ican cradle south into the tropical forest of Central and South America during the Archaic period and, indeed, why teosinte was originally brought under cultivation and domesticated. We still do not have archaeological sequences from Mexico pertaining to the earliest history of maize, so we cannot yet specify whether the fruitcases of teosinte were initial targets of selection pressure by nascent *Zea* cultivators. I have a feeling that at the outset most important domesticated plants, including maize, were used as food. Nevertheless, it is clear that *chicha* production and feasting were important aspects of social relations in many regions of the Americas. Smalley and Blake's paper lucidly and appealingly discusses these issues and will cause scholars to think about maize domestication in new and important ways.

The discussion of possible skews in bone collagen isotope ratios resulting from maize consumption primarily as calorie-rich stalk sugar or grain *chicha* is very interesting, and it highlights the growing importance to debates about maize of having good data on the bone apatite fraction. I have questioned (Piperno 1998:427–28) the appropriateness of using bone isotopes, especially collagen, from the standpoint of detecting maize consumption in the kinds of mixed tropical horticultural economies now well-evidenced from several sites in southern Central America and northern South America dating to between ca. 7,000 and 5,000 B.P. (Piperno and Pearsall 1998, Piperno et al. 2000). In these situations, many calories came from C_3 plants such as manioc, other roots and tubers, and tree crops. I was especially worried about what *chicha* drinking practiced as part of periodic ceremonial activities would do to those ratios. Smalley and Blake's consideration of how drinks made from maize stalk sugar and the grain might directly suppress a collagen bone isotope signal for maize relative to that expected for nonbeverage grain consumption adds an important new dimension to this problem.

I think that before we head straight to the ramifications of maize as an alcoholic beverage, we ought to consider more the role of *chichas* as important sources of dietary calories and fats. While it is true that one could ferment just about anything quickly in the tropical heat, nonalcoholic kinds of *chichas* made from any number of fruits and grains, including maize, are routinely consumed in the Neotropics today. These drinks, whether fermented or not, are typically high in calories and fats and may well have formed important dietary inputs and supplements in the pre-Columbian era, even if maize *chichas* were made from relatively small-grained maize cobs. One can imagine that expert horticulturalists in the tropical forest south of Mexico would have welcomed the odd maize plant and, forever seeking new ones to make drinks with, quickly experimented with its beverage-making capacities.

Bone isotope ratios on collagen from the preceramic site Cerro Mangote in Panama indicate moderate maize consumption between 7,000 and 5,000 B.P., when starch grain and phytolith evidence from nearby contemporaneous sites also clearly evidences routine processing of kernels (Norr 1995; Piperno et al. 2000, 2001). It seems that in Panama an early and appreciable focus was put on the maize grain, but, as Smalley and Blake indicate, separating beverage from kernel consumption will be difficult even when maize kernel remains are retrieved because the processing techniques for the two were probably the same or very similar and regional variability in maize use and production was probably considerable.

In the Americas more than in southwestern Asia and Europe, the roles of specific crop plants and their dietary contributions varied across regional boundaries and changed through time in ways that we are starting to detect in archaeobotanical records (e.g., Piperno and Pearsall 1998, Perry 2002). In light of the considerable empirical evidence for maize consumption dating to the Archaic period in southern Central America and northern South America (ca. 7,000 to 5,000 B.P., depending on the region), moving from a debate about whether maize spread out of its Mexican hearth before it became a staple crop to discussions of alternative uses of early maize represents a timely shift in research direction. Smalley and Blake have made a very significant contribution.

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Smalley and Blake offer a very reasonable hypothesis for explaining the widespread diffusion of maize after its initial domestication from teosinte in west Mexico. Many agree that the small cobs of early maize plants would not have been very attractive substitutes for the wild and/or cultivated foods already being consumed in different regions, but few alternative explanations coherent with archaeological and other data have been proposed. While some have similarly hypothesized an early social rather than economic role for maize, particularly in the form of *chicha* beer fermented from maize kernels (e.g., Staller and Thompson 2002, Tykot and Staller 2002), their hypothesis is provocative in suggesting that it was the sugary stalk which was initially important. But is their hypothesis supported more than others by the available archaeological and other data?

The impressive assemblage of ethnohistorical examples of maize stalk sugar use presented serves as a very plausible explanation for the chewed stalks recovered at the Tehuacán Valley cave sites, but, unfortunately, quids have not been identified at early archaeological sites elsewhere, even in the dry caves of Tamaulipas, Guitarrero, and Ayacucho where maize remains have been found. Is this simply because maize was not chewed and discarded in these caves on a regular basis? (There is, of course, no question that these cave sites cannot be considered representative of habitation sites and the activities which would have occurred at them and therefore this is absence of evidence rather than evidence of absence.)

While it is also unlikely that maize macro-remains could be recovered from an open-air site, it is very possible that an area of modestly intensive maize activity could be identified through systematic analysis of soil samples for maize phytoliths, starch grains, and carbon isotope ratios. Systematic analysis of anthrosols is becoming more common in archaeology and has potential for contributing to our understanding of early maize use, especially if stalk and cob remains can be differentiated (see Thompson and Staller 2000, Piperno et al. 2001, Pearsall, Chandler-Ezell, and Chandler-Ezell 2003).

At present, though, it is stable isotope analysis of human remains which has shed the most light on the quantitative importance of maize at different times and in different places. While significantly more published (e.g., Tykot 2002) and unpublished data are available than are presented by Smalley and Blake, their table 2 does give a fair overview of the contribution of maize to carbon isotope ratios in bone collagen. But it is not surprising that there is a major gap between the first documentation of maize by paleoethnobotanical evidence and its becoming noticeable in collagen carbon isotope ratios. The difference in ratios between C_3 plants and maize (about 14‰), the precision of a single isotopic measurement (usually no more than ± 0.2 for reference materials on most mass spectrometers but at least double that for skeletal samples), and the isotopic variation that is likely to exist within a population eating the same range of foods combine to require a positive shift of at least 1‰ to indicate the consumption of any non-C_3 foods. More important, maize would have to constitute at least 10% of the protein portion of the diet to produce noticeably different carbon isotope ratios in collagen. If maize stalks were initially important as a sugar source (fermented or not), they would contribute hardly at all to collagen, but the contribution of maize cobs to collagen would also be very minor if terrestrial and/or aquatic fauna were consumed in any quantity.

Carbon isotope ratios in bone apatite and tooth enamel would, however, reveal when maize constituted 10% of the total diet, whether in the form of protein, carbohydrates, or alcohol. Unfortunately, far fewer isotopic analyses have been done on apatite and enamel, especially for earlier time periods. Both bone collagen and apatite reflect average diets over at least several years prior to death, and therefore maize's isotopic contributions will be reduced if it is not consumed consistently from year to year. Further, it is likely that, prior to the establishment of storage facilities, maize was consumed mostly on a seasonal basis. The best way, then, to demonstrate the initial consumption of maize would be by analysis of hair or tooth enamel. Analysis of 1-cm lengths of hair would reveal dietary variation from month to month, while careful microsampling along a vertical transect of a tooth could also reveal seasonal variation. One study done of individuals from highland Ecuador shows a difference of at least 30% in maize consumption from season to season (Tykot, Ubelaker, and Wilson 2000).

Since the available evidence strongly indicates that maize did not become a staple in many areas despite being present early on at great distances from highland Mexico, I agree wholeheartedly with Smalley and Blake that we must look for explanations other than its later importance as a cereal crop to account for its precocious spread throughout Mesoamerica and in much of South America. Their hypothesis is very sound, but more research is necessary to test whether it explains well the motivation and circumstances behind the initial domestication and spread of maize.

Reply

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In his 1940 doctoral dissertation, written under the direction of Carl O. Sauer and published 60 years later, Henry Bruman (2000:57) observed:

> Sugarcane, entirely unknown in aboriginal America, was one of the first economic plants to be introduced by the Spaniards. However, a sweet cane in the broader sense was not only known but widely utilized prior to the Conquest. The Indians had learned that green cornstalks contained considerable sugar; and in many and widely separated areas, it was common practice to crush the stalks, collect the juice, and boil it down to a syrup.

Hugh Iltis, in his address as Distinguished Economic Botanist to the Society for Economic Botany in 1998, after decades of research on teosinte, asked why ancient Native Americans would have been interested in it and suggested that "teosinte was not grown for its grain, but for other culinary virtues," the primary one being its "sugar-containing pith" (Iltis 2000:30). We are pleased that most of the commentators assess our paper in the spirit in which it was offered—as an exploration of the archaeological intersections of these two pioneering contributions. Most of the respondents recognize that we were suggesting an initial hypothesis about why and how teosinte was domesticated and its descendant, maize, came to be one of the dominant food plants of the ancient New World. We are indebted to them for insightful suggestions and new ideas that will, we think, help guide future research on the topic.

Chavez's report of the lack of ethnohistoric and ethnographic evidence for the chewing or processing of maize stalks for sugar in Peru and Bolivia raises some important questions. It may be that in the Andean region there was a long-standing use of maize stalks as fodder for domesticated animals and that present-day herders and farmers rely on the maize plant for its fodder potential. This suggests the possibility that prior to the widespread introduction of sugarcane pre-Columbian Andean peoples extracted sugary juice from the stalks and then fed the debris to their camelids and other domesticated animals. Although Chavez says that no early South American chroniclers mention the chewing or processing of maize stalks, Garcilaso de la Vega (1966 [1609]: 499) reports that "an excellent honey is made from the