

The Origin and Early History of the Cultivated Barleys

A BOTANICAL AND ARCHAEOLOGICAL SYNTHESIS

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ALTHOUGH it may never be possible to determine exactly the time, place, and circumstances of the original domestication of the primary temperate cereal crops, the available evidence suggests that this took place in south-western Asia not long after the end of the Pleistocene period. Here, in the favourable environment of the flanks of the Zagros-Taurus mountains,¹ grew the large-grained annual grasses which became the progenitors of the cereal wheats and barleys. Amongst these was the wild two-rowed barley, *Hordeum spontaneum*, from which the first cultivated barleys were undoubtedly derived, but whether this single species could have given rise to the vast array of existent barley cultivars, or whether more than one ancestral form must be postulated, has long been the subject of speculation. During the last thirty years, both botanical and archaeological research has been directed towards the solution of this problem and it is proposed in this paper to collate the accumulated knowledge from both sources in an attempt to design for the cultivated barleys an acceptable phylogenetic scheme. To be tenable this must be supported by clear and irrefutable evidence and all suppositions based on inadequate data must be discarded. Botanical theories must be confirmed by the results of archaeological investigation and any discrepancy between the two must be interpreted as an indication of the inaccuracy of one or the other. In this way it may be possible to outline an evolutionary sequence which truly represents the origin and early history of one of the world's most important crops.

The cereal barleys and the barley grasses belong to the genus *Hordeum* of the grass tribe Triticeae. This tribe is characterized by its inflorescence which is a true spike in which *sessile* (stalkless) or sub-sessile spikelets² are

¹ Robert J. Braidwood and Gordon R. Willey (eds.), *Courses towards urban life*, Viking Fund Publications on Anthropology, no. 32, 1962.

² The spikelet is the unit of structure of the grass inflorescence. It consists typically of a short axis (*rachilla*) on which is borne a pair of chaffy protective bracts (the *glumes*), within which are one or more florets. Each floret has a further pair of bracts (the *lemma* and *palea*), two small scale-like structures (the *lodicules*), usually three stamens, and a pistil consisting of a single ovary, two styles, and two feathery stigmas. The ovary ripens a single seed, the thin outer

borne alternately on opposite sides of the rachis (inflorescence axis). The spikelets are arranged so that the edges of the glumes are adjacent to the axis, i.e. in the manner of the couch-grasses and not that of the rye-grasses. There is a further division of the tribe into the sub-tribes Triticineae and Hordeinae, both of which contain cereal species of great economic importance. In the Triticineae, to which wheat and rye belong, the sessile spikelets are borne *singly* at each node of the rachis while in the Hordeinae there is *multiple* insertion of sessile or sub-sessile spikelets at each node. To this sub-tribe belong the grass genera *Elymus*, the lyme-grasses of the temperate regions of the northern hemisphere, *Sitanion*, the squirrel-tail grasses of drier areas in the western states of North America, and *Hordeum*, the cereal barleys and barley-grasses, of which wild species are found in the temperate regions of both hemispheres. Whereas in *Elymus* and *Sitanion* the spikelets are two- or more-flowered, those of *Hordeum* are always one-flowered and are inserted in groups of three (the triplet of spikelets) at each node of the rachis.

It is usually considered that there are at least four distinct sections of the genus *Hordeum* of which three contain the agriculturally unimportant annual and perennial barley-grasses while the fourth, the Cerealia section, embraces the cultivated barleys and the large-grained wild forms obviously related to them. A strong indication that this section is phylogenetically distinct from the other three is given by the fact that no natural hybrids between the barley-grasses and the cereal barleys are known and artificial hybrids between them are almost impossible to obtain. Furthermore, while a polyploid series of diploid, tetraploid, and hexaploid species exists within the barley-grasses, all the cereal barleys are diploid annuals ($2n=14$) and their further classification is based not on chromosome number but on morphological variations in the ear. In *Hordeum spontaneum*, the wild brittle-eared¹ two-rowed barley, and in all forms of *H. distichon*, the cultivated tough-eared two-rowed barley, only the median spikelet of the triplet is fertile and ripens grain. This *heterospiculate* condition is shared with the true barley-grasses and seems natural to the genus. In the doubtfully wild *H. agriocrithon*, to which reference will be made later, and in all the cultivated barleys of the *H. vulgare* aggregate (the many-rowed barleys²) all three spikelets are fertile. It is with coat of which is fused to the ovary wall. This resultant specialized, indehiscent fruit is known as the *caryopsis* or grain and is the characteristic feature of the grass family, Gramineae. The whole grass inflorescence shows adaptation to wind pollination.

¹ The brittle ear, in which the triplet of spikelets is shed at maturity, is a wild characteristic. Had the mutation from the brittle to the tough condition not occurred, man would never have been able to harvest the barley crop.

² The distinction between four- and six-rowed barleys is of little botanical significance. All

the origin of this *isospiculate* condition that the barley evolutionists are most concerned.

Comparative morphological studies appear to indicate that development within the tribe Triticeae has taken place by reduction, and the situation within the Cerealia section of the genus *Hordeum* can be interpreted as a further manifestation of this tendency. The "intermedium" barleys (*H. intermedium*) cultivated in Tibet and China, in which the lateral spikelets, although fertile, show morphological differentiation and ripen a smaller grain can be looked upon as reduced forms of *H. vulgare*. Further reduction leading to loss of fertility of the lateral spikelets would result in the two-rowed *H. distichon* and the final stage would be reached in the highly specialized endemic two-rowed barley of Abyssinia, *H. deficiens*, in which the whole lateral spikelet is vestigial. If one accepts this view then evolution within the group must have proceeded from the six- to the two-rowed condition and the wild two-rowed *H. spontaneum* is eliminated as a possible ancestor of the cereal barleys.

In the absence of more concrete evidence, this type of reasoning is extremely beguiling and leads directly to the postulation that there must have existed at one time, or perhaps even still exists, a primitive brittle-eared six-rowed wild barley from which all others were derived. In 1926, the Russian botanist, Vavilov, had suggested that the centre of origin of a species of cultivated plant is that geographic region where today the greatest number of genetic varieties is to be found. On this basis such a centre of origin for the six-rowed barleys could be identified in south-eastern Asia, including China, Tibet, and Nepal. Here were to be found not only the "*intermedium*" barleys but various fully six-rowed forms including those with short-awned or awnless ears, naked grains¹ and hooded lemmas.² Furthermore, until less than a hundred years ago, only six-rowed barleys were cultivated in the vast agricultural area east of the Hindu-Kush. It seemed likely, therefore, that if a wild six-rowed barley still existed it would be discovered somewhere in south-eastern Asia.

The upholders of this point of view had not long to wait. Amongst the cereal material brought back by the Swedish Expedition to Eastern Tibet in many-rowed barleys are, in fact, six-rowed but a four-rowed condition is simulated when the spike is lax.

¹ As the barley grain ripens, a mucilaginous substance is secreted by the outermost layer of the pericarp (the ovary wall) which, as it dries out, glues lemma and palea to the developing fruit. In the naked barleys there is no such secretion and the grain threshes out freely as in wheat.

² In the hooded barleys the awn is replaced by a trilobed appendage for which there is no parallel in any other grass. This hood often carries an accessory spikelet.

1934, two grains of a hulled barley were detected in a sample of naked, six-rowed cultivated barley from Taofu near to the frontier of Szechuan. On germination these gave rise to a six-rowed hulled barley with a brittle rachis quite unlike the naked, tough-eared, cultivated barleys of Tibet. This unique form was described as a new wild species by Åberg¹ in 1940 and named *Hordeum agriocrithon* Åberg. Later its existence was confirmed by the German Tibet Expedition (1938-9) which brought back five samples of grain said to have been obtained from the market in Lhasa, 1,200 km. south-west of Taofu. Finally, among the cereal grains collected by the British Museum Expedition to Tibet (1949), Elisabeth Schiemann² identified not only *H. agriocrithon* but a second brittle-eared hulled form with reduced but fertile lateral spikelets morphologically similar to *H. intermedium*. To this she gave the name *Hordeum paradoxon* Schiem. and the status of a third wild species.

If one accepts, as did Åberg and Schiemann, the authenticity of *H. agriocrithon*, then it is possible to postulate the derivation from it, by a series of mutations and subsequent hybridizations, of the whole range of known barley forms. Between 1940 and 1955,³ stimulated by the new finds, many phylogenetic schemes for the Cerealia barleys were published in which *H. agriocrithon* was named not only as the progenitor of the six-rowed cultivated barleys but also of the wild two-rowed *H. spontaneum*. The two-rowed cultivated barleys were then either derived from the cultivated six-rowed (the monophyletic theory of the origin of the cultivated barleys) or, alternatively, from the wild two-rowed (the diphyletic theory of origin). It was inevitable that arguments should develop as to which of the two schemes was the more likely, but no one doubted that the starting-point of them both was the new wild six-rowed Tibetan barley, *H. agriocrithon*.

Unfortunately, it soon became evident that this enthusiasm was premature. The new form had never been found in a truly natural habitat, but only in association with cultivated crops. In many of its characters it was less primitive than *H. spontaneum*, and, as the six-rowed condition is recessive to the two-rowed,⁴ it was realized that even this character was more likely to be derived than ancestral. In 1947, the Russian cereal botanist, Bakh-

¹ E. Åberg, 'The Taxonomy and Phylogeny of *Hordeum* L. sect. Cerealia Ands. with special reference to Tibetan Barleys', *Symbolae Botan. Upsaliensis*, 4, 1940, p. 1.

² E. Schiemann, 'Neue Gerstenformen aus Ost-Tibet und ein weiterer Fund von *Hordeum agriocrithon* Åberg', *Ber. D. Bot. Ges.*, 64, 1951, p. 56.

³ For a clear exposition of the early work, see G. Staudt, 'The Origin of Cultivated Barleys: A Discussion', *Economic Botany*, xv, no. 3, p. 205.

⁴ F. Kh. Bakhteyev, 'Experimental data on the mode of inheritance of certain taxonomic characters in *Hordeum spontaneum*', *Genetica*, Moscow, 1965.

teyev,¹ in a paper entitled "Is *Hordeum agriocrithon* Åberg a species?" reported that he had failed to find any differences between this "species" and plants which he detected amongst the offspring of artificial hybrids between *H. spontaneum* and *H. vulgare*. Some years later Kamm² drew attention to the presence in Israel of a range of brittle six-rowed barleys among which forms morphologically identical with *H. agriocrithon* and *H. intermedium* occurred. Some of these remained constant in cultivation while others segregated for several of the diagnostic features which separate *H. agriocrithon* from *H. spontaneum* and *H. vulgare*. His observations were confirmed by Zohary³ who commented upon the almost exclusive association of these *agriocrithon*-like forms with natural hybrid swarms between the wild two-rowed and the cultivated six-rowed, which occurred wherever the parental species came into contact. He also pointed out that whereas the very specialized dispersal unit (the mature triplet) of *H. spontaneum* was extremely efficient and accounted for the high competitive ability of the wild two-rowed barley, that of *H. agriocrithon* was so constructed that the survival of this species in the wild was practically impossible. Only as a close associate of cultivated crops could it ever be perpetuated. Furthermore, except for the cultivated *vulgare* barleys which were not dependent upon efficient natural dispersal mechanisms for their continuance, all the barley grasses were disseminated by means of dispersal units of the *H. spontaneum* type. The indication is that this feature is natural to the genus and that the splayed-out triplet carrying three fertile grains is a lethal modification which in nature would lead to the elimination of forms possessing it. Under these circumstances it seemed unrealistic to consider seriously the possibility of the derivation of the cultivated barleys from a six-rowed ancestor.

The alternative view, that all forms of cultivated barley are directly descended from the wild two-rowed barley, also encounters difficulties. It has been established that the brittle ear of the wild barleys is dependent on the interaction of two complementary dominant genes *Bt* and *Bt*₂,⁴ and that both *H. spontaneum* and *H. agriocrithon* have in this respect the same genetic constitution. The tough-eared condition of the cultivated barleys, on the other hand, is produced by either of the recessive alleles *bt* and *bt*₂. The

¹ F. Kh. Bakhteyev, 'Is *Hordeum agriocrithon* Åberg a species?', *Doklady Acad. Nauk. U.S.S.R.*, LVII, 1947, p. 195.

² A. Kamm, 'The discovery of wild six-rowed barley and wild *Hordeum intermedium* in Israel', *Ann. Agr. Coll. Sweden*, 21, 1954, p. 287.

³ D. Zohary, 'Studies on the origin of cultivated barley', *Bull. Res. Council of Israel*, 9D, 1960, p. 21.

⁴ I. J. Johnson and E. Åberg, 'The inheritance of brittle rachis in barley', *J. Am. Soc. Agr.*, xxxv, 1943, p. 101.

Japanese cereal geneticist, Takahashi,¹ investigated the geographical distribution of the possible genotypes. He collected upwards of twelve hundred strains of cultivated barley from many parts of the world and subjected them to genetic analysis. The results were remarkable. Almost without exception the two-rowed barleys from the occidental region of the Old World were of the *bt bt Bt₂ Bt₂* type (Type W) whereas six-rowed barleys from the oriental region were predominantly *Bt Bt bt₂ bt₂* types (Type E). Any divergence from this simple relationship could be explained by hybridization at points where the different genotypes were brought into contact. As *H. spontaneum* has never been found wild east of the Hindu Kush mountains, and as two-rowed cultivated barleys were not introduced into the orient until about ninety years ago, it could be concluded that the two-rowed and six-rowed barleys have followed different evolutionary paths which have been, from the beginning of their history, genetically and geographically distinct.

This argument was, however, countered by Zohary² who strongly believes that *H. agriocrithon* is not a wild form but only a secondary hybrid derivative. That *H. spontaneum* has not yet been found in Tibet is not a valid objection to this view for, as he points out, botanical exploration in this region has been extremely limited. To Zohary, the demonstration by Takahashi that the east-Asiatic barleys are predominantly Type E, while west of the Hindu Kush the cultivated barleys are mainly Type W, does not necessarily imply a diphyletic origin for the cultivated barleys. Both mutations to the non-brittle condition could have occurred in *H. spontaneum* in western Asia and both could have been picked up independently by the early agriculturalists. The fortuitous introduction of Type E into the orient in already cultivated six-rowed forms, for which there seems to have been a distinct regional preference, would, according to Zohary, account for its presence there now. It is necessary to point out, however, that he gives no satisfactory explanation of the apparent restriction of Type W two-rowed barleys to the occidental region, nor is there any proof for his suggestion that there is a relatively higher selective value to the *bt₂* gene when it occurs as part of the six-row genotype.

Recent researches by Takahashi³ and his co-workers have demonstrated further geographical regularities in genotype distribution. Hiura⁴ has shown

¹ Ryuhei Takahashi, 'The Origin and Evolution of Cultivated Barley', *Advances in Genetics*, VII, 1955, p. 227.

² Zohary, *op. cit.*, p. 41.

³ Ryuhei Takahashi, 'Further studies on the phylogenetic differentiation of cultivated barley', *Barley Genetics I, Proc. of the First International Barley Genetics Symposium*, Wageningen, 1963, p. 19.

⁴ U. Hiura, 'Genetic studies of the resistance of barley varieties to powdery mildew', Ph.D. thesis, Ohara Institute for Agricultural Biology, 1959.

that practically all barleys in the oriental region are susceptible to barley mildew (*Erysiphe graminis forma hordei*) Race I, whereas those occurring in the occident include a high proportion of resistant or medium-resistant forms. Although the genetics of disease resistance in barleys is complex and cannot be discussed in detail here, Hiura has been able to deduce from his experimental data that all Type E barleys lack the genes for resistance to mildew Race I, while most Type W forms carry one or more resistance genes. Evidence of a similar regularity in the geographical distribution of the genes controlling the winter and spring habits and of those determining the length of hairs on the rachilla has also been obtained. The situation governing these regularities has been analysed by Takahashi¹ who strongly maintains that they are not compatible with an evolutionary theory for the origin of the cultivated barleys which derives all *Cerealia* barleys from the same source. He concedes the strength of Zohary's doubts concerning the wild status of *H. agriocrithon* but still cannot reconcile the genetic and phytogeographic evidence with a monophyletic theory of origin. In his paper contributed to the First International Barley Genetics Symposium in 1963, to which reference has already been made, he tentatively suggested that the apparent contradictions in the botanical evidence could only be explained by postulating *two* distinct introductions of wild two-rowed barley into cultivation separated from one another by a considerable period of time. These could have instigated two entirely independent evolutionary lines, one deriving the tough rachis from the mutation of the dominant *Bt*₂ gene to the recessive condition, and the other from the mutation of the complementary *Bt* gene. From the former, the ancient two-rowed barleys and the whole range of six-rowed forms could have stemmed, while from the latter the more recent two-rowed barleys of agriculture could have been derived. One could then accept the hybrid nature of *H. agriocrithon* and discard completely the claim of this species to be an ancestral type.

As it is impossible to test the validity of such a theory by botanical methods, it is proposed to examine it here in the light of the results of archaeological and historical research. For the first time one is able to do this with some degree of confidence. Not only has one faith in the accuracy of the more recent identifications of botanical material recovered from archaeological sites but improved methods of dating have made possible the establishment of reasonably reliable chronological sequences. Furthermore, it has at last been realized that it is essential for an archaeological field team² to include

¹ Ryuhei Takahashi, *op. cit.*, *Barley Genetics I*, p. 25.

² The example was set by Professor Robert J. Braidwood of the Oriental Institute of the University of Chicago who included Hans Helbaek as botanist, Charles A. Reed as zoologist,

natural scientists amongst its members. The task of identifying recovered botanical and zoological material is made very much easier if it is seen, immediately it is exposed, in its correct archaeological context and against the ecological background of the excavation. Much valuable information from important classical sites has been irretrievably lost because of failure in the past to appreciate the necessity of careful handling and expert examination on the spot. Equally essential is the meticulous recording of relevant data and subsequent storage under such conditions that, if necessary, the material can be re-examined and reassessed with confidence.

It is a reasonable supposition that the introduction of wild plants into cultivation would take place within the area of their natural distribution. Although it will never be possible to delineate exactly the boundaries of the habitat zone of the ancestral forms of wheat and barley at the time of their domestication, certain deductions can be made. Today the wild two-rowed barley, *H. spontaneum*, grows at altitudes up to 2,000 m. above sea level throughout a wide crescentic area in western Asia. This embraces Turkey, Iraq, Transcaucasia, Syria, Israel, Jordan, and Northern Arabia, with an easterly extension into Afghanistan. In spite of reports which appear from time to time, there are no authentic records of its having been found wild on the African continent. The wild emmer wheat, *Triticum dicoccoides*, on the other hand, is much more restricted in its distribution, although its habitat area falls within that for *H. spontaneum*. As it is likely that the two species were domesticated simultaneously, for barley and wheat are invariably found together at sites of early agriculture, it can then be inferred that this domestication took place within the area of distribution common to both. This, according to Helbaek,¹ comprises the western foothills of the Zagros mountains (Iraq-Iran), the Taurus (Southern Turkey), and the Galilean uplands (Northern Israel), a region characterized today by the diversity of its terrain and the comparatively high winter rainfall.

From what is known of the climatic conditions of the immediate post-glacial period in western Asia,² Butzer³ has constructed a map in which he

and Herbert E. Wright as geologist in his team excavating the neolithic village of Jarmo in Iraqi Kurdistan in 1955.

¹ Hans Helbaek, 'Domestication of Food Plants in the Old World', *Science*, xxx, no. 3372, 1959.

² For an account of current investigations into the climatic conditions which obtained at the time when cereals were introduced into cultivation and animals domesticated, see Herbert E. Wright, 'Climate and Prehistoric Man in the Eastern Mediterranean', in *Prehistoric Investigations in Iraqi Kurdistan*, ed. R. J. Braidwood and Bruce Howe, Chicago University Press, 1960.

³ Karl W. Butzer, *Environment and Archaeology*, London, 1965.

relates the location of early agricultural and proto-agricultural sites (c. 9000–5750 B.C.) to vegetational zones. If one were to superimpose upon this map the common area of distribution of the potential cereal domesticates, one would see that this lies entirely within the zones of deciduous mixed forests and sub-tropical woodlands, i.e. within the winter rainfall belt, and coincides exactly with the area within which the known sites of incipient and early agriculture occur. It is also interesting to note in this connection that Sauer,¹ in considering agricultural origins in the Near East, argued that because of the difficulty of cultivating a heavy and continuous sod with primitive implements, woodland rather than grassland offered the most suitable environment for the beginning of cereal cultivation. It is, therefore, possible to conclude that when man had reached the stage of his cultural development at which it was inevitable that he should start to cultivate plants, he found, growing around him, in conditions not very different from those existing today, the large-grained² cereal grasses which were to become the ancestors of the modern wheats and barleys.

The first indications of conscious agriculture in western Asia are to be found at the sites of "incipient cultivation" with radio carbon³ dates of around 9000 B.C., i.e. a date very close to that accepted as the boundary line between the Pleistocene and the Holocene. From sites such as Karim Shahir and Zawa Chemi in the Kurdish foothills and Natufian sites such as Mount Carmel and Mallaha in Central Palestine assemblages including milling stones, pestles and mortars, and flint-set sickles have been uncovered. These seem to point directly to the reaping of wild or cultivated grasses and their subsequent use as food. Although their occurrence together is suggestive, one must be very wary of jumping to conclusions, for each of these tools is known to have been used in prehistoric times for purposes other than agriculture. In fact, the sickle, which may have been an efficient means of cutting reeds or grasses for mats or bedding, is a most unsuitable instrument for the harvesting of wild grasses. At a touch from such an implement the fragile ears would shatter and the grain would be shed. It would be much more easily caught by beating it into a basket. In India, today, the wild rice,

¹ C. O. Sauer, *Agricultural Origins and Dispersals*, American Geographic Society, New York, 1952.

² The present writer recently had the opportunity of examining ears of wild two-rowed barley and wild emmer wheat which had been collected in Eastern Galilee in May 1966. The large size of the mature grain was their most striking feature and one can easily understand how early man would be attracted to such an obvious and easily obtainable source of food.

³ The limitations of the radio-carbon dating techniques are realized, but they do make it possible to establish comparative chronologies. The dates quoted in this paper are approximations to the nearest 250 years.

Oryza fatua, is harvested by the tying together of the awns of the unripe spikelets. These are shed at maturity and the little bundles are quickly and efficiently collected from the ground. The present writer has very successfully retrieved the grains of the wild two-rowed barley in this manner and, if this were indeed the practice in the past, it could be argued that the presence of the sickle indicated either that the grasses were being gathered for their straw or that the mutation to the tough-eared condition had already taken place. Unfortunately, no plant remains have been identified from any of these early sites. All that one can say is that, at the time when they were occupied, *Hordeum spontaneum* and *Triticum dicoccoides* would be easily available wild grasses.

Two thousand years later, the picture had changed completely. Excavations at Jarmo¹ under the directorship of Professor Robert J. Braidwood have revealed the existence in the seventh millennium B.C. of fully developed village farming communities situated in the foothills of the Kurdish mountains. Jarmo (radio carbon dating $\pm$ 6750 B.C.) lies at an elevation of 2,500 ft on a grass-covered, silt-floored plain in a hollow between limestone and gravel hills. That the area was tree-covered in the past is shown by the recovery of a considerable amount of oak charcoal. The Jarmo plant material was examined with great care by Hans Helbaek² and his findings are of supreme importance in the present context. Amongst the carbonized grains and the imprints in baked clay he was able to recognize not only the wild einkorn and emmer wheats (*T. boeoticum* and *T. dicoccoides*) which normally still grow together in the vicinity of the site, but also an emmer wheat bearing the stamp of a fully domesticated form. He considers this to represent an early stage in the evolution of the cultivated emmer (*T. dicoccum*). Of even greater interest are the results of his examination of the Jarmo barley which made up the bulk of the cereal finds. The kernels were hulled, straight, and unwrinkled, and some of the recovered specimens consisted of the median fertile spikelet to which the sterile lateral spikelets still adhered. These laterals were not sessile, as in the modern cultivated two-rowed barleys, but were borne on short but distinct pedicels as in *Hordeum spontaneum*. Although so similar morphologically to the wild two-rowed barley, the rachis, however, was tough and portions of the axis of the ear were found consisting of two or three internodes still attached to one another. Helbaek considers this to be "an unambiguous indication of domestication" for such plants could not

¹ For a full account of the Jarmo investigations, see *Prehistoric Investigations in Iraqi Kurdistan*, ed. Robert J. Braidwood and Bruce Howe, Chicago University Press, 1960.

² Hans Helbaek, 'The Palaeoethnobotany of the Near East and Europe', in *Prehistoric Investigations in Iraqi Kurdistan*, 1960.

survive in the wild and could only perpetuate their kind through the agency of man. We thus know with certainty, that some nine thousand years ago, a two-rowed barley directly derived from the wild form was being cultivated in northern Mesopotamia. Other sites tell the same story. The "Jarmo" barley has been recognized amongst the plant material from Tepe Sarab (c. 6750 B.C.) lying 120 miles south-east of Jarmo, and a similar two-rowed barley abounds amongst the plant remains of Matarrah, Hassuna, and Mersin—three sites of lower altitude (750 ft) and later date (c. 5750 B.C.), but of essentially the same cultural complex as Jarmo. Nowhere was there the slightest sign of six-rowed barley.

At this point the archaeological story takes a striking turn. In 1957 Helbaek was given the opportunity of examining pottery and carbonized grain from a series of sites from Khabur in Northern Kurdistan to Ur in southern Mesopotamia. He found that, although in the northern foothills two-rowed barley was grown exclusively until later Halafian times (i.e. c. 4500 B.C.), at later dates evidence of the cultivation of a six-rowed barley began to appear.¹ Furthermore, in the area south of Baghdad, i.e. in the alluvial plains of the Tigris and Euphrates rivers, no traces of two-rowed barley occurred at all, but there was, on the other hand, convincing morphological evidence for the existence of a hulled, nodding, lax-eared, six-rowed barley. As colonization of lower Mesopotamia took place some time during the fifth millennium B.C. by peoples from the northern hill country who presumably brought their cereal crops with them, one is faced with the problem of determining the source of this six-rowed barley.

There is no necessity to presuppose an ancestral six-rowed wild form, for the change from the two-rowed to the six-rowed (i.e. from the heterospiculate to the isospiculate ear) is brought about by a simple mutation from the dominant to the recessive condition of a single gene.² Helbaek³ suggests that barley was sensitive to the sudden change in its ecology and that the mutation was induced by the move from the moist conditions of its mountain habitat to the hot plains of the lowlands where cultivation was only possible under irrigation. Whether this is so or not, it is certainly true that many researchers have reported similar changes in row number in experimental material as a result of the application of a wide variety of mutagenic agents.

¹ Helbaek considers this as an indication of a two-way traffic between the hill peoples and the settlers of the plains.

² Robert A. Nilan, *Cytology and Genetics of Barley*, 1951-1962, Monograph Supplement No. 3, Research Studies, Washington State University, xxxii, no. 1, 1964.

³ Hans Helbaek, 'Ecological effects of Irrigation in Ancient Mesopotamia', *Iraq*, xxii, 1960.

Of particular interest is the report by Seveluka,¹ that changes in the environment of the growing plants have induced the mutation from the two-rowed to the six-rowed state, but more information is needed before this can be accepted. It seems unnecessary, however, to invoke alteration in the environment as a causative agent. Mutations are genetic changes which, when they occur naturally in a population, provide the variation over which selection can act. Without them there can be no evolution. It is inconceivable that the simple mutation from the dominant to the recessive condition of the gene controlling the fertility of the lateral spikelets has not occurred spontaneously over and over again in the long history of barley. In the wild, as has been pointed out earlier, there would be strong selection pressure against the new six-rowed form, but under cultivation, it would be harvested and disseminated with the parent crop. The heavy ear, with its implications of a higher yield, would undoubtedly attract the attention of a primitive agriculturalist and, as barley is naturally self-fertilized, a homozygous strain which would breed true would be exceedingly easy to establish. If experiments² which showed that six-rowed barleys outyielded two-rowed when grown under irrigation, reflect a true difference between the two forms, then the preference for six-rowed barleys shown by the early farmers of Mesopotamia would be explained. Eventually, two-rowed would fall out of cultivation altogether, as it apparently did before the end of the fifth millennium B.C. Unfortunately, archaeological evidence covering this critical stage in the evolution of cultivated barley is almost completely lacking. The period of transition during which the two varieties must have been grown together is not represented at all in Mesopotamia. Even for the period immediately following the changeover, direct evidence for cereal cultivation is scarce, although from 3500 B.C. onwards the gap in the records begins to be filled by written and pictorial data. A beautifully decorated ritual bowl from Ur³ (c. 3000 B.C.) bears a repetitive design based on an ear of six-rowed barley and cylinder seals depicting the same cereal have been recovered from the sites of the Sumerian city states of the third millennium B.C. Significantly, no illustrations of two-rowed barley have ever been found. It was a long-forgotten cereal which was not to return to the fields of Mesopotamia until well into the Christian era.

From western Asia, following the routes of the great Neolithic migrations, agriculture spread southwards to Egypt, northwards and westwards through

¹ V. I. Seveluka, 'Observations on the variability of winter barleys in the foot-hill zone of the North Caucasus', *Izvest. Timiryazev. Sel'skokhoz. Akad.*, vi, 1957.

² *Barley Newsletter*, no. 2, 1958.

³ Leonard Woolley, *Excavations at Ur*, London, 1954.

Asia Minor to Europe and, eventually, east to the valley of the Indus. We know that by the middle of the fifth millennium B.C. wheat and barley were being cultivated at Fayum in Egypt and the results of the recent re-examination by Hans Helbaek¹ of the mummified² grain from its straw-lined grain pits is of great interest in the present context.

Wheat and barley are not native to Egypt and, therefore, one would not expect the "incipient" stage in their domestication to be represented. Instead at Fayum one finds an assemblage of cereal forms which seem to be in an active state of evolution. To Helbaek, this corresponds to the variability which must have existed in these crops when they were first exposed to the new habitat conditions of the Mesopotamian alluvial plains, a phase of their evolution in this region for which, as has been seen, no archaeological record as yet exists. In Helbaek's words "both six- and two-row barley are present; both varieties, the lax-eared as well as the dense-eared of the six-row form; remains of two-row spikes that correspond exactly to ancient and modern examples of the cereal, and even a further reduced form, *Hordeum deficiens*, in which indeed the glumes of the lateral spikelets are developed, but of the flowers practically nothing is left. The deposit represents the most complete sliding scale of all imaginable mutative changes except the naked form." He goes on to note the significance of the fact that in none of the later Egyptian finds, many of them perfectly preserved, is there any instance of the two-rowed, the "deficient," or the six-rowed dense-eared forms. As upon the Mesopotamian plains, only the six-rowed lax-eared forms survive.

Whether or not these circumstance represent, as Helbaek believes, the evolutionary influence of environmental change upon cultivated plants, one of his observations seems to have passed without sufficient comment. He recognized amongst the Fayum deposits the unmistakable remains of a two-rowed barley, morphologically identical to the indigenous Abyssinian cultivated barley, *H. deficiens*. The presence of this species and other endemic cereal forms in Abyssinia had led Vavilov³ to identify this region as a centre of origin of the two-rowed hulled barleys and of the tetraploid wheats, but his theory failed to take account of the fact that the area postulated was well outside the natural distributional range of the probable wild progeni-

¹ Hans Helbaek, *op. cit.*

² Because of the hot dry climate of Egypt grain can be preserved in a near-fresh condition. Mummified grain retains many more of the diagnostic characters than does carbonized grain.

³ N. L. Vavilov, 'Geographische Genzentrier unserer Kulturpflanzen', *Z.I.A.V. Suppl.*, 1, 1925.

tors. Elisabeth Schieman¹ believed that two-rowed barley and emmer wheat were brought to Abyssinia as plants already well adapted to cultivation by man. Once there, the cultural and geographical isolation to which they have been subjected ever since, together with practice of a primitive agriculture which would favour the preservation of any mutations which might occur, would result in the area becoming an "accumulation centre" rather than a centre of diversity in the Vavilov sense. She, like Helbaek, considered environmental factors to be promoters of mutations of which the *deficiens*² condition of the two-rowed barley was one. With the discovery, however, of this form amongst the cereal remains of Fayum, there is no longer any need for such a postulation. *H. deficiens* could have reached Abyssinia from Egypt at a very early date and would thus be a relict of ancient cultivation. If this were so, one would expect it to conform to the genetic Type E barleys in which the toughness of the rachis is the result of the mutation of the dominant *Bt*₂ gene to the recessive condition (see earlier). Takahashi³ reports the occurrence of both Type E and Type W amongst the cultivated barleys of Abyssinia, but no information is available concerning the genetic nature of the tough rachis in *H. deficiens* itself. A searching study of the morphological, physiological, and genetical characteristics of the Abyssinian barleys on the lines of the investigations carried out recently in Afghanistan ought to be most rewarding.⁴

From western Asia, agriculture spread into Europe. Although the archaeological details are as yet rather sparse, there is evidence of at least three migratory waves. Of these, most is known of that which penetrated from Mesopotamia through southern Asia Minor to Greece and thence through the Balkans to the valley of the Danube and southern Russia. The period of time occupied by this phase stretches from 4200 B.C. to 2500 B.C. Cereal cultivation also extended in other directions. It had reached the Elbe valley by 4000 B.C., north-west Africa by 3050 B.C., and had crossed the channel to southern and eastern England perhaps as early as 3400 B.C.⁵ By 2650 B.C., neolithic farmers were established in Denmark.

¹ Elisabeth Schieman, 'New Results on the History of Cultivated Cereals', *Heredity*, v, pt 3, 1951.

² The *deficiens* condition is recessive to the normal two-rowed but dominant over the six-rowed.

³ R. Takahashi, 'The Origin and Evolution of Cultivated Barley', *op. cit.*

⁴ R. Takahashi, *et alii*, 'Characteristics of the wild and cultivated Barleys from Afghanistan and its neighbouring regions', *Berichte des Ohara Instituts für landwirtschaftliche Biologie*, xii, no. 1, 1963.

⁵ J. G. D. Clark and H. Godwin, 'The Neolithic in the Cambridgeshire Fens', *Antiquity*, March 1962.

The cereals cultivated in prehistoric Europe can be determined by examination of carbonized grains and grain impressions in pottery and baked clay. Unfortunately, most of the early identifications are unreliable and once more, one is indebted to the recent archaeobotanical researches of Helbaek¹ for an accurate determination of the cereal crops of early European agriculture. Three species of wheat (einkorn, emmer, and a form of bread wheat) were cultivated and two forms of six-rowed barley, the naked and the husked. Of these the naked form was much the more common during the early prehistoric periods in north-western Europe, but later it was superseded by the hulled form. At one time Helbaek believed in an independent European origin for the naked six-rowed barley, but his more recent researches, as will be shown later, suggest otherwise. No authentic finds of two-rowed barley have ever been made and Helbaek is of the opinion that this form did not arrive in Europe until classical times and did not reach northern Europe until the second millennium of the Christian era. This, of course, is what one would expect if the neolithic migrations began, as the evidence seems to show, after the disappearance of two-rowed barley from south-western Asia.

According to Sir Mortimer Wheeler,² civilization reached India fully-fledged from Mesopotamia, sometime during the third millennium B.C. It led to the establishment of the Indus valley cultures, exemplified by the cities Mohenjo-daro and Chanhudaro on the Indus, and Harappa on the Ravi some distance to the north. Their economy rested upon irrigation farming and depended upon the cultivation of club wheat (*Triticum compactum*) and a hulled six-rowed barley. Again, for undoubtedly the same reason, there is no sign of two-rowed barley. The absence of this species from the agricultural area east of the Hindu-Kush until its introduction from Europe in 1870, is not because the exclusive cultivation of six-rowed barley is related to the occurrence in this region of a wild six-rowed barley, but because agriculture was introduced into the orient at a time when two-rowed barley was no longer cultivated in the agricultural occident.

Up to this point botanical and archaeological evidence go hand in hand. The derivation of all cultivated barleys from *Hordeum spontaneum* seems to be strongly indicated. The source of endemic barleys of Abyssinia has been discovered. A convincing explanation of the absence of two-rowed cultivated barleys from the agriculture of prehistoric Europe and from the ancient

¹ Knud Jessen and Hans Helbaek, 'Cereals in Great Britain and Ireland in Prehistoric Times', *Kgl. Danske Vid. Selsk. Skrifter*, 1944; Hans Helbaek, 'Early Crops in Southern England', *Proceedings of the Prehistoric Soc.*, XVIII, pt 2, 1952.

² Mortimer Wheeler, 'Ancient India', in *The Dawn of Civilization*, London, 1961.

and modern orient has been given. Two problems only remain. Was there a second introduction of two-rowed barley into cultivation and when and where did the first naked barleys arise?

Recent researches have partly answered both of these questions and, at the same time, have suggested a currently very unpopular possibility. In 1961 Helbaek¹ reported the results of his examination of cereal material recovered during the excavations of the mound of Beycesultan in Anatolia, sponsored by the British Institute of Archaeology in Ankara. The carbonized material had been handled with great care and was in an extremely good state of preservation. Morphological details were distinct and distortion of size and shape was minimal. As this was the first ancient Anatolian grain deposit to be subjected to thorough analysis in recent times, it was of great archaeological importance. Amongst the earliest samples, dateable to the thirteenth century B.C., einkorn, emmer, and bread wheats were recognized, but the most significant feature was the recovery of a storage jar containing upwards of 4,500 grains; the majority of which were those of a nodding two-rowed barley. The only impurities were a few irregular grains which were impossible to identify with certainty and two kernels of a naked six-rowed barley. More recently still, in his preliminary report of the plant remains from the site of Nimrud (c. 700 B.C.), Helbaek² reports the occurrence of bread wheat and a husked barley which was predominately two-rowed. Once again, from approximately 4,500 grains only 60 came from six-rowed ears.

A time span of three thousand years separates the two-rowed barleys of Beycesultan from those of the later Halafian period and no authentic records of cultivation of this species bridge the gap. Did two-rowed barley have a continuous but as yet unrecorded history in the hill country in, and adjacent to, the area of its original cultivation, or must the two-rowed barleys of Beycesultan and Nimrud be interpreted as evidence of a second and quite independent introduction of this species into cultivation? Until the archaeological evidence is complete the answer cannot be given, but the possibility still remains that the two-rowed barleys of the historic period did not stem from the ancient barleys of Jarmo.

The first barleys to reach the British Isles from the continent of Europe some five thousand years ago were naked and six-rowed and their source had long been the subject of speculation. They could have arisen locally as mutations of the husked form, but their widespread distribution and early appearance in European agriculture suggested that they had come from

¹ Hans Helbaek, 'Late Bronze Age and Byzantine Crops at Beycesultan in Anatolia', *Anatolian Studies, Journal of the British Institute of Archaeology at Ankara*, XI, 1961.

² Hans Helbaek, 'The Plant Remains from Nimrud', *Nimrud and its Remains*, II, 1966.

elsewhere. The problem was solved by the discovery by Helbaek¹ of naked six-rowed barley in considerable quantity amongst the deposits of carbonized grains and seeds excavated at Çatal Hüyük in Anatolia. The occurrence of naked barley at such an early date (radio carbon determinations for Çatal Hüyük, 5850 B.C.–5600 B.C.) is remarkable, but, even more so, are the most recent finds reported by Helbaek. In a paper read to the International Botanical Congress in Edinburgh in 1964, he told how he had firm proof of the existence of this cereal in Khuzistan (c. 8000 B.C.) and in Arabia Petrea some thousand years later. As naked barley completely lacks mechanisms for the dispersal of its grains and is thus entirely dependent upon man for its continuance, it is, according to Helbaek, a reliable indicator of organized agriculture. He therefore deduces that it split off from its hulled, two-rowed parent almost immediately after cultivation began and was expressed as a fully domesticated crop plant at least three thousand years before the appearance of the hulled six-rowed barley of the Mesopotamian plains.

There is, however, one serious objection to this view. The derivation of a hulled six-rowed barley from the cultivated two-rowed requires the mutation of a single gene from the dominant to the recessive state. Before the naked six-rowed could emerge, on the other hand, two such mutations must have occurred. As it is most improbable that these would take place simultaneously and as naked two-rowed barleys only exist as the result of recent and deliberate hybridizations, then only one sequence of events is possible. Early cultivated two-rowed forms must have given rise to hulled six-rowed derivatives from which the naked six-rowed barleys must have stemmed. This, unfortunately, is at variance with the apparent chronology and so one must either accept that the archaeological record is, as yet, incomplete and that hulled six-rowed barley was cultivated at a much earlier date than has so far been established or one must start to think along entirely different lines.

Could there have been, after all, a wild six-rowed barley with a natural area of distribution in south-western Asia? Is Bakhteyev² perhaps correct in his recent assertion that wild populations of *Hordeum spontaneum* include six-rowed variants which cannot be explained by antecedent hybridity? If so, are they the source of the naked six-rowed barleys which appeared so early in the history of agriculture? Bakhteyev has suggested that there is an urgent need to organize large-scale international expeditions into the differ-

¹ Hans Helbaek, 'First impressions of the Catal Hüyük plant husbandry', *Anatolian studies, Journal of the British Institute of Archaeology at Ankara*, xiv, 1964.

² F. Kh. Bakhteyev, 'Origin and phylogeny of barley', *Barley Genetics I. Proc. of the First Internat. Genetics Symposium*, Wageningen, 1963.

ent geographical areas of distribution of *H. spontaneum* and *H. agriocrithon* to collect material for further intensive phylogenetic studies. Until this is done it may not be possible to go further towards finding a solution to the tantalizing problem of the origin of the cultivated barleys.

Letter to the Editor

MADAM,—May I request a little space in order to comment briefly on Dr Martin's valuable article which appeared in your last issue?

It is most interesting that Dr Martin finds the use of the Warwickshire land tax returns unaffected by enclosure and by avoidance and voluntary redemption of the tax; and in view of Dr Grigg's comments on the returns for Lincolnshire (volume XI, 2 of this REVIEW), and other writers' findings in Leicestershire, Bedfordshire, and Nottinghamshire, I am inclined to wonder how far the Warwickshire returns may be typical. It is also the case that some earlier investigators, who used the land tax to estimate the size of units of ownership, did not take the necessary precaution, noted by Dr Martin and Dr Grigg, of calculating the acreage equivalent for each parish examined, nor did they allow for differences in acreage equivalent between large and small owners and between varying qualities of land within parishes; nor, apparently, was consideration given to the growth of industrialized villages, and what Ashby called "village property," namely, small areas of land owned by village tradesmen and others rather than by farmers.

On the question of the accuracy of the size of holdings as estimated from the land tax returns, it does not appear to me very reassuring that in Warwickshire, after excluding parishes of contrasting soil and cultivation, and excluding also the semi-industrialized and semi-urban parishes, Dr Martin still finds in some instances errors ranging up to 36 per cent, and that 4s. of tax may represent anything from 2.7 acres to 6.6 acres. And there is still, of course, the limitation on the value of the figures derived from the returns arising from the fact that units of ownership did not necessarily represent units of occupation: some of these small owners were in fact substantial farmers. On reconsideration, I do not see any very good reason for departing from the conclusion of my article in *The Economic History Review*: that, while we cannot ignore the evidence of the land tax assessments, neither should we ignore their grave limitations as a source for agrarian history.

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