Neutrinos to survey Earth's radioactivity

A significant fraction of the energy generated inside Earth comes from the decay of radioactive elements in its crust and mantle. The radioactive isotopes uranium-238 and thorium-232 are responsible for about 90 percent of this heat.

Two groups of researchers now say it may be feasible to measure directly the global abundance of these two isotopes by detecting electron antineutrinos produced when the atoms decay. Neutrinos and their antimatter counterparts, antineutrinos, interact so little with ordinary matter that they zip readily through Earth's interior and fly off into space.

Raju S. Raghavan of Bell Laboratories at Lucent Technologies in Murray Hill, N.J., and his collaborators describe their proposal in the Jan. 19 PHYSICAL REVIEW LETTERS. Mark C. Chen and his coworkers at Princeton University detail their ideas in a report submitted to GEOPHYSICAL REVIEW LETTERS.

"We hope to get people in the geophysical community excited about this prospect," Chen says.

Scientists have long been aware of the possibility of measuring the heat produced inside Earth by detecting antineutrinos. However, it took the recent development of special detectors, large-scale versions of liquid scintillators, to make such measurements feasible.

Two massive liquid scintillation detectors are now under construction, one at the Borexino site in Italy and another at the Kamland experiment in Japan. Although both instruments are intended for other purposes, such as detecting neutrinos emanating from the sun, they would be sufficiently sensitive to pick up the low-energy antineutrinos generated by terrestrial radioactive decay.

"For the first time, we would have neutrino detectors that could look at Earth," Raghavan says. The Borexino experiment is slated to start up in 1999, the Kamland 2 years later.

Nuclear power reactors also produce antineutrinos, which could potentially contaminate the results. However, the Princeton team shows that terrestrial antineutrinos can be distinguished from reactor antineutrinos and that the uranium and thorium contributions can be determined separately.

Raghavan and his colleagues obtain similar conclusions and go on to suggest that, because one site is on continental crust and the other at the interface between continental and oceanic crust, it may even be possible to probe some aspects of the distribution of radioactive elements beneath Earth's surface.

"We could test geophysical models suggesting that most of the uranium and thorium is under the land masses rather than under the oceans," Raghavan says.

"The ratio of radioactive heat production to other sources, the distribution [of radioactive elements] between mantle and crust, and the distribution of the different nuclides are presently not known with any certainty," says geophysicist Raymond Jeanloz of the University of California, Berkeley.

If such antineutrino data could be obtained, the resulting estimate of global radioactive heat production could shed light on what fraction of Earth's energy output is simply heat left over from the massive impact early in its history that created the moon, he remarks. "Such measurements could really change the textbooks."

Chen says, however, that "it's unlikely that any one detector or combination of two detectors would have the precision to pinpoint local concentrations of uranium or thorium."

Having a third antineutrino detector might enable researchers to map the distribution of uranium and thorium inside Earth, Raghavan notes. The Amanda detector at the South Pole, for example, is equipped to detect high-energy cosmic rays, but it could be adapted to detect antineutrinos too, he says.

"With these kinds of data, one could test the conceptual foundations of modern geophysics," Raghavan says. *—I. Peterson*

Protein gives the heads-up to frog embryos

Last October, the *Sunday Times* of London published a story on the creation of cloned headless tadpoles, sparking new concerns about what human cloning might bring. Outrage over the science fiction prediction that headless clones might serve as a source of donor organs overshadowed any mention of why the experiments were done.

The scientists were searching for the molecules that drive the development of a head during embryo growth.

One such molecule has now landed in the hands of a research team headed by Christof Niehrs of the Deutsches Krebforschungszentrum in Heidelberg, Germany. In the Jan. 22 NATURE, the group describes a protein vital to the creation of heads in the frog *Xenopus laevis*.

For several years, Niehrs and his colleagues have studied a region of the growing embryo known as the Spemann organizer. This region guides the development of embryonic features by secreting specific proteins. Last year, the group proposed that the Spemann organizer induces head formation by inhibiting the actions of two proteins, Wnt and BMP, used to transmit signals from one part of a cell to another.

Although researchers have identified several Wnt and BMP inhibitors, Niehrs and his colleagues decided to search systematically for other genes that encode a secreted Wnt inhibitor. They screened pools of genes by injecting into early embryos various strands of messenger RNA, the protein-making instructions synthesized when a gene is active. They also included the messenger RNA for a BMP inhibitor.

Niehrs and his colleagues found a gene that encodes a previously unknown Wnt inhibitor. When they injected this gene's messenger RNA into frog embryos, they created animals with enlarged heads but shrunken bodies. Inspired by the German word for thick head, the scientists named the gene *dickkopf-1*.

The new work shows "the power of the *Xenopus* system for discovering new molecules involved in embryogenesis," says Eddy M. De Robertis of the University of California, Los Angeles, who in 1996 identified a protein called Cerberus, which also has head-inducing properties in frogs.

When Niehrs' group injected messenger RNA strands for both *dickkopf-1* and a BMP inhibitor, they produced Siamese twin–like tadpoles that had two complete heads. "In order to make a new head, you need to inhibit both BMP and Wnt," says Niehrs.

The researchers also showed that injections of antibodies that inactivate Dickkopf-1 created tadpoles with extremely small head structures or no heads at all.

Sergei Sokol, who studies frog head development at Harvard Medical School in Boston, notes that the antibody experiments provide "strong evidence" that the development of a head requires Dickkopf-1. A similar dependence on Cerberus and another head-inducing protein, Frzb, has not yet been shown, he says.

Sokol remains uncertain whether BMP inhibition is also needed to induce the formation of a head. Preliminary experiments by his group suggest that the right dose of a Wnt inhibitor alone may suffice.

The discovery of Wnt inhibitors used by frog embryos illustrates a key theme emerging in developmental biology, notes De Robertis. "It's much easier [for evolution] to create an inhibitor of a signaling pathway—that is, throw a spanner into the works—than to create a new signaling pathway," he says.

Since the gene encoding Dickkopf-1 continues to be active in adult animals, it's likely that the protein does more than aid embryonic development. Scientists have found that at least one Wnt-related protein can, if mutated, predispose cells to cancerous growth, which suggests that proteins such as Dickkopf-1 may rein in cell division. "Wnt inhibitors represent potential tumor suppressor genes," says Niehrs. *—J. Travis*