Westward Ho!

The Spread of Agriculture from Central Europe to the Atlantic

by Peter Rowley-Conwy

Recent work on the four major areas of the spread of agriculture in Neolithic western Europe has revealed that they are both chronologically and economically much more abrupt than has hitherto been envisaged. Most claims of a little agriculture in Late Mesolithic communities are shown to be incorrect. In most places, full sedentary agriculture was introduced very rapidly at the start of the Neolithic. "Transitional" economies are virtually absent. Consequently, the long-term processes of internal development from forager to farmer, so often discussed in Mesolithic-Neolithic Europe, are increasingly hard to sustain. The spread of agriculture by immigration is thus an increasingly viable explanation. The crucial role of boats for transport and of dairying for the survival of new farming settlements are both highlighted. Farming migrations were punctuated and sporadic, not a single wave of advance. Consequently, there was much genetic mixing as farming spread, so that agricultural immigrants into any region carried a majority of native European Mesolithic genes, not Near Eastern ones.

> *Westward ho!*
> (This was the Thames watermen's cry, indicating direction of travel to prospective passengers. By Shakespeare's time, it was a more general expression of intent to travel westward, often by boat. [*Twelfth Night*, act 3, scene 1, line 134])

Introduction: Event and Process

In this article I will consider the spread of agriculture from central Europe to the Atlantic (fig. 1). This involves four major "spread events": the Cardial of the western Mediterranean, the *Linienbandkeramik* (LBK) of the interior, the *Trægtbægerkultur* (TRB) of southern Scandinavia, and the Neolithic of Britain and Ireland.

Archaeologists often regard the appearance of agriculture in any region as a slow process of transition: the Later Mesolithic may have had a few domestic animals or plants, while the Neolithic may still have involved nomadic foraging. In this article I will, however, argue that recent work has demolished the basis for thinking that these were slow transitions. Instead, full sedentary agriculture appeared rapidly in most places. The evidence for these four spread events has been "sharpened up," rendering them chronologically more abrupt. They thus appear more as archaeological events than as processes.

"Process" implies continuity within the local group. "Event" raises the possibility of immigration. In this article I will argue that agriculture was introduced by immigration more often than is currently believed: the four spread events considered here were all probably migrations. This position is remarkably similar to that adopted by Özdoğan (2011) in his consideration of Anatolia and the Balkans; at the Wenner-Gren conference from which these articles stem, "The Origins of Agriculture: New Data, New Ideas," it seemed almost that they were two halves of the same article.

On a broader scale, the conference threw two things into sharp relief for me. The first is the contrast between the lengthy and complex origins of the Near Eastern agricultural system—as discussed by Goring-Morris and Belfer-Cohen (2011) and Zeder (2011)—and the rapid subsequent spread of that system across Europe. It seems that "origins" and "dispersals" are becoming ever more sharply differentiated as archaeological work proceeds. The second is the fact that the origin and spread of the Chinese agricultural system shows some similarity to the Near Eastern system, the complex origins (Cohen 2011; Zhao 2011) contrasting with its spread through Korea (Lee 2011) and Japan (Crawford 2011). Similar explanations may thus be emerging for the spread of agriculture at both ends of Eurasia: in temperate zones away from the centers of agricultural origins. At a still wider level, the conference served (for me, at least) to emphasize the difference between the mode and speed of the spread of the East

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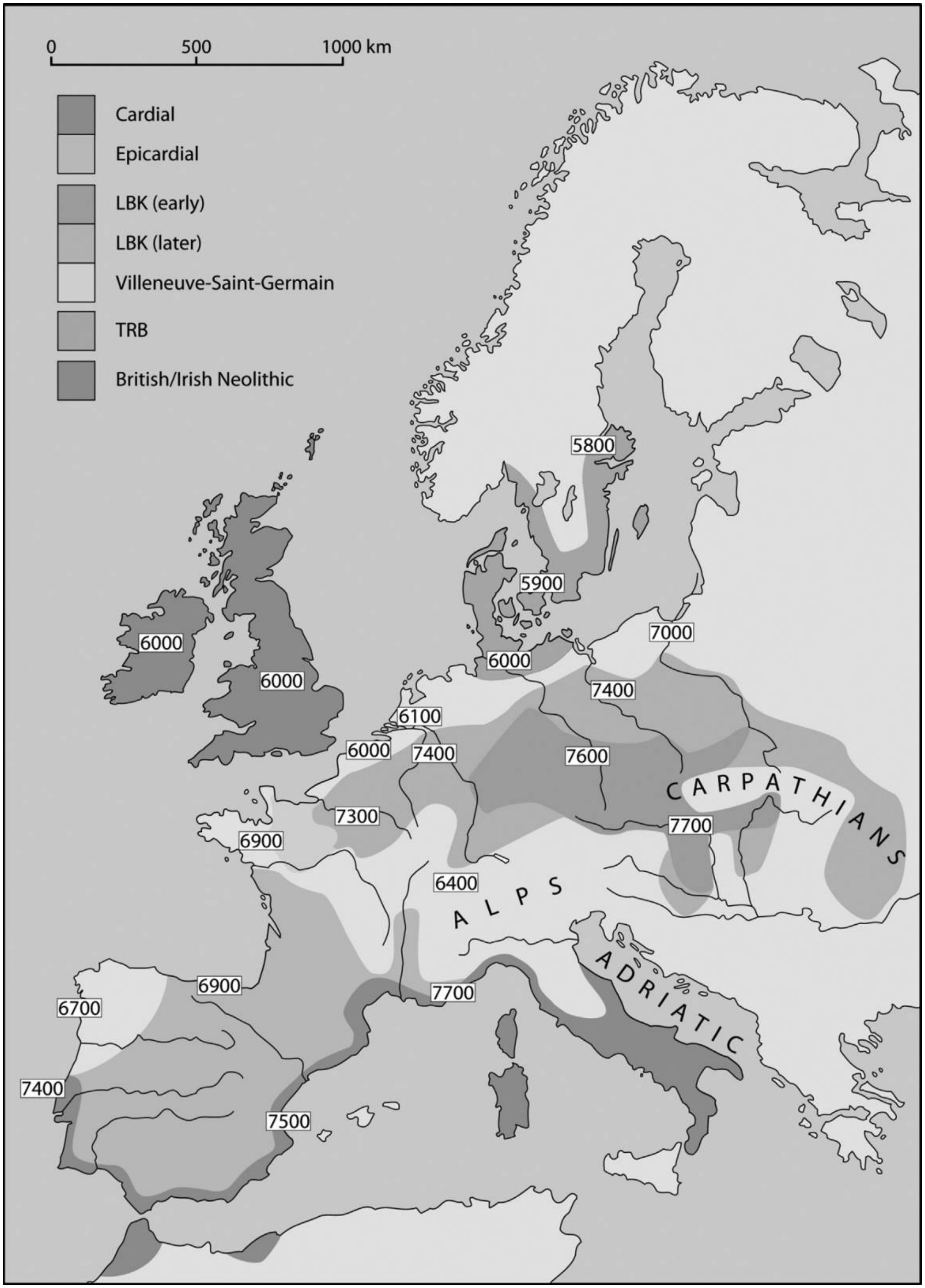

Figure 1. Map showing the major farming "spread events" discussed in this article. Dates are in calibrated years BP. A color version of this figure is available in the online edition of *Current Anthropology*.

and West Asian cereal/pulse/domestic-animal farming systems on the one hand and the Southeast Asian root/fruit system (Denham 2011) on the other: the former appears on current evidence to spread much faster than the latter.

The Debate: Immigrants or Indigenes

This debate has a long and complex history in Europe. Most scholars of course argue for a combination of the two but nevertheless tend to favor one over the other. In the middle twentieth century, immigration was the standard view (Childe 1957). In the wake of the radiocarbon revolution, British scholars began suggesting indigenous developments even though radiocarbon dating had not altered the relative dating of early agriculture in Europe: in Britain it was still later than in the near continent, and it remained earliest in the Balkans. Indigenism, however, appeared an attractive new idea forming part of a broader research agenda seeking indigenous origins for megalithic tombs and Bronze Age chiefdoms. British researchers applied indigenist arguments to early agriculture in wide areas of Europe (Barker 1985; Dennell 1983), and recent postprocessualists have followed this pattern (Thomas 1999; Whittle 1996). Continental reactions have been mixed. South Scandinavians have mainly concurred (Jensen 1982) as more recently have many Iberians (Arias 1999); but most German archaeologists mistrust Anglophone overviews and espouse migrationism (Gronenborn 1999, 2007).

Indigenism

Wild einkorn is present in the Balkans; aurochs and wild boar were widespread in Europe; some have suggested that the wild species of sheep, barley, and lentils were present as well. Various arguments for local domestication have been put forward (Barker 1985:252–253; Dennell 1983:159–163; Whittle 1996: 67; Zvelebil 1995, 2008:31). The latest reiteration is by Barker (2006:336), who adds wild goat.

Current research is unkind to these suggestions. The genetics of einkorn, barley, and lentils all indicate a Near Eastern origin (Badr et al. 2000; Heun et al. 1997; Ladizinsky 1999). Modern "wild" sheep on Mediterranean islands are in fact feral (Poplin 1979), and recent DNA studies support a Near Eastern origin (Meadows et al. 2007). The "goats" mentioned by Barker (2006:336) are actually ibex (*Capra ibex*), which have never been domesticated and have nothing to do with the origin of domestic goats. *Capra aegagrus* was domesticated in the Near East (Naderi et al. 2008). Metrical evidence is against the European domestication of aurochs (Rowley-Conwy 2003*a*); the genetic evidence agrees, demonstrating Near Eastern origins for the domestication of cattle (Bollongino and Burger 2007; Edwards et al. 2007; Troy et al. 2001). Attempts to make Europe part of a vastly expanded Near Eastern "agricultural hearth" (cf. Barker 2006:384) have thus failed. Some secondary domestications did occur: wild boar were domesticated in Europe but only after the arrival of domestic pigs of Near Eastern origin (Larson et al. 2007), and rye and oats were domesticated in the Iron Age.

Indigenism, however, receives support from human genetics. Early work used modern human blood groups in Europe to argue for large-scale immigration in the Neolithic, the famous "wave of advance" hypothesis (Ammerman and Cavalli-Sforza 1984). Recent work on mitochondrial DNA (mtDNA) indicates the opposite, that most Europeans are descended from pre-Neolithic hunter-gatherers. This is because mtDNA lineages began to diverge before the Neolithic. The most recent studies have involved the complete mitochondrial genome and indicate that this divergence started ~15,000 years ago (Soares et al. 2009, 2010).

Indigenism has therefore largely become "adoptionism." Local hunter-gatherers provided the bulk of the human genes in Neolithic and later cultures but acquired the elements of farming from neighbors who had already "gone agricultural."

Migrationism

Migrationism has received support from linguistics. However, Renfrew's (1987) argument that agriculture was carried into Europe by Indo-European speakers has met with considerable opposition. Mallory (1989:121, 126–127) pointed out that words associated with wheels, carts, and traction are related in most Indo-European languages, and because such technology did not exist before ca. 5500 BP, this suggested an Indo-European dispersal after that date. Anthony (2007) argues that if Proto-Indo-European was spoken by Europe's earliest farmers around 8500 BP, the common terminology for wagons would mean that it remained a single language spread across most of Europe for 3,000 years, diversifying only after 5500 BP, a most unlikely scenario. A more recent suggestion is that Basque, normally regarded as unrelated to any other language, may in fact have connections with other linguistic isolates, including some languages spoken in the mountains of the Caucasus, and with Burushaski, spoken in northern Pakistan. Some of the suggested connections refer to domestic cattle, sheep, and goats, to cultivated cereals, and to milking and tillage. This could imply that Basque is Europe's sole remnant of a pre-Indo-European language family that spread with the first agriculturalists (Bengtson 2009). Most European Neolithic archaeologists do not involve themselves in the linguistic debate, probably feeling that it can contribute little to the elucidation of the archaeological record.

Genetics also provides some support for immigration. The divergence dates for most European mtDNA lineages (as mentioned above) fall in the Late Paleolithic. But these studies allow perhaps 15% of modern European mtDNA to derive from Neolithic immigrants (Soares et al. 2010), so the initial introduction of agriculture was probably by immigration. The Y chromosome provides a complication. Chikhi et al. (2002) suggest that as much as 50%–65% of modern European Y chromosomes descend from Near Eastern ancestors. This does not mean that such a proportion of males immigrated in the Neolithic, however, because the movements cannot be dated (Chikhi et al. 2002:11012–11013). A recent estimate for the immigrant Neolithic Y chromosome proportion is that it might have been similar to that for mtDNA (Soares et al. 2010).

Y chromosome patterns are particularly difficult to disentangle. Zvelebil (2000:70) aptly describes the modern pattern as an "incremental palimpsest." Migrations of all kinds have occurred in the past. Armies have high Y chromosome counts and are highly mobile. Roman and Ottoman armies, to mention but two, penetrated huge areas of Europe and involved diverse males—auxiliaries and janissaries recruited soldiers not of Roman or Turkish ethnicity. The difficulties of establishing what may be Neolithic are shown by the attempt by King and Underhill (2002) to correlate immigrant Y chromosomes and Neolithic anthropomorphic figurines. Where the correlation is positive (e.g., northern Italy, southern France), Neolithic immigration is proposed, but where figurines are absent (e.g., eastern Spain), the authors resort to historically recorded Greek or Phoenician migrations 5,000 years later to account for the immigrant Y chromosomes now present in eastern Spain. This seemingly random invocation of such disparate migrations does not inspire confidence—why not Napoleon's invasion army of 1808? It ignores the archaeological unity of the Cardial phenomenon (see below), and the notion that "Y chromosome lineages = figurines" is remarkably reminiscent of the "pots = people" archaeological theories of half a century ago.

Genetics will no doubt be taken much further by the addition of ancient DNA to the discussion. This is problematic because of the possibility of contamination, but it is beginning to occur. It is likely that there will be surprises. One study of 24 LBK skeletons revealed that six of them (25%) carried an mtDNA type that is now present in just 0.2% of modern Europeans. If this tiny sample is representative, modern Europeans cannot therefore be descended from this farming population (Haak et al. 2005).

Integrationism

Our explanations must now rest on two major foundations: most Neolithic genes were native, but the major domesticates were exotic. Small-scale rather than continent-wide migrations are the best way to integrate these into one model. Agriculture in a region may have been introduced by immigrants, but that does not mean that the immigrants carried mainly Near Eastern genes (Richards 2003; Rowley-Conwy 2004*b*; Zvelebil 2005). The LBK, for example, originated in the Carpathian Basin; the population that moved westward emerged there carrying a complex mix of European and Near Eastern mtDNA and no doubt picking up more as it moved. The same is potentially true of all the spreads shown in figure 1.

One integrationist scenario is therefore migration by agriculturalists, but agriculturalists who carried largely "Mesolithic" genes from elsewhere in Europe. Small-scale alternatives to the wave of advance are envisaged as "infiltration," "trickle," or "creep" migrations. Perhaps more applicable to larger movements is "leapfrog colonization" moving beyond the farming frontier into available space (Rowley-Conwy 2004*b*; Zvelebil 2000). Several likely instances will be mentioned below.

Sharpening the Agricultural Spreads

Improved excavation and dating everywhere in Europe has put migrationism firmly back on the agenda. The following sections show how this has happened with regard to the four spread events plotted in figure 1.

The Cardial of the West Mediterranean

Twenty years ago, the northern Italian Neolithic was thought to start around 7000 BP (uncalibrated), its subsistence based largely on wild foods. The adoption of agriculture from the south was slow, sheep and cereals becoming predominant only later in the period (Barker et al. 1987). The Neolithic farther west (fig. 2) was, however, much earlier, with dates of 7520 ± 240 BP (uncalibrated) at Châteauneuf-les-Martigues and 7970 ± 150 BP (uncalibrated) at Verdelpino (Guilaine 1979). Furthermore, sheep were reported in Mesolithic contexts at several sites: at Châteauneuf, preceding the early ^{14}C date just quoted (Ducos 1977), Gazel and Dourgne (Geddes 1980, 1985), and Nerja (Boessneck and von den Driesch 1980). The role of cereal cultivation was unclear, some emmer wheat perhaps appearing at the start of the Neolithic (Lewthwaite 1986*a*).

This appeared to be a classic case of agricultural adoption by hunter-gatherers. The "filter model" suggested that agriculture moved along preexisting Mesolithic interconnections. Foragers in northwest Italy adopted only certain agricultural elements—initially only sheep—so the other items were "filtered out" and not available for transmission to the west. These transitional economies developed into full agriculture later in the Neolithic (Lewthwaite 1986*a*, 1986*b*).

Recent work has transformed this. Early Neolithic agriculture in northern Italy is now known to comprise four cereals—emmer, einkorn, free-threshing wheat, and barley—and five pulses—lentil, pea, broad bean, bitter vetch, and grass pea—from the start, indicating a rapid transmission of full agriculture from the south (Rottoli and Castiglione 2009). The earliest Neolithic in northwest Italy at Arene Candide is dated to ~7700 cal BP (Maggi and Nisbet 2000), and the fauna is dominated by domestic animals from the start (Rowley-Conwy 1997). In Portugal, Cisterna dates to ~7400 cal BP (Zilhão 2009, forthcoming), Caldeirão to ~7300 cal BP (Zilhão 1992). The claimed earlier Neolithic dates in between have been discounted: Zilhão (1993:47) has pointed out that the sites were not excavated to modern standards

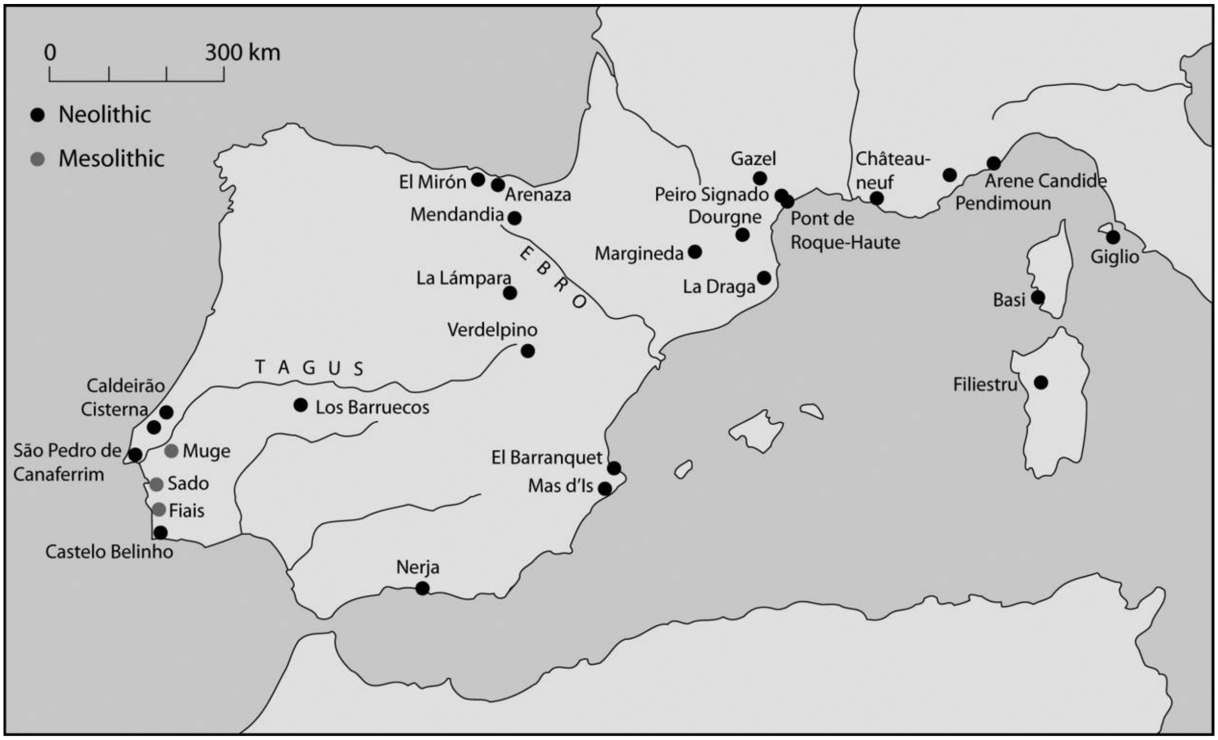

Figure 2. Map of the western Mediterranean, showing the location of sites mentioned in the text. A color version of this figure is available in the online edition of *Current Anthropology*.

and were disturbed by burrowing animals. "Mesolithic" sheep are no longer accepted because of these problems (Guilaine and Manen 2007:25–26) and the difficulty of distinguishing the bones of domestic sheep and goat from wild ibex (*Capra ibex*) and chamois (*Rupicapra rupicapra*), especially when juvenile (Rowley-Conwy 2004*a*).

Continuity from the Mesolithic is now regarded as minimal. Long considered a "cave Neolithic," the Early Cardial has recently produced major open-air settlements at La Draga (Bosch, Chinchilla, and Tarrús 2000) and Mas d'Is (Bernabeu et al. 2003), each with several structures. Farther southwest, the earliest houses so far known are at Castelo Belinho, dating to the later Early Neolithic, after ~6900 cal BP (Gomes 2008). São Pedro de Canaferrim has produced a substantial open-air settlement dating to before 7000 cal BP (Simões 1999), so earlier houses are likely to be found. Faunal assemblages contain a majority of domestic species from the start—La Draga has >90% domestic animals (Palomo et al. 2005). Cultigens predominate among the plants: the eastern Spanish Cardial economy comprises the same four cereals and five pulses as in northern Italy (Zapata et al. 2004, table 2); La Draga produced a huge sample of over half a million wheat grains (Buxó, Rovira, and Saüch 2000, fig. 103). Margineda has both Mesolithic and Neolithic layers (Guilaine and Martzluff 1995). Domestic animals first appear at the start of the Neolithic (Geddes 1995); significantly, four cereal grains in Mesolithic contexts are discounted as intrusive (Marinval 1995:72). Nothing remains of "transitional" economies.

The Epicardial of the Iberian interior has only been studied very recently. Major rivers such as the Ebro and Tagus were likely routes for colonization, though mating with local Mesolithic people may also have occurred (Arias 1999:414; Guilaine and Manen 2007:43). Very early Neolithic dates have been claimed: 8000 cal BP at Mendandia (Alday 2007) and 7800 cal BP at La Lámpara (Rojo et al. 2006:53, 60). They have, however, been criticized by Zilhão (forthcoming): pottery was present at Mendandia, but all the animals were wild (Alday 2007), while at La Lámpara the dated bone was not identified as to species. Directly dated cereal grains at La Lámpara start at ~7200 cal BP (Rojo et al. 2006; Stika 2005), the same as at Los Barruecos on the Tagus (Cerillo and González 2006). There was a delay of several centuries before agriculture spread to the northern coast, perhaps because the region was more densely settled with hunter-gatherers (Arias 2007:62). Cattle appear at Arenaza at ~6900 cal BP (Arias 2007:60) and emmer at El Mirón at ~6400 cal BP (Peña-Chocarro et al. 2005). Cultivation seems to have become restricted to the cereals as it spread northwest: just three peas were found at Margineda (Marinval 1995), and no legumes at all were found at La

Lámpara (Stika 2005) or El Mirón (Peña-Chocarro et al. 2005).

Cardial Colonists and Colonization

Most researchers now regard the Cardial phenomenon as a rapid colonization by boat (see the influential article by Zilhão 2001). This has been reinforced by the recent definition of the earliest Cardial phase, the "Impressa," at Pendimoun and Arene Candide (Binder and Maggi 2001). This has subsequently turned up also at Pont de Roque-Haute and Peiro Signado along the coast in France (Guilaine, Manen, and Vigne 2007). These two sites are only 3 km apart, but the Peiro Signado ceramics resemble those at Arene Candide, while Pont de Roque-Haute is more similar to Giglio farther around the Italian coast (Manen 2007:160–163). Pendimoun resembles sites in eastern peninsular Italy (Binder et al. 1993: 227–228). This suggests multiple leapfrog colonizations, and the recent discovery of an Impressa site at El Barranquet in Spain extends this apparent Ligurian colonization to 900 km from Arene Candide (Bernabeu et al. 2009). Even this early, the fauna is dominated by domestic animals (Vigne and Carrère 2007).

In most areas there is a radiocarbon gap between Mesolithic and Neolithic (Guilaine and Manen 2007, their fig. 2; Skeates 2003). In southern Portugal there was considerable Mesolithic occupation that, bypassed by the Cardial colonization, continued until after 7000 cal BP (Zilhão 2003, forthcoming). The Mesolithic diet was largely coastal, that of the Neolithic terrestrial (Lubell et al. 1994). DNA from the two populations differs, although neither carry the Near Eastern lineage implicated in carrying agriculture into Europe (Chandler, Sykes, and Zilhão 2005). This is consistent with Cardial immigration involving farmers of indigenous Mesolithic ancestry (cf. the "integrationist" model suggested above).

The practicalities of maritime colonization must be considered. Broodbank and Strasser (1991) discuss the Early Neolithic colonization of Crete. Forty colonizing humans would need 5–10 breeding pairs of each animal species and 250 kg of grain, weighing in total some 15–20 tons, to establish an agricultural economy. Such a cargo might be carried in 10–15 boats each carrying 1–2 tons (Broodbank and Strasser 1991:241) or fewer boats each making several voyages. A >10-m log boat comes from the Cardial lake settlement of La Marmotta near Rome (Fugazzola, Delpino, and Mineo 1995). A reconstruction was routinely able to sail 30 km in a day with a crew of 10 and plenty of space for cargo (Tichy 1999). Boats made of animal hides stretched over a frame would have been an even better option: they have greater cargo capacity but are light enough to be carried by their own crew (Case 1969). The efficacy of such boats for transport is shown by the Irish curragh (fig. 3). Whatever kind of boat they used, Cardial people took cattle, sheep, goat, and pig to Sardinia (e.g., Filiestru: Levine 1983) and also (but without the cattle) to Corsica (e.g., Basi: Vigne 1988:153). The optimal time for colonizing voyages would be late summer, after the harvest was gathered and before winter-sown crops were planted (Broodbank and Strasser 1991:241; Case 1969:178). The feasibility of such colonizing voyages is underlined by the spectacularly early evidence of Neolithic colonizers on Cyprus presented at the conference (Vigne 2011).

Survival for the first year, until the newly established cereal fields begin producing, is a further critical variable. Along the Mediterranean coasts hunting would presumably have been particularly important, but this would have been chancy, and any food supplies that could be carried with the colonists would have been extremely valuable. Cereals are heavy. Recent work suggests an alternative: dairy products. The milking of sheep and goat by Cardial people has been suggested on zooarchaeological grounds (Rowley-Conwy 1997:168, 2000). Analysis of lipids in ceramics has recently demonstrated the use of dairy products in Anatolia back to the ninth millennium cal BP (Evershed et al. 2008). Because this was the source area of the Cardial agricultural regime, it is likely that dairying spread with the other items and practices. Dairying might be critical in one particular way, because pregnant or lactating animals can be driven (Case 1969:177). Such animals could therefore presumably be carried by boat without ill effects. The presence of some lactating animals in a newly established settlement would be invaluable, providing food each day for several months, thus bridging the gap until other aspects of the economy "kicked in."

In conclusion, the Cardial phenomenon is an immeasurably sharper event than was understood 20 years ago. In its new guise it conforms with what we would expect from a migration: cultural derivation from northwest Italy, not the local Mesolithic; a very rapid spread, with the transplantation of the entire agricultural system; and the means in place to assure its spread and survival.

The LBK of Central Europe

The LBK was accepted as appearing relatively abruptly much earlier than the Cardial, so recent developments have been less revolutionary. In a landmark article, Quitta (1960:163–164, fig. 3) argued that the cultural uniformity of the LBK indicated a rapid immigration along two routes: the Elbe and the Danube/Upper Rhine. Subsequent workers mostly accept migration (e.g., Bogucki 2003; Lüning 1989; Scarre 2002), though some advocate indigenism (e.g., Price 2000*a*; Whittle 1996). Gronenborn (2003:81) argues for a migration covering 800 km in 100 years and involving a "multi-faceted combination of migrations, adaptations and acculturations" (2007: 73). Faunal assemblages usually comprise >60%–80% domestic animals, with cattle and pigs being predominant (Döhle 1997). Botanical assemblages testify to the overwhelming importance of cultigens (Bogaard 2004; Lüning et al. 1997).

The logistics of rapid migration must be considered. Early discussions envisaged shifting cultivation and temporary fields

Figure 3. Transport by Irish curragh. *Top*, pigs ready for embarking; the animals have their feet tied to prevent movement. Photo by T. Mason, from Jones (2004, fig. 157). *Bottom*, short-distance towing method; the cow has been tied up to prevent it from struggling. Photo by and courtesy of John Waddell. A color version of this figure is available in the online edition of *Current Anthropology*.

moving across Europe on a broad front (Childe 1929:46; Clark 1952:92–93). Shifting cultivation has subsequently come under heavy criticism (e.g., Lüning 1980, 2000; Rowley-Conwy 1981, 2003*b*; Sherratt 1980), though some still espouse it (Whittle 1996:160–162, 1997:22). Bogaard (2004) has convincingly shown on the basis of weed floras that LBK crops were intensively cultivated in small autumn-sown fixed plots. Distribution is patchy, which is not suggestive of a broad-front migration: settlement largely follows loess soils, forming discrete *siedlungskammer*, or "settlement cells" (Lüning 1989), sometimes widely dispersed (fig. 4). These *siedlungskammer* start with a few houses close to rivers; later, the houses multiply, and settlement spreads away from the rivers (Kruk 1980; Lüning 1989; Stehli 1989).

The forest facing the LBK immigrants was thick, with much understory and undergrowth (Kreuz 2008). Heading off to found a new *siedlungskammer* with the entire agricultural package would be a challenging enterprise. We must dispense

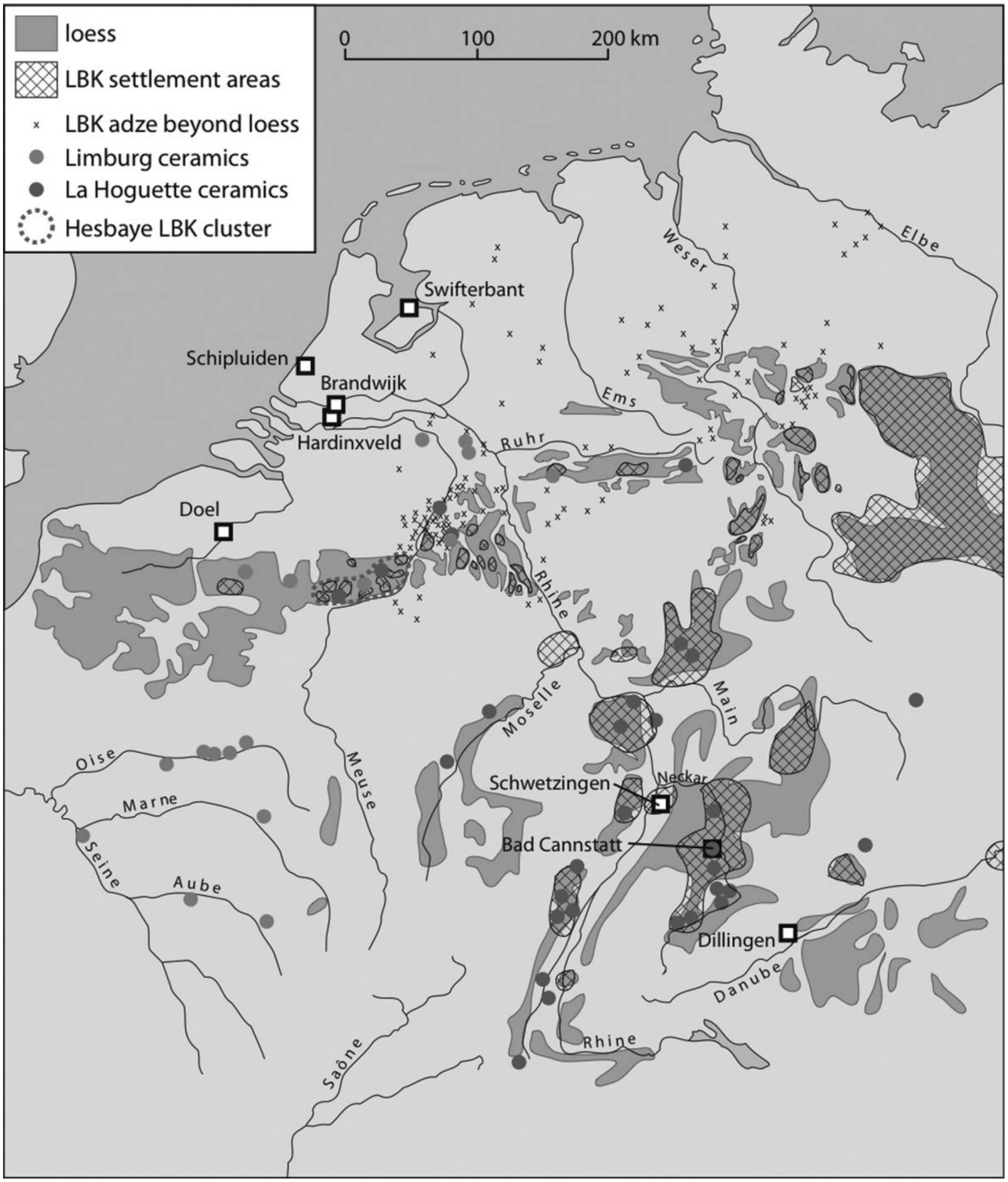

Figure 4. West central Europe at the time of agricultural colonization. The northern part of the map is based on Verhart (2000, fig. 1.15). Loess areas and settlement cells to the southeast are from the more general map in Clark (1952, fig. 45). Where these disagree I have followed Verhart. La Hoguette and Limburg pottery sites from Lüning, Kloos, and Albert (1989, fig. 2), van Berg (1990), and Lefranc (2008, fig. 5). Several Limburg findspots in the Hesbaye cluster are omitted for clarity. A color version of this figure is available in the online edition of *Current Anthropology*.

with preconceptions derived from the managed woodlands and regulated rivers of our own times. Choked undergrowth and sprawling waterways and mires would face anyone attempting to move through the landscape. In the open, cattle and pigs cluster into manageable herds, but in woodland they disperse and rapidly become uncontrollable. How then could an 800-km migration be achieved in 100 years?

The clue may lie in Quitta's (1960:163) stressing of the importance of the Elbe and Danube as routes. The *siedlungskammer* germinate near rivers (see above). Perhaps the rivers themselves were the highways along which Neolithic colonists moved. If maritime colonization was feasible for the Cardial (see above), riverine colonization is a viable hypothesis for the LBK. Many central European rivers form a nexus that would facilitate this (fig. 4). From the Elbe, travel to the Weser would be difficult. But from there, short overland moves provided access to the Ruhr and Rhine and from there to the Meuse and subsequently to the Marne and Seine. The Danube similarly runs close to the Rhine and Neckar. Considerable sections of these river systems must have been navigable in the Neolithic.

A 10-m hide boat could carry several people, a couple of dogs, two cows, two calves, and their bedding (Case 1969). After a day or so, the animals would become restive because of thirst, but on a river, with overnight stops, this would not be a problem. Recent Irish curraghs are smaller (up to ca. 6 m), but they can effectively move cattle and pigs, which can be carried inside the boat for longer moves or towed behind for shorter hops (fig. 3). Early autumn, between harvesting and autumn sowing, was an agricultural "down time" and would be the optimal time for movement. As with the Cardial, the first year in a new settlement would be critical. Hunting would no doubt be important, but once again dairy products may have played a key role. A cow that had given birth in late spring would be lactating in early autumn and might also be again in calf. This would be a way of transporting a continuously productive food supply. Bogucki (1984) has argued that the ceramic sieves found in LBK contexts were used in dairying.

LBK contacts with local foragers took a variety of forms. In much of its area, the LBK is at the head of a sequence of later cultures derived from it. This is not the case for the Villeneuve-Saint-Germain (VSG) of northwestern France (fig. 1). Scarre (2002:401) regards the VSG as the ultimate westward extension of colonizing farmers. But the VSG did not give rise to later cultures descended from it. After a couple of centuries it disappeared, replaced by a more widespread local Neolithic. Agriculturalized foragers appear to have absorbed the immigrants (Scarre 2002). The picture near the mouth of the Vistula is different. The recent discovery of several post-LBK Stroke Ornamented Pottery (*stichbandkeramik*) settlements indicates agriculture here around 7000 cal BP (Czerniak 2007). But this colonization failed, and the economy of the area reverted to hunting and gathering after this apparently brief and abortive penetration.

Elsewhere, the immigrants absorbed hunter-gatherers. Strontium isotopes in human skeletons suggest that more females than males were of nonlocal origin in the LBK cemeteries at Schwetzingen and Dillingen (Price et al. 2001). This may indicate hunter-gatherer women marrying into farming communities (Bentley et al. 2002). This pattern is not repeated everywhere, and farming practices such as long-range pastoralism are complicating factors (Bentley et al. 2003; Bickle and Hofmann 2007). However, the loss of only a few women could destabilize low-density foraging populations and might prompt the remainder to adopt farming if the unmarried males developed "cattle envy." If this suggests peaceful interaction, the same was not true farther north: in the Hesbaye region, several LBK sites were fortified, apparently against Mesolithic attack (Keeley and Cahen 1989).

"La Hoguette" and "Limburg" ceramics are problematic. La Hoguette sherds appear on the earliest LBK sites and also farther west, beyond the LBK distribution, with Mesolithic flints (fig. 4). Limburg ceramics are later, with an analogous distribution on and beyond the earliest farming settlements farther west (Lefranc 2008; Lüning, Kloos, and Albert 1989; van Berg 1990). These groups may be partially acculturated hunter-gatherers, so their ceramics on LBK sites would indicate contact (Gronenborn 1990:178; Zvelebil 2005). Economic evidence is very limited; the La Hoguette site of Bad Cannstatt has provided nine deer bones (and 39 antler fragments) and two caprine teeth (von den Driesch, in Kalis et al. 2001, table 3). Dating also is imprecise: there is no clear evidence that La Hoguette pottery predates the LBK. The suggestion that La Hoguette represents "local Mesolithic peoples who had begun to practice horticulture and herding several hundred years before the arrival of LBK" (Price et al. 2001:595) goes further than the evidence currently allows. An added complexity is that La Hoguette ceramics are derived from the Epicardial of southern France. Lefranc (2008) and van Berg (1990) argue that Limburg has a similar origin, though Lüning, Kloos, and Albert (1989) disagree. Both ceramic styles have turned up in Cardial contexts at Gazel (Guilaine and Manen 2007:46). The Rhône-Saône system is part of the river nexus mentioned above (fig. 4), thus providing a potential route to the north. Could the La Hoguette people be "Epi-epi-cardial" farming immigrants?

Beyond the Northern Frontier

The northern edge of the LBK was the longest-lived forager-farmer boundary in Neolithic Europe, lasting from ~7500 cal BP to ~6000 cal BP. To the north were hunter-gatherers: Swifterbant in the Low Countries and Ertebølle in southern Scandinavia and the Baltic. Artifactual signs of contact occur soon after the arrival of adjacent Neolithic groups. LBK arrowheads occur in the Swifterbant region from 7500 cal BP (Louwe Kooijmans 2003). Adzes also spread north (see fig. 4) into the same area (Verhart 2000, fig. 1.15) and through Poland (Bogucki 2008), reaching the Baltic by 6700 cal BP

(Hartz, Lübke, and Terberger 2007). The Swifterbant regions began making pottery around 7000 cal BP (Louwe Kooijmans 2007), the Ertebølle following around 6700 cal BP (Andersen 2007; Hartz, Lübke, and Terberger 2007), although the ceramic style owed more to northeastern Baltic types (Hallgren 2004). Things were not all one-way: Bogucki (2008) argues that T-axes of antler in the LBK derive from Ertebølle prototypes.

These artifactual contacts did not, however, lead to the diffusion of agriculture. A few domestic animals are sporadically claimed, but they rarely stand up to scrutiny. Mesolithic caprines were claimed at Deby in Poland (Domanska 1989). Objections were soon raised (Kozlowski 1990), and these claims are no longer accepted (Domanska 2003:590). Some domestic cattle and pigs were claimed at the Ertebølle site of Dabki on the Baltic (Ilkiewicz 1989). No criteria demonstrating domestication were ever put forward, but the specimens are still sometimes mentioned (Zvelebil 2004). A recent reexamination has, however, demolished these claims: domestic cattle appear at ~6200 cal BP (Kabacinski, Heinrich, and Terberger 2009). A few cattle bones at Rosenhof at ~6700 cal BP were claimed to be domestic (Nobis 1975). On metrical grounds these are probably aurochs (Rowley-Conwy 1985, 2003*a*), but they are still often cited as domestic (Hartz 2005; Hartz, Heinrich, and Lübke 2000, 2002; Schmölke 2005; Zvelebil 2004). Strong support for their identification as aurochs has come from two recent studies. Isotopes show that these animals' diet was like that of contemporary aurochs, not later domestic cattle (Noe-Nygaard, Price, and Hede 2005). Their DNA matches the European aurochs lineage, not the imported domestic Near Eastern lineage (Scheu et al. 2008). There can be little doubt that these animals were wild. The earliest domestic cattle from this area are those from Wangels, dating to after ~6100 cal BP, when caprines and cereals also occur (Hartz, Lübke, and Terberger 2007:586; Price and Noe-Nygaard 2009).

In the Netherlands, a few bones of domestic animals are claimed at ~6700 cal BP: 20 sheep/goat at Brandwijk L30 (Raemaekers 1999, table 3.49), and 15 more, with three domestic pigs and 15 domestic cows, at Hardinxveld De Bruin (Oversteegen et al. 2001). The criteria for separating the cattle and pigs into wild and domestic have not been published, but the sheep/goat (if contemporary with the rest of the materials) are clearly domestic. Louwe Kooijmans (2003:621) regards these as likely imports of joints of meat, not as locally reared animals. Cereal grains have not been found, but one barley grain comes from Doel in Belgium in a context dated to 6600 cal BP (Crombé and Vanmontfort 2007:269); there is, however, later occupation at this site (Crombé, Perdaen, and Sergant 2005:55), and the grain itself has not been directly dated (Philippe Crombé, e-mail, February 2009). Cereal agriculture is first well attested after 6100 cal BP at Swifterbant S3 (Cappers and Raemaekers 2008).

There is thus a disparity between artifacts and agriculture: 1,500 years of artifact exchange led to no economic Neolithization. As archaeologists, we like imported artifacts because they are (*a*) identifiable and (*b*) considered important. But how important were they to their Mesolithic recipients? Large quantities are known, many getting as far as Denmark (fig. 5). It is often assumed that they were sought after merely because they were exotic, engendering competition and destabilization in hunter-gatherer societies (e.g., Fischer 2002; Thomas 1996; Zvelebil 1996, 1998). But virtually all are stray finds (Klassen 2002:308–309; Verhart 2000:33); there is no archaeological reason to assume that they were regarded as in any way special by their Mesolithic users.

The LBK remains a sharp archaeological event, still best interpreted as a migration. The speed of the westward migration contrasts spectacularly with the 1,500-year pause before agriculture spread north into the Swifterbant/Ertebølle sphere. The huge lag between the spread of artifacts and agriculture suggests that the artifacts did not have any significant catalyzing effect. The way to destabilize and Neolithize hunter-gatherers is not to sell them axes but to encroach on their territory and steal their women.

Southern Scandinavia

Southern Scandinavia is characterized by the Late Mesolithic Ertebølle shell middens. The hunter-gatherer population may have been as high as about 1 individual per 2 km^2; this is similar to that of recent sedentary groups in California and the Northwest Coast and much greater than typical densities elsewhere (Rowley-Conwy 1983). For this reason alone, a substantial degree of indigenism is espoused by virtually all who consider the appearance of agriculture (e.g., Andersen 1973, 2007; Fischer 2002; Larsson 2007; Price 2000*b*; Rowley-Conwy 1999; Zvelebil 2008).

Yet even here the case can be made for some migration. Chronological sharpness is the crucial issue: if the change to agriculture is gradual, it can be portrayed as an indigenous development, merely acquiring the domestic crops and animals from elsewhere; but if it is rapid, migration becomes more likely. Numerous axes of continental Neolithic origin are found in Mesolithic Denmark (fig. 5). It is sometimes argued that these caused social developments toward Neolithization, such as the sedentary occupation of large coastal base camps (Fischer 2002). The counterargument (see above) is that the exotic artifacts had little impact: increasing population density, base camps, and territoriality as indicated by the appearance of cemeteries are better explained as a Mesolithic response to increasingly maritime conditions (Rowley-Conwy 1998, 1999). These developments in fact all took place much earlier than the arrival of agriculture in central Europe (Larsson 2007; Rowley-Conwy 1999). Coexistence between foragers and farmers and a gradual transition to agriculture are suggested at Löddesborg (Jennbert 1984). This site, however, has major stratigraphic problems and is written off by Scandinavian scholars (see Rowley-Conwy 2004*b*:87), although it is still occasionally cited (Zvelebil 2004, fig. 4.2).

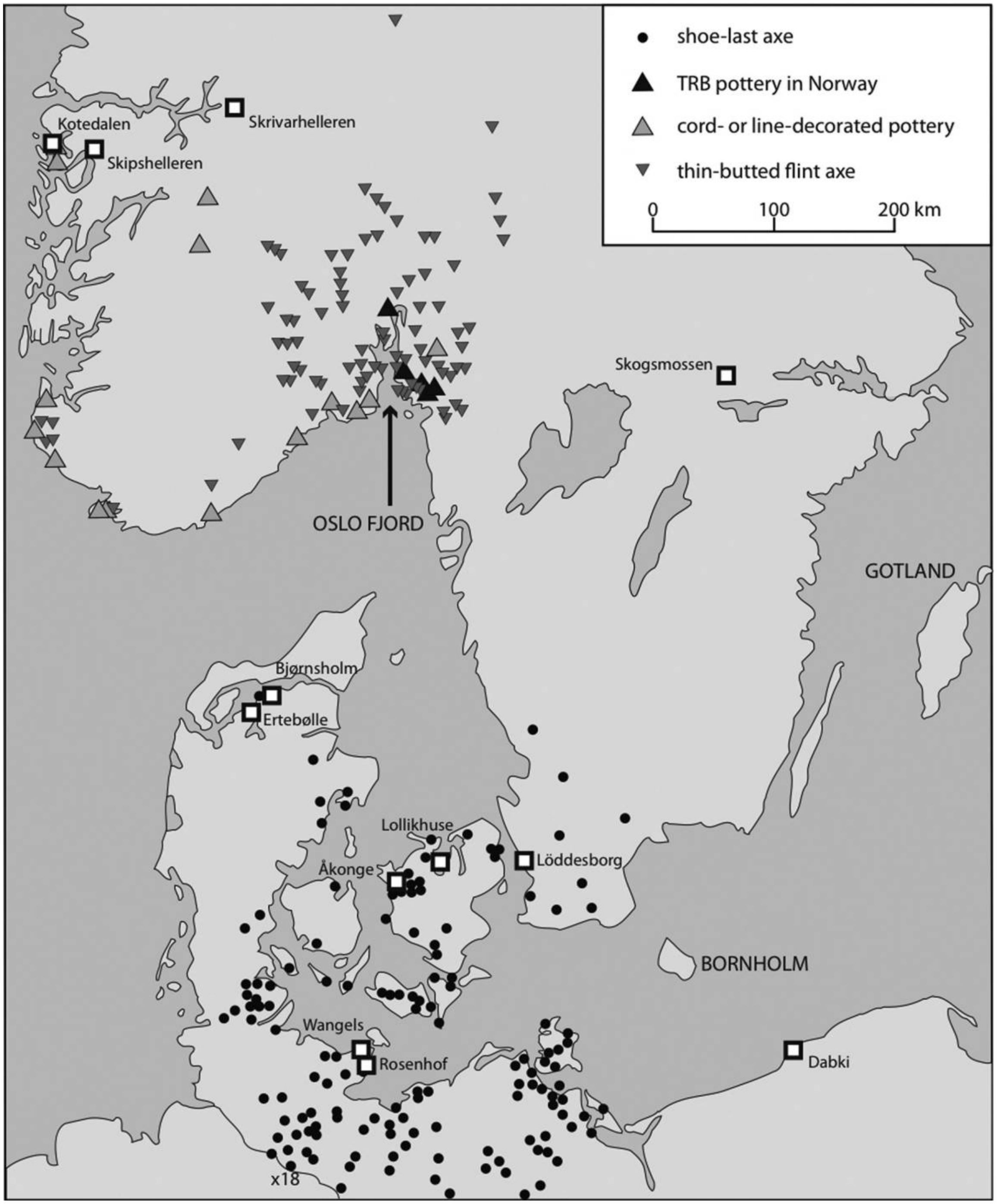

Figure 5. Late Mesolithic and Early Neolithic southern Scandinavia. Shoe-last axes of Late Mesolithic date imported from farmers to the south from Klassen (2002, fig. 20.1). *Trægtbægerkultur* and other pottery in Norway from Østmo (2007, fig. 1); Early Neolithic thin-butted axes imported from Denmark or southern Sweden from Hinsch (1955, fig. 7). A color version of this figure is available in the online edition of *Current Anthropology*.

The appearance of agriculture was quite abrupt. In Denmark there was a rapid change in settlement pattern. Some sites did continue to be occupied, but these were seasonal special-purpose camps (Rowley-Conwy 1983; Skaarup 1973). Mesolithic base camps such as Ertebølle (Andersen and Johansen 1986) or Bjørnsholm (Andersen 1991) show reduced levels of Neolithic occupation and may have become special-purpose fishing camps. Neolithic "base camps" were in inland agricultural areas. The shift to interior settlement at the start of the Neolithic was abrupt (Larsson 1986; Nielsen 1985). A classic example is the island of Bornholm, where even the earliest Neolithic occupation has a markedly inland distribution (Nielsen 2009, fig. 6). The same happens on Gotland (Österholm 1989). The pointed butted axe, characteristic of the earliest phase of the Early Neolithic, has a markedly inland distribution both in eastern Denmark (Nielsen 1977, fig. 7) and southern Sweden (Hernek 1988, figs. 4–7).

The available economic evidence also suggests an abrupt change. There is no evidence for domestic animals in Mesolithic contexts, contra Thomas (1996:314) and Zvelebil (1996: 334). One domestic cow, directly dated to ~6900–6600 cal BP, is claimed from Lollikhuse (Sørensen 2009), but the identification of the tooth remains in doubt (S. Sørensen, e-mail, March 2009). The earliest domestic cattle in Denmark are 16 specimens from Åkonge; this site is dated to after 5900 cal BP and is transitional to the Neolithic (Gotfredsen 1998). Neolithic economies are dominated by domestic species. Isotopic analysis of human bones shows an abrupt transition from a Late Mesolithic marine diet to a terrestrial Neolithic one (Tauber 1981); even farmers living close to the coast ate few marine foods (Richards and Koch 2001).

This sharp change suggests that some migration occurred even if most Neolithic mtDNA was local. The TRB in fact spreads a long way north very rapidly (Knutsson and Knutsson 2003), Skogsmossen (Hallgren et al. 1997) being near the northern limits of cultivation (fig. 5). Farming here seems to "overreach" itself, and subsequently it retreated, being replaced by the Pitted Ware culture, termed "Middle Neolithic" even though they were hunter-gatherers (Eriksson 2004). Farming probably reached southeastern Norway as well, marked by the TRB pottery in figure 5, though organic preservation is poor (Østmo 2007; Østmo and Skogstrand 2006).

This farming spread must have been by boat. There were no native aurochs on Zealand (Aaris-Sørensen 1980), so the early cattle at Åkonge were definitely imported. Farther north, agriculture was probably carried by boat up the coasts, an easier method of travel than overland (see above). Baltic crossings would require longer open-water voyages than in the Cardial or LBK. Irish curraghs can, however, make substantial voyages and weather considerable seas (Hornell 1938, sec. 5: 17–21), and a large one has even crossed the Atlantic (Severin 1978). The role of dairy products in such moves has been stressed above. If fresh milk (rather than yogurt, cheese, etc.) was to be consumed, the consumers must have the lactose-tolerant gene present in some modern peoples. Swedish researchers have recently located this gene in 13 archaeological skeletons, the oldest being Middle Neolithic (directly dated to 5308–4980 cal BP; Malmström et al. 2008). If this gene was present earlier (and elsewhere in Europe), this would have made the daily food production from a lactating animal even more valuable to migrants.

This agricultural spread apparently stopped just as abruptly as it started and did not extend west of Oslo Fjord. Atypical ceramics and Early Neolithic thin-butted flint axes imported from the farmers do occur across southern Norway (fig. 5), and in earlier times these were assumed to indicate farming (Hinsch 1955). Cereal pollen has been claimed at Kotedalen, dated to ~5800–5000 cal BP (Hjelle 1992). No charred grains were present (Soltvedt 1992), however, and domestic animals were completely absent (Hufthammer 1992, 1995). The pollen record has been strongly criticized (Prescott 1995, 1996; Rowley-Conwy 1999) because of the discrepancy between pollen and zooarchaeological evidence: the first domestic-animal bones appear at Skipshelleren and Srivarhelleren after ~4200 cal BP (Prescott 1995).

The agricultural arrival in southern Scandinavia thus appears sharp. Gradualist views of Late Mesolithic developments can be discounted despite the spread of shoe-last axes beyond the farming frontier. Western Norway presents a similar pattern: axes and ceramics were in circulation for over a millennium beyond the farming boundary. Southern Scandinavia had dense hunter-gatherer populations, which made a high genetic contribution to later agricultural populations. I suggested long ago that ecological events might have destabilized the hunter-gatherer economy around 6000 cal BP (Rowley-Conwy 1984). This idea has not found much favor, but Bonsall et al. (2002) have argued that other ecological factors may have been active at the same time. If this is so, these ecological factors achieved in a generation what 1,500 years of trading axes from farmers failed to do.

Ireland and Britain

Since the later 1960s, Britain has been the homeland of gradualistic perspectives on agricultural origins. This is one of the few models that has successfully crossed from "processual" to "postprocessual" archaeology and has indeed been taken further by the latter. The currently dominant model argues that for much of the Neolithic, Britain and Ireland remained effectively "Mesolithic," based on nomadic hunting and gathering. Cultivated cereals and domestic animals were "special" foods that were hardly utilized on a daily basis but kept in unoccupied stores for occasional consumption (Richmond 1999; Thomas 1996, 2008).

Against this, some have argued that the transition was abrupt. Unoccupied cereal stores are an unlikely notion: burnt houses full of charred cereal remains, as for example at Balbridie, are most simply interpreted as normal domestic structures, more and more of which are turning up (Rowley-Conwy 2004*b*). Cereal agriculture has long been written down, but a very large amount of evidence is now available (Jones and Rowley-Conwy 2007) that is fully comparable to the evidence for LBK cultivation (Bogaard and Jones 2007). Neolithic faunas with a predominance of wild species persistently refuse to make themselves known (Rowley-Conwy 2003*b*). Hambledon Hill, with Britain's largest Neolithic fauna dated to ∼5500 cal BP, has just been published—and it is dominated by domestic animals (Legge 2008). Dairying could again be very important (contra Thomas 2008:70–71); it has long been argued for on zooarchaeological grounds by Legge (1981) and is supported by lipid analysis of Neolithic ceramics (Copley et al. 2003), notably at the recently excavated Early Neolithic timber hall at Crathes (Soberl and Evershed 2009).

Stable isotope analysis supports an abrupt transition to terrestrial (i.e., agricultural) foods at the start of the Neolithic even in such agriculturally unpromising areas as western Scotland (Schulting and Richards 2002). The Céide Fields, a 12-km^2 agricultural field system in the west of Ireland, are Early Neolithic (Caulfield, O'Donnell, and Mitchell 1998). An "abruptist" view is thus a viable alternative to the gradualist orthodoxy.

In keeping with this, migrations are being suggested. Pride of place among migrants goes to the Orkney vole, a subspecies (*Microtus arvalis orcadensis*) quite different than the voles of the rest of Britain. Orkney voles have inhabited Orkney since some time during the Early Neolithic, as a directly dated specimen from Links of Noltland shows; it is not clear whether they arrived at the start of the Neolithic or somewhat later. The mtDNA of modern voles shows that they are probably derived from voles in the Bay of Biscay region (Thaw et al. 2004). One or more pairs of voles must have been stowaways on an Early Neolithic voyage from Biscay to Orkney—perhaps in animal bedding. This is the longest individual voyage proposed here for a curragh-type boat (fig. 6). A new study suggests that while such a voyage would be difficult in a sailing boat, a paddled boat could make the trip from Brittany around the west of Ireland to Orkney in less than 2 weeks (Callaghan and Scarre 2009).

Sheridan (2010) proposes that the Early Neolithic was introduced by several different migrations (fig. 6): the Carinated Bowl tradition may derive from northern France, reaching Scotland around 5900 cal BP; simple megaliths and their associated ceramics suggest connections from southern Brittany to western Scotland and Ireland as early as 6000 cal BP (Sheridan 2003); and northwest France and southwest England show similarities in ceramics and funerary monuments, the "Trans-Manche West" connection (Sheridan 2007; Sheridan et al. 2008). Tresset (2003) argues that the animal economy of southern England is so similar to that of northern France that direct import is likely. Sheridan (2010) states that no areas of Britain or Ireland are perfect cultural analogues of any area of Europe, so complete cultural transplantations are not proposed. The mixings and blending inherent in piecemeal leapfrog migration are the likely causes of this pattern.

A special place may be reserved for Ireland. The earliest dated cow bones from anywhere in Britain and Ireland are currently two specimens from Late Mesolithic Ferriter's Cove dating to ∼6300 cal BP; a slightly younger one comes from Kilgreany Cave (Woodman, Anderson, and Finlay 1999; Woodman and McCarthy 2003). These may have been imported as joints of meat rather than as live cattle (Tresset 2003:26), but at all events they indicate connections with the continent in the Late Mesolithic, a time when no such connections can be seen in Britain (Sheridan 2007:466). Dates for the conventional Neolithic in the west of Ireland are somewhat curious. The Carrowmore megalithic cemetery has produced very early radiocarbon dates, some before 6000 cal BP (Burenhult 2001). The early dates have been criticized (Bergh 1995:98–110). Sheridan (2003:12) nevertheless accepts that construction started at ∼6000 cal BP; if correct, that makes them among the earliest megalithic tombs in Britain and Ireland. And the causewayed enclosure at Magheraboy, just 2 km from the Carrowmore cemetery, has been dated to ∼6000 cal BP, also among the earliest in Britain and Ireland (Danaher 2007:104).

The evidence discussed here suggests that the appearance of agriculture in Britain and Ireland was about as abrupt as radiocarbon dating is currently capable of demonstrating. Because both are islands, a degree of migration is not just a viable but an inevitable explanation. Further, we must face the surprising possibility that Ireland "went agricultural" before Britain; if true, it would be the biggest leapfrog migration in Europe and the ultimate testimony to the importance of the hide boat. Thomas argues that the rapidity of the process indicates either "a massive, coordinated seaborne invasion" or local adoption by hunter-gatherers, because leapfrog migration could not achieve the same result so fast (Thomas 2008:65). But this is a false dichotomy: leapfrog migration most closely accounts for the visible patterns (see above). The couple of centuries spanned by the dates is entirely compatible with this and is similar to that documented in the other spreads discussed above.

Conclusion: Lurches of Advance

The four major spreads of agriculture (fig. 1) are all compatible with the immigration of at least a considerable proportion of farmers. The proposed scenario differs from the "wave of advance" in two important ways: first, each involved farmers carrying many genes of European Mesolithic origin, and second, the movement is sporadic and punctuated, not continuous. We must replace the monolithic "wave of advance" concept with a series of local and disparate "lurches of advance." A similar scenario may also be appropriate for southeastern Europe (see Özdoğan 2011).

The incoming farmers interacted with local foragers in a wide variety of ways. Sometimes the foragers were rapidly overwhelmed and disappeared as a separate group. All the four major spreads can be interpreted in this way, though with differing proportions of "local" and "incoming" genes

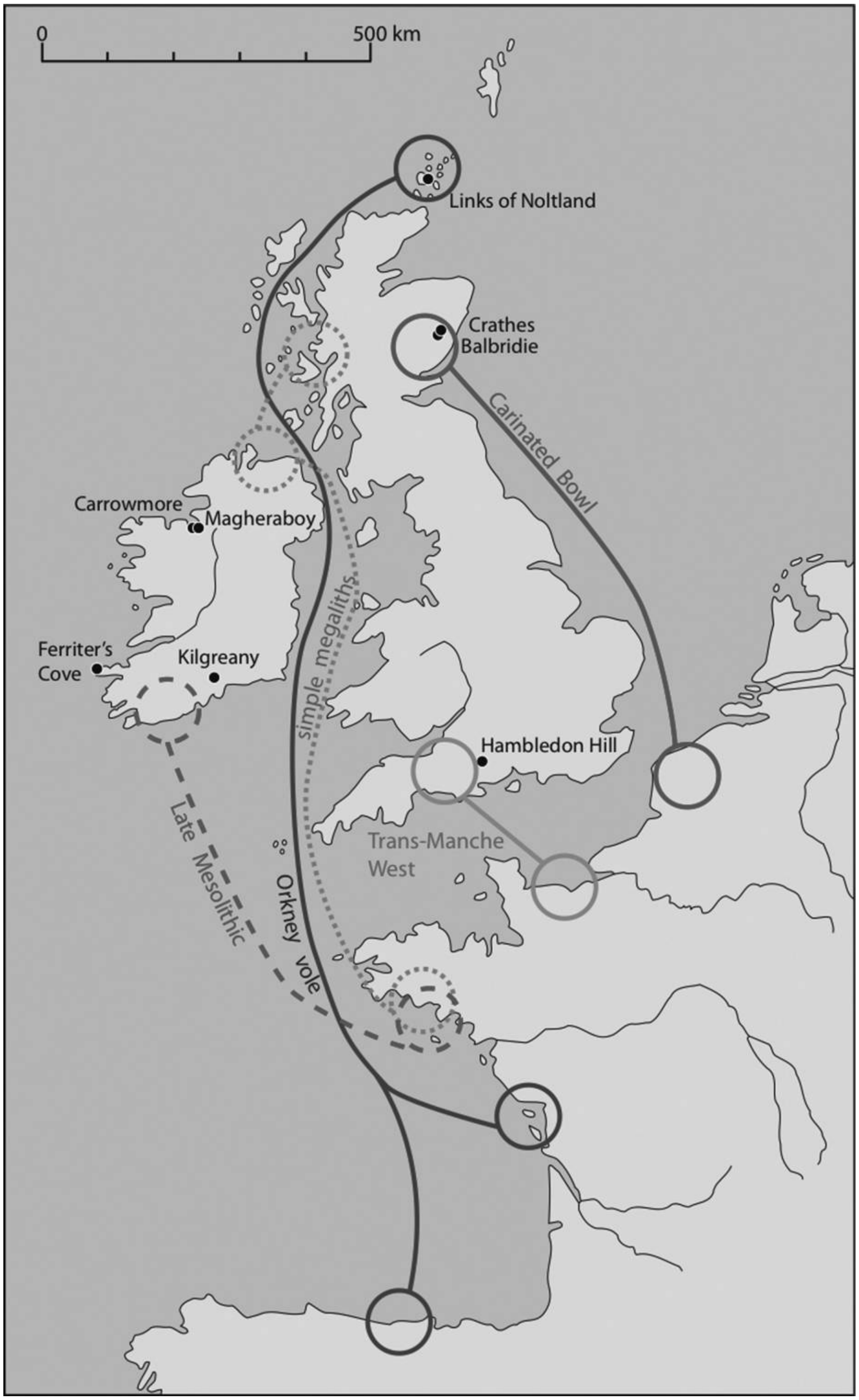

Figure 6. Map of Britain, Ireland, and the adjacent continent showing sites mentioned in the text and the connections described. A color version of this figure is available in the online edition of *Current Anthropology*.

being present in the subsequent Neolithic cultures. In some cases—for example the VSG—the incomers overreached themselves and were subsumed into a Neolithic largely "local" in character. And in two cases—the lower Vistula and eastern Sweden—farming did not root itself after its first arrival, failed initially, and was displaced temporarily by renewed hunting and gathering.

If the scenarios put forward here have any merit, various lines of inquiry need following up with more energy than hitherto. Boats and dairying are two themes I have championed; the latter is now being more generally examined, and more thought should perhaps be given to the former. Finally, the rapidity of the spreads in each area raise the long-discredited specter of environmental contexts for some of the "lurches of advance," as Bonsall et al. (2002) have suggested for Scandinavia and Britain.

Above all, the migrationist scenarios suggested here may account for one thing: why we so rarely see long-term "transitional" stages between foraging and farming. Now we see foragers, now we see farmers; but in Europe we have singularly failed to catch foragers in the act of becoming farmers. The long-term developmental processes we have expected for decades have not materialized. Farmers can evidently trade axes with foragers for centuries or longer without destabilizing them or leading them to adopt farming. "Processes" there undoubtedly are, but we need to look inside the standard deviation of a radiocarbon date to see them in action.

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