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CURRENT PROBLEMS IN RESEARCH

Domestication of Food Plants in the Old World

Joint efforts by botanists and archeologists illuminate the obscure history of plant domestication.

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Due to an increasing interest shared by both archeologists and biologists in each other's spheres of activity, considerable research is being done today on problems of the interdependence between man and nature in the more remote past. This nature-man interdependence shows nowhere more clearly than in the quest of the cultural historian to grasp the effect, upon human society, of the domestication of animals and plants. Both natural and cultural historians are also concerned with nature's reaction to this drastic intrusion upon its domain (*1*). Recognition of the profound impact of the swing to food production and of its consequences in the development of human culture is of fairly recent date (*2*), but even so, cooperation between the two branches of science has already brought about a conspicuous improvement in understanding.

We shall confine ourselves here to considering the domestication of plants, and our area for discussion under the general heading "Old World" is, in this context, restricted to Europe, North Africa, and the temperate zone of western Asia to the Indus valley. This area is defined by the circumstance that all of the initial cultural developments and diffusions within it—from the appearance of the food-producing stage onwards—depended primarily upon the cultivation of wheat and barley for subsistence.

We shall also confine ourselves primarily to consideration of plant evidence which derives from the ancient archeological contexts themselves. This does not mean that we ignore the brilliant theoretical reconstructions of the histories of various domesticated plants offered by the botanical geneticists. The merit of the studies made by such workers as McFadden and Sears, Kihara, Müntzing, Schiemann, and N. Vavilov is self-evident. As a practicing paleoethnobotanist, however, I find my own approach to the problem of the appearance and early development of domesticated plants animated by one important principle. From the archeologically derived evidence itself, it is clear that any domesticated plant is an *artifact,* a product of human manipulation. Hence, rather than corresponding strictly to clear-cut genetic principles, the history of the domesticated plants seems to show various of the perversities of the manipulator, man himself.

The locus for the domestication of a wild plant must necessarily be its area of natural distribution. Thus, a prehistoric group of people, dependent upon wild wheat as its main food grain, must have developed its subsistence pattern within the boundaries of the natural distribution of that plant species. The same applies to any culture dependent upon barley. Now, as it happens, all primary (*3*) Old World agrarian cultures whose chief bread grains are known to us grew both wheat and barley together. Therefore, we can pin down the center of emergence of the wheat-barley cultures to the common area of distribution of the two plant species.

As may be seen on the map (Fig. 1), the wild, domesticable barley, *Hordeum spontaneum,* is distributed from Turkestan to Morocco (the distribution is represented in its broad outline only). On the other hand, the large-grained, wild wheat, *Triticum dicoccoides,* grows exclusively in a small natural area within the center of this huge territory. Thus, we may conclude from present distribution studies that the cradle of Old World plant husbandry stood within the general area of the arc constituted by the western foothills of the Zagros Mountains (Iraq-Iran), the Taurus (southern Turkey), and the Galilean uplands (northern Palestine), in which the two wild prototypes occur together. We may conclude, further, that wheat played a more dominant role than barley in the advent of plant husbandry in the Old World (*4*).

A basic prerequisite for the persistence of a wild plant is a natural ability to spread over a wide area. In wild grasses the spike becomes brittle at maturity and falls apart in spikelets containing the seeds, which are carried about by wind and animals. In some grasses, such as wild wheat and barley, there is a recessive tendency to develop toughness of the spike axis, and this circumstance was most advantageous to man. Instead of collecting unripe spikes, he could reap most of the fully mature grain, providing the spike had tough axes. At the same time he would, in harvesting, recover a steadily increasing proportion of the tough-axis spikes, thus also favoring the tough-axis genes in his seed grain. In the end, no brittle-axis plants grew in his field. The toughness attained in the primary issue of the wild wheat was not, however, as great as that of some of the genetically more advanced species. Even today the structurally primitive cultivated species, Einkorn, Emmer, and Spelt, exhibit a median stage of toughness between that of the wild ancestors and that of the free-threshing species, such as Bread wheat and Hard wheat.

Expressed in a few words, the impetus behind plant domestication is the human

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drive to secure the greatest possible amount of food with the least possible labor. The means by which this goal was attained with the food plants was the furtherance of growth by tilling of the soil, the concentration of the desired growth by sowing, the exclusion or removal of unwanted plants from the tilled plot, and the protection of the crop plants against animal and bird attack.

In order to perform these activities it must at an early stage have proved practical to move the wheat down from its exposed natural habitat on the mountain slopes, at altitudes between 2000 and 4300 feet above sea level, to more level ground. A nearness to open grasslands, domestic water supply, and other accommodations for human habitation was necessary, but it was still also necessary to stay within the boundaries of areas having sufficient winter and spring rainfall.

Emmer and Einkorn

One result of this forced movement of the grain beyond its natural habitat by human transplantation was presumably the emergence of mutations, hybrids, and freaks in the wheat. A natural selection of types was begun which favored individuals that had no chance of free survival in the original habitat, and thus the biological and morphological course was set which resulted in the domesticated type of the wild *Triticum dicoccoides*, named *T. dicoccum* (Emmer). From this species all other species of cultivated wheat derive, with the exception of Einkorn, *T. monococcum*, which is the progeny of the small-grained wild wheat, *T. aegilopoides*. Neither of these species (Emmer and Einkorn) was able to survive without the care of man, their competitive powers having been stunted by the loss of their ability to disperse. On the other hand, man had become the servant of his plants in that his whole routine of life depended upon the steady and ample supply of vegetable food derived from his field.

Since as yet only one group of archeological finds, those at Jarmo, in Iraqi Kurdistan, affords the crucial combination of both the wild prototype and its more advanced domesticated issue, we will take Jarmo as our point of departure in this discussion. Jarmo is an early prehistoric site in the uplands of Iraq-Kurdistan, excavated by the Oriental Institute of the University of Chicago (*5–7*). The cultural assemblage is of a primitive, pre-Hassunan character; whether or not Jarmo is the earliest "village" or "town" type settlement known in archeology is of minor importance to us here (*8*). The main point is the fact that the wild cereals here make their earliest appearance in any known cultural context.

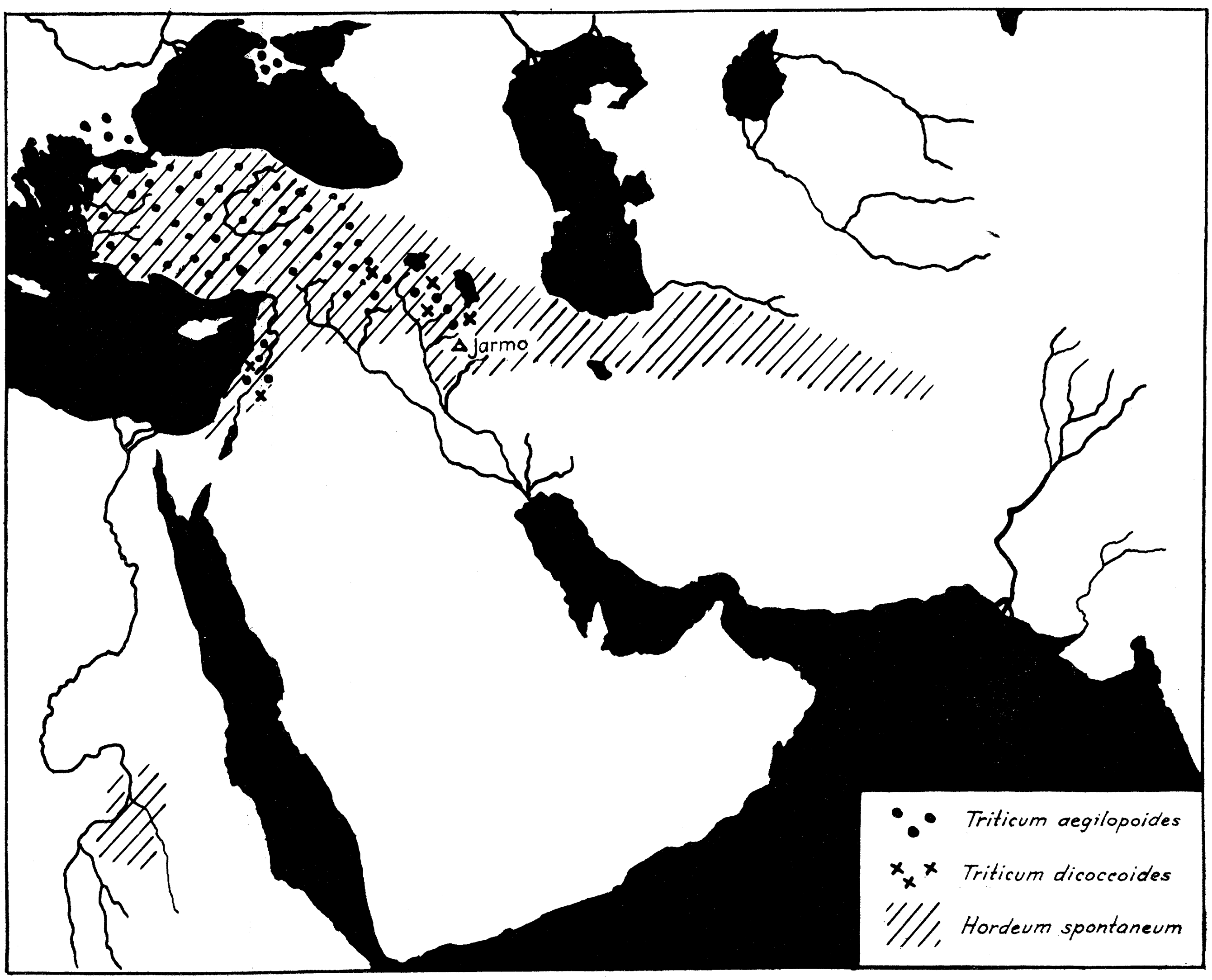

Fig. 1. Distribution of wild prototypes of cultivated wheat and barley. Wild barley is also distributed in western North Africa, beyond the bounds of this map.

The present estimate of the actual date of Jarmo is the beginning of the 7th millennium B.C.

The material recovered at Jarmo consists of imprints of grains and spikelets in baked clay and adobe, as well as carbonized grains and seeds and spikelets. In the carbonized material, evidence is available of two types of wild wheat kernels (Fig. 2): the straight, flat-bottomed type similar to *T. dicoccoides* and a smaller type with convexly curved ventral and dorsal sides, corresponding to *T. aegilopoides*. In the imprints we find very good examples of spikelets closely similar to *T. dicoccoides* (Figs. 3, 4), of large dimensions and rather coarse; on the other hand, the more advanced domesticated type, similar to Emmer, *T. dicoccum,* is represented in many specimens (Fig. 5), and also many kernels of the typical shape of Emmer are encountered in the carbonized grain. Thus, we are confronted at Jarmo with the two wild species which normally still occur together in the Kurdish localities, and further, with the offspring of the large-grained species, already characteristically transformed into Emmer (*9*). Incidentally, as in practically all other Near Eastern grain deposits (except those of Egypt), kernels and fragments of the sturdy glumes of *Aegilops* were present. In due course, the other components of the Jarmo plant deposit will be dealt with, but we shall now try to follow the spread and genetical development of the cultivated wheat.

In the 6th millennium B.C. (Hassuna period) village site of Matarrah, still in the Kurdish uplands but at a lower elevation than Jarmo (*6, 10*), we find only the cultivated Emmer. Whether or not Einkorn was also grown here has not been established. The Halafian communities of the upper Euphrates-Tigris region appear to have grown mainly Emmer, with a sprinkling of Einkorn (*11*). During this period, the 5th millennium, the colonization of the alluvial plain of lower Iraq was undertaken, and, according to the evidence now available, Emmer adjusted itself excellently to the artificial ecology of the irrigated land, while Einkorn did not (*11*). The same situation is encountered in Egypt (which was presumably colonized within the same general period)—namely, that Einkorn did not occur (*12, 13*).

From the nuclear mountainous arc, agriculture spread to the Mediterranean littoral and, presumably, all over Asia Minor. Boat traffic along the coast certainly accounts for many routes of migration, among which was that to Egypt. The crossing to Europe was effected quite early, and the end of the 5th millennium saw Einkorn and Emmer cultivated in the large loess plains stretching intermittently almost from the Danube delta to the mouth of the Rhine. When eventually this riverine–loess-plain belt had been saturated with population, new waves of migration set out in many directions, and during the 3rd millennium B.C. agricultural settlements cropped up in Switzerland, France, northern Italy, Spain, Britain, Central Europe north of the loess belt, and Scandinavia (Fig. 6). No doubt an early movement had already spread over the western coast lands of the Black Sea and penetrated into southern Russia. The two original cultivated wheat species adjusted themselves more or less successfully to the increasingly harder climates as farming cultures moved northwards. Einkorn reached its peak in Asia Minor, while in Britain it seems never to have got above the status of a poor relative (*14*).

The migrations were not, however, all in southerly and westerly directions. The movement that brought the alluvial plain of Mesopotamia under cultivation probably branched out and settled the high plateaus of Iran, and the early Indus valley agricultural centers were established some time in the late 3rd to early 2nd millennium B.C. There is also evidence that there was agriculture south of the Aral Sea before the middle of the 2nd millennium (*15*).

Club Wheat and the vulgare Group

The very first time archeologically excavated and dated plant material was handed over to a botanist for identification, a wheat species was established which does not conform to the characteristics of a straight-line descendant of the two wild species, *Triticum dicoccoides* and *T. aegilopoides*. In Michelsberg culture deposits in Switzerland, Oswald Heer, in 1865, identified unmistakable remains of Club wheat (*T. compactum* s.l.) (*16*). Whereas Einkorn and its progenitor are diploid (2×7 chromosomes) and Emmer and its progenitor are tetraploid (4×7 chromosomes). Club wheat belongs to the Bread wheat (*vulgare*) group, which is hexaploid (6×7 chromosomes). Modern genetical research has established experimentally that crossing of Emmer and the oriental wild grass, *Aegilops,* may produce hexaploid wheat with several features in common with the *vulgare* group (*17*). This explanation presupposes the emergence of the *vulgare* group in the Near East, but although a considerable amount of material from this part of the world has been investigated, Club wheat has not been found in early archeological contexts, while in later contexts it appears only in minor proportions in comparison with the occurrence of Emmer. On the other hand, in some of the Swiss middle-to-late 3rd-millennium finds, Club wheat was practically the only species found (*18*).

Fig. 2. Carbonized kernels (from Jarmo) similar to the wild wheats, *Triticum aegilopoides* and *T. dicoccoides.* In the upper left-hand corner is a specimen of the Emmer type kernel (× 4).

A summing up of available archeological information regarding Club wheat gives the following picture: In Egypt in the predynastic (late 5th millennium B.C.) find of Merimde beni Salame (*13*) —and possibly also in Fayum (*19*)— stray grains of Club wheat were established, and the same was the case in the late 4th millennium find of el Omari (*13*). On the contrary, no *vulgare* type wheat is encountered in the large deposits of uncarbonized wheat which abound in the early and middle dynastic tombs (3rd and 2nd millennia B.C.). Poorly documented samples of Club wheat in the Egyptian Agricultural Museum suggest the recurrence of the species late in the 1st millennium B.C. (no provenance is given, and thus the dates can only be guessed) (*20*). In Iraq the earliest appearance is represented by an imprint from Jemdt Nasr of about 3000 B.C. (*11*) and a few imprints of the middle of the 3rd millennium in the Habur area in the north (*11*). The earliest proper cultivation of Club wheat in Iraq is documented by a find from eastern upper Iraq (*11*), covering a few centuries around 2000 B.C. During the 2nd millennium we find the traces of the species being cultivated in Asia Minor, Syria (*20*), and Palestine. Everywhere that Club wheat appears in the Near East it occurs together with Emmer; only at about 1000 B.C. and later (*21*) does it occur more frequently than the old-fashioned wheat. It is recorded from upper Iraq in late Assyrian times, for example, but still in small proportions (*20*).

In the light of this scattered occurrence of the species in the Near East, whence it must nevertheless be supposed to have come, the profuse and consistent occurrence of Club wheat in the 3rd millennium B.C. in Europe is, mildly speaking, confusing. In Europe, it definitely occurs in cultural contexts which must be described as being of indigenous European origin. It would seem that the spe-

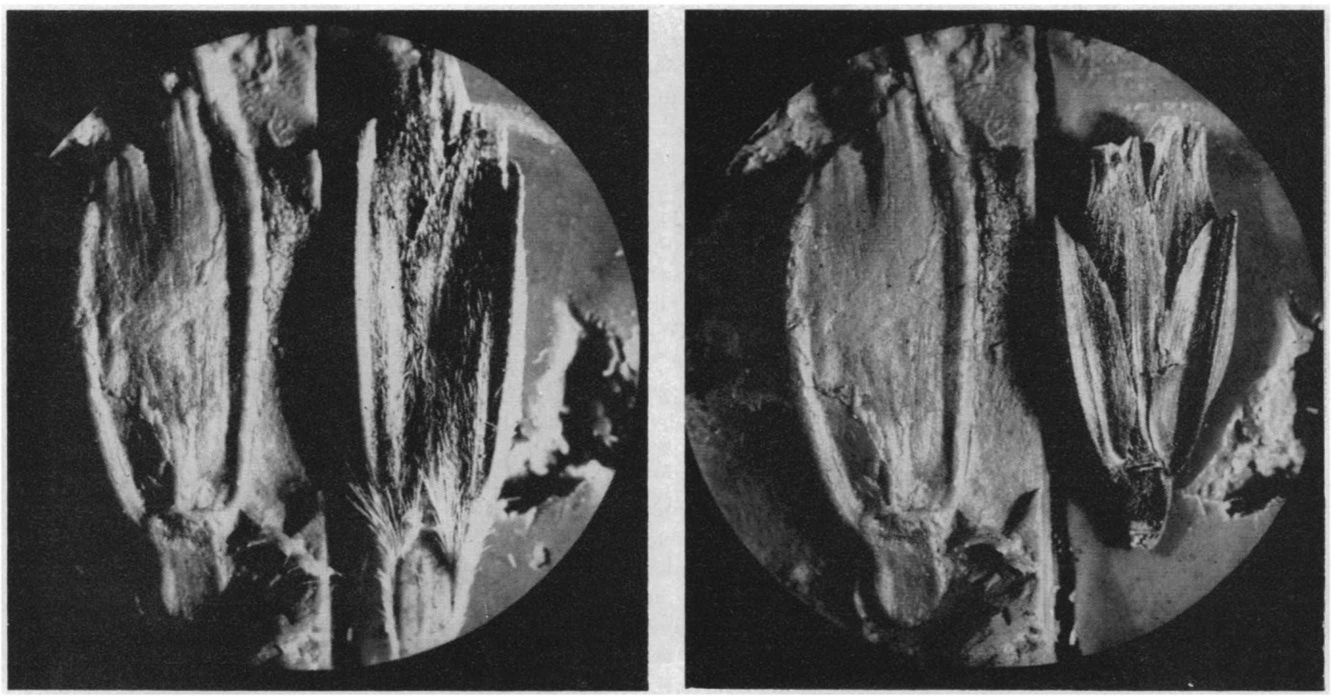

Fig. 3. (Top) Cast of Jarmo imprint of the ventral side of a *T. dicoccoides* type spikelet compared with (top left) a spikelet of the wild species and (top right) an Emmer spikelet from Fayum in Egypt, the earliest uncarbonized Emmer known (× 4). Fig. 4. (Bottom left) Cast of Jarmo imprint of dorsal side of *T. dicoccoides* type spikelet compared with an Emmer spikelet from Fayum (× 4). Fig. 5. (Bottom right) Imprint of Emmer spikelet from Jarmo (× 4).

cies only became important when it arrived in areas with heavy summer rains, such as the Alps, but that thereafter it adapted itself to such varying conditions within the continent as those, for example, in Spain and Denmark. It is present in the earliest known deposits of cultivated plants in Switzerland (*20*), and imprints of Club wheat were found, together with those of Einkorn and Emmer, in the earliest archeological findings of agriculture in Denmark (*22*). It is suggested that it was from Switzerland that plant husbandry was introduced into Spain, where there are frequent occurrences of Club wheat.

It may well be that Club wheat emerged as a hybrid in the Near East but that the ecological circumstances did not favor its development into a definite species in its natural surroundings. It may also be that it disappeared and recurred later as a kind of freak during the early phases of agriculture, and that, brought to other climatic regions as a weed in the Einkorn-Emmer fields, it found its balance and produced a rather hardy type which flourished in mountainous environments. In my opinion, the assumption that this happened somewhere in Asia Minor would provide a workable theory for explaining the above-mentioned discrepancies. On the whole, Asia Minor is something of a terra incognita as far as paleoethnobotany is concerned; too few finds from this territory have been recovered and offered for investigation, and the area must necessarily have been most important in certain genetical developments which, on the basis of the known material, we are quite unable to understand. Ecologically heterogeneous, this landscape would without doubt have influenced the gene balance of many plants (*23*) taken through its valleys and over its mountains from the cultural melting pot of the nuclear arc.

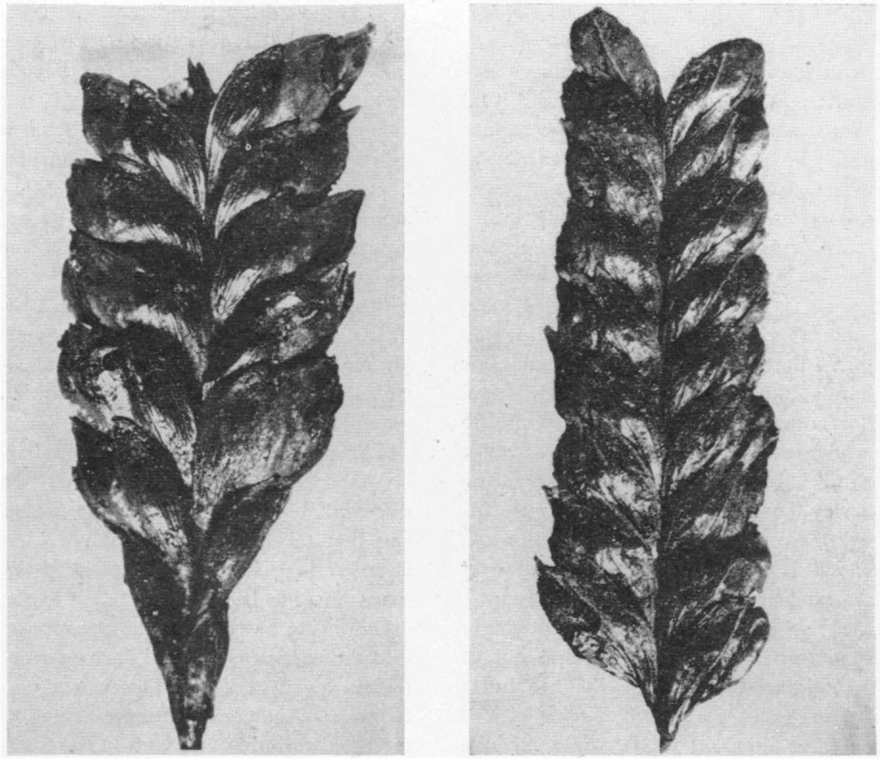

Fig. 6. Carbonized spike portions from early 2nd millennium northern Italy pile dwellings; Emmer (left) and Einkorn (right) (× 4).

Spelt and Other Later Wheats

Still another hexaploid wheat appears in the subalpine area of Europe. Spelt (*Triticum spelta*) was discovered in cultural levels of the early-middle 2nd millennium B.C. in Switzerland (*24*), southern Germany, and northern Italy (*20*). This species has the semitoughness and structural habit of Einkorn and Emmer, except that its internode adheres to the spikelet by its lower end and not, as in the two others, by the upper end. Genetics has demonstrated that a similar form may be produced by crossing Emmer and *Aegilops,* and since the peculiar articulation is found in *Aegilops* only, the explanation has a certain appeal (*17*). However, Spelt has never been found in prehistoric deposits outside Europe, and present cultivation of this species is restricted to certain Central European mountainous districts and a few other places where it is known to have been introduced in historical times by people coming from Central Europe (*25*). If it is taken for granted that the hexaploid wheats do owe their emergence to hybridization with *Aegilops,* it is perhaps not beyond the limits of possibility that a reshuffling of genes under severe mountainous conditions could have resulted in a local retrogression creating a form possessing at the same time the main structural habit of Emmer, a mode of articulation inherited from *Aegilops,* and a cytological composition that ranges it along with the *vulgare* wheats.

Scanning the Near Eastern wheat field today, we note that Emmer is no more to be found and that Club wheat is absent and Bread wheat rare and of no importance. The field is populated by wheats structurally parallel to the *vulgare* group but cytologically allied to Emmer, having 4×7 chromosomes.

We can only guess at the phylogenetic origin of the very diversiform group of these tetraploid naked wheats, which comprise Hard wheat (*T. durum*), Rivet wheat (*T. turgidum*), Polish wheat (*T. polonicum*), and several characteristic subspecies. They may have originated through mutation or through hybridization between extreme varieties of Emmer or even through interspecific crossings.

Hard wheat is the most important of the group. As opposed to the free-threshing species of the *vulgare* group, it flourishes in areas where there is a fairly modest amount of winter rain or irrigation and a completely dry ripening season. It is the wheat of the summer-dry steppe regions all over the world. The first evidence of this species occurs among the noncarbonized wheat deposits of the Ptolemaian (post-300 B.C.) period in Egypt (*26*). In the course of a few hundred years it seems to have spread all over the Near East, occupying the plains as well as the mountain tracts, at the expense of Emmer. The last stronghold of the latter is Abyssinia, where it probably was introduced with agriculture in late Egyptian dynastic times, while it was still being cultivated in Egypt itself, and where it is still being grown under the name of *Adjaz.*

Barley

As mentioned in the opening paragraphs, all of the known ancient Old World agrarian cultures (of the regions under discussion) grew barley as well as wheat. Returning to the earliest material at our disposal, we find that barley makes up the bulk of the plant remains in the Jarmo find. The kernels are hulled, straight, and unwrinkled, and some specimens consist of the median fertile floret with one of the lateral, male florets attached (Fig. 7). The lateral florets are not sessile, as they are in modern two-row barley, but have a short pedicel. In all these features, the Jarmo barley conforms rather closely to the wild, two-row, *Hordeum spontaneum,* which is naturally distributed all over the nuclear arc and far beyond. Indeed, the Jarmo kernels are somewhat larger than those of the wild species, but of most interest is the fact that, to judge by some axis portions consisting of two or three internodes (*9*), the spike was not brittle as in the wild form but had attained at least a certain degree of toughness. This is an unambiguous indication of domestication, since the wild spike falls to pieces when dry, even if it is not completely ripe. Not one fragment was encountered to indicate the occurrence of the six-row form of barley.

In its native districts the wild barley occurs practically everywhere. I never saw a field of any crop in Kurdistan in which wild barley was not to be found growing as a weed. From man's very first attempt to till the soil, this would have been the case, and barley must have been drawn into domestication together with the first wheat, through automatic selection of the tough-axis individuals in the course of reaping. In this sense barley might already be termed a "secondary" cultivated plant (*3*). It would eventually have lost most of its prickly and very coarse character (which, even now, keeps the oriental cattle from eating the wild spikes) and have become comparable to wheat in characteristics making it suitable for human consumption.

For a long time only this species was grown in Kurdistan. It abounds in the Matarrah material, and as late as Hellenistic times (*20*) it was the principal barley of this hilly region, as it still is today.

When, in the 5th millennium B.C., agriculture was extended to the river basins of Mesopotamia and Egypt, two-row barley disappeared and was replaced by the six-row species. Two-row barley has been postulated for Fayum in Egypt (*19*), but the evidence is not unambiguous, and among some 2000 imprints of plant material from ancient lower Iraq (Mesopotamia) that I examined, there is abundant proof of the occurrence of the lax-eared, six-row barley but not one imprint of the two-row spike (*11*). Not until the 9th century A.D. does the two-row form of barley make its appearance in the archeological material from the Mesopotamian plain (*11*).

The problem of how the six-row barley emerged has been discussed ever since the last century, when the matter was first taken up for serious consideration. A long series of complicated explanations has been offered, each explanation being based upon the assumption that the earliest cultivated barley was of the six-row type (*27*). This was a perfectly reasonable assumption, since all of the prehistoric barley found in the Swiss pile dwellings and in the Egyptian tombs was undoubtedly six-rowed. At the time, there was no archeological evidence to show that these finds were from periods much later than the initial domestication of barley, and that they could not be taken as indicators of the progenitor of barley. Now we are able to show that two-row barley was cultivated some 4500 years before the first hoe turned the soil of Switzerland and about four millennia before the first pyramid was built. Furthermore, it has been shown that barley cultivation started within the distributional area of the only possible progenitor.

Also, we are now able to demonstrate that the six-row form replaces the two-row form of barley as soon as agriculture moved into the artificial ecological environment of the irrigated plain. It is a logical conclusion that this forcible change of ecology brought about the mutation that resulted in the six-row spike. That the natural qualification for the mutation actually exists is borne out by modern experiments showing the transition from two- to six-row spikes in response to radiation treatment (*28*). If this change can be produced artificially, the necessary genes must be present in the species; genes cannot be created.

Since the early 7th millennium B.C., endless interbreeding has produced varieties of barley of almost every conceivable morphological composition, adapted to the most varying climatic and ecological conditions. For example, there are two-row and six-row spikes with hulled or naked kernels of many different colors, some as dense as Club wheat, some as lax as Spelt, having florets with exaggerated development of the glumes, or with a trifurcate appendage in place of the awn; even freak spikes with a branching axis exist. *Hordeum spontaneum* grows only in the area indicated in Fig. 1 and in western North Africa, while barley is cultivated almost from the Equator to the North Cape, and from Japan to Ireland, as well as in huge areas in the two Americas and in Australia, and at elevations from 1100 feet below sea level, at the Dead Sea, to some 12,000 feet above the sea in the Himalayas. The naked forms did not emerge along the hilly flanks of the river basins of southwestern Asia and were never grown there; they appear at such widely dispersed places that it must be taken for granted that they have appeared independently in response to ecological pressure. We find them cultivated today in Abyssinia, central Asia, and the Far East, and in prehistoric finds the naked forms appear in Turkey (*20*) and in western and northern Europe and Scandinavia, but not in Egypt (*29*), the nuclear arc of southwestern Asia, Italy, or Switzerland. The same applies for the dense-eared form of six-row barley. It does not appear in the Mesopotamian plain, but there is evidence of it in the Fayum find in Egypt. The earliest occurrence of dense-eared, six-row barley is probably the Mersin find (*30*), but unfortunately this find is not precisely stratified, although it may be considered to belong to a level not later than the Hassuna period (about 5750 B.C.). Whether it emerged directly from the cultivated two-row form or by way of the six-row lax-eared form is not clear, but certain anatomical features support the former alternative.

Here again we need evidence from the mountainous parts of Asia Minor. In Europe, dense-eared barley is characteristic of the subalpine area, while it seems to be lacking in the plains and in the northern and western coast lands (*14, 31*). To judge by its present-day distribution, dense-eared barley might be described as a mountain form.

This is, very briefly, the story of plant domestication compiled on the basis of first-hand study of the actual remains of the ancient plants of a large portion of the Old World. But it is by no means the whole story. Undoubtedly, the possession of domesticated wheat and barley were the principal factors in the

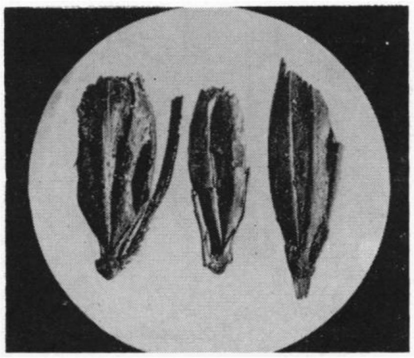

Fig. 7. Carbonized triplets of two-row barley from Jarmo (× 4).

immense expansive power of the first agrarian cultures in the Near East and later in Europe, but many other plants were forced into subservience to feed the increasing millions of mankind.

Other Food Plants

The domestication of weed grasses took place at later periods and far from the centers of natural distribution of these grasses (*3*). Thus, rye and oats were introduced into Europe as weeds in the wheat fields—rye probably from western central Asia and oats from the Near East or Eastern Europe. Oats attained the status of a crop plant during the 1st millennium B.C., and rye was brought into secondary domestication in Central Europe shortly before the birth of Christ. Broomcorn millet appears for the first time about 3000 B.C. in Jemdt Nasr in Mesopotamia (*11*); although it does not seem ever to have achieved any great importance in the Near East, it rose to a high level of importance in the Far East, while in Europe it was widely cultivated about 2000 B.C. (*32*). The progenitor of broomcorn millet is not known, whereas another useful member of the genus, Italian millet, is considered to be the straight-line descendant of the wild green millet, *Setaria viridis.*

The pea family also added considerably to the stock of domesticated plants. In Jarmo we already find evidence of the use of field pea (Fig. 8), lentil, and blue vetchling for food, although we cannot claim that they were deliberately cultivated at that time. Fourth-millennium, B.C., finds in Egypt demonstrate the presence of lentil, and Swiss deposits of the 3rd millennium contain pea and blue vetchling, while lentil is encountered in several localities in Hungary. The horse bean appears around the Mediterranean during the 3rd to 2nd millennium B.C., and later it spread to most of Europe, arriving in Britain in the late 1st millennium B.C. Chick-pea, which today is a much-cultivated plant in southern Europe and western and central Asia, occurs in Palestinian finds of the 4th millennium or possibly even earlier (*20, 33*).

All the plants discussed above are useful principally because of their content of starch, but vegetable oil also has always been highly valued as human food. From the Jarmo find and other evidence it appears that oil-bearing food was easily secured by gathering the fruit of wild trees—acorns and pistachios in the Jarma area and, in other regions, hazelnuts, acorns, and olives. Moreover, the early agriculturalist found the wild species of the flax genus, *Linum bienne,* which he domesticated. As early as the 5th millennium B.C. the definite and highly useful species, *L. usitatissimum,* was grown in the foothills of the Kurdish mountains (*11, 34*) as well as on the alluvial plains of Mesopotamia (*11, 35*) and Egypt (*19*).

While in the foothills the seeds were rather small, the linseeds from the plains attained an increasingly larger volume as time passed. It seems as if this development was associated with irrigation. The plant also spread to Europe, and it is found in habitation sites in Switzerland of the early 3rd millennium B.C. Here, however, the seeds were of the same size as those grown in the foothills of Kurdistan some two millennia earlier (*36*). Furthermore, the existence of Neolithic flax in Spain, Holland, and England has been established.

Since we find the earliest traces of cultivated flax in the same general region in which wheat and barley were domesticated, at a period much earlier than that of the Swiss pile dwellings, and since the wild flax, *L. bienne*, is abundantly distributed in this same region as a winter annual (like the Neolithic Swiss variety), it is reasonable to conclude that the Swiss flax was part of the agricultural assemblage introduced, presumably by way of the Danube basin, from the Near Eastern nuclear area.

This view is not new. It has already been presented by Heer, De Candolle, and Könicke. Neuweiler's concept, that the pile-dwelling flax was derived from the native Swiss wild species, *L. austriacum,* can be shown anatomically to be untenable. The recent archeological findings in Iraq form the final link in the chain of evidence (*37*).

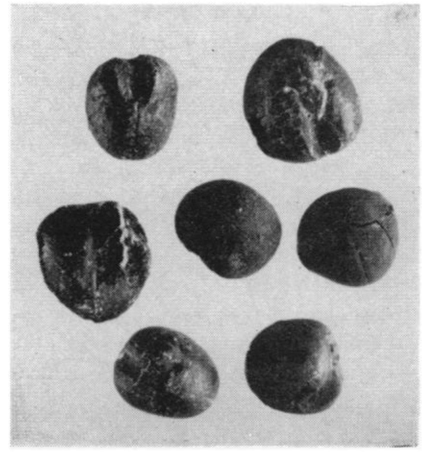

Fig. 8. Carbonized seeds of field pea from Jarmo (× 4).

The wine grape, which is naturally distributed in mountainous forests in certain parts of the Near East, was cultivated in the 4th millennium B.C. or earlier. Traces of this plant are dispersed and rare, and it is too early as yet to tell its story (*20, 38*). Olive and date also are encountered in Palestinian (*20*) and Egyptian finds, respectively (*39*), of the 4th millennium B.C., but both species may be supposed to have been exploited and even domesticated at an earlier time. Although apple, pear, cherry, fig, olive, and wine grape were naturally distributed in various parts of Europe, we have no evidence of their cultivation west of Greece until the 1st millennium B.C., and particularly in Roman times. Indeed their fruits were exploited from very early times, but it seems as though the idea of orchard husbandry and viticulture (*40*) was introduced from the East, together with domesticated varieties of the species.

Even from this brief sketch it will be clear that the actual and well-dated plant remains of the prehistoric and early historic past—be they in the form of mummified or carbonized material or imprints in baked clay—are of the greatest interest to both the cultural and the natural historian, and thus to science generally. The cultural historian seeks to know the economic background for the achievements and migrations he is able to visualize through his excavations, and in its ultimate definition, economy means food. The botanist is anxious to know whence the cultivated plants came, how long a time it took them to develop their present form and the physiological qualities which differentiate them from the wild species, how this development came about, and, not least, from which wild plants or combinations of plants the domesticated forms descended. By keeping a meticulous record of stratification, modern archeology has means by which to tell the date of plant material, and by specialization the botanist will, in the long run, learn to identify the battered remains of the plants. Thus, by joining hands, the two sciences establish a third, paleoethnobotany, which endeavors to help delineate man's victories and defeats in his battle against nature for survival and multiplication, and to unravel the complicated history of the plants upon which even modern civilization is ultimately dependent.

References and Notes

1. R. J. Braidwood, *Yearbook of the American Philosophical Society* (1955), p. 311.
2. J. Iversen, *Danmarks Geol. Undersøgelse II* (1941), p. 66.
3. Primary domestication involves specific and conscious attention to a wild plant in its natural habitat; secondary domestication is the segregation, for intentional cultivation, of a weed growing in cultivated soil which already unintentionally has been subjected to a process of selection through being reaped along with the intended crop. In the cases of rye and oats, this segregation occurred far from their centers of natural distribution; by comparison, barley is secondary only insofar as human intention is concerned, not in respect to habitat.
4. Barley might have been selected for domestication in any place from Central Asia to the Atlantic, but since we know of no ancient culture based upon barley alone, and since evidence of domesticated wheat distinguishes that portion of the wild-barley area in which incipient agriculture has been established archeologically, the conclusion is inevitable that wheat was the species that caused man to attempt plant domestication in the first place.
5. R. J. Braidwood, *Bull. Am. Schools Oriental Research* 124 (1951).
6. ———, *The Near East and the Foundations for Civilization* (Univ. of Oregon Press, Eugene, 1952).
7. ———, *Science* 127, 1419 (1958).
8. ———, *Antiquity* 31, 73 (1957), and K. M. Kenyon, *ibid.* 31 (1957); but see 7 and F. E. Zeuner, *Palestine Exploration Quart.* 55 (1958).
9. H. Helbaek, *Ann. Repts. Inst. Archaeol. Univ. London, Rept. No. 9* (1953), p. 44; ———, in R. J. Braidwood *et al.*, in preparation.
10. R. J. Braidwood *et al.*, *J. Near East Studies* 11, 1 (1952).
11. On behalf of the Oriental Institute of the University of Chicago and the Iraqi Government I undertook, in 1957–58, an investigation of traces of early plant husbandry in Iraq. Relevant pottery and carbonized material were examined in European museums and in the Iraq Museum in Baghdad, and field investigations were carried out in numerous sites of ancient cities in lower Iraq, from Aqer Quf, north of Baghdad, to Ur and Eridu in the south. Throughout this article reference is made to the main results of this project. See also T. Jacobsen and R. M. Adams, *Science* 128, 1251 (1958).
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16. O. Heer, *Die Pflanzen der Pfahlbauten* (Zürich, 1865).
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18. W. U. Guyan, *Das jungsteinzeitliche Moordorf von Thayngen-Weier; Das Pfahlbauproblem* (Schaffhausen, 1954).
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20. H. Helbaek, unpublished investigation.
21. ———, in O. Tufnell *et al.*, "The Bronze Age," *Lachish IV* (Oxford Univ. Press, London, 1958).
22. ———, *Arboger for Nordisk Oldkyndighed* (1954), p. 198.
23. See, for exam J. R. Harlan, *Sci. Monthly* 72, 87 (1951) and *Am. Naturalist* 85, 97 (1951), on the great diversity and rapid evolution of plants in Turkey.
24. E. Neuweiler, *Vierteljahresschr. naturforsch. Ges. Zürich Beih.* 100 (1956).
25. H. Helbaek, *Acta Archaeol.* 13, 97 (1952).
26. V. L. Täckholm and M. Drar, *Flora of Egypt* (Cairo, 1941), vol. 1.
27. I except here, of course, the concept of F. Koernicke that the wild *H. spontaneum* was the progenitor of all cultivated barley, a proposal which has been consistently rejected. See the brief survey of theories regarding the derivation of barley in E. Aberg, *Symbolae Botan. Upsaliensis* 4 (1940).
28. N. Nybom, *Acta Agr. Scand.* 4, 430 (1954).
29. Many reports on Egyptian grain postulate the occurrence of naked barley in prehistoric and dynastic deposits. No documentation has ever been published, and according to my experience, which includes examination of many grain finds, the postulate is unfounded.
30. I examined a sample of the barley from Mersin at Reading University and found it to be a small-grained hulled form of *H. hexastichum.* Its date, as pronounced by V. Gordon Childe, who brought the sample back from Mersin, was "well into the fourth millennium, probably earlier."
31. *H. hexastichum* has very often been reported for northern European prehistoric grain finds; most of these "reports" are manifestly unjustified.
32. F. Netolitzky, *Kaisl. Akad. Wiss. Wien* 123, 1 (1914).
33. Because of a protruding hilum and radicel point, the seeds of this species suffer rather more than most in the carbonized state and are therefore in many cases not recognizable in prehistoric material.
34. Arpachiyah, Halafian period.
35. Ur, Early Ubeidian period.
36. H. Helbaek, *Kuml* (Aarhus, 1959).
37. H. Helbaek, in preparation.
38. ———, appendix to P. J. Riis, "Hama, les cimetières à crémation," in *Nationalmuseets Skrifter* (Copenhagen, 1948), pp. 205–207.
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Age of Sex-Determining Mechanisms in Vertebrates

Distribution of differentiation patterns indicates the evolutionary path of genes and chromosomes.

Emil Witschi

In vertebrates hermaphrodism may occur as an exceptional condition. However, as a rule the production of eggs and sperm is separately managed by female and male individuals. In most species the basic sex ratio—that is, the proportion of males and females unaffected by differential mortality or selection—is close to equality. It has been shown that this balance is maintained by a self-perpetuating genetic mechanism. One of the sexes produces two types of germ cells—female-determining and male-determining ones; this is the digametic sex. The two types of gametes are produced in equal numbers because they result from a difference in genic content between partners of a single pair of chromosomes, the sex chromosomes or heterochromosomes. Geneticists designate the condition of somatic cells and of primary gonia that have uneven pairs of chromosomes or genes (hereditary factors) as heterozygoty. *Hence, the digametic sex is also heterozygous.* It produces two types of gametes in equal numbers, because the unequal chromosome pairs become mechanically segregated during a maturation division, each gamete receiving one or the other of the partners. The other sex produces only one type of gamete. It is unigametic, because the sex-chromosome pair of its gonia consists of even partners, which are the equal of one only of the heterochromosomes of the digametic sex.

To understand this article it is important to realize that this genetic and chromosomal mechanism of sex determination occurs in two patterns, depending on which sex is the heterozygous and digametic one. If, as in man (or the opossum) this is the male, then one designates the partners of the hetero-

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