Domestication of Corn

Archeological excavations have uncovered prehistoric wild corn and show how it evolved under domestication.

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The problem of the origin of corn has intrigued botanists and other students of plants for more than four centuries. The plant was unknown in any part of the Old World before 1492, while in the New World it was the basic food plant of all pre-Columbian advanced cultures and civilizations, including the Inca of South America and the Maya and Aztec of Middle America (*1*). Although these facts point strongly to its American origin, some writers have continued to argue eloquently for an Old World origin. A living wild form of corn has never been discovered, despite the extensive searches for it which have been carried on in various parts of the hemisphere. The absence of a wild form has been conducive to speculation—sometimes reaching the point of acrimonious debate—about its probable nature. There has, however, been general agreement that modern corn is unique among the major cereals in its grain-bearing inflorescence (the ear), which is completely enclosed in modified leaf sheaths (the husks), the plant being thus rendered incapable of dispersing its seeds. How, then, did wild corn, which to survive in nature must have had a means of dispersal, differ from modern cultivated corn? Where did it grow? How did it evolve under domestication? These are some of the questions that comprise the corn problem.

Close collaboration in recent years between archeologists and botanists has furnished at least partial answers to all of these questions, and has also contributed to solving the problem of the beginning of agriculture in America and the rise of prehistoric cultures and civilizations.

The first substantial contribution of archeology to the solution of the corn problem was the finding of prehistoric vegetal material in Bat Cave in New Mexico, excavated by Herbert Dick, then a graduate student in the Peabody Museum of Harvard University, in two expeditions, in 1948 and 1950. Accumulated trash, garbage, and excrement in this cave contained cobs and other parts of corn at all levels, and these cobs and parts showed a distinct evolutionary sequence from the lower to the upper levels (*2*). At the bottom of the refuse, which was some 2 meters deep, Dick found tiny cobs, 2 to 3 centimeters long, which were dated by radiocarbon determinations of associated charcoal at about 3600 B.C. Anatomical studies of these cobs led to the conclusion that the early Bat Cave corn was both a popcorn (a type with small, hard kernels capable of exploding when exposed to heat) and a pod form (a type with kernels partly enclosed by floral bracts which botanists call glumes and the layman knows as chaff) (*3*).

Because the Bat Cave corn was both a popcorn and a pod corn, Mangelsdorf undertook to produce a genetic reconstruction of the ancestral form of corn by crossing pod corn and popcorn and backcrossing the hybrid repeatedly to popcorn. The final product of this breeding was a pod-popcorn bearing small kernels enclosed in glumes on ears arising from the upper joints of the stalks (*3*). This reconstructed ancestral form had two means of dispersal: seeds borne on the fragile branches of the tassel and seeds on ears at high positions on the stalk which at maturity were not completely enclosed by husks. The reconstructed ancestral form served another useful purpose in showing the archeologist approximately what to look for in seeking prehistoric wild corn.

Prehistoric Corn in Northern Mexico

A second important collection of prehistoric maize came from La Perra Cave in Tamaulipas in northeastern Mexico, excavated in 1949 by MacNeish, who was then associated with the National Museum of Canada. The specimens from this cave, like those from Bat Cave, showed a distinct evolutionary sequence from the lower to the higher levels of the accumulated refuse (*4*). The earliest corn, dated 2500 B.C. by radiocarbon determination of associated wood and leaves, was identified as an early form of a still-existing race, Nal-Tel, which Wellhausen *et al.* (*5*), who have classified the present-day maize of Mexico, described as one of the four Ancient Indigenous races of Mexico. These earliest cobs were somewhat larger than the earliest cobs from Bat Cave and so gave some support to the assumption that the two radiocarbon dates involved, 3600 and 2500 B.C., might be relatively if not absolutely correct.

While excavating La Perra Cave, which is located in eastern Tamaulipas, MacNeish also made some preliminary soundings in several caves in southwestern Tamaulipas which persuaded him that still earlier corn, perhaps even prehistoric wild corn, might be found in the lower levels of the refuse of these caves. Accordingly in 1954, with the assistance of David Kelley, then a graduate student in anthropology at Harvard, he excavated two caves, Romero's Cave and Valenzuela's Cave, in Infiernillo Canyon. The earliest corn from these caves proved, disappointingly, to be not earlier than the La Perra corn but slightly later, about 2200 B.C. (*6*). It was, however, of a race different from the La Perra corn and showed some resemblance to the Bat Cave corn.

Of even greater interest was the discovery in Romero's Cave of a few specimens of teosinte, the closest relative of corn. Well-preserved specimens of the fruits of this plant occurred in a level dated 1400 to 400 B.C. Fragments identified as teosinte occurred in feces in a level dated 1800 to 1400 B.C. Since teosinte has not been found growing in Tamaulipas in modern times, it may be assumed either that

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its range is more restricted today than it was several thousand years ago or that teosinte was planted with corn as a method of improving it, a practice reported by Lumholtz (*7*) to be characteristic of certain Indians of the western part of Mexico.

While the excavations in Tamaulipas were in progress, another series of excavations was being made in caves in the states of Chihuahua and Sonora in northwestern Mexico by Robert H. Lister of the University of Colorado. In one of these caves, Swallow Cave, Lister uncovered at the lowest levels several tiny cobs similar in shape and size to the Bat Cave cobs, though slightly larger. Since it seemed inadvisable to sacrifice these to obtain radiocarbon determinations, they have not been dated. However, the fact that they occurred at a considerable depth (about 2 meters below the surface) and in a preceramic context suggests a substantial age. These earliest Swallow Cave cobs were identified as prototypes of Chapalote (*8*), another of the Ancient Indigenous and still-existing races of corn of Mexico described by Wellhausen *et al.* (*5*).

During this same period another important discovery was made when Barghoorn *et al.* (*9*) identified as pollen grains of maize some fossil pollen isolated from a drill core taken at a depth of more than 70 meters below the present site of Mexico City. This pollen was assigned to the last interglacial period now estimated by geologists to have occurred about 80,000 years ago. Since this period antedates the arrival of man on this continent, the pollen was thought to be that of a wild maize which once grew in the Valley of Mexico and has since become extinct. Other pollen, considered to be that of cultivated corn, occurred abundantly in the upper levels—above 6 meters. The earliest of these upper-level pollen grains are assigned to the later part of the post-glacial optimum and are therefore no earlier than the earliest corn from Tamaulipas or New Mexico. Although the criteria used in identifying the fossil pollen grains have been questioned (*10*), more recent studies made by Barghoorn and his associates, using phase microscopy, have revealed features in which the pollen grains of corn and its relatives differ conspicuously and have confirmed the earlier identifications. There now seems to be no doubt that at least some of the fossil pollen grains were those of corn. Thus, this fossil pollen settles two important questions: it shows that corn is an American plant and that the ancestor of cultivated corn is corn and not one of corn's relatives, teosinte or *Tripsacum*.

On the basis of his excavations in Tamaulipas and the discovery of fossil corn pollen in the Valley of Mexico, MacNeish concluded that the evidence for the earliest domestication of maize and the beginnings of agriculture in America must be sought further south. A reconnaissance made in Honduras and Guatemala in 1958 yielded no results of promise. Excavations in 1959 of Santa Maria Cave in Chiapas in southern Mexico uncovered corn and other vegetal material, including pollen, but none older than that which had already been found further north. Turning northward again, MacNeish made a reconnaissance of sites in Oaxaca and Puebla which led to the conclusion that the Tehuacán Valley of southern Puebla and northern Oaxaca might, because of its dry climate and ever-flowing springs, offer the most promising site so far discovered for seeking prehistoric wild corn and the beginning of agriculture. A preliminary sounding in 1960, in one of the numerous caves in the cliffs surrounding the Valley, uncovered cobs which were thought to be those of wild corn. Full-scale excavations conducted the following season confirmed this.

The physical features of the Valley of Tehuacán are described by MacNeish in another article in this issue (see page 533), which also describes the culture phases that have been recognized. At first glance this valley, with its semiarid climate and its predominantly xerophytic, drought-resisting vegetation, may not seem to be a suitable habitat for wild corn, and in earlier speculation about where wild corn might have grown we did not associate it with such plants as cacti and thorny leguminous shrubs (*1*). Closer examination, however, suggests that the habitat furnished by this arid valley may, in fact, have been almost ideal for wild corn. The average annual rainfall at the center of the valley is low (approximately 500 millimeters a year) and becomes somewhat higher both south and north of the center. About 90 percent of the annual rain usually falls during the growing season, from April through October.

The other months are quite dry—in midwinter the Valley is virtually a desert—and comprise a period during which the seeds of wild maize and other annual plants could have lain dormant, ready to sprout with the beginning of the summer rains and never in danger of germinating prematurely and then succumbing to the vicissitudes of winter. Thus, although the perennial vegetation of this valley, which year after year must survive the dry winter months, is necessarily xerophytic, the annual vegetation (and wild maize would have been an annual) need not be especially drought-resistant. Modern maize is not notable for its drought-resistance and probably its wild prototype was not either.

The corn uncovered by MacNeish and his associates in their excavations of the caves in Tehuacán Valley is, from several standpoints, the most interesting and significant prehistoric maize so far discovered. (i) It includes the oldest well-preserved cobs yet available for botanical analysis. (ii) The oldest cobs are probably those of wild maize. (iii) This maize appears to be the progenitor of two of the previously recognized Ancient Indigenous races of Mexico, Nal-Tel and Chapalote, of which prehistoric prototypes had already been found in La Perra and Swallow caves, respectively. (iv) The collections portray a well-defined evolutionary sequence.

Prehistoric Corn from Five Caves

Before considering the corn itself, we should say a word about the caves in which the remains of maize were uncovered. Five major caves which were excavated—Coxcatlan, Purron, San Marcos, Tecorral, and El Riego—yielded maize in archeological levels. The caves were situated in three or four different environments, which might have had considerable bearing upon the possibility of wild corn's growing nearby and which might have affected the practice of agriculture (see Fig. 1).

Coxcatlan Cave, first found in 1960, was one of the richest in vegetal remains. Excavations revealed 28 superimposed floors or occupational levels covering two long unbroken periods—from 10,000 to 2300 B.C. and from 900 B.C. to A.D. 1500. Fourteen of the upper floors, those from 5200 to 2300 B.C. and from 900 B.C. to A.D. 1500,

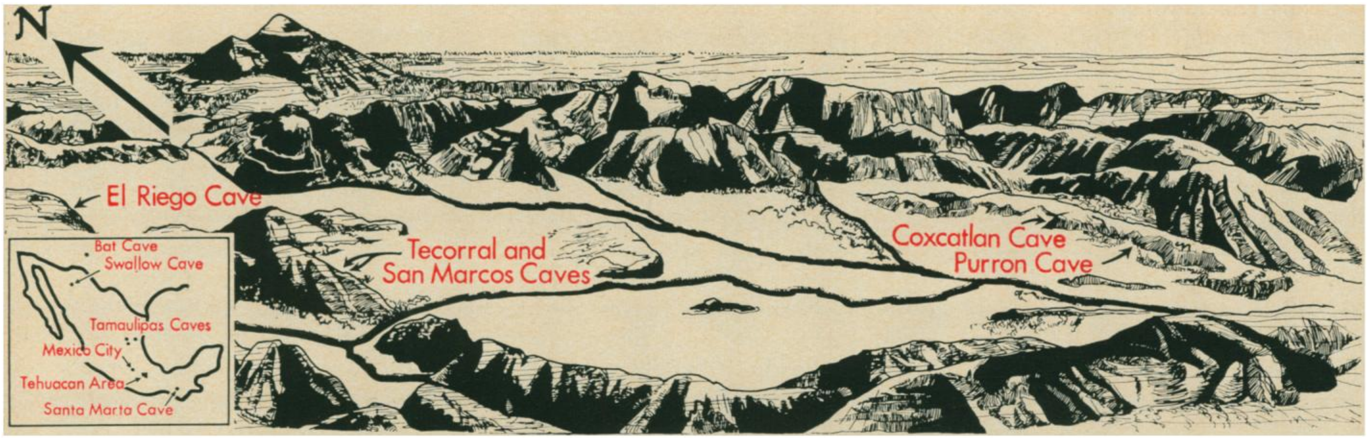

Fig. 1. The principal physical features of the Valley of Tehuacán, Mexico, and the approximate locations of the five caves in which remains of prehistoric corn were uncovered. The insert shows the locations of other archeological sites which have yielded evidence on the origin and evolution of corn.

contained well-preserved corn cobs. The cave, a long narrow rock shelter, is situated in the southeastern part of the Valley in one of the canyons flanking the Sierra Madre mountain range (Fig. 1). The shelter faces north and looks out on a broad alluvial plain covered with grasses, mesquite, other leguminous shrubs, and cacti. Supplementing the meager annual rainfall is some water drainage from the nearby mountain slopes and this would have made it possible for wild or cultivated corn to grow during the wet season. In other seasons of the year irrigation would have been necessary for corn culture.

A few miles south of Coxcatlan, in the same set of canyons, is Purron Cave. This is a somewhat smaller rock shelter but it contains a long continuous occupation (25 floors) from about 7000 B.C. to A.D. 500. It is archeologically much poorer than Coxcatlan and only the top 12 floors (from 2300 B.C. to A.D. 500) contained preserved remains of food plants.

El Riego Cave, situated in the north end of the Valley (Fig. 1) only a mile north of the modern town of Tehuacán, is a deep recess which contained an abundance of preserved specimens. Its five archeological zones, however, do not extend far back in time and were deposited between 200 B.C. and A.D. 1500. The cave is in the travertine face of a cliff and faces south. Under

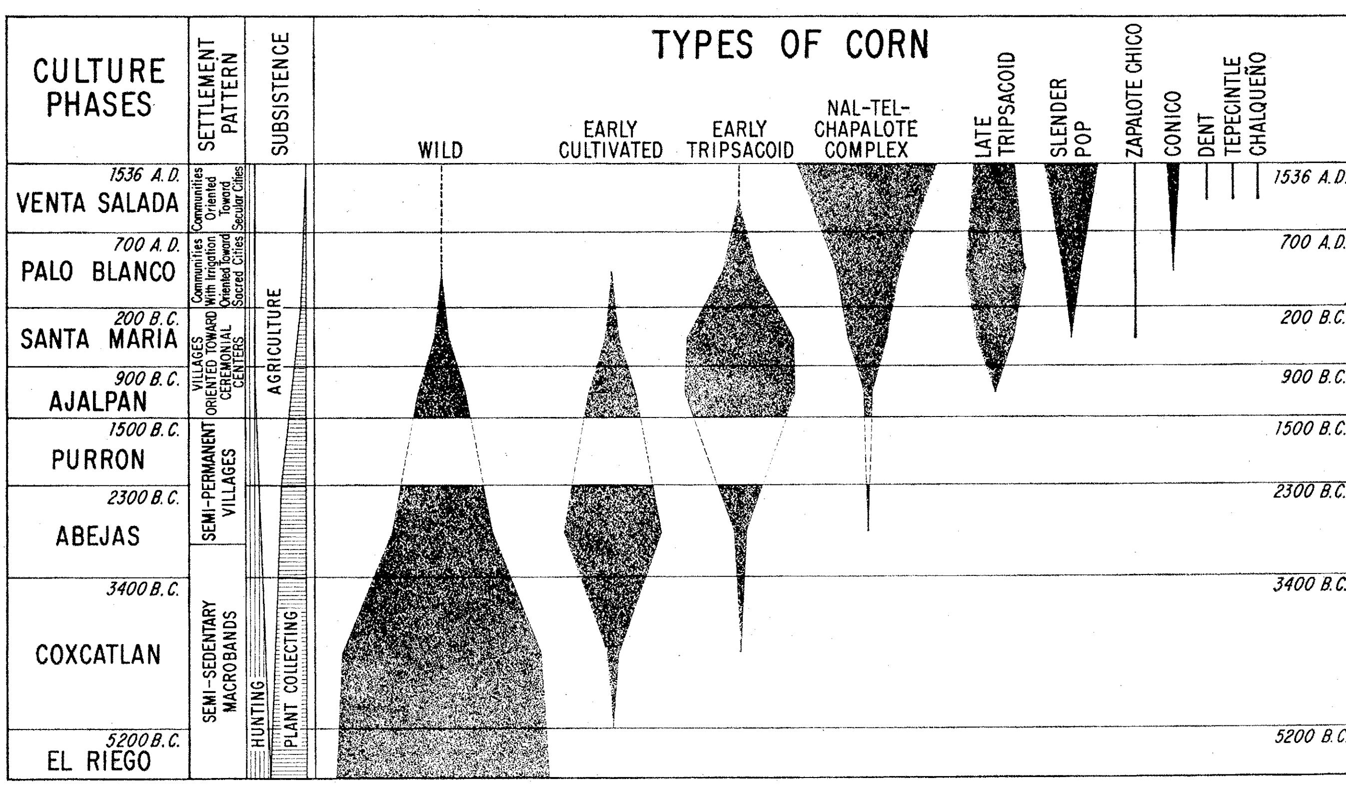

Fig. 2. Frequency polygons, in terms of percentages of number of cobs identified, showing changes in the types of corn in the Valley of Tehuacán from 5200 B.C. to A.D. 1536. Specimens of prehistoric corn were almost totally lacking for the Purron culture phase, which is recognized by other types of artifacts.

these cliffs and flowing out from them are the famous Tehuacán mineral springs, and the soils in front of the cave are fertile and well watered. Because of the fertile soils and the abundant water there is an oasis-like vegetation around the cave. This is an excellent area for agriculture and it may even have originally supported a vegetation too lush for wild corn to compete with.

The last two caves, San Marcos and Tecorral, occur in a steep canyon in the west side of the Valley (see Fig. 1). They are small shelters situated side by side, facing east. Tecorral contained three floors and only the top floor (about A.D. 1300) had a few corn cobs. San Marcos, however, was very different; although small, it yielded five superimposed floors with an abundance of preserved maize and other remains. The top four floors have been dated, by the carbon-14 method, at about 4400 B.C., 3300 B.C., 1100 B.C., and A.D. 300, respectively, while the earliest one is estimated to have been laid down about 5200 B.C. The shelters look out over broad alluvial terraces covered by grass and small thorny trees. Plants collected from this canyon bottom reveal a number of endemics—species not found elsewhere in the Valley. The surrounding travertine-covered canyon walls and hilltops, however, have a vegetation like that of the Sonoran Desert. The area receives water in the rainy season and much of it floods the lower terraces. All occupations found in the caves were from the rainy seasons. Agriculture would have been possible in the rainy season with or without irrigation. The alluvial terraces would have furnished an almost ideal habitat for wild corn.

In all, 23,607 specimens of maize were found in the five caves; 12,857 of these, or more than half, are whole or almost intact cobs. There are, in addition to the intact cobs, 3273 identified cob fragments and 3880 unidentified cob fragments. Among the remaining specimens are all parts of the corn plant: 28 roots, 513 pieces of stalks, 462 leaf sheaths, 293 leaves, 962 husks, 12 prophylls, 127 shanks, 384 tassel fragments, 47 husk systems, 6 midribs, and 600 kernels. There are also numerous quids, representing 64 chewed stalks and 99 chewed husks.

The prehistoric cobs from the five caves can be assigned to six major and five minor categories. The frequency polygons of Fig. 2 show graphically the time of first appearance of a type of corn, the corresponding cultural periods, and the relative prominence (in terms of percentages) of the number of identified cobs for each of these categories. The polygons show patterns similar to those exhibited by artifacts, and for good reason—man's cultivars are artifacts as surely as are his weapon points or pottery. A brief description of the types of maize represented by these categories follows.

Prehistoric Wild Maize

The earliest cobs from the El Riego and Coxcatlan cultural phase, dated 5200–3400 B.C., are regarded as being those of wild corn for six reasons. (i) They are remarkably uniform in size and other characteristics and in this respect resemble most wild species. (ii) The cobs have fragile rachises as do many wild grasses; these provide a means of dispersal which modern corn lacks. (iii) The glumes are relatively long in relation to other structures and must have partially enclosed the kernels as they do in other wild grasses. (iv) There are sites in the Valley, such as the alluvial terraces below San Marcos Cave, which are well adapted to the growth of annual grasses, including corn, and which the competing cacti and leguminous shrubs appear to shun. (v) There is no evidence from other plant species that agriculture had yet become well established in this valley, at least in the El Riego phase or the earlier part of the Coxcatlan phase. (vi) The predominating maize from the following phase, Abejas, in which agriculture definitely was well established, is larger and more variable than the earliest corn.

This combination of circumstances leads to the conclusion—an almost inescapable one—that the earliest prehistoric corn from the Tehuacán caves is wild corn. We shall assume here that it is.

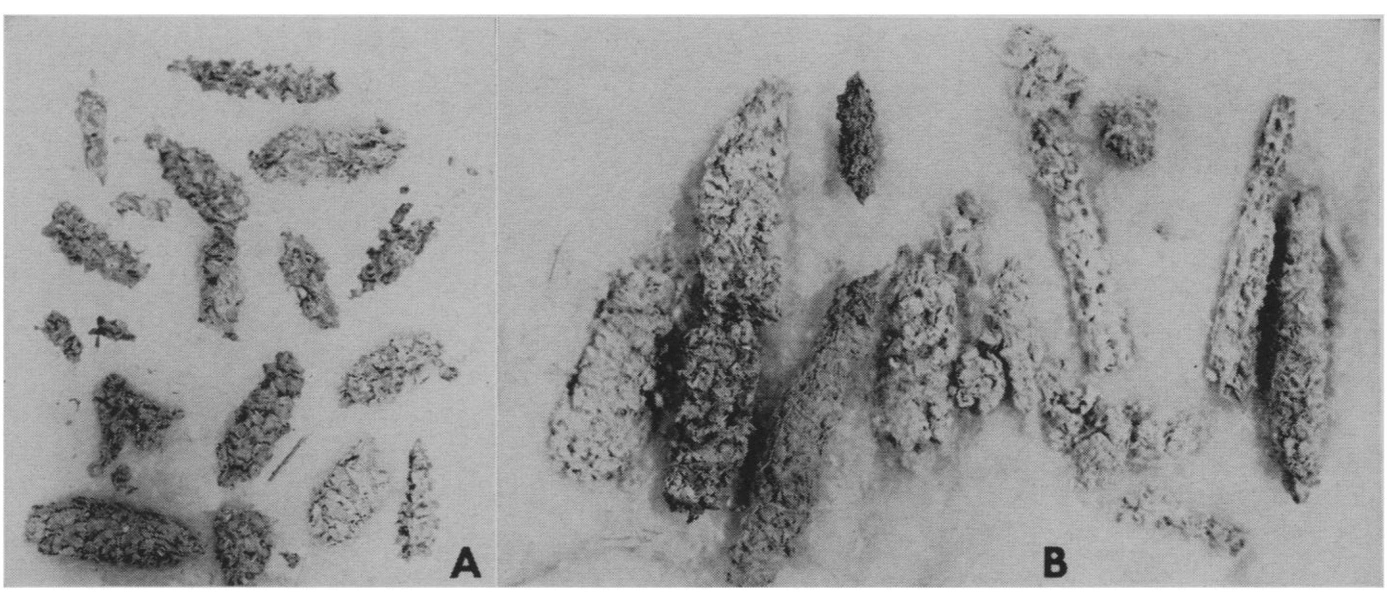

Fig. 3. (*A*) Cobs of wild corn from San Marcos Cave, representing the Coxcatlan culture phase, dated 5200 to 3400 B.C. These cobs are characterized by uniformity in size of the intact cobs, relatively long glumes, and fragile rachises. (*B*) Cobs of early cultivated corn from San Marcos Cave, representing the Abejas culture phase, dated 3400 to 2300 B.C. These are larger and more variable than the cobs of wild corn but are similar to them in having long glumes and fragile rachises. (Actual size)

Fig. 4. Artist's reconstruction of wild corn based on actual specimens of cobs, husks, a fragment bearing male spikelets, and kernels uncovered in the lower levels of San Marcos Cave. The husks probably enclosed the young ears completely but opened up at maturity, permitting dispersal of the seeds. The kernels were round, brown or orange, and partly enclosed by glumes. (Actual size)

The intact cobs of the wild corn vary in length from 19 to 25 millimeters (Fig. 3*A*). The number of kernel rows is usually eight but a few cobs with four rows were found. None of the earliest cobs have kernels, but the number of kernels which they once bore can be determined by counting the number of functional spikelets. These vary from 36 to 72 per cob. The average number of kernels borne by the earliest intact cobs of wild corn from San Marcos Cave was 55.

The glumes of the spikelets are relatively long in relation to other structures and are soft, fleshy, and glabrous (lacking in hairs). On some cobs the glumes are rumpled, probably as a result of the forcible removal of the kernels. The cobs have the general aspect of a weak form of pod corn.

The spikelets are uniformly paired and are attached to a slender, soft, and somewhat fragile stem (technically known as a rachis) in which the cupules, or depressions in the rachis, are shallow and almost glabrous, bearing only sparse, short hairs.

Most of the wild-type cobs were apparently once bisexual, bearing pistillate (female) spikelets in the lower regions and staminate (male) spikelets above. Of 15 apparently intact cobs from San Marcos Cave, ten had stumps at the tip where a staminate spike had presumably been broken off. In this respect the Tehuacán wild maize resembles corn's wild relative, *Tripsacum*, which regularly bears pistillate spikelets below and staminate spikelets above on the same inflorescences.

The uniformly paired spikelets and relatively soft tissues of the rachis and glumes provide further proof, in addition to that furnished by the fossil pollen of the Valley of Mexico, that the wild ancestor of cultivated corn was corn and not one of its relatives, teosinte or *Tripsacum*.

The wild maize declined somewhat in prominence in the Abejas phase, where it comprises 47 percent of the cobs. It persisted, however, as a minor element of the corn complex until the middle of the Palo Blanco phase, dated at about A.D. 250.

What caused the wild corn finally to become extinct? We have for some years assumed that two principal factors may have been involved in the extinction of corn's ancestor. (i) The sites where wild corn grew in nature might well be among those chosen by man for his earliest cultivation. (ii) Wild corn growing in sites not appropriated for cultivation but hybridizing with cultivated corn, after the latter had lost some of its essential wild characteristics, would become less able to survive in the wild. Of these two causes of extinction the second may have been the more important. Corn is a wind-pollinated plant and its pollen can be carried many miles by the wind. It is virtually inevitable that any maize growing wild in the Valley would have hybridized at times with the cultivated maize in nearby fields, which was producing pollen in profusion. Repeated contamination of the wild corn by cultivated corn could eventually have genetically "swamped" the former out of existence.

There is now good archeological evidence in Tehuacán to suggest that both of these assumed causes of extinction were indeed operative. The alluvial terraces below San Marcos Cave, where wild corn may once have grown, now reveal the remains of a fairly elaborate system of irrigation, indicating that the natural habitat of wild corn was replaced by cultivated fields. Abundant evidence of hybridization between wild and cultivated corn is

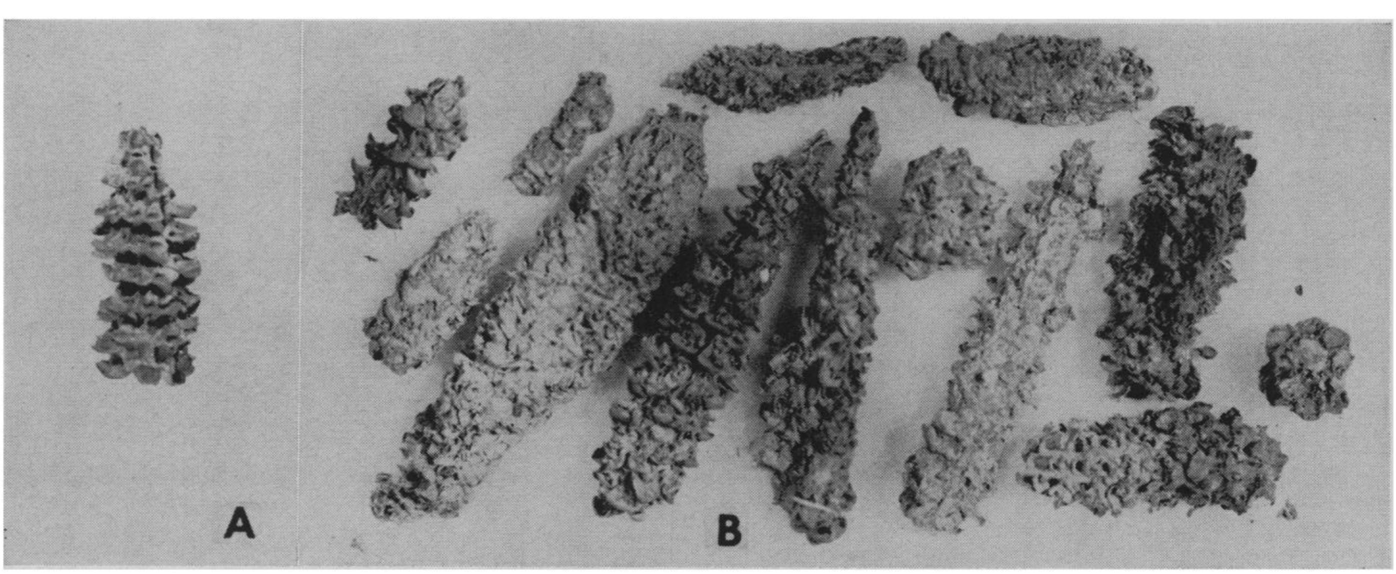

Fig. 5. (*A*) Cob of early tripsacoid corn. This is characterized by stiff indurated glumes. It is thought to be the product of hybridization of corn with one of its relatives, teosinte or *Tripsacum*. (*B*) Various hybrid combinations resulting from the crossing of Tehuacán early cultivated corn with the early tripsacoid corn and backcrossing to both parents. (Actual size)

found in the prehistoric cobs. We have classified 252 cobs as possible first-generation hybrids of wild corn with various cultivated types and 464 cobs as backcrosses of first-generation hybrids to the wild corn.

Is there a possibility that wild corn may still be found in some remote and inaccessible locality in Mexico or elsewhere? We suspect not. Whatever wild corn may have persisted until the 16th century was almost certainly rapidly extinguished after the arrival of the European colonists with their numerous types of grazing animals: horses, burros, cows, sheep, and—worst of all—the omnivorous and voracious goats. To all of these animals young corn plants are a palatable fodder, one that is to be preferred to almost any other grass.

Wild Corn Reconstructed

A well-preserved early cob, an intact husk system consisting of an inner and outer husk from the Abejas phase in the San Marcos Cave, and a piece of staminate spike from the Ajalpan phase of the same cave provide the materials for a reconstruction of the Tehuacán wild corn. This is illustrated in actual size in Fig. 4. An ear with only two husks was probably borne high on the stalk and its husks opened at maturity, permitting dispersal of the seeds. Other early specimens show that the plants lacked secondary stalks, technically known as tillers; the leaf sheaths were completely lacking in surface hairs; the kernels were somewhat rounded and were either brown or orange.

In its lack of tillers, its glabrous leaf sheaths, its rounded kernels, and the color of its pericarp, the Tehuacán wild corn differs quite distinctly from a third Ancient Indigenous race of Mexico, Palomero Toluqueño, described by Wellhausen *et al.* (*5*). This finding suggests that the latter may have stemmed from a different race of wild corn growing in another place. Fossil corn pollen from the Valley of Mexico suggests still a third locality where wild corn once occurred. It is becoming increasingly apparent that cultivated corn may have had multiple sites of origin, of which southern Mexico is only one, but the earliest one so far discovered.

The corn which we have called "early cultivated" is similar to the wild corn except in size (Fig. 3*B*). It has the same long soft glumes and the same soft, somewhat fragile rachises. It is probably a direct descendant of the wild corn, slightly modified through growing in a better environment. Initially the better environment may have been nothing more than that produced by the removal, by man, of other vegetation competing with wild corn growing in its natural habitat. Later the corn was actually planted in fields

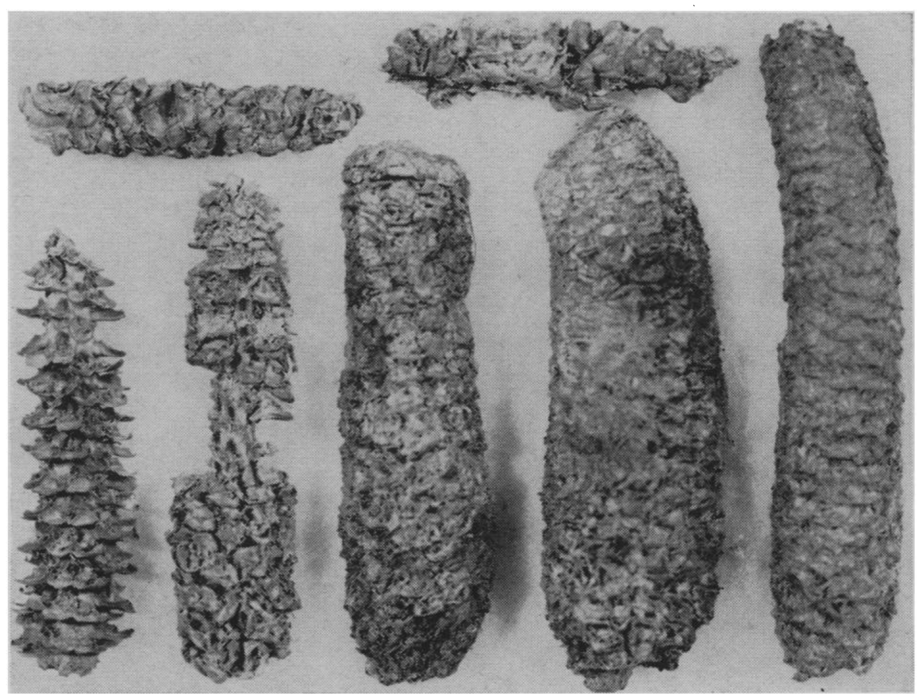

Fig. 6. Cobs from a single cache in San Marcos Cave, showing the great variation which followed the hybridization of the Tehuacán corn with the early tripsacoid corn. The two small upper cobs are wild-type segregates. (Actual size)

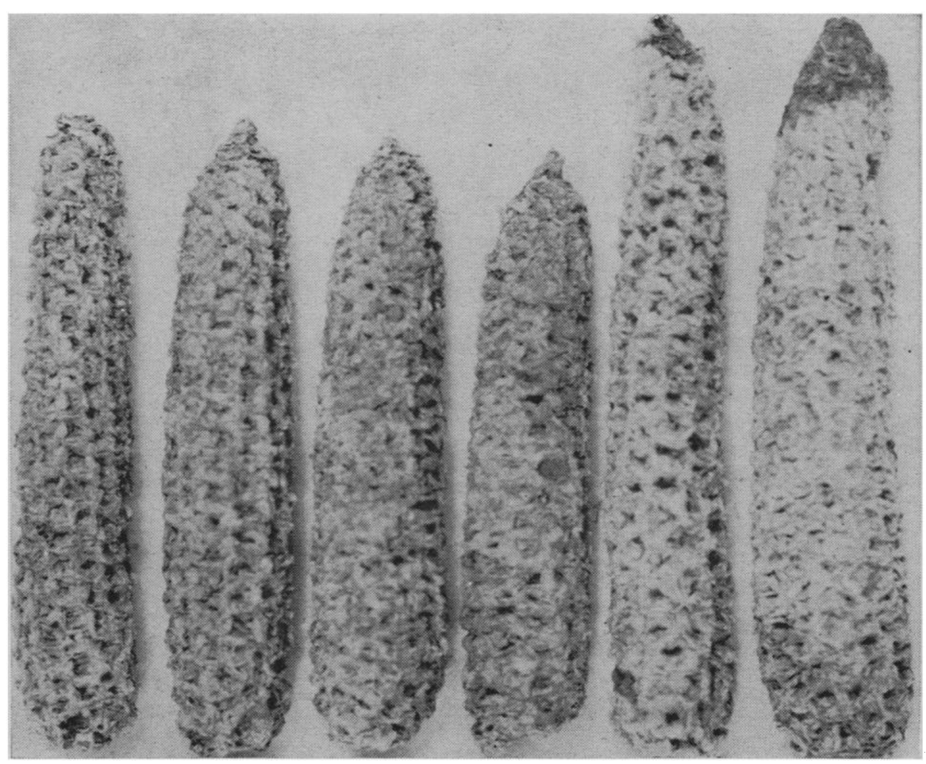

Fig. 7. Cobs of the Nal-Tel-Chapalote complex from San Marcos Cave representing the Palo Blanco phase, dated A.D. 200 to 700. It was this corn, the product of hybridization between the Tehuacán corn and the early tripsacoid, which, in providing an adequate food supply, contributed to the rise of an advanced culture and civilization in Tehuacán Valley. (Actual size)

chosen for the purpose. Still later it was irrigated.

Exactly when the maize was first cultivated in Tehuacán Valley is difficult to determine. Two cobs classified as early cultivated appeared in the Coxcatlan culture, dated 5200 to 3400 B.C., but we cannot tell whether the cobs represent the upper or lower part of this phase. Since remains of the bottle gourd and two species of squashes (*Cucurbita moschata* and *C. mixta*), as well as tepary beans, chili peppers, amaranths, avocados, and zapotes, occurred at this phase, there may have been at least an incipient agriculture and it is not unreasonable to suppose that maize, too, was being cultivated. However, two cobs scarcely furnish conclusive evidence on this point.

What we can be certain of is that during the Abejas phase, dated 3400 to 2300 B.C., this corn was definitely a part of an agricultural complex which included, in addition to maize, the following cultivars: the bottle gourd, *Lagenaria siceraria*; two species of squashes, *Cucurbita moschata* and *C. mixta*; *Amaranthus* spp.; the tepary bean, *Phaseolus acutifolius*, and possibly also the common bean, *P. vulgaris*; Jack beans, *Canavalia enciformis*; chili peppers, *Capsicum frutescens*; avocados, *Persea americana*; and three varieties of zapotes. Among the 99 cobs representing this phase, 45 (almost half) were classified as early cultivated. Thereafter this type gradually decreased in relative frequency, becoming extinct before the beginning of the Venta Salada phase at A.D. 700.

Other Prehistoric Types

Making its first appearance in the Abejas phase but represented there by a single cob, and becoming well established in the Ajalpan phase, is a type which we have called "early tripsacoid" (Fig. 5*A*). The term *tripsacoid* is one proposed by Anderson and Erickson (*11*) to describe any combination of characteristics which might have been introduced into corn by hybridizing with its relatives, teosinte or *Tripsacum*. In both of these species the tissues of the rachis and the lower glumes are highly indurated and the lower glumes are thickened and curved. Archeological cobs showing these characteristics are suspected of being the product of the hybridization of maize with one of its two relatives.

Since neither teosinte nor *Tripsacum* is known in Tehuacán Valley today and since neither is represented in the archeological vegetal remains, we suspect that the tripsacoid maize was introduced from some other region, possibly from the Balsas River basin in the adjoining state of Guerrero where both teosinte and *Tripsacum* are common today.

The introduced tripsacoid is a corn somewhat similar to the race (Nal-Tel) described by Wellhausen *et al.* (5) but smaller. This introduced corn evidently hybridized with both the wild and the early domesticated corn in the Tehuacán Valley to produce hybrids with characteristics intermediate between those of the parents. First-generation hybrids, in turn, backcrossed to both parents to produce great variability in both cultivated and wild populations (Figs. 5*B* and 6).

The introduced tripsacoid maize, together with its various hybrids, was the most common maize during the Ajalpan and Santa Maria phases from 1000 to 200 B.C. Thereafter it declined in frequency until it became almost extinct in the Venta Salada phase. But this complex apparently gave rise to two still-existing races of Mexico, Nal-Tel and Chapalote, and to a prehistoric type which we have called "late tripsacoid."

The earliest cobs from the Tehuacán caves were, because of their shape and glabrous cupules, thought to be prototypes of Chapalote, one of the Ancient Indigenous races described by Wellhausen *et al.* This race is today found only in northwestern Mexico in the states of Sinaloa and Sonora. Archeologically it is the predominating early corn in all sites excavated in northwestern Mexico and the southwestern United States.

Some of the later cobs from the caves, because their cupules were beset with hairs, a characteristic of the early Nal-Tel of La Perra Cave, seem to resemble this race more than they resemble Chapalote. Also, since Nal-Tel is found today in southern Mexico, it would not be surprising to find its origin there.

Actually Nal-Tel and Chapalote are quite similar in their characteristics, the principal conspicuous difference between them being in the color of the kernel, which in the former is orange and in the latter chocolate brown. Our hope that the first kernels to appear among the remains would enable us to distinguish between the two races was not realized. Of the kernels occurring in the Santa Maria phase, about half were brown and the other half orange, and both brown and orange kernels were also found in the later levels. Being unable, by any single criterion or combination of characters, to distinguish the cobs of the two races, we have designated this category the Nal-Tel-Chapalote complex (Fig. 7).

It was this corn, more than any other, which initiated the rapid expansion of agriculture that was accompanied by the development of, first, large villages and, later, secular cities, the practice of irrigation, and the establishment of a complex religion. If it is too much to say that this corn was responsible for these revolutionary developments, it can at least be said that they probably could not have occurred without it. Perhaps it is not surprising that present-day Mexican Indians have a certain reverence for these ancient races of corn, Nal-Tel and Chapalote, and continue to grow them although they now have more productive races at their command.

A type which we have designated "late tripsacoid" corn differs from the early tripsacoid primarily in size. It comprises principally the more tripsacoid cobs of the Nal-Tel-Chapalote type and were it not that it includes some tripsacoid cobs of a slender popcorn, it could be considered part of the Nal-Tel-Chapalote complex to which it is closely related and with which it is contemporaneous. If the tripsacoid cobs resembling Nal-Tel or Chapalote are considered along with these late tripsacoid cobs, this complex seems even more likely to have been the basic maize of the Tehuacán cultures from 900 B.C. to A.D. 1536, representing about 65 percent of all the corn at the end of the Venta Salada phase.

A type called "slender pop" has very slender cylindrical cobs, many rows of grain, and small rounded kernels, yellow or orange. This may be the prototype of a Mexican popcorn, Arrocillo Amarillo, one of the four Ancient Indigenous races described by Wellhausen *et al.* (*5*). This race, which is now mixed with many others, occurs in its most nearly pure form in the Mesa Central of Puebla at elevations of 1600 to 2000 meters, not far from the Tehuacán Valley and at similar altitudes.

Appearing first in the Santa Maria phase between 900 and 200 B.C., the slender pop increased rapidly and steadily in frequency, comprising 20 percent of the cobs in the final phase.

Judged by its cobs alone, the slender

pop might be expected to be less productive than Nal-Tel or Chapalote, and its increased prominence deserves an explanation. A plausible one is that, although the ears are small, the stalks may have been prolific, normally bearing more than one ear. The present-day race to which it bears some resemblance and to which it may be related is prolific, usually producing two or three ears per stalk.

Minor categories include cobs and kernels which appear in later levels and which are recognized as belonging to several of the modern races of Mexico described by Wellhausen *et al.* (*5*). They occur much too infrequently to be of significance in the total picture of food production but they are important in showing that these modern Mexican races were already in existence in prehistoric times. The only previous evidence of this was the fact that casts of ears appear on Zapotec funerary urns.

Other Parts of the Corn Plant

In all, 3597 specimens of parts of the corn plant, other than cobs, were found in the five caves. These specimens confirm the conclusions reached from the study of the cobs. There has been no change in the basic botanical characteristics of the corn plant during domestication. Then, as now, corn was a monoecious annual bearing its male and female spikelets separately, the former predominating in the terminal inflorescences and the latter in the lateral inflorescences, which, as in modern corn, were enclosed in husks. Then, as now, the spikelets were borne in pairs; in the staminate spikelets one member of the pair was sessile, the other pediceled. The only real changes in more than 5000 years of evolution under domestication have been changes in the size of the parts and in productiveness.

The importance of these changes to the rise of the American cultures and civilizations would be difficult to overestimate. There is more foodstuff in a single grain of some modern varieties of corn than there was in an entire ear of the Tehuacán wild corn. A wild grass with tiny ears—a species scarcely more promising as a food plant than some of the weedy grasses of our gardens and lawns—has, through a combination of circumstances, many of them perhaps fortuitous, evolved into the most productive of the cereals, becoming the basic food plant not only of the pre-Columbian cultures and civilizations of this hemisphere but also of the majority of modern ones, including our own.

Summary

Remains of prehistoric corn, including all parts of the plant, have been uncovered from fire caves in the Valley of Tehuacán in southern Mexico. The earliest remains, dated 5200 to 3400 B.C., are almost certainly those of wild corn. Later remains include cultivated corn and reveal a distinct evolutionary sequence which gave rise ultimately to several still-existing Mexican races. Despite a spectacular increase in size and productiveness under domestication, which helped make corn the basic food plant of the pre-Columbian cultures and civilizations of America, there has been no substantial change in 7000 years in the fundamental botanical characteristics of the corn plant.

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Crystalline Deamino-Oxytocin

The biological activities of this potent analog of oxytocin appear to be related to size of ring.

Derek Jarvis and Vincent du Vigneaud

When the structure of oxytocin, a hormone produced by the posterior pituitary gland and isolated from it in highly purified form (*1, 2*), was being investigated, evidence was obtained that the hormone contained a disulfide ring (*3*). That the backbone of this ring consisted of 20 members was established by the total synthesis of oxytocin (*4*) according to the structure (Fig. 1) postulated from studies in this laboratory on degradation of the hormone (*4, 5*). An identical structure was independently postulated by Tuppy (*6*).

The occurrence of a 20-membered disulfide ring in this octapeptide amide structure for oxytocin represented the first time that such a disulfide ring had been encountered in nature. Subsequently, a disulfide ring of the same size was shown to be present in insulin (*7*). A 20-membered disulfide ring was also found to occur in 8-arginine-vasopressin (*8, 9*), 8-lysine-vasopressin (*8, 10*), 8-arginine-vasotocin (*11*), and isotocin (4-serine-8-isoleucine-oxytocin) (*12*).

With the establishment of the presence of this novel structural feature in oxytocin, studies were initiated to evaluate its importance to the manifestation of some of the biological activities characteristic of this hormone. Oxy-

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