100 YEARS AGO

Suppose I toss a penny, and let it fall on the table. You will agree that the face of the penny which looks upwards is determined by chance, and that with a symmetrical penny it is an even chance whether the "head" face or the "tail" face lies uppermost. For the moment, that is all one can say about the result. Now compare this with the statements we can make about other moving bodies. You will find it stated, in any almanac, that there will be a total eclipse of the moon on December 27, and that the eclipse will become total at Greenwich at 10.57 p.m.; and I imagine you will all feel sure on reading that statement, that when December 27 comes the eclipse will occur; and it will become total at 10.57 p.m. It will not become total at 10.50 p.m., and it will not wait until 11.0 p.m. You will say, therefore, that eclipses of the moon do not occur by chance. What is the difference between these two events, of which we say that one happens by chance, and the other does not? The difference is simply a difference of degree in our knowledge of the conditions. The laws of motion are as true of moving pence as they are of moving planets…

From *Nature* 22 September 1898.

50 YEARS AGO

That Newton had a just appreciation of the work of Huygens and fully understood it is significant, because Huygens signally failed to comprehend Newton's full achievement, although he realized Newton's greatness as a mathematician and as an experimenter. He criticized Newton's fundamental work on colour because it did not explain the ultimate nature of colour – "Besides, if it should be true that the rays of light, in their original state, were some red, others blue, etc., there would still remain the great difficulty of explaining, by mechanical principles, in what consists this diversity of colours". He did not understand Newton's "But to examine how Colors may be explained hypothetically is beyond my purpose". Huygens himself wrote little about colour, since the problem as he conceived it, to find a mechanical explanation, seemed to him intractable. … To say this is not to disparage Huygens, whose fundamental achievements make a formidable list.

From *Nature* 25 September 1948.

Other traffic may have run in the opposite direction. For example, it is thermodynamically difficult to form peptides out of individual amino acids in the open ocean, but amino acids have been converted to peptides in experiments that are claimed to model hydrothermal settings[11]. We don't know whether amino acids themselves can form at vents, but they might have been produced copiously at the Earth's surface[12], and would also have arrived on meteorites[13]. So perhaps they were delivered from the surface to the vents, and only there linked into peptides.

But none of these possibilities should be overplayed; there is still too much we do not know. For example, nitrites and nitrates would have been created by a number of sources on the early Earth, including lightning in clouds of volcanic ash[14], and then reduced to ammonia by Fe^{2+} in the ocean[15]. These mechanisms may have produced as much ammonia as the mineral-catalysed reduction identified by Brandes *et al.*[1].

It is intriguing to ask how early terrestrial hydrothermal environments differed from the wet, organic-molecule-rich environments in the parent bodies of carbonaceous chondrite meteorites early in the Solar System's history[3]. Evidence from mineralogy and organic chemistry makes it clear that the Murchison meteorite, for example, experienced liquid water for the first 10,000 years or so of its history, during which time its amino acids were probably synthesized. Yet there is no evidence for peptides in Murchison[16], and in general it appears that prebiotic evolution in that object did not proceed beyond simple monomers. Why not? Does this cast doubt on the hydrothermal-origins hypothesis, or was something missing, or the time too short? Within the deep interiors of large asteroids, where liquid water may have persisted for a hundred million years, could prebiotic chemistry have proceeded much further[3]? This is, after all, comparable to the time available[8] for the origin of life on Earth. □

Christopher Chyba is at the SETI Institute, 2035 Landings Drive, Mountain View, California 94404, and in the Department of Geological and Environmental Sciences, Stanford University, Stanford, California 94305, USA.
e-mail: chyba@seti.org

1. Brandes, J. A. *et al. Nature* **395,** 365–367 (1998).
2. Gold, T. *Proc. Natl Acad. Sci. USA* **89,** 6045–6049 (1992).
3. Chyba, C. F. & McDonald, G. D. *Annu. Rev. Earth Planet. Sci.* **23,** 215–249 (1995).
4. Carr, M. H. *et al. Nature* **391,** 363–365 (1998).
5. www.jpl.nasa.gov/ice_fire//AO_002.htm
6. Stevens, T. O. & McKinley, J. P. *Science* **270,** 450–453 (1995).
7. Anderson, R. T., Chapell, F. H. & Lovley, D. R. *Science* **281,** 976–977 (1998).
8. Sleep, N. H. *et al. Nature* **342,** 139–142 (1989).
9. Holm, N. G. *Orig. Life Evol. Biosph.* **22,** 5–14 (1992).
10. Sagan, C. & Chyba, C. *Science* **276,** 1217–1221 (1997).
11. Huber, C. & Wachtershauser, G. *Science* **281,** 670–672 (1998).
12. Schlesinger, G. & Miller, S. L. *J. Mol. Evol.* **19,** 376–382 (1983).
13. Chyba, C. & Sagan, C. *Nature* **355,** 125–132 (1992).
14. Navarro-Gonzalez, R., Molina, M. J. & Molina, L. T. *Geophys. Res. Lett.* **25,** 3123–3126 (1998).
15. Summers, D. P. & Chang, S. *Nature* **365,** 630–633 (1993).
16. Cronin, J. R. *Orig. Life Evol. Biosph.* **7,** 343–348 (1976).

Plant domestication

Getting to the roots of tubers

Peter D. Moore

Starch, derived from the roots of tuberous plants, is the staple dietary energy resource for the peoples of many tropical countries. These plants, such as manioc (or cassava, *Manihot esculenta*; Fig. 1) and sweet potato (*Ipomoea batatas*), are widely used, yet little is known about their origins. Undoubtedly they evolved in Central and South America, but beyond that there is little evidence of where or when they were first brought into cultivation. The main problem for archaeologists is the lack of fossils — unlike the grasses, tuberous plants have no persistent parts that survive in sites of former cultivation or food preparation. But an approach that may open up new opportunities for tracing the roots of Neotropical agriculture is now reported in the *Journal of Archaeology*. Dolores Piperno and Irene Holst[1] show that starch grains belonging to some of the plants in question have survived on the surfaces of prehistoric stone tools.

Old World archaeologists tracing the history of the cereals have many advantages over their New World colleagues. Grasses store their starch in tough seeds that are easily carbonized and preserved in an intact state, allowing them to be identified with precision to species level. The grasses also contain opal phytoliths — silica bodies with distinctive, often angular, shapes — that are relatively inert and survive after organic tissues have decomposed. Moreover, the domesticated cereals produce pollen grains with features that allow them to be separated from other grasses, providing opportunities for the history of cereal-based agriculture to be traced. By contrast, the Neotropical starch-producing root crops, such as manioc, have no identifiable phytoliths, produce few pollen grains and do not carbonize, so it has been difficult to work out their history.

Starch grains vary in size, shape and structure, and it has been claimed that they are distinctive enough to allow species determination[2]. So if starch grains could be found in a datable situation, they could provide evidence for the use of certain plants in the past — including the Neotropical root crops whose history has proved so elusive. The most obvious place to look for such starch grains is on the tools used for grinding and

P. KARUNAKARAN/HOLT STUDIOS

Figure 1 **Ancient roots — heaps of harvested manioc (*Manihot esculenta*) for sale at a market. Piperno and Holst[1] show that starch grains from manioc, and other Neotropical root crops, have survived on the surfaces of ancient stone tools.**

preparing food. It has been shown that the stone hunting weapons of prehistoric societies may carry traces of the victim's blood, and that the haemoglobin can be identified to species level[3]. It is possible that the rough surfaces of grinding tools could, similarly, carry a residue of informative starch grains.

This approach was used by Thomas Loy[4] in his research into prehistoric remains from the Solomon Islands. He examined stone tools, dating from 27,000 years ago, and found starch grains belonging to *Colocasia esculenta* (taro). This plant has a starch-rich corm (an underground, swollen stem base), and is now widely cultivated in the tropics. Loy's finding provided circumstantial evidence for use of this plant as food in the late Pleistocene and, possibly, even its early domestication. The work also confirmed the potential of starch-grain analysis as a means of tracing the history of early food plants.

Piperno and Holst[1] have now applied similar techniques to investigate manioc and arrowroot (*Maranta arundinacea*) in the humid tropical lowlands of Panama. They examined a number of archaeological sites from which milling stones were available, and extracted starch grains from the crevices in the rough surfaces of these stones using a binocular dissecting microscope and a needle. Not only did they find starch grains, but they also had considerable success in identifying these on the basis of an extensive type collection that they had established. The oldest site was a rock shelter where grinding cobbles dating from the pre-ceramic stage (8,000 to 5,000 years ago) were recovered from sediments in which phytoliths of bottle gourd, squash and maize had been found. Starch grains that compared well with those of manioc were found on the cobbles, confirming the early use of this plant in the lowland tropics. The authors also found starch grains of maize and arrowroot on these implements.

Much more work needs to be done on the taxonomy of starch grains, particularly those from potential crop species. But these preliminary results seem to establish that a variety of starch-producing plants, including manioc, were being exploited in central Panama about 7,000 years ago. Although we do not know whether these plants were gathered from the wild, or whether they were cultivated, palaeolimnological work in the area indicates some slash-and-burn clearance of the forest at that time. This strengthens the case for the development of agriculture as an explanation for the presence of these plants. The occurrence of other known crop species in association with the manioc and arrowroot gives weight to this argument.

Most important of all is the confirmation that recognizable starch grains can persist over many millennia in the Neotropics — this opens up new opportunities for determining, with precision, how these crop species with an invisible past were domesticated. □

Peter D. Moore is in the Division of Life Sciences, King's College, Campden Hill Road, London W8 7AH, UK.
e-mail: peter.moore@kcl.ac.uk

1. Piperno, D. & Holst, I. J. *Archaeol. Sci.* **25,** 765–776 (1998).
2. Banks, W. & Greenwood, C. T. *Starch and its Components* (Edinburgh Univ. Press, 1975).
3. Loy, T. H. *Science* **220,** 1269–1271 (1983).
4. Loy, T. H. in *Tropical Archaeobotany* (ed. Hather, J. G.) (Routledge, London, 1994).

Daedalus

A magnetic speaker

The crudest component of a sound system is its loudspeaker. The most flawless recording, perfectly digitized, recovered and ultra-linearly amplified, must still be heard via a clumsy cone of plastic or paper flapping about in time with it. Daedalus now has a better idea. His new 'Paraspeaker' has no moving parts at all.

The Paraspeaker exploits the fact that the oxygen of the air is paramagnetic. So it is attracted into, and compressed by, a magnetic field. Vary that field at an audio frequency, and the pressure must vary in sympathy. This, says Daedalus, is why many transformers produce a steady hum, though they have no moving parts. The air around the transformer is alternately compressed and released by its stray magnetic field, and speaks up at its line frequency. Well — twice that frequency, actually. For, annoyingly, the induced pressure varies not with the field, but the square of the field. This gross nonlinearity doubles fundamental frequencies, and adds other frightful distortions as well.

Daedalus is undismayed. Electronic signal-processing is so fast and precise these days that this and other problems can be sorted out electronically in real time. The Paraspeaker will simply be a large coil of wire set in a hole in a baffle-board; but the electronics driving it will be subtle and complex. The audio signal will go through a square-rooter and programmable signal conditioner while it is still digital. After analog conversion, a dedicated amplifier will feed it to the Paraspeaker.

The Paraspeaker will be a ferociously inductive load; even the best analog amplifier may falter in driving it. The signal conditioner has the job of tweaking the digital signal so as to cancel the aberrations that it will meet downstream. Once programmed to counter the flaws of the following amplifier, it will ensure that a perfect signal reaches the Paraspeaker. So perfect sound will emerge. Its vacant central hole will be an open window on transparent, flawless sound.

The hi-fi community will be entranced. Yet the major benefactors will be the boom-box community, and its victims. For the boom box has but one advantage over a system using headphones: it avoids their discomfort and blanking out of ambient sound. But Paraspeaker earphones, being simply hollow coils, do not obstruct the ears. They can be worn 24 hours a day. The music addict will be able to enjoy his narcotic endlessly, without deafening the rest of us with his damnable loudspeakers.

David Jones