in a process known as fractionation. Last year biochemist Noreen Tuross of the Smithsonian's Conservation Analytical Laboratory showed just how complex fractionation can make things—by using herself as a guinea pig. Tuross ate a strict vegetarian diet that included no animal protein of any kind. When she sampled the nitrogen isotopes in her own fingernails, she found ratios that made it look as though she had been surviving largely on animal protein. She then warned her colleagues that an increase in nitrogen-15 can be a sign of protein deficiency—and not by any means a sure sign of a diet that is high in animal protein.

And there are other pitfalls. Isotope ratios can be altered by contamination in the lab or in soils where the bone was found or by decay after the animal has died. Different species may fractionate isotopes differently, and factors such as age, size, feeding behavior, and gut anatomy can influence the ratios. Even atmospheric nuclear tests and the industrial revolution have changed the carbon ratios in plants. Says isotope geochemist Marilyn Fogel of the Geophysical Laboratory of the Carnegie Institution of Washington: "When you start to think of all of that, you wonder why these methods work at all. Thank God, they do work."

Fogel's relief reflects the importance of the questions that isotopy is now capable of answering. "Diet is the key to some of the most important questions in evolution," says Paul L. Koch, a postdoctoral fellow at the Smithsonian. The question of what specific environmental niche a species occupied can in part be answered by some traditional archeological methods or by sampling fossilized seed and pollen associated with human and animal remains. But isotopic ratios are capable of providing a much more direct and definitive answer.

So far isotopes have provided an excellent window into diets of the relatively recent past—particularly where collagen is present. Collagen is the major protein in bone, and lab techniques for determining its isotopic ratios are well established. "In some of its applications, isotopy is becoming routine," says van der Merwe, who splits his time as a professor at Cape Town and Harvard University. "It's the kind of stuff that most archeologists working in the Americas use. As a matter of course, they deal with the collagen in skeletons to get dietary information about maize."

Using those methods, van der Merwe helped prove that hunter-gatherers in North American woodlands began to cultivate maize later than expected, at about A.D. 1000. He is using the technique to help settle a debate among archeologists about whether prehistoric people who lived along the coast of Ecuador at about 3100 B.C. subsisted on seafood or on maize they had cultivated. Michael J. DeNiro at the University of California at Santa Barbara identified plants cooked by Indians living in the Upper Mantara Valley of Peru as early as 200 B.C. by measuring isotopes found in residues on the inside of their cooking pots.

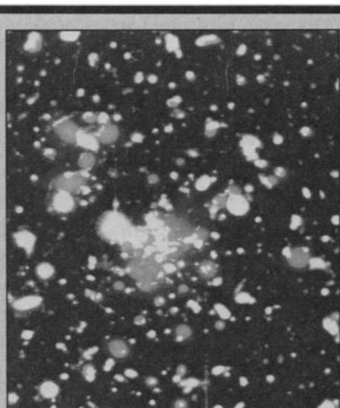
Collagen, however, has its limitations as a material for isotopic analysis—and these have helped to determine the current limits for the technique. Collagen lasts only about 10,000 years in the tropics, making it useless for studying older specimens. As a result, much of the interest at last week's conference was sparked by new methods that could allow researchers to dig deeper into the past. "It is time to break out of the collagen bonds," van der Merwe said at the conference.

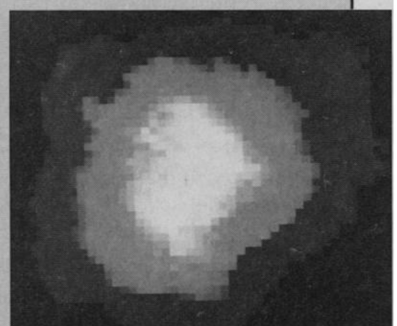
But efforts to break the collagen bonds are still highly experimental, and some in the field remain skeptical. Lee-Thorp's work with isotopes in apatite from tooth enamel in hominids and other primates is promising, but colleagues are waiting for more experiments to verify her findings before they can be fully accepted. Many in the field remember a disappointing earlier attempt to use apatite in determining isotope ratios that was shot down by DeNiro and Margaret Schoeninger of the University of Wisconsin in a 1982 article.

But more researchers are beginning to test apatite, and some are trying to extract other isotopes, such as oxygen, hydrogen, and strontium, from noncollagenous sources. So far, their results have been mixed, and Koch of the Smithsonian reported that he'd had little success in trying to interpret oxygen isotope ratios from the apatite of humans who lived some 5000 years ago in Tennessee.

Nonetheless, it's inevitable that these methods will be tried on remains of early hominids in an attempt to reconstruct the world in which they lived, says van der Merwe. One of his postdocs at Cape Town is already using isotopy to study the climate at the time of a mass extinction in the Permian, more than 200 million years ago. This kind of work begins to change the entire scope of isotopy. "This takes us into global change," says Tuross. "It gives a way to study past ecosystems and how animals and humans interact with the environment. And that's just the beginning. These are complex signals, and they are giving us far more information than we ever anticipated."

■ ANN GIBBONS





J. Anthony Tyson

Seeing the Unseeable. For two decades now, astronomers have been trying to comprehend a near-mystical substance known as "dark matter"—the invisible ectoplasm that seems to comprise at least 90% of the mass in the universe, and that makes itself known only by its gravitational effects on the visible stars and galaxies. Theorists have speculated that the stuff consists of intergalactic rocks, weakly interacting particles left over from the Big Bang, or even miniature black holes. But nobody has ever actually *seen* it.

Until now, that is: as the images shown here suggest, J. Anthony Tyson and his colleagues at Bell Laboratories have recently found a way to make rough maps of the dark matter that resides in clusters of galaxies. Their technique starts with a long, long telescopic exposure of the cluster—in this case, the cluster Abell 1689 (left). If the exposure is long enough, says Tyson, it will eventually reveal a dense patchwork of faint, irregular blue blobs behind the cluster, with each blob presumably being a very distant galaxy just bursting into life. But the blobs are not oriented at random, as they are in exposures of empty sky: the gravitational field of the cluster bends their light and distorts them into short arcs that are more or less concentric with the cluster center. A computer analysis of the arcs can therefore map out the mass in the cluster—and that mass must include the dark matter as well as the ordinary stars (right).

The resulting maps reveal that in most clusters the dark matter does indeed spread throughout intergalactic space, says Tyson. Moreover, it vastly outweighs the visible galaxies. He and his colleagues are now halfway through the analysis of some 14 clusters. And with the help of several international collaborators, they hope to have data from 30 clusters by the end of the year. The resulting images probably won't tell us what the dark matter actually is, says Tyson, "but they will certainly constrain the theoretical models."

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