

Breaking Ground

Plant Domestication in the Neolithic Levant:
The “Core-Area One-Event” Model

Avi Gopher, Simcha Lev-Yadun and Shahal Abbo



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Israel

*Dedicated to Ofer Bar-Yosef
Scholar, teacher and mentor*

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Preface

In 1997 a phylogenetic study of einkorn wheat by Heun *et al.* was published in *Science*, indicating, in so many words, that the domestication of einkorn took place in the northern Levant, in modern southeastern Turkey not far from the cities of Diyarbakır and Şanlıurfa (near Mt. Karacadağ). That innovative study appeared a few years after two of us (S.L.-Y. and S.A.) had already started contemplating the idea of a northern Levantine origin for Near Eastern plant domestication, eventually formulated as a hypothesis by Simcha Lev-Yadun in 1996. The Heun *et al.* (1997) paper was one of the triggers that brought the three of us together, pooling our combined knowledge on the botany, genetics and agronomy of the package plants and the archaeology of the Pre-Pottery Neolithic (PPN) Levant. This resulted in the suggestion of what we call in the title of this work the “*core-area one-event*” model for plant domestication in the Neolithic Levant (first published in *Science*, Lev-Yadun, Gopher and Abbo 2000). We thought then, in the late 1990s, that a series of converging lines of evidence supports such a model. These included at the start:

- The geobotany, i.e., the fact that a small region in the northern Levant is the only place that hosts all the progenitors of the eight package plants to be domesticated;
- Wild progenitor stocks with close genetic affinities to domesticated forms that were found in that region;
- The presence of remains of these wild plant species in archaeological sites of that small region prior to plant domestication;
- The limited distribution of the chickpea progenitor that is found only in this (core) area;
- The earliest domesticated cereals were found in this region;
- The area was a very early, active, vivid and innovative Neolithic cultural center;

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- The above-mentioned genetic study by Heun *et al.* (1997) pointing to the same area;
- A genetic study of lentil (Ladizinsky 1999) also pointed to this area.

Soon after the publication of the *Science* paper in 2000, we decided to design a long-term project focusing on plant domestication. In 2002 another founder crop, emmer wheat (a pivotal element in plant-based economies to this day, being the progenitor of both durum and bread wheat) was genetically analyzed (Özkan *et al.* 2002), and its geographic origin, i.e., the place it was first domesticated, was found to be in the same area of the northern Levant as that where Heun *et al.* (1997) had concluded that the einkorn wheat was domesticated too. A serious problem throughout those years was the fact that the center (place of origin) of domestication of the Neolithic Levant was considered to be the southern Levant, and especially the Damascus basin and the Jordan Valley. This conception was based on data from Tell Aswad (not far from Damascus) and from Jericho, and was a ruling paradigm in plant domestication studies, as clearly expressed in a 1999 summary paper by A. Garrard. One of us (A.G.) was quite closely acquainted with the stratigraphy, chronology and finds of Jericho and was also aware of the stratigraphic and dating problems concerning the old Tell Aswad excavation, as well as the renewed excavations at Tell Aswad by Danielle Stordeur that resulted in a reconsideration of its stratigraphy and chronology. First published in 2003 (Stordeur 2003a; 2003b), the revision of the Tell Aswad chronology (for details, see Box 2.1) heralded, in our view, the fading-out of the idea that plant domestication originated in the southern Levant.

Soon after the new data from Tell Aswad were published, we decided to issue a short statement in support of our “core-area one-event” model of northern Levantine origins for plant domestication. It was late 2003 and we thought that now, with the availability of new genetic data and the clarification of the archaeological picture in favor of our 2000 and 2001 papers (Lev-Yadun, Gopher and Abbo 2000; Gopher, Abbo and Lev-Yadun 2001), it was time for an interim, better supported summary than the one we could prepare in 2000. This, however, never happened, and instead we delved into long years of work that yielded a series of other papers on specific and selected aspects of plant domestication, including fieldwork, experimental work and exploration of major issues of plant domestication (see Chapter 1). During those years we considered publishing a review paper and continuously fortified the old draft of the yet unfinished paper, using our results, new ideas that developed through time, new insights from the work of others, and our accumulated experience. These inputs were sometimes designed as independent papers on various relevant topics (see Chapter 1 and Bibliography). Of course, new studies in all realms—new

PREFACE

excavations and archaeological as well as archaeobotanical finds, new high-precision radiocarbon dates and new genetic studies—kept being incorporated into the expanding text of our originally short note of 2003. This was all profitable, as our knowledge accumulated and our ideas, prominent among them our “core-area one-event” model—crystallized, matured and became more carefully nuanced.

A few years ago we embarked on an attempt to summarize our work, and opted for production of a readable text for a general readership and knowledge-seekers in Hebrew. This was published in 2016 by two of us (A.G. and S.A.). Shortly afterwards we translated that book into English, and it was accepted for publication by Cambridge University Press (forthcoming). Concurrently, in 2015 we felt it was time to publish our unfinished review paper, with its detailed discussion in support of our model. However, the text, although originally supposed to be brief and concise and hence suitable for publication in a professional journal, was now an overlong essay. We were experienced enough to be aware of the fact that present-day academic platforms have difficulty in handling tiring, long and detailed bulks of discussions, either on the podia of academic professional conferences or in print as journal papers. In late 2018, therefore, we decided to look for a possible venue through which to publish it as a book. A talk with Ms. Myrna Pollak, then director of the Publications Department of Tel Aviv University’s Institute of Archaeology, led to a meeting with Prof. Israel Finkelstein. That resulted in the present work, which is now—as we meant it to be—a text with a full academic apparatus and detailed discussions, even if polemic—on plant domestication in the Levant.

Although the 2016 Hebrew book and its translation were written by two of us (A.G. and S.A.) while our third partner (S.L-Y.) was busy with two other single-author books, we came together for the present volume without any difficulties, as good old friends, to reunite with a common goal in mind. The text presented here was treated, updated, and somewhat changed to include new works, together with some explanations on specifics in archaeology, botany, genetics or agronomy wherever relevant to plant domestication research in the Levant and the contents of this monograph. The result lies before you.

* * *

To avoid disturbing the flow of reading and the need to move between a current page and the end of the book for comments, the notes to the main text are presented in full at the base of the relevant page. We emphasize that these notes are inseparable parts of the text and are required for a full understanding of the main text.

PREFACE

The main text of the book is accompanied by a series of boxes, which clarify various ideas and aspects that are mentioned in the text and that we consider important. These boxes contain detailed archaeological descriptions of sites, finds, terminologies used, aspects of the thought framework within which we operate, and detailed discussions on well-cited papers. We hope that these texts are presented in a sufficiently clear way for interested, knowledge-seeking readers.

Within quotations, additions provided by us are indicated by square brackets.

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Responsibility for the content of this book (including any errors or inaccuracies) is, of course, ours alone.

CHAPTER 1

INTRODUCTION: PREPARING THE GROUND

This introductory chapter sets the bedrock for this detailed and sometimes polemic work on plant domestication in the Pre-Pottery Neolithic (PPN) Levant and clarifies our basic views on this groundbreaking cultural and historical transformation that took place some 10,500 years ago. It includes sections on a series of plant domestication-related aspects, including a statement on the two contrasting plant-domestication models debated in recent years and the various lines of evidence used to make an educated choice between these two models, as well as a brief history of the research and our goals. The theoretical framework is mentioned here and is further elaborated on in Chapter 7.

The Context

Studies of plant domestication in the Neolithic Levant (Near East; for nomenclature, see Box 1.1) over the last two decades have in essence mostly thrived under what might be called the “protracted autonomous” model. This model emphasizes three major aspects:

- a protracted, millennia-long, process of plant domestication;
- a geographically autonomous, non-centered domestication (i.e., several independent domestication foci within the Levant);
- the unconscious nature of plant domestication.

We propose an alternative model for plant domestication in the Levant. According to this model, domestication was knowledge-based and conscious, took place in a centered (i.e., geographically limited) core area and was a short, single event. Our proposed “core-area one-event” model is based on evidence and considerations drawn from geobotanical, archaeobotanical, agronomic, genetic and archaeological fields. Using these data we probe questions of the time and space within which

Levantine plant domestication occurred, as well as how it transpired and what ensued following domestication. Throughout this essay we contend, sometimes in quite a polemic way, with the plethora of varying statements made in this field of research in recent years.

Box 1.1: Geographic Nomenclature: Near East, Levant, Fertile Crescent, West or Southwest Asia

Some of the major archaeological sites from which archaeobotanical and archaeological remains serve as evidence relevant to plant domestication and the origins of agriculture in the Levant are depicted in the map below (Fig. 1.1 ; see also Fig. 1.3). In terms of present-day geopolitics, the area under discussion includes parts of Turkey (mostly southeast), Syria, Iraqi Kurdistan, west and southwest Iran, Lebanon, Israel, the Palestinian Authority and Jordan. Farming cultures and domesticated plants spread from their Levantine homeland (core area) to central and western Anatolia, Thrace, Greece, Bulgaria and Cyprus, in a westerly direction (into Europe); to Georgia, Armenia, Azerbaijan, Afghanistan, Pakistan and western India (reaching the Indus Valley) in an easterly direction; to the southern Levant, Egypt and other parts of Africa in a southerly direction, and north of the Black Sea into the Crimea, Ukraine and Russia.

Unlike widely accepted ecological, geological and botanical terminology, geographic terminology often reflects historical and geopolitical circumstances as well as cultural trends. As such, many geographic terms are heavily loaded with various meanings that echo a history of colonialism, political conflicts and cultures. The eastern Mediterranean basin and adjacent territories are no exception; consequently, different authors have used different terminologies when referring to the same regions. For example, during the 19th century, the term Near East referred to the territories under control of the Ottoman Empire, including the Balkans and large parts of North Africa. Today, however, the area usually defined as the Near East does not cover either North Africa or the Balkans. More recently, the politically correct and seemingly more neutral expression West Asia or Southwest Asia is used to describe the region that includes what we, as Near Easterners or Levantines, refer to as the Near East.

We opted to use the term Levant in this work to describe the region under discussion. The terms Levant and Near East were both coined in western Europe.

Since the early 20th century, the term Levant has been used to denote the territories that were under British and French mandates after World War I. According to present-day political boundaries, the Levant includes Lebanon, Syria, Jordan, Israel and the Palestinian Authority. Current use of the term Near East usually refers to a larger area, including—in addition to the Levant—Egypt, the Arabian Peninsula, Iraq and Turkey. Here we also refer to parts of western Iran in this framework although they are not formally included.

In the archaeological literature the term Levant, as used since the mid-20th century, includes the Euphrates and Tigris Valleys, parts of Iraq and areas of eastern Turkey. Thus, when we write pan-Levantine, we refer to a wider scope than the current political definition. Here too, parts of western Iran are sometimes included.

The Fertile Crescent is another term used in the literature discussing plant domestication in the Near East/Levant. Named thus by Breasted (1916) because of its lunate silhouette, it extends from Khuzestan Province in Iran, across the Zagros Mountains in western Iran (Kurdistan), to the river valleys of the Euphrates and Tigris in Iraq, southeastern Turkey and northern Syria, and then westward towards Lebanon, the Mediterranean district of Israel, Jordan and the Palestinian Authority, finally spanning southward towards the Nile (see Fig. 1.1). Our decision to mainly use the term Levant derives from the role of the region in European history, e.g., as the homeland of Christianity, a target for the Crusades and a long-term overland gateway to India and to Central and East Asia. As is evident from the history of modern research of the region (e.g., Abbo and Gopher 2017), most scholars who operated in the region, such as geographers, historians, archaeologists and botanists, were either Europeans or Americans, i.e., Westerners; hence this region was referred to as part of the so-called “Orient” (*sensu* Said 1979). The term Near East that we used in the past, and still use in our publications, is occasionally used here too.

In our view, the domestication of a package of plants in the Neolithic Levant some 10,500 calibrated (Cal.) years ago is one of the most significant examples of the ingenuity of humankind throughout history. This major innovation, its assimilation and development into a sustainable economic system, and its early and rapid geographic spread first within and soon afterwards beyond the Levant, is the subject of this book. We do not discuss the domestication of animals in the Levant, which took place at about the same time and place and was another highly important aspect of the Agricultural Revolution (see Box 1.5 on pp. 24–26). The sociocultural dynamics

that led to and constituted an integral part of the Agricultural (Neolithic) Revolution¹ as a whole, plant (and animal) domestication included, are presented in the final parts of the book, focusing on the northern Levant. The “why” question of plant domestication and the Agricultural Revolution as a whole remains open, as we consider the answer to be almost inevitably related to one’s school of thought, as well as to academic and personal backgrounds.

Of fundamental importance, and inherent in this work, is the distinction between the Agricultural or Neolithic Revolution—an overarching transformation in human perception, social order and economy—and plant domestication, which is one of the components or building blocks of that revolution (and see Box 1.2).

Box 1.2: The Agricultural Revolution and Plant Domestication: Scales and Contents

The Agricultural Revolution or Transformation was one of the most significant milestones in the history of humankind. It was an overarching change that affected all avenues of human perception, society and economy, and it set the stage for the modern world we know today. Viewing these immense processes as Neolithization, à la Jacques Cauvin, we may regard the transformation as a “Neolithization of the mind” (with new cognitive maps) so to speak, a Neolithization of society (with new social institutions), of gender relations, community, household, family and home, a Neolithization of subsistence economy, technology, annual seasonal scheduling, and more—all long-term, bumpy perceptual and socioeconomic processes. Plant domestication, on the other hand, was a swift event in archaeological terms and resolutions, and likewise in biological terms. Yet this innovation, like any other, had to undergo a long-term sociocultural process in order to become an established, dominant, viable and sustainable economic system—i.e., agriculture.

In recent years the talk on plant domestication (meaning the act or the domestication episode itself) is mixed, in more than a few cases, with the talk

1. We prefer to use the term “Agricultural Revolution” rather than “Neolithic Revolution” (the term coined by Gordon Childe), because the former connects in a more natural way to plants and plant domestication and because this work is oriented towards understanding the establishment of plant-based agriculture. We use the latter term, albeit rarely, when discussing Neolithization processes in the Levant.

about the Agricultural Revolution as a whole and the beginning of agriculture (see, e.g., Asouti and Fuller 2013; Willcox 2018). Plant-domestication discourse is thus dominated by a spirit of blurring. What most of the protagonists of this discourse talk about is the establishment of agriculture as a socio-economic system, which was indeed a protracted process. They also emphasize the sub-regional variability characterizing the establishment of agriculture, thus broadcasting a picture that may be interpreted as reflecting autonomous local developments. Also basically neglected is the inescapable variability of local cultural sequences and culture makeup into which innovations (including plant and animal domestication) are adopted, and which naturally relate to local conditions within the Levant and in the large tracts of the geography to where domesticates, humans and agriculture spread. Lacking, therefore, is a clear, precise and refined distinction between the establishment of agriculture as a sustainable system, on the one hand, and domestication, on the other. Such a limiting discourse, when exacerbated by the adoption of David Harris' model for plant domestication and the beginning of agriculture (see below) as a linear time-trajectory-oriented model [in contrast to the spirit of Harris, its original author (1996a)], provides a proper background for protracted, millennia-long "domestication" processes (and see Asouti and Fuller 2013, where this model, although first presented in its original form, is then modified).

A higher archaeological resolution, made possible in many cases by using detailed high-resolution archaeological studies and available ^{14}C dates, is not usually employed by supporters of the protracted model. This is also true for the essential distinction of plant domestication from crop evolution under (post-) domestication (see Box 1.4), which would clearly provide a higher resolution and clarify several of the problems concerning plant-domestication research in the Levant. This general tendency of presenting blurred processes and a low resolution (much lower than can be achieved under present-day circumstances) is strongly connected to the blurring of past dynamics, and creates a false landscape suitable for the protracted, millennia-long processes of plant domestication in the Levant (see Chapter 7)—thus generalizing in the spirit of the "Great Synthesizer" (Flannery 1976). This metaphoric landscape eventually covers global tracts of land, runs through from the Paleolithic era deep into the Neolithic period, is featureless—i.e., free of any particular historical or cultural context—and is therefore, in many ways, not very useful.

History of the Research: A Brief Background

The “Agricultural Revolution” or the “Neolithic Revolution” as first presented by Gordon Childe (1928; 1936) represents a major transition in human history—an immense process of change in human perception, behavior and socio-economics from an economy based on hunting-gathering to an economy based on food production. In terms of large-scale prehistoric time frames (millions of years), this may justifiably be viewed as revolutionary—hence the term “Revolution.” Among its most important components is the Levantine domestication of both plants and animals, only the former of which is discussed by us (for a brief summary on animal domestication, see below, Box 1.5). We would like to reiterate the distinction we follow throughout our work, and in this book, between the Agricultural Revolution as a whole and plant (or animal) domestication as one of the components of this large-scale, multi-faceted cultural transformation (see Box 1.2). This distinction is important since the two represent totally different historical scales (see our short discussion in Chapter 7 on Braudel’s historiographic scales), and mixing them may result in significant misinterpretations. It is also important since mixing the two scales lowers both their archaeological and their biological resolution and is misleading. The Neolithic Levant is one of the oldest and most significant primary domestication centers in the world owing to the fact that its domesticated founder-crop package, comprising mainly cereals and legumes, is still of major agro-economic significance, underpinning the development of an economic system upon which we still depend today. Notably, the Levantine center of domestication is the only one where farm animals were also domesticated already during the PPN period (more or less at the same time that plants were domesticated), and these remain among the major livestock of humankind to this day.²

The geographic scope of this book is the Levant in the eastern Mediterranean, as presented in Box 1.1, and it includes areas of present-day southeastern Turkey (in the north), Syria, Lebanon, Israel, the Palestinian Authority, the Sinai Peninsula (Egypt), the northern Arabian Desert (Fig. 1.1) and, at times, Cyprus. We also include relevant areas of Iran and Iraq in our discussions.

The time frame discussed here covers mostly the Neolithic period in the Levant, starting sometime after 12,000 years Cal. BP, and includes the PPN and the Pottery Neolithic periods (Fig. 1.2), ending in the 7th millennium Cal. BP. Earliest evidence

2. In other domestication centers in the world, animals were domesticated thousands of years later in an agricultural landscape (the “directed pathway” to domestication *à la* Zeder 2012, and see Larson and Fuller 2014).



Fig. 11: Map of the East Mediterranean—southwestern Asia; 1) Çayönü; 2) Mureybet; 3) Tell Abu Hureyra; 4) Tell Aswad; 5) Jericho

of domesticated plants found in Levantine Neolithic sites is dated to ca. 10,500 Cal. BP.³

The basic Neolithic domesticated founder-crop assemblage of the Levant was defined by Zohary and Hopf (1988), based on botanical finds from many Levantine Neolithic sites. In its primary form it included three cereals, four legumes, and flax, the last supplying both fiber and oil (Table 1.1; and see Zohary, Hopf and Weiss 2012). This assemblage was later dubbed “the package.” With the exception of bitter vetch and einkorn wheat, all package crops have remained major world crops to this day.

It has become generally accepted that this crop package had spread as early as the PPN from the Levant to the eastern Mediterranean islands, and later to Europe as well as to parts of Africa and West Asia, while in several other parts of the world different agro-packages were independently domesticated (e.g., Bellwood 2005; Diamond 1997; Harlan 1992). These include (but are not limited to) maize and common bean brought under domestication in present-day Mexico; rice and soy beans domesticated in China; sorghum, African rice and cowpea domesticated in sub-Saharan Africa; and sunflower, marsh-elder, chenopod and pumpkin domesticated in northeastern North America. An interesting aspect of all of the above cases is that

3. Note that clear evidence for plant domestication postdates the beginning of the PPNA period by over a thousand years.

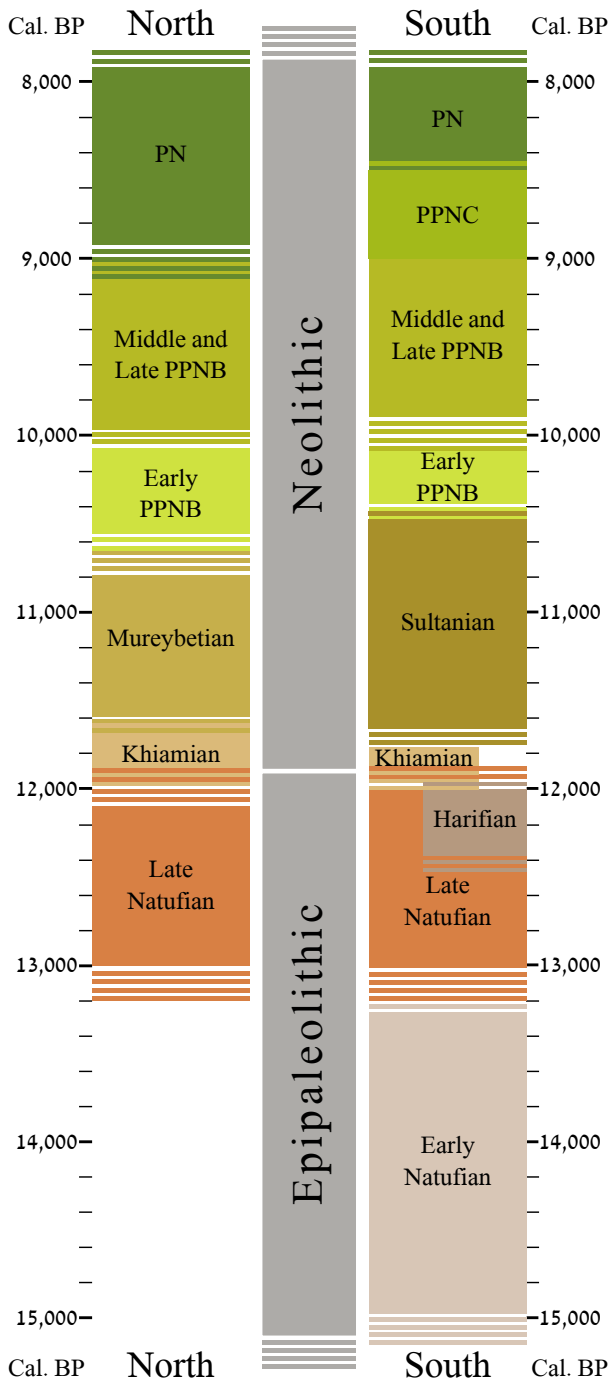


Fig. 1.2: Geo-chronocultural sequence of the northern and southern Levant (calibrated years BP)

Table 1.1: Founder crops of Near Eastern Neolithic agriculture and their wild progenitors^I

Common Name	Scientific Name of Domesticated Species	Scientific Name of Wild Progenitor
Einkorn wheat	<i>Triticum monococcum</i>	<i>Triticum boeoticum</i>
Emmer or durum wheat ^{II}	<i>Triticum turgidum</i>	<i>Triticum dicoccoides</i>
Barley	<i>Hordeum vulgare</i>	<i>Hordeum spontaneum</i>
Lentil	<i>Lens culinaris</i>	<i>Lens orientalis</i>
Chickpea	<i>Cicer arietinum</i>	<i>Cicer reticulatum</i>
Pea	<i>Pisum sativum</i>	<i>Pisum humile</i>
Bitter vetch	<i>Vicia ervilia</i>	<i>Vicia ervilia</i>
Flax or linseed	<i>Linum usitatissimum</i>	<i>Linum bienne</i>
Faba bean, also known as broad bean ^{III}	<i>Vicia faba</i>	Unknown

- I The discussion on domestication of plants in the Neolithic Levant refers to this group of grain crops.
- II Bread wheat, now the most common wheat crop on earth, is the product of an ancient interspecific hybridization event that occurred under domestication between domesticated emmer cultivars and wild *Aegilops tauschii* after the Levantine crop package reached the Caspian basin (e.g., Dvorak *et al.* 2012).
- III Faba bean, although not considered a founder package crop, may, in our view, be added to this list since it appears in many of the relevant site assemblages of botanical finds, even though its progenitor is as yet unknown—a longstanding challenging enigma.

they each comprise nutritionally and agronomically balanced crop complexes (Abbo, Lev-Yadun and Gopher 2010b; Harlan 1992; Smith and Yarnell 2009).

From the mid-20th century to the present day, we have witnessed many developments in the study of plant domestication throughout the world and especially in the Levant. A wealth of botanical remains retrieved from archaeological sites has become available. Relevant experimental work with living plants was carried out, including the gathering of grain crops from the wild and processing the yield, and the growing and processing of plant resources, e.g., by sowing, weeding, harvesting and threshing of cereals (including wild species) under controlled conditions, using agro-techniques and reconstructed prehistoric-like tools, such as sickles, sickle blades and threshing sledge blades (e.g., Anderson 1992; 1999; Hillman and Davies 1990a; 1990b; 1992; 1999; Willcox 1992; see also Abbo *et al.* 2011; 2015; Astruc *et al.* 2012; Tzarfati *et al.* 2013). Controlled collection (harvest) exercises of the progenitors and relatives of package species in the wild were conducted in order to learn about the practicalities of collecting in the wild and their bearing on the incentives and

mechanisms of plant domestication (e.g., Abbo *et al.* 2008a; 2008b; 2013b; 2015; Harlan 1967; Kislev, Weiss and Hartmann 2004; Ladizinsky 1975; Unger-Hamilton 1989; 1992). These studies were supplemented by ethnographic and ethnoarchaeological observations of traditional and pre-industrial societies, and this helped to elucidate the role of these plants as food staples (e.g., Elazari-Volcani 1930; Hillman 1984; Russell 1988; 1995; Simms and Russell 1997; Ulaş 2021; and see, for example, Green and Bogaard 2018).

A major growing trajectory since the late 1990s, and especially during the 2000s, is the analysis of DNA markers in present-day crops and in their wild progenitors, in search of the wild stock genetically closest to the cultigen. Such studies have pointed to the most closely related recent progenitor stocks of several Neolithic founder package species and hence their likeliest locales of domestication, including possible genetic evidence for their spread as domesticated crops in the early days of agriculture (e.g., Badr *et al.* 2000; Heun *et al.* 1997; Kilian *et al.* 2007; Ladizinsky 1999; Luo *et al.* 2007; Mori *et al.* 2003; Özkan *et al.* 2002; 2005; Salamini *et al.* 2002; Civián and Brown 2017; Pankin and von Kroff 2017; Weeden 2018; Oliveira *et al.* 2020; Pourkheirandish *et al.* 2015; 2018a; 2018b; Nave *et al.* 2019). Attempts to tackle plant domestication directly, using ancient DNA extracted from botanical remains (seeds) originating in relevant Neolithic sites, have not yet produced much impact. In very recent years, however, studies based on ancient DNA have appeared, and these may be expected to “open novel perspectives in fostering genetic gain in breeding programs” (Pont *et al.* 2019).⁴

Studying the spread of Near Eastern agriculture to Europe, West and Central Asia and North Africa is an important issue since the core-area one-event model predicts the spread (migration of domesticated plant populations) from a center of domestication, and this can be detected by temporal-spatial patterns found within archaeological and archaeobotanical assemblages (e.g., Braidwood 1960; 1967; 1975; Colledge and Conolly 2007; Colledge, Conolly and Shennan 2004; 2005; Zohary and Hopf 1988; 1993; 2000; Zohary, Hopf, and Weiss 2012; Abbo and Gopher 2017; Fig. 1). Such migration can also be detected by reconstructing genetic footprints of introgression (wild to domesticated gene flow and vice versa), i.e., by following the pattern of DNA polymorphisms (variation) among relevant populations (e.g., Cavalli-Sforza 1996; Abbo *et al.* 2006; see Pinhasi, Fort and Ammerman 2005; and Luo *et*

4. The study is based on a long series of ancient DNA sequences extracted from various plant species, including maize and sunflower in the Americas (the oldest samples some 6,000–5,000 years old), as well as barley from Israel (dated to ca. 6,000 years ago) and a long series of wheat samples from Turkey (dated to between 8,400 BP and 740 CE).

al. 2007; Mori *et al.* 2003; Özkan *et al.* 2005 for wheat; and see Box 5.1). The protracted autonomous model, on the other hand, is not expected to leave such spatial patterns, either among the archaeological-archaeobotanical data or among the DNA patterns of respective crops and their wild relatives. Plant and animal genetics have also been used to help reconstruct the spread of agriculture (e.g., for plants, Coward *et al.* 2008; Jones *et al.* 2012; Salamini *et al.* 2002 and many others, and just a few examples for animals: Naderi *et al.* 2007; 2008; Lv *et al.* 2015; Frantz *et al.* 2015). Additional lines of evidence, when combined for reconstructing spread, come from human genetics (Ammerman and Cavalli-Sforza 1984; and see, e.g., Skoglung *et al.* 2012) and from linguistic data (e.g., Bellwood and Renfrew 2002; Bouckaert *et al.* 2012; Gray and Hamilton 2003). In recent years, fossil human genomes, based on DNA extracted from ancient human skeletons, have been used to reconstruct the movements of populations as agriculture and domesticates (plants and animals) were spreading from their areas of origin. A few studies related to Near Eastern cases depict a complex picture of local (farming) populations in the Levant (including the Zagros, Iran) that were already spreading in all directions during Neolithic times (Lazaridis *et al.* 2016 and references therein).⁵ The local origin of early farmers in Turkey (Feldman *et al.* 2019 and references therein) corroborates a very recent study on the spread of these human populations into Europe, and the takeover of Spain by these farming populations as early as 7,500 years Cal. BP (Olalde *et al.* 2019). We can only make an educated assumption that this line of research will grow considerably in the near future.

Basic Assumptions Underlying This Study

From the outset, an element in our framework of thought was the rejection of “push models” for explaining the Agricultural Revolution as a whole and plant domestication in particular. We view any cultural change as a fully conscious action of human agency, sitting on an ideological (perceptual) infrastructure and accompanied by knowledge-based decision making and social dynamics. We should emphasize, at the risk of stating the obvious, that we have never underestimated the capabilities of past humans and see no reason to assign any past cultural change to unconscious dynamics, serendipity or “prehistoric accidents,” as suggested by Hughes *et al.* (2007) for domestication of *Leucaena* sp. in Mexico. This is crystal clear in the case

5. Following this paper, local farmers of the southern Levant and the Zagros (Iran) mixed with farmers of Anatolian origins and later with hunter-gatherers of Europe. These populations spread into Europe, East Africa and northward into Eurasia.

of plant domestication in view of the fact that plants (and animals) domesticated in the Pre-Pottery Neolithic Levant as part of the Agricultural Revolution are important elements of our modern-day economy, and this is also the case for other founder plant packages domesticated in other world regions, such as rice and soy beans in Southeast Asia or maize and beans in Mesoamerica (see above).

Acknowledging pan-Levantine Neolithic connections and regarding the Levant as an active Neolithic interaction sphere (*koine*, à la Jacques Cauvin) have also, from the start, been part and parcel of our view on the Agricultural Revolution and plant domestication.

Another idea we adopted from the outset, following the studies of the 1980s, was the primacy of the northern Levant in some cultural aspects and the evidence for their “diffusion” from the north to other parts of the Levant. The evidence was mainly archaeological and included the presence of materials of northern origins, such as obsidian throughout the Levant, lithic technological and typological aspects (already studied by one of us [A.G.] in the 1980s; Gopher 1989a; 1989b; 1994) that originated in the northern Levant, elements of architecture (rectangular structures), and—of relevance to this account—the exclusive origins of domesticated package crops such as chickpea in the northern Levant. This does not in any way imply a lower rate for Neolithic dynamics in the southern Levant; on the contrary, that region had its own story, but it did not include a primary local plant domestication.

Finally, we believe that a detailed survey of the various relevant datasets plotted on geographic and temporal maps, carried out as accurately as possible, is critical for understanding plant domestication and their spread as crops, as well as for selecting a parsimonious model that describes plant domestication.

It is our contention that domestication of the PPN Levantine crop package was a knowledge-based, conscious and short (episodic) event, i.e., within the archaeological resolution of the Neolithic period as based on ^{14}C dating, that is to say ± 50 years (within a century) in clear cases or ± 100 years (within two centuries) in the event that there are problems or that the dates were made at an early stage of ^{14}C dating. We further contend that such developments had taken place in a specific single-core area in southeastern Turkey and northern Syria, some 300 km in diameter (see red circle in Fig. 1.3), which is limited and well defined geographically, botanically and culturally (Abbo, Lev-Yadun and Gopher 2010a; Gopher, Abbo and Lev-Yadun 2001; Lev-Yadun, Gopher and Abbo 2000), some 10,500 years Cal. BP. Hence, our core-area one-event model.

It should be noted that the scale of discussions on plant domestication in this monograph covers only the Levantine domestication center. Therefore, our claim for

a centered (core-area) model is limited to this primary domestication center (see above and Box 1.1), and our aim is to present a detailed account of only plant domestication.

Investigating Levantine Plant Domestication

It would be in the interest of knowledge-seeking readers that, in presenting our work over the last two and a half decades, we point out its singularity, logic and innovativeness with a view to promoting our core-area one-event model. Our work on plant domestication issues was directed so that we could go into “cracks” and sensitive areas of plant-domestication research, which includes thinking (theoretical and terminological issues) and analyzing available datasets (sites, stratigraphies, chronologies, archaeobotanical assemblages, genetic data, and more), while seeking a parsimonious model of plant domestication. It was also designed to test possible answers to questions of where, when, at what pace, and how plant domestication transpired. To this end we survey our work and present it in chronological order, indicating our topics of interest and how each of these contributes to a better understanding and a better choice of the more parsimonious model of plant domestication in the Levant.

One of our earliest studies tackled the unique story of the chickpea, among the most intriguing species of the domesticated founder crop package. The wild progenitor of domesticated chickpea has the most limited geographic distribution of all known package progenitors, thereby emerging as the botanical “definer” for delimiting the geography of the core area. Furthermore, chickpea is unique in that when growing it in fields, early farmers had to face serious agronomic difficulties that are of no concern in the case of the other founder crops. These include the need to overcome the effects of a devastating fungal disease when grown in fields (dense crop populations) during winter (Abbo *et al.* 2003), and hence the need to turn it into a spring-sown crop. To convert chickpea from a winter annual plant to a summer crop, Neolithic farmers needed to identify and isolate types with no vernalization requirements (Abbo, Lev-Yadun and Galwey 2002). Despite the immense agronomic challenges (Ladizinsky and Abbo 2015), they did not give up on growing chickpea. Later, we attempted to provide an answer to the question what made chickpea so important for the Neolithic domesticators. Our answer is based on the nutritional qualities of chickpea as a “super food,” as well as its potential demographic and social effects (Kerem *et al.* 2007; and see Box 1.3).

A more general approach to the work that we adopted from the start was to challenge the prevailing hypotheses on plant domestication in the Levant (and in other world regions), which laid the foundations for many studies on

plant-domestication issues carried out in recent decades. The first of these was the dump heap hypothesis. A survey of the biology of the plants involved (i.e., wild progenitors of the eight founder package crops) opened the way to refutation, based on rather simple biological facts and arguments, of the dump heap hypothesis (Abbo *et al.* 2005). However, deeper and more nuanced critics of this hypothesis, with its deep historical roots as well as its major role, explicit or implicit, in plant-domestication models based on the idea of plant-human mutualism (e.g., Rindos 1980; 1984; Purugganan and Fuller 2011; Smith 2001; 2007a; 2007b; 2011; 2015; Zeder 2015; 2017), were published only later (Abbo, Lev-Yadun and Gopher 2012; Abbo and Gopher 2017; 2020; Gopher, Lev-Yadun and Abbo 2017).



Fig. 1.3: Distribution of wild progenitors of Levantine founder grain crops (circle shows core area)

A) Chickpea

Sites with relevant finds include: 1) Çayönü; 2) Cafer Höyük; 3) Nevalı Çori; 4) Göbekli Tepe; 5) Dja'de; 6) Jerf el Ahmar; 7) Mureybet; 8) Tell Abu Hureyra; 9) Hallan Çemi Tepesi; 10) Qermez Dere; 11) M'lefaat; 12) Tell Aswad; 13) Yiftaḥel; 14) Jericho, Netiv Hagdud, Gilgal I; red triangle denotes Karacadağ

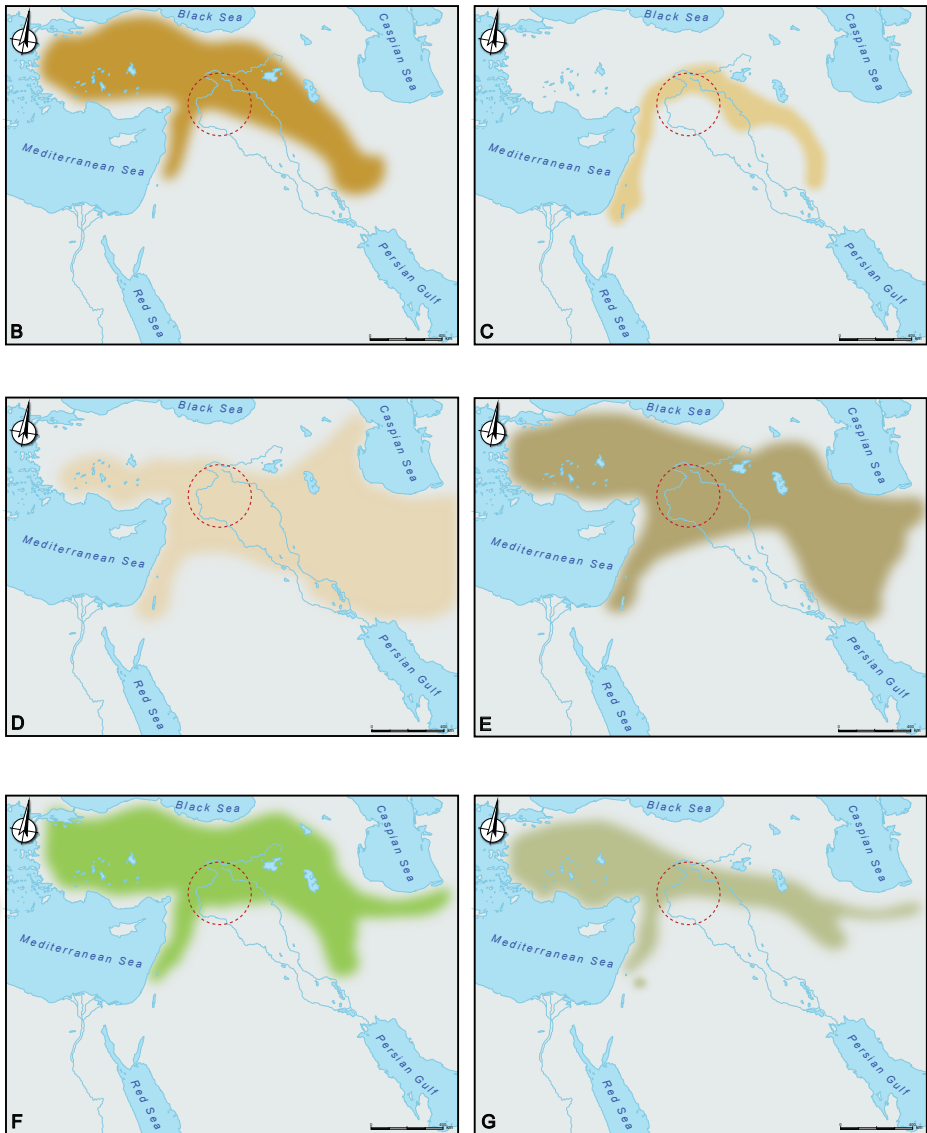


Fig. 1.3 (continued): Distribution of wild progenitors of Levantine founder grain crops;

- B) Einkorn wheat
- C) Emmer wheat
- D) Barley
- E) Lentil
- F) Pea
- G) Bitter vetch

Box 1.3: Chickpea Domestication as a Prehistoric Agro-biotech Entrepreneurship

Domesticated chickpea (*Cicer arietinum*) was derived from the wild species *Cicer reticulatum* (Ladizinsky and Adler 1976). Transformation of this relatively rare species, with its distribution limited only to southeastern Turkey, into an important grain legume is one of the outstanding achievements of the Neolithic domesticators and their ingenuity. In this box we briefly discuss the morphological and physiological traits that we have studied over the years in the context of chickpea domestication.

As with lentil (Ladizinsky 1987; see Box 2.6) and pea (Abbo *et al.* 2011), the most decisive trait underlying chickpea domestication must have been free germination. All of the studied wild *Cicer* sp. accessions show a high degree of seed dormancy. It is unclear how the Neolithic people identified free germinating chickpea stocks; however, as argued by Ladizinsky (1987; 1993) and as demonstrated experimentally by Abbo *et al.* (2011), it certainly could not have happened via the presumed millennia-long “pre-domestication cultivation” stage postulated by Fuller (2007; and see Chapter 2), since this would mean that for many years there was no crop gain at the end of each growing season.

Most domesticated chickpea cultivars succumb to ascochyta blight, a destructive disease caused by the fungal pathogen *Didymella rabiei*. The asexual spores of this fungus are dispersed by rain splash (e.g., Shtienberg *et al.* 2000). In the Mediterranean basin, infection by sexual or asexual *D. rabiei* spores will result in total crop destruction if the crop is grown during the rainy season.¹ Notably, most of the tested wild chickpea accessions are also highly susceptible to this pathogen (e.g., Abbo *et al.* 2007). Hence, in antiquity, without fungicides, the only practical option to minimize ascochyta disease damage was to sow chickpea in late March or early April. Such out-of-season sowing (in nature, the wild progenitor germinates following the first significant autumn rains), reduces the risk of infection and may prevent ascochyta epidemics (Abbo *et al.* 2003).

This practice (probably the most ancient out-of-season agro-technology) of dryland spring sowing (towards the end of the rainy season)² involved a heavy

1. In the wild, being a rare plant characterized by a patchy distribution, it is protected from devastating epidemics.
2. Chickpea is mostly a dryland crop, except in desert regions where agriculture is totally dependent upon flood irrigation (such as the Nile Valley or lower Mesopotamian river valleys).

penalty in terms of yield. This is because under the Mediterranean climate, the residual soil moisture available to the spring-sown crop places it at a disadvantage compared with an autumn-sown crop. The persistence of the Levantine Neolithic farmers in continuing to grow chickpea despite its vulnerability to the destructive pathogen and given its reduced yield potential strongly suggests that chickpea was highly appreciated. Perhaps it was the nutritional quality of its grains (e.g., Kerem *et al.* 2007) that provided the incentive to develop the agro-technology of spring-sowing that was imperative for stable production.

Identification of a vernalization response (i.e., advancement of flowering date as a result of exposure to a cold growth period at the seedling stage) exposed a new dimension of the ancient achievement of chickpea domestication (Abbo, Lev-Yadun and Galwey 2002). No such response is known in domesticated chickpea, and claims for vernalization sensitivity in the cultigen are viewed as an artifact (Summerfield, Ellis and Roberts 1989). Flowering advance following vernalization was demonstrated in *C. reticulatum* and also in other wild annual *Cicer* species (Abbo, Lev-Yadun and Galwey 2002; Ben-David and Abbo 2005). This would indeed be expected from a species native to southern Anatolia, a region with snowy winters. The vernalization response of wild chickpea is mediated via a combination of both major and minor gene effects (Abbo, Lev-Yadun and Galwey 2002; Samineni *et al.* 2016; Pinhasi van-Oss *et al.* 2016), and is subject to strong environmental influence. Consequently, selection for spring types (vernalization-insensitive) in chickpea must have been a difficult and delicate process that occurred under domestication, i.e., with the advent of free germinating stocks. This probably took much longer than selection for more stable phenotypes, such as pod indehiscence in pea or spike disarticulation in wheat and barley.

As noted by Ladizinsky (1979b), upon maturity the wild chickpea pods remain intact on the plants longer than observed in wild pea, wild lentil and wild bitter vetch (Abbo *et al.* 2009: Fig. 2). At the time, Ladizinsky (1979b) viewed this as a pre-adaptation for domestication and suggested that this trait had attracted the attention of the Neolithic domesticators, thus providing a likely explanation as to why this wild species was domesticated. However, given the immense agronomic difficulties associated with securing stable chickpea yields, it is clear that its partial pod indehiscence can hardly explain the insistence of the Neolithic domesticators to embark on such an enterprise and to maintain it despite the abovementioned agro-biotech challenges.

A possible answer may be found in the work of Kerem *et al.* (2007), showing that seeds of domesticated chickpea contain twice as much total tryptophan as seeds of the wild progenitor *C. reticulatum* and that the difference is even more pronounced with respect to free tryptophan (Kerem *et al.* 2007). Tryptophan, which is an essential amino acid for humans and must be accessed via the diet, is the precursor of brain serotonin and is therefore implicated in numerous biological and social functions. It was recently demonstrated that no significant genetic correlation exists between chickpea seed tryptophan content and the flowering vernalization response (van-Oss *et al.* 2018). This means that the Neolithic domesticators must have selected for both traits independently. Therefore, high-tryptophan seeds or spring stocks not requiring vernalization are unlikely to have arisen as a correlated response to selection for either of these two important traits.

All in all, it seems that contrary to prevailing paradigms, the domestication of chickpea (and also of other legumes) cannot possibly be viewed as a millennia-long pre-domestication cultivation (to obtain a free germinating stock), or via the prey-predator pathway (a rare, poorly yielding wild plant), or via the automatic-unconscious selection scenarios (with no genetic correlation between tryptophan content and vernalization response). On the contrary, each step in chickpea domestication, and its later improvement under domestication to become a globally important grain legume crop, must have necessitated keen observations, ingenuity and meticulous manipulative abilities (Ladizinsky and Abbo 2015). In Kerem *et al.* (2007), we highlighted some of the repercussions of a tryptophan-enriched diet for Neolithic health, demographics, and social behavior within large, dense, sedentary farming communities. An enriched tryptophan diet improves infant development and daily scheduling by inducing satiety and thus prolonging the gaps between meals and sleepiness; it brings about higher ovulation rates and thus better prospects for more frequent births—an important factor in a time of demographic growth such as the Neolithic era; a high tryptophan intake improves performance under stress and increases distinction ability in the social sphere, which may be of relevance to sedentism and the following increased social tension; it promotes dominance in an era of decreasing egalitarianism and increasing social complexity; it promotes investigative behavior in an era of major socio-economic changes; and it promotes increased self-confidence and also acts as an anti-depressant, which could have been a significant attribute in a dynamic time such as the Neolithic period (for details, see Kerem *et al.* 2007 and references therein).

Another aspect that we investigated quite early in our work was a model for the spread of domesticates within the Levant and beyond. We consider the spread issue to be highly significant, since it can be viewed both in the archaeology of the Neolithic period (Abbo and Gopher 2017: 505, Fig. 1; and see Box 5.1) and in the biology of the spreading plant populations. By re-interpreting published wheat DNA polymorphism data (Abbo *et al.* 2006), we pointed out the documented genetic “ripples” left by the wave of advance of Neolithic wheat farming from its core area. This approach was based on the understanding that demographic expansions of a domesticated plant species within a landscape of its wild type leave their mark, via geneflow, in the pattern of DNA polymorphisms of the respective populations. Likewise, the spread of cultural phenomena can be traced by dating archaeological finds and reconstructing their direction and pace of expansion, as done by one of us with respect to the Neolithic within the Levant since the 1980s (e.g., Gopher 1989a; 1989b; 1994; 1996). This combined approach is useful for charting the spread of domesticates and early farming into ecosystems initially dominated by populations of the wild progenitors. In addition, such reconstructions can benefit the high-resolution power offered by both archaeology and biology when we contemplate alternative prevailing multi-centered protracted-domestication scenarios (e.g., Fuller, Willcox and Allaby 2012).

We then embarked on fieldwork that included surveys, controlled collection of seeds of several wild progenitors of package plants and setting up experimental field nurseries, and evaluated the possible efficiency of collecting package progenitors (especially legumes) in the wild (Abbo *et al.* 2008a; 2008b; 2013b; 2015) and looking for crucial traits underlying legume domestication (Abbo *et al.* 2009). Our principal conclusion was that the most important (even critical) domestication-syndrome trait in grain legumes was seed dormancy (Abbo *et al.* 2011). This turned the spotlight on the idea first formulated by Ladizinsky already in the 1980s, namely “domestication before cultivation.” Acceptance of Ladizinsky’s theoretical considerations and our experimental results has the potential to turn several of the common views on plant domestication in the Levant on their head, e.g., rejecting the option of a millennia-long, protracted pre-domestication cultivation process for legumes.

We also reviewed the arguments in favor of multiple Near Eastern plant domestication foci (Abbo, Lev-Yadun and Gopher 2010a). In our critical evaluations of frequently cited papers advocating multiple domestications of barley, emmer wheat and lentil, we found them to be suffering from weakness in several aspects. Their main drawback was the lack of genuine cultural independence or of the

appropriate archaeological context (e.g., Azhaguvel and Komatsuda 2007; as well as Morrell and Clegg 2007), which is imperative for claiming independent domestication centers within the Levant (Abbo, Lev-Yadun and Gopher 2010a).

We also struggled to reconstruct past recruitment of species for domestication, based on the idea that the desired phenotypes were available in the region's natural standing genetic variation (see Doebley, Gaut and Smith 2006), i.e., that they were present in wild populations. Recognition of the extent of the wild progenitors' standing (natural allelic) genetic variation led us to acknowledge the capabilities of hunter-gatherers in finding such desired plants and mutants for domestication. This is contrary to the prevailing thinking about plant domestication, which is dominated by models based on unconscious selection processes (e.g., Purugganan and Fuller 2011; Zohary 2004). We view this as a derogatory attitude and an underestimation of the proficiency of the Neolithic domesticators who selected our predominant crop plants (see concluding remarks in Abbo, Lev-Yadun and Gopher 2010a; 2014; Abbo *et al.* 2013b).

Contrary to claims concerning isolated (autonomous) episodes of cereal domestication (in cultural, ecological and agronomic terms), we have emphasized the agronomic imperatives of a diverse crop package that includes both cereals and legumes (Abbo, Lev-Yadun and Gopher 2010b) on top of the long-recognized diet-compensatory nature of the selected Near Eastern species. The yield-stabilizing potential of the Near Eastern founder crop package is one of the best testimonies to the ingenuity of the Neolithic domesticators and their decision making (Abbo, Lev-Yadun and Gopher 2010b).

A concept that we consider to be quite powerful is the distinction between plant domestication and crop evolution after domestication (Ladizinsky 1998b; Abbo *et al.* 2014; and see Box 1.4). In our view, refraining from applying this distinction constitutes a serious obstacle in plant domestication research in the Neolithic Levant and is an important reason why a protracted-domestication scenario (along with unconsciousness) is the prevailing model. The biological nature of this distinction, if adopted, may free plant-domestication research in the Levant from many of the difficulties that blur the picture. Application of this concept emphasizes the low parsimony of the protracted autonomous domestication paradigm and stresses the fact that ignoring this distinction is a major reason for the low resolution (agronomic, genetic, archaeological) dominating current Levantine plant domestication research (see Abbo and Gopher 2017; 2020).

As part of our critical evaluation of the prevailing domestication models, we also addressed several popular conceptual constructs. One of these is the presumed extra

labor (dubbed labor-trap) associated with post-harvest processing of domesticated cereal crops (Fuller, Allaby and Stevens 2010), which was proven incorrect by controlled threshing experiments of wild and domesticated wheat genotypes and their hybrid derivatives (Tzarfati *et al.* 2013). Another construct relates to claims for experimentation with or auditioning of potential plants for domestication and cultivation failures, with consequent loss of crops and lost lineages in crops (e.g., Melamed, Plitmann and Kislev 2008; Gross and Olsen 2010). Note that we do not deny the possibility that certain species were domesticated and later abandoned. However, this requires a whole set of archaeobotanical evidence, such as that presented for the North American knotweed (*Polygonum erectum*) by Mueller (2017). For the time being, when addressed in detail, such claims for Near Eastern lost crops lack the critical genuine evidence (Abbo *et al.* 2013a).

Box 1.4: Plant Domestication vs. Crop Evolution under (Post)-Domestication

A central theme in recent plant domestication studies is the presumed millennia-long protracted domestication process. Needless to say, such a reconstruction should be evaluated in light of published archaeobotanical data, experimental evidence, and an understanding of the biology of the Levantine crops and their wild progenitors. Studies of living wild plants and their derived domesticated forms show a multitude of morpho-physiological differences, collectively termed the “domestication syndrome” (Hammer 1984): for example, spike non-shattering in domesticated cereals as opposed to spike shattering in the wild, the sweet almond kernels as opposed to the bitter and toxic wild almond kernels, and free germinating domesticated lentil or pea seeds but strong seed dormancy in the wild. It should be noted, however, that domesticated crop plants are dynamic genetic entities that constantly evolve in response to selection pressures exerted by their growth environment (climate fluctuations, pests and disease epidemics), as well as those operated by their growers (selection for ease of processing, special taste or quality preferences and more). Therefore, it cannot be assumed that all the parameters differentiating between current domesticated crop plants and their wild progenitors were associated with the pristine domestication events, termed “initial domestication” by some researchers (e.g., Smith 1997; see Zeder 2017). In other words, many traits that are present among the domesticated gene pools may have arisen under (post)-domestication. Such

features are often termed “improvement” or “diversification” traits. We call them “crop-evolution traits” after Ladizinsky (1998b).

Recently, we introduced the concept of a “crucial domestication trait,” i.e., a trait that is imperative for profitable cultivation (e.g., free germination in chickpea, pea, or lentil), thereby making it possible to distinguish between genuine domestication traits and crop-evolution (post-domestication diversification) traits (Abbo *et al.* 2014). In numerous crop cases, crucial domestication traits were shown to exhibit a clear wild/domesticated dimorphism¹ and to be inherited in a simple way (one or a few controlling genes) whereas crop-evolution traits mostly show a marked phenotypic continuum between the wild and the domesticated genepools, with their inheritance controlled by many genes.

It is argued that by adopting the assumption of pre-domestication cultivation (e.g., Fuller 2007; Harris 2009; 2012; Hillman 1996; 2000; Hillman *et al.* 2001; Riehl, Zeidi and Conard 2013; Weiss, Kislev and Hartmann 2006; Willcox 2008; 2009; 2012b; 2013) and consequently a protracted millennia-long domestication process, one needlessly opts to operate within an intellectual framework that does not allow differentiation between crucial, decisive domestication traits, together with their respective chromosomal loci, and those that evolved later, during crop dissemination and improvement following the domestication episode.² Therefore, in our view, in addition to the lack of experimental evidence to support it, the protracted-domestication assumption undermines the resolution power of studies of both plant domestication and crop evolution, from the cultural (see Chapters 6 and 7) as well as from the biological perspectives.³

1. A situation in which two different morphological (and/or physiological) types exist, one among the wild populations while the other is a feature of domesticated cultivars (including landraces). Usually, such phenotypes are conditioned by the allelic variants in a single (major, Mendelian) gene. Such a genetic system dictates that intermediate types are extremely rare and therefore selection for either phenotype is quite easy and hence rapid.
2. An example could be seed size in cereal (and legume) species that were domesticated. The seed size of domesticated crops does show a tendency towards growth over time in many cases, but it is not a crucial domestication-syndrome trait in our view, and thus when taken into consideration it hampers a proper reconstruction of plant domestication. However, if we accept it as a crop-evolution trait, the issue is immediately resolved and becomes irrelevant, making the entire turmoil redundant (see below, Box 2.2 and Table 8.1).
3. Note that Tanno and Willcox (2006a), Allaby, Fuller and Brown (2008), Purugganan and Fuller (2011) and their followers implicitly or explicitly opt to bulk together genuine domestication-syndrome traits (spike non-shattering in cereals, legume seed free germination) alongside later, crop-evolution traits (i.e., seed size) unrelated to the pristine domestication episode. This poor biological (agronomic, genetic) and cultural resolution is the crux of the protracted-domestication concept (Abbo *et al.* 2014; Abbo and Gopher 2017).

Goals

The principal research issue currently debated by archaeologists and plant-domestication researchers concerning plant domestication in the Neolithic Levant is focused on the question which model best reconstructs the actual history of plant domestication: the core-area one-event model, which views Levantine Neolithic plant domestication as knowledge-based, conscious and occurring in a limited core area and within a short, single event, or alternatively, the protracted autonomous (non-centered) unconscious model, which has thrived in Near Eastern Neolithic studies over the past decade and a half.

The major goal of this publication is to present and explain our core-area one-event model. A second goal is to map the geographic spread of the Levantine PPN crop package already in Neolithic times. A third is to test the two debated plant domestication models by providing parsimony measures for each of them.

To achieve these goals, we first discuss in detail the terminology used in plant-domestication research relevant to the understanding of plant domestication in the PPN Levant (Chapter 2). We assign an important role to terminology in shaping the way plant domestication in the Levant is perceived.⁶ We emphasize and discuss in detail the term “cultivation”—a pivotal concept upon which the protracted autonomous model relies. We then discuss the timing and length (pace) of plant domestication in the Levant (Chapter 3), and consider its geography (Chapter 4) by pinpointing a core area based on a set of independent lines of research (geobotany, archaeobotany, archaeology, genetics). We discuss the spread of domesticates within and beyond the Levant (Chapter 5), suggesting a framework (the ripple-wave of advance pattern) for its reconstruction that is significant for deciding on a choice between the two contrasting domestication models. Through these discussions we present and challenge the foundations of the prevalent protracted autonomous model of plant domestication in the Levant, and point out its methodological and factual drawbacks and its low parsimony.

In Chapter 6, we present the cultural context of plant domestication in the Levant that we consider fundamental for understanding plant domestication and the Agricultural Revolution in the Levant as a whole. This includes a brief cultural background on the late Epipaleolithic period (mainly the Natufian culture ca. 15,000–11,600 years Cal. BP) and the Pre-Pottery Neolithic A (PPNA) period (ca.

6. Terms and words used in scientific discourse are never neutral and are, explicitly or implicitly, conveyors of ideas and agendas of their users. This is true for all the protagonists of the discourse, no matter what view they are promoting.

11,600–10,600 or 10,500 years Cal. BP), both periods predating the appearance of non-brittle/non-shattering (domesticated) cereal remains; and the early Pre-Pottery Neolithic B (PPNB) period (ca. 10,600/10,500–10,200/10,100 Cal. BP) in the northern Levant (with minor essential comments on the southern Levant). The middle and late PPNB (ca. 10,200/10,100–9,000 Cal. BP) are rarely mentioned. This chapter also presents a brief account of imagery (art) assemblages in these periods as reflectors of the symbolic array and changes in human perception and socio-economy that took place during the Neolithic period in the northern Levant. A short comment about incentive—why domesticate?—appears at the end.

The concluding discussion in this study (Chapter 7) presents brief statements on the framework of thought in plant-domestication research in the Levant, including comments on our own views. It summarizes the terminological issue, clarifies the distinction between plant domestication and crop evolution under domestication, which we consider fundamental (see Box 1.4), and it raises issues of nutrition and agronomy related to the selection of species and chosen phenotypes for domestication. We do not elaborate on animal domestication, which we did not study in detail (but see Box 1.5).

Box 1.5: Animal Domestication in the Neolithic Levant in Brief

The Levantine domestication center was eventually the only one that included, from the outset, domestication of a package of animals known as the “Big Four”—goat, sheep, cattle and pig.¹ The short summary on animal domestication presented here is heavily based on and mostly quoted from a recent study by Gila Kahila-Bar Gal (forthcoming, and references therein). Although for many inherent reasons, the patterns characterizing animal domestication clearly differ from those characterizing plant domestication, we consider the two domestications comparable since we believe them to be similarly structured, reflecting the results of a similar ideological/perceptual and cultural infrastructure.

The progenitors of domesticated animals were present in the Near East (Fertile Crescent, Levant) and are known to have been hunted in Paleolithic times, as

1. Only later were other animals domesticated in other regions of the world, as is, for example, the case of the horse, which was domesticated in the Central Asian steppe 5,500–4,000 Cal. BP.

observed in archaeozoological assemblages of the Epipaleolithic period (23,000–15,000 Cal. BP) and in Natufian archaeozoological assemblages (15,000–ca. 11,600 Cal. BP), as well as in the early, pre-domestication Neolithic period.

The geographic distributions of the wild progenitors of all livestock show a habitat overlap in an area extending from central Turkey to the western parts of Afghanistan and from the Caspian coast to the Persian Gulf and the Indian Ocean, i.e., an area of roughly 3,000 × 400–700 km. This area includes the much smaller core area that we suggest for plant domestication.

Genetic and genomic databases tend to indicate a Levantine origin for the “Big Four” livestock package. The “center” indicated by these studies encompasses the core area that we suggest for plant domestication.

While the chronology of animal domestication is still under debate, a date between 11,000–10,000 years Cal. BP would be acceptable to many researchers. In the spirit of our suggestions for plants, we would say that the date is most probably ca. 10,500 years Cal. BP (Vigne *et al.* 2017).² The pace of animal domestication is difficult to determine, as most of their domestication-syndrome traits are behavioral and are therefore elusive in the archaeozoological record.

Once domesticated, the “Big Four” livestock package (like the package of domesticated plants) spread throughout the Levantine PPN interaction sphere and beyond.

Animal domestication was an educated knowledge-based process with respect to the choice of species (from the naturally occurring fauna) and the selection of favorable (domestication-syndrome) traits. Enhancement (improvement) of livestock production by selection and breeding continued over time and is still ongoing.

The domestication of animals had many socio-economic as well as significant perceptual repercussions:

- Their mere presence in human settlements and the inevitably changed interrelationship between humans and animals. Various agro-eco-systems were developed later—e.g., sedentary pastoralism and pastoral nomadism—each showing characteristic adaptations.

2. Although Vigne *et al.* (2017) hold a view of a “protracted” domestication, they note (p. 753): “It has become clear that the process developed over several millennia, from the Late Epipaleolithic to the late PPNB, even though the earliest phenotypic modifications of animals are not visible before the early PPNB (ca. 10.5 ka cal BP).”

- Animal domestication influenced the health of both human and animal populations, because of the exposure of human populations to new pathogens and/or changes in pathogen abundance and genetic makeup. Moreover, resistance to these diseases by people of the Eurasian land block helped them to rule many other parts of the world over the last 600 years (Crosby 1986; Diamond 1997).
- Animals provide not only meat (a dietary protein source) but also secondary products that have become an integral part of the human diet and economy. They include milk (with genetic changes in humans allowing milk digestion as adults), dairy products, hair/wool, hides, horns, and later, work (traction by bovids), transportation, and more. Milking started quite early and is a significant element concerning Neolithic communities and demography.
- Livestock husbandry is directly related to the domestication of plants utilized as animal feed. Some of those plants, e.g., bitter vetch, were grown as fodder from the very beginning, while others were domesticated and added later (e.g., alfalfa, clovers and grass-pea). In any case, the stems and leaves of cereals and legume plants have probably been used as fodder since the beginning of agriculture.
- In recent traditional societies where animal traction and animal-based transportation played important roles in the economy, a considerable percentage of the arable land had to be devoted to growing animal feed of various types, including fibrous plant parts as well as starch- and protein-rich feed materials, e.g., grains. Agricultural production in the industrialized nations following World War II was modernized by replacement of many millions of draft animals with motorized machinery. This enabled farmers to devote increased areas, formerly allocated to feed production, to grain production for human food. For example, the emergence of Canadian rapeseed (Canola) as a major oil crop, for human consumption (rather than industrial uses), was economically feasible because it mostly replaced the production of oats that once were required as farm animal feed.

Presenting the Different Opinions

Several essential questions on plant domestication can be posed as “simplistic” dichotomies, i.e., “either-or” issues (e.g., Abbo, Lev-Yadun and Gopher 2011). It is pertinent to note here that researchers in recent years have tended to oppose “either-or” dualist traditions (e.g., Barker 2013; Finlayson 2013; “the inadequacy of conventional either-or categorizations” of forager and farmer, Harris 2012: 22). In contrast, the presentation of plant (and animal) domestication in terms such as autonomous (diffused, non-centered), protracted and unconscious (automatic) is, in our opinion, often merely a reflection of a jargon guising the “either-or” concept rather than a matter of content. In our view, the use of paired dichotomies is a comfortable working device, and we will introduce and use such paired dichotomies with respect to central issues of Levantine plant domestication (cf. summary in Abbo, Lev-Yadun and Gopher 2011), along some of which this text is structured. These include, among others, “paired” issues such as:

- **Locality:** did plant domestication take place in a specific, well-defined, highly localized core area within the Levant or did it occur independently (autonomously) in different places within the Levant (diffused)? If in a single area, where was it located?
- **Process:** did domestication occur in an exclusive, single episode for each species (monophyletic) or were there multiple domestications per species (polyphyletic)? Was each species domesticated autonomously (independently) or was a crop package domesticated as a whole, i.e., in a singular timing? This raises the question: how did the Neolithic founder crop package coalesce?
- **Intent:** was the process incidental or circumstantial, i.e., a result of evolutionary mutualism, or was it a designated human initiative?
- **Selection:** were the choices of plant species and the selection of specific stocks within the respective species conscious or unconscious?
- **Time frame and pace:** was the pace of domestication fast or slow, contracted or protracted?

The above series of paired topics has the power to delineate complex interrelationships that merge into one another in complex ways. It is difficult to separate the answers to those distinct yet interrelated questions, but we argue that making a decision or taking a stance concerning a “leading” pair, e.g., in favor of the localized (centered) core-area option, can tip the balance concerning undecided “paired topics.” Such a decision

may promote certain conclusions and eventually help to create a coherent cultural and biological scenario of plant domestication in the Levant that accords well with the currently available data. On the other hand, opting for the alternative, geographically diffused “autonomous” (non-centered) model of independent domestication processes for each plant and in different locales in the Levant would lead a different way, which, in our view, raises difficulties and leaves many unresolved questions.

CHAPTER 2

IS THE TERMINOLOGY USED IN PLANT-DOMESTICATION RESEARCH OF THE LEVANT ADEQUATE?

In this chapter we present, examine and sharpen the terms most commonly used in the literature vis-à-vis plant domestication in the Levant, with special emphasis on the term “cultivation.” We should clarify again that our use of the term “Agricultural Revolution” refers to the whole sociocultural and economic dynamic of change (or Neolithization, as dubbed by archaeologists; and see Box 1.2 above), while “plant domestication” refers only to this specific component of that revolution. We find this distinction between the large-scale *Longue durée* (Agricultural Revolution) and the episode (*Brève durée*)¹ of plant domestication to be critical to the understanding of our suggested core-area one-event model for plant domestication, as presented in the coming chapters (see Chapter 6 for further footnotes on historiography). This cardinal distinction has not always been observed in the literature, and ignoring it may cause quite significant problems in the construction and assessment of plant-domestication models.

Definitions in Dictionaries and in Professional Literature

The term “foragers” is defined as “Any society that depends on a combination of hunting, fishing, and gathering wild foods for subsistence. Until ca. 12,000–11,000 years ago, all peoples were foragers” (Collins English Dictionary). Foraging is described as “wild plant-food procurement” (see Harris 1989: 17; 1996a: 4) and is the term commonly used to fully characterize the relationship between humans and plants for millions of Paleolithic years.

1. Note that this is limited to resolution of the archaeological and archaeobotanical data according to ¹⁴C dating.

Following Ladizinsky (1998b: 4–8) and the Collins English Dictionary,² “cultivation” is “the planting, tending, improving or harvesting of crops of plants and also preparation of ground to promote their growth”; “domestication” means “to bring or keep (wild animals or plants) under control of cultivation, to accustom to home life, to adapt to environment”; and “agriculture” is the “occupation of cultivating land and rearing crops and animals.” In the literature on plant domestication in particular, the terms “cultivation” and “domestication” carry different meanings as a result of their long use by generations of scholars. Thus, “cultivation” relates to sowing (without which seeds are prone to predation by birds, rodents and ants) and the growing of wild plants with some (undefined) degree of manipulation or intervention (such as short- or long-distance displacement, land clearing or tilling) without consciously selecting any genetic types or establishing the dependence of plants on humankind for their survival. “Domestication” (of grain crops of the Neolithic package in our case; see Table 1.1) usually refers to a selection-based genetic manipulation, which encouraged new domesticated plant types that were often fully dependent on humans for their survival, owing to the loss of their natural (wild-type) adaptation traits such as seed dispersal and/or seed dormancy (Harlan, de Wet and Price 1973).

These evolutionary changes were the result of either unconscious selection due to cultivation and harvesting practices or conscious selection and sowing of specific types in fields cared for by humankind. Similar definitions were offered by Barbara Bender, Charles Redman, Charles Reed, Richard MacNeish, Jack Harlan, and Gordon Hillman and Stuart Davies (see Ladizinsky 1998b: 6). Following Hillman and Davies (1992: 114), the above definitions may be summarized using the one offered by Garrard:

... domesticated crops are regarded here as plant populations which have undergone genotypic changes as a result of unconscious selection factors resulting from cultivation and harvesting practices or the conscious selection of seed/plant types with particular attributes desirable to farmers. This has usually rendered the crops dependent on human intervention for their survival, through loss of wild-type adaptive features. (Garrard 1999: 68)

Agriculture or plant agriculture was in many cases related to in economic terms describing an economic system based on the cultivation of crops regardless of their phenotype, e.g., with “substantial dependence on plants grown by man” (Bronson 1977: 25).

2. Following Ladizinsky’s ordering, the terms implicitly indicate a prevailing *a priori* view on the process of plant domestication (see also Garrard 1999; Harris 1989; 1996a; 1996b).

In a different frame of thought, cultivation, domestication and agriculture were regarded as “a series of new relationships formed between people, land, plants and animals” (Redman 1978: 93), as an “environmental manipulation within the context of the human co-evolutionary relationships with plants” (Rindos 1984: 100), or as an ongoing relationship of intervention initiated and sustained by humans (Smith 1998a; 1998b; 2001). Those views present a range of possible relationships, or manipulations, from minimal (e.g., pruning), through low-level food production, to domestication and agriculture. Domestication may also be regarded (as by Smith 2007a; 2007b) as taking place within a broader behavioral context of strategies for human niche construction, i.e., ecosystem engineering, that include “sowing, burning, weeding, irrigation, transplanting, and mulching” (Smith 2007b: 1797). All of these activities were part of a long history of integrated systems of human environmental management (see also Rowley-Conwy and Layton 2011; Smith 2011), often termed “traditional or aboriginal resource management” (see also Anderson 2005; Gerritsen 2008).

In the last two decades, the concept of cultivation (and pre-domestication cultivation) and the use of the term “cultivation” have become fundamental aspects of many reconstructions concerning Neolithic and even Epipaleolithic plant domestication, as well as of the beginnings of agriculture in the Levant. Claims for cultivation, and especially pre-domestication cultivation, have been massively used in recent literature as “evidence” of sorts, in support of a protracted domestication scenario. We consider it imperative to scrutinize the many statements regarding cultivation (and pre-domestication cultivation, see below), the role they play in the study of plant domestication, and the quality of evidence on which they are based. We therefore devote a separate section to a discussion of cultivation in order to take a deeper look at this somewhat baffling term.

The Term “Cultivation” as Used in Plant-Domestication Research in the Levant

Cultivation is justly considered by students of the Agricultural Revolution and plant domestication to be a significant cultural marker of a change, reflecting new perceptions in the relationships between humans, plants and land, as well as new behavioral patterns (e.g., Bar-Yosef 2011; Bar-Yosef and Meadow 1995: 65; Harris 1989). It is also usually viewed as a momentous stage in the process of plant domestication and the rise of agriculture. Some researchers consider cultivation a prerequisite for plant domestication, having provided the arena

for the gradual unconscious (automatic) emergence of the domesticated genotypes (e.g., Colledge 1998: 121; Fuller 2007; Gepts 2004; Nesbitt 2002: 115; Zohary 2004; and see Heiser 1988), thus giving birth to the term “pre-domestication cultivation.” However, Harris (1989), who ascribed great importance to the exact definition of the various terms as an integral part of his four-stage model for plant domestication, opposed a progressive/diachronic view and presented those terms not as a representation of a prehistoric sequence, but rather as an “evolutionary continuum” that is neither unidirectional nor deterministic (see below).

The term cultivation, as introduced by Helbaek (1960) in the context of the Agricultural Revolution in the Levant, was comprehensively defined only a decade later (Helbaek 1970). Cultivation, according to Helbaek:

... is a complex of measures by which ecology is influenced in order to further the growth and output of one or more plant species. Natural vegetation is suppressed or removed; the microbiology of the topsoil is changed by hoeing or ploughing; seeds of the desired species are dispersed at suitable density, or seedlings planted, in certain conditions water is drained off the terrain, in others it is supplied artificially. During the growing season weeds are suppressed and predatory animals warded off. (Helbaek 1970: 194)

As for its relationship to domestication,

Cultivation is a matter of governing the ecology while domestication depends on some physiological inefficacy in plants of which man takes advantage... Cultivated plants need not be domesticated—indeed, cannot by any means be so from the outset—whereas on the other hand, a domesticated plant can exist only as a cultivated plant. (Halbaek 1970: 194)

While this definition is sharp and clear, the archaeological visibility of the activities mentioned by Helbaek (1960; 1970) is rather low. Being, by definition, wild from the outset, the remains of presumably cultivated wild plants in archaeological sites are indistinguishable from those gathered in the wild. Convincing or unequivocal evidence of land clearing is difficult to discern and, indeed, has not yet been presented for the early stages of agriculture in the Levant. Traces of weed suppression and animal warding off are archaeologically translucent at present. Traces of agro-techniques used in the caring of plants, such as tillage (hoeing) or irrigation, are not easily identified in Neolithic sites, at least for the early parts of the Levantine Neolithic period, leaving investigators with only indirect evidence or no evidence at all.

Specific tools and installations have also been suggested as possible evidence of cultivation. Most of these, however, are not unique to the Neolithic period and have been found in earlier sites. For example, sickles and sickle blades, proposed to demarcate cultivation, are occasionally found in Epipaleolithic sites starting 23,000 years ago and in Natufian sites starting ca. 15,000 years ago (Bar-Yosef and Belfer-Cohen 1991; Bar-Yosef and Meadow 1995; Valla 1995), i.e., considerably earlier than the suggested dates of cultivation or documented morphological domestication of plants.³ This is also the case for stone pounding and grinding tools (see the 23,000-year-old site of Ohalo II by the Sea of Galilee, Piperno *et al.* 2004;⁴ or Paleolithic examples provided by Mercader 2009—and these are only two out of many other examples; see Revedin *et al.* 2010; Mariotti Lippi *et al.* 2015).

Another example is the notion of storage installations as evidence for pre-domestication cultivation, a view that falls short on two counts. First, although rare, small-scale installations (stone-lined and lime-plastered) do appear, and have been interpreted as storage facilities from the Natufian (e.g., Valla 1995: 173 and Pl. 4). Secondly, although the Pre-Pottery Neolithic A (PPNA) is richer in installations considered to be silos of cultivated grain, whether wild or domesticated (e.g., Bar-Yosef and Gopher 1997: 57–58, 61, Fig. 53.23; Finlayson *et al.* 2011; Kuijt 2008; Kuijt and Finlayson 2009), such installations in the southern Levant show no evidence of stored seeds or of other plant remains, leaving any agricultural implication mere speculation.⁵ Notably, for the PPNA site of Jerf el Ahmar in the northern Levant (i.e., within our suggested core area)

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3. Single sickle blades—flint items showing harvesting gloss characteristic of contact with stems of cereals, i.e., harvesting—were found in Early Epipaleolithic sites, including Ohalo II (Snir *et al.* 2015) and Nahal Hadera V (unpublished—A.G.).
 4. A study by David Eitam, however, claims that this type of object from Ohalo II could not have served efficiently for pounding or grinding cereals, as evidenced by its small production abilities (Eitam 2013), as suggested by Piperno *et al.* (2004). On the other hand, Eitam and Schoenwetter (2020) consider the narrow conical mortars of the Natufian as a central component designed to dehull wild barley and to mill cereal grains into fine flour for bread making. The latter authors view cereals and bread consumption as significant in Natufian subsistence economy, and as defining the Natufians, in the spirit of Smith (2001), as low-level food producers. Of note in this regard is the recent paper by Arranz-Otaegui *et al.* (2018) presenting evidence for the preparation and consumption of bread-like products by Natufian hunter-gatherers (dated to ca. 14,000 years Cal. BP) at the site of Shubayqa 1 in Jordan.
 5. For example, the PPNA site of WF16 in southern Jordan was presented as including an array of storage facilities and as a “storage site” for PPNA communities (Finlayson *et al.* 2011; Kuijt and Finlayson 2009), yet the archaeobotanical records for cereals and legumes of that site, as published in the final report by Kennedy (2007), amount to no more than a single whole (identifiable with difficulty) grain of a cereal (possibly barley) and three possible pulse seeds, about which “... it was impossible to tell if they were lentils, pea or vetches,” finally presented as *Viciae*. One should mention here the basket from Gilgal I, House XI (see Box 2.4).

the evidence for storage is far from convincing;⁶ the same is true for additional PPNA sites.

Two claims pertaining to cultivation were voiced by excavators of the Middle Pre-Pottery Neolithic B (MPPNB) site of Tell Halula on the Euphrates. One concerns the presence of limestone hoes (Ibáñez *et al.* 1998),⁷ seemingly used for tillage. The other relates to potential water-harvesting techniques indicative of some type of irrigation.⁸ Even if we accept these two aspects as evidence for cultivation, the Tell Halula findings—dated mainly to the tenth millennium Cal. BP (at least half a millennium later than the earliest evidence for domesticated plants in the very region of this site)—are too late in the Pre-Pottery Neolithic B (PPNB) to be relevant as reference for pre-domestication cultivation or plant domestication in this area.

Another presumed indication of cultivation is displacement, i.e., the moving of plant species beyond their natural range, as deduced from their present and past distributions. Below we present two examples commonly used by supporters of a displacement claim, but which we find lacking. One is the case of the chickpea. Tanno and Willcox (2006b) presented charred chickpea seeds from Early Pre-Pottery Neolithic B (EPPNB) Tell Ain el-Kerkh in northwestern Syria (second half of the eleventh

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6. Willcox and Stordeur (2012: 107) report that the archaeobotanical samples originated from diverse contexts and that “Direct evidence of storage from *in-situ* charred crops was not found.” They further state that “Indeed storage-like structures consisting of small cells ... contained higher than average frequencies of cereals,” adding that cell 5 in building 30 (EA30, level II/W [i.e., the later part of the sequence of the site] was a silo based on its small low [“closable”] opening (p. 108). They go on to state that such silos are “... typical of traditional Syrian silos still used today ...,” concluding that “the earlier phases [at Jerf el Ahmar] no storage structures were found” (p. 109). Notably, in a summary statement by Willcox (2018) he expresses his “almost pride” in the storage facilities and structures of Çatal Höyük (dated to the very late PPN and mostly to the Pottery Neolithic period, i.e., at least a millennium and a half after the documented beginning of plant domestication), and remarks that “While such structures are not uncommon on earlier sites, the charred contents in these cases represent the fill and not the original stored products” (Willcox 2018: 91). Later in that short summary he notes that we still do not know whether PPNA and PPNB sites had communal grain storage.
 7. This argument, however, has not been followed up by Ibáñez in the past two dozens of years, and no additional supporting evidence has appeared either at Tel Halula or at other Neolithic sites in the region. Large southern Levantine bifacial (mainly flint) tools, such as axes, adzes or chisels, considered in the past to be used for hoeing, do not reveal use-wear traces of hoeing, but rather of tree felling and woodworking (e.g., Barkai 2005; Barkai and Galili 2003; Yerkes and Barkai 2004; 2013; Yerkes *et al.* 2003; Yerkes, Khalaily and Barkai 2012; Yerkes, Galili and Barkai 2014), and this is the case for bifacial tools throughout the Neolithic period, the Pottery Neolithic included.
 8. This contention was based on a comparison between photosynthetic carbon-isotope discrimination in local crop plants and archaeobotanical data from Tell Halula (e.g., Araus *et al.* 1999; 2001; 2007). Note, however, that the irrigation claim was subsequently withdrawn by the same research group (Araus *et al.* 2014).

millennium Cal. BP),⁹ suggesting that chickpea was displaced and cultivated there. Such a displacement, assuming that no change occurred in the distribution of *Cicer reticulatum*, the wild progenitor of domesticated chickpea,¹⁰ implies full domestication for the Tell Ain el-Kerkh chickpea finds because without a free germinating phenotype, no chickpea cultivation can be assumed (Abbo *et al.* 2011). Indeed, some of the well-preserved excavated chickpea seeds at Tell Ain el-Kerkh are rounded, i.e., they differ in shape from the wild progenitor and are similar in shape to certain current domesticated chickpea cultivars (e.g., Fig. 1 of Abbo *et al.* 2014). The nearest known populations of the wild progenitor are some 230 km away to the north-northeast of the site (near Besni, Adiyaman province, Turkey). Tanno and Willcox (2006b) thus provide a credible indication for the timing of chickpea domestication that must have taken place prior to its arrival at Tell Ain el-Kerkh, and—following the seed morphology—most probably indicates the spread of a domesticated stock and not a displacement of wild stocks (see n. 9 and Chapter 5, esp. n. 2 on p. 113).

The second example concerns the identification of einkorn from Jericho (e.g., Garrard 1999), an important case owing to its frequent citation as evidence for early plant domestication in the lower Jordan Valley, i.e., in the southern Levant. Despite the problems noted concerning the Jericho einkorn data (Nesbitt 2002: 127), some researchers (e.g., Fuller, Willcox and Allaby 2011; Fuller, Asouti and Purugganan, 2012a; Weiss, Kislev and Hartmann 2006) accept it as proof of multiple (i.e., autonomous) einkorn domestication, and hence of its displacement. Einkorn has never been reported as a traditional southern Levantine crop, and its natural distribution range is found mainly in the northern Levant and across Asia Minor from the Trans-Caucasus to the eastern Balkans (Harlan and Zohary 1966). The documented wild population closest to Jericho occurs in the Lebanon Mountains (*ibid.*), hundreds of kilometers to the north of Jericho, in a significantly colder and more humid environment. Most of the studied domesticated einkorn cultivars are extremely late-flowering relative to barley or emmer wheat, and many einkorn cultivars require vernalization (a growth period of close to 0 °C temperatures) to facilitate timely flowering. This may explain why einkorn was never adopted as a crop in the southern Levant, especially in the extremely hot lower Jordan Valley. Given the

9. Botanical finds at Tell Ain el-Kerkh (northwestern Syria) are presented for the EPPNB stratum as a whole, with no division into sub-layers. Since the oldest date(s) originate in the low sub-layer 9, and since we are unable to determine where in this layer the seeds were located, this important archaeobotanical assemblage awaits a future detailed report. The dating of Tell Ain el-Kerkh in the supplementary materials of Purugganan and Fuller (2011) is based on five ¹⁴C dates with a (median) EPPNB date of 8,430 Cal. BCE (10,380 Cal. BP), while Asouti and Fuller (2013) dated those findings to a range of 8,540–8,320 Cal. BC (10,490–10,270 Cal. BP) based on four ¹⁴C dates.

10. This is in line with Willcox's (2005) assumption for cereals, but is in contrast to a note by Tanno and Willcox (2006b) implying a possible change in the distribution of the wild progenitor of chickpea.

biology and the agronomy of einkorn (either wild or domesticated), it is hard to assign to it the status of a southern Levantine crop, let alone a wild progenitor. Therefore, despite the suggested (indirect) identification of einkorn (by impressions of three spikelets of a tough rachis type in one mudbrick) at Jericho in the PPNA (during the twelfth millennium and the first half of the eleventh millennium Cal. BP), we concur and think that these data should be reconsidered (see Nesbitt 2002: 127). Notwithstanding this, if the case of the Jericho einkorn is accepted as evidence for displaced einkorn cultivation (for details, see Box 2.1), it implies a northern Levantine origin (where it is native), hence lending additional support to a northern core-area model, as the current work suggests.

We argue that no reliable data supporting plant domestication in the southern Levant are available for pre-Neolithic (Natufian), for Pre-Pottery Neolithic A, or even EPPNB¹¹ sites. This lack of evidence is of relevance for sites that are the major sources of questionable data for plant domestication—Jericho, Tell Aswad IA,¹² and Iraq ed-Dubb. In Box 2.1 we offer a closer look at these sites and show that the presented evidence and arguments have serious deficiencies and shortcomings, rendering the claim for a southern Levant “center” or “sub-center” of plant domestication based on these sites ultimately irrelevant.

One of the lessons to be learned from these cases is that in any discussion of plant domestication, only unequivocally botanical data should be considered. The cases of Jericho and Tell Aswad exemplify the problems associated with data that originate in old excavations using old recovery methods. The lack of direct chronological evidence from studied seeds is crucial, and the context and setting of the sites are important for decisions on their relevance for plant domestication. Most of all, however, the claim that plant domestication originated in the southern Levant ultimately suffers from two cardinal shortcomings: first, that the progenitors of two major Neolithic package species (e.g., einkorn, chickpea) simply do not grow in the southern Levant, and secondly, that available genetic data for package species other than certain barley cultivars (e.g., Badr *et al.* 2000) localize their closest wild genetic stocks, and hence their domestication, to the northern Levant.¹³

11. The archaeobotanical record in the southern Levant shows no domesticated plants in its EPPNB sites and only few in its MPPNB (10,200/10,100–9,400/9,300 Cal. BP) sites (e.g., Ain Ghazal [Rollefson *et al.* 1985] or Yiftahel [Kislev 1985; Kislev, Garfinkel and Zohary 2012]). Recent discoveries of pulses in PPNA (ca. 10,200 Cal. BP) sites in the Galilee, northern Israel (Caracuta *et al.* 2015), should be mentioned in this respect, as they were assigned to the EPPNB, although their ¹⁴C dates are basically no older than the range presented in this footnote.

12. This is the oldest so-called PPNA layer in Henry de Contenson’s excavation at the site in the 1960s. This is where the data, following a study of the archaeobotanical finds by van Zeist and Bakker-Heeres (1985), which were used to support early plant domestication in the southern Levant, originated.

13. For barley, some of the domesticated stocks originated in the northern Levant (Pourkheirandish *et al.* 2015; Civián and Brown 2017; Civián *et al.* 2021; and see Chapter 4).

All in all, then, the archaeobotanical data from the sites discussed in Box 2.1, as important as they are, may play only a relatively minor role in the debate on cultivation or Levantine plant domestication. Discussions in recent years tend to focus primarily on pre-domestication cultivation and the evidence required for supporting or negating it, and in this respect, on the study of plant remains that are interpreted as weeds of cultivation, which has become central to this line of research. In the following, therefore, we expand on these two issues.

Box 2.1: On the Quality of Evidence for Early Plant Domestication in the Southern Levant: Three Test Cases

Jericho

The Jericho “finds of einkorn” have for many years served as evidence for a southern Levant plant domestication in the Jordan Valley. This claim has gained a place of honor and has become a frequently quoted, almost canonized, source. Critiques were initiated by Mark Nesbitt as early as 1998 (Nesbitt and Samuel 1998) and in a more direct way since the early 2000s (e.g., Nesbitt 2002; Colledge 2004).

The botanical data from Neolithic Jericho published by Hopf (1983) were used by Jones, Allaby and Brown (1998), Garrard (1999: Table 3), Colledge (2001; 2004), and others (e.g., Fuller, Willcox and Allaby 2011; 2012; Purugganan and Fuller 2011) to support a southern Levant domestication of cereals. Inconsistencies in their use of those data, as pointed out by Gopher, Lev-Yadun and Abbo (2013), indicates that their claim for early domestication of cereals in the PPNA and PPNB strata of Jericho is based on questionable data and cannot be reliably supported. Reported samples include emmer (possibly), barley grains and chaff, as well as einkorn¹ (possibly

1. Wild einkorn was found in several northern Levantine Natufian and PPNA sites, and was also suggested to be found in southern Levantine PPNA Jericho (not as a seed, but as interpreted from a mudbrick impression) and at Iraq ed-Dubb. Garrard (1999) claimed an early appearance of domesticated einkorn in Jericho PPNA, but see our comments above and Nesbitt (2002: 127). Domesticated einkorn was found as early as the EPPNB in the northern Levantine Euphrates area (Nesbitt 2002) and in southern Levantine Jilat 7 (Colledge 2001: 144 and Table 6.5 on p. 162; accepted by Nesbitt 2002). The Jilat 7 finds, however, are dated to ca. 10,000 Cal. BP, and see the suggestion, in Asouti and Fuller (2013), of a range of 8,200–7,350 Cal. BCE (10,150–9,300 Cal. BP) for these finds, i.e., several centuries after einkorn domestication in the northern Levant. Moreover, the candidacy of Jilat 7 for harboring the earliest domesticates in the region seems to merit further thought, due to its nature as a small desert site. Domesticated einkorn is present in later MPPNB and Late Pre-Pottery Neolithic B (LPPNB) sites in the Levant.

non-brittle rachises as seen in mudbrick impressions; Hopf 1983). However, problematic stratigraphy, together with the even more problematic dating of the mudbricks and of the levels or sediments from which the archaeobotanical finds originated, led to scholarly disagreement regarding the domesticated nature of cereals in the Jericho PPNA sample (Nesbitt 2002; Nesbitt and Samuel 1998: n. 3). A good summary of this issue can be found in a statement by Nesbitt:

...material from Jericho reached full publication in 1983, by which time virtually all the domesticated material had been reassigned to the PN (8th and 7th millennia Cal. BP), and the remaining PPNA period material (still dubious) is dated to 9,300–9,200 BP [uncalibrated—our addition].² (Nesbitt 2004: 38)

Moreover, according to Colledge, ¹⁴C dating shows that:

... in the case of the domestic cereals found in PPNA levels at Jericho, after re-examination of the contextual associations of the samples from which they were taken [i.e., stratigraphic stages within the PPNA], it was suggested that they were contemporary in date [as shown by ¹⁴C dating] with the later EPPNB [in the northern Levant], thus providing evidence supporting the idea of the dispersal of the founder crops from the northern Levant at this early stage, to the south and west (to Cyprus) from the areas in which, it has been proposed, they were domesticated [i.e., from the core area in the northern Levant].” (Colledge 2004: 57)³

Regarding Levantine PPNA, mainly from Jericho, in comparison to wheat and barley finds from EPPNB Kissonegra Mylouthkia in Cyprus, Colledge, Conolly and Shennan (2004) concluded that Jericho (like Cyprus) was not the source, but rather the recipient of domesticated plants. We do not discuss MPPNB Jericho here as

2. In calibrated years, this would be ca. 1,000 years earlier.
3. Considering Jericho’s latest PPNA dates, PPNA dates from Zaharat Adh-Dhra’ 2 (ZAD 2; Edwards *et al.* 2004), and EPPNB dates from Motza (Moza) (Yizhak *et al.* 2007), a gradient (i.e., retardation effect) emerges on a north (early)–south (late) axis within the Levant (e.g., Gopher 1989a; 1989b; 1994). By inference, then, even if the later phases of PPNA Jericho (and, for that matter, of ZAD 2 as well) had yielded domesticates, these would still be several centuries later than the early parts of the northern Levantine EPPNB. This notion is further supported by dates provided by Fuller, Asouti and Purugganan (2012a: Table 2), assigning the onset of the EPPNB in the northern Levant to 10,750 or 10,700 Cal. BP while the southern Levantine PPNA continued for a few more centuries. This would prevent any archaeologically viable potential of the southern parts of the Levant (including Jericho and the purported PPNA Tell Aswad) from representing an innovative (primary, autonomous) center of domestication.

it spans mostly the tenth millennium Cal. BP (ninth millennium uncalibrated BP), rendering any of its archaeobotanical finds too late to be relevant to the onset of domestication of founder package plants.

Tell Aswad IA

Domesticated emmer wheat from Tell Aswad IA was first dated to ca. 11,000 years Cal. BP (following the excavator Henry de Contenson) or slightly later (10,700 Cal. BP). This served as the most significant evidence claiming that the southern Levant, and specifically the Damascus basin, was where cereals were first domesticated in the PPNA. Despite this, one of us suggested almost three decades ago, on the basis of the flint tool industry, that this layer must be later than claimed by the excavators and should in fact be assigned to the PPNB (Gopher 1994: 260). Renewed excavations of Tell Aswad indeed resolved the issue of chronology at this site (Stordeur 2003a; 2003b; Stordeur *et al.* 2006; 2010). The reassessed stratigraphy and new ¹⁴C dates (Stordeur *et al.* 2010; Willcox 2005)⁴ showed that there are no PPNA layers at Tell Aswad. EPPNB presence, too, is scarce or missing in some parts of this large tell site. Based on new ¹⁴C dates from plant materials originating in both the old and the new excavations, the oldest dates from Tell Aswad range between 10,450 and 10,150 Cal. BP, close to the end of the eleventh millennium Cal. BP (Willcox 2005: 535, Table 1).⁵

4. Willcox, a team member of the new excavation at Tell Aswad, re-dated emmer grains from phases IA and IB of the original excavation by Henri de Contenson. Using accelerator mass spectrometric (AMS) dating (GrA-25913, GrA-25915, GrA-25916, GrA-25917), he established a date range of 9,300–9,000 uncalibrated BP (Willcox 2005). This would denote a date in the second half of the eleventh millennium Cal. BP (possibly not earlier than 10,400 Cal. BP), indicating that the EPPNB was most probably younger than that.
5. Claims put forward to support independent, autonomous plant domestication in the Damascus basin (e.g., Fuller, Willcox and Allaby 2011; 2012; Purugganan and Fuller 2011) seem to have been based on incomplete data regarding the site of Tell Aswad (Gopher, Lev-Yadun and Abbo 2013). While Stordeur *et al.* (2010; cited in Fuller, Willcox and Allaby 2012) offered twelve ¹⁴C dates from the new excavation (including three AMS dates), and the new dates from materials excavated during the old de Contenson excavation provided 14 dates (including four AMS dates), Fuller, Purugganan and their colleagues used 13 ¹⁴C dates for their calculations, thus leaving readers to wonder what data combination of the 26 available dates was utilized and what criteria were used to select them. The discrepancy in the number of dates is further accentuated in view of the fact that these authors (Purugganan and Fuller 2011) cited Colledge (2004) for Tell Aswad ¹⁴C dates, where only ten dates are listed for this site. The presentation of Tell Aswad ¹⁴C dates was later partly amended by some of those authors (Asouti and Fuller 2013, Supplement A: 28–29).

Iraq ed-Dubb

Surveyed and excavated in the late 1980s and early 1990s, this site in Jordan includes both Late Natufian and PPNA layers dated to 13,500–11,500 and 11,500–10,500 Cal. BP, respectively (Kuijt 2004; Kuijt and Goodale 2006). Challenges to the dating, however, emerge from three different perspectives. First, available dates were made on wood charcoal (n=6) and nut fragments (n=2) rather than on seeds, a fact of potential significance since such materials may yield older dates. A second challenge derives from the paucity of the published botanical data (Colledge 2001; Nesbitt 2002; Savard, Nesbitt and Jones 2006). Finally, possible disturbances by recent herders cannot be ruled out considering the dung layer found on top of the sequence (Palombo, Mabri and Kuijt 1990), as well as “known intrusion of plant materials from upper levels to lower” (Nesbitt 2004: 38). We therefore echo Nesbitt (2002) by saying that this small cave and terrace site is not the ideal case on which to base a claim regarding the beginning of plant domestication (see also Nesbitt 2004: 38) and the beginning of agriculture in the southern Levant PPNA. This is especially true considering that larger neighboring Jordan Valley village sites, including Jericho, Netiv Hagdud, Gilgal I and the late PPNA ZAD 2, all of which yielded well-preserved archaeobotanical finds, show no signs of domestication.

In summary, these three southern Levantine “PPNA” datasets have been criticized by various scholars for almost three decades now. Willcox (2004a; 2005) expressed doubts regarding both the suggested PPNA at Iraq ed-Dubb and findings from the original (Henry de Contenson) excavation of Tell Aswad IA data, since the radiocarbon dates obtained were not from seeds. Willcox (2005) added that at PPNA Netiv Hagdud, at Dhra, at WF16⁶ and at the late-PPNA site ZAD 2—and following Weiss Kislev and Hartmann (2006), we may add the site of Gilgal I as well—there are sufficient ¹⁴C dates, but that none of these sites shows domesticated package plants. Thus, Willcox actually ruled out the southern Levant as the source of domesticated plants, thereby implicitly supporting a northern origin for the domestication of most package plant species except for barley, which, he maintained, was domesticated first in the southern Levant. Colledge (2001; 2004; Colledge, Conolly and Shennan 2004), in her critical review of the southern Levant data (see below) and her summary statements,⁷ also provided

6. See n. 5 on p. 33 above and Kennedy (2007).

7. For southern Levant EPPNB, the claim for domestication is based on domesticated einkorn (which does not grow in this region) identified by Colledge at Jilat 7 (see Garrard 1999; Nesbitt 2002; and see above, n. 1 in Box 2.1).

everything needed to refute a southern Levant origin of plant domestication. In addition, she talked explicitly about a spread from the northern Levant (Colledge 2004: 57; and see the above discussion on Jericho). The presence of imported package plants on the island of Cyprus (in EPPNB) also casts doubt on the possible origins of domesticated package plants in the southern Levant. Peltenburg, for instance, argued, in a quite straightforward way:

... Reliance is placed on dates from three sites, but those from Jericho are equivalent to relevant dates from Çayönü in the north, and Danielle Stordeur's recent reinvestigations of Tell Aswad (personal communication)⁸ raise serious questions about the existence of any Early PPNB there [let alone PPNA]. This leaves the anomalously early dates from Iraq ed-Dubb to sustain the southern Levant primacy argument, so further evidence is clearly required. (Peltenburg 2004: 52)

It is noteworthy in this context that a recent paper by Bar-Yosef Mayer *et al.* (2015) on seafaring in the eastern Mediterranean shows that the chances of reaching Cyprus from the southern Levantine coast are much lower than from the northern Levantine coasts of Turkey owing to seafaring conditions and sea currents. We join Willcox, Colledge, Peltenburg and others in rejecting a southern Levantine source for EPPNB Cypriot domesticated plants.

8. These have since been published; see, e.g., Stordeur 2003a; 2003b; Stordeur *et al.* 2006; 2010.

Pre-Domestication Cultivation and Weeds of Cultivation

Serious attempts to construct a systematic framework that would allow for the identification of cultivated wild species (pre-domestication cultivation) were made as early as in the 1970s (e.g., Pullar 1977; see Hillman 1975), but more frequently since the 1980s.

The term “pre-domestication cultivation” was coined by Hillman (in Moore 1975) while attempting to better understand cultivation. Hillman and Davies (1992: 121; 1999: 75) defined this term, as well as the related term “non-domestication cultivation,” quite rigorously in the framework of their study, in which they concluded that the domestication of einkorn could have been achieved within a time frame spanning anywhere from 20 years to two centuries (Hillman and Davies 1990a; 1990b; 1999).

This catchy term has since evolved into a concept that implicitly indicates yet another stage in the sequence of the human–plant relationship eventually arriving at domestication, and carries a broad range of new meanings.

One of the most important studies in this connection was based on the archaeobotany of Tell Abu Hureyra (e.g., Hillman, Colledge and Harris 1989; Hillman and Davies 1990a; 1990b; 1992: 121; 1999: 75). Four aspects were defined as useful by Hillman (2000) and by Hillman *et al.* (2001) when they proposed pre-domestication cultivation in the Natufian (13,000 Cal. BP years old) layer 1 of Tell Abu Hureyra:

- the presence of seeds of the so-called “weeds of cultivation”;
- the geographic displacement of particular food plants;
- shifts in use-wear patterns on flint sickle blades (see Unger-Hamilton 1989);
- a change in the size of seeds.

Given their centrality to the issue and considering the history of the debate and its complexity, it is essential to review these four aspects through a careful and detailed survey of publications of major protagonists and to follow the dynamics of their arguments over time. These include the works of Gordon Hillman (who instigated the discussion), Sue Colledge and George Willcox. Here we present a critique of these four points (without following their above order).

Grain and Seed Size

Increase in seed size is not necessarily a sign of cultivation and/or domestication. On the contrary, in some cases, like that of domesticated *Triticum parvicoccum*, a selective pressure worked in favor of a reduced seed size (see Kislev 1979–80; 2009). Moreover, increased seed size could have originated in post-depositional circumstances. For example, Harlan (1995: 79) described the swelling of seeds of einkorn wheat during charring, up to the point where they resembled seeds of bread wheat. He concluded that, at least for cereals, charring could shorten the grain while increasing its width and depth (thickness). Willcox (2004b; see Box 2.2 for the sites studied and general comments) argued that the increase in seed size was not the result of a plastic phenotypic response (a result of growing conditions, i.e., cultivation), but instead was characteristic of a genetic change in the population. Notably, however, the trend did not continue, and there was no further increase in cereal-seed size in the Euphrates area for several millennia.¹⁴ In a

14. “Thus, there was no increase in grain size between the late tenth millennium and the late seventh millennium (BP Non Cal.), at least within the confines of this investigation, indicating that grain size was stable following the initial increase” (Willcox 2004b).

later publication, Willcox (2012a: 171–172) again raised the possibility that increasing grain size is related to cultivation and suggested, as an alternative, that the plump-grained population was introduced from elsewhere, indicating displacement. He also cited the assertion of Fuller (2007) that the increase in grain size was the result of genetic selection. However, in Asouti and Fuller (2013: 308) we find the statement: “Larger grain size is selected for by soil clearance, tillage, and seed planting,” i.e., by cultivation. Note, however, the experimental data by Kluyver *et al.* (2013; 2017), refuting the later claim.¹⁵ Either way, whether by genetics (i.e., selection that changed allele frequencies) or by cultivation (environmental effect), the considerable overlap in seed size between the wild einkorn or emmer and their respective domestic types does not qualify this trait to constitute sufficient evidence for cultivation or for domestication or for both, and certainly not as the sole evidence for either phenomenon (see also Abbo *et al.* 2014). For further notes on grain size and plant domestication see Box 2.2.

Box 2.2: Grain Size as a Measure for Plant Domestication

An increase in size of the economically important (target) organ of domesticated forms relative to their wild progenitors is an almost universal phenomenon. Indeed, it features in almost every account of plant domestication (Harlan, de Wet and Price 1973) and is generally accepted as a central element of the domestication syndrome (e.g., Hammer 1984; Olsen and Wendel 2013). It is therefore natural for students of plant domestication to attempt to track the chronology of the evolutionary change that caused the prominent difference in grain size between our domesticated crops and their wild progenitors (see also Arranz-Otaegui *et al.* 2016).

The first systematic exploration of trends in grain size among Levantine archaeobotanical assemblages was by Willcox (2004b). Dimensions of einkorn and barley grains recovered from Neolithic sites (PPNA Jerf el Ahmar and Dja'de) were compared with those of grains obtained from an adjacent late Neolithic (PN) site (Tell Kosak Shamali). Grain sizes from early and late substrata of PPNA Jerf el Ahmar

15. Clearly and cautiously, Willcox says (2018: 92): “An increase in seed size is well-documented in the paper of Fuller *et al.* 2018 (in the same volume), but is this the result of genetic changes or improved growing conditions?”

itself were also compared. The scatter plots of grain-size data show a trend of increase from early to later PPNA occupation levels of this site (Willcox 2004b).

Different interpretations for the documented diachronic increase in grain dimensions of einkorn, barley and emmer have been offered over the years. However, none of the papers on this subject has taken into account the considerable phenotypic overlap between wild and domesticated barley, emmer, chickpea or lentil, as indicated by Abbo *et al.* (2014).

Since changes in grain dimensions have continued throughout historical periods and to this day, it is methodologically wrong to assign to grain size a diagnostic value vis-à-vis plant domestication, since in essence it is a crop-evolution (post-domestication) trait (Abbo *et al.* 2014).

Shift in Use-Wear Patterns on Sickle Blades

This aspect was never developed into a crystallized argument and remains an isolated claim by Unger-Hamilton (1989), used also by Hillman, Colledge and Harris (1989) and by Hillman and Davies (1990a; 1990b; 1992; 1999). A couple of decades ago, Colledge (1998) maintained that neither traces of use wear on flint sickle blades (e.g., Unger-Hamilton 1989) nor changes in grain size (Hillman, Colledge and Harris 1989) provides clear-cut, undisputed evidence of pre-domestication cultivation. Recent attempts to use new methods in use-wear analysis on samples from Natufian and Neolithic sickle blades from the Levant have indeed failed to provide clear results, despite their professed potential (Ibáñez, González-Urquijo and Gibaja 2014). Further results, based on experimental harvesting and treatment of larger archaeological flint sickle blade samples, have not fully resolved the issue (Abbo *et al.* 2021; Ibáñez *et al.* 2016). In any case, the argumentation on which the entire idea is based is problematic (Box 2.3).

Some of the questions put forward in this box seem to find answers in explicit or implicit statements by supporters of the protracted autonomous model of plant domestication in the Levant. The logic that guides Ibáñez and his colleague is directly and strongly related to and based on this model, as presented in recent years in studies mainly by George Willcox and colleagues, as well as by Dorian Fuller and colleagues. These authors, in heralding the protracted autonomous model of plant domestication in the Levant, seem to assume that the mixture of non-shattering and shattering types of cereals in the archaeobotanical record results from the occurrence of both types within a population of the same field (e.g., Willcox 2012a). For example, Purugganan

and Fuller (2011: 181), in reference to Willcox, Buxo and Herveux (2009: 156), say that “...at least for non-shattering, both forms are present in the crop and are so similar that the Early Neolithic farmers may have simply considered them the same crop and could not consciously differentiate cultivated from wild forms in the field.” According to Willcox, Fornite and Herveux (2008: 324), “On a more general level, gathering and cultivation of wild cereals probably occurred simultaneously over a long period, which is why we see no sharp division from one economy to another, the transition being extremely gradual.” How, then, would Ibáñez make the distinction based on green vs. dry harvesting in a mixed field? Is it at all possible? Or was it logical for the Neolithic (or pre-Neolithic) farmer? And if the use wear indicating harvesting of green cereals indeed relates to cereals collected in the wild, then again, how is it related to presumed domestication dynamics? Moreover, the aspect of replenishment (see Box 2.4, Case 2) claimed by Willcox and others (Willcox 2012a: 170; and see below in this chapter) emphasizes an additional related problem since it would mean, again, that the shattering and non-shattering types grew together in the same field (Abbo *et al.* 2021).

In summary, we find it hard to believe that Neolithic farmers deliberately grew mixtures of shattering and non-shattering cereal stocks for millennia. Still, even if the scenario of shattering and non-shattering growing in the same field is accepted (as it is by supporters of the protracted autonomous model), several problems remain inherent in the evidence advanced in its support. We have no doubt that it is possible to distinguish between the use wear related to the harvesting of green cereals and to that of dry cereals under the microscope, and following a straightforward set of controlled experiments (*sensu* Ibáñez, González-Urquijo and Gibaja 2014; Ibáñez *et al.* 2016). Nevertheless, we find the logic underlying the claim that pre-domestication cultivations can be identified by studying use wear on sickle blades to be flawed and irrelevant to the problem we face.

Box 2.3: Cultivation, Domestication and Use-Wear Analysis of Sickle Blades

The basic idea underlying the studies attempting to support pre-domestication cultivation, in this case by analyzing flint sickle blades from relevant archaeological sites, is that there will be a detectable difference between use-wear signs on flint sickle blades used to harvest shattering (i.e., wild) cereals vs. non-shattering (domesticated) cereals. The argument, as

presented, maintains that harvesting of wild cereals would be profitable only if carried out while they are still partially green (otherwise a considerable portion of the yield would be lost as a result of spikelet shattering), whereas domesticated cereals can be harvested when they reach full maturity and the culms are dry. In our view, there is an inherent problem of logic in this idea as a whole (see Abbo *et al.* 2021). First, if harvested when spikes are not fully ripe, some of the grains may eventually shrivel and be of poor nutritional quality. This is because it is only upon full physiological maturation that the conversion of simple carbohydrates into starch is completed. Second, in nature, wheat and barley spikelets can be efficiently collected from the ground even several months after shattering, as shown by Kislev, Weiss and Hartmann (2004).

Viewing the issue in a broader perspective: pre-domestication cultivation serves the protracted autonomous model, which suggests that the slow rise of non-shattering cereals continues (by unconscious, automatic selection) over pre-domestication cultivation time, until the non-shattering types take over or dominate the managed cereal population. That is to say, this model postulates a long series of situations in which the shattering and non-shattering types appear together, in varying percentages, throughout the protracted process of domestication and hence in the archaeobotanical records (e.g., Willcox 2012a: 178–179). Delving more deeply into a preliminary simulation of what this means in practice yields several questions: Where do the mixed (shattering and non-shattering) plants grow? Do they grow together in the same cultivated field? If so, can the different types growing in a mixed stand be harvested (by sickles) selectively, i.e., the shattering ones while partially green, without trampling the remaining (non-shattering) plants, or—if one chooses to harvest the non-shattering plants while ripe—without losing part of the yield of the shattering ones? And how can the different genotypes be identified before shattering occurs? If harvested together, how will this be reflected in use-wear marks on flint sickle blades? Has anyone presented a gradient of use-wear patterns that parallels the presumed changing frequencies of shattering/non-shattering individuals during the various phases of pre-domestication cultivation (as presented recently by Fuller *et al.* 2018 [see below])? Or do the different cereal stocks (shattering and non-shattering) grow in separate managed fields or plots? If so, why would one bother to maintain a field of shattering (wild) cereals close to one's own field sown with

non-shattering cereals stocks? In addition, if the recovered archaeobotanical findings of wild types were in fact not cultivated but rather represent gathering from the wild, as was indeed the case for thousands of years before domestication, then does the entire argument (about whether the increasing percentage of non-shattering types occurs by automatic selection or by some other means) translate into a totally different story, remote from domestication and irrelevant (Abbo *et al.* 2021)?

Geographic Displacement (along the Euphrates?)

Beyond the two examples presented above for the displacement of chickpea and of einkorn, Hillman and colleagues (Hillman 2000: 397–398; Hillman *et al.* 2001), based on a detailed analysis of the archaeobotanical remains and a reconstruction of the Late Natufian environment of Tell Abu Hureyra 1 (ca. 13,000 Cal. BP), suggested that cultivation (and domestication) might eventually imply displacement of particular food plants over rather short distances along the Euphrates and some of its tributaries. In our opinion, this suggestion falls short for many reasons; suffice to say that a riverbank site such as Tell Abu Hureyra offers specific conditions that may promote other, more parsimonious, explanations for plant displacement, such as transportation from up-river or from locally wetter habitats (see Bar-Yosef 2014a).¹⁶

Weeds of Cultivation

The most intriguing aspect mentioned by Hillman, Colledge and Harris (1989) is the proposed presence of weeds of cultivation. The work of Gordon Hillman and the case of Tell Abu Hureyra seem particularly well suited for assessing the notion of pre-domestication cultivation, as they offer large samples and one of the most detailed archaeobotanical reports available for the Neolithic Levant. However, the list of Natufian (Layer 1) plant remains that are claimed to have accompanied cultivated fields (i.e., weeds of cultivation) consists primarily of plants identified at the family and genus levels, and only rarely at the species level. Mostly, these genera include a large number of species of which only a few, at best, are known as genuine field weeds (see details below on the genera *Galium* and *Centaurea*).

16. Note that accepting the presence of Pre-Pottery Neolithic (PPN) sites on Cyprus (including PPNA and EPPNB—and some would claim even earlier sites) must involve seafaring in the open sea; this makes suggestions for river transportation quite feasible options.

The lack of detailed species identification undermines the reliability of any statement concerning their nature as weeds of cultivation or as wild plants of other habitats. Thus, even Hillman, being aware of the problem, admitted that the plants he considered to be weeds of cultivation in this Late Natufian layer could also be “...plants of wadis, wadi banks, valley bottoms and N-enriched ruderal habitats” (Hillman 2000: 347). De Moulins (2000: 401, 408, 412) reached similar conclusions concerning the much later PPNB archaeobotanical finds at the same site (ca. three millennia later, in fact). While she contended that a specific family or genus could reflect “weeds of dry land cultivation,” she also stated that these “...may also be [considered] native to steppe and woodland” or that they may have originated in “...moist steppe and open areas of parkland ... sometimes growing as weeds”—rendering her original claim inconclusive.

Despite their favorable viewpoint towards pre-domestication cultivation, both Hillman (2000) and De Moulins (2000) leave open the question of whether or not the potential weedy nature of the identified taxa is indicative of agricultural operations. Both are very careful in their statements on weeds of cultivation prior to their assertion that these are indeed weeds of cultivation and that the finds are in fact sufficient to support the case for pre-domestication cultivation. It is important to note here that Hillman, Colledge and Harris (1989, following a summary of the data from Late Natufian Tell Abu Hureyra Layer 1) had concluded that the evidence was insufficient to indicate cultivation of cereals and pulses:

The implication of this result for the archaeobotany of steppe sites is clear. Conspicuous abundance of seeds of supposedly “segetal” species in association with remains of wild-type cereals or pulses does *not* [emphasis in the original] necessarily indicate that the cereals or pulses were under cultivation; such “weed” seeds could equally have been derived from natural steppe. (Hillman, Colledge and Harris 1989: 254)

Thus: “Viewed separately, the lines of evidence remain inconclusive. Taken together, however, lines (b) and (c) (as listed by Hillman, Colledge and Harris 1989) strongly suggest that the wild-type cereals present in the Epipaleolithic [Natufian Layer 1] levels at Abu Hureyra were not cultivated” (Hillman, Colledge and Harris 1989: 257). This conclusion was later reversed (Hillman 1996; 2000; Hillman *et al.* 2001; see also Harris 2009; Willcox 2009), further accentuating the inconclusiveness of the data.

The work and writing of Sue Colledge regarding cultivation and pre-domestication cultivation are very important, since she was a central participant in the issue for some three decades and authored (or co-authored) noteworthy relevant papers. Her insights are significant, drawing on archaeobotanical materials from Tell Abu Hureyra and

several other Neolithic sites in the northern and southern Levant, as well as from Cyprus. Initially, when participating in the authorship of Hillman, Colledge and Harris (1989), she argued against cultivation at Tell Abu Hureyra Late Natufian Layer 1 and implicitly supported a fast domestication process, as did Hillman at that time. By the 1990s, however, her focus of interest had shifted to the study of archaeobotanical assemblage compositions, as she attempted to provide evidence for cultivation (e.g., Colledge 1998, resulting from her Ph.D. dissertation from the University of Sheffield, summarized in Colledge 2001; 2002). To infer the management or cultivation of the landscape, Colledge preferred to rely on differences in botanical remains originating in various archaeological sites. At the same time, however, Colledge (1998: 121), like others, claimed that domestication is conditioned by a previous phase of cultivation (likewise, see Fuller 2007; Harlan, de Wet and Price 1973; Harris 2012; Nesbitt 2002: 115; Willcox 2012b: 92). She supported her statement by experimental work such as that described in Hillman and Davies (1990b; 1992),¹⁷ concluding that certain methods of land preparation (agro-techniques) and harvesting are prerequisites for the automatic (i.e., unconscious) increase in frequency of domestic-type genetic variants among cultivated populations of wild cereals. For example, Colledge (1998) introduced a quantitative study of archaeobotanical assemblages from several selected Neolithic sites in Syria and Lebanon (Mureybet, Tell Aswad, Ghoraife, Ramad, and Ras Shamra, together covering the PPN and early PN periods) in which a change was evident over time, manifested in “vegetational fingerprints” concerning specific weeds of cultivation. Although she concluded that these changes serve as evidence for land preparation, i.e., cultivation, she remained indecisive. Citing Zohary (1973: 648),¹⁸ she later stated that “. . . weeds are rarely indicative of specific locations, and are unlikely, therefore, to be useful indicators of local cultivation” (Colledge 2001: 24), or, in other words, that it was not easy, if at all possible, to discern whether the proposed weeds were

17. Replicated experimental harvests were conducted in natural stands of wild einkorn in Turkey. In addition, a brittle rachis accession of einkorn was grown for two consecutive seasons at the farm of the University of Wales College of Cardiff using a replicated split-plot design (Hillman and Davies 1990a; 1990b). However, the first year’s crop was ruined by a spring drought that was followed by an extremely wet summer, and the second experiment was sown too late and developed no ears (probably owing to high vernalization requirements, see Box 1.3). Therefore, all the conclusions and considerations about the presumed role of husbandry in the “domestication process” were based on the field exercises conducted earlier in Turkey (Hillman and Davies 1990a: 61).

18. Zohary suggested that eu-segetal plants (currently inhabiting only cultivated grounds) possess indicative potential and may have existed prior to human plant management of any kind, i.e., in a “pre-segetal” era, in various specific disturbed habitats, such as ant nests, landslides, or wadi banks, as well as disturbances as a result of human activities. The weediness of these species, however, would be less reliable in pre-agrarian or early agrarian sites where previously undisturbed locations were subjected to cultivation. These circumstances thus call for caution in considering cases involving eu-segetal plants.

primary natural vegetation or secondary, and were thus actual weeds related to cultivation (Colledge 2001: 22–24). These taxa, therefore, cannot be used as safe indicators of past cultivation. In the summary note of her 2001 book, however, Colledge maintained that:

Pre- or no-domestication cultivation of wild cereals was suggested for Natufian and EPPN sites where field weeds were identified. It was considered likely that the presence of wet-loving taxa in several of the sites was evidence for cultivation on land with high groundwater. It was also possible to propose that the data indicated an increase in intensity of land use at the later sites by which time crop-based agriculture was well established in the Levant. (Colledge 2001: 24)¹⁹

An increase in intensity of land use—a very cautious statement—was eventually offered by Colledge.

In endeavoring to further develop the notion of vegetational fingerprints for pre-domestication cultivation (Colledge 2001; 2002; Colledge, Conolly and Shennan 2004), Sue Colledge again reached similar conclusions while attempting to identify pre-domestication cultivation mainly among PPNA and EPPNB in late twelfth–late eleventh millennium Cal. BP samples at the Mureybet site. Colledge assumed that a slight increase in the proportion of field weeds “may be an indication of disturbance of the land by tillage” (e.g., Colledge 2002: 150). This idea, however, was rejected in an earlier investigation of the archaeobotany of Mureybet (van Zeist and Bakker-Heeres 1984: 198). Weeds were also denied the power to demarcate “proto-agricultural” practices (i.e., cultivation) in a chronologically subsequent site (PPNB Tell Sabi Abyad) by the statement that these taxa “are not conclusive in this respect because usually they cannot be identified to the species level. Moreover, these taxa could equally well have formed part of the natural (plateau) steppe which was probably grazed by the domestic animals” (van Zeist and de Roller 2000: 142). Finally, in a more recent reassessment of cultivation of wild plants at Late Natufian Tell Abu Hureyra 1, Colledge stated that “. . . cultivation is not needed to explain the changes

19. We note that high-water-table areas—the so called “favorable habitats”—where wet-loving plants were (supposedly) cultivated are not prone to cultivation in many Levantine settings. This is true even when modern machine traction and chemical weed control are used. Such areas are usually flooded during the rainy winter, and hence not amenable to hoeing or plowing; they cannot be sown prior to the late spring when the soil is no longer waterlogged and is aerated, and they are therefore useless for growing cool-season Levantine cereals and/or legumes (except, perhaps, for the late-sown chickpea). In addition, under Mediterranean conditions an all-year-round high groundwater table promotes, and in many cases sustains, dense reed and tamarisk stands (see Zohary 1973: 643), which are very aggressive and competitive plants. For these reasons, almost as a rule, traditional Levantine grain farming is not based on high-water-table ecologies.

in proportion of plant taxa” (Colledge and Conolly 2010: 136), concluding that a model that does not include cultivation of cereals and legumes in the Late Epipaleolithic is “more parsimonious” (Colledge and Conolly 2010: 137). We read this statement as an important summary of a long and intricate process of study and contemplation, and we fully agree with it.

Lastly, in this context, we take a look at the prominent proponent of pre-domestication cultivation, George Willcox, who conducted detailed studies on archaeobotanical assemblages in the region (e.g., Willcox, Fornite and Herveux 2008; Willcox and Stordeur 2012; Willcox 2012a; 2012b; 2012c) and published lists of potential weed taxa and quantitative data concerning their increase over time (e.g., Willcox 2012a; 2012b: Table 4.2, p. 101; 2012c, Tables 2–3, pp. 165–166, and references therein; Willcox and Stordeur 2012). Showing some hesitation concerning early pre-domestication cultivation, Willcox nevertheless writes: “... we should not totally discount the possibility of cultivation at Natufian sites” (Willcox 2012c: 166). In contrast, he is quite firm regarding the existence of cultivation in the PPNA: “The establishment of a more dependable list of potential taxa demonstrates that the Neolithic weed flora was already established by the PPNA. In the middle Euphrates area this was over a millennium before the appearance of morphological domestication” (Willcox 2012c: 167). Nevertheless, he expresses reservation about his statements on the PPNA (2012c: 167), noting that: “...this present study is too incomplete to draw firm conclusions with regard to the origins and spread of arable weeds.” (and see also the comment below on Table 4.2 of Willcox 2012a and identification of weeds to the species level).

A notable statement by Willcox concerning the PPNA site of Jerf el Ahmar explains a general mindset among researchers advocating pre-domestication cultivation: “Fifteen taxa that have no known use and are typically weeds of cultivation in modern fields and on Bronze Age sites, where cultivation is not in question, were [interpreted] as weeds of cultivation” (Willcox 2012b: 100). Since the weed argument is so central to our understanding of potential cultivation (and pre-domestication cultivation), we delve deeper here into this important archaeobotanical work. A critical look at it raises a few significant difficulties:

- The taxa listed by Willcox (2012b: 101, Table 4.2; 2012c: 165, Table 2) were identified to the genus level only. It is important to notice that names of species listed by Willcox in this table as weeds of cultivation (in the rightmost column) are not identified archaeobotanical finds of the relevant period, but rather species known as current or recent historical weeds of cultivation.
- The vast majority of the species classified under the genera listed by Willcox

(*ibid.*), including some 250 wild species in Israel and 800 wild species in Turkey, are not weedy. The numbers of species we present here are based on a survey of these genera and on an examination of each of the listed genera in the local floras (Zohary 1950; 1962; Feinbrun-Dothan and Danin 1991; Davis 1965; 1967; 1970; 1972; 1975; 1978; 1982).

- Many of these potential (but archaeologically unidentified) species also occupy non-segetal plant formations, rendering them unlikely markers of cultivation.
- Some of the species considered to be potential weeds of cultivation, including those appearing in Willcox (2012c: 165–166, Tables 2 and 3), are in fact summer plants and are therefore irrelevant as weeds of winter crops, which were more typical of early farming in the Levant, and included, for example, *Heliotropium europeum*, *H. rotundifolium*, and *Teucrium spinosum*.
- Willcox argued that excavated seeds of plant species that supposedly have no use may have been weeds of cultivation,²⁰ a claim that is, at best, open to discussion. Assuming, as we do, that Neolithic people could and did use wild plants in many different ways, very few taxa listed by Willcox (2012b; 2012c) remain potential weeds. Uses overlooked by Willcox include, for example, extraction of oil from *Heliotropium rotundifolium* seeds (see Kislev 1997), fibers from *Thymelaea hirsute* for making strings/ropes and different plant parts for medicines (e.g., *Galium aparine*).

The central aspect of our criticism remains the necessity for identification at the species level. We give two examples.

The genus *Galium* includes 25 species in the southern Levant and 101 species in the northern Levant, of which only one (*Galium tricornutum*) is clearly a weed of cultivation (see Kislev, Garfinkel and Zohary 2012 for the MPPNB site of Yiftahel). Moreover, some *Galium* sp. seeds were uncovered as early as in the Middle Paleolithic (MP) (60,000–50,000 years BP) Kebara Cave (Lev, Kislev and Bar-Yosef 2005), where there has never been a claim for cultivation, as well as at the 23,000-year-old site of Ohalo II. A recent paper by Snir *et al.* (2015) discussing the archaeobotany of Ohalo II provides a list of proposed weeds (or what they term “proto-weeds”) identified to the species level, but several of those species are used as food plants and several other species can be used as medicinal plants. Moreover, and as the

20. This approach was applied in other archaeobotanical accounts as well—e.g., Riehl, Zeidi and Conard (2013) on Chogha Golan.

argument goes, it is likely that in pre-agricultural times, species with weedy tendencies were native to naturally disturbed habitats such as riverbanks, landslide areas, or gravel. Note that Ohalo II is a lakeshore site, situated in close proximity to the Jordan River's southern outlet from the Sea of Galilee—a location rich in a range of niches such as unstable banks affected by seasonal water-level changes and flow intensity, with all these habitats found just a few minutes' walk from the site. Such an ecological setting, or even the disturbances related to human activity in the site and its environs, may provide an alternative (and more likely) explanation for the presence of seed remains from the species listed in Table 2 of Snir *et al.* (2015).

Additional early archaeobotanical finds of *Galium* were found in the Late Natufian Stratum I of Mureybet, as originally reported by van Zeist (1970) and later by van Zeist and Bakker-Heeres (1984) and by Willcox (2008).²¹ As a genus, then, *Galium* appears either to accompany human niches in general or to be collected as a non-target plant (see Abbo *et al.* 2008b), regardless of cultivation.

Another example is the genus *Centaurea*, which boasts 25 species in Israel and 172 species in Turkey, but of which only two are well-known weeds. Clearly, as recognized by Willcox (2012c), identification to the species level is hindered by various factors. However, until species are clearly identified, the genus-level potential for signifying weeds of cultivation remains unsafe and, in many ways, irrelevant.²²

We thus echo Willcox's statement that such finds are merely “[interpreted] ... as weeds of cultivation” (2012c: 165, header of Table 2), emphasizing that this is only one of several possible and no less parsimonious interpretations and should remain as such until reliable taxonomic evidence, allowing for a firmer statement, is available.

Following the above discussion, in our opinion, the state of our knowledge and the available data do not lend themselves to any conclusive statements concerning weeds of cultivation among most of the currently available archaeobotanical finds in pre-Neolithic, e.g., early layers of Körtektepe (Rössner *et al.* 2018, and see their

21. These include only single items, as is also the case in samples where archaeobotanical finds identified as weeds are often reported as being of low quantities, occasionally comprising only single/few items that could have reached the site in many different ways.

22. We believe that species identification is essential also for late prehistory and early historical times, when agriculture had already been well established. The case of MPPNB Yiftahel (Kislev, Garfinkel and Zohary 2012) has clear identification to the species level; only one weed species—*Galium tricornerutum*—was identified. The case of the Pre-Pottery Neolithic C (PPNC) site of Atlit-Yam, a site submerged under the Mediterranean Sea south of the Haifa port, is also a good example. Dated to the latest part of the PPN period (9,000–8,500 Cal. BP)—a millennium and a half after the appearance of plant domestication in the northern Levant—it clearly shows weeds of cultivation identified to the species level (Hartmann-Shenkman *et al.* 2015). A few finds of proposed weeds of cultivation were identified at the species level at Chogha Golan (Riehl, Zeidi and Conard 2013), but these too are from the MPPNB (see Abbo, Lev-Yadun and Gopher 2013, and below, Box 2.4).

footnotes on Tell Abu Hureyra) or in early PPN times, e.g., at PPNA sites such as Körting Tepe (Riehl *et al.* 2012; Rössner *et al.* 2018), Dja'de (Douché and Willcox 2018), or even PPNB Aşıklı Höyük PPNB (Ergun 2018). Even where archaeobotanical finds are solid and well preserved, research is currently unable to discern whether any such finds considered as weeds of cultivation are genuinely so, let alone whether or not their presence resulted exclusively from cultivation.²³ Presumed remains of pre-domesticated cultivated wild taxa and weeds of cultivation still have a long way to go in order to be exclusively explained by cultivation, and a parsimonious explanation for their co-appearance is still lacking. By the same token, we consider it premature to present quantitative data on their presence as direct evidence for cultivation.²⁴ The concept of “measuring” and graphically plotting the rise in frequencies of weeds of cultivation is widely accepted as support for the protracted autonomous model of plant domestication in the Levant (e.g., Fuller *et al.* 2018). However, as long as most of the presumed weeds are identified only to the genus level, as shown above as a demonstration for the genera *Gallium* and *Centaurea*, such “quantitative trends” are of no diagnostic value (for such a trend in the site of Chogha Golan, see Riehl, Zeidi and Conard 2013; Abbo, Lev-Yadun and Gopher 2013, and Box 2.4).

Thus, the case for cultivation in general, and for pre-domestication cultivation in particular, seems to be based on poor taxonomic resolution, as well as on circumstantial evidence combined with assumptions and hypotheses that remain, at best, controversial. Neither the archaeological nor the archaeobotanical records are at present unequivocally indicative of cultivation (or of pre-domestication cultivation) in pre-Neolithic (Natufian) or in PPNA Levantine sites, and it remains practically invisible. It should therefore be considered with caution, as is the case with any unproven intellectual construct. The use of pre-domestication cultivation has, however, become a dominant trend (e.g., Asouti and Fuller 2013; Fuller 2007; Gepts 2004; Smith 2001; Weiss, Kislev and Hartmann 2006; Willcox, Fornite and Herveux 2008; Willcox, Buxo and Herveux 2009; Zeder 2015), reflecting, at least to some extent, non-critical reading and a lack of scrutiny. It also marks a departure from the caution that characterized the “elders” of

23. We would accept a definition of plant remains as weeds of cultivation when a plant is identified to the species level and is known as a weed of cultivation. This is usually the case for samples originating from sites that post-date plant domestication, (see n. 22 on p. 53).

24. As noted in the previous footnote, where archaeobotanical finds are identified to the species level we have no difficulty in accepting their presence. However, this usually relates to late (post-domestication) archaeobotanical samples, such as the cases of Chogha Golan (see n. 22 on p. 53), Yiftahel, or Atlit-Yam (see comments and discussions in this chapter and in Box 2.4). The case of the 23,000-year-old site of Ohalo II is an unusual and important case, where the proposed weeds of cultivation have been identified to the species level (and defined as “proto-weeds”) (Snir *et al.* 2015; but see, earlier in this chapter, an alternative explanation for their presence).

plant-domestication research in the Levant, such as van Zeist, Hans Helbaek, Mordechai Kislev and Gordon Hillman—the principal practicing archaeobotanists who identified plant remains at archeological sites in the 1960s and for some 50 years thereafter.

To summarize this discussion and to highlight the problems presented above, we refer the reader to three illustrative and frequently quoted cases published in the 2000s concerning claims for cultivation or pre-domestication cultivation (Weiss, Kislev and Hartmann 2006; Willcox, Fornite and Herveux 2008; Willcox, Buxo and Herveux 2009; Riehl, Zeidi and Conard 2013), which we address in detail and in quite a polemic way (Box 2.4; see also Table 8.1 on pp. 169–173).

Box 2.4: The Claims for Pre-domestication Cultivation and Counter-arguments

Claims for pre-domestication cultivation, made more than a decade ago by Weiss, Kislev and Hartmann (2006), by Willcox, Fornite and Herveux (2008) and by Willcox, Buxo and Herveux (2009), have frequently been cited in reviews that offer reconstructions of both cultural and biological (domestication-related) aspects of the Neolithic Revolution in the Levant (e.g., Allaby, Fuller and Brown 2008; Brown *et al.* 2009; Smith 2007a; 2007b; Zeder 2008; 2015; Bar-Yosef 2017). Another article highly pertinent to the issue is about pre-domestication cultivation at Chogha Golan, Iran (Riehl, Zeidi and Conard 2013). All of these articles exemplify the insufficiency of data in sustaining such claims, which, under close scrutiny, demonstrate a multitude of problems in their data and in the methodology used (including circular reasoning), and show low parsimony (e.g., Abbo, Lev-Yadun and Gopher 2012; 2013).

Case 1: Weiss, Kislev and Hartmann 2006

Promoting an autonomous model for plant domestication in the Levant, Weiss, Kislev and Hartmann (2006) claim that plant cultivation in PPNA archaeobotanical assemblages was identified based on two criteria: seed quantity and the presence of weeds of cultivation.

The first criterion is “the presence of a conspicuous quantity of seeds in greater amounts than would have been yielded by harvesting local natural stands of the wild plant” (Weiss, Kislev and Hartmann 2006: 1608–1609). This claim, made with reference to the lower Jordan Valley, is an indirect claim for displacement, because

the wild progenitors of most of the founder package crops are not found around the site (see below).

One example regarding their claim for PPNA cultivation based on “conspicuous quantity” is lentil. The assemblages that they note, however, contain rather small quantities of lentil—PPNA Jerf el Ahmar (Middle Euphrates, 267 seeds × 0.03 g per seed = 8.01 g); PPNA Netiv Hagdud (lower Jordan Valley, 205 seeds × 0.03 g per seed = 6.15 g). Weiss, Kislev and Hartmann (2006) refer their readers to the site of Yiftahel, where outstanding quantities of lentil were found (Kislev 1985; Kislev, Garfinkel and Zohary 2012). Yiftahel, however, is an irrelevant example, because this site is well dated to the MPPNB (for various chronological ranges, see Purugganan and Fuller 2011; Asouti and Fuller 2013; Weiss and Zohary 2011),¹ i.e., around a millennium later than Netiv Hagdud or Jerf el Ahmar, and about half a millennium subsequent to plant (including lentil) domestication in the northern Levant. MPPNB Yiftahel, therefore, cannot attest to pre-domestication cultivation in the PPNA. Another case of a “conspicuous quantity” of seeds noted by these authors is that of oats and barley (120,000 and 260,000 seeds, respectively) from the PPNA site of Gilgal I in the lower Jordan Valley. Recovered from Locus XI, also known as House XI, a “...sub-rectangular in shape structure/house with mud walls” (Kislev, Hartmann and Noy 2010: 252), these finds were discovered “...stored in asphalt-lined basket containers” (Kislev, Hartmann and Noy 2010: 251), along with flint items, grinding stones, bone tools and imagery items. However, such a quantity of seeds, amounting to 3 kg of oats and 8 kg of barley seeds, could easily have been obtained by two or three people in several hours of gathering among wild populations (see Abbo *et al.* 2008a; Harlan 1967; Kislev, Weiss and Hartmann 2004; Ladizinsky 1975) in appropriate ecologies that are located in the nearby Judean Hills, only a few kilometers to the west of this PPNA site. Alternatively, as also shown by these authors, these quantities could have been collected from the ground even from fallen spikes (Kislev, Weiss and Hartmann 2004, for wild barley and wheat). This case, therefore, shows that cultivation is neither the only possible nor the most likely explanation for the presence of these oats and barley finds. Moreover, it is hard to understand how and why oats and barley would have been cultivated under such arid conditions in the lower Jordan Valley where they

1. In Purugganan and Fuller (2011, supplement) the representative ¹⁴C date for Yiftahel of 9,825 Cal. BP is based on four readings; in Asouti and Fuller (2013) the range of 10,150–9,600 Cal. BP of the same archaeological horizon is based on three readings; Weiss and Zohary (2011) established the range of 10,100–9,700 Cal. BP.

cannot grow naturally.² Yet another case mentioned by Weiss, Kislev and Hartmann (2006) is that of rye in the Late Natufian at Tell Abu Hureyra 1, which, however, is irrelevant to the “conspicuous quantity” criterion since only a few rye seeds were identified there (Hillman 2000; Hillman *et al.* 2001).

The second criterion used by Weiss, Kislev and Hartmann (2006) for identifying PPNA cultivation is “the presence of pre-domesticated [wild, to be domesticated in the future] seeds that are mixed with plant seeds that grew as weeds in contemporary [i.e., Neolithic] fields” (Weiss, Kislev and Hartmann 2006: 1609). In this claim, however, the authors presuppose the presence of pre-domestication cultivation, i.e., the existence of wild plants sown by humans (and thus a cultivation context—plot, field, or managed land). They then suggest that some plants in the archaeobotanical assemblage represent weeds of cultivation that grew in the same managed lands. Finally, the authors use both of those assumptions to support their claim for pre-domestication cultivation. This is a classic case of circular argumentation lacking grounding in evidence. Similar circular argumentation was pointed out by Abbo, Lev-Yadun and Gopher (2012; 2013) concerning the argument of Fuller (2007) in favor of weeds of cultivation, because it is based on the assumption that there was “necessarily a stage of production (cultivation) that precedes morphological domestication” (Fuller 2007: 904). Such an assumption obscures any interpretation concerning the presence of seeds of presumed weeds as evidence for cultivation. Moreover, Weiss, Kislev and Hartmann (2006) do not specify which weeds are diagnostic of PPNA pre-domestication cultivation, and their only specification relates to *Galium tricornutum* as a weed that accompanied lentil at MPPNB Yiftahel, which again is a much later irrelevant post-domestication example, as pointed out above (and see also Kislev, Garfinkel and Zohary 2012).

In addition to the above, we note that wild cereals and legumes that were eventually domesticated appear in the archaeobotanical record much earlier than the PPNA. The Middle Paleolithic Kebara Cave, used by Neanderthals some 60,000–50,000 years ago, yielded a “conspicuous quantity” of 247 lentil

2. At present, Jericho, situated in the lower Jordan Valley just north of the Dead Sea, enjoys an average of 136 mm annual rainfall, while the area of PPNA Gilgal I and Netiv Hagdud, located 14 km farther to the north, receives on average 187–191 mm annually (Israel Meteorological Service). However, it has been claimed that there was higher annual precipitation during the PPNA (e.g., Bar-Yosef and Gopher 1997; Hovers 1997: 8; Kislev 1997: 229; Tchernov 1994; 1997: 241). To support dense wild populations of oat and barley, the required annual rainfall would have to have been at the very least double (380 mm).

seeds (Lev, Kislev and Bar-Yosef 2005), an amount comparable to the PPNA cases cited by Weiss, Kislev and Hartmann (2006). Some 2,500 seeds of barley and over a hundred seeds of wheat, among other taxa, were found at 23,000-year-old Ohalo II (Weiss *et al.* 2004; and see Snir *et al.* 2015 with somewhat different numbers as a result of the gradually advancing analysis of the finds from this site). Why, then, following their own logic, is cultivation not considered for the Middle Paleolithic Kebara Cave, similarly to the claims made by Snir *et al.* (2015) regarding (proto) “small-scale trial cultivation” in early Epipaleolithic Ohalo II? And by the same token, why were the PPNA Gilgal I, Netiv Hagdud, or even PPNA Jericho inhabitants considered to be cultivators (Weiss, Kislev and Hartmann 2006), whereas the earlier communities were not? Is it the mere presence of wild cereals and legumes in early Neolithic sites that makes them cultivated?

Case 2: Willcox, Fornite and Herveux 2008

Studying the question of cultivation, Willcox, Fornite and Herveux (2008) argue in favor of pre-domestication cultivation based on both old and new archaeobotanical data from sites located in the Middle Euphrates Valley. We refer to the 2008 paper because it is a clearly stated and detailed work, but such arguments continue to appear in Willcox’s work a decade later (see Willcox 2018; Douché and Willcox 2018). The Willcox, Fornite and Herveux (2008) paper offers five lines of evidence to support cultivation:

- The presence of plants such as wild einkorn, wild rye, and lentils outside their natural habitats, indicating displacement;
- The gradual adoption³ of founder crops such as barley, emmer, and single-grained einkorn in the Middle Euphrates;
- The presence of weeds of cultivation;
- A gradual decrease in archaeobotanical assemblages of wild plants such as small seeded grasses;
- A change in the size of barley seeds.

We briefly address each of these contentions.

3. The authors use the term “adoption” rather than “domestication”; the logic underlying this choice of term is unclear.

- Why grow plants outside their natural habitats, especially in light of considerations regarding local adaptation, as elaborated by Willcox (2005)?
- The claim for gradual adoption of crops is based on finds of wild forms (Willcox, Fornite and Herveux 2008: Table 11). It is therefore unclear why they were termed “crops.” Being morphologically wild, how can their crop status be determined as different from all other wild contemporaneous or earlier remains?
- The claim for the presence of taxa with weedy affinities is not sufficiently detailed, lacking specificity beyond the genus level. Even if this claim is accepted, their presence is not necessarily related to cultivation (see above).
- The gradual decrease in the assemblages of some types of wild plants, such as small seeded grasses, is based on two lines of evidence. The first is provided by Weiss *et al.* (2004), who focused on the 23,000-year-old waterlogged site of Ohalo II. Not only is this site much earlier than the Neolithic, but the concluding comments of Weiss *et al.* (2004) concern the Neolithic period and are in this case an interpretation, rather than data-based. The second is a claimed decrease in seed percentages of certain types of wild plants, e.g., small-seeded *Stipa*, *Hordeum bulbosum*, between the Late Natufian and the PPNB (based on data from Abu Hureyra Layers 1, 2 and 3; Mureybet I, II and III; Jerf el Ahmar I and and Dja’de;⁴ Willcox, Fornite and Herveux 2008: 322, Fig. 5, Tables 9 and 10). However, a closer look at Table 10 in Willcox, Fornite and Herveux (2008) shows a parallel decline in the ubiquity of wheat and rye during the same time frame. This inclination suggests that the decline in frequency of wild plants is not necessarily related to the status of any of these species as a food source, let alone to their cultivation or domestication, but may well represent entirely different phenomena (e.g., see Nadel *et al.* 2004, on plants brought into the site of Ohalo II for bedding). Moreover, the assumption, *à la* Lev, Kislev and Bar-Yosef (2005), that all vegetal remains found on site must be food remains is unsubstantiated and misleading. Why assume, for example, that *Stipa* sp. was ever a significant food source whereas large-seeded wild einkorn and emmer were abundant?

4. Based on the Dja’de report by Coqueugniot (2000) without specifying the stratigraphy of the samples used. Willcox considered the Dja’de samples the latest of the four sites presented in Willcox, Fornite and Herveux (2008).

There is no evidence of its collection from wild habitats or of post-harvest processing to support such a notion.

- To avoid redundancy, we refer readers to our comments on grain size above, where we discuss arguments offered by Willcox, Fornite and Herveux (2008) on pre-domestication cultivation, and to Box 2.2. Suffice to say here that an increase in the seed size of cereals as a reflector of pre-domestication cultivation is under debate and that, in our view, the considerable overlap in seed size between wild and domestic cereal types (and similarly for grain legumes) prevents any fruitful discussion on the issue (Abbo *et al.* 2014).

Willcox, Fornite and Herveux also claimed that seed stocks would have been “...regularly replenished from wild stands to counter poor harvests, which may have been frequent in the arid middle Euphrates” (2008: 323). Taken at face value, one might wonder what this statement really means regarding the sustainability of the new “cultivation system” or the “gradual adoption of founder crops” (see above). Would it not imply an agronomic failure? Phrased differently, “... particularly during famine years ... inhabitants would be forced to consume seed stock and then would have to gather from the wild to renew their stock in order to continue cultivation” (Willcox 2012a: 170). It seems to us that this statement hints that cultivators would have had to start anew the “unconscious voyage” towards domestication with every new seed stock gathered from the wild. In our view, such a long drawn-out practice would not have allowed for the establishment of the quantitative trends presented in archaeobotanical assemblages, either in terms of seed dimensions or in frequencies of wild vs. domestic forms (for both grain size and frequencies of non-shattering cereals, see, e.g., Tanno and Willcox 2006a; Willcox, Fornite and Herveux 2008; Willcox, Buxo and Herveux 2009; Willcox 2012a; 2012b; 2012c; Fuller *et al.* 2018). Moreover, if wild populations had provided yields that allowed for regular seed replenishment, why did the adjacent cultivated plots regularly fail?

Additional arguments aimed at strengthening the claim for cultivation, although made by Willcox later, are important and merit attention. The arguments of indirect evidence indicating cultivation (Willcox and Stordeur 2012; Willcox 2012a; 2012b; 2012c) are mostly based on data from PPNA Jerf el Ahmar, PPNA and/or EPPNB Dja'de (see n. 4 in this box) concerning elements of material culture and context. These include: a) the presence of storage facilities for grain, attested to both by the installations and by the presence of bones of the house

mouse (*Mus musculus domesticus*; n=6 at Dja'de; n=1 at Jerf el Ahmar) and rodent droppings (n=221 at Dja'de; n=47 at Jerf el Ahmar) (Willcox 2012a; 2012b); b) concentrations of grinding equipment in specific contexts (Willcox 2012a; 2012b); c) the presence of chaff in large quantities in mud walls at Jerf el Ahmar (Willcox and Stordeur 2012; Willcox 2012a; 2012b); and d) intensive use of cereals indicated by an increase in both size and quantity of harvesting blades (sickle blades and sickle handles) compared to earlier sites.⁵ Neither separately nor in combination do these data necessarily indicate cultivation, and each could be explained by other forces, while the argument of Willcox (2012b: 99) that “this coincides with an increased reliance on cultivation” is again circular. These may indicate, at best, what Willcox calls “large-scale use of cereals at Jerf el Ahmar,” but not cultivation, let alone domestication.

Case 3: Riehl, Zeidi and Conard 2013

The report of Riehl, Zeidi and Conard (2013) suggests pre-domestication cultivation of wild cereals and legumes in PPNA Chogha Golan (12th and first half of 11th millennia Cal. BP).⁶ The stratigraphy of the site includes 11 horizons, from XI (the earliest) to I (the latest). This report is yet another case of circular argumentation combined with a problematic statement on alleged arable weeds, as usual mostly identified to the genus level only (Riehl, Zeidi and Conard 2013), which is insufficient to support a cultivation claim. We have already noted that these genera comprise hundreds of species in regional floras, with only one or very few species known as weeds, and have pointed to the fact that the archaeobotanical finds are mostly too few to indicate weediness (see above, as well as Abbo, Lev-Yadun and Gopher 2013). Only two presumed weeds were defined to the species level at Chogha Golan—*Reseda luteola*, which is not only a mere weed but also a well-known ancient dye

5. It is notable that once a protracted model of domestication stretching throughout the Neolithic period (the PN included) is accepted, the aspect of sickle blade frequencies notwithstanding, PN sickle blades are smaller than those of the PPNB and the PPNA, at least in the southern Levant. A detailed discussion on the place of sickle blades in Neolithic flint tool compositions and the argumentation based on Neolithic sickle blade techno-typology (see Maeda *et al.* 2016; Abbo *et al.* 2021) are beyond the scope of this discussion.

6. This site report was later augmented by additional papers (Riehl *et al.* 2014; Riehl 2016; Weide *et al.* 2015; 2017; 2018). While the authors have improved species definitions and nuanced their arguments, they have not changed their basic claim for early pre-domestication cultivation at Chogha Golan.

plant (Cannon and Cannon 1994), and *Medicago radiata*, a plant typical of undisturbed steppe habitats. Moreover, if possible arable weed remains from horizons XI–II of Chogha Golan are indicative of cultivation and if “domesticated species evolved through management of their wild progenitors,” as asserted by Riehl, Zeidi and Conard (2013: 65), one must perforce wonder why their proportion declines during the proposed cultivation period (their Fig. 2 and supplementary materials) only to increase upon horizon II, where morphologically domesticated emmer eventually appears.

Riehl, Zeidi and Conard (2013) also suggested pre-domestication cultivation of lentil. However, experimental nurseries (Abbo *et al.* 2011) have reaffirmed Ladizinsky’s (1987) hypothesis that no profitable option exists for wild-type legume cultivation due to their strong seed dormancy. Hence, lentil cultivation required a domesticated non-dormant seed stock from the outset (Ladizinsky 1987; and see Box 2.6). Therefore, accepting the suggested PPNA lentils as cultivated means that we accept that they were in fact domesticated, thereby rendering redundant any assumptions regarding the millennia-long management or cultivation process as a prerequisite for domestication (e.g., Riehl, Zeidi and Conard 2013; Tanno and Willcox 2006a; Fuller 2007; Asouti and Fuller 2013; Fuller *et al.* 2018). To conclude: at Chogha Golan the clearly domesticated types appear only in horizon II, around 9,800 Cal. BP, postdating the domestication of these crops in southeastern Turkey and northern Syria by some 700 years (Abbo, Lev-Yadun and Gopher 2010a; Lev-Yadun, Gopher and Abbo 2000). We thus deduce that the botanical remains from PPNA Chogha Golan represent foraging by hunter-gatherers rather than cultivation (and see Bar-Yosef 2014b). For further discussion of arguments concerning pre-domestication cultivation in PPNA Chogha Golan, as advanced by Weide *et al.* (2018), see Abbo and Gopher (2020). Note a recent retraction from claims about possible weeds of cultivation as indicators of pre-domestication cultivation (Weide *et al.* 2021).

Given its centrality to the protracted autonomous model of plant domestication in the Levant, the issue of cultivation remains an active arena of research. Therefore, before moving on, we would like to add a note on recent evolving terminology of the term “pre-domestication cultivation” and present newly introduced sub-phasing in this connection. First, we present some new terms related to cultivation and to

pre-domestication cultivation, introduced by Snir *et al.* (2015) following a study of the 23,000-year-old Epipaleolithic site of Ohalo II. As quoted from that paper, these new terms include small-scale “trial cultivation,” “intentional systematic cultivation,” “successful intentional cultivation” and “small scale, elementary cultivation.”²⁵ These are augmented by the use of an additional term for weeds of cultivation, namely “proto-weeds” (defined in that publication as “... the first wild plants that entered and thrived in early human-affected habitats, which subsequently led to the evolution of weeds”).²⁶ We shall not delve into a lengthy discussion of these terms, but make do with noting that this multitude of attempts at coining new terms reflects, in our view, a sense of caution as well as a lack of confidence concerning the pre-domestication concept as a whole, especially when discussing Ohalo II, a site dated to 23,000 years Cal. BP.

Another newly introduced development in the discourse on pre-domestication cultivation concentrates on defining its sub-phases (Fuller *et al.* 2018). Pre-domestication cultivation was divided into three phases based on frequency data of non-shattering spike-rachis remains (see Box 2.5) and supported by data on change in seed size (Box 2.2; Fuller *et al.* 2018). These include: “incipient pre-domestication cultivation” (IPDC) (less than 20% non-shattering rachises), “entrenched pre-domestication cultivation” (EPDC) (20%–80% non-shattering rachises, 10%–30% increase in average seed size) and “domesticated cultivation” (DC) (greater than 80% non-shattering rachises and >20% increase in average crop seed size)” (Fuller *et al.* 2018: 61).

This recent stage in the history of the term “pre-domestication cultivation” and the issue of cultivation as a whole is an example of the entangled life of what was from the very beginning a rather naïve and problematic construct (see below, n. 27)

25. The sentence with the quoted terms contains four descriptors of cultivation, which we have some difficulty in accurately understanding since definitions are lacking. However, they represent a whole array of cultivation-related issues, namely, “intentionality” (but how could cultivation be unintentional?), and the “stage and scale,” as well as the degree of “success” of cultivation.

26. While this sounds like a step forward in the research on pre-domestication cultivation, nuancing its deeper history, it raises some questions: What is the difference between proto-weeds and weeds? What will turn a proto-weed into a weed? Until when do proto-weeds continue to appear? How does all this relate to identifying cultivation and pre-domestication cultivation using weeds? Is it just another way of expressing and supporting, or promoting, a protracted process of domestication? We consider this study (Snir *et al.* 2015) to be of major importance since the authors were highly professional in identifying the finds to the species level, which is rare in other studies, even of much later sites. Such identification, however, does not promote the ideas of early and long pre-domestication cultivation stages; on the contrary, it merely strengthens the idea that for many practical reasons such plants can be found in non-cultivation sites. Alternatively, such plants may have enriched the archaeobotanical remains as a result of seed cleaning and other processing operations, while in effect, such remains may have merely been non-target contaminants brought to the site (Abbo *et al.* 2008b).

on the Hillman and Davies experiments, above), theoretically weak, relying on circular argumentation, advocated by a framework of thought based on low resolution,²⁷ lacking sound support from archaeological and archaeobotanical evidence (see earlier discussion in this chapter) and based on a long series of primary and secondary assumptions (see Table 8.1 on pp. 169–173).

The Concept of Cultivation and the Use of the Term

Why, then, is the term “cultivation”—together with its derivative “pre-domestication cultivation” and further sub-phasing—despite all underlying problems and ambiguities, used so intensively in the discussion of Near Eastern plant domestication and the onset of agriculture? Obviously, because it makes a major contribution and provides the necessary arena for the protracted (unconscious) scenario. Moreover, cultivation and pre-domestication cultivation are apparently archaeologically “attractive,” bringing together both human cultural-behavioral aspects and plant biological evolutionary processes. Additionally, cultivation is “historically flexible,” spanning an undefined duration, and thus it may articulate with archaeological cultural sequences (e.g., the beginning of the Late Natufian or the very beginning of the Neolithic period), accounting for changes in the archaeological record. It may also be related to assumed climatic changes occurring at the end of the last glacial period (e.g., Bar-Yosef 1998a; 1998b; 2004; 2011; Bar-Yosef and Belfer-Cohen 2002; Bar-Yosef and Meadow 1995; Hillman 2000; Hillman *et al.* 2001). Moreover, “cultivation” and “pre-domestication cultivation” are conceptually acceptable, being grounded in common sense and in a progressive logic, i.e., they offer a scenario in which people were manipulating land and plants, possibly for a long time, while unconsciously (automatically) selecting for types of plants and finally fully taking them over—a linear, easily digestible, scenario. Lastly, and perhaps ironically, the presently elusive archaeological and archaeobotanical records of cultivation render advocacy for cultivation almost irrefutable.

Altogether, “cultivation” and “pre-domestication cultivation” as terms used in plant-domestication research have become rather confusing, and when examined carefully they exhibit many problems:

27. When pre-domestication cultivation is taken as a prerequisite for domestication and viewed as some millennia-long unconscious process, and/or when its primary analysis is of low resolution, it is impossible to increase resolution *post factum*. Thus, using this as an argument to support a protracted model of domestication is tautological, and internal subdivision of this stage will not be a positive move—especially when based on erroneous elements such as the percentage of non-shattering rachises and seed/grain size (see Boxes 2.2 and 2.5).

- They have inherent logic contradictions.
- Cultivation is difficult to identify in the archaeological record.
- They lack a practical, agronomically feasible, reconstruction since it is not clear how things happened in the Neolithic fields.
- The issue is problematic because the supporters of the notion of pre-domestication cultivation claim repetitive replenishment from the wild in bad crop years, when seed corn is consumed (see above and Box 2.4); this would add another obstacle to the acceptance of such a scenario since the shattering/non-shattering ratio would have to drop and rise anew over and over again (see above, n. 7 in Box 2.5).
- Arguments relating to experimentation (auditioning) of various plant species in pre-agricultural times—e.g., the Epipaleolithic period or the beginning of the Neolithic, i.e., in the PPNA; see Snir *et al.* 2015; Weiss, Kislev and Hartmann 2006), or experimentation with species that were later termed lost crops (Fuller, Asouti and Purugganan 2012a; Melamed, Plitmann and Kislev 2008)²⁸—further complicate the “quantitative” value of the term “pre-domestication cultivation.”
- The important argument in support of pre-domestication cultivation relating to the presence of weeds of cultivation has been discussed above and shown to be quite problematic, especially because of its low resolution in the identification of plant remains from the relevant archaeological sites, i.e., that there are very few, if any, identifications to the species level. When appropriate identifications of Neolithic field weeds were made to the species level, the remains originated from occupation horizons postdating the appearance of domesticates, such as in the case of Horizon II in Chogha Golan (Riehl, Zeidi and Conard 2013) discussed above. This is also the case in most of the other reliable identifications of weeds of cultivation at the species level, at sites such as MPPNB Yiftahel, Pre-Pottery Neolithic C (PPNC) Atlit-Yam, and see n. 22 on p. 53). The case of Ohalo II is outstanding and is remarked on separately (see earlier in this chapter).

28. In essence, the notion that the “founder crop package” (Table 1.1) as defined by Zohary and Hopf (1988) is only a relic of what was a larger repertoire of plants, some of which were merely auditioned as candidates for cultivation and/or domestication (and were rejected), while others may have been crop plants in their own right but were lost or abandoned for various reasons in antiquity (e.g., Fuller, Asouti and Purugganan 2012a; Melamed, Plitmann and Kislev 2008). However, upon close examination, most of the supposed Near Eastern lost crops cases lack genuine evidence for having ever been crops, while yet other finds have simpler and more likely explanations (Abbo *et al.* 2013a).

The Term “Cultivation” as We See It

To avoid further confusion, we do not suggest alternative terms, but prefer to briefly explain our own usage of the terms “agriculture,” “domestication” and “cultivation” and the consequences of each for the study of Near Eastern plant domestication.

The term “agriculture,” as used in this book, refers to the fully-fledged economic system based on domesticated species.²⁹ “Domestication” is used as a biological term, referring to major genetically controlled phenotypic features such as non-brittle rachis, free germination, changes in biorhythms, loss of toxicity and other defenses, which enabled people to gain domination over the chosen species and use them in new, man-made ecological settings. As such, domestication reflects a human initiative. In cultural terms, domestication is the event following the decision (and execution) of that human initiative during which humans had consciously chosen certain species, and selected particular genetic stocks and distinct phenotypes among their chosen species, for growing.³⁰ Thus, domestication is the act of obtaining and growing distinct phenotypes of desirable plants through educated, knowledge-based human action.

As used here, the term “cultivation” follows, in many ways, Helbaek’s (1970) definition quoted above, and relates to the set of activities by which an active person treats the land and the plants, including stocking seed corn, sowing, tending, weeding, harvesting, selecting, cleaning and sorting. Cultivation is thus a chain of husbandry operations, in an agronomic arena, reflecting any human intervention in the life of wild or domesticated plants. As such, it seems likely to represent a behavior that reflects a new human perception of land and plants. Cultivation is therefore not merely a gradual amplification or improvement of the foraging subsistence strategy, but rather a manipulation of land and plants in a new (cultural) setting that attests to a new state of mind (e.g., Carneiro da Cunha 2019).³¹ In our view, cultivation breaches the hunter-gatherer’s ideology and therefore cannot be discussed in terms of aboriginal hunter-gatherer land management or low-level food-production systems that are typical of almost all present-day foraging societies (Smith 2001; Anderson

29. The distinction between “agriculture” and “farming” is that agriculture is a system in which “... farming and/or herding predominate the activities of a particular community and determine the main diet, although hunting and gathering may continue,” whereas farming means “... utilization of domestic plants and/or animals for food as well as other resources” (Price and Bar-Yosef 2011: S163). Both definitions expand the scope beyond plants and, while acceptable, we do not make such distinctions.

30. The statement on plant and animal domestication made by Price and Bar-Yosef (2011: s165) is not adopted here.

31. Following a paper by Tim Ingold (2000) and borrowing his term “from trust to domination” originally used for human–animal relationship.

2005; Gerritsen 2008; Pascoe 2014; Abbo and Gopher 2020). Again, and in other words, it represents a change in the relationships between humans (culture), land and plants (nature). In effect, cultivation in this new setting defines the agronomic arena in which an intentional (conscious and deliberate) selection takes place in favor of plants' morpho-physiological features preferred by the cultivator. Those features are our present-day biological markers of plant domestication.³² Following plant domestication, an ongoing process of “crop improvement” (crop evolution under domestication) takes place, partly because of the cultivation activities (Abbo *et al.* 2014) and driven mainly via relentless conscious selection for adaptation, yield, quality and stability by generations of traditional farmers in antiquity³³ and, more recently, in modern breeding programs.

Phrasing the two domestication models described at the beginning of this book using the terms defined in this section—“cultivation” and “domestication”—results in two alternative, mutually exclusive, narratives of cultivation and domestication. The first advocates that selection was conscious and well-educated and that therefore domestication was quite rapid, whereas the second proposes an unconscious and random selection process over a relatively long time. The two models also differ with respect to whether plant domestication was centered (in a core area) or autonomous (diffused). Here we present the two narratives.

The Random Unconscious/Automatic Narrative (Fig. 2.1A)

For reasons unknown, which are not likely to impact the dynamics of this narrative, Neolithic community members decided to sow seeds of wild plants, especially cereals such as barley and wheat, somewhere in their native distribution range. It is logical to assume that if they had not been directed by any specific preference but had randomly sampled the native populations of such species, the sampled seeds would have mostly comprised the common wild morphotypes of the selected species. The domestic-like mutant alleles, i.e., those that in retrospect have greater advantage for

32. In their definition of cultivation, Price and Bar-Yosef (2011: S163) viewed cultivation as the “... 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.” While we concur with this definition, we do not use it since it might, if even implicitly, hint at unconscious processes that we do not endorse.

33. This selection started from the very beginning, for each of these crops, by the cultivators of over ten thousand years and to this day. These long-term and tedious selection processes resulted in many thousands of landraces worldwide, most of which were decimated as a consequence of adoption of new varieties from modern plant-breeding programs. Hopefully, recent keen efforts of conservation in an attempt to preserve whatever remains of the tremendous variability of traditional agriculture (and could still be of help to modern agriculture) will be successful.

growers (would-be farmers), yet rarely appear in nature (e.g., Kamm 1974), might have found their way into this random sample as well or may have emerged (via mutations) in the cultivated fields. This would have triggered an “automatic” (unconscious) selection of domestic stocks (morphotypes) in the new man-made field ecologies, following certain practices or husbandry regimes (namely, cultivation)³⁴ that worked in their favor (e.g., Helbaek 1959; Hillman and Davies 1990a; 1990b; 1992; 1999; Zohary 2004).

The derogatory³⁵ attitude that ascribes to the Neolithic “cultivators” an inability to distinguish brittle from non-brittle mutants and the suggested frequent replenishment of the seed stock from the wild (e.g., Willcox 2012b; Willcox, Buxo and Herveux 2009; Purugganan and Fuller 2011) are but two arguments characteristic of the protracted model of plant domestication. Both arguments would have resulted in a long stage of the so-called pre-domestication cultivation and would have dictated a slow domestication process (e.g., Kislev 1998; Purugganan and Fuller 2011; Tanno and Willcox 2012; Willcox 2012a: 179).³⁶ Moreover, if cultivators were continuously unaware of any subtle phenotypic frequency changes in their plots or fields, their lack of purposeful mutant selection would have necessitated a particularly long domestication process, longer even than the thousands of years suggested by Purugganan and Fuller (2011) or by Tanno and Willcox (2012). It follows that along the timeline of this scenario (Fig. 2.1A), if T1a reflected the first sowing of randomly (unconsciously) sampled wild seeds, then T2a would have been determined by the increasing frequency

34. For example, Hillman and Davies (1990a; 1990b; 1992; 1999) claimed that cultivated (wild) plants would tend to go through a fast selection leading to domestication under a series of assumptions concerning the cultivation regime, such as harvest by sickles or by uprooting, harvest when crops are near ripening, annual shifting of the cultivated area, and the use of seed stocks from the previous season—all of which are acceptable requirements, although, again, not supported by clear archaeological datasets (see above). Hillman thus endorsed a fast domestication over a period of a few years and up to 200 years, based on the biology and genetics of package cereals (Hillman 2000: 417; Hillman and Davies 1990a; 1990b; 1992; 1999).

35. In a paper published some years ago (Abbo, Lev-Yadun and Gopher 2014) we expressed our astonishment that even researchers who attribute an indispensable role to conscious and knowledge-based selection do not mention the ever-present common denominator in plant domestication throughout the world, namely, human conscious decision-making. In our view, the human “mind” and the “science of the concrete” *à la* Lévi-Strauss deserve to be discussed as an integral component of plant domestication.

36. Interestingly, while Willcox *et al.* (2012a: 179) claimed that Neolithic cultivators were unable to differentiate domestic-type cereal morphologies, they nevertheless attributed to them proficiency as plant breeders in the very same paper and on the same page, as well as in an earlier paper (Willcox, Buxo and Herveux 2009: 156). Similarly, Kislev, Hartmann and Bar-Yosef (2006) claimed, on the basis of keen archaeobotanical observations, that domestication of the common fig (*Ficus carica*) in the PPNA was fast (immediate) and relied upon wise human selection for a suitable (parthenocarpic) type from nature, whereas their attitude to domestication of grain crops was quite different.

of the domestic-like mutants found in the archaeobotanical assemblages of relevant sites (e.g., Tanno and Willcox 2006b; but see Box 2.5), or by the time that domestic types became dominant and hence distinguishable to the Neolithic cultivator. Note that T2a would have been conscious, whether it followed a knowledge-based fast selection from the wild or a slow process in which man-made ecologies automatically selected for domestic-like mutants. This would imply a rather long gap between T1a and T2a, allowing for unconscious selection of mutants (e.g., Fuller, Allaby and Stevens 2010; Purugganan and Fuller 2011; Tanno and Willcox 2006a; 2012).

**Box 2.5: Percentage of Non-shattering Rachises
in Archaeobotanical Assemblages: What Do They Mean?**

The idea of “measuring” the pace of domestication by plotting frequencies of shattering against non-shattering rachises in cereals of archaeobotanical assemblages has been in vogue during the last three decades (e.g., Hillman and Davies 1990a: 46; Hillman 2000; Tanno and Willcox 2006a). The slow change (increase) in the ratio of non-shattering spikes has been used in recent plant-domestication research as one of the criteria supporting a millennia-long process of plant domestication (e.g., Fuller, Asouti and Purugganan 2012b). These quantitative trends supposedly “measure” the “advancing” millennia-long domestication process posited by the protracted autonomous model of plant domestication in the Levant. Recently, this measure (frequencies; shattering/non-shattering ratio) was used to subdivide the pre-domestication cultivation “phase” into sub-phases (Fuller *et al.* 2018). We would like to invest some thought in this idea as a whole and test its logic, validity and contribution to the reconstruction of plant domestication in the Levant.

The study by Gordon Hillman (2000) on the archaeobotanical assemblages of the Late Natufian Tell Abu Hureyra layer 1 is a conspicuous example (see Chapter 3, esp. n. 2 on p. 80) of the use of quantitative trends in frequencies of archaeobotanical finds to promote statements on plant domestication. It was George Willcox, however, who systematically used archaeobotanical data quantitatively to reconstruct change over time during the so-called domestication process (e.g., Willcox 2004b). Tanno and Willcox (2006a) present the relative frequencies of shattering vs. non-shattering einkorn spikelets

recovered from northern Levantine sites spanning a timeline of over 4,500 years, from 10,200 Non Cal. BP Qaramel to 6,500 Non Cal. BP Kosak Shamali.¹ In that paper they present, for the first time, archaeobotanical data that in their view undermine earlier reconstructions of a rapid emergence of a domesticated cereal as suggested by Hillman and Davies (1990a; 1990b; but see above in this chapter on Hillman's change of view on the issue). Indicating that domestication traits such as free germination or spike indehiscence are not readily visible, Tanno and Willcox (2006a) suggest that cultivation (of wild types, or mixed with low frequency of domestic types) could have lasted for over a millennium before a domesticated crop (i.e., dominated by non-shattering rachises) would emerge. In so doing, Tanno and Willcox (2006a) in fact formulate a gradualist domestication model. However, at 7,400 years Cal. BP (their latest samples), farming of the domesticated founder Neolithic crops had already been established for 3,000 years and had spread far away from the Levant in all directions to Asia, Europe, and Africa, rendering their claim irrelevant (Lev-Yadun, Gopher and Abbo 2006).

Based on this rationale, Allaby, Fuller and Brown (2008) followed suit and presented their genetic expectations from such a gradualist (re-branded "protracted") domestication model, i.e., taking for a fact that the establishment of a domestic variety requires several millennia of pre-domestication cultivation.² Later, Purugganan and Fuller (2011) adopted Willcox's approach and plotted relative frequencies of non-shattering for a number of cereal species from a range of archaeological sites spanning several millennia and from several domestication centers worldwide (see above and Box 2.5). Likewise, Purugganan and Fuller (2011) plotted diachronic data of grain dimensions in a cereal (emmer), legumes (e.g., pea, lentil), sunflower and melon. In presenting these data over time, Purugganan and Fuller (2011) claim to be able to estimate the rate of evolutionary change "during domestication," and use their reconstruction to argue for unconscious domestication dynamics, emphasizing the alleged

1. The dates used in the present text are in most cases calibrated dates BP. Tanno and Willcox presented uncalibrated dates BP in their 2006a paper; the calibrated range they deal with is thus from ca. 12,000 Cal. BP to 7,400 years Cal. BP (base of the late Neolithic site Kosak Shamali), i.e., spanning over 4,600 years.
2. Those authors also claimed, based on the same argument, that the monophyletic einkorn domestication of Heun *et al.* (1997) is erroneous and should be reinterpreted as polyphyletic.

inability of the Neolithic farmers to “consciously differentiate cultivated from wild forms in the field.”³

While the trend to advance quantitative arguments on the frequency of shattering vs. non-shattering cereals in archaeobotanical assemblages along a chronological axis is common, in our opinion it is highly problematic. Some comments on the issue: Kislev, Bar-Yosef and Gopher (1986) claimed that the presence of the lower, non-shattering part of barley from PPNA Netiv Hagdud is evidence for cultivation. Kislev later withdrew this claim and stated that barley shows a relatively high percentage of non-shattering lower spike parts in the wild as well, and therefore the presence of such remains is not reliable as evidence for barley cultivation (Kislev 1992). In conclusion, it became clear, some three decades ago, that the percentage of non-shattering spikes plays no role in distinguishing cultivated from wild barley.

The protracted model of plant domestication brings the question of shattering vs. non-shattering frequencies back to the fore. A cardinal issue in crop mixture would be the question how this “mix” came about. We mention the problematics of the issue in Box 2.3, when discussing the possible distinction of cultivation from domestication using use-wear analysis on flint sickle blades. Here, we question the practical “how” aspects of this mixture through the lens of supporters of a quantitative approach to the protracted, millennia-long domestication process. We relate to two aspects: how the mixture came about and whether the Neolithic participants in the process were aware of the situation. Regarding the first, if we follow the logic of the “protracted” argument, the process of changing frequencies of shattering vs. non-shattering must have taken place in the field cultivated by Neolithic people (so that automatic, unconscious selection could take place, see Abbo *et al.* 2021; the second is that they were not aware of the difference between shattering and non-shattering, or did not even notice it (*sensu* Willcox 2008; 2009; Puraggannan and Fuller 2011, and see Box 2.3). In a more recent paper by Douché and Willcox (2018: 54) the authors re-discuss the issue and provide answers to the question why wild types persist in the archaeobotanical record. They list four possibilities:

3. The above arguments, as discussed by Abbo *et al.* (2014), were shown to be totally unacceptable and to result from the fact that those authors conceptualize plant domestication as including millennia of later crop-evolutionary changes under domestication.

- Cultivation and gathering from the wild continued side by side;
- Cultivation techniques were such that selection for domestic types was low;
- Domestic types could be more susceptible to damage than wild types, which would lead to wild types being over-represented;
- Wild cereals propagated as arable weeds alongside their domestic counterparts.

They claim that had these been the reasons, it would nuance the protracted domestication paradigm.⁴

In the same paper, Douché and Willcox, while discussing Tell Aswad, note (2018: 55): “... the mixture of wild and domestic types in the archaeobotanical ‘populations’ at Aswad, which persisted for so long and which goes against theoretical selection predictions (Zohary 1989; Hillman and Davies 1990a; 1990b), could result from identification bias, low selection cultivation techniques and occasional gathering from the wild, for example, after a poor harvest, or simply wild forms behaved like arable weeds.”⁵ Two comments are warranted here: 1) this statement reiterates the poor capabilities of Neolithic farmers to cultivate and/or to distinguish what happens in their fields,⁶ and 2) it repeats the problematic need to replenish the fields (with seeds collected in the wild), which we have already mentioned (see above). The possible behavior of the progenitors of package plants as weeds has already been discussed (see nn. 23 and 24 on p. 54; and Abbo *et al.* 2005).

In summary, the quantitative approach to the shattering/non-shattering issue, as well as the use of this ratio to indicate a protracted process of domestication, suffers from flaws in logic and assumptions that would not withstand scrutiny, whether agronomic, biological,⁷ or cultural-behavioral (Abbo *et al.* 2021).

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4. Interestingly, Willcox, Fornite and Herveux (2008: 324) wrote: “On a more general level, gathering and cultivation of wild cereals probably occurred simultaneously over a long period, which is why we see no sharp division from one economy to another, the transition being extremely gradual.”
 5. For archaeobotanists, this statement on an identification bias at Tel Aswad is unclear, since they use their own new analysis of botanical remains from the 2000s excavations by D. Stordeur.
 6. Echoing old statements by Willcox—e.g.: “Without a plant breeder’s hindsight, cultivators probably felt secure and confident with the crops as they were, and it did not occur to them to attempt crop improvement” (Willcox 2012a: 179).
 7. The aspect of repetitive replenishment (see above and Willcox 2012a: 170) would add another obstacle to acceptance of such a scenario, since the shattering/non-shattering ratio would have to start its course over again following every replenishment episode, thereby ruling out the possibility of tracing the presumed gradual change in frequency of the different morphotypes.

The Conscious Selection and Domestication Narrative (Fig. 2.1B)

In conscious, knowledge-based sowing, the selection of seed corn from the wild would have followed a logic that works in favor of stocks, i.e., domestic-like mutants that were attractive to humans from the outset—for example, the free germinating lentil stock accessed from the wild *à la* Ladizinsky (1987; and see Box 2.6). The feasibility of this proposition depends on the extent to which such domestic-like morphotypes were discernible. Indeed, natural non-brittle variants would be rather visible among wild wheat or barley populations a few weeks after their full ripening (mid- to late summer; Kamm 1974). It is therefore quite reasonable to assume that such unique plants would have been selected for sowing. A recent paper by Avni *et al.* (2017) on wild emmer indeed suggests that even a single mutation in only one of the *Br* (brittle rachis—the wheat spike axis) loci is capable of conferring a partial non-shattering phenotype that is rather visible in natural stands. The process of domestication would thus have been completed quite rapidly (e.g., following the reasoning of Harlan, de Wet and Price 1973; Hillman and Davies 1990a; 1990b; 1992; 1999; Honne and Heun 2009; and Zohary 1996).

For such a conscious, knowledge-based selection, the collection of seed corn in nature and the actual sowing of the preferred seeds would be defined as time T1b, reflecting the point in time when the transformation in the relationship between human and plant (particularly for sowing) had matured to become practical. Time T2b, then, would be the point when the selection of domestic-type morphotypes had turned successful, providing a stable year-to-year yield in the new setting. In this scenario, T2b could have followed T1b quite soon, possibly according to a timeline that is too short to be identified by the current archaeological resolution for the Levantine Neolithic.

Three additional points concerning these two scenarios should be kept in mind. The first is that for us—and for the core-area one-event model—early buds of domestication reside in T1b, involving at the onset not only the choice of species to be manipulated, but also a highly conscious, knowledge-based selection of preferred genetic types.³⁷ In this context, we see no *a priori* reason to assume that Neolithic people failed to distinguish between brittle and non-brittle ear types or to identify the subtle qualities—agronomic, taste and nutritional—of many of their foods, including sources of seed corn. The second point is that we endorse the

37. See Willcox (2012a: 179) for his distinction between choice and selection: “... we should not confuse choice with selection. Early farmers may have chosen crops or landraces for which they had a preference—for example, wheat over barley—or they may have exchanged varieties, but this is not selection.”

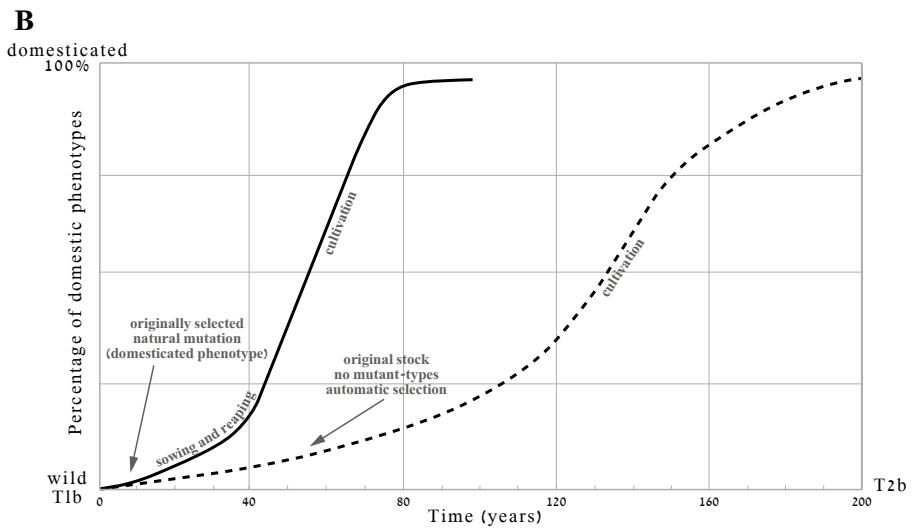
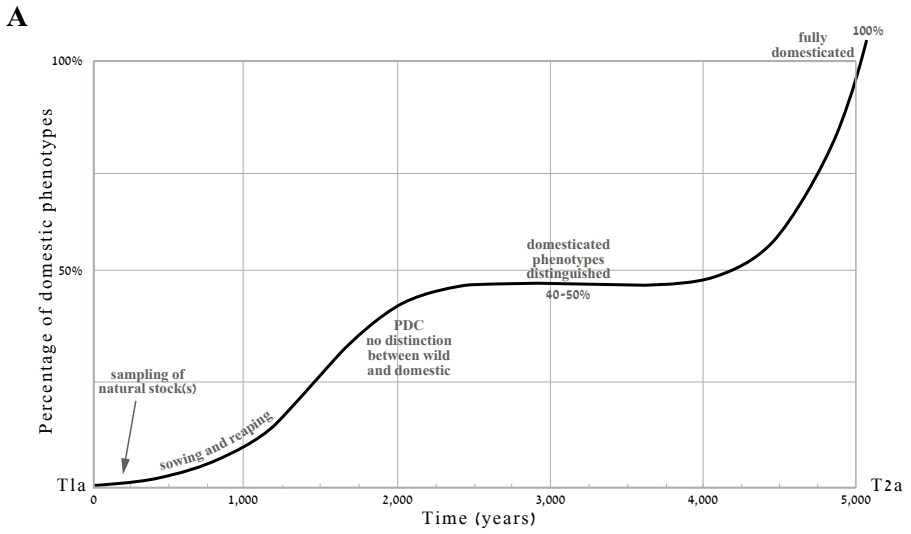


Fig. 2.1: Schematic illustrations of the random, unconscious automatic scenario (A) and the conscious selection and domestication narrative (B) (note that the time scale is different in the two graphs)

view stipulating that practical domestication took place in a cultivated ecology and that we consider it evident that the early fields could also have harbored wild morphotypes. It remains to be investigated, however, whether the mixed (wild and domesticated) archaeobotanical assemblages are the result of mixed fields or of a combination of farming and continued gathering from the wild (see comments in Boxes 2.3 and 2.5, and see also Douché and Willcox 2018; Abbo *et al.* 2021). The third point to be kept in mind is that it was only under domestication that additional evolutionary changes occurred (owing to farmers' selection activities, see below), which provided the archaeological record with more readable data (e.g., Abbo *et al.* 2014).³⁸ In addition, the crystallization of a new, annually repetitive (seasonal) chain of operations made it possible to identify more clearly the characteristics of cultivation, as in the case of weeds of cultivation that appear after domestication, when cultivation is already on its way (e.g., Hartmann-Shenkman *et al.* 2015; and see n. 22 on p. 53).

To summarize our definitions: by “domestication,” we are referring to a clear biological and archaeological fact as seen in plant phenotypes. We are acutely aware of the fact that a plant can theoretically be domesticated while its morphological wild-type phenotype remains unchanged (e.g., there might be a change in its biochemistry or its seasonality), thus rendering such phenotypes archaeologically invisible. By “cultivation,” we mean human husbandry operations. We acknowledge that our suggested timeline of cultivation—the process occurring between T1b and T2b (see above)—may have been too short to be identified by present-day archaeological resolution.³⁹

One should bear in mind that this discussion about cultivation and pre-domestication cultivation might be relevant only for cereals. This is because no economically viable option of pre-domestication cultivation exists for Levantine grain legumes, on account of their strong seed dormancy (Abbo *et al.* 2011; Ladizinsky 1987). Therefore, upon acceptance of Ladizinsky's (1987) principle of “domestication before cultivation” legumes model (Box 2.6) and given the fact that the same people domesticated both cereals and legumes, this discussion would have been decided long ago in favor of a rapid conscious, knowledge-based domestication scenario.

38. For example, the separation between crop seeds (e.g., to be processed and consumed) and weeds (discarded with chaff and other waste) might have affected the archaeological record by enriching the assemblage of presumed weeds of cultivation (Abbo *et al.* 2008b).

39. We feel obliged to alert readers to the fact that in earlier works (e.g., Abbo, Lev-Yadun and Galwey 2002; Abbo *et al.* 2003; 2006) we used the term “cultivation” in the conventional way, but owing to our contentions above we have opted for more precision in our terminology (e.g., Abbo, Lev-Yadun and Gopher 2012).

Box 2.6: Lentil Domestication before Cultivation

The distribution of wild lentils (*Lens* sp.) includes the Mediterranean basin, Asia Minor through to central Asia and eastward to Tajikistan (Ladizinsky 1993). In nature, wild lentils are mostly confined to primary habitats with shallow soil pockets, where they are free of competition from species with a more aggressive growth habit, such as wild cereals. Across this range wild lentil populations are patchy, with each local patch hosting a sparse stand that often constitutes just a few individuals. Wild lentils are characterized by a low seed yield and strong seed dormancy resulting from the impermeability of their seed coat to water (Ladizinsky 1987; 1989; 1993). Under natural conditions only about 10% of the seeds will germinate in the subsequent autumn, although the germinating individuals do not represent genetic variation in this trait of seed dormancy because their next-generation seeds germinate at the same rate. Lentil seed dormancy and low seed yield (approximately ten seeds per plant) have a clear adaptive value in semi-arid wild habitats characterized by shallow stony soil. Experimental evidence showed that when sowing 100 wild lentil seeds only 10% germinated, each of which produced ten seeds on average, resulting in about the same seed amount as the amount sown. This situation does not provide an incentive to continue further sowing (Ladizinsky 1987; 1989; 1993; and see illustrations in Abbo *et al.* 2009; 2014). Domesticated lentil seeds are non-dormant, a trait controlled by one dominant gene (Ladizinsky 1987; 1993). The mutation rate in this gene is unknown, but even at a rate as high as 10^{-5} , a non-dormant seed (mutant) is likely to appear in one out of 10^5 individual plants following the sowing of millions of seeds. Selection in favor of such a mutant under cultivation would require hundreds of years of perpetual sowing without any yield gain. In wild stands such a mutant is ill-adapted in the long run, for two reasons:

- It will multiply annually by a factor of ten until the poor habitat is no longer able to support the population;
- The non-dormant genotypes will most likely be quickly eliminated if a long dry period follows the first effective rain, a common feature of the semi-arid habitats of wild lentils across the Mediterranean and eastward to central Asia.

Ladizinsky suggests that the puzzle as to how non-dormant lentil seed variants evolved could be solved by assuming that affluent (high-density) non-dormant wild lentil populations may have attracted the attention of hunter-gatherers who regularly visited those spots for seed collection (see, e.g., data on lentil seeds from the Kebara cave some 60,000–50,000 years BP; Lev, Kislev and Bar-Yosef 2005).¹ Such repeated harvests have the capacity to prevent local population explosion (Ladizinsky 1987; 1993). When seeds from such exceptional populations were used for sowing, the yield was satisfactory and encouraged further sowing. Consequently, according to Ladizinsky's model, lentil domestication, i.e., the emergence of an ill-adapted, non-dormant variant in wild populations, most probably preceded lentil cultivation.

1. In a way, akin to the prey (harvest) pathway to domestication of Zeder (2012) and Larson and Fuller (2014).

CHAPTER 3

THE TIMING AND LENGTH OF LEVANTINE PLANT DOMESTICATION: IS A PROTRACTED DOMESTICATION MODEL RELIABLE?

The timing of plant domestication in the Levant is established through the development of high-resolution archaeological fieldwork combined with accelerator mass spectrometric ^{14}C dating, which allows for the dating of single seeds. The ^{14}C database originates from many sites, including excavations conducted in the 1950s (e.g., Jericho by Kathleen Kenyon) and 1960s (e.g., Tell Aswad by Henri de Contenson). Dating samples included wood charcoal, seeds, or nut fragments. There have been some disagreements concerning calibration, as well as the use of various statistical measures and specific mathematical procedures in assessing ^{14}C dates. Inconsistencies, inaccuracies, small numbers of dates per site (or layer) and sometimes a selective use of the available dates have also been sources of disagreement (Gopher, Lev-Yadun and Abbo 2013). Nevertheless, the various ^{14}C databases have converged to a general archaeobotanically and archaeologically solid date for plant domestication, which is accepted by most plant-domestication researchers. Accepted dates for plant domestication in the northern Levant, as reflected in cereals, have thus been attributed to the Early Pre-Pottery Neolithic B (EPPNB), ca. 10,500 years Cal. BP (e.g., Lev-Yadun, Gopher and Abbo 2000: 1602; Zeder 2008; Zohary, Hopf and Weiss 2012: 1, and indirectly by Willcox 2012a: 174) to 10,600 years Cal. BP (Colledge, Conolly and Shennan 2004; Weiss and Zohary 2011: S47), or even somewhat earlier for those who assign earlier dates to the beginning of the EPPNB.¹ In addition, some

1. In some recent publications, the calibrated onset of the EPPNB in the northern Levant (including sites and layers with domesticated plants) is dated to as early as 10,750 Cal. BP. There are, however, some inconsistencies, even by the same authors in different publications. For example, the Pre-Pottery Neolithic A (PPNA) ends at 10,550 Cal. BP while the EPPNB starts at 10,750 Cal. BP (Fuller, Willcox and Allaby 2012: Table 2), presenting an overlap of some two centuries, while Asouti and Fuller (2012; 2013) ascribe the onset of the EPPNB to 10,650 Cal. BP. Moreover, in an earlier paper, the EPPNB seems to start at ~11,150 years Cal. BP (Asouti 2006: Table 2, p. 92), an inconsistency of over half a millennium. A range of 12,450–10,150 of calibrated ^{14}C years for the PPNA appears in the same paper and table. We trust that some of these are no more than technical mistakes.

sites in Syria and Turkey were excavated under pressures that characterize salvage archaeology in sites that were thereafter flooded by artificial lakes as a result of dam construction (e.g., Mureybet and Tell Abu Hureyra, Tabqa Dam; Nevali Çori, Ataturk Dam; Jerf el Ahmar, Tishrin Dam) and are no longer available for further sampling.

A single outstanding exception assigns both cultivation and domestication to the Late Natufian, some two and a half millennia earlier than indicated by other data. Hillman (2000: 388) suggested cultivation of large seeded legumes² at Tell Abu Hureyra 1 based on their rising frequencies in the latest phase of the Natufian layer 1, as well as the domestication of rye based on seed morphology (shape) and size as early as ca. 13,000 years Cal. BP (Hillman 2000; Hillman and Colledge 1998; Hillman *et al.* 2001). The significance of Hillman's suggestion for rye, if accepted, is that plant domestication would have been almost a direct reaction to the presumed effects of the Younger Dryas: "...the start of cultivation [including rye domestication] at Abu Hureyra was triggered specifically by environmental change" (Hillman 2000: 417 and see his comments Nos. 5–7 on p. 421;³ for comments on the effect of the proposed climatic change on the beginning of agriculture). Hillman's evidence, however, was derived from only a few rye seeds combined with the presumed presence of weeds of cultivation—a small and problematic archaeological and archaeobotanical record (see above).⁴ Neither is his suggestion supported by evidence from any other site of similar chronology.⁵ It is thus unsurprising that Hillman's claim for rye domestication never gained momentum or acknowledgement and is presented with reservations in summary volumes and research papers (e.g., Bellwood 2005: 52; Colledge and Conolly 2010; Colledge, Conolly and Shennan 2004; Fuller,

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2. Hillman (2000: 388) proposed that large seeded legumes were taken into cultivation in the later part of the Natufian sequence of Tell Abu Hureyra layer 1. While the mere presence of large seeded legumes does not necessarily indicate cultivation, accepting the notion of their cultivation must imply that they were in fact free germinating (that is, domesticated; *sensu* Ladizinsky 1987; see Abbo, Lev Yadun and Gopher 2011a), thus making redundant the concept of pre-domestication cultivation as a (biological) prelude to legume domestication (see discussion in this chapter, and see also Chapter 2, Box 2.6).
 3. Interestingly, Hillman, following his experimental results (Hillman and Davies 1990a; 1990b; 1992; 1999), suggested no pre-domestication cultivation for rye, meaning that domestication must have been of brief duration, i.e., episodic. This pertains to the fact that there is no supporting evidence at Tel Abu Hureyra and, we would guess, also to the fact that had it not been assumed to be brief, it would lose the articulation (incentive) with the drier and cooler Younger Dryas.
 4. Hillman *et al.* (2001) reported nine morphologically domestic rye grains (attested as such by their size, plumpness), of which five were ¹⁴C dated, three of them showing late Epipaleolithic (Natufian) dates and two showing later, Neolithic dates.
 5. Hillman *et al.* (2001) suggested similar scenarios for Neolithic sites such as Mureybet and Jerf el Ahmar in the middle Euphrates as well as for Netiv Hagdud in the Jordan Valley. These three sites, however, are at least a millennium later than Tell Abu Hureyra 1, representing a considerable chronological and cultural gap.

Willcox and Allaby. 2011; Fuller, Asouti and Purugganan 2012a; 2012b; Nesbitt 2002; Weiss and Zohary 2011; Willcox and Stordeur 2012; Willcox 2012a; 2012b; 2012c; Zeder 2006; Zohary, Hopf and Weiss 2012), or completely ignored even by scholars who view climatic change as a possible trigger for plant cultivation and domestication (e.g., Bar-Yosef 2004; 2011).

A second factor in the timing question of plant domestication is the pace of the process. This comprises two elements of totally different scales:

- The biology of relevant species and their actual domestication;
- Socioeconomic aspects and the cultural process, i.e., the adoption of domesticates and their integration until they became part of a sustainable economic system, and the full perceptual assimilation of a food-producing way of life and its implementation in the Neolithic cultural fabric.

For the socioeconomic dynamics and the cultural process (known as Neolithization) very few scholars, if any, would claim a rapid unfolding, and most, including ourselves, would reconstruct a complex multifaceted dynamic Neolithization process (e.g., Gopher 2012; and see Box 1.2), whereas the case for the biological aspect of plant domestication currently has two major scenarios: fast vs. slow. The fast scenario suggests that for most package species (cereals and legumes), the biological change underlying domestication occurred as a rather rapid single event spanning just a few decades (20–30 years) or up to 200 years (e.g., Garrard 1999; Hillman and Davies 1990a; 1990b; 1992; 1999; Ladizinsky 1987; Zohary 1996; 1999; see also Colledge, Conolly and Shennan 2004: s38–s39).⁶ Such calculations are made under different assumptions and working hypotheses concerning plant-domestication syndrome traits, conditions and place of domestication, agro-techniques used, seed stocks used, ripening stage at harvest, and other factors (for an example of such assumptions see Hillman and Davies 1992; 1999; and see Chapter 2, n. 34 on p. 68).

The slow scenario is currently at the heart of an ongoing debate. Tanno and Willcox (Tanno and Willcox 2006a; Willcox 2002; 2004a; 2004b; 2005) suggested a slow domestication process (lasting hundreds of years, and perhaps even several millennia) for each crop (but see comments by Lev-Yadun, Gopher and Abbo 2006, and by Hartmann, Kislev and Weiss 2006, refuting this suggestion). Tanno and Willcox (2006a: Fig. 1f) based their argument on the dynamics of brittle vs. non-brittle ear in archaeobotanical remains. These were interpreted as reflections of allele (wild type vs. domesticated) frequency in the

6. Notably, Hillman *et al.* (2001) still talked about a rapid domestication and conscious selection.

(cultivated) populations. While we disagree with their conclusions (Abbo *et al.* 2021), a geographic pattern (gradient) that emerges from their chronological ordering of the sites they present coincides with the core-area model (*sensu* Lev-Yadun, Gopher and Abbo 2000). According to their data, the earliest domesticated cereals originated in the northern Levant, while in the southern Levant all archaeobotanical remains of domesticated cereals are chronologically younger. This is also in accordance with the “ripple” or “wave of advance” pattern (henceforth “ripple-wave of advance pattern”) suggested by Abbo *et al.* (2006; and see below, including Fig. 3.1).

The pace of Levantine plant domestication became a central issue upon advancement of the protracted domestication model (e.g., Tanno and Willcox 2006a; Allaby 2010; Allaby, Fuller and Brown 2008; Brown *et al.* 2009). The roots of this idea may have originated with Hole (1984: 50), who described Levantine plant domestication processes as starting in the Early Kebaran culture (starting ca. 20,000

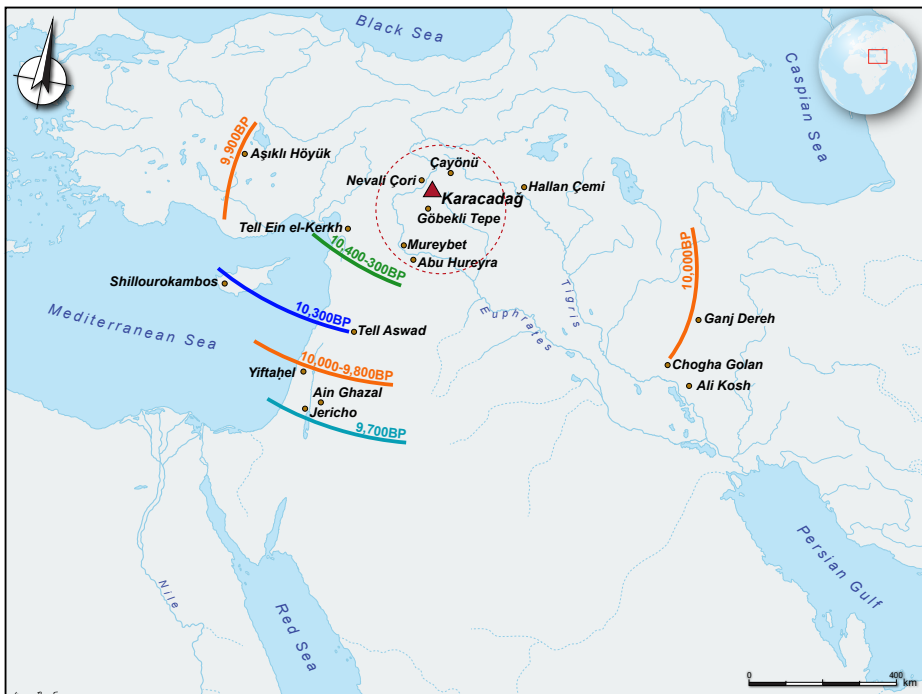


Fig. 3.1: The “ripple-wave of advance” model—the case of the Near East

Cal. BP) Epipaleolithic period⁷ (see also Moore 1982). This proposition was intensively promoted by Fuller (2007), and in more recent years has relied on several contentions,⁸ which in our view were tautological or erroneous. When distilled from the multitude of papers it seems to have been based on the following arguments (partly already mentioned above):

- An assumption regarding the necessity of a pre-domestication cultivation phase (e.g., Fuller 2007; Weiss, Kislev and Hartmann 2006) that, from the outset, is teleological in nature (e.g., Jones and Brown 2007: 41).
- Circular reasoning concerning weeds of cultivation (e.g., Weiss, Kislev and Hartmann 2006; see Box 2.4 and Abbo, Lev-Yadun and Gopher 2012). That is, if it is assumed that a pre-domestication phase is necessary (and therefore expected that weed remains will be found), then the alleged presence of such remains cannot serve as a proof for what was the starting assumption. Exacerbating the situation, in most cases there were no botanical identifications to the required species level.
- Linear regressions derived from the percentages of domesticated plant remains at particular archaeological sites, combined with site ages and the postulate that domestication alleles conferring non-brittleness move (from their multiple origins) across the entire range of wild populations, viewed as a metapopulation (Purugganan and Fuller 2011). However, the structures of the populations are quite different, because most of the wild progenitors of the founder crops do not function as panmictic populations but rather are mostly self-pollinating plants (see below). A major weakness of the linear-regression approach is the fact that the data used originated in different sites, with no convincing sequence over time from any single site. Use of the available data from multi-layered sites such as Cafer Höyük, Çayönü (Turkey), or Jerf el Ahmar (Syria) in the northern Levant, or for that matter Jericho in the southern Levant, was never directed towards amending this deficiency. Aspects of this notion of population genetics and their archaeological weaknesses were discussed in depth by Heun *et al.* (2012), who showed that because wheat, barley, lentil and pea are self-pollinating species, geneflow across their populations does not follow the

7. We assume that if Hole (1984) had possessed the archaeobotanical data from the 23,000 years old Ohalo II (published in later years), he would have eventually used it to support his arguments, but that was not available at the time.

8. Including the protracted suggestion and the early start of this move (Epipaleolithic and even earlier) and see Fuller, Asouti and Purugganan (2012a; 2012b) and Fuller *et al.* (2018).

basic assumptions embedded in Purugganan and Fuller (2011), or in the models of Fuller, Asouti and Purugganan (2012a; 2012b), thereby altogether refuting the genetic validity of that approach.

- Erroneous assumptions regarding the post-harvest labor required for extracting grains from wild vs. domesticated cereal types (Asouti and Fuller 2013; Fuller, Allaby and Stevens 2010). This presumed “labor trap” was directly addressed by controlled threshing experiments.⁹ The results showed that the domesticated non-brittle ear trait is a major labor-saving trait (Tzarfati *et al.* 2013), contrary to the assumptions of Fuller, Allaby and Stevens (2010), and refuting the recently proposed hypothesis regarding extra labor associated with the domesticated phenotype (non-brittle spike) and its presumed role in extending the time frame of the domestication episode.
- An erroneous assumption concerning geneflow, that is, the introgression of wild-type alleles into the nascent crop (domesticated) populations and their potential for diluting domesticated genotypes. The argument goes that geneflow of wild alleles into managed nascent crop populations prevented or delayed efficient selection in favor of domesticated genotypes for as long as cultivation did not emerge from within the natural range of the wild progenitor (e.g., Allaby 2010), that is, for as long as populations of wild progenitors were growing in close proximity to human-managed populations. This assertion, however, rests upon an additional assumption, namely that ancient cultivators were unable to distinguish brittle (wild) from non-brittle (domesticated) cereal types in their fields, as echoed in Willcox, Buxo and Herveux (2009: 156), and reiterated in Purugganan and Fuller (2011: 181). We argue, in contrast, that claiming such ineptness on the part of the Neolithic farmers is inappropriate since it underestimates the knowledge that was available to the Neolithic communities (Lévi-Strauss 1966; and see concluding remarks in Abbo, Lev-Yadun and Gopher 2012). Moreover, if native Mesoamericans were able to domesticate and dramatically change the characters of a cross-pollinating

9. Threshing experiments were conducted with wild and domesticated emmer and with hybrid progenies derived from crosses between wild and domesticated emmer wheat (Tzarfati *et al.* 2013). The results show that the transition from a brittle hulled wild phenotype to non-brittle hulled phenotype (landraces) was associated with an approximately 30% reduction in threshing time, whereas the transition from the latter to non-brittle free-threshing cultivars was associated with an approximately 85% reduction in threshing time. Similar trends were obtained with groups of recombinant inbred lines showing extreme phenotypes of brittleness and threshability. Hence, in tetraploid wheat, both non-brittle spike and free-threshing types are labor-saving traits that increase the efficiency of post-harvest processing, which could also have been an incentive for rapid domestication of the Near Eastern cereals.

species such as maize well within the native range of its wild progenitor (Matsuoka *et al.* 2002), as well as to routinely use the wild relatives for improving (rather than diluting) their crops (Wilkes 1977), we cannot see why Levantine farmers would not have been able to domesticate their self-pollinating (and therefore reproductively almost fully isolated) wild crop progenitors (e.g., Zohary 1999).

In addition, the following considerations are either ignored or misinterpreted by advocates of the protracted domestication model and may, if taken into account, cast serious doubt on its validity:

- Ignored evidence for domesticated chickpea seed shape finds from EPPNB Tell Ain el-Kerkh as published by Tanno and Willcox (2006b), attesting to its rapid domestication (see Chapter 2, n. 9 on p. 35 and Chapter 5, n. 4 on p. 113). Contrary to the protracted model, the multitude of rounded (domesticated-like) chickpea seed remains at this site presents direct archaeobotanical support for the notion of a rapid, rather than protracted, domestication of grain legumes in the Levant.
- Ignored experimental evidence denying the possibility of a long pre-domestication cultivation of Levantine grain legumes. Replicated field experiments with wild and domesticated pea (Abbo *et al.* 2011) have corroborated the hypothesis suggested by Ladizinsky (1987) that no profitable option exists for pre-domestication cultivation of wild Levantine grain legumes. These results indicate that the Levantine domestication of grain legumes must have been a rather short episode following an educated choice of species and genetic types.
- Confusion of crop evolutionary changes in seed size over time (which are still ongoing, and see Box 2.2) with the plant domestication episodes, as noted by Abbo, Lev-Yadun and Gopher (2012) and Abbo *et al.* (2014). We acknowledge the almost universal phenomenon of heavier grains of current domesticated forms relative to their wild progenitors. However, we argue that it is impossible to use grain dimensions to document the domestication episode. This is true, for example, for domesticated emmer, barley, lentil and chickpea, which display considerable phenotypic overlap of grain weight between wild and domesticated variants (see also Abbo *et al.* 2014).¹⁰

10. So, while grain dimensions are excellent descriptors of crop evolutionary changes over time, the distinction between plant domestication and post-domestication crop evolution is biologically valid (as shown experimentally for pea; Abbo *et al.* 2011; and see Hufford *et al.* 2012 for maize). Thus, grain size is irrelevant to the domestication episodes of the Near Eastern grain crops.

As detailed above, in our view there are many reasons to question the validity of the protracted domestication model and more than enough reasons to refute it altogether, since for the time being it is not accompanied by sufficient evidence to support its underlying assumptions and reconstructions (see also below, Table 8.1 on pp. 169–173).

GEOGRAPHIC ORIGINS OF LEVANTINE PLANT DOMESTICATION

The question of geographic origins of Levantine plant domestication involves two major issues. The first is whether plant domestication had taken place independently (autonomously) in different foci across the region, or whether a single core area within the Levant had served as the place where the assemblage of crop plants was domesticated. Secondly, if the latter, where was this core area?

Autonomous-Diffused vs. Core-Area Models

If true to life, an autonomous model for plant domestication would be reflected in the respective affinities of different domesticated crop strains for a range of wild stocks native to different regions where the presumed autonomous domestications would have taken place (i.e., following a polyphyletic pattern). This, however, is not the case, as the studied crops show no such genetic-affinity patterns with their wild progenitors. Almost as a rule (barley is a well-known exception), Levantine Neolithic crops show evidence of a single (monophyletic) origin (e.g., Abbo, Lev-Yadun and Gopher 2010a; Allaby, Brown and Fuller 2010; Heun *et al.* 1997; Salamini *et al.* 2002; Zohary 1996), as is the case for maize (Matsuoka *et al.* 2002), sunflower (Blackman *et al.* 2011; Harter *et al.* 2004) and pearl millet (Oumar *et al.* 2008) in other world regions.

In this context, it is worth mentioning the papers of Zohary (1996; 1999) who used a combined approach in addressing the question of monophyletic vs. polyphyletic origin of Levantine founder crops.¹ His classical method relies on three lines of evidence:

- Genetic patterns indicative of founder effects in the domesticated genepool relative to their wild progenitors.

1. In Zohary 1999 this is all explained in detail.

- Based on the understanding that there are a number of loci, both structural and regulatory, which if mutated may result in a domesticated phenotype in each of the principal domestication traits (e.g., seed dispersal or seed dormancy), it is logical to assume that if, in all cultivars of a crop, a given domestication trait is found to be governed by the same gene (or the same combination of genes), this may suggest a single origin of that crop.
- Presence in the general area not only of the immediate wild progenitor of a particular crop, but also of additional congeneric species that had similar potential but were not domesticated, may also suggest a single domestication event of that crop.

Notwithstanding recent claims for no domestication-related reduction in genetic diversity in a number of crops (Allaby, Ware and Kistler 2019), the founder effect—the first line of evidence presented by Zohary (1996; 1999)—is considered a universal phenomenon among crop plants (e.g., Ladizinsky 1985; 1998a). However, a narrow genetic variation within the domesticated genepool may still be the result of several domestication events (and/or later genetic bottlenecks) and may therefore not be exclusively indicative of a monophyletic origin.

Evidence concerning the second criterion of Zohary (1996; 1999), i.e., the number of loci controlling domestication traits among Levantine crops, has accumulated since the time of his writing. Back then, it appeared that einkorn wheat, emmer wheat, lentil, pea and chickpea had all presented a pattern indicative of a single origin, whereas more than one domestication event had been suggested only for barley and bitter vetch, owing to the presence of two independent loci governing their seed-dispersal mode. Concerning barley, a third allele for spike non-brittleness was recently found (Civáň and Brown 2017), but apparently it had originated in a wild population near our suggested core area. At present, however, we have evidence for at least two independent loci (chromosome groups 2 and 3) affecting spike brittleness in emmer wheat (e.g., Peleg *et al.* 2011; Thanh *et al.* 2013; Avni *et al.* 2017; and references therein). In such cases, however, it is unclear if all loci were involved in the pristine domestication episode or, alternatively, if certain loci acquired the domesticated allele after domestication. Therefore, following the rationale of Zohary (1999), it would be prudent to assume at least two domestication events for emmer wheat,² as in the case of barley.

2. Although we do not know whether (and have no good reason to assume that) the two genes were selected for at the same time and place.

These data require that we reconsider the original working assumptions implicit in Zohary's (1999) method. First, there is no reason to assume that all the loci affecting any given domestication trait had to be involved in the pristine domestication episode. After all, crop populations are dynamic genetic entities and continue to accumulate genetic variations owing to random mutations and introgressions, even under domestication. This is the essence of the so-called crop-evolutionary processes (e.g., Abbo, Lev-Yadun and Gopher 2012; Abbo *et al.* 2014; Ladizinsky 1998a). Secondly, this issue is intimately related to the concept of "crucial domestication traits" (see discussion by Abbo *et al.* 2011 and Ladizinsky 1993 on pea and lentil respectively, and see Abbo *et al.* 2014), and the way in which individual researchers define the domestication syndrome of any particular crop. For example, Weeden (2007) suggested that a minimal number of 15 genes was critical for domestication of pea. Does this immediately imply that there were more than a dozen (up to 15) independent pea-domestication episodes? The strong seed dormancy of wild pea (and similarly of wild lentil, chickpea and bitter vetch) suggests that in such cases, only the free-germination trait can be considered as crucial for cultivation and hence for domestication. The immediate implication is that most of the other phenotypes associated with present-day domesticated cultivars may have accumulated later, under domestication, after a putative single domestication episode. A similar explanation can apply to the two loci governing the brittle rachis trait in both barley and emmer wheat. Therefore, much stronger emphasis should be given to Ladizinsky's approach, by which traits that were not subject to direct human selection (e.g., plastome or chromosomal linear order), and which show no phenotypic continuum between the wild and the domesticated genepools, should be preferred when inferring crop-plant ancestry (see Box 4.1). These traits allow for a more reliable identification of the ancestral domesticated stocks (see Abbo, Lev-Yadun and Ladizinsky 2001). Similarly, closer attention should also be given to the phylogenetic methods based on the DNA pattern of wild and domesticated populations (e.g., Heun *et al.* 1997).

**Box 4.1: The Wild Stock of Domesticated Lentil:
A Powerful Genetic Approach**

Knowing that Neolithic domesticators could not have selected directly for specific chromosomal stocks or chloroplast genome types, Ladizinsky (1999) employed a set of discrete genetic diagnostic traits to identify the putative ancestral stock of domesticated lentils. Indeed, despite the well-documented

ability of hunter-gatherers to identify subtle taste, nutritional and other qualities of food and medicinal plants (e.g., Lévi-Strauss 1952a; 1966; Terashima 2005), in most cases this knowledge could not have been translated into direct selection in favor of distinct chromosomal or plastome stocks. The only exceptions are unique cases in which a certain desired and discernible phenotype (e.g., taste, quality, growth habit) is under the direct (or pleiotropic) control of a unique chromosomal linear order, or of a specific nuclear-cytoplasmic interaction.

The first criterion adopted by Ladizinsky (1999) was the chromosomal linear order as inferred from the pairing pattern of meiotic chromosomes in hybrid plants. To that end, Ladizinsky conducted extensive field trips and assembled a diverse collection of wild lentil accessions (*L. orientalis*, the immediate wild progenitor of the cultigen), covering its entire natural range from the Near East through to Tajikistan. These accessions were used to study the patterns of meiotic chromosomal pairing in hybrid progeny obtained from crosses between accessions of the wild progenitor from different regions. Similarly, Ladizinsky studied the meiotic chromosome pairing in hybrids from crosses between domesticated lentil cultivars. Last, and highly relevant to our discussion, he studied the chromosomal pairing pattern in hybrids obtained from crosses between domesticated and wild accessions (Ladizinsky 1979a; Ladizinsky *et al.* 1984). One important conclusion of those hybridization experiments was the understanding that all tested lentil cultivars have the same karyotype (one out of several cytotypes found in the wild progenitor) and a similar chromosomal linear order.

Interestingly, Ladizinsky's hybridization experiments exposed a similar chromosomal linear order among *L. orientalis* accessions from Cyprus, Syria, Turkey, Iran, Turkmenistan, Uzbekistan and Tajikistan. However, none of the tested accessions from Israel (Mount Hermon included) shared this standard (domesticated) chromosomal arrangement. That fact, which was unfortunately overlooked by Weiss, Kislev and Hartmann (2006), undermines a southern Levant lentil domestication.¹ The theory underlying the prevailing understanding, therefore, was that the domesticated lentil genepool may have originated via repeated multiple adoptions for domestication in any or in several of the above

1. Weiss, Kislev and Hartmann (2006) clearly say that the first step (loss of dormancy) occurred in the northern Levant, and that it spread to the southern Levant, but the subsequent steps (pod indehiscence) presumably took place in the southern Levant. This statement as a whole was not based on any direct evidence and remains mere speculation.

regions. However, more than one chromosomal arrangement was identified in wild lentils from Turkey and also from Iran (Ladizinsky *et al.* 1984; Ladizinsky and Abbo 2015). This observation reduces the likelihood of multiple lentil domestication in different regions. This is because it is unlikely that multiple chance sampling in several locations in Turkey and Iran (with its varied chromosomal types) would have consistently picked up only the identical karyotype common to all tested domesticated lentil cultivars.²

The second diagnostic tool used by Ladizinsky 1999 was the chloroplast DNA (cpDNA) polymorphism pattern. Consistent with a monophyletic origin of the crop, domesticated lentil cultivars are monomorphic³ (see summary in Ladizinsky 1999). The third diagnostic test that he employed was crossability, namely the potential to obtain viable hybrid seeds and fertile progeny from the hybrid plant in crosses between domesticated cultivars and wild accessions that share the cpDNA polymorphism pattern of domesticated lentil.

By combining the above three diagnostic criteria, Ladizinsky (1999) was able to identify one wild lentil accession from eastern Turkey (near Tokat) and two from northwestern Syria (near Idlib) that shared the domesticated lentil karyotype and cpDNA pattern, that showed regular meiotic chromosome pairing, and which produced fully fertile progeny following hybridization with standard domesticated tester lines. It could be argued that genome-wide sequence comparisons are more powerful, i.e., have better statistical reliability, because they rely on many thousands of data points. It should be borne in mind, however, that such estimates

2. Much in the spirit of the “preemptive domestication” notion of Jared Diamond (1997) (see Chapter 6 below, and see below in this section and n. 11 on p. 100). Notably, Zohary (1996) suggested a single event of domestication for each of the package crops separately, i.e., a monophyletic origin for each of the species. Yet, since Zohary also acknowledged the presence of the progenitors of all of the founder crops in the northern Levant, this could implicitly be viewed as a core area. He did not, however, accept the notion of a single domestication event: “There is a scholarly debate as to whether agriculture originated in several places across a wide area, including the Levant and northern Fertile Crescent ... or whether it evolved in only one part of the Fertile Crescent, such as southeast Turkey (e.g., Lev-Yadun, Gopher and Abbo 2000). Although current archaeobotanical data support the first view, this critical question required more archaeobotanical and radiocarbon dating evidence to support any definitive finding” (Zohary, Hopf and Weiss 2012: 1).
3. Monomorphism is a condition in which no variability is found in a certain trait (or gene/DNA sequence), as opposed to polymorphism, where two or more allelic variants of a gene, a non-coding sequence or (in this case) the entire plastome are found within a population of the organism.

of genetic affinity (in essence, DNA sequence similarity) do not necessarily reflect the crossability potentials across the well-established species boundaries in their respective taxa (for a detailed discussion, see Ladizinsky and Abbo 2015: 19). This can easily be understood when considering a study by Alo *et al.* (2011); while confirming the status of *L. orientalis* as the progenitor of domesticated lentil, these authors also grouped accessions that belong to a different (cross-incompatible) species (*L. lamottei*) together with *L. orientalis* and its domesticated derivative *L. culinaris*. This suggested that DNA pattern-based phylogeny does not on its own suffice to allow determination of ancestry or species relations.

To conclude, the discrete polymorphism pattern of the three genetic diagnostic tools used by Ladizinsky (1999), namely, cross-compatible vs. incompatible, standard vs. different karyotype, and cpDNA patterns, lends strong support to the notion of a monophyletic lentil domestication. After all, what is the likelihood that different communities across the Levant with similar cultural landscapes would have chosen seed corn having the same combination of karyotype, cpDNA stock and cross-compatibility? Likewise, the nature of those genetic criteria confers high reliability on Ladizinsky's (1999) identification of the wild ancestral stock of domesticated lentil.

The question of a single domestication event pertains not only to single species as proposed by Zohary (1996; 1999), but also to domestication of the initial crop package, i.e., founder crops, as a whole, as proposed by Lev-Yadun, Gopher and Abbo (2000; see also Abbo, Lev-Yadun and Gopher 2010a; 2010b; Abbo and Gopher 2017; Gopher, Lev-Yadun and Abbo 2017). To this date, however, there is no reliable evidence of the formation of independent crop packages in the different putative Levantine domestication subcenters, as claimed by Willcox (2005).³ From both the agronomic and the nutritional perspectives this is a serious weakness in the narrative of autonomous (independent) domestication compared to the proposed inclusive (package-domestication) model (see Abbo, Lev-Yadun and Gopher 2010a; 2010b). Multiple events manifest in autonomous scenarios for plant domestication are currently in vogue, as reflected in some summaries of plant and animal domestication

3. Interestingly, Willcox (2018) claimed that plant domestication was autonomous for each species and in specific local geographical conditions, yet, later in the same paper, all the package plants are (erroneously) described as growing everywhere in the Levant, and there is no sign of the "autonomous" history and no impact of local, specific conditions, or what may be inferred as "local adaptations." How can that be explained?

in the Levant (e.g., Asouti and Fuller 2013; Brown *et al.* 2009; Fuller 2007; Fuller, Willcox and Allaby 2011; 2012; Fuller *et al.* 2018; Smith 2007a; Willcox 2005; 2013; 2018; Zeder 2008; 2015; and for certain aspects, also Zeder 2017). Those scenarios often quote “hard core” studies such as Weiss *et al.* (2006) or the work of Willcox (Willcox 2002; 2005; Willcox, Fornite and Herveux 2008; Willcox, Buxo and Herveux 2009; and see detailed discussion in Box 2.4). Looking closely at those studies, we find that one of the arguments concerns experimentation that led to the domestication of various species simultaneously (Weiss, Kislev and Hartmann 2006), where the success (pre-domestication cultivation) or failure (no domestication cultivation) of these processes would have occurred autonomously *à la* Colledge (2001: 224). Those alleged failures in domesticating some potential crop species were recently dubbed “additional founder crops,” “lost crops” or “lost genetic lines” (Fuller 2007; and see also Allaby 2010; Fuller, Willcox and Allaby 2011: 631; Gross and Olsen 2010); or “failed trials with new techniques” (Snir *et al.* 2015; and see our discussion below).

Meticulous scrutiny of several such cases, however, seems to refute the claim, at least where the presence of adequate evidence is concerned (Abbo *et al.* 2013b). The concept of “experimentation,” tempting or logical though it may appear, is vague and archaeologically translucent. It raises more questions than answers, and the botanical data may provide other and more parsimonious explanations (see below, Table 8.1): How does the experimentation scenario accord with the idea of unconscious plant domestication proposed by the same authors? Does not an experiment require attention to the selection of candidates and their performance, as well as a careful evaluation of the results for the different plants in the experiment? How are we to know if experiments were conducted with those species? Did Neolithic people experiment with the full variety of species as listed in archaeobotanical records, for example, in the cases of Natufian Mureybet or Tell Abu Hureyra, or in Pre-Pottery Neolithic A (PPNA) Mureybet and Netiv Hagdud (see Melamed, Plitmann and Kislev 2008), or Gilgal I (see Weiss, Kislev and Hartmann 2006)? Were experiments carried out at Pre-Pottery Neolithic B (PPNB) Tell Abu Hureyra (De Moulins 2000), at Pre-Pottery Neolithic C (PPNC) Atlit-Yam (Galili 2005; Kislev, Hartmann and Galili 2004; Hartmann-Shenkman *et al.* 2015), or at later Neolithic sites showing many non-domesticated species? Why would experimentation be limited to those periods only? What about earlier, Paleolithic, communities? Why not speculate on experimentation for the many edible species found in 60–50 Ky-old Paleolithic Kebara Cave (Lev, Kislev and Bar-Yosef 2005), or early Epipaleolithic Ohalo II (Kislev, Simchoni and Weiss 2002; Weiss *et al.* 2004) as suggested by Snir *et al.* (2015)? The narrative concerning collective

memory and deep cultural traditions (Fuller, Willcox and Allaby 2011) indeed suggests that we should place greater emphasis on earlier human cultures in our attempt to understand plant domestication, rather than only on subsequent cultures (e.g., Neolithic), during which time domestication had taken place. This journey to our deep Paleolithic past, as well as the superlatives about our Paleolithic ancestors (Fuller, Willcox and Allaby 2011: 643), was launched for an entirely different reason.⁴ Couldn't people collect plant species throughout prehistory, including taxa to be domesticated later, without experimenting or endless auditioning of different candidates (e.g., *à la* Smith 2007b) for domestication?⁵ In our view, the mere preservation of any plant species in Paleolithic or Neolithic sites (including those that later became crop plants) is insufficient to claim either experimentation (including auditioning) or pre-domestication cultivation (see Box 2.4 in reference to Weiss, Kislev and Hartmann 2006).

Willcox (2005), based on a summary of his work with cereals of major archaeobotanical assemblages from Syria, offered an answer to the question of whether there is a core area, as well as an interpretation of the “one event/multiple events” narrative (see also Willcox 2002). This was further developed in his later papers (Willcox, Fornite and Herveux 2008; Willcox, Buxo and Herveux 2009; Willcox 2012a; 2012b; 2012c; 2013; 2018; Willcox and Stordeur 2012, summary). His model (Willcox 2005) is based on the present distribution, natural habitats and availability of wild cereals, and assumes “multiple events—multiple centers” (i.e., autonomous) domestication, as the page header of his paper indicates. He plotted the present distribution of wild cereals on geographic-temporal charts and argued

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4. In the “journey” of Fuller, Willcox and Allaby to our deep Paleolithic past, the authors state that “... helping plants multiply and manipulating landscape compositions was part of the collective memory of *Homo sapiens sensu stricto* since the Middle/Upper Paleolithic, and that such knowledge has been passed down to recent hunters-gatherers who practiced such techniques” (Fuller, Willcox and Allaby 2011: 642–643). Moreover, those authors claimed (mobilizing the legacy of our deep prehistoric ancestors) that “... anatomically modern humans used fire systematically to alter vegetation” (*ibid.*). Admittedly, however, “... in the absence of sedentism and large-scale systematic processing of particular species (such as cereals) little is preserved of such activities in the archaeological record” (*ibid.*). These authors claim that “... there is no reason to believe that sowing and tending of plants was a great idea of a few core area foragers of the early Holocene upper Tigris valley, but instead it was shared ancestral knowledge of *Homo sapiens* that could be drawn upon as local circumstances warranted” (*ibid.*). We cannot avoid the impression that such archaeological argumentation including (but not limited to) a journey to our deep Paleolithic past was called upon in order to conceal or avoid an entirely different attitude; for example, Purugganan and Fuller (2011: 181), in referring to Willcox, Buxo and Herveux (2009: 156), that “... at least for non-shattering, both forms are present in the crop and are so similar that the early Neolithic farmers may have simply considered them the same crop and could not consciously differentiate cultivated from wild forms in the field” (see also Box 2.4).
5. And if this is not the case, how did hunter-gatherers survive until late historical times? Did they fail in all their experiments? Were they blind to successful ones in their regions? Or perhaps they did not experiment at all?

that in each sub-region of the Levant specific cereals were domesticated, each suited to the specific local ecological conditions. These species, he claimed, had survived and remained dominant in their sub-regions for thousands of years (e.g., barley in the south, einkorn in the north). Underpinning his argument are the assumptions that the distribution of cereals was similar throughout the Holocene and has not shown much change since then and that not every cereal species is found everywhere in the Levant (which is, of course, true). Thus, each cereal was domesticated where it was (and still is) present and better adapted. According to that hypothesis, it is unsurprising to find evidence for barley domestication in the southern Levantine Jordan Valley (evidence that was not presented in his paper), while einkorn and rye are found in the north (Middle Euphrates). The simultaneous appearance of barley and emmer wheat in both the south and the north of the Levant would therefore indicate that the two were domesticated in both areas, i.e., more than once. Willcox (2005) did not discuss the available genetic evidence negating his model and showing a northern Levantine emmer domestication (Salamini *et al.* 2002; Özkan *et al.* 2002; and further developed in Özkan *et al.* 2005). Note, too, a later study by Luo *et al.* (2007), also corroborating the notion of northern Levantine emmer domestication.

Indeed, each of the wild progenitors of the founder crops (both cereals and legumes) has its own ecological affinities (see Abbo *et al.* 2009; Zohary, Hopf and Weiss 2012). Employing the logic that different natural distribution ranges can be taken as convincing evidence for multiple autonomous domestications (*sensu* Weiss, Kislev and Hartmann 2006; Willcox 2005; Zeder 2008), that particular argument can easily be overturned by showing that the wild progenitors of all Levantine founder crops are quite abundant and appear together only in a single area in southeastern Turkey and northern Syria, and that in certain settings in that region they even grow side by side, supporting the notion of a core area (Fig. 4.1; and see Abbo, Lev-Yadun and Gopher 2010a). Specifically, the natural distribution ranges of the three wild cereals—barley, einkorn and emmer—coincide in the Karacadağ (core) area, suggesting (alongside archaeobotanical and genetic evidence) that their domestication took place at that locale as part of the simultaneous domestication of the entire founder crops package (Lev-Yadun, Gopher and Abbo 2000). Regrettably, Willcox (2005) does not discuss legumes, but we can add that the wild progenitor of chickpea is native only within or in very close proximity to our proposed core area (Lev-Yadun, Gopher and Abbo 2000).⁶ Moreover, Willcox's own table (Willcox 2005: 535) shows that the only area in which archaeological evidence exists for all species of concern in our

6. The progenitor of bitter vetch is not known to exist south of Jebel Druze and Mount Hermon.

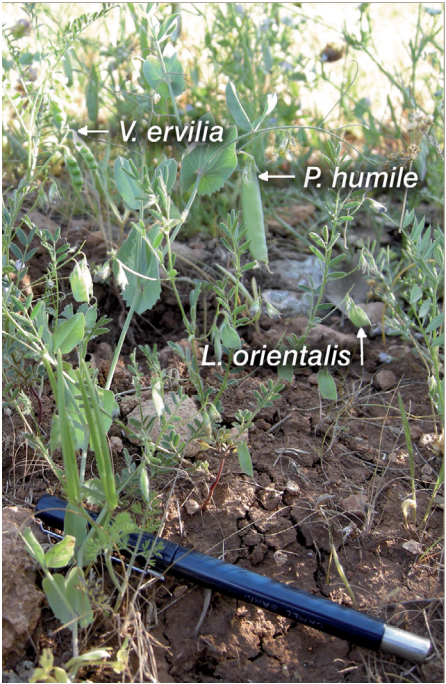
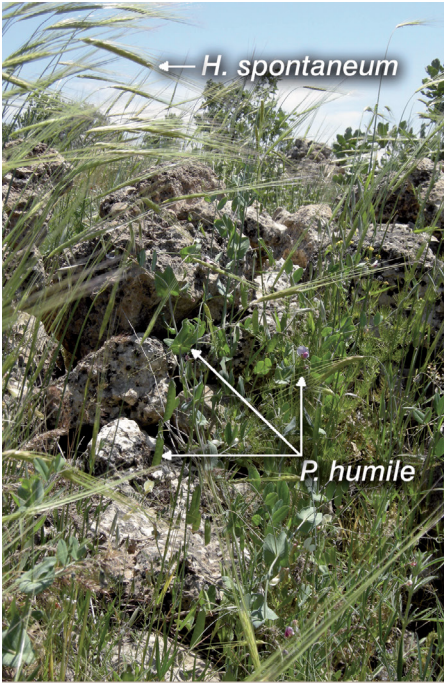
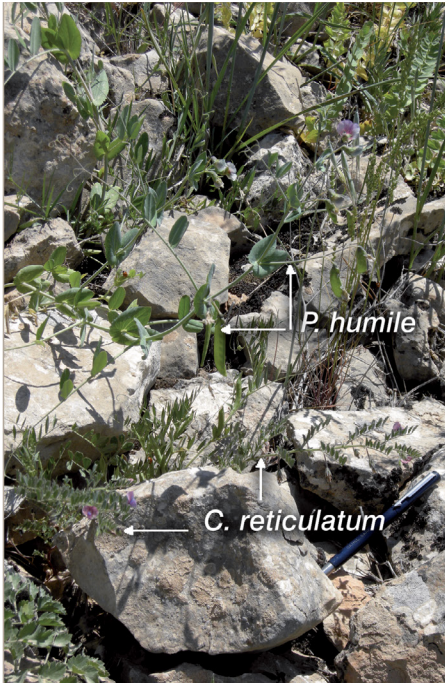


Fig. 4.1: Panel showing the sympatric occurrence of the wild progenitors of Levantine grain legumes; in addition, barley can be seen in the top right photograph (taken in the Mardin province, southeastern Turkey by Shahal Abbo)

book is the northern Levant—southeastern Turkey and northern Syria—i.e., the specific area proposed by Lev-Yadun, Gopher and Abbo (2000) as the core area of domestication.

Thus, the data and arguments of Willcox (2005) may, after all, support a highly localized single domestication event *sensu* Lev-Yadun, Gopher and Abbo (2000). Interestingly, a similar pattern of multiple diffused polyphyletic origins was put forward by Zeder (2008) for Levantine animal domestication.⁷ The natural distributions of the likely domesticated stocks of goats, sheep, cattle and pig all coincide in an area encompassing the core area of plant domestication that we proposed in the past (Lev-Yadun, Gopher and Abbo 2000) and still do (see also Zeder 2008, Fig. 1).⁸ Even Fuller, Willcox and Allaby (2011: 638) admitted that at Çayönü, located within our suggested core area, there is evidence indicating that all four of those domesticated animals appeared there quite early (see n. 9 on p. 98).

Proponents of the autonomous model of plant domestication (e.g., Fuller, Willcox and Allaby 2011; 2012; Fuller, Asouti and Purugganan 2012a; 2012b; Fuller *et al.* 2018; Kilian *et al.* 2007; Willcox 2005) share the general idea that ancient communities had the potential—which indeed they realized—to experiment with plants while initiating cultivation and unconsciously “selecting” for and finally achieving full domestication of local plants. This process, however would have taken many hundreds of years even under stable climatic conditions (Weiss, Kislev and Hartmann 2006), perhaps a millennium (within the PPNA; Willcox and Stordeur 2012; Willcox 2012a; 2012b), or several millennia—continuing deep into the late Pre-Pottery Neolithic (PPN) and into the Pottery Neolithic (PN), when agriculture had already spread out of the Levant into Europe and Africa (Asouti and Fuller 2013: 305, 308; Tanno and Willcox 2006a)—or even longer (Purugganan and Fuller 2011), perhaps starting as early as in the Epipaleolithic (Fuller 2007; Moore 1982; Snir *et al.* 2015).

7. Interestingly, Zeder (2015), quoting Larson and Fuller (2014), says that: “Nuclear genome research, for example, has demonstrated that what seemed to be multiple independent domestication events in various livestock species are more likely attributable to introgression between introduced domesticates and indigenous wild populations.” This type of argumentation is crucial for plants as well, and may tip the balance in major disagreements. We should keep in mind that Allaby, Fuller and Brown (2008) and Brown *et al.* (2009) argue the opposite, i.e., that what seems to show a monophyletic fingerprint may actually have been a concealed polyphyletic scenario (but see Civián *et al.* 2021).

8. A recent summary by Gila Kahila Bar-Gal (forthcoming) shows the area where the geographic distributions of the progenitors of the “Big Four” animal package of the Levant (goat, sheep, cattle and pig) overlap, and it includes the area we suggest as the core area of plant domestication.

The model for multiple autonomous domestication locales also lacks an element describing how the different local crops (staples) eventually coalesced⁹ to form a harmoniously combined, agronomic and nutritionally balanced founder crop package. This model also raises questions of utility. As explicitly stated by Willcox (2005), the multiple autonomous domestication model suggests that communities cultivated or domesticated a single crop. Does this model imply, then, that a single species was the staple for each of the autonomously domesticating communities? How should one characterize the logic for such behavior—as agronomic, economic, or dietary? Alternatively, are the authors suggesting that in each of the supposedly autonomous sub-centers a local, agronomically balanced crop package was domesticated? Is there any evidence for such local domestication foci from archaeobotanical assemblages recovered anywhere across the Fertile Crescent (Levant)? How is it possible and why would a (southern Levantine) community, for example, engage in the process of adopting a crop species such as chickpea, bitter vetch, or einkorn, that originates many hundreds of kilometers away? If, for instance, chickpea had been domesticated in the southern Levant, its wild progenitor would have been *Cicer judaicum* that grows in Israel and not *C. reticulatum*, and we should then have two domesticated *Cicer* species. And if, following Weiss, Kislev and Hartmann (2006),

9. Following the environmentally based suggestion of Willcox (2005) for intra-Levantine autonomous domestications based on natural habitats and availability of the progenitors of the various package species, Fuller *et al.* (2018) talked about autonomous domestication centers within the Levant and argued (*ibid.*: 64) that "... there was a coalescence of crops across the region resulting in increased crop diversity on a site by site basis [towards the end of the domestication process]." First, why would an environmental logic advocating autonomous domestications of single suitable species (following both Willcox and earlier work by Fuller and colleagues) change to allow for a coalescence with unsuitable species? Did the environment change during the thousands of years of protracted-autonomous domestication? Has this environmental change been geographically differential so that it accords well with a model of (intra-Levantine) autonomous domestications or any coalescence of species? Does it not contradict, at least to a certain extent, some of their argument about using environmentally suitable species in each region? Moreover, when referring to the available data, Fuller *et al.* (2018: 64) said: "It is worth noting that the increase in crop diversity is most marked in the northern Fertile Crescent region, but is still evident in the southern and northern Levant." It would be nice to mention an older statement by Fuller: "... the overall crop package is more diverse in this core region than elsewhere, based on the range of taxa found at Çayönü, Nevalı Çori, and Cafer Höyük. Perhaps this was the region where all of the crops were first combined, but this would appear to have happened before all were morphologically domesticated ..." (Fuller, Willcox and Allaby 2012: 629). This is quite a surprising statement for a supporter of the protracted-autonomous model—almost a converted view. Moreover, Fuller and colleagues made a statement that related to animals as well, in a *World Archaeology* (2011) paper about the domestication of animals, and interestingly, they again mention a core-area site *sensu* Lev-Yadun, Gopher and Abbo (2000), saying: "Only at Çayönü, which has one of the longest sequences, is there possible evidence for all four domesticated animals quite early, although the dominance of domesticated sheep and goat appear later than the earliest evidence for pig and cattle herding ..." (Fuller, Willcox and Allaby 2011: 638). Why, then, struggle so intensively against the core-area one-event model and rely on dubious assumptions while the data are quite clear, following their own statements?

there was an experimentation/cultivation/domestication sub-center in the southern Levant, how can one explain the emergence of such a locale in the lower Jordan Valley, where—out of the eight Neolithic package plants—only the wild progenitor of barley may have been available?

Kilian *et al.* (2007), based on a DNA polymorphism study of einkorn, suggested culturally independent domestication events, given that all of the putative domestication subcenters depicted (see Kilian *et al.* 2007: race β of einkorn wheat in their Fig. 1) occurred within an area of some 300 km in diameter, mostly overlapping the core area suggested by Lev-Yadun, Gopher and Abbo (2000). Earlier work by Blumler may help place this model in context. Blumer's summaries of the subject in the early 1990s (Blumler 1991; Blumler and Byrne 1991), predating the presently available DNA analyses, argued that available data and theoretical models do not support independent multiple domestication events, and they questioned the cultural independence of the (so-called) "autonomous" domestications. In commenting on the "dispersed specific model" in Kilian *et al.* (2007), Heun, Haldorsen and Vollan (2008) rejected claims for multiple einkorn domestication episodes (and see Abbo, Lev-Yadun and Gopher 2010a); and eventually Kilian *et al.* (2009) themselves reconsidered their earlier interpretations and statements, adopting the view of Abbo *et al.*: "Local wild populations were domesticated in a core area of the Fertile Crescent and were then gradually dispersed throughout the region (Abbo *et al.* 2006)" (Kilian *et al.* 2009: 104).

Returning to Zohary's third line of evidence regarding the presence of wild edible congeneric species in a process of a monophyletic, single-event domestication: we borrow the term and idea of "preemptive domestication" (Diamond 1997), postulating that the successful domestication of one species precludes the need to domesticate other plant species with similar potential. The notion of preemptive domestication was indirectly and briefly mentioned by Wains (1975) with reference to pea domestication, as well as by Zohary (1996; 1999), in support of their claim for a monophyletic origin of the Levantine founder crops. However, the idea was clearly put forward, re-coined and discussed in detail by Diamond (1997: 179–180). The preemptive principle does not suggest that the domestication of a cereal would prevent the adoption of a legume; rather, it relates to similar species. The choice of package legumes and of a single species among a wider range of available and suitable wild candidates among the genera *Cicer*, *Lens* and *Pisum* provides a good example in support of a preemptive domestication pattern. This would be applicable to species such as chickpea (with its three sympatric wild species and two additional

allopatric species),¹⁰ lentil (three sympatric species) or pea (three sympatric species) (Abbo *et al.* 2009; Zohary 1996; 1999). Following the proposed preemptive domestication, the likelihood that a domestication event in a plant species will repeat itself (in the presence of similarly useful wild species) is low, and if it is nevertheless repeated, it seems unlikely that it would always involve the same combination of specific taxa (Zohary 1999).¹¹ The idea of preemptive domestication indeed offers a conceptual alternative to the autonomous (multicenter) model and generally lends support to a “core-area one-event” model of Levantine plant domestication.

Pinpointing the Core Area

The “where” question is central to our discussion and, as stated in our introductory chapter, may govern the understanding of many other aspects of Levantine plant domestication and help generate a coherent cultural and biological plant domestication scenario. Answering the “where” question of plant domestication requires a joint investigation of geobotanical, archaeological and archaeobotanical dating (preferably of the seeds themselves) and genetic relatedness concerning both wild and domesticated plant populations. Based on those lines of evidence we have suggested a well-defined, relatively small geographical core area in southeastern Turkey and northern Syria as the origin for all Levantine Neolithic grain crops (Abbo, Lev-Yadun and Gopher 2010a; Gopher, Abbo and Lev-Yadun 2001; Lev-Yadun, Gopher and Abbo 2000; and see Fig. 1.3 in this book).

A localized origin of crop plants is an old idea dating back to De Candolle (1884), Childe (1936; 1951; 1952), Vavilov (1951) and others, but the locale suggested in those early sources is usually quite large (sometimes thousands of kilometers across) and not well defined. Braidwood was the first to initiate an interdisciplinary field project to actively search for this location. His working hypothesis was that the area in question, the cradle of agriculture, should have the biological potential of relevant wild-progenitor species. Following his work in Iraqi Kurdistan and Turkey, and based on the limited archaeology, botanical finds and environmental reconstruction available at the time, Braidwood proposed the “nuclear zone

10. The terms “sympatric” and “allopatric distribution” describe the geographic proximity of plant (or animal) species in natural habitats. “Sympatric distribution” describes the condition where two or more species are found in great physical proximity, while “allopatric distribution” describes the condition where those species do not inhabit the same habitat or even the same geographic area.

11. The description by Diamond (1997: Chapter 13) of the evolution of writing may provide a cultural analogy for the preemptive domestication concept, in that it is unlikely to happen again within a short time frame within the same cultural interaction sphere.

hypothesis” (see short summary in Redman 1978: 95–97), suggesting that domestication had emerged within the piedmont hills and lower inter-mountain valleys of the Zagros-Taurus arc (the “hilly flanks”) (Braidwood 1960; 1967; 1975). In the mid-1960s, Harlan and Zohary (1966) suggested that early Near Eastern cereal domestication had occurred in the Fertile Crescent arc. With new developments and based on much larger archaeobotanical databases, botanical observations, genetic data and archaeological considerations, including more accurate ¹⁴C dating, Zohary and Hopf later proposed the “Near East” (Zohary and Hopf 1988; 1993; 2000) as the core area. More recently, Zohary suggested “Southwest Asia” (Weiss and Zohary 2011; Zohary, Hopf and Weiss 2012: 1–2) as the origin of plant domestication—too broad a definition to be useful in the present discussion.

Bar-Yosef and colleagues proposed the “Levantine corridor”¹² as the elusive “core area” (e.g., Bar-Yosef 1995; 1998a; Bar-Yosef and Belfer-Cohen 1991; 1992; Bar-Yosef and Kislev 1989; Bar-Yosef and Meadow 1995), emphasizing the role of the lower Jordan Valley and the Damascus basin. In later publications, Bar-Yosef more specifically pointed to a “core area” in the middle and upper Euphrates and Tigris valleys, stating: “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 ... [Younger Dryas, i.e., in the Late Natufian] ... and the idea spread rapidly southward” (Bar-Yosef 2011: S181; see also 2014: 69, 71–72; 2017). Advocating a single-event model, Garrard (1999: 82)¹³ concluded that the Damascus basin and the Jordan Valley in the southern Levant represent the region where domestication started. He reached this conclusion on the basis of two lines of evidence: first, that no evidence was found for plant domestication in Iraq or southeastern Turkey before the middle of the eleventh millennium Cal. BP,¹⁴ and secondly, that supportive evidence was found in the Damascus basin (at Tell Aswad Layer IA of the old

12. “Levantine corridor” is a loose term used to describe the corridor linking Africa and Europe via Turkey.

Literature entries relevant to plant domestication and the Neolithic Revolution describe this area as the narrow strip from the Arava Valley south of the Dead Sea to southeastern Turkey, including the Jordan (Rift) Valley, the Lebanese Beq’a Valley, parts of central Syria, the middle Euphrates and the area spanning from it up to the Çayönü area in the north (e.g., see maps in Bar-Yosef 2002; Bar-Yosef and Meadow 1995).

13. “The data lends support to the findings of genetic research which suggests a few rather than multiple origins for certain of the founder crops in the region” (Garrard 1999: 82).

14. We presume that Garrard was aware of Hillman’s data regarding Tell Abu Hureyra Layer 1 (e.g., Hillman 1996; Hillman and Colledge 1998; and see above), as well as the finds concerning identification of the progenitor population of einkorn wheat at Karacadağ in southeastern Turkey (Heun *et al.* 1997), but for some reason preferred to quote Jones, Allaby and Brown (1998).

de Contenson excavation, the dating of which misled many investigators; see above), the Jordan Valley (Jericho PPNA) and the PPNA site of Iraq ed-Dubb (Jordan) in the form of domesticated cereals from ca. 11,500–11,000 Cal. BP¹⁵ (see Box 2.1).

Pioneering genetic studies towards the turn of the 21st century by Heun *et al.* (1997) provoked a lively debate in *Science* concerning the origins of domestication. Based on nuclear DNA markers combined with archaeological and archaeobotanical data, Heun *et al.* (1997) suggested a specific core area for einkorn wheat domestication in the region of Mount Karacadağ, southeastern Turkey. Quoting Blumler and Byrne (1991), Heun *et al.* (1997) also suggested that single human groups may have domesticated all primary crops of the region. Many researchers accepted the genetic identification of the progenitor population of einkorn, yet challenged the specific location that was pointed out for its domestication. For example, Jones, Allaby and Brown (1998) argued that the core area of plant domestication was situated in the Damascus basin (i.e., Tell Aswad) and in the Jordan Valley (i.e., Jericho, Netiv Hagdud and Gilgal I),¹⁶ some 700 km to the south of the area proposed by us, and that it had occurred as early as ca. 11,500–11,100 Cal. BP (their 8,000–7,700 uncal. BCE). Their argument was that “On a global scale, centers of past domestication will not be vast distances [away] from centers of present genetic diversity, but the match is likely to be approximate” (Jones, Allaby and Brown 1998: 303). Their claim, however, was based on supposedly analogous examples of domestication of maize in America and rice in China. Accepting the identification of the progenitor population of einkorn, Hole (1998) also contested its cited location, arguing that the conditions (mainly the climate immediately following the Younger Dryas) in the region of Karacadağ were not suitable for domestication, referring to evidence from Tell Abu Hureyra located in a more arid zone than Karacadağ. The alternative he suggested for domestication was the area of the middle Euphrates, some 200 km to the southwest of Karacadağ, “... regardless of where the progenitors of any economic species lived” (Hole 1998: 303). Nesbitt and Samuel (1998) pointed out that the archaeological sites on which Jones, Allaby and Brown (1998) had based their argument, such as Jericho and Tell Aswad, had yielded no relevant well-dated botanical evidence for domestication. Instead, those authors used data from Cafer Höyük and Tell Abu Hureyra 2A, located in the area of the middle Euphrates, to assign domesticated einkorn, emmer and barley to dates that are several hundred years earlier than those assigned to available data from the southern Levant. Further support for their

15. The dates given here were estimated following the uncalibrated dates mentioned by Garrard (1999).

16. As we have pointed out before, the Tell Aswad and the Jericho data have been revised (see Box 2.1), while Netiv Hagdud and Gilgal I show no domesticates.

hypothesis comes from the earlier presence of charred remains of wild einkorn in this region at sites such as the [Late] Natufian Tell Abu Hureyra 1 (ca. 13,000 Cal. BP) and Mureybet I (ca. 12,150–11,650 Cal. BP), as well as from PPNA Jerf el Ahmar (ca. 11,000 Cal. BP). While Nesbitt and Samuel (1998) accepted the argument of Heun *et al.* (1997) concerning Karacadağ as the origin of domesticated einkorn, they perceived the evidence regarding other species as unclear. In a later summary, Nesbitt (2002) concluded that the domestication of plants and the shift to agriculture took place during the Early Pre-Pottery Neolithic B (EPPNB). While advocating independent domestications in different parts of the Levant, Nesbitt (2004: 40) later admitted: “It’s difficult to say if this is because of the rapid spread of ideas or because of similar pressures operating on hunter-gatherer communities across the different regions.”

In 2000 we joined the discussion, proposing a core area situated in southeastern Turkey and northern Syria—the only region where the current natural distributions of the wild progenitors of all eight founder crop species overlap (Gopher, Abbo and Lev-Yadun 2001; Lev-Yadun, Gopher and Abbo 2000; and details below). We found support for this claim in the study of Heun *et al.* (1997) and its results for einkorn, as well as in additional genetic data on lentil (Ladizinsky 1999), the restricted distribution of the chickpea progenitor and additional genetic, archaeobotanical and archaeological data, as elaborated below.

The contrasting position is represented by Willcox (2005) and by Weiss, Kislev and Hartmann (2006), who advocated autonomous domestication models. Similarly, a plethora of publications by Fuller and colleagues advocated an autonomous—diffused, non-centered, protracted—model of plant domestication (e.g., Asouti and Fuller 2013; Fuller 2007; Fuller, Allaby and Stevens 2010; Fuller, Willcox and Allaby 2011; 2012; Fuller *et al.* 2018; Purugganan and Fuller 2011).

To summarize, two contrasting views are currently on stage concerning the “where” of plant domestication. One model suggests an autonomous, mosaic, non-centered pattern of plant domestication. It promotes independent multiple domestications of single plant species in different parts of the Levant (and in other parts of the natural distribution of these species across Asia), operated by local communities that embarked on cultivation of various plant species. That would have resulted, according to this model, in their domestication after a millennia-long protracted unconscious process. We have already discussed some aspects of the unlikely probability of autonomous plant domestication. In our view, the combination of geobotanical, archaeological, archaeobotanical and genetic evidence, as detailed below, does not support this model.

The second model, which is the subject of this book, is the “core-area one-event” model, whereby the domestication of all package plants was initiated by communities (small groups of people, see Blumler 1991) in a relatively small and well-defined core area in the northern Levant: southeastern Turkey and northern Syria (Abbo, Lev-Yadun and Gopher 2010a; Gopher, Abbo and Lev-Yadun 2001; Lev-Yadun, Gopher and Abbo 2000). A high potential of wild edible plants, some suitable for domestication, was available in this area to the Neolithic population, which had shown great ingenuity by achieving the highly successful recruitment of a suite of plant species that were domesticated quite rapidly. We contend that the genetic stocks of the Levantine crop package, as well as the idea and culture of agriculture, spread—like other Neolithic innovations—from this core area, first throughout the Levant (and into Cyprus) and subsequently beyond it.

Resolving this dispute is fundamental to our understanding of both the biological and the cultural mechanisms of plant domestication and the spread of domesticated plants and agriculture within the Levant. Pinpointing the geographic origins of domestication may also help to answer questions concerning the rapid spread of agriculture beyond the Levant to other continents, namely, Europe, Africa and other parts of Asia. Following are some comments on the lines of evidence on which we base our arguments in favor of a “core-area one-event” model.

Archaeobotany

The archaeobotanical data used by Lev-Yadun, Gopher and Abbo (2000) and by Gopher, Abbo and Lev-Yadun (2001) in support of their claim for a core area in the northern Levant were as follows: founder package species were found in their wild state in the archaeobotanical record of pre-Neolithic sites in that region, e.g., in the Late Natufian Tell Abu Hureyra 1 and Mureybet I, both dated to the thirteenth millennium Cal. BP (see also Savard, Nesbitt and Jones 2006), as well as in Neolithic (PPNA) sites such as Jerf el Ahmar, Mureybet III, Çayönü (the Basal Pits and the Round Plan subphases), Nemrik, Qermez Dere and M’lefaat—all dated to the twelfth and the beginning of the eleventh millennium Cal. BP. The earliest domesticated package plants in the Levant were found in northern Levant EPPNB sites such as Çayönü (PPNA/EPPNB); for a later summary, see Nesbitt (2002), who mentions domesticates in the Round Plan sub-phase as well as in the later Grill Plan and Channeled Buildings sub-phases, where domesticated einkorn and emmer were dated to ca. 10,500–10,200 Cal. BP. Other EPPNB evidence originates from Tell Abu Hureyra 2A (as far as EPPNB occupations can be traced there) and relates to the two early botanical samples mentioned by De Moulins (1997: 91; see Nesbitt

2002), as well as Cafer Höyük and Nevalı Çori, yielding domesticated wheat dated to ca. 10,400 Cal. BP (for a discussion on the dates, see Haldorsen *et al.* 2011).

While endorsing a northern Levantine core area, we also argue that no reliable data supporting plant domestication in southern Levantine sites have been found for pre-Neolithic (Natufian), PPNA, or even EPPNB strata (Gopher, Abbo and Lev-Yadun 2001; and see papers by Colledge 2004; Nesbitt and Samuel 1998; Peltenburg 2004). The notion of early Neolithic (PPNA) plant domestication in the Damascus basin and the lower Jordan Valley suffers from a critical shortcoming, in that the progenitors of some Neolithic package species simply do not grow in the southern Levant (e.g., einkorn, chickpea). Moreover, the available genetic data for package species (other than some of the domestic barley types) show their closest wild genetic stocks—and hence their probable area of domestication—in the northern Levant (see next section). The datasets supporting the notion on which plant domestication in the southern Levant were based—namely, the archaeobotanical finds from three sites: Jericho, the old de Contenson excavation of Tell Aswad IA, and Iraq ed-Dubb—were later declared to be controversial (Colledge 2004: 56), and the issue has since, for the most part, been resolved. Nevertheless, we consider it beneficial to recommend that readers take a closer look at these three cases (see also Box 2.1, n. 16 on p. 102 and Chapter 6, n. 16 on p. 131).

Many new Levantine archaeobotanical datasets have since become available, and numerous research papers have been published in professional journals on various aspects of plant domestication in the Levant. Good examples of such papers are a volume in honor of Gordon Hillman edited by Fairbairn and Weiss (2009) and a recent thematic issue of *Paléorient* (2018), also devoted to the memory of Gordon Hillman, titled “Exploitation and Use of Plant Resources in Prehistoric Southwest Asia.” These include both Epipaleolithic and Neolithic (PPNA and PPNB) datasets, which have been added to our inventories and databases. These, however, have not changed our view on a northern Levantine core area of plant domestication ca. 10,500 Cal. BP, and the new data were not sufficient to confirm a southern (or any other) Levantine domestication center. Likewise, to our regret, those new data have not inspired a revision of the protracted-autonomous model, and thus, the debate remains ongoing.

Genetics

Genetic data available to Lev-Yadun, Gopher and Abbo (2000) when they made their claims concerning the core area of plant domestication included the following cases:

- The tested cytogenetic lentil types (Ladizinsky 1999) are found in the core area region (although not exclusively there);

- The genetic affinities and chloroplast DNA profiles of lentil (Ladizinsky 1999; and see Box 4.1);
- The maternally inherited chloroplast DNA type of domesticated barley is not found south of the Sea of Galilee (Neale *et al.* 1988; and see Zohary 1999: 137);
- The einkorn wheat DNA reported by Heun *et al.* (1997) indicates a northern Levant (core area) origin;
- The cytogenetic work of Ben-Ze'ev and Zohary (1973) on pea, albeit without pointing to an accurate location (Zohary and Hopf 2000: 105).

Badr *et al.* (2000) subsequently published a nuclear DNA study suggesting an option of a northern Levant origin for domesticated barley (in fact, they suggested two areas of origin, the additional one being in the southern Levant).

Additional DNA polymorphism studies with emmer wheat and reported after 2000 indicated that the likely founder stocks of this important package crop plant had also originated in the northern Levant (Özkan *et al.* 2002; 2005; Salamini *et al.* 2002). Those studies showed the area of emmer wheat origin to be in the Diyarbakır region, in the same area as that suggested by Heun *et al.* (1997) as the origins of einkorn, and within the core area delineated by Lev-Yadun, Gopher and Abbo (2000). Further genetic evidence, of the same nature for the origin of emmer wheat was provided by Yahiaoui, Brunner and Keller (2006: Fig. 4) and by Luo *et al.* (2007). The origin of domesticated barley, however, is still a matter of debate. Many students of the subject have drawn attention to the complexity of barley domestication processes, and no firm conclusions have been reached concerning the number of domestication events or its area of origin (e.g., Badr *et al.* 2000; Cíváň and Brown 2017; Dai *et al.* 2012; Igartua *et al.* 2013; Ladizinsky 1998a; Molina-Cano *et al.* 2005; Morrell and Clegg 2007; Neale *et al.* 1988; Poets *et al.* 2015; Allaby 2015; Pourkheirandish *et al.* 2015; Takahashi 1955; Zohary 1996; 1999; Czajkowska, Jones and Brown 2019). Proposals concerning multiple barley-domestication events now cover over six decades (e.g., Takahashi 1955), and the notion of multiple barley domestications has gained further support from the work of Morrell and Clegg (2007), as discussed in this chapter and in Chapter 5. Claims for a Moroccan (Molina-Cano *et al.* 2005) or an Ethiopian (Igartua *et al.* 2013; Orabi *et al.* 2007) center of barley domestication may be dismissed on the grounds that genuine wild barley is not native to those world regions (e.g., Schiemann 1951; Harlan and Zohary 1966; von Bothmer *et al.* 2003; for a review on barley domestication, see Pankin and von Korff 2017).

An interesting contribution to the debate concerning the origin of domesticated barley was published as this book was being prepared for publication. After more than two decades of contemplation, theoretical modeling and actual data analyses (e.g., Allaby and Brown 2003; Allaby, Fuller and Brown 2008; Brown *et al.* 2009), resulting in forceful advocating polyphyletic origins for the Near Eastern cereals, the group of Terence Brown have eventually come to the conclusion that the population genetics of wild and domesticated barley indicates “descent from a single founding population, which emerged in the western Fertile Crescent” (Civáň *et al.* 2021). Hence, a careful minimalistic summary of the barley case would indicate that a PPN core-area origin in the northern Levant is highly feasible.

We are unaware of extensive germplasm sampling of wild *Linum bienne* (the immediate progenitor of domesticated flax) across its rather wide natural distribution. Allaby, who usually supports a polyphyletic origin for other Near Eastern package species (Allaby, Fuller and Brown 2008; see also the discussion in Abbo, Lev-Yadun and Gopher 2010a), suggested a different scenario for flax. Based on the available accessions, Fu and Allaby (2010) postulated that flax has a monophyletic origin, thus representing a single event associated with Turkish wild accessions. Like the case of wild flax germplasm, accessions of wild bitter vetch (*Vicia ervilia*) are also quite rare in gene banks. According to Zohary, Hopf and Weiss (2012) its distribution extends from Asia Minor to the southern Levant, reminiscent of the distribution of genuine wild einkorn. However, Ladizinsky reported wild bitter vetch from the Karakala region in Turkmenistan, and more recent surveys have shown that it also grows in Armenia and in Nakhchevan, Azerbaijan (Ladizinsky, Abbo, unpublished field diaries). As yet, no phylogenetic work has been conducted with wild and domesticated bitter vetch, and it is therefore impossible to infer the geographic origin of its domesticated stock. On the other hand, a recent phylogenetic study by Kreplak *et al.* (2019) based on genome sequencing of wild and domesticated pea stocks has identified a wild accession sampled near Lake Van in eastern Turkey (somewhat north of the core area) as a stock closely related to the tested domesticated cultivars, supporting a northern Levantine origin of domesticated pea.

Archaeology

In identifying the origins of Near Eastern plant domestication we used archaeological evidence to support the geobotanical, archaeobotanical and genetic lines of evidence (Abbo, Lev-Yadun and Gopher 2010a; Gopher, Abbo and Lev-Yadun 2001; Lev-Yadun, Gopher and Abbo 2000). The core area we suggested in southeastern Turkey and northern Syria (Fig. 1.3) seems to be not only where the crop package

(assemblage) was domesticated and from where domesticated founder plants spread throughout the Levant, but also a highly important center of Neolithic cultural innovation of unprecedented scale, as expressed, for example, in PPNA sites such as Mureybet III, Jerf el Ahmar, Göbekli Tepe, Dja'de Dj I, II, Körtik Tepe I.2-VI, Tell Abr 3 and Tell Qaramel, as well as in EPPNB sites such as Çayönü, Navali Çori, Göbekli Tepe, Mureybet IV, Cafer Höyük, or Dja'de Dj III. Some of the Pre-Pottery Neolithic cultural traits characterizing this region are unique and are unknown in other regions of the Levant, such as monumental T-shaped stone sculptures (human representations; Schmidt 2012b: 111), sculptural elements in stone such as three-dimensional animal and human figures, relief (high and low) images of animals, abstract (geometric) wall paintings (Coqueugniot 2000; 2014) and more. Some Neolithic innovations from this part of the northern Levant have spread to other parts of the Levant. This includes the case of the new technology for producing long straight (non-curved, non-twisted) flint blades from bidirectional “naviform” cores. These blades were used to produce sickle blades and arrowheads—the “flag” production trajectory of the PPNB lithics, which included new flint tool types such as the Helwan arrowhead type (Gopher 1989a; 1989b). New types of ground stone implements such as the “stepped” quern, possibly used for grinding cereal grains (Gopher 1996; 1999) appeared as well. These late PPNA and EPPNB innovations reached the southern Levant a few hundred years later, at the beginning of the southern Levant PPNB, ca. 10,400 Cal. BP or even somewhat later (Edwards *et al.* 2004; Khalaily *et al.* 2007; Yizhak *et al.* 2007; see also Gopher 1994: 170–225). This was also the case for materials such as obsidian from central Anatolia and possibly from other parts of Turkey, which reached the southern Levant as early as the Late Natufian (Khalaily and Valla 2013) and continued throughout the Neolithic period, indicating long-term active trade networks through which such transference of innovations was made possible (Gopher, Barkai and Marder 1998; Gopher, Abbo and Lev-Yadun 2001; and references therein); and for cinnabar (vermilion, mercury sulfide) imported from Anatolia (Goren 2001), and—later in the Neolithic period—for chlorite (Rosenberg, Getzov and Assaf 2010). This was also the case for other cultural elements (e.g., Goring-Morris and Belfer-Cohen 2014, and references therein; see also Kozłowski and Aurenche 2005: 83). It is thus plausible to assume that the area was a potential source of seeds and agro-techniques, and for their spreading.

In summary, regardless of ensuing claims, there seems to be a general—explicit or implicit—agreement among researchers that our suggested core area in southeastern Turkey and northern Syria (Lev-Yadun, Gopher and Abbo 2000; Gopher, Abbo and Lev-Yadun 2001) was indeed a center of domestication for most, if not all, of the

package species (e.g., Cauvin 2000a; Civáň and Brown 2017; Colledge 1998; 2004; Colledge, Conolly and Shannon 2004; Fuller, Willcox and Allaby 2011; Heun *et al.* 1997; Hillman 2000; Hillman *et al.* 2001; Ladizinsky 1999; Pourkheirandish *et al.* 2015; 2018b; Salamini *et al.* 2002; Schmidt 2012a; 2012b; Weiss, Kislev and Hartmann 2006; Weiss and Zohary 2011; Willcox and Stordeur 2012; Willcox 2005; 2012a; 2012b; 2012c; Zeder 2006; Zohary, Hopf and Weiss 2012;). This may also have been the case for domesticated livestock (Kahila Bar-Gal, forthcoming and references therein; and see Zeder 2008: Fig. 1; see also Box 1.5, and n. 8 on p. 97).

CHAPTER 5

THE SPREAD OF DOMESTICATED PLANTS WITHIN AND BEYOND THE LEVANT

Knowledge of the origins and spread of agriculture worldwide has emerged in recent years, giving a clear global picture (e.g., Bar-Yosef 2011; Bellwood 2005; Bellwood and Renfrew 2002; Diamond 1997). The Levant as a primary center of plant domestication attracted research on the spread of domesticates on a continental scale focused mainly on Europe, while the spread of domesticated plants within the Levant or towards other parts of West Asia and North Africa attracted much less scholarly attention until only very recently. The Levant is a good arena for such a detailed study because of its unique nature as a quasi-laboratory, rich in data as a result of many years of intensive archaeological, geobotanical, archaeobotanical and genetic research. We therefore believe that it is time to look more closely at regions such as the Levant, in order to better assess the spread and adoption of domesticated plants and the agricultural system as a whole.

Intra-Levantine Spread of Domesticated Plants

The literature on the spread of crop package domesticates, or of the idea of cultivation, or of agriculture as an economic system within the Neolithic Levant is rather scanty. Spread mechanisms (both cultural and genetic) are hardly discussed, if at all. Following is a brief survey of some statements recorded on the topic. We focus on the spread of founder package domesticates.

Colledge (2004: 57) suggested that the spread of domesticated (package) plants from the Levant started at ca. 10,800/10,700–10,400/10,300 Cal. BP (Colledge's 9,500–9,200 uncalibrated BP), generally corresponding to the beginning of the Early Pre-Pottery Neolithic B (EPPNB) in the northern Levant, and heading southward and westward. While not explicitly identifying or advocating a core area within the Levant, she implicitly suggests that the package originated in the northern Levant, namely southeastern Turkey and northern Syria. From there, she notes, it migrated

southward to the Damascus basin and to the Jordan Valley through the Levantine corridor, as well as westward to the Mediterranean coast in the EPPNB. The pace of this spread was not discussed, yet it seems that westward it was quite fast, as expected for neighboring adjacent areas, while the spread to the southern Levant was somewhat slower.

Following Weiss, Kislev and Hartmann (2006), the spread of lentil from the northern Levant southward to the lower Jordan Valley appears to have taken a few centuries. They suggest a two-staged domestication process for lentil, stipulating a first stage characterized by free germination (loss of seed dormancy) occurring in the northern Levantine Pre-Pottery Neolithic A (PPNA) period, then rapidly spreading southward and reaching the Jordan Valley still in the PPNA. The second stage, manifest by pod indehiscence, may have occurred "...some hundreds, or even thousands of kilometers away from the center of its founder stock germplasm," that is, in the southern Levant (Weiss, Kislev and Hartmann 2006: 1610). Not only is this reconstruction based on two archaeologically translucent (lentil) traits, but it is also unsupported by any evidence. Moreover, it is unclear why Weiss, Kislev and Hartmann (2006) perceive their second stage of lentil domestication as a good enough reason to suggest that lentil was eventually domesticated in the lower Jordan Valley PPNA, especially since in most lentil varieties complete pod indehiscence has not been achieved to this day (e.g., Muehlbauer *et al.* 1997). Assuming that Weiss, Kislev and Hartmann (2006) indeed accepted, if only implicitly, the arguments of Ladizinsky (1987; see also Abbo *et al.* 2011) about free germination as the first and most important aspect of its domestication, then lentil domestication would have been rapid and would have taken place in the northern Levant, where its wild progenitor grows. Moreover, Weiss, Kislev and Hartmann (2006), based on their "conspicuous quantity" of 205 seeds (as noted and discussed above—see Box 2.4) and also on the issue of *Gallium tricornutum*, a known weed of lentils, suggested that lentil was cultivated in arid Jordan Valley PPNA sites such as Gilgal I or Netiv Hagdud. Yet their best example of this weed species is from Yiftahel, a much later site in the Mediterranean zone of the Lower Galilee in northern Israel, which provides one of the earliest instances of sound evidence showing domesticated lentil in the southern Levant and dated to the Middle Pre-Pottery Neolithic B (MPPNB) (Kislev 1985; Kislev, Garfinkel and Zohary 2012), i.e., at least half a millennium and up to a millennium later. Interestingly, a later summary statement on lentil domestication by Zohary, Hopf and Weiss (2012: 81) makes no mention of two domestication stages starting in the area where the wild progenitor occurs, i.e., the northern Levant (our core area).

Nevertheless, despite the challenges (low resolution, lack of data, various flaws in existing data), considered in conjunction the archaeobotanical and archaeological finds provide us with some information on the spread of domesticates within the Levant.

The spread of horse bean (*Vicia faba*, also known as broad bean), a grain legume traditionally not included in the Neolithic founder package, and of an unknown wild progenitor from the northern Levant, is not easily reconstructed. Although not a common find, the faba bean has been reported in Pre-Pottery Neolithic archaeological sites, and its appearance in EPPNB sites in Turkey—such as Çayönü or Nevali Çori (together with other domesticates)—justifies, in our view (and see Tanno and Willcox 2006b; and Tsuneki *et al.* 2006), its inclusion as the ninth member of the founder crop package. Its early presence at northern Levantine EPPNB Tell Ain el-Kerkh (ca. 10,400 Cal. BP; see Chapter 2, n. 9 on p. 35; Tanno and Willcox 2006b), which is quite close to our suggested core area, and its subsequent presence in large quantities in MPPNB in Israel further support the notion of a Neolithic cultural flow from north to south within the Levant.¹ Recently excavated and radiometrically dated finds of *Vicia faba* in two possible EPPNB sites in northern Israel (Caracuta *et al.* 2015)² further support this north-to-south pattern.³

The case of chickpea suggests a rapidly moving domesticated grain crop, since its natural distribution area—near our suggested core area—is limited.⁴ Yet a relatively large sample was found in northwestern Syria, only some 200 km west of the fringes of the core area, at EPPNB Tell Ain el-Kerkh (ca. 10,400 Cal. BP or somewhat later), along with a large number of faba bean seeds (see above). These remains (138 seeds of chickpea and 437 of faba bean) included whole grains, half grains and grain fragments (Tanno and Willcox 2006b: 198, Table 2). The round

1. A few instances of (domesticated) horse bean (*Vicia faba*) seeds are known from southern Levantine sites dated to 10,200/10,100–9,400/9,300 Cal. BP, such as Ain Ghazal (Rollefson *et al.* 1985) or Yiftahel (Kislev 1985; Kislev, Garfinkel and Zohary 2012).
2. However, the horse bean (*Vicia faba*) reported from the site of Aḥihud is assigned to the very end of the EPPNB and dated to ca. 10,200 Cal. BP or somewhat later (Caracuta *et al.* 2015).
3. Six carbonized seeds dated to ca. 14,000 Cal. BP from El Wad cave (Mount Carmel, Israel) were recently identified as belonging to the Viciae tribe. One of the six showed unique morphological features of small-seeded *Vicia faba* (Caracuta *et al.* 2016). On the basis of this single carbonized seed, the authors claim to have identified the elusive ancestor of the domesticated broad (faba) bean, insinuating that it may have existed in that region of northern Israel. However, based on a single seed, and with no known living wild relative (needed for use in conducting the required hybridization experiments or comparative morphometric analyses), this suggestion should be taken with great caution.
4. An alternative was implicitly suggested by Tsuneki *et al.* (2006), as well as by Tanno and Willcox (2006b), whereby chickpea was not domesticated in the core area that we suggested, which is considered to be the natural distribution of its wild progenitor *Cicer reticulatum*, but rather around the Rouj basin in western Syria, implying that its past distribution area was somewhat larger than the present one.

shape of some of the chickpea grains at Ain el-Kerkh (a trait absent in the wild progenitor but known among certain domesticated cultivars), together with their short distance from the core area, further support the early and rapid spread of domesticated species from the suggested core area. This is significant, as the finds from Tell Ain el-Kerkh (Tanno and Willcox 2006b; Tsuneki *et al.* 2006) are only a century or two later than similar finds from the core area.

Another interesting example is found in Cyprus, representing the continuing westward spread from the core area to the Mediterranean coastal areas and onto the islands.⁵ Over the last two decades, a wealth of new data from Cyprus has become available and indicates the presence of EPPNB (10,400–10,300 Cal. BP) domesticated plants such as emmer and einkorn wheat, as well as barley (Colledge 2004). This is also the case for animals, where stock animals previously unknown on the island, such as caprines and cattle, were found (see Vigne 2008; Vigne *et al.* 2009; 2011; Vigne, Briois and Guilaine 2019). Unmistakably wild animals, such as fallow deer, red fox, cat and rodents, also reached Cyprus at this time. The Cypriot evidence (Colledge 2004; Colledge and Conolly 2007; Colledge, Connolly and Shennan 2004) is not early enough to support a claim of independent domestication on the island, but it may be viewed as an excellent indication of the fast spread of domesticates from the northern Levantine core area. This is significant, considering the effort involved in importing these species overseas. Given its isolation, the Cypriot case probably indicates a demic spread, i.e., a migration of people, carrying with them a package of plants (and animals). Rather than a single voyage, this seems to have involved a regular “shuttle line,” i.e., continuous contact to and from Cyprus (see Bar-Yosef 2014a: 75), through which animals and package plants arrived prior to the Pre-Pottery Neolithic B (PPNB) and domesticates arrived during the EPPNB (see Manning *et al.* 2010, and below) and later (Vigne, Briois and Guilaine 2019). Cautious statements were also made regarding PPNA (10,800–10,600 Cal. BP) plant remains at the site of Klimonas, indicating early cereal cultivation on the island of Cyprus (Vigne *et al.* 2012). These, however, await verification in light of additional finds from both this site and other sites predating the PPNB on the island.

The attempt we made to better understand the dynamics of the spread of domesticates was based mainly on a summary of available archaeobotanical space-time data, as well as of data on materials and technologies. We suggested a possible

5. For Cyprus, this included the proposed introduction of wild and domesticated plant and animal species that do not occur naturally on the island (Colledge 2004; Vigne *et al.* 2011; 2012; Vigne, Briois and Guilaine 2019).

reconstruction in a mini-review of “The Big (agricultural) Bang” in emmer wheat, representing a dynamic wave of agricultural advance from the northern to the southern Levant (*sensu* Abbo *et al.* 2006; see also Tanno and Willcox 2006a; and comments by Hartmann, Kislev and Weiss 2006; Lev-Yadun, Gopher and Abbo 2006; Luo *et al.* 2007; Özkan *et al.* 2005; Yahiaoui, Bunner and Keller 2006: 91, Fig. 4 and data). This model stipulates that within the Levant, radiating waves (ripples) of spread from a core area in the northern Levant can be reconstructed from genetic data (see above, Fig. 3.1).

The Ripples-Wave of Advance Pattern

The “ripples-wave of advance” approach derives from two sources of data: genetic-archaeobotanical and archaeological-cultural. In simple genetic terms, we rely on the fact that demographic expansions and the migrations of plants leave their mark in the patterns of DNA polymorphisms among the invaded populations (Abbo *et al.* 2006; and see Pinhasi, Fort and Ammerman 2005; and references therein). Likewise, the newcomers also absorb local alleles. This exchange of genetic variation (gene flow) would eventually result in high complexity because of ongoing genetic input from the invaded wild populations into the newly migrating domesticated populations and vice versa. In the course of the spread of domesticated populations across the wild geographical landscape, these gene flow (introgression) events left their genetic mark (Luo *et al.* 2007), prompting the ripples-wave of advance pattern as depicted by DNA polymorphism studies for emmer wheat (e.g., Mori *et al.* 2003; Özkan *et al.* 2005; and see Box 5.1).

Box 5.1: Spread of Domesticates in the Geography: Meeting the Local Plant Populations

Assuming that the first “cultivation” attempts (or propagation of the first identified domestic stocks) were carried out within the natural range of the wild progenitors (Schiemann 1951), and given that the first nascent fields (planted with either selected domesticated types or morphologically wild types) were miniscule genetic islands within a massive wild landscape of the various progenitor species, it is reasonable to assume that the predominant direction of cross pollination, when this occurred in plants that are predominantly selfers, must have been mostly from the wild into

the much smaller managed (i.e., domesticated) plant population. Such a process of exchanging of genetic variation is often termed introgression (e.g., Anderson 1961), a term originally used to describe the exchange of genes and or alleles between closely or distantly related but independent genetic entities (e.g., Heiser 1973). In this sense, managed wheat, barley or pea populations that are propagated by farmers and used both for consumption and as sources of seed corn for future growing seasons can be seen as distinct genetic entities. As such, any gene flow (by cross pollination mediated by wild pollen) from other sources, such as surrounding sympatric wild relatives, may be considered as introgression, i.e., as wild alleles flowing into the partially isolated managed population. Likewise in modern times, when arable fields are larger than the remaining wild populations, domesticated alleles invade the wild gene pools.

Works concerning barley, both by Morrell and Clegg (2007) and by Jones *et al.* (2008), should also be considered in the context of the ripples-wave of advance pattern. Morrell and Clegg (2007) maintain that the phylogenetic pattern they observed could not have resulted from wild-to-domesticated introgressions and rather represents not only a Levantine locale (Occidental) of domestication but also an independent Oriental domestication. Jones *et al.* (2008), however, observed DNA sequences typical of the flowering gene *Ppd-H1* in European barley cultivars that are closely related to those found in wild Iranian barley. While those two studies certainly provide strong evidence for the well-known role of wild germplasm occurring east of the Levant in the evolution of domesticated barley (e.g., Takahashi 1955), they do not by themselves testify to the independent domestication of barley in these region(s), or likewise the claim for Tibetan barley domestication (e.g., Ren *et al.* 2013), or the formation of the *Agriocrithon* type by crossing of wild barley with domesticated six-row barley (e.g., Schiemann 1951). As stated in our introduction as well as in our definition of the term “domestication,” an independent domestication requires both biological (genetic) and cultural evidence. Therefore, without well-dated archaeological and archaeobotanical data from specific sites east of the Levant pertaining to the respective collection sites of the wild accessions used by Jones *et al.* (2008), Morrell and Clegg (2007) and Ren *et al.* (2013), the DNA phylogenetic patterns are best explained as reflecting the spread of a cultural phenomenon. Domesticated barley was first introduced to the eastern region along with the arrival of other Levantine package crops. Indeed, Civián *et al.* (2021), based on population

genetic profiling of wild and domesticated barley, support a similar reconstruction of the spread of domesticated barley out of its presumed origin in the western Fertile Crescent. Being native to the region and with its inherent weedy tendencies (e.g., Abbo *et al.* 2005; Hamidi 2012), wild *Hordeum spontaneum* most probably invaded the newly introduced cultivated fields in Iran as it does to this day. Being of local origin, its phenological and physiological adaptations to the growing conditions, as well as to the local pests, pathogens and herbivores, must have been superior to those of the introduced Occidental (Levantine) germplasm. It therefore comes as no surprise that such local types acquired a domesticated phenotype of non-brittle spikes and thus became part and parcel of the ancient landraces of the area (i.e., east of the Fertile Crescent, *sensu* Morrell and Clegg 2007). Such a scenario is perfectly in line with the well-known classification of domesticated barley into Oriental and Occidental cultivar groups (Takahashi 1955). A more distant example demonstrating such a trend was clearly documented at the DNA level (domestication and adaptation loci) regarding the introduction of maize into the highlands of Mexico (Hufford *et al.* 2013). That pattern could be identified only because of the migration of a domesticated population that “absorbed” some local wild genes as it moved further away from its core area.

The spatial pattern and time series of wheat archaeobotanical remains (Tanno and Willcox 2006a) have already been discussed above. These show a radiating pattern from the proposed core area outwards (see Abbo *et al.* 2006; Lev-Yadun, Gopher and Abbo 2006; and Fig. 3.1). As indicated above, a similar pattern emerges from reports by these same authors on EPPNB chickpea remains (Tanno and Willcox 2006b).

Archaeologically, too, the spread of cultural phenomena shows movement in the geographical and cultural landscapes in the form of a ripples-wave of advance pattern. A spread within the Levant from the north to the south can be traced for various archaeological finds, some of which we have already mentioned here (see section on archaeology in Chapter 4), including lithic technologies and tool types (Gopher 1989a; 1989b; 1994; 1999), materials such as obsidian (e.g., Gopher, Barkai and Marder 1998; Gopher, Abbo and Lev-Yadun 2001; and references therein) and other materials (Goren 2001; Rosenberg, Getzov and Assaf 2010) or other cultural elements (e.g., Goring-Morris and Belfer-Cohen 2014; and references therein; Kozłowski and Aurenche 2005: 83). So, why not seeds and agro-techniques?

Various lines of evidence, including ¹⁴C-dated package plant remains in sites, time series of wheat archaeobotanical remains, and the flow of cultural elements, all lend support to the Levantine ripples-wave of advance reconstruction. We argue, moreover,

that without a highly localized (core area) domestication event, no such temporally or spatially directed patterns could have been detected, either by DNA polymorphism data or by dated archaeobotanical and archaeological assemblages.

The ripples-wave of advance reconstruction presented here for the Levant may also be applicable in other regions and on larger, even continental, scales. The spread of the Levantine domesticated plant package (and of agriculture as a system) to Europe had occurred after the Levantine package and agricultural tradition had already been on the way for a long time and were well established. Both old and new waves of advance reconstructions relating to the spread of Levantine farming systems indicate a movement rate of the “Neolithic front” in the order of one kilometer per year on average (e.g., Ammerman and Cavalli-Sforza 1971; 1984; Braidwood 1967; 1975; Cavalli-Sforza 1996; 2001; Pinhasi, Fort and Ammerman 2005) or perhaps even faster (Weninger *et al.* 2006; Lazaridis *et al.* 2016). Sue Colledge and colleagues (Colledge and Conolly 2007; Colledge, Connolly and Shennan 2004; 2005) traced the spread of the Levantine plant package to Europe via two major routes based on distinct archaeobotanical fingerprints and genetics (e.g., Coward *et al.* 2008). One path proceeded through the eastern Mediterranean islands colonizing Cyprus and Crete, and then through Greece and into Western Europe along the Mediterranean, while the other passed through central Anatolia, Thrace and the Balkans into central Europe (see Özdoğan 2014 for the second path, emphasizing the cultural elements of this spread). Those authors advocated a demic expansion, suggesting that the diffusion mechanism was “...an influx of farmers into favorable ecological zones, replacing through assimilation or displacement what were in all probability very small populations of hunters-gatherers.” (Colledge, Connolly and Shennan 2004: 41; see Bar-Yosef 2014: 75; for a similar view on Cyprus, see Zohary and Hopf 2000: 243–246; Zohary, Hopf and Weiss 2012: 4; for a more cautious statement, see Ammerman and Cavalli-Sforza 1984; Bellwood 2005; Zvelebil 2002).

In recent years, as genomic research has developed and extraction of DNA from human remains of the relevant periods has become commonplace, the possibilities of reconstructing and verifying suggestions such as the above are growing (as already mentioned in Chapter 1). A few recent papers may exemplify this new state of affairs *vis-à-vis* the Levantine domestication center. One is a study of ancient DNA (aDNA) from human remains, indicating a movement of local populations from Iran into the Eurasian steppe and from Turkey into Europe (Lazaridis *et al.* 2016). A second report indicates that the early farmers of Turkey were local populations (Baird *et al.* 2019); and a third, taking the approach of analyzing human genomes, shows in quite a clear way and based on relatively large samples that an originally Levantine population

of farmers, together with their plants and animals, reached Spain ca. 7,500 years Cal. BP and within a short time became dominant in the Spanish population (Olalde *et al.* 2019). This long journey of about 3,000 km to Spain took place over some 3,000 years, which is in accordance with rates of the spread of agriculture estimated in past studies (e.g., Ammerman and Cavalli-Sforza 1971). Another paper, based on aDNA extracted from human remains found in Britain, points to a replacement of British hunter-gatherer populations by Neolithic farmers of Aegean origins (Brace *et al.* 2019).

CHAPTER 6

THE CULTURAL BACKGROUND OF PLANT DOMESTICATION IN THE LEVANT

The domestication of plants reflects a significant change in human-plant and human-world relations, a shift in human perception from one of nature as a “giving environment”—the way hunter-gatherers had perceived it (Bird-David 1990)—to a view of the environment (plants included) as a subject of regular manipulative extraction, i.e., domination (Ingold 2000; Carneiro da Cunha 2019). As a long-term historical process, the Agricultural Revolution as a whole drove the wedge between humanity and nature deeper, leading to an irreversible increase in alienation between these two entities and setting the ground for the modern human condition. This, in our view, is the deep undercurrent, slowly evolving time-scale aspect of that history—or, to borrow a term from Braudel, its *longue durée*.

This chapter describes the general background of the northern Levantine cultures of the Late Epipaleolithic (Natufian) and the Early Pre-Pottery Neolithic periods,¹ and includes comments on the geography of the region and the nature of the sites, as well as on their architecture and economy and some aspects of their material culture. Imagery (art) assemblages of these sites are introduced here, on the assumption that they reflect the ideological and social discourse of their time, as well as perceptual changes that had transpired within these communities over time. A full and detailed discussion on the cultural aspects of plant domestication and the Agricultural Revolution as a whole is beyond the scope of this account. We do, however, present a series of topics centered on cultural aspects of plant domestication and the Agricultural Revolution as a whole. Comments on our framework of thought and on the way we view past dynamics of plant domestication appear at the beginning of Chapter 7.

At the outset we reiterate, first, that we view plant domestication within a cultural framework in which the perceptual-ideological aspect is central to the changes

1. The differences between the northern and southern Levant are not discussed in detail, but are, rather, mentioned in footnotes where relevant to our statements.

preceding the Agricultural Revolution as a whole, and to plant (and animal) domestication in particular. Secondly, within the schools of thought in archaeology presented here (see Box 7.1), we find ourselves closest to a contextual view (see Chapter 7). As opposed to recent statements on a contextual archaeological approach that simplistically confuse description or discussion of archaeological contexts with contextual thinking in archaeology, we by and large identify with this school (covering some 40 years of research), while also taking notice of many of its components, especially the centrality of human agency.

The Geography and Cultural Context of the Core Area and the Neolithic *koine*

The Levant is a highly varied region both geographically and ecologically. The suggested core area (Lev-Yadun, Gopher and Abbo 2000), located in southeastern Turkey and northern Syria, currently enjoys annual precipitation of 200–600 mm or more, depending on exact locale (see maps in Riehl *et al.* 2015; Willcox 2012b: 93, Fig. 4.1). It is plausible that during the Pre-Pottery Neolithic A (PPNA) and Early Pre-Pottery Neolithic B (EPPNB) the climate was somewhat wetter than at present (see Willcox 2007; 2008; 2012b; Willcox, Buxo and Herveux 2009).² In addition, the area is endowed with two predominant permanent rivers, the Euphrates and the Tigris, and their many tributaries. Only this area hosted (and still hosts) the wild progenitors of all eight Neolithic package plants that became domesticated (see Lev-Yadun, Gopher and Abbo 2000). Looking back, as shown by Diamond (1997), it is clear that similarly rich parts of the world often coincide with primary centers of domestication bearing many advantages over regions lacking such resources, and indeed, this can be historically followed to the present (e.g., Hibbs and Olsson 2004).

The suggested core area is located in a zone influenced by several major cultural *koine* (interaction spheres), sub-*koine* or cultural complexes (Fig. 6.1), such as the Levant, the Zagros zone, Anatolia (central Turkey), the Mesopotamian lowlands, the highlands of western Iran, the Trans-Caucasus, and the farther Trans-Caspian lowlands (Braidwood 1967; 1975; Mellaart 1975), as well as the large Arabian deserts to the south-southeast. Others have described the area of the northern Levant (including our core area) as bordering what was called the Iraqi-Iranian province (to the east and southeast), the Levantine province (to the south and south-southwest) and the

2. This is the case in the southern Levant too. The case of the lower Jordan Valley is an example (Kislev 1997; Tchernov 1997), although its temperatures and annual rainfall are not easily reconstructed.

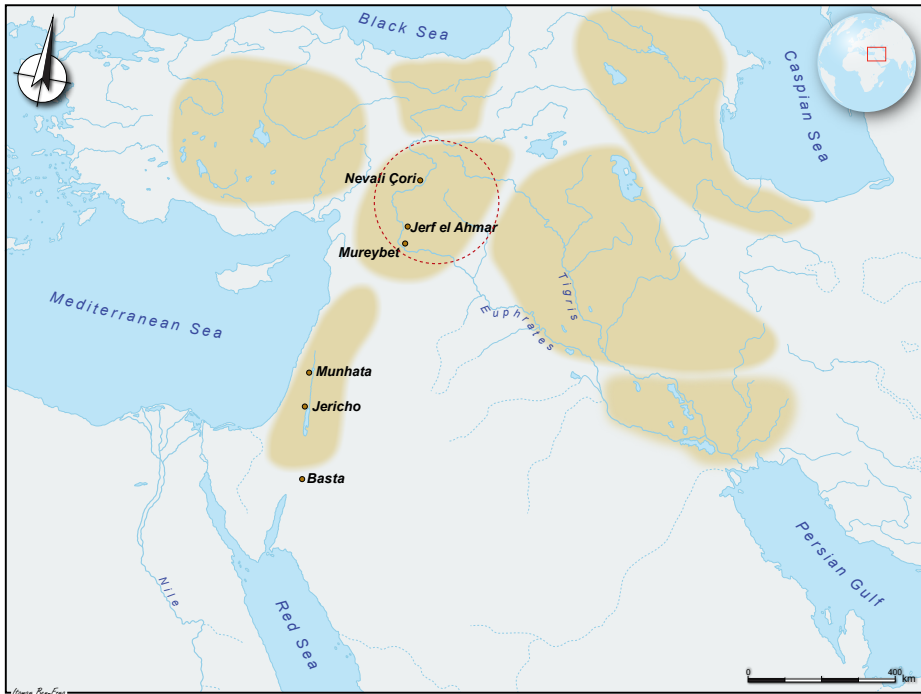


Fig. 6.1: Major cultural *koine* of the Levant (on a modified base map, from Kozłowski and Aurench 2005)

Caucasian-Caspian province (to the north and northeast) (see Kozłowski 1999: Chapter 6.7 for palaeohistorical maps). A geocultural picture with a “golden triangle” was depicted by Kozłowski and Aurenche (2005: 46, Map 0.12; see also Asouti 2006) with its tips touching the Syrian Mediterranean coast in the west, the Zagros zone in the north, and the Iranian highlands in the east. The Euphrates area (middle and upper, including our core area) is situated at the heart of this triangle, at “...the junction of the three main territorial divisions ... [in a contact zone] ... which is defined not only by several elements of the lithic industry but especially by art and architecture” (Kozłowski and Aurenche 2005: 46). A statement by Özdoğan (2014: 77) also supports the singularity of southeastern Turkey and northern Syria (Euphrates) area: “The differences between the Early Neolithic cultures of central Anatolia and southeastern Turkey are now becoming much more apparent.” This location of our suggested core area may have enabled its ancient populations to become acquainted with an array of culturally varied worldviews, traditions, resources and technologies (e.g., Kozłowski and Aurenche 2005: 83). People in such junctions, or contact areas, where different

cultural units met, were exposed to a plethora of information flows,³ and possibly subjected to a constant demand to acquire skills for applying diverse knowledge sets (Lévi-Strauss 1952b: 41–45). Özdoğan (2014: 80–81) viewed the sharing of knowledge and innovations as a marker, and indeed, one of the main designators, for defining the core area of Neolithization, stating: “It is also possible to assume that sharing of knowledge brought prestige and that it might have been considered as wealth.” While the borders of such cultural entities may be meaningful ethnically, linguistically, historically or otherwise, material culture as well as many other sociocultural and perceptual aspects no doubt crossed these borders, instilling in the inhabitants significant consciousness and sensitivity with regard to their identity or status, as well as their behavior and practice. The northern Levant PPNA may also have provided a suitable background for a social array in which possession and wealth accumulation may have played an important and growing role, while the hunter-gatherer ethos was still embedded in the social and ritual arenas and subsistence economy was still based on hunting and gathering. This gap between ideology and reality (see below, section on northern Levantine imagery) could have constantly caused crises and/or sustained instability and social restlessness (e.g., Bar-Yosef 2014b;⁴ Benz and Bauer 2013a; 2013b). It would also have provided a suitable background for change, perhaps driving individuals, families, households or whole communities to engage in new ways of social interactions and production (see, e.g., Mithen 2007; Benz and Bauer 2013b; and indirectly Busacca 2017).

This size-limited yet centrally located core area would have inspired awareness of and attentiveness to diverse cultural modes and behaviors, possibly alongside higher tolerance to neighbors (without compromising group identity), to innovations and to social flexibility. Such a socio-cultural setting would have constituted a perfect background for the initiation of practical innovative moves such as plant domestication, as well as for following through on these innovations within the complex sociopolitical discourse and the likely conservative opposition until they were finally integrated into the system. Perhaps this blend of circumstances helps explain why plant

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3. Traditionally, the definition of an archaeological culture (entity) is based on identifying recurring material-culture assemblages appearing in a well-defined geographic unit and chronological range. As stated by David Clarke (1978): “Culture consists of a polythetic set of artefact types that consistently recurs in assemblages within a limited geographical zone.” He adds that such a culture is “an entity of high information content and specific sociocultural system.” This, in our view, is a central part of the definition reflecting the perceptual-ideological sphere of any cultural entity.
 4. He suggests that Göbekli Tepe was a center of a cultural entity organized as a chiefdom with all the social repercussions—by itself a suggestion that would indicate a leap compared to earlier Epipaleolithic entities—a climax of sorts, which following Bar-Yosef (2014b), occurred “...possibly due to intra societal conflict” (p. 159) or “a revolt” (p. 165).

domestication indeed took place in that specific and relatively small region. Small scale seems to be a paramount condition for the described developments, and it substantiates the role of human agency.

Acceptance of our core-area model would thus place the center of the Neolithic plant domestication within specific geographic boundaries and cultural settings, encouraging a new human perceptual-ideological landscape (see, for example, Cauvin 1999; 2000a; 2000b; Hodder 2011; Watkins 2004; 2008; 2010; 2011). Following their newly established perception of nature and of their own society,⁵ and using their skills, technology, and long-term experience and knowledge, these communities may well have adopted and domesticated a plant (and animal) package that was immensely successful, highly nutritional, productive and manageable. Given the specific and different plant resources of other sub-regions of the Levant and their cultural makeup, it seems highly unlikely that the same domestication scenario, with identical plant species and similar cultural features, could have repeated itself in other parts of the region. Thus, much in the spirit of the “preemptive domestication” of Diamond (1997), it is our contention that plant domestication was a single event or episode, contextually specific in both time and place. The special conditions and cultural processes involved are manifest in many relevant archaeological datasets, which we describe in brief but do not discuss in detail in this account.⁶

The Northern Levant: A Concise Archaeological Survey

Our knowledge of the cultural background preceding the Agricultural Revolution as a whole (and plant domestication in particular) in the northern Levant is quite poor (Fig. 1.1). Upper Paleolithic and Early Epipaleolithic records are meager, while Early Natufian records (ca. 15,000–13,000 Cal. BP) are missing altogether (Baird

5. The question of why a change in perception and relationships with nature transpired at that time remains open; yet sedentism is an explanatory option both physically (a large, permanent, dense built environment) and perceptually (a change in the way of negotiating nature; changes in mobility patterns; a loss of freedom of movement in the landscape). Another option is overdone ritualistic activities and the demands they inflicted on hunting-gathering societies both economically and socially; and we could add more. Each of these suggestions, however, may be tackled by an additional “why” question, and it becomes a never-ending story (and see discussion below).

6. This is based mainly on selected publications such as those by Cauvin (2000a; 2000b; 2001), Stordeur (2010), Schmidt (2012a; 2012b), Benz and Bauer (2013b), Busacca (2017) and others, emphasizing the new perceptual and social milieu as drawn from psychic and neurological aspects, pointing out intensified ritual activities (e.g., Göbekli Tepe), or as seen through an ontological perspective—all of which result in depicting instability and restlessness in the PPNA, before plant (and animal) domestication in the EPPNB. In other words, despite all innovative aspects, the PPNA shows more characteristics of an end rather than of the beginning of an era (and see Grosman *et al.* 2016; Shaham and Grosman 2019).

2012; Özdoğan 2014; Schmidt 2012b and references therein).⁷ The northern Levant, including the core area, offers only a limited Late Natufian picture emerging from a small number of excavated sites, such as Tell Abu Hureyra 1 (Moore 1991; 2000) and Mureybet I (Cauvin 1989; Ibáñez 2008), both of which are located on the middle Euphrates, were occupied mostly during the thirteenth millennium Cal. BP, and partly overlap the time span of the Younger Dryas. No domesticated plants were found in those sites (but see Hillman 2000; Hillman *et al.* 2001; and see our discussion concerning rye in Chapter 3), although remains of wild progenitors of the package species were found.

These Late Natufian sites are interpreted as year-round settlements, boasting small round huts that were cut into the ground (present at Tell Abu Hureyra 1 and, despite their absence, assumed also to have been present in Mureybet; Ibáñez 2008: 663) alongside installations, mainly hearths and cooking pits, but with no clear storage installations. It is difficult to estimate site size since these Late Natufian layers are found in the deepest layers of large tell sites, which have been excavated only to a limited extent. We may, nonetheless, estimate small site sizes in the order of a few thousand square meters (e.g., some 2,000–3,000 square meters for Tell Abu Hureyra 1; Moore 2000: 106, Fig. 5.2). Subsistence economy at these sites was based on a wide variety of collected plants, including cereals, legumes (both small- and large-seeded) and fruits, complemented by hunted equid, gazelle, bovid, wild boar, fallow deer,⁸ sheep, hare, fox, and a variety of birds and fish. Dogs would have been present by this time and already domesticated, as evidenced directly at Tell Abu Hureyra and indirectly at Mureybet. Mention should be made of the recently published Late Natufian (ca. 13,000 Cal. BP) layer of Dederiyeh at central western Syria, having a round structure and an archaeobotanical assemblage relatively rich in cereals (Tanno *et al.* 2013), but showing no domesticates.

In the subsequent twelfth and early eleventh millennia Cal. BP, the record of PPNA sites unearthed in the northern Levant⁹ (Figs. 1.3 and 3.1) becomes much richer and includes sites such as Çayönü (with its Basal Pits and Round Plan sub-phases), Halan Çemi Tepesi, Demirkoy, Körtik Tepe, Gusir Höyük and Hasankeyf Höyük on

7. The southern Levant, considered the homeland of the Natufian, yielded a significantly richer and better-known record of the early Natufian (starting ca. 15,000 years Cal. BP). This attests to significant changes in the archaeological landscape, including possible sedentary base camps, compared to the preceding Epipaleolithic period (23,000–15,000 Cal. BP).

8. Evidence of a woodland in the area.

9. Some variation may be detected between the northern and the southern Levantine PPNA sites. The northern Levant PPNA was replaced by the EPPNB somewhat before the middle of the eleventh millennium Cal. BP, whereas in the south the PPNA continued for an additional couple of centuries.

the Tigris, as well as Mureybet II–III,¹⁰ Jerf el Ahmar, Tell Abr 3, Dja’de (Dj I) on the Euphrates, and Tell Qaramel farther west of the Euphrates sites. Farther away, in the lowlands of Mesopotamia, the sites of Nemrik, Qermez Dere, and M’lefaat were found, and PPNA was also reported from the lower layers of Chogha Golan in Iran. Of note are the especially large-scale lower levels of PPNA Göbekli Tepe (Schmidt 2012a; 2012b), as characterized by an outstanding large-scale site exceeding 10 hectares in span and 15 meters in depth, found near the city of Şanlıurfa on the Euphrates.

Following the Younger Dryas, the main PPNA sites listed above are usually interpreted as sedentary year-round sites (but again, for a different view, see Asouti and Fuller 2013; and see discussion below). Other than the enormous site of Göbekli Tepe most of these sites are smaller, spanning only a few hectares and deposition depths of two to eight meters. The architecture in these PPNA sites is mostly round in shape, occasionally with rectangular intra-structure subdivisions (e.g., Mureybet III, Jerf el Ahmar, Tell Abr 3; see Haklay and Gopher 2020a), and very rarely fully square or rectangular (as in, e.g., latest phases of Jerf el Ahmar). These sites also boast impressive public or communal buildings and areas. Domestic structures (see Verhoeven 2004; Watkins 1990; 2004; 2006) are somewhat obscure and are interpreted as related to communal (nondomestic) structures (see Asouti and Fuller 2013: 321–322), or as missing altogether, as in, e.g., Göbekli Tepe (Schmidt 2012b: 93, 105, 236–238; but see comments by Banning 2011; also see comments on the southern Levant PPNA site of WF16 in Jordan by Finlayson *et al.* 2011). PPNA changes and innovations are also manifested in lithic technology, with the appearance of new tool types such as arrowheads (El Khiam type) and bifacially knapped flint axes (tranchet axes in the southern Levant and different types, such as erminettes, in the north) or polished stone axes, as well as groundstone tools.

10. Data for Mureybet II are scarce, but indicate that the Neolithic in the northern Levant began with the Khiamian of Mureybet upper Phase I and Phase II that preceded the more massive PPNA Mureybetian Phases IIIA–IIIB. The limited record of the Khiamian exhibits similar characters to those mentioned above, including round houses, both semi-subterranean and free standing, and a hunter-gatherer subsistence economy. The imagery (art) world of the Khiamian includes an assortment of body ornaments (various stone beads of different materials, shapes and colors, as well as pendants made of sea shells and stone). Among the three stone figures found here, one may be a human representation (Stordeur and Lebreton 2008). These inspired Cauvin (2000a; 2000b) in the formation of his ideas concerning the onset of agriculture. The Khiamian is also present in the southern Levant (where the term Khiamian was coined), slotted in the chrono-stratigraphy between the Natufian and the Sultanian culture of the PPNA. It is a somewhat frustrating entity in its paucity and nature, which seem far removed from the revolutionary jump one might expect to see at the beginning of the Neolithic period. Hardly any architectural data are available for the Khiamian in the southern Levant because of the limited excavations. Here too, economy is based on hunting-gathering. For more information on the rare Khiamian imagery items, see Hershman and Belfer-Cohen (2010) and references therein.

This new cultural landscape of the northern Levant PPNA reflects communities devoid of domesticated plants or animals, with the notable exception of dogs. Unlike the egalitarian pristine hunter-gatherer societies (for the southern Levant, see Kuijt 1996; 2000), we view the northern Levant PPNA setting as a suitable background for a society in which possession, possibly including knowledge, may have played an increasingly important role in the form of bestowment (gift giving), as well as wealth accumulation.¹¹ These could possibly have led to social inequality that would have affected the organizational infrastructure, promoted competition, or perhaps initiated “political” circulation (or out-circulation) of surplus goods, and possibly including human working power too, at the level of the single individual and/or of households, small kin-groups, or selected corporate groups. Eventually, and in accordance with the available data, all of this probably took place while the hunter-gatherer ethos had not yet been lifted and was still deeply embedded in social and/or ritual arenas. The case of PPNA Göbekli Tepe may serve as an example for a hunting-gathering economy that had grown beyond its natural hunter-gatherer context, and in our view must therefore have been either the cause or the result, or both, of instability and restlessness, i.e., of a disturbed equilibrium. This leap, in many respects, distinguishes this PPNA from earlier Epipaleolithic lifeways. It is not a “push” crisis, i.e., one based on an external stress, but rather an internal sociocultural development (e.g., Benz and Bauer 2013b). Perhaps, as Steven Mithen relates to it (citing a term of the psychologist Nicholas Humphrey) as a “misapplication of social intelligence,” it can be argued that social intelligence may have played a key role in the origin of farming (Mithen 2007). To some extent, we would see this state of affairs as a good example of what Jacques Cauvin would have viewed as part of the framework of a perceptual (psychic) change.

We therefore accept suggestions of Özdoğan (1999; 2014 and references therein) and of Schmidt (2012a: 159), envisaging a rich, complex hunter-gatherer economy and social system, possibly characterized by growing inequality (see also Benz and Bauer 2013b) as a background to the social dynamics of PPNA communities in the northern Levant that immediately preceded the advent of domesticated plants (and animals) in southeastern Turkey and northern Syria. As stated by Özdoğan:

The picture of the pre-Pottery stage has gone through dramatic changes during the last decade or so. Terms such as stratified society, pristine temples, monumentality, mega settlements, organized labor, specialized craftsmen, pictograms, organized trade systems or even sedentary hunter-gatherers that would have been inconceivable to

11. See Bowles and Choi (2013) on private property (and land ownership) in later farming societies.

associate with the Neolithic Period have now become routine expressions in describing the recent findings of sites such as Göbekli Tepe or Körtektepe. (Özdoğan 2014: 88)

This view of the early Neolithic period (PPNA) prior to domestication strongly reflects and is well in accordance with the spirit of Cauvin's statements in his book, *The Birth of the Gods and the Origins of Agriculture* (2000a). This stage is actually the background that Cauvin (2000a; 2000b; 2001) was talking about—a perceptual-ideological change based on psychic aspects, or what Benz and Bauer (2013a; 2013b) would call the neurobiological, emotional change. The directly related social developments result from a rise in inequality and a decrease in sharing (Benz and Bauer 2013b: Fig. 2, p. 13). We argue that these psychic, neurological and emotional elements would have operated as important agents in promoting food production, and in preparing the sociocultural infrastructure necessary for the extensive change between Pre-Pottery Neolithic A and B (see below). The socio-politics involving communal and supra-communal rituals and ceremonial cycles were all present, fully fledged and crystallized, in the PPNA archaeological record of the northern Levant (see Asouti and Fuller 2013). Simply stated, it is the scale, the sedentism, the aggregation (temporary or full) and the demanding monumentality in places such as Göbekli Tepe that brought about the restlessness in which the change in perception and ideology was simmering. It could have been single human agents or successful functionaries (shamans, following Benz and Bauer 2013b) who took part in creating and taking advantage of this unrest, and who took control of the ritual arena and the community or society as a whole (Benz and Bauer 2013b). Had this been the case, a change in economy and a move to production, which would need to depend on the incorporation of a change in the old, deeply ingrained hunter-gatherer ethos (Naveh and Bird-David 2014; and see below), would be a feasible route to take.

The cultural climax of the northern Levantine PPNA sites, as uniquely manifest in the outstanding site of Göbekli Tepe, was achieved by hunter-gatherer societies and must have required enormous efforts that were very well organized. The immensity of these efforts would have necessitated not only an essential change in the economy but also, and more importantly, a crossing of the perceptual Rubicon of egalitarian social life in a sociopolitical dialogue which, whether reasonably calm or severely conflictive (see Bar-Yosef 2014b), would have required an open and intensive discourse that could not have been concealed (contra Kuijt 1996). The PPNA socio-cultural milieu, as described above, seems to have provided both necessary and sufficient perceptual and socio-cultural conditions for the divorce from the pristine hunter-gatherer way of life. This ideological struggle over the primordial hunter-gatherer ethos is the bedding on which the practical applications

of new lifestyles, as manifest in the Neolithic Revolution—or, in our case, in plant domestication—have grown.

The next set of sites in the northern Levant region that included the suggested core area consists of EPPNB sites from the second half of the eleventh millennium Cal. BP,¹² such as Çayönü (Erim-Özdoğan 2011; Özdoğan 1999), Nevali Çori (Hauptmann 1993; 1999), Mureybet IV (Cauvin 1989; Ibáñez 2008), Dja'de Dj III (Coqueugniot 2000; 2014) and Cafer Höyük (Cauvin *et al.* 1999; 2011) (see Figs. 1.3 and 3.1). All of them are tell sites ranging in size from just a few hectares to 20 hectares (e.g., Tell Abu Hureyra EPPNB, following Moore, Hillman and Legge 2000: 475–493), while ranging over a few meters in depth. All of these sites are considered to be sedentary.

The architecture of these sites changed from round to rectangular shapes, with free-standing buildings rather than sunken or half-sunken ones, while exhibiting a clear presence of domestic installations, e.g., Dja'de (Coqueugniot 2000; 2014) or Göbekli Tepe (Schmidt 2012a; 2012b). New EPPNB architectural innovations are also seen in the form of the “grill” and the channeled architectural plans (see Haklay and Gopher 2019).¹³ These sites boast some outstanding public communal architecture, including the Nevali Çori temples (Hauptmann 1999; 2011), the Skull Building of Çayönü (Erim-Özdoğan 2011) and the House of the Dead at Dja'de (layer Dj III, Coqueugniot 2000). These EPPNB sites manifest change and innovation in their lithic industries, in particular the use of bidirectional naviform cores for the production of long (non-twisted, non-curved) flint blades, e.g., Dja'de (Coqueugniot 2000; 2014).

The northern Levant EPPNB sites are the first to show a changed economy, featuring domesticated plants and animals (Vigne *et al.* 2017). All in all, EPPNB developments in various technologies, house plans, social organization, burial customs (see below) and subsistence economies can be viewed as revolutionary in the life of Neolithic communities and in the archaeological landscape (Gopher 2020). The magnitude of these changes, taken together, seems to elicit general agreement among scholars of this period regarding the perceptual change that must have characterized these communities. This is true not only for obvious proponents of the

12. Until recent years the southern Levantine EPPNB was not very well known, to the extent that some researchers argued against its existence (e.g., Kuijt 2003; Kuijt and Goring-Morris 2002; note the disagreement between the two authors). It is now becoming elucidated, however, as new data and ¹⁴C dates are accumulated, e.g., at the site of Motza (Khalaily *et al.* 2007; Yizhak *et al.* 2007) and see also Gopher (1996; 2020) and Birkenfeld (2018).

13. In line with the southward flow of northern Neolithic innovations, these architectural innovations possibly reached the southern Levant during the later PPNB (in southern Jordan).

issue, such as Klaus Schmidt (2012b: 221),¹⁴ but also for researchers who argue in favor of continuity and similarity between the PPNA and the EPPNB (e.g., Stordeur 2010; Willcox and Stordeur 2012; Asouti and Fuller 2013). Despite a recent tendency to lump these periods as well as these cultural entities together (e.g., Asouti and Fuller 2013; Stordeur 2010; Stordeur and Willcox 2009; Willcox and Stordeur 2012), the differences between them are acknowledged even by the cultural “lumpers” themselves. For example, based on Asouti and Fuller (2013):

- **Sedentism/Mobility:** While investing a major effort throughout their paper to convince readers that sedentism is only one out of many options on a blurred mobility spectrum and should not be viewed simplistically as a correlate of farming,¹⁵ and after assuming a slow pace for biological domestication, Asouti and Fuller (2013: 328, 330–331) conclude by saying:

The establishment during the second half of the ninth millennium [in the EPPNB] of sedentary communities at sites such as Çayönü, Nevalı Çori, and Jericho that probably formed regional nodes of ritual activity (including mortuary rites) likely acted as a catalyst for significant, albeit at present poorly documented, shifts in landscape perceptions and plant management practices. Such changes were manifested, for example, in the appearance of the earliest known indicators of the domestication syndrome in cultivated plants on the Southwest Asian mainland...¹⁶

(and see also Fuller *et al.* 2018).¹⁷ Jargonized though it may be, the latter is a description of sedentary sites in our suggested core area (see n. 16 for Jericho) inhabited by farmers of domesticated plants.

- **Architecture:** The transformation in social space, manifested through changed architecture as seen at Çayönü, Dja’de (both with a grill plan), Nevalı Çori and others.

14. Göbekli Tepe, for example, comprised both PPNA and EPPNB layers with clear differences between these layers in many realms, yet some elements show continuity.

15. Based on Eder (1984, exploring the impact of subsistence change on mobility and settlement pattern in a tropical foraging economy), Asouti and Fuller 2013 adopt a flexible view of mobility and settlement patterns. They negate a directional evolutionary continuum from mobility to sedentism and offer a more versatile picture of dwelling practices that could have involved diverse and interchanging degrees of residential and logistic mobility. They also envision manifestations of mobility occurring on the scale of solitary individuals, task groups, single households, groups of households or entire local groups, and they negate polarized distinctions between mutually exclusive notions of mobility and sedentism.

16. Note that there is most probably no EPPNB layer at Jericho, but rather a later Pre-Pottery Neolithic B; see also Box 2.1.

17. While the geographic term used (Southwest Asian mainland) is large and open enough, this statement seems to maintain EPPNB sedentism.

- Burial customs: A shift in mortuary practices, as reflected in the House of the Dead at Dja'de EPPNB, and the “Skull Building” of Çayönü.¹⁸
- Lithics: Technological innovations reflected in a new and standardized blade production technology for sickle blades; change in symbolic value of harvesting tools: “Standardized blades were characteristic of the PPNA/EPPNB transition and were generally rare on the site, being predominantly used for the production of sickles.” (Stordeur and Abbès 2002).¹⁹ These observations, together with the occurrence of tool blanks in caches, suggest the heightened symbolic value of harvesting implements in this transitional period (Stordeur and Abbès 2002; Asouti and Fuller 2012: 322).²⁰
- New caching behavior, especially for flint and stone tool blanks.
- Economy: finally, the emergence of plant and animal domestication.²¹

In summary, the currently available data indicate significant distinctions between the PPNA and the EPPNB in many spheres. These accentuate the restrictive consequences of the lower resolution, i.e., the result of lumping the PPNA and EPPNB together, which distorts history, as it is based on a narrative of fluidity and cultural continuity. A higher archaeological resolution that makes a distinction between the PPNA and the EPPNB, which together cover some 1,500 years, would

18. Dja'de in the Middle Euphrates, Çayönü in the Tigris area. Note should be taken of the EPPNB site of Qarassa in the Damascus Basin (Ibáñez *et al.* 2010; Ibáñez, Gonzalez-Urquijo and Braemer 2014; Santana *et al.* 2012; 2015), where new burial customs were reported as well as the move from rounded to square houses, the appearance of naviform, bidirectional blade technology and long, tanged projectile points, as well as symbolic innovations *vis à vis* human iconography (e.g., Ibáñez, Gonzalez-Urquijo and Braemer 2014).

19. Interestingly, the aspect of sickle blades was later treated in detail and on a large scale by Maeda *et al.* (2016; including Dorian Fuller), where a different view was taken of sickle blades made on bidirectional blades (their Group 3) and “... the production of sickle blades was not specialized with respect to other lithic types” (p. 231), or “... fine bi-directional blades ... rather than specialized production of sickle blades” (p. 232). Beyond contradicting their own statement and ignoring the statement by Stordeur and Abbès (2002) that they quote, this is, at best, a misunderstanding of the purpose of bidirectional blade production as stated by Stordeur and Abbès (2002).

20. Following Stordeur and Abbès (2002), the main purpose of producing bidirectional (non-curved, non-twisted) blades in the northern Levant was for sickle blades. This is also the case in the southern Levant, where such blades were first used as sickle blades and later (when discarded), were used or recycled into other tool types such as arrowheads, burins, scrapers and more. Regrettably, this was not considered by Maeda *et al.* (2016) as a PPNA/PPNB innovation in sickle-blade technology. Although they considered this production trajectory to be highly specialized, it was not considered a specialized sickle-blade production since the blades were used for other lithic tool types as well.

21. This evolution, however, is described as taking place in southeastern Turkey during the eleventh millennium Cal. BP, that is to say (most probably, to be cautious) in the EPPNB—which, following these authors, starts at 10,750 or 10,650 Cal. BP and ends at 10,150 Cal. BP (their Table 1).

facilitate a clearer and more nuanced account by pointing out changes, including plant domestication, that took place over shorter periods of time. The resolution offered in recent years by ^{14}C dating should call for the application of a higher resolution not only between the PPNA and EPPNB, but also within each of these periods and their cultural entities.

In our view, the EPPNB shows significant changes in many cultural elements and may thus be described in terms of an important Neolithic turning point that clearly separates it from the PPNA (see also Gopher 2020). On the other hand, despite their long list of EPPNB innovative aspects (listed above), the picture depicted and the conclusion drawn by Asouti and Fuller (2013) are different. Indeed, an open-eyed summary of the Asouti and Fuller (2013) story on “...potential mobility patterns proposed for Early PPNA cultivator-forager communities” (their Table 5, p. 318) might reveal an interesting picture: if we strip their site-by-site description and their narrative from its jargonized and evasive (yet, in a way, cautious) wording it depicts a picture of locally wandering Levantine individuals, households or whole communities (rather like Bedouins) for both the PPNA and the EPPNB, gathering and hunting while roaming the area, visiting once in a while (or seasonally) otherwise unoccupied sites where they may have cultivated or attended to plots with cereals and legumes (while unconsciously and slowly working their own way towards full domestication), meeting social partners, eating and having ceremonial feasts, exchanging information and probably also genes, and burying their dead.²² This is clearly expressed in a supportive commentary by Barker (2013) on the Asouti and Fuller (2013) paper, viewing it as innovative and summarizing the essence of their statements by saying that “...sedentism cannot be treated simplistically as a key signature of ... settling down and growing food” (p. 332). Based on his experience, Barker (2013) views the early Neolithic Levantine sites as “...important locales where (we assume) otherwise mobile forager-cultivators came together on a seasonal basis for communal ritualized activities related to food consumption rather than the ‘settlements’ of the kind normally envisaged when archaeologists use that term [sedentism]” (p. 332). We cannot

22. In our view, this text conceals an attitude that may be read as Orientalistic (*sensu* Said 1979), akin (if even unconsciously, and based on naïve romanticism) to a Western approach exemplified by Westerners who visit the Levant to this day and are disappointed by the absence of camels roaming the streets. This, in our opinion, is one of the reasons why the picture is depicted in wide brush strokes and suffers from a low resolution. As strange as it may sound, this may echo the difficulties in accepting the old “*Ex Oriente Lux*” statement first made in the late 19th century and early in the 20th century by archaeologists such as the Swedish Oscar Montelius and later in the 20th century, further supported by Gordon Childe vis-à-vis pyrotechnologies, metallurgy, urbanism, great innovations of the mind and religion.

deprive our readers of Barker's whimsical touch by failing to include his remark that the Neolithic people we are talking about

...would have been completely baffled by an archaeologist working on the emergence of agriculture giving them a questionnaire with headings such as “are you a hunter-gatherer or a farmer? (delete as appropriate),” “are you mobile or settled? (ditto),” and “please list your subsistence activities” as a section in the questionnaire separate from “please list your religious practices.” (Barker 2013: 332)

This is a somewhat disdainful questionnaire, at least for the reason that no relevant Near Eastern ethnographies are available as such groups are long gone. However, Barker may have consulted some biblical and pre-biblical Near Eastern historical records in which answers to some of his questions may be found, saving him the inconvenience associated with a trip to the desert in search of Near Eastern aborigines (and see also n. 22 on p. 133).

The processes of perceptual, cultural and social change between the PPNA and the EPPNB described here involved a multitude of social agents, parties, and interests—all engaged in the political arena of the time and employing political means to promote new ideas and ways of life, including ideological (and manipulative) symbolic elements incorporated in “propaganda” campaigns. These are evidenced in all realms of life and material culture, and are especially visible archaeologically in imagery (or art) objects. Imagery items in this context are “active material representations” or visual representations (such as figurines), that “...succeed in creating realities that people view and accept as truthful and appropriate” (Bailey 2005: 120). In other words, imagery items not only represented but were also actively involved in shaping Neolithic ideological spheres and perceptions of reality. While not exclusive to Neolithic societies, the role of imagery items in the Neolithic period was significant because this “...was a period in which the scale of the manipulation of people and resources increased through the application of new abilities to rearrange reality to suit individuals' needs and in doing so, to create an artificial world” (Bailey 1996: 294).²³ Because of their complex role and high communication potential, we devote the next section to imagery items, with the object of opening a window onto the cultural dynamics of early Neolithic societies in the northern Levant.

23. The following text makes intensive use of ideas and quotes from Bailey (2005), although his statements were originally made with reference to the Neolithic Balkans. The ideas and phrasing are also relevant for the Levant, and we accept them as can be understood from the 1990s and later studies on imagery items of the Pottery Neolithic period in the southern Levant by one of us (Gopher and Orrelle 1995; 1996; 1999; Gopher and Eyal 2012).

Northern Levantine Imagery: A Reflector of Ideological and Social Change

The outstanding effect of imagery items—and in particular 3D figures—on the human mind to this day stems primarily from their obviously visible traits. Their second source of power is their role as “instruments of thought” (Schmandt-Besserat 1998: 14), influencing people by provoking thought and reaction (Bailey 2005: 1–3). We too believe that visual representations, especially of the human body, “...are never politically innocent, nor are they inherently stable” (Bailey 2005: 142) and that they are “...potent tools within the contemporary political struggles running through Neolithic households and villages” (Bailey 2005: 186; see also Gopher and Orrelle 1996; Goring-Morris and Belfer-Cohen 2002). Imagery items are active storages of information in that they convey messages by serving as boards upon which ideological (symbolic) and social information is perpetually presented for people to read and absorb and to which they may react. Given its predominant role in personal and communal socio-political and economic contexts, information broadcast by imagery items may relate to the availability and potential of social resources, including behavioral norms, decision making, rulings, or issues of status and promotion within the community. Imagery items, in our view, thus serve as an important element reflecting how the human world is conceptually arranged, by defining and shaping personal and community identities and worldviews.

From a slightly different perspective, Neolithic imagery items may be regarded as condensed, meaning-laden visual symbols that stand for and depict a complex system of ideas that may challenge—rather than merely reflect—established systems, and contest ancient ritual forms of the former (hunter-gatherer) regime (on such symbolism for a later part of the Neolithic period, see Gopher 2012; Gopher and Eyal 2012; Gopher and Orrelle 1996: 274). We may thus also view imagery items as a possible means of manipulation employed in a struggle that was both ideological and political, where the influential power of visual representations served as a rhetoric aimed at challenging existing establishments while subverting, blocking, or disrupting a reality that was no longer relevant in the eyes of the challengers (Bailey 2005).²⁴ We therefore believe that imagery items provide us with the opportunity to simultaneously investigate both the obvious (visible) and the concealed battles of

24. In many ways this depicts the pioneering views of Jacques Cauvin’s ideological (and psychic) change and the struggle it evoked in late Epipaleolithic and early Neolithic communities of the Levant. We add here that only strong cohesive (corporate) groups within these Neolithic societies could have made things happen on scales like that seen at Göbekli Tepe or other such sites. This scale however, is a manifestation of a state of affairs inapplicable to those who preserve a genuine hunter-gatherer ethos and ideology (and see n. 4 on p. 124).

ideological oppositions (see also Goring-Morris and Belfer-Cohen 2002). We base our short discussion on the idea that imagery items, as symbol carriers, bear meanings that are both obvious and accessible to every member of the community, while also masked and targeted at small, select groups (for definitions and discussion, see Goring-Morris and Belfer-Cohen 2002: 67).

Two additional points are of relevance to Neolithic imagery items in general and to the PPNA in particular:

- Imagery items of the Neolithic period are a visual rhetoric constituting a “language” that we may fail to understand or listen to because of our Western education and worldviews.
- Whether such items are mere depictions, representations of symbolic meanings or values, or are reflectors of reality (actual or desired) during specific times and in contexts of ritual or other social activities is a difficult question to answer. If representational, it would be pertinent to ask why depictions and representations of plants are altogether missing despite their vital role in the changing EPPNB socio-economy, or whether their absence is simply due to their fabrication using a medium consisting of perishable materials. And if such imagery items had been an integral part of a ritual or social event, could they be part of a transformation in a context or an encounter that included humans, non-humans and possibly spiritual or supernatural beings reached through the activities taking place in it?

In the following we present and discuss some imagery items of the northern Levant.

In general, the northern Levant Neolithic yielded exceptionally rich imagery assemblages, including fascinating stone sculpting, which reflect a complex and dynamic symbolic milieu, a suite of prestigious tradable materials and items, and elements (including monumental) of ritual activities (Özdoğan 1999; Schmidt 2012a and references therein; 2012b; Stordeur 2010; Verhoeven 2004). A comprehensive comparison of pre-Neolithic, PPNA and EPPNB imagery assemblages is beyond the scope of this account. Therefore, following a brief description of available imagery assemblages, we shall limit ourselves to some comments reflecting the dynamics delineated above.

It is important to note that the imagery items reflecting the symbolic world of the people we talk about, their communities and their discourse, are “full partners” and possibly even reflexive drivers of the Agricultural Revolution as a whole, and of plant domestication in particular (see distinction between the

revolution and plant domestication in Chapter 1, especially Box 1.2). We present them in this spirit, while reiterating that plant domestication is an important component of this overarching revolution and is therefore fully relevant to this discussion.

The Late Natufian in the northern Levant yielded a very limited imagery assemblage.²⁵ Both Mureybet IA (Cauvin 1999; Ibáñez 2008; Stordeur and Lebreton 2008) and Tell Abu Hureyra 1 (Moore, Hillman and Legge 2000: 174) have yielded only a few incised bone items and a few stone items with geometric incisions. No animal or human representations were found among these assemblages, and body ornaments are limited to single stone beads from Mureybet. This limited array of imagery (art) items and body ornaments reveals little, but the very absence of animal or human figures is probably not without significance.²⁶

The PPNA northern Levantine inventories of imagery items are rich and varied, representing a step-up when compared with the earlier poor record of imagery items of the northern Levant (see above, and n. 41 on p. 143). Cauvin (2000a: 25–29) notes that these assemblages include a growing number of human figures, including females, arguing that their Neolithic nature reflects a symbolic revolution. While this statement may in general hold for the small samples of imagery assemblages of the southern Levantine PPNA (both the Khiamian and the later Sultanian), where animal figures are represented poorly if at all (e.g., Hershman and Belfer-Cohen 2010 and references therein), it is clearly not

25. In contrast, the Natufian in the southern Levant has yielded a richer inventory of imagery items. The wealth of these Natufian imagery assemblages by itself attests to a change compared to the preceding scanty Epipaleolithic Kebaran and Geometric Kebaran records (e.g., Bar-Yosef 1997; Edwards 2013; and see Maher, Richter and Stock 2012). This fact alone may be interpreted as indicative of social and cultural “noise” arising long before the Agricultural Revolution, and possibly related to early sedentism or the growing size of the community. Among southern Levantine Natufian imagery, a small number of amorphous, potentially human figures appear, usually made of stone, while body ornaments of various types and materials abound. These are well-crafted items exhibiting an abundance of cut, perforated and polished beads, as well as pendants made of stone, marine shells, animal bones and carnivore teeth. Other items characterizing Natufian imagery include animal figures sculpted in stone or on the bone haft of a sickle—altogether quite a typical hunter-gatherer inventory of representations (e.g., Bar-Yosef 1997; Belfer-Cohen 1991; Valla 1995; see also Edwards 2013 for body ornaments and decorated objects; and Bar-Yosef Mayer, Porat and Weinstein-Evron 2013).

26. If the notion that an abundance of imagery items (including body ornaments) reflects an eventful occasion, such as social activities of some sort or a discourse over a debated issue, then a lack of imagery items may represent a calm social time. Taking this further, it would mean that the great debate on the Agricultural Revolution had not yet opened. Yet, and in this spirit (see n. 25 above about the southern Levant), the conspicuous appearance of body ornaments testifies that something was happening, but this—in our view—was more about society, identity and status than perceptual or economic change.

similarly applicable to the northern Levant PPNA imagery assemblages, which are noticeably rich in animal representations²⁷ (and see discussion below).

The northern Levantine PPNA imagery items were made mainly on stone and represent a plethora of impressive figurative representations of animals including raptors (vulture) and other birds (crane, bustard, duck), high-rank felid predators (panther, lion, sculpture on Pillar 27 at Göbekli Tepe), cattle (fully figurative or as signs interpreted as bucrania representations), pigs, foxes (the only canid), scorpions, snakes and insects. Animals that had become domesticated later in the Neolithic period, such as goats and sheep,²⁸ are almost entirely absent, as is the already domesticated dog. Among these assemblages, human figures are rare and are characterized mostly by a few female items of stone and clay and some 3D sexually ambiguous (Kuijt and Chesson 2005) human representations from Mureybet IIIA (Stordeur and Lebreton 2008: 620–624, Figs. 1–4). Worthy of note are two small gypsum human figures from PPNA Dj'ade (Dj I), which are relatively clear and were interpreted as male and female (Coqueugniot 2014). It is also noteworthy, however, that Cauvin (2000a: 25–29) claimed that these are all female representations: "...whether they are naturalistic or schematic, [they] have clear indications of their sex" (Cauvin 2000a: 25).

Additional human representations, generic in nature, are embodied in the impressive large T-shaped stone statues of PPNA Göbekli Tepe, including single ones with human hands, e.g., Pillar No. 18). These are interpreted, according to their shape, as human representations even in cases where no human body parts are clearly depicted (Schmidt 2012b: 111–113).²⁹ Owing to their highly impressive presence, they make an important contribution to our understanding of the entire symbolic array of Göbekli Tepe, as well as of large parts of the PPNA, including its later parts in the northern Levant.³⁰ Notable too is a whole array of body ornaments (including beads, pendants and shaped marine and land shells) as well

27. This and other aspects in Cauvin's book (2000a) have thus been criticized for decontextualization, i.e., the use of data and examples significantly separated in both space and time from the main (core area) context (e.g., Hodder 2001). Similar methodological drawbacks, possibly the result of insufficient data or the temptation to use available high-quality data, repeatedly occur in all-embracing review studies (e.g., Stordeur 2010: 124, concerning the vulture; Schmidt 2012b: Chapter III: 146–150, concerning the boar, or p. 118 concerning the bull).

28. This is significant, pointing to a special relationship between humans and these animals, which differs from the relationships with cattle and pigs that were also part of the "Big Four" domesticated animals (see also Box 1.5).

29. Their very shape, and the separation of cranial from post-cranial parts, are sufficient for this purpose.

30. There are many suggestions for interpreting this, but in our context this is a hunter-gatherer "drift," both in the content (human figures, even if generic) and in the scale or magnitude concentrated at this site (and there are additional known sites in that region that show such T-shaped pillars).

as decorated vessels and incised stone pallets, which may have played a role in the same ideological or political discourse. An additional PPNA medium that appears to be of symbolic expression is the uniquely decorated and painted (black, white and red) wall at PPNA Dja'de Layer Dji (Coqueugniot 2014).³¹ Besides the sites already mentioned, the imagery scene described above is fully or partially relevant for the northern Levantine PPNA sites of Tell Abr 3, Qaramel, Jerf el Ahmar, Hallan Çhemi Tepesi and Nemrik (the latter site conspicuously characterized by birds and snakes) (e.g., Cauvin 2000a; 2000b; Schmidt 2012a and references therein; 2012b; Stordeur 2010), and Körtik Tepe.³²

When compared to the preceding Late Natufian, the PPNA scale and settlement patterns in the northern Levant might arouse expectations of an array of symbolic imagery that represents a departure from the animal-dominated hunter-gatherer assemblage, rather than one that characterizes the PPNA. However, the symbolic array from the PPNA of the northern Levant seems rather to reflect a hunter-gatherer discourse—i.e., a climax of sorts in terms of hunter-gatherer scales known in the region. The PPNA imagery, although especially abundant at Göbekli Tepe, includes few if any sheep and goats, and is not characterized by representations of women, fertility, or sexuality (inasmuch as these are represented by female imagery items), whereas such items typify imagery assemblages of later parts of the Neolithic period. The generic human T-pillar figures in the PPNA sequence at Göbekli Tepe (including the latest PPNA figures),³³ some of which exhibit clear human body parts (hands), may perhaps be an exception to this general trend. The appearance of soon-to-be-domesticated cattle and pigs on these T-shaped pillars is a complex matter that needs to be accounted for; the cattle, for example, may be explained in the framework of Cauvin's model (Cauvin 2000a; 2000b) as a representation of male power and virility (but see Schmidt 2012b: 118 for an opposing interpretation).

In our view, the abundance of PPNA imagery reflects a time of change (social and/or ritual noise) when new ideas, inventions and innovations were introduced, discussed, debated and struggled over, within and perhaps also between communities.³⁴ This time of “socio-ritual noise” or “symbolic noise” may have reflected a battle

31. It is a geometric pattern (Coqueugniot 2000; 2014).

32. Especially rich in body ornaments and decorated vessels (e.g., Özkaya and Coşkun 2009).

33. Following Dietrich *et al.* (2013), the latest dates from Enclosure A are at the very end of the PPNA (ca. 10,600/500 Cal. BP and into the EPPNB), while Enclosures C and D provide much earlier dates, starting almost one millennium earlier.

34. These are probably the ideas and perceptions that represent the changing human-world, and possibly person-to-person, relationships that Cauvin would call the symbolic revolution and that we would view as a perceptual revolution (see n. 6 on p. 125, n. 10 on p. 127 and n. 24 on p. 135).

over a new ideology, a new set of priorities, new scales, or new subsistence practices. This restless time would have settled down when political oppositions and sources of conflict had been appeased and the new ideas and practices assimilated into the cultural and socio-economic systems. This last stage, however, may have been achieved and become visible only later, during the EPPNB. The PPNA may thus be viewed as a precursor of the EPPNB, an incubation stage of sorts, in which an ideological struggle over the socio-economic structure of the community had taken place. In effect, this period would seem to have hosted a deepening rift between reality in PPNA sites and the dwindling hunter-gatherer ethos.

It is during the “noisy” PPNA period of the northern Levant that the perceptual change should be sought, and especially so in the north, where the Natufian imagery is evidently so restricted. The restlessness resulting from the growing gap between millennia-old perceptions (ethos, ideology, cosmology) and life realities reached a climax in the PPNA and prepared the ground for the EPPNB, where some innovative elements, including plant domestication, were already being realized. Looking at PPNA Göbekli Tepe as an example, albeit an extreme one, it appears that human-animal relations were at the center of the scene. Following Busacca (2017) and his interpretation based on what he calls “relational ontologies,” i.e., that the animals seen in the imagery at Göbekli Tepe are not representational, but rather depict reality itself, like in Palaeolithic times when humans and non-humans had an ongoing relationship of equals. This would mean that the Göbekli Tepe imagery items depict a relationship between animal and humans in the spirit of a hunter-gatherer ethos, but that the physical setting (the context) of the encounter (*à la* Busacca 2017) between humans and animals, with the stage being the circular enclosures of Göbekli Tepe, differs quite dramatically from what would be expected of hunter-gatherers. The fact that animals of many species are mounted on a generic human figure would, in our view, indicate that the major topic on the agenda was the relationships of humans with animals as part of nature, and the struggle of humans to dominate them.³⁵ We can only wonder why the plant part is concealed altogether, or almost so (see Benz and Bauer 2013b and references therein), or depicted in a way we do not yet understand. Interestingly, the shift from “relational epistemologies” to an objectification of animals and plants was observed in a hunter-gatherer society in

35. In studies by one of us (Gopher and Orrelle 1996; 1999) it was argued that the multitude of gender-ambiguous imagery, and the fact that male and female elements appear on the same (human) platform, support viewing these imagery items as part of a negotiation (a conflict?) over gender status of women in a changing socioeconomy of the early Pottery Neolithic in the southern Levant (see also Gopher and Eyal 2012). In this spirit, the multitude of animal depictions mounted on human-like platforms would indicate the centrality of the topic in PPNA Göbekli Tepe.

southern India that was forced, during the second half of the 20th century, to change from hunting and gathering to farming. The repercussions of that economic shift in the worldview of the people involved were dramatic (Naveh and Bird-David 2014), and can provide us with a possible background to such changes that could have taken place in the EPPNB of the northern Levant. These changes will most probably also include what was viewed as the changes in the psychic realm (Cauvin 2000a; 2000b) and in neurobiological and emotional aspects (Benz and Bauer 2013b) that climaxed in gaining domination over plants and animals.

The EPPNB imagery assemblage of the northern Levant is very rich, boasting extremely impressive sculpted imagery items and employing a variety of media. In contrast to the picture that had emerged from the earlier PPNA assemblage, the northern Levantine EPPNB imagery assemblages present quite a different portrayal, starting as early as the onset of that period. The frequency of animal representations decreased, while human figures increased not only in number but also in complexity, and included representations of women engraved in stone (e.g., the lying or birth-giving woman from Göbekli Tepe, Schmidt 2012b: 221–226), in bone (Dja' de Dj II, III, Christidou, Coqueugniot and Gourichon 2009; Coqueugniot 2000; 2014) and in clay (e.g., Nevali Çori; see Morsch 2002; Stordeur 2010 and references therein).³⁶ These items represent new types of discourse and symbolism that differentiate the EPPNB from the PPNA, although animal imagery items are still present. Animal symbolism of the PPNA hunter-gatherers³⁷ is said to have emphasized the theme of death and the dead, manifest in threats (large cats, leopard), decay (vulture) and danger, albeit with a healing potential (snake), while also accentuating aspects of masculinity and strength (cattle) (Stordeur 2010; and see also some comments in Cauvin 2000a; 2000b; 2001).³⁸ The new EPPNB setting, in contrast, turns the spotlight towards aspects of fertility, sexuality (Schmidt 2012b: Chapter V), and women, painting a significantly transformed picture.

36. A remarkable EPPNB human figure—a carved bone wand showing two human faces, one on each side—from the site of Qarassa, Syria, was recently published by Ibáñez, Gonzalez-Urquijo and Braemer (2014).

37. Impressively mounted on a generic human platform; this raises questions about whether what we are seeing is a representation of interrelationships with animals or of power and domination over animals.

38. We should, however, also consider other interpretations, which may present us with a different picture; e.g., Schmidt (2012b: 118) claims that cattle do not necessarily represent masculinity, and on pages 185, 198 he claims that the snake can be seen (together with the Scolopendra) as a guard or defender, and not only as a symbol of danger and death; on page 76, birds and especially raptors are seen as symbols of communication with the supernatural, and on page 138 as messengers of the divine; and even for Stordeur's wily fox, Schmidt (2012b: 186–188) suggested other possible symbolic meanings. So the picture might be more complex, since penetrating a symbolic meaning is always open to debate and may never be fully possible (Goring-Morris and Belfer-Cohen 2002).

This transformation of the EPPNB is, in our view, a manifestation of old symbolic markers used with new, transformed, meanings (as is commonly the case with symbols), which have been adjusted and orchestrated to reflect a new discourse that postdates the tensions accompanying the PPNA debates and struggles after they have already subsided. As stated by Goring-Morris and Belfer-Cohen (2002: 72), threatened old cannons would have fought back in an attempt to cope with the “...new bewildering challenges stemming from external and internal changes.” This could well have been the case in the northern Levant between the PPNA and the EPPNB—a battle, whose outcome had already been determined, between the conservatives (hunter-gatherers) on the one hand and innovators’ messages of change on the other.

The claim that the PPNA and EPPNB in the northern Levant are symbolically similar and are dominated by items of wild animal imagery (Stordeur 2010) is too general to withstand a survey of the full array of other changes seen in the EPPNB (as discussed in the previous section of this chapter, headed “The Northern Levant: A Concise Archaeological Survey”). While it is true that the northern Levantine EPPNB—at least its early part—was not exclusively dominated by the new symbolic array, which centered on anthropomorphous male and female figures and included more representations of domesticated animals, it is also true that this assemblage differed in its makeup from that of the predating PPNA. Both the PPNA and the EPPNB are perceived, even by Danielle Stordeur (2010), as periods of intensive innovation and change, including the domestication of plants and animals, and culminating in a substantially changed economy and lifestyle.

We can readily accept suggestions advocating a view of the northern Levant PPNA symbolism as an extreme reflection³⁹ of the Palaeolithic hunter-gatherer ethos and practices on an extraordinary scale that may cause and/or reflect the instability and restlessness (and see Cauvin 2000a; 2000b; 2001; and an interpretation by Mithen 2007) as mentioned above. This does not contradict the idea that changes took place in the PPNA itself, as is evident in various cultural aspects. Breathtaking sites such as Göbekli Tepe, even if viewed as representing a climax of the Palaeolithic hunter-gatherer ethos, cannot be regarded as representative of the common or pristine “classical” hunter-gatherer condition. As such, they could not possibly have remained stable for long periods of time before eventually failing to confront and cope with the challenging new social, economic and political changes. In this respect, we would say that the array of imagery items

39. This is not a mere climax, but rather an outlier—a leap that calls into question the very society within which it has taken place and that takes apart the ethos and logic of hunter-gatherer existence.

of the EPPNB also reflects a “loud ritual”⁴⁰ as well as significant socio-economic change, which subsided only after agriculture had become established as a sustainable economic system in the northern Levantine Middle Pre-Pottery Neolithic B (MPPNB). In fact, we see a correlation between the magnitudes of this “loudness” and the climax that had erupted following the incubation processes among PPNA hunter-gatherer communities.⁴¹

While cautiously treading around the beginning and the institutionalization of proto- or early religion in the early Neolithic period as does Cauvin (1994; 2000a; 2000b; 2001), we maintain our focus on the conspicuously active ideological spheres of the northern Levantine PPNA and EPPNB, suggesting a dynamic array of social negotiations and ideological changes.⁴² The EPPNB, almost necessarily, would have required—and actually manifests—a socioeconomic reorganization accompanying plant (and animal) domestication to adjust to the wide array of changes across all aspects of everyday life.⁴³

Whether the changed symbolic array (the “symbolic revolution” *à la* Cauvin) preceded the changing economy or vice versa, or whether they were simultaneous, remains an open debate among archaeologists. Cauvin’s work, coining the view of “symbols before economy” (Cauvin 1994; 2000a; 2000b; 2001), stands in opposition to the economic-environmental explanation of the Agricultural Revolution as a whole (e.g., Bar-Yosef 2001b; 2011), and plant domestication in particular (e.g., Hillman 2000; Hillman *et al.* 2001). Cauvin’s thesis indeed suffers from some data-related problems, but given that it emphasizes and is in many ways more in line with ideological and mental (psychic) factors of the human agent (see definitions of this school of thought in Box 7.1), it is surprising that it

40. By “loud ritual,” we mean that the rich and abundant symbolic expressions, as presented in imagery items, proclaim the distinctiveness of the messages these symbols were broadcasting (e.g., Knight 1999: 239; Knight, Power and Watts 1995), either offensively or in defense (Harrison 1992) of intensive socio-economic developments and societal reorganization occurring at the time.

41. As far as the northern Levant record goes, this seems to be the case, with very little imagery in the sparse available knowledge we have of this region in the Late Natufian. In the south the picture is different, and the fact that late Natufian imagery assemblages are (quantitatively) dominated by body ornaments may be relevant, but we will not elaborate here on this possibility.

42. Struggle over ritual power, however, would not be foreign to such dynamics, and this may have been a vehicle leading to “revelation” and a change in the relationship with the supernatural, recruiting it in an attempt to establish a new ancestral entity of a higher level than the existing ones (see short discussion in Haklay and Gopher 2020b).

43. In the southern Levant the developments are somewhat different, as is their scale. The PPNA is dominated by anthropomorphic figures, not animals. The EPPNB is not very well known; it is possibly shorter in span than in the north; the single imagery items from Motza include human as well as animal figures (Khalaily *et al.* 2007). Like the PPNA, the southern Levant EPPNB provides no data on domesticated plants (or animals).

was not warmly welcomed at the time by supporters of a contextual approach such as Ian Hodder (2001), and was rejected by other researchers as well (e.g., Bar-Yosef 2001a; Kuijt and Chesson 2005; Schmidt 2012b: 231; and, to an extent, also Stordeur 2010). The meager Late Natufian northern Levantine database provides no firm basis for Cauvin's view of "symbols before economy." As for the PPNA and the EPPNB, siding with his view would depend on one's view of plant domestication. Supporters of the protracted-autonomous model of plant domestication, i.e., a long and early starting stage of cultivation or pre-domestication cultivation and an unconscious and/or unintentional process, are likely to oppose Cauvin's (symbolic) driving force and take the opposite stand, namely, economy first (e.g., Stordeur 2010; Willcox 2018). This is particularly true of researchers who at times view the PPNA and EPPNB as lumped units spanning almost a millennium and a half (e.g., Stordeur 2010; Willcox and Stordeur 2012; and the "Early PPN" of Asouti and Fuller 2013: 301). Proponents of the core-area one-event model, on the other hand, would readily adopt Cauvin's "symbols before economy," on the assumption that a change in perception, ideology and symbolism was a necessary requirement for domestication, and that this change had occurred either prior to or in tandem with it (e.g., Watkins 2010; Abbo and Gopher 2017; 2020).

However, the above expectations from this early and—to a degree—naïve discussion are not so simple, for the following reasons.

- Cultivation prior to domestication is in itself a significant change in lifeways that cannot take place in isolation and without having an impact on the communities involved, even if not specifically targeted on domestication.
- The sequence for Levantine plant domestication suggested by supporters of the protracted autonomous model of plant domestication incorporates long series of auditioning (and experimentation) with plant candidates for domestication. However, such a sequence would infer, even if implicitly, that the perceptions of human-world/land relationship, as well as the behavioral changes essential for becoming and being a cultivator, would need to evolve over a prolonged period and become effective prior to the much later domestication, and would thus lead to the conclusion "symbols (perception and behavior) before economy."⁴⁴ This inconsistency is inevitable if one chooses to view cultivation and plant domestication, as well as experimentation (including its inherent imperatives of awareness), as aspects that have occurred unconsciously.

44. That is, a high accordance with Cauvin's views (although he was not part of this debate).

- The situation becomes even more complex if one then also takes into account some statements by major supporters of the protracted-autonomous model, pointing out cultural factors of plant domestication (e.g., Asouti and Fuller 2013; Fuller, Allaby and Stevens 2010; Fuller *et al.* 2018) that eventually entail perceptual elements.

In summary, the PPNA, and especially the Göbekli Tepe climax, was still a time of hunter-gatherers—not a modal one, nor even a non-modal hunter-gatherer situation, but rather a remarkable end of an era, and obviously reflecting a changing discourse. The EPPNB that followed it embarked on a new way of life with a significant economic change, and was the first to exhibit domesticates, thus revolutionizing a crucial element of the hunter-gatherer lifestyle. Even if the swan song of the hunter-gatherer's ethos continued deep into the PPNB, and even into the subsequent Pottery Neolithic (PN) period (see Gopher 2012 for the southern Levant), the northern Levant EPPNB was the period where the divorce from the pristine hunter-gatherer ethos took off and where important components of the Agricultural Revolution, including plant domestication, resided.

CHAPTER 7

REFRAMING THE “CORE-AREA ONE-EVENT” MODEL

In this chapter we focus on some aspects that we consider fundamental to our argument for the “core-area one-event” model. Since we opted to present detailed discussions as our argumentation unfolded in previous chapters, here we discuss only a few selected aspects that are needed in order to better clarify this model. These include another discussion on the terminology and its meanings, the “recruitment” (choice) of package plants and its dietetic and agronomic qualities, and the distinction between plant domestication and post-domestication crop evolution.

We start the chapter with comments on our framework of thought. Instead of presenting this aspect, in the more conventional tradition, at the beginning of the book, we touched upon it only briefly in Chapter 1 as we considered the subsequent detailed chapters to be essential background to understanding that framework and its centrality to our statements in the next chapter. Our framework relates to evolutionary theory (including cultural evolution),¹ but mainly to the archaeological arena in which plant domestication research takes place. For the sake of clarity, and in order to avoid disrupting a fluent reading, brief descriptions of the archaeological schools of thought mentioned here are given below in Box 7.1.

Framework of Thought

Researchers in recent years have tended to view culture and cultural changes (or “cultural process”) within a macroevolutionary—the Extended Evolutionary Synthesis—historical perspective. Domestication, being a dramatic case of cultural change, is considered to be a useful phenomenon in such studies. Moreover, and in a wider framework as stated by Zeder:

1. See the PNAS issue of July 25, 2017 for a series of papers including a review by Mesoudi (2017 and references therein).

One of the challenges in evaluating arguments for extending the conceptual framework of evolutionary biology involves the identification of a tractable model system that allows for an assessment of the core assumptions of the extended evolutionary synthesis. The domestication of plants and animals by humans provides one such case study opportunity. (Zeder 2017: 1)

Since archaeological schools of thought reflect evolutionary frameworks of thought, the developments in archaeological thinking have become part of this ongoing evolutionary discussion (see n. 1 on p. 147). Box 7.1 presents a brief schematic background to the discussion in this chapter, facilitating a better reading of the archaeological views of the evolutionary debate. Although not a detailed survey on developments in archaeological theory, and not fully referenced or accompanied by lengthy explanations, we hope that this will provide the reader with a general road map that might be helpful.

Box 7.1: Archaeological Schools of Thought in a Nutshell¹

Archaeology has been established as a systematic discipline since the late 19th century and has developed into what was later called the “Culture History” school. This mode of archaeological thinking was generally based on inductive scientific dynamics and characterized by a normative view of culture, i.e., the view that norms of behavior are transmitted from generation to generation, from parent to offspring, and can be recognized by their material manifestations. It was basically a particularistic, or local, historical reconstruction and it usually explained change as a reaction to external developments² (e.g., diffusion).

Well established by the mid-20th century, this consecutive, “old” way of thinking was then severely attacked by a “new” archaeology, led by neo-Darwinian evolutionary thinking and based on extreme (Popperian) hypothetico-deductive scientific logic. Archaeology was now considered more as anthropology (i.e., synchronic) and less as history (diachronic), and culture was viewed as an “extrasomatic” means of adaptation. Society was viewed as a functioning organic system, while cultural change was considered as a perpetual attempt to sustain

1. Based on Abbo and Gopher (2017).

2. For example, a climatic change or migrations, or political developments in later historic times.

system equilibrium and was explained by adaptations to the environment (not by diffusion) and by internal social dynamics and reorganization. One of the most successful aspects of “New” (also called “Processual”) Archaeology has been its middle-range theoretical level, involved in basic archaeological questions such as the formation of archaeological sites and post-depositional processes in them. These aspects were mediated by a profusion of experimental work as well as ethnographic and ethno-archaeological studies, some of which also became part and parcel of plant-domestication studies (e.g., Hillman 1984; Hillman and Davies 1990a; 1990b; 1999; Abbo *et al.* 2008a; 2008b; 2015; Willcox 1992).

Negative reactions to New Archaeology began already in the 1970s and accelerated in the 1980s and 1990s. The “Post-Processual” or “Contextual Archaeology,” which was presented as an alternative, emphasizes the ideological landscape and its central role in human behavior and decision-making, and returns to particularistic, historical thinking. Human agency, not only diffusion or other external influence, has become central in explaining cultural change. A radical wing of this school of thought, based on the emergence of the Frankfurt school of critical theory in the early 20th century, advocates an interpretive view that relates to material culture as a text, with all the baggage that text reading brings with it. This view emphasizes both the active agents of past societies and the contexts and agendas of present-day researchers.

Beyond the general frameworks of thought presented in Box 7.1, there have been many additional developments in archaeological thinking and theory over the years and various suggestions have been made, opening new options for interpreting the archaeological record. These include, for example, Ian Hodder’s theory of human/things entanglement (Hodder 2016 and references therein; 2018), which eventually focused on the relationship between humans and things; and a “psycho-social” approach focused on the reciprocal dialectical dynamics of the brain’s matrix with environment and society (mostly based on neurobiological studies; see, e.g., Benz and Bauer 2013a; 2013b, and references therein; see also Mithen 2007), to mention just a couple of such developments that were recently cited in relation to plant (and animal) domestication research in the Levant.

The intensive discussions on archaeological frameworks of thought seem, however, to have cooled down, at least to some extent. The post-modern world and the communications revolution seem to have diminished the need to explain and to

maintain hard-core rigid frameworks, while “multivocality” on almost every aspect of life, and certainly including socio-cultural sciences, has taken off and is now in vogue. In this respect, we find ourselves today in a free era, with a legitimacy to use whatever the theoretical space offers. Nevertheless, the archaeological (and biological) infrastructure on which we rely, and through which all interpretations are presented and examined, remains as it was—namely, the central array providing the databases on which every interpretation, based on any framework of thought, is tested, and either validated or refuted. What archaeologists do, beyond systematically recovering the archaeological record in their excavations, is to organize the data they recover and assign them to archaeological entities of various scales and levels. These include so-called “archaeological cultures,” which are past entities defined by recurring assemblages of material culture (including every aspect of what we expose in archaeological excavations) that can be clearly defined both chronologically and geographically and allow reconstruction of dense time-space networks/grids).² Yet, as already mentioned (see Chapter 6, n. 3 on p. 124), we adopted an additional aspect for the definition of culture, i.e., that it is “. . . an entity of high information content and specific socio-cultural system” (Clarke 1978), or, in other words, that an archaeological culture consists of interacting communities that hold a similar worldview, similar ideology, a similar perception of the world and a similar socio-economy.

Culture History is the school that concentrates on extraction of the archaeological record and its proper organization in answering “what,” “where,” and “when” questions of the past. Indeed, there is no archaeology without a culture history that incorporates a systematic identification and definition of local stratigraphic and historical sequences, assemblages of material culture, contexts and relative chronology accompanied by absolute ¹⁴C dating. The useful aspects offered by the optimistic New Archaeology—especially its middle-range level, which has become quite a practical archaeological tool—are a welcome addition in the attempt to answer questions of “how.” The focus on structural and organizational aspects of social systems, as offered by New Archaeology, is important and relevant in the reconstruction of past societies and how they operated. While the post-processual “contextual” school was at first (in the 1980s and 1990s) viewed as radical, we operate nowadays in a post-postmodern world and are therefore familiar with contextual and interpretive thinking, extreme or radical though it may be. The almost naïve compromise, suggested by Colin Renfrew (1993) and later expanded upon by Renfrew

2. For us, as “splitters”, this should be done at the highest possible resolution, i.e., aiming at analytically and systematically defining the smallest definable units.

and Zubrow (1994), between the neo-Darwinian New Archeology and the postmodern contextual thinking—i.e., “Cognitive Processual Archaeology”—is still a practical runaway refuge, but is becoming less and less protective.

Beyond all that, we believe that any cultural change is a derivative, an ultimate (immediate or later) outcome of a changing perceptual world, bestowing a new worldview and a new apprehension of the place of humans in the world. This is also exemplified by the Agricultural Revolution as a large-scale overarching process, and by domestications (including that of plants) within it.

We believe that the battle for any cultural change or socio-cultural process resides in an individual’s mind, perception, ideology, comprehension of her/his place in the world and in his/her own community and society, and that this is as true for the present as it was for the past. Thus, when a change is being incubated, it inherently includes a wave of information aimed at the consciousness—and likely also the political interests—of a target population, as part of socio-cultural discourse debating about or struggling over a change, and which ends either in accepting and adopting the change or in rejecting it. With this in mind, we can define ourselves only as “contextual archaeologists” (not without some critiques), since we believe that it is in the landscapes of the perception and deep structures of the single human agent, as well as of human communities and societies, that the capabilities of the individual and the community, their judgments and resulting decisions on how to behave and to change, can be found and identified. We believe that individuals and communities of the past could not have existed in a perceptual and mental vacuum. Thus, for hunter-gatherers to become food-producing farmers they must have undergone a deep cultural transition, a mental and perceptual shift enveloping changes in ways of thinking, in basic relationships with other people, in existing socio-political arrangements and in relationships with nature and the world at large. In other words, hunter-gatherers were not likely to domesticate a plant or an animal while a hunter-gatherer ethos was the rule. Full control over nature or natural resources, an asymmetrical and dominating relationship with natural resources, a manipulative spirit, or a strategy of intent towards intensification (as in Western society) could not have been feasible for hunter-gatherers without deep perceptual changes, since those characteristics strongly contradict the ethos of hunter-gatherer societies as we (and other investigators) know and envision them (e.g., Carneiro da Cunha 2019; Abbo and Gopher 2020; and see Viveiros de Castro 2019 for an overarching view).

So, while standing on the shoulders of giants for the basics of Culture History and using whatever we find acceptable from New Archaeology, we believe that mental aspects and perception are the crux of cultural change and that once such a

change has been debated and ripened, the inevitable cultural/ideological/mindset leap (punctuation) will be accompanied by a long process of assimilation that will change the socio-economic landscape. Navigating the landscape of consciousness and mental processes, or deciphering the records of ancient worlds, is not an easy journey, nor is it easy to locate oneself within such landscapes as they transpire through the archaeological record. This is also a reason why we decided to expand to some extent, in the previous chapter, on aspects of imagery items and symbolism. We believe that the world of imagery incorporates and broadcasts the messages relevant to the communities in which it is found and that it reflects human discourse.

A final note in this connection: an archaeology of contexts is not “Contextual Archaeology,” which is a school of archaeological thinking (see Box 7.1, the above paragraphs and the discussion section below).

The recent outburst of debate on theoretical frameworks in “domestication research” or in “the archaeology of agricultural origins” (Gremillion, Barton and Piperno 2014a; 2014b; 2014c; Zeder 2014; 2015; 2017; Smith 2014; 2015) reflects, on the one hand, a general theoretical battle between the neo-Darwinian (Modern Synthesis) and macro-evolutionary or Extended Evolutionary Synthesis theories (for short comments see, e.g., Laland *et al.* 2014; Wray *et al.* 2014). On the other hand, it is essentially an archaeological debate too, though more limited in scope, between processual (neo-Darwinian) and contextual (post-processual) archaeological schools of thought vis-à-vis plant and animal domestication (for a brief road map, see Box 7.1). Research on domestication of both plants and animals is considered an appropriate and comfortable arena for testing evolutionary models and the principal debated issues and standpoints (see Zeder 2017), and it enables workers in the field to relate to both the general evolutionary and the archaeological spheres, which, in our view, go hand-in-hand in quite a natural way with plant-domestication research.

A central aspect in the discussion on selecting a model for plant domestication in the Levant (which we mentioned as one of the dichotomous pairs listed in Chapter 1) is that of consciousness, and it is inseparable from the other pairs, as we stated while presenting those dichotomies. Put simply, if in a politically incorrect way, this issue boils down to the question of whether humans were aware of their actions while domesticating plants (and animals) or if the process was based on automatic coevolutionary processes—an unintended cultural accident, so to speak. Whereas many participants in the debate state that human agency is central to their arguments, we think that not a few of them may be viewed as being dismissive of human agency and intent. The neo-Darwinian approach of Gremillion, Barton and Piperno (2014a) contends that human agency has no explanatory power. Zeder (2015), on the other

hand, endorses human agency in the framework of a macro-evolutionary attitude, and especially its perspective of cultural niche construction (see Box 7.2) advocating a coevolutionary, mutualistic, circumstantial domestication scenario for the Levant that ultimately leaves only a limited role to human agency in terms of contextual (post-processual) archaeological thinking (see Box 7.1; Abbo and Gopher 2020).

The above brief comments regarding processual (new) vs. contextual (post-processual) archaeology may serve as a suitable background and an opportunity for some comments on the old school of Culture History (see Box 7.1). Although dismissed for its non-explanatory descriptive nature, culture history, if meticulously applied, can nevertheless reach reasonably detailed space-time grids, and when used in an open-minded way it provides a basis for portraying and reconstructing specific, local geographic and historical contexts of a complex nature. Augmented by the resilient middle-range perspective of processual archaeology, it may produce a reasonable landscape for the study of plant domestication and other aspects of the Agricultural Revolution in the Levant. In this respect, it is worth noting that the historical framework we employ for plant domestication in the Levant generally follows and makes use of ideas derived from the historiographic principles of Braudel (2001). His scheme is instrumental and allows short historical events to be distinguished from longer, deeper processes and their undercurrents. We find the deeper/longer processes suitable for the study of the Agricultural Revolution as a whole, while the shorter scheme is suitable for plant domestication in particular. Borrowing from Braudel and freely adjusting to our own time scale and resolution, we see his *longue durée* (“long-span”) aspect, in the case of plant domestication, as reflecting cultural changes, including changes in perception regarding human–environment (world) and human–plant relations, the establishment of the supernatural (and more), giving birth to a new culture–nature relationship, and eventually culminating in the transformative Agricultural Revolution. Braudel’s *Conjectures* (the “medium span”) is related to changes in the socio-economic fabric of the relevant communities as well as to changes in the socio-political sphere. In the case of plant domestication, this historical span relates to changes in the nature and scale of settlements, including specific location, size, depth of sediments (reflecting length and intensity of occupation), architectural layouts, settlement patterns in the landscape, level of sedentism, and more. The medium span is also associated with any negotiations over new trends: social reorganization, economic aspects, technological systems (innovations and their adoption and assimilation), work scheduling, labor division, and more. *La brève durée* (the

“short span”), as we see it, refers to historical events or episodes (*histoire événementielle*, meaning a history of events). Such events *à la* Braudel, in the context of the relevant Neolithic archaeology, might be the appearance of a new technology (e.g., flint-blade production), an episode of change in harvesting tools (sickles and sickle blades), and others. For us, this short span is associated with plant-domestication episodes instigated by small-scale communities in southeastern Turkey and northern Syria, leading a plant package into domestication ca. 10,500 Cal. BP.³ A meticulous look at the historiographic levels is important, for example, in the case of distinguishing short plant-domestication episodes from long crop-evolution processes, which, ever since domestication, have continued to this day (Abbo, Lev-Yadun and Gopher 2012; Abbo *et al.* 2014; see below and Box 1.4). These two extreme historical scales underlying the story of plant domestication in the Levant include on the one hand, longer, slower and deeper currents reflecting changes in the socio-economic order and in human (culture) vs. world (nature) relationship, and on the other hand, the short, episodic domestication events.

The common trend in plant-domestication research on the Levant is to envisage long-term protracted processes. This has inadvertently brought about a spirit of “great synthesizing” (*à la* Flannery 1976), accompanied by the use of a low archaeological resolution, both in summary statements and, surprisingly, also in detailed studies. This counterintuitive lowered resolution in plant-domestication research, a trend that is currently in vogue, relates to both the biological and the cultural aspects. The lowered resolution is not about “great synthesizing,” but rather, in our view, about blurring of borders and opening of possibilities for generalizations that leave no room for including small-scale mini-models or even considering them. These generalizations are based on a domestication model with a long list of assumptions that are difficult to support, both because it is disconnected from detailed scrutiny of the available archaeological and biological data and because of some problematic argumentations concerning several of its tenets (see below, Table 8.1 on pp. 169–173). In some cases this results in the recruiting of various analytical procedures which, from the outset, are directed to accommodate the generalizations of the protracted autonomous model (e.g., Ibáñez, González-Urquijo and Gibaja 2014; Ibáñez *et al.* 2016 [and see Box 2.3]; Maeda *et al.* 2016; cf. Abbo *et al.* 2021).

3. It may also refer to local “corrections” in the areas at which domesticates arrived, such as the adoption of local, better adapted plants and/or the use of specific technologies locally developed for the newly arrived practice.

A conspicuous archaeological example is the pooling together of the Pre-Pottery Neolithic A (PPNA) and the Early Pre-Pottery Neolithic B (EPPNB) (e.g., Stordeur and Willcox 2009; Stordeur 2010; Willcox and Stordeur 2012; see also Asouti and Fuller 2013). The Pre-Pottery Neolithic (PPN) array is thus divided into two blocks, one of them including both the PPNA and the EPPNB (ca. 11,600–10,200/10,100 Cal. BP) and the other the Middle and Late Pre-pottery Neolithic B (MPPNB and LPPNB, ca. 10,200/10,100–9,000 Cal. BP; see, e.g., Asouti and Fuller 2013). The imposed poor resolution combines well with the protracted model; however, it hinders the opportunity to scrutinize the details of the cultural histories under discussion. Thus, for example, in lumping together the PPNA and the EPPNB, and at times also the later PPN and even the Pottery Neolithic (PN), one is bound to accept a protracted domestication model, thereby outweighing any discussion even before it starts. Lacking subdivision, the PPNA and the EPPNB both lose the unique character of the cultural units they represent, and a most significant, well-documented historical borderline is blurred and is thus lost altogether. Besides our discussion above, see notes by Asouti and Fuller (2013) on cultural differences between the PPNA and the EPPNB; those authors present clear differences between them, including economic ones and including plant (and animal) domestication, but they nevertheless lump the PPNA and the EPPNB together in the spirit of the protracted domestication model that they maintain. Moreover, this practice exposes any discussion of a cultural viewpoint to significant risk. Thus, for example, Rosen (2013: 336) praises Asouti and Fuller (2013) for their "... value of blurring the lines between agriculture and foraging," and she goes on to suggest: "Just as we can now blur the lines between forager and cultivator, it is possible to blur the line between Late Pleistocene and Early Holocene economic adaptations." This statement is ineffective from the viewpoint of socio-cultural environments, and scales such as Epipaleolithic-Neolithic (e.g., Maher, Richter and Stock 2012) are, in our view, merely a loss of the resolution acquired by decades of immense scientific efforts, while rendering much of the good work of archaeologists irrelevant or redundant. Such long-term historical scales are also immaterial to the biological processes involved in the domestication of annual and vegetatively propagated perennial species alike (e.g., Hillman and Davies 1992; 1999; Ladizinsky 1987; Abbo *et al.* 2011; Abbo, Gopher and Lev-Yadun 2015). As for annuals, the common resolution used is clearly not relevant for legumes, and similarly for cereals, unless one opts to assume lack of consciousness on the part of the domesticators and a protracted process preceded by a long stage of pre-domestication cultivation as a prerequisite for domestication (see Chapters 1 and 2). Another

serious drawback of low-resolution studies⁴ is that they ignore the crucial distinction between plant domestication on the one hand and crop evolution after domestication on the other—a distinction that may be helpful in sorting out time scales of plant domestication. Had aspects of the spread of domesticates in the geographic landscapes and in the studies on introgression processes in package plants both been taken into account, this might have provided an additional line of evidence of a higher resolution. As for vegetatively propagated perennial species (mainly trees), the story is somewhat more complex. We agree that the package of trees typical of the Levant was domesticated millennia later than the annuals, mostly in the PN and Chalcolithic periods (Zohary and Spiegel-Roy 1975; Abbo, Gopher and Lev-Yadun 2015), and that the ease of cloning a desired fig tree (or, similarly, pomegranate or grape vine) by the use of branch cuttings (e.g., Zohary 2004) would mean its immediate adoption for cultivation, i.e., for domestication. There is, however, a point of interest concerning the fig vis-à-vis resolution. Based on notable archaeobotanical observations, and without resorting to cloning, Kislev, Hartmann and Bar-Yosef (2006) claimed that the common fig (*Ficus carica*) was domesticated during the PPNA in a rapid (immediate) move, based on wise human selection for a suitable (parthenocarpic) type from nature. Notably, Kislev and his associates never made a similar claim—i.e., a conscious, knowledge-based decision and a rapid episode of domestication—for grain crops. Their suggested trajectory (conscious and quick rather than unconscious and protracted) rendered redundant the view of “long and attenuated” domestication (in this case for a tree),⁵ much like the case of identification of free germinating grain legume stocks (Ladizinsky 1987; and see Box 2.6).

Whatever the reason, those who praise lowering resolution and blurring the history depicted for the Epipaleolithic and Neolithic periods in the Levant miss the point of any scientific endeavor, by mobilizing low resolution to support and advance a model of a protracted plant domestication despite its deficiencies (e.g., see Boxes 2.2 and 2.5).

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4. The oft-quoted Tanno and Willcox account (2006a) can be used as an example. They show a long time-axis that presented a process of cereal domestication lasting over 4,000 years [throughout the Pre-Pottery Neolithic, into the Pottery Neolithic and through to the Chalcolithic period, see Box 2.5 (but see Lev-Yadun, Gopher and Abbo 2006; Hartmann, Kislev and Weiss 2006)]. Additional low-resolution statements can be found in Stordeur and Willcox 2009; Willcox and Stordeur 2012; Weiss, Kislev and Hartmann 2006; Snir *et al.* 2015; Fuller 2007; Purugganan and Fuller 2011; Asouti and Fuller 2013; Maeda *et al.* 2016; Fuller *et al.* 2018; Willcox 2018, and more.
 5. For a suggested protracted domestication process of trees see Fuller and Stevens (2019). When comparing arboriculture and cereal domestication they say: “The patterns of change seen in stone size and shape support a protracted gradual morphological evolution for arboreal domesticates (see Fuller *et al.* 2018), similar to that seen for the domestication of annual crops (see Fuller *et al.* 2014).”

Culture History (see Box 7.1), old-fashioned though it may seem, is a powerful and useful particularistic approach. When accompanied, even if modestly, by controlled experimental work and a fair treatment of the perceptual-ideological-symbolic array (see Renfrew 1993; Renfrew and Zubrow 1994), it can provide rewarding insights. Criticizing Culture History as a school of thought (e.g., Asouti 2006; Kuijt 1996; 2000; 2003 and references therein) is unjustified if it is not practiced in its appropriate scope. Such criticism reflects a problem of performance rather than one of approach. A clear and detailed (maximally split) culture history for each region and sub-region, at least at some stage of research, is a basic tool for evaluation and interpretation prior to generalization. In our view, it is both unacceptable and counter-productive to lower resolution while attempting a deeper scrutiny and analysis of complex and delicate processes, just as it is improper to mix different historical scales or to dispense with some of those scales. The potential of contextual⁶ (post-processual) approaches has yet to be realized in Near Eastern domestication research, as such approaches are currently employed only in a limited general manner (e.g., Schmidt 2012b; but see Hodder 2016, Chapter 4; and also Busacca 2017). The “contextual” approach of Asouti and Fuller (2013; see comments by Matthews and Fazeli Nashli 2013), for example, amounts to a history of contexts, a “concealed” historical (Culture History) narrative based on site stratigraphies and the typology of mainly architectural features lacking the details and precision needed for such a statement. New studies in Levantine Neolithic sites are similar in nature in that they show no attempt to argue in a “Contextual Archaeology” manner or to present “Contextual Archaeology” arguments that would eventually depict a particular historical story of the Levant—i.e., a particular, regional “Culture History”—admittedly still inescapably the beating heart of any archaeological reconstruction.⁷

Many of the protagonists of the debate on plant domestication in the Levant who accept and recognize the varied historical pathways to domestication assume in advance a long continuum of management strategies leading to it; thus, the protracted story becomes a given from the outset, and all other arguments are aligned to it. This is revealed in their ignoring of the distinction between plant domestication and crop evolution after

6. We reiterate that describing archaeological contexts exposed in archaeological sites and relating archaeobotanical finds to these contexts, or what has been called in recent years “a contextual approach” (Asouti and Fuller 2013; or “contextual insights,” see Tengberg and Douché 2018), is an archaeology of contexts, but is not a contextual archaeology. On the contrary, while contextual (post-processual, interpretive archaeology) maintains a central role for the individual human agent, the protracted autonomous scenario talks about unconscious domestication scenarios of plant domestication, thus undermining a central aspect of contextual archaeology (see a brief comment by Matthews and Fazeli Nashli 2013) and eventually becoming, by definition, anti-contextual archaeology.

7. The case of the Neolithic site of Ganje Dareh in Iran and the history of its dating and re-dating (Zeder and Hesse 2000) is a good example.

domestication, and in not a few cases, also of the distinction between agriculture (as a system) and domestication. In tandem, and almost inevitably, the story is also presented as based on an automatic, unconscious selection, and in many ways, as a co-evolutionary mutualistic relationship between humans and plants (and also animals). We disagree with the protracted-continuum aspect of this domestication scenario, as we argue throughout this account. We do not conform to its logic. We maintain, rather, that:

- once plant domestication is differentiated from crop evolution after domestication, and domestication is differentiated from agriculture (see Chapter 1);
- once consciousness is inserted into the process, i.e., that domestication is knowledge-based; and
- once a symmetrical (mutualistic) relationship between humans and plants in the spirit of Niche Construction Theory is set aside,

the stage then remains open for a cultural, conscious, knowledge-based plant domestication model, initiated and performed by human agents (individuals and/or communities) of the Neolithic Levant.

In short, we consider human agency to be a key component in plant domestication (Abbo *et al.* 2011; Abbo, Lev-Yadun and Gopher 2011; 2014; Abbo and Gopher 2017; 2020), and we oppose circumstantial reasoning or co-evolutionary (mutualistic) domestication.

We do, of course, accept the need for an all-embracing general theoretical view and for synthetic generalizing views. However, as historical particularists, we prefer at present to focus on the local scale of a well-known center of plant domestication rather than to generalize about macro worldwide scenarios. We view the Levantine local scale as an opportunity to construct detailed scenarios and micro-models, which may eventually converge to allow for the formulation of broader, regional and supra-regional, or global models.

Box 7.2: Niche Construction Theory vis-à-vis Plant Domestication

The Niche Construction Theory is an element of evolutionary theory focused on the processes by which organisms alter their own local physical environment and/or that of other species, thereby altering the selection pressures operating on themselves and on other sympatric organisms. Many animal and plant species have the ability to modify their own habitats. Examples include secretion of

different molecules from roots (to enhance nutrient uptake from the soil and acquire symbionts), change of soil texture by earthworms, pond creation by beavers and nest-building by birds. If genetic variation for the ability to build dams exists in a population of beavers, or if there is genetic variation among plant species for the ability to secrete efficient compounds to their rhizosphere, the immediate result will be greater fitness of those individuals that perform better in their own niche-construction operations (Odling-Smee, Laland and Feldman 1996). During the last two decades, several students of plant domestication have recruited Niche Construction Theory to explain plant domestication (e.g., Smith 2007a; 2007b). Viewing plant domestication via the niche-construction perspective means that all the traditional land or resource management activities of hunter-gatherers may be considered as analogous (in part) to the animal niche construction. Traditional management manipulations¹ include, among other activities, vegetation clearance, controlled burning, pruning, coppicing, tilling, selective removal of non-target species and transplanting (e.g., Anderson 2005). In addition, some investigators may envisage a sort of subsistence continuum stretching from pristine hunting-gathering through to increasing levels of environmental interactions, domestication of plants and animals, and traditional agriculture up to modern industrialized systems (Smith 2001). This view relies heavily on ethnographies documenting a range of late historical and recent societies (e.g., Smith 2001; 2011; Anderson 2005; Kelly 1995; and see Pascoe 2014).

The view of domesticating plants as only one station along a protracted journey from minimal intervention of pristine hunter-gatherers to agriculture goes hand-in-hand with viewing the subsistence economy of historic native Americans as proto-agriculture (Anderson and Wohlgemuth 2012). It should be noted, however, that even the monumental land-management activities, as described by Anderson (2005) for California or by Pascoe (2014) and see Gerritsen (2008) for Australia, did not develop into the industrial economy typical of the Near East, Mesoamerica, or China. Rather, they represent a different decision-making pattern of ancient humans opting for an entirely different social and economic alternative (e.g., Abbo and Gopher 2020; Lévi-Strauss 1952b).

1. These land-management techniques, found in many pre-industrial human societies (e.g., Smith 2001; Anderson 2005; Carneiro da Cunha 2019), should not (and cannot) be mistaken for claims on Levantine pre-domestication activities, as discussed in Chapter 2 (and see Abbo and Gopher 2020).

Niche Construction Theory has become a central framework of thought in plant domestication research worldwide, including in the Levant. For some researchers it serves to promote the view of plant (and animal) domestication as a sort of partnership—a relationship between (but not limited to) domesticator (human) and domesticated—and it is a protracted and unconscious process (e.g., Willcox 2013; 2018; Fuller *et al.* 2018; Larson and Fuller 2014; Purugganan 2019). Ethnographies widely used to promote such views (Smith 2001; 2011; Harris 2012; or for that matter, Asouti and Fuller 2013; and others; and see, for example, Chapter 6, n. 15 on p. 131) are, for the most part, not very helpful in the case of the Levant (for a detailed discussion, see short, direct or indirect comments in Abbo and Gopher 2017, and in Abbo and Gopher 2020).

Terminology in Plant-Domestication Research and Its Meaning

A highly influential contribution to the modeling of plant domestication was made by David Harris, who combined insights on anthropological, ecological, socio-economic, botanical and evolutionary aspects. His classical multi-staged model (Harris 1989) is structured as an evolutionary continuum of interactions between people and plants, which gradually gave rise to plant domestication and agriculture—an idea with roots in Merrill (1933: 328) and echoing Darwin's (1868) scenario. The model comprises four stages:

- Foraging, i.e., wild food gathering and hunting;
- Cultivation of wild plants or pre-domestication cultivation;
- Systematic cultivation of wild plants; and eventually
- Agriculture based on domesticated forms (*sensu* Fuller 2007; and see Allaby 2010).

Implicit in Harris' model is that the commencement of stage 4 is mediated by the selective propagation of domesticated genotypic and phenotypic variants that occur throughout stage 3 (Harris 1989: Fig. 1.1), i.e., that domestication is dependent on cultivation. Harris himself emphasized his evolutionary continuum and stressed that he meant neither a unidirectional nor a sequential or a deterministic scenario. At the same time, cultivation was considered—and still is—by others (explicitly and implicitly) as an early stage of a linear, unidirectional process leading plants through a protracted, unconscious genetic selection process into domestication. This is echoed

by the term “pre-domestication cultivation” (see Chapter 2, and the above discussion; Abbo and Gopher 2020). Harris fine-tuned his model over the years (e.g., Harris 1996a; 1996b; 1998; 2002), maintaining his basic evolutionary continuum. He emphasized “transitional” lifeways (between hunting-gathering and agriculture) and their flexibility, i.e., either to develop, or not develop, into agriculture.⁸ He also decoupled—fully or partially—agriculture from domestication, thus blurring the conceptual boundary between the two. Harris later revised his 1989 model and depicted three (rather than four) modes of food procurement and production (Harris 2007: 1, Fig. 2.1):

- Foraging practices (see Abbo *et al.* 2005; Abbo, Lev-Yadun and Gopher 2011; Abbo and Gopher 2017; 2020) (wild plant food procurement);
- Wild food production (pre-domestication cultivation);
- Agriculture (based mainly on domesticated crops).

In that revision, Harris (2007) stressed that this clear-cut distinction between his three modes of subsistence serves analytic purposes only, whereas reality comprises mixed subsistence systems characterized by a gradual decrease in dependence on wild foods⁹ and a simultaneous gradual increase in dependence on domesticated crops (Harris 2007: legend to Fig. 2.1).

Although Harris (1989: 11) stressed the importance of accurately defining the terms that researchers use, he himself joined the growing tendency to see the interaction between humans and plants, domestication included, as a fluid, indistinct (blurred) continuum of transitional situations¹⁰ and, in so doing, distorting the sharpness and

8. True, there is an option of no-domestication cultivation, as referred to by Colledge (2001: 224) (and see above, Chapter 2), but when viewed from our perspective, it is illogical to assume such practice (Carneiro da Cunha 2019), given the long history of relationships between hunter-gatherers and farmers that eventually brought about the almost total extinction of hunter-gatherers worldwide, although their ethos and lifeways still survive in specific niches here and there, distorted though they may be. The Australian case is a horrifying story, and is directly related to the beginning of agriculture, as it portrays not only the common story of hunter-gatherer decline, but also the concerted effort to manipulate the history of its unfolding (see Gerritsen 2008; Pascoe 2014).

9. In fact, wild food collection has continued throughout the ages and continues to this day by people engaged in many sorts of economic systems.

10. The alternative—i.e., that domestication and farming take place while gathering from the wild continues—is much simpler and has much higher parsimony. Gathering (as well as fishing and hunting) continued and still continues to this day on a large scale in some parts of the world, including areas dominated by agriculture. Attaching “gathering” to a process of complex and diverse situations, and attempting to provide a complex answer to their existence, is awkward, and necessitates making a series of assumptions that are hard to accept. Why should domestication or farming and wild plant food gathering be mutually exclusive?

accuracy provided by his own terminology. The inevitable loss of resolution and the avoidance of reference to the archaeological data resulted in a growing reliance on diverse ethnographic and ethnohistoric data (e.g., Harris 2012; see also Smith 2001; 2011; and references therein, and Harris 2006). Typical of this trend is the use of Harris' model by Asouti and Fuller (2013: 303, Fig. 2). To Harris' scheme, those authors added archaeological indicators as well as quantitative trends in archaeobotanical data, and in particular, an increase in presumed weeds of cultivation, in the frequency of non-shattering (domesticated) cereal types, and in grain sizes over time¹¹ (for discussion on these aspects see Boxes 2.2 and 2.5). Additional aspects were added to the scheme in a quasi-quantitative manner, including an increased dependence on cultivated plants, an increasing input of human labor (one aspect of this was refuted experimentally by Tzarfati *et al.* 2013), and trends of rising or falling yields per area unit of managed land—all depicted along a time axis. The problematic nature of some of the presumed trends in the data (e.g., Heun *et al.* 2012; Abbo *et al.* 2014) notwithstanding, these linear reconstructions of quasi-quantitative trends are presented in the above-mentioned spirit (e.g., Asouti and Fuller 2013: 303, Fig. 2), blurring borders between otherwise distinct phenomena. The protracted autonomous model flourishes in this poor-resolution environment, which is disconnected from some of the relevant available data sets, both archaeological and biological, as well as from the actual genetics and agronomy of the crop plants discussed.

Distinguishing Plant Domestication from Crop Evolution

In two reviews (Abbo, Lev-Yadun and Gopher 2012; Abbo *et al.* 2014), we emphasized the distinction between plant-domestication episodes and post-domestication crop-evolution processes. This conceptual (and practical) distinction gains strong data-related and experimental support from several lines of research.¹² The distinction is not unanimously accepted, however, as is evident from the frequent use of the

11. In so doing, Asouti and Fuller (2013) strip Harris' model (1989) of its non-directionality and turn it into a diachronic scheme aligned with the archaeological data.

12. For example, as outlined, our experimental work with wild pea suggests that only a single trait, namely free germination, can be considered as a genuine domestication trait (Abbo *et al.* 2011). It therefore follows that the multitude of additional morphological and physiological differences between wild and domesticated pea (e.g., Aviezer and Lev-Yadun 2015; Weeden 2007) evolved subsequently to the domestication episode, i.e., under domestication, or as part of the ongoing evolutionary history of domesticated pea (Abbo, Lev-Yadun and Gopher 2012). Similar reasoning underlies the work of Hufford *et al.* (2012) on maize, endorsing a similar view regarding the solid biological basis for acknowledging the distinction between domestication episodes and crop evolutionary processes, improvement and diversification under domestication, and in modern times, scientific plant breeding.

somewhat oxymoronic term “crop domestication” (e.g., Fuller 2007; and see Hillman and Davies 1999). In our past writings we too have fallen into this terminology trap (e.g., discussion in Abbo *et al.* 2003), and have therefore taken special care here. In fact, and as reiterated above, the biology of the Levantine grain legumes does not allow for cultivation prior to the advent of free germination (i.e., domesticated) types (*sensu* Ladizinsky’s 1987 “domestication before cultivation”, and see Box 2.6). Therefore, the scatter plots of Purugganan and Fuller (2011), which allegedly depict the temporal (domestication) dynamics of grain dimensions in lentil and pea, should simply be seen as representing post-domestication crop evolutionary trends rather than evidence for protracted domestication processes. We argue that adopting the above distinction may help resolve many of the current disagreements concerning plant domestication, while relying on solid biological and genetic grounds and devoid of the need to resort to intellectual constructs and the use of various assumptions (e.g., regarding consciousness, necessity of pre-domestication cultivation, extra labor associated with domestication; see Table 8.1). No less important, and related to archaeological resolution, the distinction between plant domestication and crop evolution is imperative because it offers better genetic and evolutionary resolution power while relating to plants in both their wild and domesticated forms.

Recruiting Package Plant Species: Nutrition, Agronomy and Consciousness

A consideration of species recruitment may shed light on the nature of Levantine plant domestication. The Levantine package combines flax (a fiber and oil crop) with both cereals and grain legumes, thereby providing balanced nutrition (Zohary and Hopf 1988). In addition, this crop package also represents an excellent agronomic (i.e., grain yield) compensation potential operating on two levels, one between the two main crop groups (legumes and cereals), and the other within each of these crop groups (Abbo, Lev-Yadun and Gopher 2010b). With respect to the first level, Near Eastern cereal and legume crops have contrasting responses to the seasonal rain profile. Therefore, under Levantine dryland conditions, in years when cereal yields are relatively low the legume yields are relatively high, and vice versa (for a detailed discussion see Abbo *et al.* 2009; Abbo, Lev-Yadun and Gopher 2010b). At the second level, each crop group displays an adaptive maturity gradient presenting a range of abilities to cope with water shortage. Among the cereals this is observed with the early flowering and early grain maturation of barley, the medium seasonal maturity of emmer, and the late flowering of einkorn—all providing an insurance of sorts in

the face of unpredictable seasonal rain patterns (Abbo, Lev-Yadun and Gopher 2010b). Similarly, among the legumes, lentil can yield under marginal conditions, while pea and faba bean thrive under lush conditions and chickpea yields best with early spring precipitation immediately following sowing (Abbo *et al.* 2003; Abbo, Lev-Yadun and Gopher 2010b).

In our opinion, it is almost impossible to view the selection in favor of specific mutants from the available standing genetic variation present in wild populations (see Doebley, Gaut and Smith 2006), or the selection of plants in a cultivated field (crop evolution), through a lens of unconscious dynamics. Similarly, it is difficult to explain the emergence of an agronomically and nutritionally balanced crop package in terms of circumstantial events or long-term predator–prey (the prey or harvest pathway-like relationships, *à la* Zeder 2012; 2018). Some of those species were unlikely to have been a major food source prior to domestication, considering the low per-habitat yield of the wild forms of Levantine legumes—which, in addition, are not amenable to profitable cultivation because of their pronounced seed dormancy (Abbo *et al.* 2008a; 2013b; Ladizinsky 1987; Ladizinsky and Abbo 2015). We also stress that any assumed experimentation (*à la* Smith 2007a; 2007b; 2011; Weiss, Kislev and Hartmann 2006; Snir *et al.* 2015), be it long- or short-term, must—by definition—have necessitated careful attention, from the outset in choosing the candidates, and all the way through for reviewing the specific performance of each potential species until eventually opting for the successful ones. The immense success in securing grain yields of the vulnerable chickpea via the unique agrotechnology of spring sowing of an originally winter plant (Abbo *et al.* 2003; and see Box 1.3), and the selection in favor of a nutritionally superior type (high tryptophan content) within the domesticated chickpea genepool (Kerem *et al.* 2007; van-Oss *et al.* 2018), are compelling examples of the ingenuity, skills, and deep understanding by Neolithic people of their surrounding natural (and later agricultural) environment.

Naturally, we do not deny the inevitable effects of correlated responses to selection, whether at the initial seed corn stocking or later on under domestication. Such responses, however, cannot be considered as examples of unconscious selection. We argue that ancient farmers, like successful present-day traditional farmers, were always aware of minute details and events in their fields and were attentive to the quality of their produce. Plant domestication, therefore, must have been driven by a knowledge-based recruitment of species and a conscious selection resulting in an almost perfect plant package, not only ensuring productivity under fluctuating environmental conditions, but also nutritionally balanced and rich. There is no better support for this than the mere fact that throughout history, little has been added to

this plant (or animal) repertoire in the Levant or to domesticated plant packages in other primary domestication centers worldwide (Lévi-Strauss 1966). These good old packages continue to be the major feeders of humankind. Even the last century's modern agronomy and breeding efforts, which were aimed at improvement of grain crops, were concentrated on species of these reliable packages that were domesticated thousands of years ago.

CHAPTER 8

THE “CORE-AREA ONE-EVENT” MODEL IN PERSPECTIVE

In this final chapter, we summarize by bringing together the different lines of evidence and main points supporting the “core-area one-event” model of plant domestication in the northern Levant.

The origin of plant domestication in the Levant is found within a single, relatively small and geographically well-defined core area situated in southeastern Turkey and northern Syria. This is the only region where all the wild progenitors of the eight founder package species of Neolithic agriculture appear together. We suggest that this is where they were all domesticated, thereby rejecting the option of the southern Levant—the Damascus basin and the lower Jordan Valley—as the locale of early Neolithic plant domestication. Continuously accumulating evidence indicates that the genetic stocks of the progenitors of several package species that gave rise to the domesticated forms are present in only a limited area of their broad distribution, namely, the suggested core area. This is the case for emmer and einkorn wheat, for chickpea, lentil and pea, and for at least two of the three possible domesticated barley stocks (but see Cíván *et al.* 2021). The progenitor of bitter vetch still lacks the accurate genetic data needed to pinpoint its geographical origin. As for flax, it was offered a monophyletic origin in Turkey (Allaby *et al.* 2005) and the progenitor can also be found in the core area (see Chapters 2 and 4).¹ Archaeobotanical evidence exists for all of these package species in their wild forms in Late Natufian and Pre-Pottery Neolithic A (PPNA) sites of the suggested core area prior to domestication and up to the middle of the eleventh millennium Cal. BP. Also in this area is the earliest evidence for domesticated plants in the Levant, beginning ca. 10,500 Cal. BP, as follows:

1. *Vicia faba* has no known wild progenitor (see Table 1.1 and its footnotes). It is found in Neolithic archaeological sites of the southern Levant (with a single seed dated to the Natufian; see Chapter 5, nn. 1–3), and it also appears in northern Levantine sites in the PPNA and Pre-Pottery Neolithic B (PPNB).

- Archaeological evidence indicates that the suggested core area was a prominent and active cultural center from which Neolithic innovations and materials spread to other parts of the Levant (see also Chapter 6). This is supported by ^{14}C dates recording the flow of Pre-Pottery Neolithic (PPN) cultural and material elements from the northern Levant to the south, as well as to the west. This area also exhibits a shift in site nature and organization, architecture, burial customs, economy and many material aspects, as well as in imagery items from the beginning of the Early Pre-Pottery Neolithic B (EPPNB), together with clear and direct evidence of plant and animal domestication.
- The spread of domesticated plants within the Levant from the north to the south is in line with the spread of other Neolithic cultural elements. For emmer wheat and chickpea, based on available molecular genetic data or on archaeobotanical remains or both, this may be described as a ripples-wave of advance pattern, radiating out of the proposed core area (see, e.g., Fig. 3.1 and Abbo *et al.* 2006). These ripples are also notable in the works of other researchers, regardless of the domestication model they endorse (e.g., Kilian *et al.* 2007; 2009; Özkan *et al.* 2005; Tanno and Willcox 2006a: Fig. 1; Willcox 2005: Table 1; Riehl *et al.* 2013; see also Colledge, Conolly and Shenan 2004; 2005; Colledge and Conolly 2007; 2010; Coward *et al.* 2008).²
- Considering the above points and following Occam's razor approach, it seems logical to take advantage of this wealth of independent data sources and lines of evidence as we point to the region we suggest to be the core area of Levantine plant domestication. Our past suggestions (Abbo *et al.* 2010a; Gopher *et al.* 2001; Lev-Yadun *et al.* 2000), as well as those we make here, seem to accord well with the available old and newly accumulated data, and they show high parsimony compared with other alternatives. If we accept the alternative protracted autonomous model of Levantine plant domestication, we must also accept a long series of assumptions, some of which require further, secondary, assumptions, and many of which turn problematic when closely scrutinized. In contrast, the "core-area one-event" model requires fewer assumptions to begin with, and given the available data, those assumptions are easier to accept (Abbo and Gopher 2017). Table 8.1 is a heuristic device that juxtaposes the protracted autonomous model and its assumptions against the assumptions of the "core-area one-event" model, thus providing a measure of parsimony for each model.

2. Recent papers based on ancient DNA show a migration of Levantine populations of farmers westward into Europe (Lazaridis *et al.* 2016; Olalde *et al.* 2019; Brace *et al.* 2019).

Table 8.1: A parsimony measure of the two alternative plant domestication models, presented as a list of assumptions underlying each model¹

Assumptions of the Protracted Autonomous Model	Validity of the Protracted Autonomous Model's Assumptions	Assumptions of the Core-Area One-Event Model
Genetic Considerations		
It is impossible (or nearly impossible) to domesticate plants in the presence of the wild progenitors because of the introgression of wild-type alleles (e.g., Allaby 2010).	See Wilkes (1977) and Hufford <i>et al.</i> (2012), showing the opposite for maize in Mexico.	Not needed, because the Levantine grain crops are selfers.
Preemptive domestication is not accounted for.	See Diamond (1997: 179–180) and see pp. 99–100 above.	Preemptive domestication is a valuable concept, biologically and culturally.
Plant domestication was polyphyletic per species (Allaby, Fuller and Brown 2008; Brown <i>et al.</i> 2009). Simulations supporting this scenario rely on a protracted assumption embedded in the model.	A polyphyletic signal is not seen without an embedded protracted component (Heun <i>et al.</i> 2012; Salamini <i>et al.</i> 2002; confirmed by Allaby, Brown and Fuller 2010, and see Ross-Ibarra and Gaut 2008).	Plant domestication was monophyletic, both per species and per package.
The population of wild species (progenitors) and of the autonomous (multiple) cultivated islands behave like meta-populations in which alleles conditioning the domesticated phenotypes flow freely across the entire range of the corresponding species.	In self-pollinating species (wheat, barley, pea, lentil, chickpea), it is mistaken to view the entire range of each of these species as a panmictic population with free geneflow. Moreover, how does free exchange of domesticated alleles accord with autonomous domestication of the different domestication foci (e.g., Willcox 2005)? Wouldn't this assumption negate the autonomous aspect of the model (Heun <i>et al.</i> 2012)?	Not needed.
Domesticated morphotypes could not have been identified by Epipaleolithic or Neolithic foragers in nature and/or by cultivators in their cultivated plots (e.g., Purugganan and Fuller 2011).	Domesticated phenotypes are available as part of the standing genetic variation in the wild (see Kamm 1974). The knowledge of and attentiveness to their environment by hunter-gatherers (see, e.g., Anderson 2005; Lévi-Strauss 1966) makes relying on protracted cultivation for their appearance redundant.	Neolithic people were fully capable of identifying useful phenotypes in the wild and in their plots or fields.

¹ Based on Table 1 in Abbo and Gopher 2017 with minor modifications.

Table 8.1 (continued)

Assumptions of the Protracted Autonomous Model	Validity of the Protracted Autonomous Model's Assumptions	Assumptions of the Core-Area One-Event Model
Behavioral and Cultural Aspects		
<p>A long stage of cultivation (pre-domestication cultivation) is a prerequisite for domestication (e.g., Gepts 2004; Fuller 2007; Willcox 2012a; 2012b; 2012c; Asouti and Fuller 2013; Fuller <i>et al.</i> 2018).</p>	<p>There is a biological option for rapid domestication of package cereals (Hillman and Davies 1990a; 1990b; 1992; 1999). There is no option for protracted cultivation of grain legumes owing to strong seed dormancy (Abbo, Lev-Yadun and Gopher 2011; Ladizinsky 1987).</p>	<p>Not needed.</p>
<p>The context of plant domestication was circumstantial. Humans adopted "camp-following" plants or species that thrive in disturbed habitats and on refuse heaps (Engelbrecht 1916; Hawkes 1969; Laland and O'Brien 2010; O'Brien and Laland 2012; Rindos 1984; Smith 2007a; 2007b; Martin-Robles <i>et al.</i> 2019; and see Zeder 2015; 2017) relating to domestication pathways, including the commensal pathway that may be relevant for two of the package species, einkorn wheat and barley.</p>	<p>Under meticulous botanical scrutiny, weedy and/or ruderal tendencies do not conform to the biology of the species that were domesticated in the Levant other than for barley and einkorn wheat (Abbo <i>et al.</i> 2005).</p>	<p>Not needed.</p>
<p>The process was characterized by numerous "false starts" and failures, as well as some successful starts from which the package of founder crops emerged. In view of this, the Levantine crops do not represent a selected package but rather the remains of an erratic process (e.g., Gross and Olsen 2010; Fuller, Asouti and Purugganan 2012a).</p>	<p>The appearance of an agronomically and nutritionally balanced crop assemblage (Abbo, Lev-Yadun and Gopher 2010b; Helbaek 1959) is not in line with this assumption. In addition, see Abbo <i>et al.</i> 2013a concerning the alleged "evidence" for the "lost crops" claim.</p>	<p>Not needed.</p>

Table 8.1 (continued)

Assumptions of the Protracted Autonomous Model	Validity of the Protracted Autonomous Model's Assumptions	Assumptions of the Core-Area One-Event Model
Weeds increase with the protracted timeline of plant domestication (e.g., Hillman, Colledge and Harris 1989; Colledge 2002; Willcox 2012a; 2012b; 2012c; Riehl, Zeidi and Conard 2013).	The data fail to demonstrate this claim (see discussion in Abbo, Lev-Yadun and Gopher 2012). For example, the data of Riehl, Zeidi and Conard 2013 do not conform with their own interpretation (Abbo, Lev-Yadun and Gopher 2013).	Not needed.
Plant remains that are of no use to humans are likely to represent weeds of cultivation (e.g., Riehl, Zeidi and Conard 2013; Willcox 2012c; Douché and Willcox 2018).	Given that identification in many cases is only to the genus level (in genera including many non-weedy species), such a claim is rather weak. And would that mean that weeds, albeit present, were not used? Indeed, many of the listed "alleged weed" genera contain species with known uses.	Not needed.
Cereal crop processing after domestication is a "labor trap" lowering domestication incentives and resulting in selection pressure in favor of the wild-type phenotype.	Experiments have demonstrated the opposite (see Tzarfati <i>et al.</i> 2013). Further, see a claim for a labor trap that presumably triggered a rapid selection in favor of the domesticated non-shattering type (Kislev 1984).	Not needed.
Storage installations attest to cultivation (e.g., Asouti and Fuller 2013; Kuijt and Finlayson 2009; Willcox and Stordeur 2012; Willcox 2012a; 2012b; 2012c).	Natufian or PPNA installations provide no direct evidence of stored grains. The use of such installations for foraged wild plants or for other uses cannot be excluded.	Not relevant.
The use of plant material for construction attests to cultivation (Willcox and Stordeur 2012).	Foraged wild cereals required processing to extract the grains. The remains could have been used later for various purposes.	Not relevant.
Rodent droppings attest to cultivation (Willcox and Stordeur 2012; Willcox 2012a; 2012b; 2012c).	Why need this be the sole explanation for the presence of mice or other rodents in the sites? Rodents already appear as commensals in the late Epipaleolithic sites of the Levant and are interpreted as indications of sedentism (Tchernov 1984; 1991).	Not relevant.

Table 8.1 (continued)

Assumptions of the Protracted Autonomous Model	Validity of the Protracted Autonomous Model's Assumptions	Assumptions of the Core-Area One-Event Model
There will, by definition, be no spread of domesticates for as long as the supposed (sub)-centers remain independent (autonomous).	The arrival of <i>Cicer</i> (with seed morphology of domesticated types) at EPPNB Tell Ain el-Kerkh, considering its wild-progenitor distribution, as well as the case of Cyprus, indicates a rapid spread of domesticates already in the EPPNB.	Spread of domesticates is correlated with spatio-geographic dynamics of other cultural elements (Gopher 1989a; 1989b; 1994).
Resolution, including cultural resolution, can be lowered, and cultural change is not directly correlated with cultivation and plant domestication. Thus, Epipaleolithic communities may be included and the PPNA and EPPNB (and later periods too) can be lumped together at need and viewed as a continuum (implicit in Asouti and Fuller 2013; Fuller <i>et al.</i> 2018).	This is a “waste” of resolution earned by hard field and laboratory work, e.g., the PPNA and EPPNB show a multitude of differences in settlement patterns and site nature, architecture, burial customs, material culture and technology, symbolic behavior and economy (plant domestication included), and should remain distinct.	Cultural change is a major phenomenon and is directly correlated with plant domestication. Use of the highest available resolution may help to reach a refined historical and evolutionary reconstruction of plant domestication in the Levant (Abbo <i>et al.</i> 2014; Abbo and Gopher 2017).
The protracted process of domestication and the increase in domesticates on account of wild plants along time will be expressed in the quantity of sickle blades and in the level of specialization in their production (Maeda <i>et al.</i> 2016). This may also be expressed in a changed relationship with sickle blades, their contexts and their symbolic value (Asouti and Fuller 2013; Fuller <i>et al.</i> 2018).	While it is clear that sickle blades can potentially reflect aspects of plant domestication, the studies quoted here demonstrate that the significant shift and the change vis-à-vis sickle blades occurred at the very end of the PPNA and the very beginning of the EPPNB. None of the arguments raised would indicate a protracted process. Analysis of late Pottery Neolithic assemblages of sickle blades is not relevant to plant domestication or the origin of agriculture.	While our model does not require any assumptions concerning sickle blades, we do reiterate that a new blade-production technology (for long, non-curved and non-twisted blades) was directed to producing the blades for sickle blades. This originated in the northern Levant and was an important factor from the very beginning of the EPPNB.
Grain size is a diagnostic domestication trait, and it increases in the course of the protracted process of domestication (Willcox 2004b; 2012a; Fuller 2007; Fuller <i>et al.</i> 2018).	Wild vs. domesticated comparison indicates that seed size is a crop-evolutionary change, rather than a domestication trait (Abbo <i>et al.</i> 2014).	Not needed.

Table 8.1 (continued)

Assumptions of the Protracted Autonomous Model	Validity of the Protracted Autonomous Model's Assumptions	Assumptions of the Core-Area One-Event Model
<p>A piecemeal rise in frequency of non-shattering types characterizes the protracted establishment of the domestic stocks and reflects a low selection rate under cultivation (Tanno and Willcox 2006a; Purugganan and Fuller 2011; Fuller <i>et al.</i> 2018; Willcox 2012a; 2018).</p>	<p>There is no indication that the archaeobotanical remains used to support this statement indeed prove cultivation, and it is not clear exactly what they do represent since no direct evidence from Neolithic fields is available (Abbo <i>et al.</i> 2021). Collecting from the wild continued—and why would it not? How, then, would an increase in non-shattering types be measured in a mixture of unknown properties?</p>	<p>Not needed. Domestication was an episodic (fast) event.</p>
<p>A co-increase in sickle-blade frequencies and in the frequency of non-shattering cereals supports a protracted development of agriculture (not domestication) (Maeda <i>et al.</i> 2016). An increased investment in sickle blades was observed over time, and the production became more standardized.</p>	<p>The presented quantitative trends vary in the different regions. What constitutes a “rising investment” in sickle blades, and how is it related to or measured? Does the significant change to bidirectional, naviform blade production that characterizes the very end of the PPNA and the Pre-Pottery Neolithic B (EPPNB included) represent a rise in investment, or is it, as they claim, “not specialized” vis-à-vis sickle blades (see Chapter 6, n. 19 on p. 132)?</p>	<p>Not needed.</p>
<p>Use-wear characteristic of dry, non-shattering harvest (as opposed to use-wear of green, shattering harvest) will be observed in the sickle-blade assemblages (Ibáñez, González-Urquijo and Gibaja 2014; Ibáñez <i>et al.</i> 2016) with changing frequencies of shattering and non-shattering cereals.</p>	<p>The practicalities of a cultivated field with mixed shattering and non-shattering cereals would not easily allow such a distinction (Abbo <i>et al.</i> 2021; and see Boxes 2.3 and 2.5).</p>	<p>Not needed.</p>

Our centered approach may appear to differ from current mainstream research trends, which emphasize consensus around the protracted autonomous model. Recent summaries on the site of Göbekli Tepe and Neolithic Turkey by Schmidt (2010; 2012a; 2012b), implicitly accepting a core-area (one-event?) model, similarly express concerns about “finding our way back to quite a diffusionistic point of view...” (Schmidt 2012b: 160).³ First, at least on our part, this does not result from an *a priori* view against “autonomous” convergent evolutionary (including cultural) processes. We see merit in the global convergent evolutionary model of plant domestication, yet we deem it too general and insufficiently proficient for the scale of each primary domestication center. Going into detail in each domestication center would not allow the general global picture to iron out the detailed local reconstructions, and in the case of the Levant, such detailed reconstruction supports no geographically autonomous model of plant domestication. We see no contradiction between our views regarding the global and local levels. Second, the history that we outline here for the Levant has been systematically revealed through resilient reliable archaeological and biological data, observations and analyses.

In short, we believe that the humans who were involved in plant domestication in the Neolithic Levant were highly capable people who were also carriers of ideologies and creators of a rich symbolic, social and ritual arena involving the full range of human actions, thoughts and apprehensions. Viewing these ancient people as performing unintentionally, unconsciously, or without awareness, with consequences both for themselves and for their surrounding landscapes, or without sociopolitical implications, is unacceptable. Based on the lengthy discussions and treatments of important aspects of the issue and of the available data presented here on plant domestication, it is clear that they were knowledgeable, practical and conscious people who, by virtue of the plants (and animals) they decided to domesticate, were able to outsmart millennia of traditional farming as well as the modern agronomic science that has followed ever since. It seems in place to borrow, and to use here once again, a statement by Claude Lévi-Strauss in the opening chapter of *La pensée sauvage*:

No one today would any longer think of attributing these enormous advances (“the mastery of the great arts of civilization—of pottery, weaving, agriculture, [growing

3. Diffusion is one of the characteristic explanations of normative (“old”) archaeology (the Culture History school) and one of the first aspects discarded as a possible explanation for change by processual (new) archaeologists. Today we have evidence derived from human genomes of prehistoric populations, indicating quite clearly that diffusion of people (migration) took place and is relevant to the spread of domesticated plants and animals (see above and Olalde *et al.* 2019; Brace *et al.* 2019).

plants] and the domestication of animals”) to the fortuitous accumulation of a series of chance discoveries or believe them to have been revealed by the passive perception of certain natural phenomena. (Lévi-Strauss 1966: 13–14)⁴

Incentive—Is There an Explanation Why?

Answering the “why” question, or fathoming the incentive for plant domestication (and for the Agricultural Revolution as a whole), has always been challenging and goes through interesting processes of change and diversification. Some of the suggestions made by supporters of the protracted autonomous model of plant domestication are in accordance with their view that the process was unconscious. An enlightening recent example is to be found in a summary statement by Willcox:

Fifteen or twenty years ago we were still asking the “Why” question concerning the origins of agriculture. Today an evolutionary approach is taken in which there is no “Why” question; there is no driving force, only fortuitous processes and events which cause economies to evolve without direction. (Willcox 2018: 92)

This honest statement by an archaeobotanist who closely cooperated in many archaeological field and laboratory endeavors in the Neolithic Levant, indicates—even if implicitly—that the space for human agency was limited and that domestication and the beginnings of agriculture were, and remain, materialistic evolutionary processes for him (cultural evolution is not mentioned). It is fair to assume that Willcox was referring to the origins of agriculture and not directly to plant domestication, although it is also logical to assume that he was including plant domestication (yet such mixing of terms is not exceptional). Other supporters of the protracted autonomous model do put forward social arguments, and again Fuller *et al.* (2018: 69) wrote: “These trends suggest a role for inherent internal drivers, as might be predicted from entanglement theory (e.g., Hodder 2012; 2016; Fuller *et al.* 2016) versus external stimuli such as climate shifts.” Later, in the same paragraph, Fuller *et al.* (2018: 69) related it to the controlled availability of stored cereals and pulses, as well as of special foods made from them, and remarked that “One of the reasons these foods may have been required could have been to supply feasts and feasting for funerals and for commensal politics that likely played a part of the social

4. It may be worthwhile to add a statement on the issue by a scholar of a clearly different background (White 1959: 283–284): “we are not to think of the origin of agriculture as due to the chance discovery that seeds thrown away from a meal subsequently sprouted. Mankind knew all this and more for tens of thousands of years before cultivation of plants began.”

world (Hayden 2014a; 2014b).” While this latter statement is encouraging, it relates mainly to the origins of agriculture as a whole, rather than directly and exclusively to plant domestication (i.e., to that single component of agriculture). Although we welcome the denied correlation between the appearance of morphologically domesticated cereals (following a protracted millennia-long process) and the advent of agricultural economies, and even more so the suggested timeline of the two (Fuller *et al.* 2018: 69), we would suggest a different timeline and use the distinction between plant domestication and crop evolution post-domestication to investigate this correlation anew. Unconsciousness, as mentioned frankly by Willcox (2018), is not a problematic term and can be rejected (or accepted by whoever agrees with it). Yet many supporters of the protracted autonomous model are fully aligned with explanations that assign a role in plant domestication to human agency.

The Agricultural Revolution was a complex process comprising fundamental biological dynamics of plant (and animal) domestication alongside sociocultural dynamics—by nature, two inherently different processes (see Box 1.2). For the biological aspect, our “core-area one-event” model suggests that plant domestication was a rapid episode, occurring per species and per package and followed by millennia of plant (crop) evolution, which still occurs under domestication to this day. For the sociocultural perspective, in what might be called Neolithization (see a series of papers in Manen, Perrin and Guilaine 2014), we envisage processes that involve complex changes. Taking place throughout the Levant, these sociocultural processes might have been uneven and rough, continuing within Pre-Pottery Neolithic societies and into the Pottery Neolithic period and exhibiting a diverse, complex picture in both time and space.

Having suggested answers to the “when,” “where,” and “how” questions of plant domestication—and through it, partially, of the Agricultural Revolution as a whole—it is only natural that we should also at least attempt to answer the “why” question. We do not suggest that people were pushed into plant domestication by any external factor. Nor do we suggest that plant domestication was an automatic non-directed process, an unintended side effect of human (mis)behavior or a natural outcome of evolutionary mutualistic (prey–predator) dynamics. Rather, we see plant domestication as a knowledge-based, directed, conscious development executed by creative people with a new perception of nature and taking advantage of their long-accumulated and refined knowledge.

We acknowledge that how we view the incentive to domesticate plants (and animals) and to embark on a new career as food producers, revolutionizing human socioeconomics (and demography) to a point of no return, is a truth that is in the eye of the beholder

(Smith, freely quoted in Price and Bar-Yosef 2011: S172). So, too, is the attempt to provide an answer to the question why Neolithic people became farmers.

It is true, however, that we should also turn our search for incentives to human agency—not only to Neolithic human agents, but also to modern agents with their own individual contexts and backgrounds, views and ideologies, perceptions and agendas. Even if underestimated, human agency still remains the key field in which to search for the answer to the “why” inquiry. Inasmuch as it relates to the here and now, the answer to the “why” question is individualized by what each of us thinks of past people and what we assign to external stress as well as to internal social (community or individual) decisions and choices. This is a question that digs deeply into our perception of humanity and society vis-à-vis nature, our academic background, as well as the interpretive orientation reflecting our view on the human condition (Lévi-Strauss 1952b). It is, therefore, a quintessential philosophical and ideological issue. As such, it is likely to remain unresolved.

The archaeological and archaeobotanical data, even if unanimously accepted, remain fragmented and partial and are unlikely ever to convey the full picture of the past. Opting for responsive (“push”) scenarios (e.g., climate change) will always be easier than endorsing scenarios emphasizing human initiative and cultural choices. Nevertheless, we choose to opt for the latter scenario, and therefore, in our view, the available data show that the emergence of plant domestication and the Agricultural Revolution as a whole, as manifest in the Levant, was not merely a response to external stress. Rather, we see these major occurrences as instigated by a change in perception, in awareness and in the human–world relationship.

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Plant domestication in the Neolithic period, some 10,500 years ago, was a component of the Agricultural Revolution—an immense transformation in human ideology/perception and behavior that changed humanity forever. The Levant is among the world's oldest primary Neolithic domestication centers, and indeed, domesticated Levantine crops (wheat, barley, pea, lentil, chickpea, faba and flax) currently feed billions of people and are indispensable drivers of global economy. In this book the authors unfurl their claims mainly regarding two aspects of plant domestication—the how and the where. They present a unique model pointing out that plant domestication unfolded as a single, rapid, conscious and knowledge-based episode and that it originated in the northern Levant—and more specifically, in southeastern Turkey and the Middle Euphrates of northern Syria. The “core-area one-event” model advanced here is coherent, shows high parsimony, is based on a minimal number of assumptions and is supported by multiple lines of archaeological-cultural, archaeobotanical, geobotanical, agronomic and genetic evidence.

Plant domestication and the beginning of agriculture were the starting point of a new state of mind, a new human perception of the natural world, and a full divorce from the primordial hunter-gatherer ethos of sharing and egalitarianism, setting the stage for modern civilizations. Humans became manipulative producers, enslaved by perpetual economic intensification and growth, eventually tracked to specialized and differentiated-ranked societies based on wealth. Many of us believe, in a very modern way of thinking, that we are doomed to endlessly grow, and that a standstill or a retreat are economically and politically disastrous, and may result in a restless world—perhaps leading to the end of modernity as we know it. Notwithstanding the above, the fact that the most basic component of our life here and now—our food—is still, to this very day, based on the uniquely wise crop choices made by our Neolithic forefathers in the Levant and in other domestication centers worldwide merits no less than admiration and modesty on our part.



Emery and Claire Yass
Publications in Archaeology
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