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The Environmental Setting for Plant Domestication in the Near East

Wild cereal grains may not have entered the Near East until the end of the Pleistocene 11,000 years ago.

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The archeological record indicates that the first known plant domestication occurred in the foothills of the Zagros-Taurus Mountains of southwestern Iran, southeastern Turkey, and adjacent parts of Iraq and Syria (Fig. 1). Emmer wheat (*Triticum dicoccoides*), einkorn wheat (*T. boeoticum*), and barley (*Hordeum spontaneum*) had been domesticated by at least 9000 years ago, and peas, lentils, and other legumes were probably domesticated at about the same time (*1–4*). The morphological changes in the seeds that enable some of the domesticated forms to be recognized developed over many generations of probably unconscious selection by early gatherers of the wild forms, which occupy the same general areas. Even today, stands of the wild forms are common enough and productive enough to provide a substantial food resource. The domestication of these plants was gradual, and many centuries passed before either cultivation or the herding of sheep and goats, which developed concurrently, became the major economic base of the people (*5*). Hunting and fishing, as well as gathering of a wide variety of plant foods, were the principal base of subsistence for hundreds of thousands of years before the first plants and animals were domesticated, and they remained as major activities during the transition period. Fishing continues to be locally important.

Many archeologists today believe that the origin of agriculture in the Near East and elsewhere reflects a gradual, purely cultural transition in the presence of an essentially uniform environment or, if evidence for regional environmental change exists, that the change was unimportant in bringing about this new way of life, which had such profound repercussions for cultural evolution over the whole world. Recent pollen studies in the Near East, however, provide support for the thesis that environmental change actually set the stage for plant domestication. It is here proposed that at the time of the last Pleistocene glaciation, the dry-summer climate now characteristic of the Mediterranean Sea area, along with its associated plants (including the wild cereal grains that were later domesticated), had been displaced to the south, specifically to the area of Morocco. It is suggested that the climatic change terminating the Pleistocene resulted in the migration of certain food plants from the Morocco area to the eastern Mediterranean region, and that concomitant cultural changes led to the domestication of these plants in their new area. No claim is made that the environmental changes by themselves determined the course of cultural history. Rather, the climatic events were a necessary ingredient in producing optimal conditions for plant and animal domestication.

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Background

The traditional view of Near East climatic history is that glacial climates in higher latitudes were accompanied by pluvial climates in lower latitudes. In this view, when the Scandinavian ice sheet expanded and when all of Europe north of the Alps was converted to tundra, the storm tracks that today invade western Europe were shifted south of the Alps, bringing rain to the Mediterranean area and causing the expansion of temperate forest there. And when the ice sheet retreated, the climate became drier, as it is in the Near East today. According to the concurrently developed oasis theory of Childe (*6*), this type of change restricted plants, animals, and man largely to areas of localized water supply, and the proximity of the three bred familiarity and then domestication.

Earlier work had suggested that Pleistocene glaciation in the Mediterranean mountains was minor compared to that in temperate latitudes. However, the discovery in the Zagros-Taurus range that the snow line there was depressed as much as that in the Alps, or even more, gave support to the hypothesis that pluvial conditions accompany glaciation in low latitudes, because such deep depression of the snow line implies an increase in moisture as well as an increase in cold (*7–9*). When these studies were made the chronology of local deglaciation and climatic change could not be determined, so their possible effects on cultural development could not be evaluated. It was assumed that simple altitudinal shifts in the climatic and vegetational belts could best explain the relations—that is, that the forest simply moved from the mountains to the foothills and piedmont, and that the ecological life zones were essentially maintained at different elevations (*10*).

Pollen Studies of Vegetational History

To approach the problem of vegetational history more directly, and to obtain dates for the events in the paleoclimatic sequence, a program of lake sedi-

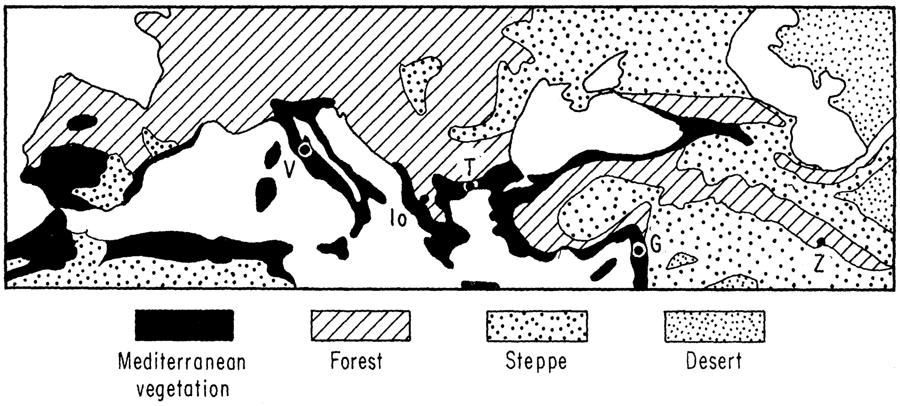

Fig. 1. Map of Mediterranean area, showing present distribution of Mediterranean vegetation and location of pollen sites mentioned in the text: *V*, Vico; *Io*, Ioannina; *T*, Tenagi Philippon; *G*, Ghab; *Z*, Zeribar (in Zagros Mountains). During the last glacial interval of the Pleistocene, the Mediterranean vegetation is believed to have been displaced to the south along the Atlantic coast of Morocco, the temperate forest became restricted to the mountains of the Balkan Peninsula and Italy, and the steppe expanded westward from Iran and the Soviet Union to Spain. The area north of the Alps was largely tundra.

ment studies, particularly pollen analysis, was initiated in the Zagros Mountains (Fig. 1). The results (Fig. 2) provide evidence that glacial climates in higher latitudes do not necessarily accompany pluvial climates in lower latitudes (*11*). Before about 11,000 years ago the vegetation in the now-wooded lower portions of the mountains was marked by a steppe with *Artemisia* (wormwood) and chenopods (pigweed family), implying a relatively cool, dry climate such as that found today in the higher parts of the Anatolian and Iranian plateaus, which now have a similar pollen rain (*12*). The previous assumption that the extensive glaciation in the high mountains implies greater precipitation in this entire region was thereby invalidated:

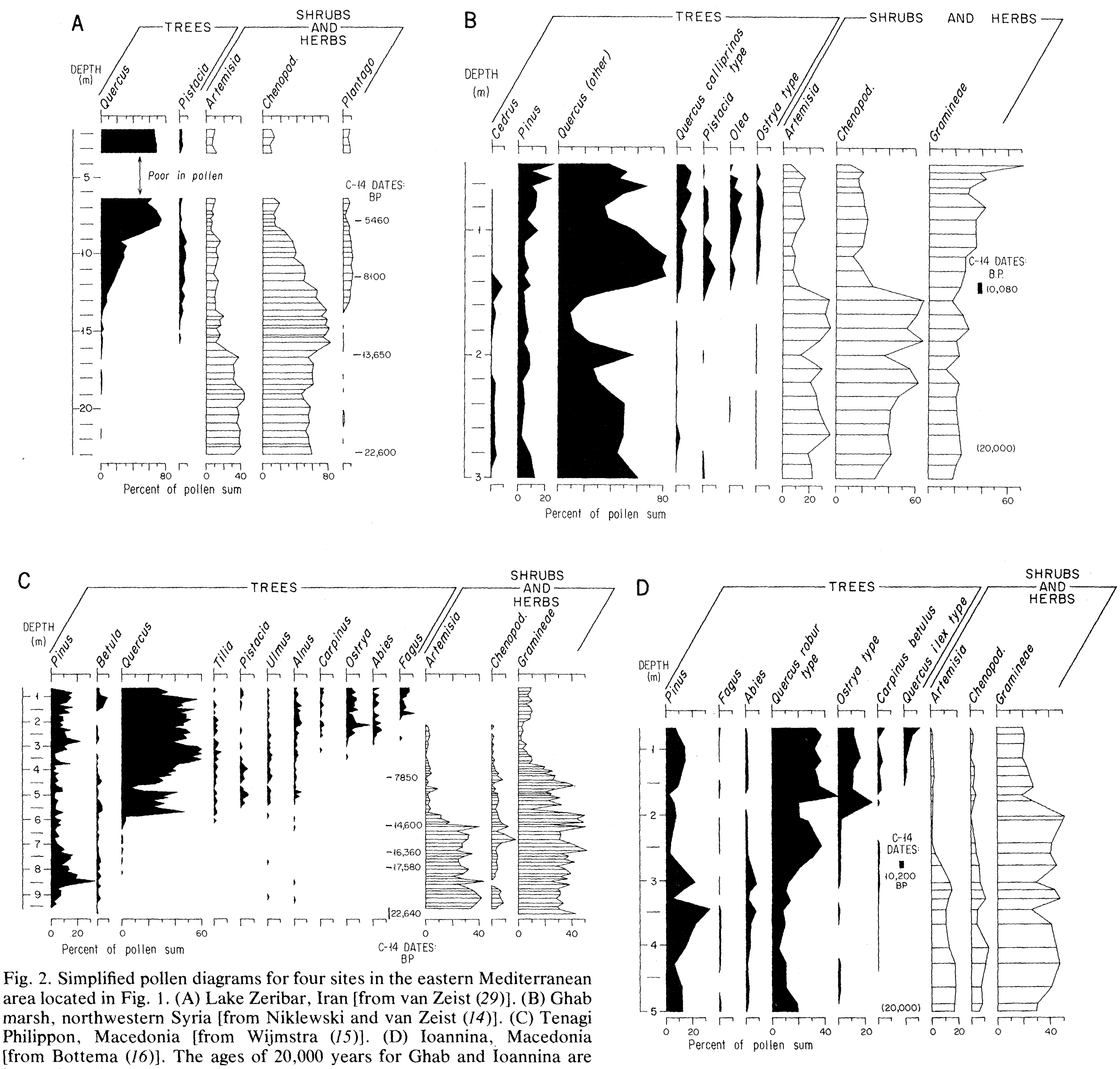

Fig. 2. Simplified pollen diagrams for four sites in the eastern Mediterranean area located in Fig. 1. (A) Lake Zeribar, Iran [from van Zeist (*29*)]. (B) Ghab marsh, northwestern Syria [from Niklewski and van Zeist (*14*)]. (C) Tenagi Philippon, Macedonia [from Wijmstra (*15*)]. (D) Ioannina, Macedonia [from Bottema (*16*)]. The ages of 20,000 years for Ghab and Ioannina are interpolated between two carbon dates.

lowering of temperature must, therefore, have been the only factor in bringing about the glaciation.

It was then postulated that oak woodland immigrated to its present range about 11,000 years ago not from the piedmont but from a refuge close to the Mediterranean, and that it was accompanied as well by the immigration of wild cereal grains, especially emmer, which accompanies oak woodland today (*13*).

Subsequent pollen studies in other parts of the north Mediterranean region support the inference that the late Pleistocene climate of this entire area was cold and dry, rather than moist (Fig. 2). Pollen profiles from the Ghab depression east of the coastal mountains in northwestern Syria (*14*), two sites in southwestern Turkey (*4*), the great marsh of Tenagi Philippon east of Salonika in eastern Macedonia (*16, 17*), the marsh of Ioannina in the mountains of northwestern Macedonia (*16, 17*), the Lake of Vico near Rome (*18*), and sites in both southern and northern Spain (*19*) indicate that the late Pleistocene vegetation in these areas was primarily steppe, dominated by *Artemisia*, chenopods, and grasses. Only in the Syrian and Turkish sites is there evidence for trees (oak, pine, or cedar) associated with the steppe. Radiocarbon dating at several of these sites indicates that the steppe vegetation yielded to forest about 11,000 years ago or as late as 8,500 years ago in Turkey.

The only site that does not fit this pattern is Lake Huleh in Palestine (*20*). The available pollen profiles from there, however, are much less detailed than the Syrian diagram 300 km to the north, and the assignment of a pluvial climate for the late Pleistocene should be considered tentative.

For the Macedonian site of Tenagi Philippon, the dominant chenopod pollen type for the Pleistocene levels as determined by scanning electron microscope resembles two genera that are found today primarily in the Pamir and other parts of the southern Soviet cool steppe (*21*). This finding constitutes positive evidence that the Asian steppe expanded southwest during the maximum of the last glacial period to cover the Mediterranean lands as far west as Macedonia, and presumably all the way to Spain. The entire Sahara was as much a desert as it is today and left no record of human occupation (*22*). Europe north of the Alps was marked by tundra. The extensive coniferous and deciduous forest belts that today cover most of Europe and intervene between the Soviet tundra and steppe were not present at that time,

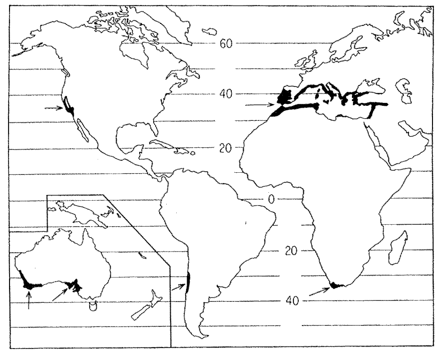

Fig. 3. Map showing the present world distribution of Mediterranean-type climate and vegetation.

except for enclaves at moderate elevations in some of the mountains of the Balkan Peninsula and Italy, where moisture was greater than at lower elevations but temperatures not too low for tree growth.

About 11,000 years ago the steppe changed to open woodland or to forest. In some diagrams the recorded change is abrupt, in others it was transitional from 14,000 to as late as 6,000 years ago, perhaps reflecting variable responses of local areas to increases in precipitation or temperature or both, as well as possible delays in the migration of trees from Pleistocene refuges. Although other changes have occurred in subsequent time in some areas, perhaps related to human disturbance (*23*), the general pattern for the Holocene is fairly uniform. Oak pollen dominates, and several of the sites are characterized as well by pollen of other temperate trees that are found in the various regions today, such as pine, hornbeam, hop hornbeam, elm, linden, alder, hazel, beech, and fir. These trees thrive today in the temperate forests of Europe north of the Alps as well as in those parts of the north Mediterranean area at medium elevation where the forest cover has not been largely removed by man.

Of greater significance in the climatic history than temperate forest expansion, however, is the first major occurrence at many sites of pollen of certain trees, namely, evergreen oak (*Quercus ilex, Q. coccifera, Q. calliprinos*), olive, and pistachio, which today are largely confined to the distinctive Mediterranean climatic belt, characterized by winter rain and summer drought (Fig. 2). Specifically, oak pollen of this type occurs continuously in the Holocene levels at Ghab and Ioannina. At Tenagi Philippon, the oak shown in the diagram is primarily the *Q. ilex* type (*15*). At Ghab, *Olea* shows a continuous curve in the Holocene; although olive species occur in East Africa, the best region for olive cultivation is along the boundaries of the Mediterranean. *Pistacia* pollen shows continuous occurrence in the Holocene section of the profiles at Ghab and Tenagi Philippon, as well as at Zeribar in the Zagros Mountains. Although *Pistacia* species are found beyond the Mediterranean area, to Pakistan in the east and the Canary Islands and even Mexico in the west (*24*), the genus is most common in the Mediterranean region.

Mediterranean Climate

A Mediterranean climatic pattern today occupies the transition between the belt of prevailing westerly winds and the subtropical dry belt on the western sides of all continents at the appropriate latitude (30° to 35°)—not only around the Mediterranean Sea but also in California, Chile, South Africa, and southern Australia (Fig. 3). Rains are brought when the westerlies move south in the winter, and the summer drought occurs when air from the dry belt expands to the north. In the area under consideration, this climatic pattern extends far eastward, because the winter storms have an easy passage along the lowland of the Mediterranean Sea, which involves no barriers and in addition provides more moisture than is normal in Mediterranean climates. In fact, secondary storm centers develop over Cyprus and over the Black Sea. In the summer, air from an expanded Azores high-pressure area becomes relatively dry as it subsides in its eastward flow across the Mediterranean region.

In the California example, eastward extension of the Mediterranean-type climate is limited in part by mountains and in part because the subtropical dry belt is not so massive as that in North Africa, and moist air from the Caribbean brings convective showers in the summer as far west as southeastern California. In Chile the mountains and the narrow land mass similarly restrict the Mediterranean climate zone to the west coast.

During the Pleistocene, the Asiatic steppe, which is marked by summer rain as well as by winter rain, expanded to the southwest into the north Mediterranean region. It was bordered north of the Alps by tundra, which covered the rest of Europe as far as the ice margin. The dryness of the Mediterranean region at this time can be attributed in part to the fact that the sea during the Pleistocene was cooler than the Mediterranean Sea is today and thus yielded less moisture to Atlantic air masses than does the present

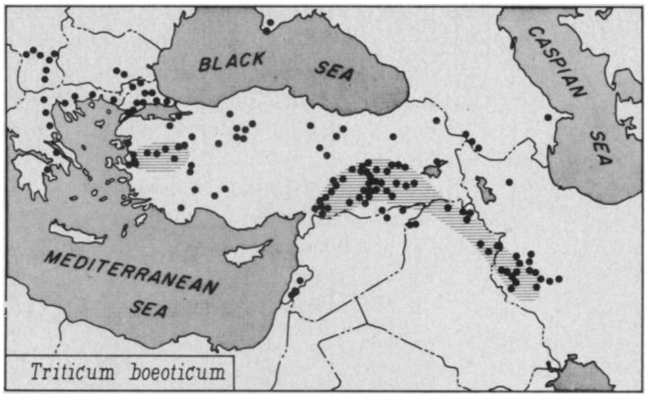

Fig. 4. Location of present stands of wild einkorn (*Triticum boeoticum*) in the eastern Mediterranean region (*14*). Shaded pattern shows primary range. Wild stands of emmer, barley, peas, and lentils have a similar distribution (*25*, *26*).

Mediterranean. However, the major winter storms must have been displaced south of the Mediterranean, that is, to northwestern Africa. They probably did not extend so far to the east as they do today, because a long sea like the Mediterranean did not extend eastward from northwestern Africa to provide an additional moisture source.

In any case, the transitional Mediterranean-type climate had to exist somewhere in the region, for it is a basic result of the axial tilt of the earth as the earth revolves around the sun. This climate is so distinctive that a characteristic flora must always have accompanied it. Search for an ice-age refuge for this flora might thus center in Morocco or elsewhere in northwestern Africa. If appropriate lakes or marshes suitable for pollen stratigraphic studies can be located, a proper test of the hypothesis can be made.

Domestication of Plants

This paleoclimatic reconstruction of the late Pleistocene has important implications for the problems of where, how, and why plants were domesticated. Today, the wild wheats and wild barley that became the primary domesticates have a distribution that is confined to at least part of the region of dry-summer climate (*25*)—the Zagros-Taurus Mountains and adjacent plateaus and piedmont, with extensions southward to the Palestinian plateaus, and in one case westward to Greece (Fig. 4), and in another case to Cyrenaica. Legumes that were domesticated have a similar distribution today for wild forms (*26*). Although their distribution is not coincident with that of the principal indicators of the Mediterranean climate (olive, for example), these wild grains and legumes do not occur outside this climatic zone. They are not found in Italy or Spain, perhaps because the rainfall is just too great there. The reconstruction depends on the assumption that the plants involved required a dry-summer climate in the Pleistocene just as they do today. Cereal-grain pollen (wild or domestic) cannot be distinguished with certainty from that of other grasses in routine pollen counts, so the grass-pollen profile itself does not provide evidence for the immigration of these three species into the eastern Mediterranean (*1*). And legumes are small pollen producers. However, other indicators of dry-summer climate (for example, evergreen oaks, olive, and pistachio) give evidence of the change to the Mediterranean climatic pattern.

Thus, if emmer, einkorn, barley, and the legumes in question migrated to the Zagros-Taurus area about 11,000 years ago as a result of the change from dry climate at the end of the Pleistocene, then the stage was set for their domestication in that area. It is possible that the immigration of these plants into an area with an already established flora brought about hybridization, polyploidy, and other manifestations of genetic variability. Emmer is a tetraploid wheat. There is no evidence that the cereal grains actually evolved as species by genetic change after the immigration rather than at a much earlier time, but the new genetic contact with other grass populations may have created some types of cereal grains readily responding to human selection.

Man was already present in the area, as evidenced by numerous middle and late Paleolithic cave sites, with indicators of a subsistence pattern of hunting and gathering (*27*). The change to dry climate apparently had little effect on the availability of wild game animals, for the bones found both in Paleolithic and post-Paleolithic sites include wild sheep, goat, and red deer. The mountains contain rugged ridges, steep gorges, gentle slopes, and other geomorphic features that provide a diversity of habitat for wild game. The bedrock is primarily limestone, which is weathered to form caves and overhangs suitable for winter shelter for early man. Although Pleistocene summers may have been mild and well suited to extended travel by hunting parties, the winters must have been extremely cold and snowy, as indicated by the evidence for expanded glaciers.

With the temperature increase at the end of the Pleistocene, winters may have become tolerable even outside the caves, and year-round open sites could be established. Perhaps the fact that there was more space around open sites than in caves encouraged year-round maintenance of young sheep and goats brought in from the hunt, and the level terrain provided more space and more sun than in caves for the germination of discarded seeds gathered from wild plants.

Several colleagues have cautioned against my postulating that most people lived in caves during the Paleolithic and abandoned cave-living at the end of the Pleistocene. They suggest that the traditional view associating Paleolithic man with caves and later people with open sites may have been derived from the facts that (i) archeologists look in caves for Paleolithic man; (ii) archeologists in search of food-producers look for open sites; (iii) Paleolithic open sites are hard to find because they did not have house structures of mud or stone that would have resulted in artificial mounds being formed on the landscape, and because many accumulations of artifacts have been scattered by subsequent plowing and other disturbance; and (iv) large Paleolithic open sites are known from the Russian plains and from the loess region of southeastern Europe.

I maintain that in spite of the considerable amount of surface surveying that has been done in the Zagros Mountains, remarkably few surface Paleolithic sites have been discovered, and almost all cave sites found have contained only Paleolithic deposits and few or no deposits of more recent age. These facts can be reasonably explained by considering that winters in the Zagros in Paleolithic times were quite severe, that caves were excellent shelters, and that such shelters would be less necessary for human survival after the end of the Pleistocene when winters ameliorated and the technology of mud-brick architecture began to be developed. The questions could be settled for the Zagros Mountains, at least, by additional, careful, objective archeological surveys in areas where both caves and open valleys exist.

The cultural changes that were involved in the gradual domestication of the cereal grains and legumes cannot be reconstructed from archeological evidence in any detail, and for the present hypothesis they are not critical. The principal point is that geologic, climatic, biologic, and cultural conditions in the foothills of the Zagros-Taurus Mountains 11,000 years ago or shortly thereafter were for the first time combined in a manner favorable for plant domestication. The success of the cultural transformation that ensued is attested by the relatively rapid spread of agriculture to other parts of temperate Eurasia, and by the increased complexity of sociopolitical organization in the Near East based on an agricultural economy.

If the Mediterranean-type vegetation, including the three cereal grains and legumes in question, thrived in the late Pleistocene in some refuge such as northwestern Africa, one might reasonably ask why these plants were not domesticated there and then. Perhaps the other elements in the formula were not suitable. Moroccan prehistory is not well known. Certainly there is no record of domesticated plants until long after the events described here (*28*). In any case, it should be possible to design archeological and paleoecologic studies in Morocco—especially in the Atlas Mountains—to test many aspects of the hypothesis.

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Science, Values, and Human Judgment

Integration of facts and values requires the scientific study of human judgment.

Kenneth R. Hammond and Leonard Adelman

Scientists and policy-makers are uncertain how scientific facts are to be integrated with social values. For their part, scientists are uncertain whether their contributions should be restricted to presenting the facts, thereby leaving the policy judgment entirely to the political decision-makers, or whether they should also advise politicians which course the scientist believes to be best. And politicians, for their part, are uncertain how much scientific information they are supposed to absorb, and how much dependence they should place on scientists for guidance in reaching a judgment about policy (*1*). As a result, "the scientific community continues its seemingly endless debate about the role of science and scientists in the body politic" (*2*).

One principal reason for the "endless debate" is that scientific progress has increasingly come to be judged in the context of human values. These judgments find their ultimate expression in the forming of public policy because it is during that process that the products of science and technology are integrated, or aligned, with human values; it is during that process that scientific and technological answers to questions of what can be done are judged in the context of what ought to be done.

The key element, therefore, in the process of integrating social values and scientific facts is human judgment—a cognitive activity not directly observable and generally assumed to be recoverable

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