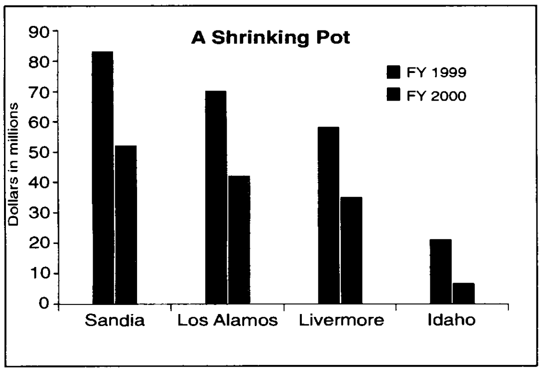
DOE LABS

## Congress Shrinks Lab Chiefs' Flexible Funds

If you don't like the way an institution is run, go after its budget. Congress has just applied that logic to a special fund controlled by the directors of the Department of Energy's (DOE's) national laboratories, slashing the amount available for hiring young scientists and funding high-risk research. Four national labs, including the three nuclear weapons centers, have been hit especially hard by the reductions, which lab officials hope to reverse next year. Lawmakers say that some reprogrammed money has been mismanaged in the past and that the cuts are needed to keep the labs focused on priorities determined by Congress.

The accounting change restricts the flexibility that Congress gave lab directors in 1991, when it created an account called the Laboratory Directed Research and Development (LDRD) fund. The mechanism currently allows each lab to divert up to 6% of the funds it receives from the federal government and other sources to carry out relatively small research projects, usually costing from $25,000 to $500,000 per year. The money is awarded to lab scientists through a competitive process. Language in the 2000 DOE budget bill signed into law last month, however, would reduce the LDRD tax (divertible funds) to 4% and exempt environmental cleanup programs—a major piece of the budgets of several labs—from any tax.




**Less discretion.** Some DOE labs are reeling from cuts in a so-called "lab-directed" research account.

Although smaller DOE labs often do not impose the maximum tax for a variety of reasons, some of the larger labs, including the Los Alamos and Sandia nuclear weapons laboratories in New Mexico and the Lawrence Livermore laboratory in California, have used it to amass annual funds of $50 million or more (see graph). Lab administrators say the money has been essential for attracting young researchers with fresh ideas and for backing risky research, such as forays into materials and computer science, that have evolved into lab mainstays. "LDRD provides us with cherished freedom and creativity in basic research," says Dan Hartley, Sandia's vice president for laboratory development.

But LDRD spending has also attracted scrutiny—and criticism—from some members of the House Appropriations Committee. Representative Ron Packard (R–CA), chair of the spending panel that oversees DOE's budget, and other lawmakers are unhappy that LDRD siphons funds from programs Congress has approved, such as environmental cleanup efforts, and that some labs have funded projects of little relevance to DOE's mission. "The concern is that when you give a lab director $70 million to spend, it will be used for their priorities, not the nation's," says one House aide. Opponents of LDRD funding have pointed to internal DOE reviews over the last decade that have found instances of mismanagement of LDRD dollars and accounting practices that diverted more funds than were allowed under the rules. In past years the Senate has rebuffed House efforts to scale back or eliminate LDRD. But this year, after the House voted to cancel the program, Senate negotiators succeeded in restoring only part of the funds.

At Los Alamos National Laboratory, the change has produced a "traumatic" 40% cut in the lab's $70 million LDRD budget, which wholly or partly funds hundreds of scientists, says Klaus Lackner, acting associate director for strategic and supporting research. To avoid layoffs, he says the lab is shifting some scientists to weapons projects with more stable funding and focusing the remaining LDRD money on supporting young researchers and funding projects—such as those in the life sciences—unlikely to find backing elsewhere. "We started from the premise that postdocs must be able to go on," he says.

At Sandia, where LDRD funds have dropped from $83 million to $52 million, officials worry that the funding uncertainty could cause "some of our brightest, youngest people" to leave, Hartley says. Similar fears are being voiced at Livermore, which lost $23 million of its $58 million LDRD budget. "We are focusing our resources on protecting our long-term strategic investments," which supplement existing work in such areas as computing and the effects of aging on nuclear weapons, says Rokaya Al-Ayat, Livermore's deputy director for LDRD.

Also hard hit by the change was the Idaho National Engineering and Environmental Laboratory, which relies heavily on environmental cleanup funds that can no longer be taxed for LDRD funds. The lab's new director, Billy Shipp, is confident that he and DOE headquarters staff can find a way to continue many existing activities despite a cut from $21 million to $6 million, in part by getting congressional permission to use money from other programs.

Lab officials are also thinking about the best way to restore LDRD funding in next year's appropriations bill. Bill Appleton, Oak Ridge's deputy director for science, says scientists must convince House members that LDRD "is one of the few ways that the labs have of doing innovative research that has major payoffs down the line." At stake, say he and other lab officials, is their ability to attract the best talent and stay at the forefront of science.

–DAVID MALAKOFF

PALEONTOLOGY

## Fossils Give Glimpse of Old Mother Lamprey

Evolution went on a creative spree about 540 million years ago. Over the course of less than 20 million years during the Early Cambrian period, a huge diversity of animals appeared for the first time, including many of the major groups living today, such as arthropods, mollusks, and various sorts of worms. Notably missing from this party—known as the Cambrian explosion—was any member of our own lineage, the vertebrates. Until now the oldest unambiguous vertebrate fossils dated back 475 million years. But this week our genealogy took a giant leap back in time. Chinese and British paleontologists reported in *Nature* that they have found the fossils of 530-million-year-old vertebrates—fossils that have other paleontologists in awe. "I was absolutely amazed the first time I saw these fossils. They're just unbelievable," says Phillippe Janvier, a paleontologist at the Museum d'Histoire Naturelle in Paris who is an expert on early vertebrates.

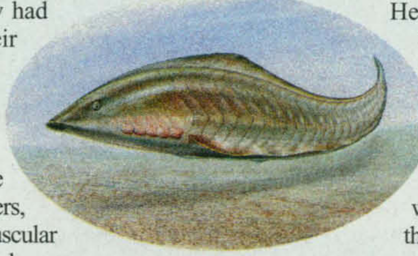
You might expect that such ancient creatures would be primitive, transitional forms linking us to our pre-vertebrate past. Yet surprisingly, the fossils are actually full-fledged vertebrates—more advanced, in fact, than some vertebrates alive today. As a result, paleontologists think fossils of even older vertebrates must be waiting to be discovered, perhaps in rocks dating from well before the Cambrian explosion.

The two fossils come from a site in southern China called Chengjiang, already famous for its Cambrian treasures, where the fine-grained rock retains impressions of muscles and other soft tissues. "Chengjiang really takes your breath away," says Simon Conway Morris, a paleontologist at the University of Cambridge. After learning that two different teams of paleontologists, one led by Degan Shu of Northwest University in Xian, had unearthed the vertebrate fossils, Conway Morris

CREDIT: DOE

traveled to China this April to analyze them with Shu and other Chinese colleagues.

They found that the two fossils represented different species, and although the fossils measured only a couple of centimeters long, the researchers could recognize key vertebrate traits. They had rows of gills, and their muscles were arranged in W-shaped blocks along their flanks, a pattern unique to vertebrates. "They were presumably filter feeders, but they have these muscular bodies and things which we cautiously interpret as an eye," says Conway Morris. "And so presumably they could go along at a fair pace if they had to, and they might have grabbed prey."



**The way we were.** Artist's conception of ancestral vertebrate, about 2 centimeters long.

The researchers then tried to find a place for the fossils in vertebrate evolution. A number of researchers believe that vertebrates evolved from an ancestor something like *Amphioxus*, otherwise known as the lancelet. *Amphioxus*, which lacks eyes or fins and looks rather like a miniature anchovy fillet, has a notochord—a primitive backbone. The first vertebrates added new traits to that body plan, such as a skull with a brain; later vertebrates acquired jaws and fins. The most primitive vertebrate alive today is the hagfish, a jawless fish, and the second-most primitive is the lamprey.

Conway Morris and his colleagues concluded that the fossils fall into a surprisingly advanced position. One of the species, which the researchers named *Haikouichthys*, is most closely related to the lamprey. The other fossil—tortuously named *Myllokunmingia*—is more primitive (its gills are simpler), but Conway Morris says it is still a closer relative to us than to the hagfish.

Features seen on both fossils may help answer the controversial question of how early vertebrates evolved the paired fins that later gave rise to arms and legs (*Science*, 23 April, p. 575). The new fossils show what look like two long folds of tissue running along their underside—exactly what some theories of fin evolution predicted. "We think there's a reasonable case for a double arrangement," says Conway Morris.

Janvier, who has argued that the paired fins came much later, has his doubts. "From what I could see of the fossils, it's not 100% certain." He is also uncertain about the fossils' placement on the vertebrate family tree, because many details of the creatures' anatomy have been lost. He has no doubt that they are vertebrates, but says, "I wouldn't put my money on the exact positions."

If Conway Morris is right about the creatures' sophistication, however, millions of years of vertebrate evolution must have preceded them, reaching back before the Cambrian explosion. Some researchers already suspected as much, based on the clocklike divergence of genes in different animal lineages. According to a new study by Blair Hedges of Pennsylvania State University in University Park, for example, vertebrates got their start 750 million years ago. "Some of my colleagues who take molecular clocks seriously will be skipping for joy" over the new finds, Conway Morris acknowledges ruefully.

He himself doesn't think vertebrates got their start so long ago. He suspects the first ones arose just before the Cambrian Period, about 565 million years ago. The traces of these ancestral creatures, he thinks, may be waiting, still unrecognized, among the fossils known as the Ediacaran fauna. "These stem groups are all lurking down there," Conway Morris maintains, "but we're just too dim to see them."

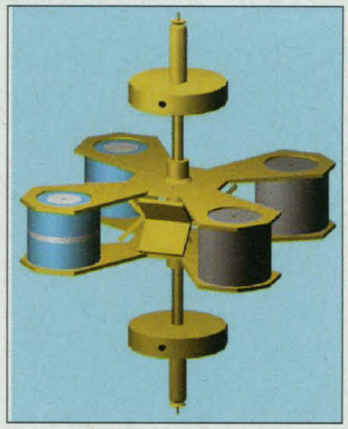
–CARL ZIMMER

Carl Zimmer is the author of the book *At the Water's Edge*.

PHYSICS

## Gravity's Gravity Vindicates Einstein

Between them, general relativity and quantum theory explain all of nature's forces, and yet they refuse to be married. The strong and weak nuclear forces and electromagnetism are all described by quantum theories that mesh in a very satisfactory way. On the other hand, general relativity—Einstein's theory linking the force of gravity to the geometry of space and time—steadfastly refuses to be seduced into the quantum fold. "A goal in physics is to unify all the forces, that is, to combine gravity with the other three in one grand theory," says Blayne Heckel of the University of Washington, Seattle.



**Earth (and moon) in the balance.** Toy celestial bodies rest on a torsion balance, designed to detect differences in their response to the sun's gravity.

Like so many others, Heckel, Eric Adelberger, and their Seattle colleagues don't know how nature might entice the two parties to walk together down the aisle. So the Seattle group has instead looked for the possible progeny of such a match. One such child would be a difference in the way gravity acts on mass and on gravitational energy itself. But this hypothetical love child, expected in some scenarios of a deep connection between gravity and the quantum world, is nowhere to be found, the group determined.

Einstein built his theory of general relativity on the premise that gravity acts equally on all forms of mass-energy. Experimenters have shown that nuclear binding energy and energies due to electromagnetic interactions do indeed obey this "equivalence principle." For example, a proton and a neutron combine to make an object with less mass than the component parts; the binding energy holding the two parts together accounts for the missing mass. Yet experiments show that the combination and the individual parts free-fall at the same rate in a gravitational field.

But no one has yet shown that gravitational energy responds to the pull of gravity in the same way as all other forms of mass-energy do. Some theories—including string theory, the current favorite in the attempts to synthesize a quantum theory of gravity—suggest it might not. "Many theorists expect that at some point we will find a difference," says Heckel.

Lab experiments can't study the impact of gravitational binding energy, since the energy tied up in the mutual pull of fragments of lab-sized objects is minuscule. The place to look, Kenneth Nordtvedt of Montana State University suggested more than a decade ago, is in the tug of the sun on the moon and Earth. Although Earth's gravitational binding energy is small—a mere half a microgram per kilogram—because Earth is big, around 3 trillion tons of its mass is transformed into pure gravitational energy. The moon's gravitational binding energy is around 2000 times smaller, but still big enough to displace the center of the moon's orbit relative to Earth if the sun's gravity treats mass and gravitational binding energy differently.

Spotting these effects means monitoring the Earth-moon distance to high accuracy. By using lunar laser ranging, in which a laser beam bounces off reflectors dropped off on the moon by astronauts, Nordtvedt and others tracked this separation to centimeter accuracy and found, within the limits of the experiments, that the Earth and moon do indeed fall towards the sun at the same rate.

Nordtvedt himself pointed out a loophole, however: Some quantum gravity theories suggest gravity might act differently on the Earth and moon because of compositional differences such as Earth's

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