

LETTERS

U.S.-Polish Exchanges

Jeffrey L. Fox's reference to cessation of scientific exchanges between the United States and Poland following imposition of martial law and the expulsion of an American diplomat from Warsaw (News and Comment, 10 Aug., p. 605) presumably refers only to official government exchanges. The exchange program between the National Academy of Sciences and the Polish Academy of Sciences has continued uninterrupted since the original memorandum of understanding was signed in 1966.

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Human Rights in Central America

We the undersigned attended the symposium "Science and Crisis in Central America" at the AAAS annual meeting in New York on 28 May. We were appalled to learn of the situation faced by scientists and technicians in Central America. As pointed out at the symposium by Julio Quan, former director of the Center for Population Studies at the University of San Carlos in Guatemala and now living in exile in Costa Rica, scientists seek the truth, and in countries like Guatemala and El Salvador the truth is considered subversive. This has resulted in terrible repression of many scientists in these countries. Assassinations, disappearances, incarceration, and torture of scientists are common in Guatemala and El Salvador. According to Ricardo Calderon, former secretary general of the University of El Salvador, more than 250 scientists and technicians and 300 university students have been assassinated or have disappeared in El Salvador alone.

Scientists are also a special target of attacks in Nicaragua, in this case by the "contras" supported by the U.S. government. The contra forces have announced their intention to eliminate technically trained persons, Nicaraguan or foreign, who are working with the Sandinista government, and they have murdered dozens of agronomists, doctors, nurses, and teachers. The hundreds of newly trained pest management technicians in Nicaragua's innovative cotton boll weevil control program, for exam-

ple, fear for their lives as a result of their newly acquired knowledge, and the several hundred U.S. citizens working in a technical capacity are similarly put in jeopardy. These attacks on scientists and destruction of the projects on which they work are resulting in a serious regression of science and development in the region.

In light of the passage of the resolution on human rights by the AAAS council at the New York meetings, we ask the AAAS to investigate the situation of science in Central America and to speak out officially and forcefully.

We recognize that the Committee on Scientific Freedom and Responsibility of the AAAS has already focused its attention on the scientific community in South and Central America, and AAAS through its participation in Interciencia has promoted scientific cooperation in the region. We encourage an expansion of efforts in this regard, providing whatever resources are necessary to expand on what has already been done with regard to the acute situation in Central America.

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References

1. Toronto *Globe and Mail*, 2 May 1983, p. 1; J. Collins, *What Difference Could a Revolution Make? Food and Farming in the New Nicaragua* (Institute for Food and Development Policy, San Francisco, ed. 2, in press).

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Learning in the Womb

I would like to clarify some of the statements made in the article "Studying learning in the womb" by Gina Kolata (Research News, 20 July, p. 302). The original work on in utero taste-odor aversion conditioning in the fetal rat was conducted by Greg Stickrod at the University of Oregon in the Psychology Department. His findings were then replicated in my laboratory, and we—Stickrod, Daniel P. Kimble (also of the Uni-

versity of Oregon Psychology Department), and I—published the findings jointly (1). Stickrod was the pioneer in this area, and he should be credited with the "discovery" of this phenomena.

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References

1. G. Stickrod, D. P. Kimble, W. P. Smotherman, *Physiol. Behav.* 28, 5 (1982); *Peptides* 3, 881 (1982).

The Origin of Maize

According to the catastrophic sexual transmutation theory (CSTT) of Hugh H. Iltis (25 Nov. 1983, p. 886), the maize ear originated by a transmutation in teosinte of the target area for expression of the secondary male traits to also include the female spike. This transmutation supposedly accounts for the archeological record in which there seems to be a sudden despecialization of the teosinte female spike with a concomitant loss of induration, a reduction of cupules and a reactivation of the second member of paired spikelets. But the oldest maize cobs still resemble the teosinte ear more than its tassel with respect to both cupule development and glume shape.

The phenotype of the tassel seed mutants of maize should be an example of what happened according to the CSTT. But the morphology of neither tassel seed maize nor of tassel seed teosinte fits Iltis's theory. In both cases female development in the tassel is associated with the fruit-case derivatives for cupules, induration, and glume shape typical of their normal target areas. Even with normal teosinte and maize, the female areas within the mixed (bisexual) inflorescences that usually terminate tillers are also associated with these fruitcase derivatives as expressed in their ear type, contrary to the expectations of the CSTT.

It is also significant that the long rachilla characteristic of the oldest cobs is absent in both the ear and tassel of teosinte, so it could not be derived from transmutation from the tassel. Rather, the long rachilla is one of several pleiotropic effects that are controlled primarily by a series of multiple alleles at the tunicate locus. These other effects include softer, longer female glumes and some cupule reduction—traits that, according to Iltis's theory, would be attributed to transmutation, but more proba-

bly came from domestic selection for a tunicate allele.

The effects of a weak tunicate allele still occur in *Chapalote*, an ancient indigenous race of maize in Mexico. Its phenotype in *Chapalote* is considered by Mangelsdorf (1) to be similar to that of its prehistoric precursor in the oldest cobs from Bat Cave, New Mexico, and probably to that of certain of the oldest known cobs from caves near Tehuacán, Mexico. Since Iltis does not refer to any role for the tunicate locus during the origin of maize, the domestic advantages of an elongate rachilla in the ear need to be mentioned. The long rachilla not only elevates the kernel to a position near the apex of the glumes and, thereby, exposes the kernel except for a little membranaceous tissue from the lemmas and paleae, but it also reflexes the spikelet away from the cupule and, thereby, makes it threshable. Protection from birds at this stage becomes dependent upon an enclosure of the entire ear by husk leaves borne on the shank.

Iltis also states that "no key genes differentiating maize from teosinte have ever been found." He explains, "This is because, in fact, they do not as such exist." The fact is that genes controlling the key traits are known: *Pd:pd*, paired compared with single female spikelets, and *Tr:tr*, many compared with two-ranked spikes. All combinations of these genes occur in the F_2 and, although the phenotypes of the teosinte alleles tend to be unstable in a highly evolved maize background, their expression can be stabilized through selection. As a single event in the origin of maize, the transmutation suggested by Iltis should segregate as a simple Mendelian factor in the F_2 of hybrids and, thereby, yield only maize and teosinte (2). This is not the case.

The morphology of the oldest maize cobs and the genetics of maize-teosinte hybrids make the contentions of Iltis untenable.

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References

1. P. C. Mangelsdorf, *Proc. Am. Philos. Soc.* **127**, 215 (1983); *Maydica* **28**, 89 (1983).
2. W. C. Galinat, *Maydica* **28**, 121 (1983).

The catastrophic sexual transmutation theory (CSTT) of Iltis is a classic example of putting the cart before the horse. Recent genetic experiments suggest that annual teosinte, the closest relative of corn, and for more than a century regarded as its ancestor, may instead be its progeny. Hybrids of *Zea diploperennis*,

a perennial teosinte discovered by Iltis *et al.* (1) in Jalisco, Mexico, with a primitive Mexican popcorn race Palomero Toluqueño have yielded second-generation and backcross populations in Florida, Texas, and Argentina, in which plants possessing the essential botanical characteristics of annual teosinte have occurred in significant numbers. Some of these hybrid plants and "ears" (pistillate spikes) are remarkably similar to those of living races of annual teosinte (2). Yet Iltis dismisses the concept of annual teosinte's hybrid origin (3) as "wild" and ignores the published results that support it.

The author's assertion that the concept of a hybrid origin of annual teosinte is precluded by biochemical experiments can be questioned. The results of these sophisticated experiments are consistent in showing corn to be more closely related to annual teosinte than to any of its other relatives, a fact that has not been disputed for more than a century. What the experiments do not show is whether that close relationship is due to annual teosinte's being the ancestor of corn or to corn's being the ancestor of annual teosinte. The two concepts, although identical with respect to genetic relationships, differ in their chronological relationships. Parents are invariably older than their progeny. What does archeology tell us about the relative age of corn and annual teosinte? The answer is unequivocal!

Well-preserved remains of all parts of corn plants have been uncovered by MacNeish in once-inhabited dry caves in the Tehuacán Valley of Mexico. The earliest of these are dated by radiocarbon determinations at approximately 5000 B.C. They are true corn with all of the botanical characteristics of modern corn except size (4). In contrast, the earliest authentic remains of teosinte, turned up by MacNeish in caves in Mexico, are dated at approximately 1500 B.C. (5). Furthermore, in four other sites in which evidence of both corn and teosinte occur, the corn consistently precedes the teosinte, in one case by about 2000 years (6).

The CSTT does not explain corn's explosive evolution, which began about the time of annual teosinte's first appearance in the archeological record. It does not explain corn's almost incredible diversity, greater than that of any other crop plant, of which the cover picture accompanying the article shows but a small sample. It does not explain corn's heterosis (hybrid vigor), whose sophisticated exploitation in hybrid corn production has revolutionized U.S. agriculture

in the last half-century. Yet all of these facts are easily explained by recognizing that modern corn is a complex hybrid in which *Zea diploperennis*, whose discovery we owe to Iltis, has played a major role.

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References

1. H. H. Iltis, J. F. Doebley, R. Guzman, B. Pazy, *Science* **203**, 186 (1979).
2. J. Camara-Hernandez, P. C. Mangelsdorf, *Bussey Inst. Harv. Inst. Publ.* **10** (1981), p. 31; P. C. Mangelsdorf, L. M. Roberts, J. S. Rogers, *ibid.*, p. 39.
3. H. G. Wilkes, *Crop Improv.* **6**, 1 (1979).
4. P. C. Mangelsdorf, R. S. MacNeish, W. C. Galinat, *Science* **143**, 538 (1964).
5. ———, *Bot. Mus. Leaflet. Harv. Univ.* **22**, 62 (1967).
6. P. C. Mangelsdorf, *Proc. Am. Philos. Soc.* **127**, 215 (1983).

The catastrophic sexual transmutation theory (CSTT) maintains that the female maize ear was derived from the terminal central spike of the *male* teosinte tassel, which terminates primary lateral branches. It is based on (i) the indisputable homology of the maize ear to the central tassel spike of *Zea*, and (ii) the terminal position of the maize ear at the end of a primary branch, a position occupied in any robust native-grown teosinte plant by a tassel. The first of these homologies has long been accepted by Galinat, Mangelsdorf, and others, albeit within maize only. As S. J. Gould (1) recently reemphasized, evolutionary deductions must be based on correct interpretations of homology; in *Zea* evidently a difficult cross to bear for all concerned. Homologous structures need not look alike but, whether in maize or man, positional criteria are crucial and must be respected. Although Galinat (2), unlike Mangelsdorf, is now a staunch defender of the derivation of maize from teosinte, he suggests that the maize ear is derived from one of the many clustered lateral female ears (spikes) of teosinte. Lately (3), in addition, he appears, in his illustrations, at least, to have accepted portions of the CSTT, which has added greatly to the confusion, especially of anthropologists (4).

Derivation of the maize ear from the teosinte ear, as Galinat (2, 3) suggests, not only involves insurmountable positional difficulties, but does not explain how the immensely hard, permanently closed cupulate fruitcases bearing single spikelets changed into shallowly cupped rachids bearing soft-glumed, paired-free spikelets in the 7500-year-old Tehuacán maize. The oldest archeological maize ears do not resemble teosinte ears more than tassel spikes, as Galinat suggests.

The resemblance is only superficial, as both ears bear seeds. The oldest maize ears share with teosinte tassel branchlets (especially with feminized ones) many more *basic* characters: soft, elongate glumes, many more than 6 to 12 rachids, and flexible, only shallowly curved, laterally expanded and flattish inflorescence axes (rachids) bearing paired and free spikelets. Whatever lignification and condensation exists is characteristic of tassel feminization (for example, in "tassel seed," smut-infected tassels that changed sex, and any of the mixed tiller inflorescences). Galinat (2) has written that "[i]n the oldest known archeological maize cobs, the cupule is obsolete," an exaggeration which points to the derivation of what is called the cupule in maize (only partly homologous to the cupulate fruitcase of teosinte) from the flat, elongate rachid of a tassel. In fact, pressure of developing grains on soft meristematic tissue of the rachid induces invagination, the female hormones being released after fertilization of the ovule, rachis condensation and rachid and glume lignification (this occurs even in adjoining rachids bearing unfertilized spikelets). Aside from sexuality, all basic morphological differences between teosinte and maize are not between the teosinte and maize ears, but between the teosinte ear and the teosinte tassel spike, both on the same plant, controlled by the same genes, and structurally homologous. There are no essential morphological, cytogenetic, genetic, or biochemical differences between teosinte and maize, only structural-developmental ones related to sexuality (that is, femininity expressed on a male teosinte background, degree of apical dominance).

Galinat's other arguments are equally tenuous. No one disputes the adaptive utility of a long rachilla. Rachilla and pedicel length are determined by the structure of the ear and the harvest needs of man: the fatter the grain or the thinner the rachis, or both, the longer the rachilla and pedicel have to be. The tunicate locus, which produces a more or less striking atavistic abnormality, has not been demonstrated to have anything to do with the origin of maize, nor for that matter with the characteristics of *Chapalote* or the archeological maize from Bat Cave or Tehuacán.

Although minor, all the morphological differences between modern maize and teosinte are multifactorial (polygenic), a fact emphasized by the CSTT, with the original sexual transmutation a rapid process of threshold selection (Waddington's "genetic assimilation") for tassel feminization linked to branch condensa-

tion, which moved the tassel into a zone of female hormonal expression. What triggered the catastrophic sexual transmutations we do not know for sure. But increased feminization and therefore apical dominance were the key results, concentrating the nutrients into an efficient sink and thus benefiting by, and responding to, human selection. That the catastrophic sexual transmutation was a catastrophic process (not "a single event", as stated by Galinat), is due to maturation timing in a branch, where the apical tassel matures first and, once past the sexual threshold and female, rapidly arrogates all nutrients of the branch to itself. Since the primitive, basic morphological characteristics of the *Zea* tassel evolved by natural selection in teosinte and its ancestral genera over a period of millions of years, they are deeply canalized by probably hundreds of genes, and no sexual switch, no matter how dramatic it seems, will change their basic expression. And the five key genes that Galinat is looking for are for the most part already expressed in the teosinte tassel. Thus the rare maize abnormality *Pd:pd*, paired spikelet versus single spikelet, cited by Galinat has not been shown (and need not be invoked) to have been the factor necessarily involved in changing the single teosinte grains to paired ones in the maize ear. Whether an ear is two-ranked or many-ranked is due less to specific genes than to the degree of apical dominance, for, in "branched" maize, maize-teosinte hybrids, or even multi-eared branches of ordinary maize, the terminal ear is always many-ranked and the lateral ears on the same branch are often two-ranked. Certainly, increase in rank number (that is, condensation) is one of the main morphological characters selected by man gradually over time and is polygenic, to increase yield and harvestability. That an occasional factor appears to be shortcutting the multifactorial nature of such increases is no proof that this particular locus played any role in the process. While Galinat expects "the transmutation . . . to segregate as a simple Mendelian factor in the F_2 of hybrids . . .," the CSTT makes it clear that, in a suite of characters, that is now so deeply canalized no such segregation is to be expected.

As much as I love *Zea diploperennis*, being one of its godfathers, I must disavow the crucial role Mangelsdorf has assigned to it in the origin of maize. By setting up "annual" teosinte as a hybrid of a now extinct, mythical "wild maize" with *Zea diploperennis*, Mangelsdorf continues the confusion created by some

of the hybridization concepts of his tripartite hypothesis. His own hybridizations of *Zea diploperennis* with maize do not demonstrate the hybrid origin of "annual teosinte" (of which there are at least four distinct basic types) and, although fascinating in the immense diversity of intermediate forms produced, it is not true except in a superficial sense that some of these possess the "essential botanical characteristics" of the Mexican annual teosinte, whether one believes them to be ancestral to maize or not. The question is, "Are these similarities based on evolutionarily meaningful characteristics?" The answer is clearly no. *Zea diploperennis* belongs to the relictual, morphologically more primitive section *Luxuriantes* of *Zea* (5) and much recently published work (6-8) shows it to be radically different from maize and its biochemical twin, the annual "Guerrero" ("Balsas") teosinte (*Z. mays* ssp. *parviglumis*), the probable ancestor of maize (7, 8).

On morphology alone, *Zea diploperennis* and the other teosintes of section *Luxuriantes* must be immediately dismissed as potential progenitors of maize, because their characteristic many-nerved, winged outer glumes and flattened male spikelets are unknown in this cultigen and all Mexican annual teosintes.

Archeology abundantly supports the CSTT (7). The Tehuacán remains are indeed maize. Mangelsdorf refers only to the teosinte obtained from archeological excavations in Tamaulipas. In fact, the oldest known teosinte remains, from near Mexico City, are at least as old as Tehuacán maize (9).

Despite Mangelsdorf's and Galinat's comments, the CSTT gives the first reasonable explanation of the explosive evolution of maize, a dramatic shift in resource allocation to the terminal segment of the fruiting branch, which, first-maturing, soon assumed a self-reinforcing apical dominance enhanced by human selection.

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References

1. S. J. Gould, *Nat. Hist.* **93**, 12 (1984).
2. W. C. Galinat, *Bull. Torrey Bot. Club* **102**, 313 (1975).
3. ———, *Maydica* **28**, 121 (1983).
4. R. I. Ford, *Q. Rev. Archeol.* **4**, 12 (1983).
5. J. F. Doebley and H. H. Iltis, *Am. J. Bot.* **67**, 982 (1980).
6. H. H. Iltis and J. F. Doebley, in *Plant Biosystematics*, W. F. Grant, Ed. (Academic Press Canada, Toronto, 1984), p. 587.
7. J. F. Doebley, *Ann. Mo. Bot. Gard.* **70**, 32 (1983).
8. ———, M. M. Goodman, C. W. Stuber, *Syst. Bot.* **9**, 203 (1984).
9. J. L. Lorenzo and L. González Q., *Bol. Inst. Nac. Anthropol. Hist. Mexico City* **40**, 41 (1970).