The laser gyro promises to be faster still, and just as accurate. The gyro consists of a glass block 1.2 meters on a side, with a square channel a meter on a side bored through it. The channel is filled with helium and neon gas. Researchers excite the gas with radio waves, and the whole device acts as the cavity of a helium-neon gas laser, producing two coherent beams, traveling in opposite directions. Mirrors at each corner guide the beam around the ring.

The two counterrotating beams interfere with each other to produce a so-called standing wave—a fixed pattern of several million bright and dark spots, called nodes and valleys, crammed into the ring. "This standing wave is standing still in absolute space," says Hans Bilger of Oklahoma State University in Stillwater, a ring laser expert who helped design C-II, but the wave moves relative to the gyro. "If you rotate the physical housing of this standing wave, then this housing rotates around the standing wave, and if you look through a mirror at the standing wave, then you simply see valleys and nodes walking by you," he says.

Earth's rotation has exactly that effect, causing 79 nodes of the standing wave to pass by any point on the gyro every second. To detect changes in Earth's rate of rotation, the researchers must measure variations in this node rate to an accuracy of one in 10 million. "We are getting toward parts per million, and I believe we shall be there in a few weeks' time," says Stedman. Ultimately, he says, "we hope it will be able to pick up something like lunar tides." That would require a sensitivity of four parts in 100 million, he says, which he calls "quite a tall demand."

For a start, any variations in temperature would prove disastrous because thermal expansion in the glass could change the laser's path length and thus its frequency. So the researchers installed the instrument in an artificial cave 30 meters underground, where the temperature is stable to a few hundredths of a degree. They are also stabilizing the size of the ring using "adaptive optics" techniques. The researchers constantly compare the ring laser frequency to an extremely stable reference laser, and correct for any discrepancies by bending one of the mirrors with an actuator.

Already, though, the ring is picking up the rotational component from the seismic waves of nearby earthquakes. And even if C-II does not reach the sensitivities needed to explore the mechanisms affecting Earth's rotation, its successor might. The team is seeking funds for a larger, 4-meter ring laser that they hope to install in a cave to be built in Wettzell, Germany, around 2002.

–Alexander Hellemans

Alexander Hellemans is a writer in Naples, Italy.

EVOLUTION

'Living Fossil' Fish Is Dethroned

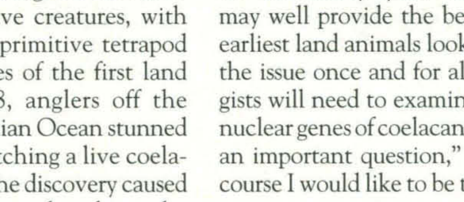
About 370 million years ago, a restless faction of the fishes traded in their fins for feet and set out to colonize land. Biologists have debated for decades exactly which members of the fish family made this bold move—and therefore which of their descendants are our closest living gilled relatives. Now it seems that the popular favorite, the "living fossil" known as the coelacanth, is out of the running.


Coelacanth

AMERICAN MUSEUM OF NATURAL HISTORY

That's the tentative conclusion reached by two researchers who have completed the most comprehensive survey to date of coelacanth mitochondrial DNA (mtDNA). Mitochondria, organelles that serve as power plants in all higher cells, carry their own small complement of genes that mutates over evolutionary time, enabling scientists to infer how long any two species have been diverging by comparing their mtDNA. In this month's issue of the German journal *Naturwissenschaften*, geneticists Axel Meyer of the University of Konstanz in Germany and Rafael Zardoya of the Museo Nacional de Ciencias Naturales in Madrid, Spain, report that the mtDNA of lungfish—an ancient class of air-breathing fish found in Africa, Australia, and South America—is closer than that of the coelacanth to the mtDNA of land animals such as frogs.

That's "an interesting piece of information," says S. Blair Hedges, an evolutionary biologist at Pennsylvania State University in University Park. He explains that knowing which extant fish is closest to the first terrestrial tetrapods, or four-legged creatures, might tell biologists which key anatomical innovations enabled our fishlike ancestors to conquer the land. "It helps reconstruct what the organisms looked like at that time, and maybe what environmental factors may have been involved," says Hedges, who published a study in 1993—based on several mtDNA sequences—that also pointed toward the lungfish.


Lungfish

SOUTHERN ILLINOIS UNIV. MUSEUM, CARBONDALE

Paleontologists of the 19th and early 20th centuries knew coelacanths only from the fossil record, but that was enough to convince them that the unattractive creatures, with lobed fins that resemble primitive tetrapod limbs, were close relatives of the first land animals. Then, in 1938, anglers off the Comoro Islands in the Indian Ocean stunned the scientific world by catching a live coelacanth, the first of many. The discovery caused such a sensation, says Meyer, that the coelacanth-tetrapod connection "is still the predominant textbook dogma. It has to do to some degree with the romance of it."

In the 1980s, paleontologists began finding hints that the dogma might be wrong. For one thing, features of fossil and living lungfish such as their external nasal openings—important for any animal that needs to breathe and chew at the same time—pointed to lungfish, not coelacanths, as the closest sister group to the tetrapods. At the same time, molecular biologists such as the late Allan Wilson at the University of California, Berkeley, had begun to examine the evolutionary relationships of species by comparing similar fragments of their mitochondrial genes, which are often simpler and easier to analyze than nuclear genes. That allowed Wilson and Meyer to announce in a 1990 paper that tetrapods arose from the branch of the evolutionary tree leading to the lungfish, not the coelacanth. Later, Hedges and two colleagues reported similar findings.

As researchers sequenced more coelacanth mtDNA, however, the creature edged back into contention. In the July issue of *Genetics*, for example, Meyer and Zardoya reported that a statistical comparison using the complete coelacanth mtDNA sequence didn't point unambiguously to either lungfish or coelacanths as the tetrapods' closest sister group. As Hedges points out, however, mtDNA may mutate at different rates in different lineages, sometimes resulting in phylogenetic trees that contain "highly significant but wrong" groupings. Indeed, when Meyer and Zardoya reanalyzed their data for their latest study, they concluded that they could "clearly reject" the possibility that coelacanths are the closest sister group to tetrapods. (The possibility that coelacanths and lungfish are equally close relations of tetrapods, although unlikely, could not be formally ruled out.)

That means that traits seen in the lungfish, such as external nostrils and modifications in the circulatory system and blood chemistry, may well provide the best clues to what the earliest land animals looked like. But to settle the issue once and for all, says Meyer, biologists will need to examine the more complex nuclear genes of coelacanths and lungfish. "It's an important question," Meyer says, "and of course I would like to be the one to answer it."

–Wade Roush