether Lewis reported that their expedition of 43 people consumed 1 bison/day (Lewis and Clark 1805), making 365 bison/year for 43 humans or up to 3,560,000 bison/year for 430,000 humans. To simplify, if this predation is funneled in the death rate $d$ of a stationary population—which corresponds to the inverse of the life expectancy at birth $e_c$—then the size of the bison metapopulation corresponding to this death rate is $P = d \times e_c$. If we accept $e_c = 13.5$ years for bison in the wild (Wilson, Hills, and Shapiro 2008), then for a population of 43, 4,300, and 430,000 human predators, one obtains a bison population of 4,927, 492,750, and 49,275,000 bison, respectively, which is increasingly unrealistic.
References Cited


Flannery, K. 1969. Origins and ecological effects of early domest-


Erratum

In the paper “Holocene population history in the Pacific region as a model for worldwide food producer dispersals” by Peter Bellwood, published in this supplement and electronically published on May 13, 2011 (http://www.jstor.org/stable/10.1086/658181), there is an error in the first paragraph of the section titled “The Spread of Neolithic Pottery from Taiwan into the Philippines and Indonesia.” Near the end of the first paragraph of the section, in the final sentence, the phrase “sites such as An Son in” was mistakenly inserted. The sentence should read, “Reranum and Chaolaiqiao still have some residual cord marking (fig. 2R), and the close similarities in red-slipped pottery between these two sites raise the possibility that a direct migration from southeastern Taiwan to Itbayat could have occurred between 2200 and 2000 BC.” The publisher regrets this error.