AGRICULTURE

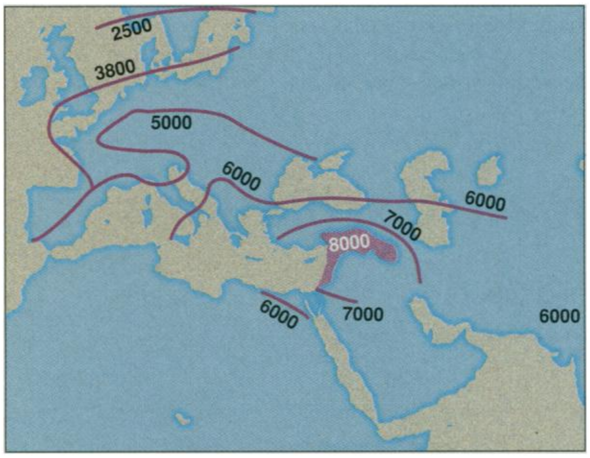
Location, Location, Location: The First Farmers

Jared Diamond

Human history's most important event since the last Ice Age was the first rise of agriculture in Southwest Asia's Fertile Crescent. The origin of agriculture triggered a long train of economic, political, and technological developments, which began there and spread outward. As one example, this wave of changes explains why this journal, published in a land originally inhabited by Native Americans, is nevertheless written in a language of the Indo-European language family that arose 10,000 years earlier and 10,000 miles distant, in or near the crescent. Why did agriculture first develop in the narrow swath of hills extending only from southeast Turkey to western Iran (see the figure)? A report on page 1312 of this issue (*1*) helps answer that question by pinpointing the site of domestication for einkorn wheat, one of eight so-called "founder crops" that launched crescent agriculture around 9000 B.C. (*2*).

Botanists already knew that cultivated einkorn's ancestor was a very similar wild cereal that still grows in natural habitats in the crescent (*3*). It was unknown, however, where within the crescent wild einkorn was first taken into cultivation. Heun *et al.* (*1*) analyzed DNA from 68 lines of cultivated einkorn, plus 261 wild einkorn lines sampled over the crescent's whole expanse as well as outside the crescent.

Among those wild lines, the most distinct genetically proved to be a group of 11 from the Karacadağ mountains of southeast Turkey. Those 11 also turned out to be the ones genetically most similar to cultivated einkorn, and so presumably the crop's immediate ancestors. This discovery is compatible with previous nonmolecular evidence. The Karacadağ mountains were already known to support stands of wild einkorn so dense and extensive that they were being harvested by hunter-gatherers even before einkorn's domestication. Nearby archaeological sites contain remains of both wild and cultivated einkorn and are among the crescent's oldest farming sites.



The spread of food production from the Fertile Crescent. The purple-shaded area is the crescent itself, where food production was established by 8000 B.C. Lines denote how far food production, on the basis mostly of Fertile Crescent crops and livestock, had spread by the indicated dates (calibrated radiocarbon B.C. dates). Based on maps 2 and 20 of (*3*), as modified in (*4*).

What are some of the broad implications of these findings? Genetically and morphologically, cultivated einkorn is quite similar to wild einkorn in general. Now that the specific wild ancestral line has been identified as being even more similar to the crop, we can better appreciate why einkorn's domestication was so easy and quick. The crescent's archaeological record shows that at most a few centuries were required for the transition from hunter-gatherer villages harvesting wild plants to farming villages planting fully domesticated crops. For einkorn (and probably for the other founder crops as well), that transition required changes in only a few genetic loci, which account for the few morphological changes distinguishing the crop from wild einkorn (*1*).

But those few changes were of great value to the earliest farmers. They included heavier seeds and denser seed masses (yielding a crop even more productive than its wild ancestor), plus a firm stalk making seeds more easily harvestable by preventing them from dropping to the ground. Repeated cycles of sowing, growing, and harvesting wild einkorn would have selected automatically for those mutations (*3*). The first cultivators could have had no conscious intent to produce a crop, and no way of anticipating how radically agriculture would change their societies.

These few, simple changes during einkorn's domestication contrast sharply with the drastic biological reorganization required for the domestication of Native Americans' leading cereal, maize, from its wild ancestor, teosinte. This difference alone helps explain why densely populated agricultural societies arose so much earlier and developed so much more rapidly in the crescent than in the New World.

Can we attach any significance to the new finding that, within the crescent, einkorn was domesticated specifically in southeast Turkey rather than at some other site? Here we find another clue to the early rapid rise of crescent agriculture. In different parts of the crescent lived wild species ancestral to some of the world's earliest and most useful species of crops and livestock. With the discovery by Heun *et al.* (*1*), we can pinpoint the origins of three of the crescent's eight founder crops (chickpea, bitter vetch, and now einkorn) to eastern Turkey. Grapes and olives were domesticated nearby to the south; sheep, pigs, goats, and cattle close by in possibly the central, north central, eastern, and western crescent, respectively; and barley, emmer wheat, peas, lentils, and flax in still-to-be-identified parts of the crescent. Only slightly to the northeast of the crescent, on the shores of the Caspian Sea, grows the wild grass *Aegilops squarrosa*. When it hybridized with cultivated emmer wheat spreading east from the crescent, the result was bread wheat, the most valuable single crop in the modern world. Thus, the crescent's diversity of useful wild plant and animal species, living in close proximity to each other, enabled the crescent's first farmers quickly to assemble a balanced package of domesticates meeting all of humanity's basic needs: carbohydrates, protein, oil, milk, animal transport and traction, and vegetable and animal fiber for rope and clothing (*3*, *4*).

That valuable package spread rapidly through and beyond the crescent (see the figure), not only outcompeting hunter-gatherer economies in productivity, but also preempting alternative sequences of plant and animal domestication that might otherwise have arisen elsewhere in western Eurasia. The spread was accelerated by the west-east axis of the whole Eurasian continent as well as of the crescent itself, permitting crops, livestock, and people to expand at the same latitude without having to adapt to new day lengths, climates, and diseases. Cultivated einkorn's rapid diffusion from the Karacadağ

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mountains preempted possible independent domestications of einkorn elsewhere in its wild range. The rapid diffusion of both einkorn and emmer in turn preempted widespread cultivation of other related domesticable wild grasses, such as Timopheev's wheat. In contrast, the New World's north-south axis required domesticates to adapt to changes of latitude as they spread. The resulting slow spread of crops within Native America permitted numerous independent domestications of the same crop or of related crops (for example, squashes and cottons) in different areas. Within less than 2000 years of the beginnings of domestication in the crescent, its results had been carried east and west to launch the origins of food production over a huge swath of Eurasia (see the figure), from Pakistan to the Balkans (*3*). Food production's expansion over the Americas, Africa, and the Indian subcontinent was much slower because of the north-south axes of those landmasses (*4*).

In short, einkorn domestication in the Karacadağ mountains exemplifies the enormous head start that western Eurasian societies gained from Fertile Crescent biogeography. For history's broad patterns, as for real estate investment, location is almost everything. Plant and animal domestication was prerequisite to the growth of large, dense, sedentary human populations, in which the food-producing activities of part of the population yielded storable food surpluses to feed non–food-producing parts of the population. Hence, food production triggered the emergence of kings, bureaucrats, scribes, professional soldiers, and metal-workers and other full-time craftspeople (*4*). Literacy, metallurgy, stratified societies, advanced weapons, and empires rested on food production. In addition, smallpox and the other crowd epidemic diseases of Eurasia could evolve only in those dense, sedentary human populations living in close contact with domesticated animals, whose own pathogens evolved into those specialized pathogens afflicting us (*4*). Thus, a long straight line runs through world history, from those first domesticates at the Karacadağ mountains and elsewhere in the Fertile Crescent, to the "guns, germs, and steel" by which European colonists in modern times destroyed so many native societies of other continents.

References and Notes

1. M. Heun *et al.*, *Science* **278**, 1312 (1997).
2. All dates that I cite are so-called calibrated radiocarbon dates, which are corrected for temporal fluctuations in atmospheric carbon isotope ratios and thus correspond to approximate calendar years. The dates in (*1*) are younger because they instead are uncalibrated dates.
3. D. Zohary and M. Hopf, *Domestication of Plants in the Old World* (Oxford Univ. Press, Oxford, ed. 2, 1993).
4. J. Diamond, *Guns, Germs, and Steel: The Fates of Human Societies* (Norton, New York, 1997).

PALEOCLIMATOLOGY

Millennial Climate Oscillations

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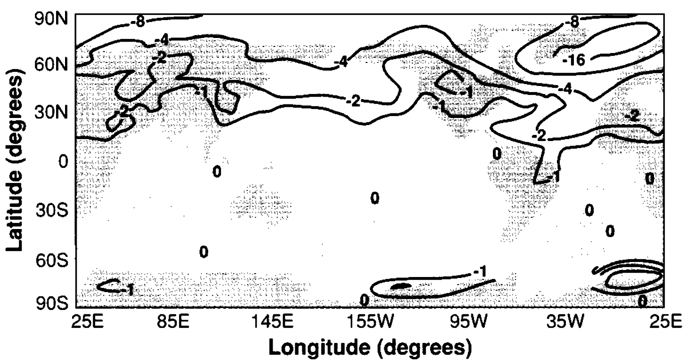
Changes in Earth's orbit around the sun influence the seasonal distribution of energy on Earth, driving the climate system in and out of ice ages in a quasi-predictable manner. As paleoclimatologists struggle to solve remaining mysteries related to the ice ages, they are faced with the prospect of explaining large, rapid millennial climate changes, which are far too frequent to be a linear response to the relatively slow changes in Earth's orbital configuration, known as Milankovitch forcing. Millennial oscillations during the last glaciation are remarkable. The beginning of each cycle is marked by a 5° to 8°C rise in air temperature over Greenland in just decades to centuries. After 1000 to 2000 years of moderate temperatures, the region plunged rapidly back into frigid conditions, only to warm again and start the next millennial climate cycle.



Sensitivity experiments with a coupled ocean-atmosphere general circulation model suggest a widespread response to millennial climate oscillations originating in the North Atlantic. When a strong meltwater pulse is injected into the model's surface North Atlantic, convective overturn ceases, causing cooling, the greatest of which (up to 16°C) occurs in the North Atlantic. The cooling is transmitted to the North Pacific (up to 4°C) primarily by the atmosphere, but the ocean plays an important role by amplifying the response (*15*).

Since the realization that records from North Atlantic sediments can capture the dramatic millennial climate oscillations of the last glacial period (*1*), first seen in ice cores, several research teams have detailed, one-for-one, their marine equivalent (*2*). Millennial oscillations have also occurred closer to the present: The current period of relative warmth, which began about 11,000 years ago (the Holocene), is less stable than generally realized, and the Little Ice Age is only one of several cool events occurring during this time (*3–5*). On page 1257 of this issue, Bond and his colleagues present the first records from the marine realm that are long enough and detailed enough to compare the characteristics of glacial and Holocene millennial oscillations (*6*).

By counting the number of rock fragments in sediments from the Denmark Strait and eastern subpolar North Atlantic, Bond *et al.* identified times of increased iceberg passage over the two sites during the glaciation and Holocene. Compositional changes of this lithic material and variations in the relative abundances of polar and subpolar surface-dwelling fauna suggest that ice-rafting events (that is, the transport of materials by icebergs) were associated with the southward penetration of cooler waters from the Greenland and Iceland seas. Although an order of magnitude smaller than their glacial counterparts, the Holocene oscillations occurred at a similar pace, every 1000 to 2000 years. This rate is indistinguishable from the 1450-year cycle identified by Mayewski and colleagues (*7*) in a Greenland ice-core record of a proxy for the size and intensity of the polar atmospheric circulation. Moreover, Bond *et al.* demonstrate that, like glacial oscillations, Holocene variations in the subpolar North Atlantic are

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