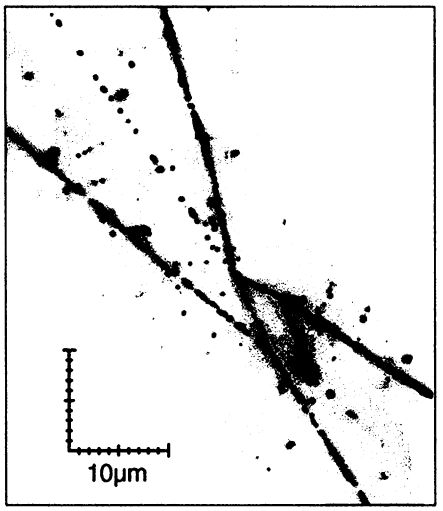


Xi no more. Emulsion at KEK captured demise of a Ξ^- particle and creation of ${}^{6}_{\Lambda\Lambda}$He.

cles with strange quarks attract each other. For this reason, they have been scrambling to get two Λ particles together to measure how tightly they are bound. "It's the number that everyone's after," says Robert Chrien, of Brookhaven National Laboratory in Upton, New York.

Unfortunately, scientists can't produce beams of Λ particles needed to measure the attraction directly. "The only way to get the lambdas to interact is to put them in the same nucleus," says Chrien. "You can't do the measurement any other way." Though scientists have inserted a single Λ particle into nuclei such as beryllium-7 (*Science*, 9 March, p. 1877), creating "hypernuclei," they have failed to get two Λ particles into the same nucleus—until now.

Last week, Ken'ichi Imai of Kyoto University in Japan presented a picture of an emulsion that provides good evidence of the creation and destruction of ${}^{6}_{\Lambda\Lambda}$He (helium-6-lambda-lambda): an ensemble of two protons, two neutrons, and two Λ particles. At the KEK high-energy accelerator in Tsukuba, Japan, Imai and his colleagues smashed kaons—two-quark particles with a strange component—into a diamond target, creating xi-minus (Ξ^-) particles, which each contain two strange quarks. An emulsion, an expensive version of a photographic plate, captured an event that looks for all the world like a Ξ^- particle being absorbed by a carbon atom, creating a ${}^{6}_{\Lambda\Lambda}$He along with less interesting byproducts. From this first glimpse of the ${}^{6}_{\Lambda\Lambda}$He, "the lambda-lambda interaction energy was determined for the first time," says Imai. "It's pretty clean," says Chrien, whose team at Brookhaven has come up with slightly weaker evidence of a different doubly strange hypernucleus, ${}^{4}_{\Lambda\Lambda}$H (hydrogen-4-lambda-lambda).

According to these experiments, the lambda-lambda attractive energy seems to be fairly weak—about 1 million electron volts (MeV), much less than the estimate of 4 or 5 MeV reported in an earlier, dubious claim of a doubly strange hypernucleus. The new number is more in line with expectations. "One MeV will make a lot of theorists happy," says Chrien.

Both groups stress that these events are still early results; scientists will need to produce more doubly strange hypernuclei to be certain about the binding energy. But Ed Hungerford of the University of Houston says the recent advances in strange physics are extremely encouraging. "It's an extra degree of freedom for illuminating nuclear structure," he says. So for once, physicists can be forgiven their extra dose of strangeness. **–CHARLES SEIFE**

ARCHAEOLOGY

Spreading the Word, Scattering the Seeds

Did civilization follow the plow? An alluring model of the dispersal of language and agriculture meets resistance

CAMBRIDGE, U.K.—In 1987 Colin Renfrew's story sounded compelling, like a logical extension of Napoleon's observation that an army marches on its stomach. As the Cambridge University archaeologist first framed it then, throngs of farmers, grown strong on newly domesticated crops—wheat and barley in the west, rice in the east—swept across the land beginning 100 centuries ago. Armed with seeds, genes, and language, they pushed aside indigenous hunter-gatherers like a plow through virgin soil. Renfrew's "farming-language dispersal hypothesis" became a leading explanation for the present distributions of language and culture in Europe, Africa, and Polynesia.

But not everyone was eager to jump on the oxcart. Many scholars were suspicious of the grand aspirations of the farming-language hypothesis and of its archaeologist proponents, who they say tend to ignore unfavorable linguistic data. "The phenomenon of major expansion is very real," says linguist Roger Blench of the Overseas Development Institute in London, but "it's inconceivable that there is just one explanation."

Renfrew and Peter Bellwood of Australian National University in Canberra—the pioneer of the hypothesis in the Pacific islands—recently held a conference* here to confront the challenges and foster more genuine collaborations. But new studies presented from India and Southeast Asia further threaten the hypothesis, weakening the case for cereal crops as engines of linguistic dispersal. Along with ongoing controversy over Europe, this adds a heavy burden of complexity to the Renfrew-Bellwood model. "The initial hope of easy answers is being replaced by the realization that there's more to do," Renfrew says.

His original hypothesis—framed in the 1987 book *Archaeology and Language*—pictured culture, biology, and language marching in triumphal lockstep. Testing and elaborating the theory required interdisciplinary input. Archaeologists map the movement of cultures by following a trail of pots, tools, and seeds. Geneticists map the movement of populations by comparing genetic markers of people in one region with those of people in their hypothesized homelands. And linguists map the movement of languages by reconstructing ancient tongues from the shared vocabularies of modern ones. When a family of languages has similar agricultural terms—"wheat," say, or "harvest"—the linguists infer that before the languages branched apart, the ancestral speakers were farmers.

If Renfrew's hypothesis is right, then when these disparate scientists put their maps together, the arrows should point in the same direction, indicating a concerted agricultural dis-

Fantastic voyage. On canoes like this one, the Austronesians traveled from Taiwan to islands in Southeast Asia starting 4500 years ago.

CREDIT: CAMBRIDGE UNIVERSITY MUSEUM OF ARCHAEOLOGY AND ANTHROPOLOGY

* Examining the Farming/Language Dispersal Hypothesis, 24–27 August.

persal of genes, crops, and words. A wealth of interdisciplinary evidence gathered since 1987 has led Renfrew to refine his hypothesis, allowing individual arrows to sometimes wander off on their own. New reports from the Cambridge conference suggest that wandering arrows may be the rule and lockstep spread the exception.

In India, for example, Renfrew and Bellwood have proposed migration pathways from the fertile crescent—where the Near Eastern agricultural "package" of wheat, barley, sheep, and cattle originated 10,000 years ago—along the Arabian coast, reaching India as early as 8000 years ago. The hypothetical Elamo-Dravidian language family—which includes the Dravidian languages Tamil in India and Brahui in Pakistan, and the extinct Elamite language in Iran—shows a nice, sweeping distribution in the same direction.

Dorian Fuller, an archaeobotanist at University College in London, offers a different story. His excavations show that indigenous southern Indian crops such as mung bean and foxtail millet appeared in southern India 4800 years ago, with wheat and barley arriving 600 years later. The Near Eastern crops apparently stalled for 3000 years in northwest India before farmers developed monsoon-tolerant wheat. Also undermining Renfrew's hypothesis is new work on Dravidian linguistics. Preliminary analyses suggest that the Dravidian words for native southern Indian crops are older than the words for the Near Eastern agricultural package. So Dravidian may be native to India and unrelated to Elamite. Finally, genetics does reveal a migration from the Near East to India, but the large margin of error means it could have happened 20,000 years before the birth of agriculture, says Toomas Kivisild, a geneticist from the Estonian Biocenter in Tartu.

The latest picture from India "snaps quite a sizable arrow," says Cambridge archaeologist Martin Jones. And one of Jones's former students is bending an even bigger arrow: the "Austronesian" expansion into the Pacific, a centerpiece of the farming-language hypothesis.

Victor Paz, an archaeologist at the University of the Philippines in Quezon City, questions the significance of rice agriculture as a force behind the early Austronesian dispersal. Speakers of this language family—which includes more than 1000 languages spanning Madagascar to Easter Island—left Taiwan about 4500 years ago in outrigger canoes carrying distinctive red pottery and reached Polynesia about 1500 years later. Reconstruction of the Austronesian mother tongue reveals ancient words related to rice, confirming that these mariners were initially rice farmers.

But when Paz inspected the relevant archaeological sites, he found almost no rice alongside Austronesian-style pottery between Taiwan and Borneo. Instead, residents were eating tubers such as yams and taro, according to recent images of unearthed plant remains using scanning electron microscopy. "Every time you see the pottery in an archaeological context, it's almost second nature to assume that you have rice agriculture. But now we know for a fact that that's not true," Paz says.

Genetics further complicates the picture. Studying mitochondrial DNA sequences, Stephen Oppenheimer of Oxford University and his colleagues have shown that contemporary Polynesians—a small Austronesian offshoot—hail from eastern Indonesia, not Taiwan, and predate the Austronesian expansion (*Science*, 2 March, p. 1735). So crops, languages, and genes were often moving in quite different directions, ruling out the sweeping, unified expansion of the early farming-language model.

Bellwood disputes many of the dates offered by geneticists but has given some ground on the archaeology. "I am willing to agree that rice might not have been as important as we once thought," he says. "But rice was still there at the beginning." And, he agrees, the Austronesians abandoned it at some point. What's unclear is whether they retained their farming way of life or simply foraged, fished, and farmed in whatever combination suited their latest island home. Bellwood and Paz both plan new excavations to clarify what crops, if any, drove the expansion.

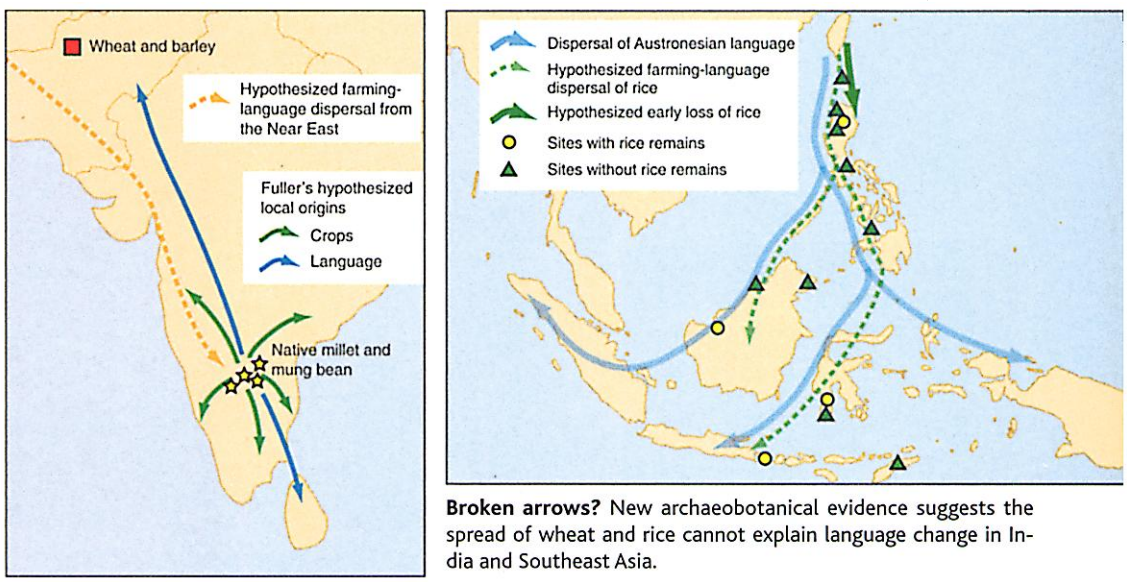
Europe, the continent for which Renfrew conceived the hypothesis, is under siege as well. Complicating the picture, European languages and crops come from different homelands, at least according to most linguists. And conference participants raised other reasons for skepticism over how tightly culture, genes, and language are bound together in Europe. For example, "language shift," in which a group adopts an outside language but not outside genes, is more common than most archaeologists accept, linguists say. This is how Hungarian and Turkic languages spread in Europe, millennia after farming arrived. Furthermore, hunter-gatherers may often have held their ground against the advance of farmers, as evidenced by the strong contribution of preagricultural genetic markers to modern European genotypes.

Some experts see all this complexity as a crippling blow to the hypothesis. But Renfrew views complexity as the inevitable product of better data. "It's always the case with a simple explanation that you have to look at a more detailed level," he says. "And things are more detailed at the detailed level." Many of the objections are isolated examples that don't threaten the larger model, he argues. According to Renfrew, on the continental and global scales, language and agriculture move together in consistent if imperfect synchrony.

Researchers from both sides of the debate have now rejected what Jones calls "the amoebic view of culture," in which civilizations spread without ever interacting with the people around them. But for the farming-language dispersal hypothesis to survive, it will have to accommodate such complications as local domestication and the discontinuity of crops, languages, and genes.

Renfrew thinks his hypothesis will survive these growing pains. "One can say that models are made to be used," he says, "and we've gotten some good mileage out of this one."

–BEN SHOUSE



Broken arrows? New archaeobotanical evidence suggests the spread of wheat and rice cannot explain language change in India and Southeast Asia.

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