Next, the Dutch experimenters plan to replace the rubidium ions with hydrogen nuclei—protons. Theoretical calculations show that the capture step should work just as well for hydrogen as it does for rubidium, says another team member, theoretical physicist Francis Robicheaux of Auburn University in Auburn, Alabama. If all goes well, next year the team hopes to apply the technique at CERN to create antimatter.

Abundant antiatoms would certainly give physicists much to think about. For example, general relativity holds that an atom and its antimatter counterpart should have identical masses, but some versions of string theory disagree. Serious discrepancies between predictions and observations could revolutionize theories of matter. "If you want to discover something interesting and unusual," Gabrielse says, "you have to look at unusual places."

–ALEXANDER HELLEMANS

Alexander Hellemans writes from Naples, Italy.

EVOLUTION

Stretching the Reign Of Early Animals

To paleontologists, fossils are crucial, but so is time. Fossils tell the who of evolution, but for the how and why, paleontologists need to put together a story in which events occur in the right order and unfold at a realistic pace. Nowhere is that task more demanding than in the murky realm of the Ediacara, frond- or disc-shaped blobs of living matter that preceded the more familiar (if still bizarre) creatures of the Cambrian explosion 543 million years ago. Cryptic Ediacaran fossils are hard enough to connect to later animals, but ordering them in time has been if anything harder. Groping for firm dates, paleontologists had been forced to rely on wiggles in the changing isotopic composition of the rock encasing Ediacara.

No more. On page 841 of this issue of *Science*, geochronologist Mark Martin of the Massachusetts Institute of Technology and his colleagues report that they have determined the age of the most diverse Ediacaran fauna through highly precise uranium-lead radiometric dating of a layer of volcanic ash. The technique—which overthrows isotopic wiggle counting as the best means of keeping Ediacaran time—has produced a surprisingly early date. It not only doubles the length of the late Ediacaran reign but also revises a strange and mysterious chapter in the early history of life.

The oldest, simplest Ediacara are found in the Mackenzie Mountains of northwest Canada in rocks thought to be about 600 million years old, but the most diverse and complex Ediacara seemed to come 50 million years later. That's right in a narrow window of time—the last 6 million years before the Neoproterozoic era gave way to the evolutionary commotion of the Cambrian—when complex, mobile organisms, including perhaps the last common ancestor of modern multicellular life, emerged.

For all their tantalizing significance, though, the Ediacaran layers offer few distinctive fossils to serve as bookmarks in the geologic record. Instead, for more than 5 years researchers have pegged their geologic calendars to the ratio of two isotopes of carbon. The ratio changes with shifting environmental conditions, such as ice ages and varying biological productivity.

On either side of the late Neoproterozoic flowering, the carbon-isotope ratio rises and falls in roller coaster–like spikes and troughs. In some rocks from the latest part of the Neoproterozoic, however, it appears to level off around values of +1 to +2 per mil. Taking the coincidence at face value, paleontologists tried assuming that all of the most diverse deposits of Ediacara—even those lacking carbon ratios, such as the original find in the Flinders Ranges of South Australia—were the same age as those of the "+2 plateau." It seemed to work.

Now a volcanic ash bed has blown that tidy assumption sky-high. Martin and his colleagues found the bed in the Ediacara-bearing cliffs along the coast of the White Sea, 100 kilometers northwest of Arkhangelsk and 1100 kilometers north of Moscow. Once an ash bed is found—and more and more are turning up as geochronologists join paleontologists in the hunt—the key is separating out the mineral zircon. By measuring the amount of lead produced in zircon grains through the steady radioactive decay of uranium, geochronologists can determine the age of zircon formed in the Neoproterozoic with a precision of better than 1 million years. Extracted and analyzed, the White Sea zircons yielded an age of 555.3 ± 0.3 million years.

"The date is exciting," says paleontologist Guy Narbonne of Queen's University in Kingston, Ontario. "It's nearly 10 million years older than we might have expected for the Flinders, Australia, Ediacara, yet [the two Ediacaran faunas] are indistinguishable" in diversity and complexity. Apparently, the assumption paleontologists had drawn from the carbon isotopes—that the most diverse Ediacaran fossils have similar ages—does not always hold, says Narbonne.

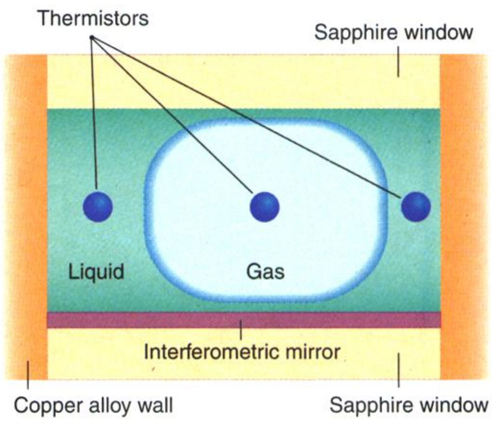
This first absolute date among the most diverse Ediacara changes the history of life by pushing back the emergence of large, complex organisms. One of those creatures may have been the long-sought animal whose descendants split into the two great lineages of modern life: the protostomes—mollusks, annelids, and arthropods—and the deuterostomes—the echinoderms and chordates. Obviously, "high-precision uranium-lead dating will be extremely critical in sorting out Neoproterozoic evolution," says Narbonne. Keep an eye peeled, paleontologists. –RICHARD A. KERR

Older still. Animal exotica from Russia's White Sea are getting more ancient.

THERMODYNAMICS

Backward Heat Flow Bends the Law a Bit

When the teachers go on strike during an episode of *The Simpsons*, the 8-year-old overachiever Lisa burns up her excess energy by creating a perpetual motion machine. Her father, Homer, is furious. "In this house," he barks, "we obey the laws of thermodynamics!" Most houses do. But now a space-borne experiment has for the first time accomplished what the second law of



Topsy-turvy. In a sealed cell, thermistors showed that fluid drew heat from cooler walls.

CREDITS: (TOP TO BOTTOM) M. MARTIN/MIT; (INSET) A. BRONNIKOV; SOURCE: *PHYSICAL REVIEW LETTERS*, VOL. 84, NO. 18, 1 MAY 2000

thermodynamics seems to forbid: transfer of heat from a cold surface to a hot liquid.

The groundbreaking experiment was carried out onboard the Mir space station last year as part of the French-Russian Perseus mission. By warming a copper-and-sapphire-walled cell filled with a drop of liquid sulfur hexafluoride and one tiny bubble of gaseous sulfur hexafluoride in near-zero gravity, scientists triggered a slight compression of the bubble. That gentle squeeze raised the temperature of the gas above that of the cell walls. For this to happen, heat must have been transferred from the cooler walls to the hotter gas, scientists report in the 1 May *Physical Review Letters*.

It's a weird result—but then, the sulfur hexafluoride on Mir was a weird fluid. Common sense tells us that liquids are different from gases. Liquids are dense, gases are light. Molecules in a liquid are weakly bound together; gaseous molecules are free. But at a certain critical temperature and density—45.54°C and 0.737 grams per cubic centimeter for sulfur hexafluoride—those distinctions disappear. "It can't decide if it is a gas or a liquid," says John Hegseth, a physicist at the University of New Orleans in Louisiana who took part in the experiment. "It is both and neither." And once a fluid reaches the critical point, you can forget all the intuition you developed by watching water boil.

In a normal liquid, heat is transferred in one of three ways. First, it can diffuse from hot regions to cold regions. This is what happens when you heat a pan of water on the stove. Second, hot bubbles of gas or liquid can rise up against the pull of gravity and deposit heat in the cooler, overlying liquid. This process is called convection, and it creates the familiar bubbles in boiling water. There is also a third, little known way to transfer heat: the piston effect. When the liquid surrounding a bubble is heated, it expands, which compresses the bubble and warms the gas. Diffusion and convection both transfer heat so rapidly that the piston effect is usually negligible.

Things are different near the critical point. As the sulfur hexafluoride in the cell approaches it, bubbles form in the liquid. The two-phase fluid also becomes acutely compressible—in other words, squishy. Heat from the cell walls raises the liquid pressure, instantaneously compressing and heating the gas in the bubbles. Because the fluid is so squishy, the piston effect heats the gas much faster than diffusion can carry energy back to the liquid, and the bubble temperature overshoots that of both the wall and the liquid. In the microgravity of Mir, there is no convection to compensate for the temperature imbalance.

Within seconds of raising the cell wall temperature, Hegseth's team found that the bubble temperature had risen 23% above that of the wall. Although ground-based experiments and computer simulations had suggested that the piston effect might cause such a rise, scientists were surprised by the magnitude of the change. "They called me right away and asked me to check the result," says Fong Zhou, a physicist at the Jet Propulsion Laboratory in Pasadena, California. Zhou quickly modified the computer code he had used to simulate the piston effect on the ground. After removing the effect of gravity, his simulation reproduced the Mir experiment results almost perfectly, Zhou says.

Despite appearances to the contrary, the experiment didn't really break the second law of thermodynamics, Hegseth says. Strictly speaking, the law applies not to changes in temperature but to changes in entropy—a related but different property. What's more, it applies only to systems in thermodynamic equilibrium. Inside the cell on board Mir, conditions were changing so fast that they left equilibrium behind. Only temporarily, however: After about 2 minutes, the second law reasserted itself, and the bubble cooled back down to the same temperature as the wall and the fluid. The counterintuitive heat flow was a transient temperature overshoot, Hegseth says—no lapse, no miracle, just "a weird way to get back to equilibrium."

–MARK SINCELL

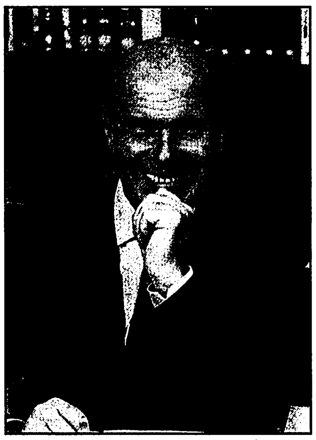
Mark Sincell is a science writer in Houston.

BIOMEDICAL POLICY

New Minister Hopes to Create an Italian NIH

One of Italy's top cancer researchers has been appointed health minister in the new government of Prime Minister Giuliano Amato, raising hopes that the nation's sagging biomedical research effort might receive a badly needed boost. Umberto Veronesi, founder and scientific director of the European Institute of Oncology (EIO) in Milan, was tapped last week to replace outgoing minister Rosy Bindi. His appointment is a break from the tradition of naming politicians rather than scientists to the post.

One of Veronesi's major tasks, he says, will be to reorganize the system for funding Italian biomedical science, which badly trails that of many other Western countries (*Science*, 3 July 1998, p. 49). And he must work quickly: Amato's caretaker government—Italy's 58th since the end of World War II—will face a general election in March or April 2001. "The prime minister said I have just 1 year," Veronesi told *Science*. "That is why it is better to have an expert than a politician as health minister during this period."



CREDIT: EIO

Renaissance man? Umberto Veronesi intends to reform Italy's biomedical funding.

Not wasting any time, Veronesi has begun crafting a 10-year plan to beef up Italy's biomedical research institutions. A key pillar is the creation of a public agency—similar to the U.S. National Institutes of Health (NIH)—that would provide extramural grants for fundamental biomedical research. Such an agency does not currently exist in Italy, where most of the roughly $250 million the government spends each year on biomedical research goes to institutes run by the health and research ministries. Although it has continued to support a few outside programs, such as AIDS research, the Italian government has mostly weaned biomedical scientists from direct government grants. Even the National Research Council, once an important source of such grants, has recently restricted its funding mostly to its own institutes (*Science*, 30 October 1998, p. 855).

As a result, biomedical research has become increasingly dependent on funding from charities and industry. Veronesi's own EIO is no exception: It gets most of its support from Italian cancer charities and private donations. In addition to reinstating some government grants, researchers are hoping the new minister will encourage more private funding. "Veronesi has campaigned for tax deductions for private donations to cancer research," says gene therapy researcher Claudio Bordignon, scientific director of the private San Raffaele Institute in Milan. "This would be a major change for Italian science and should be extended to all biomedical research."

Whether or not Veronesi gets a chance to design his reform package and sell it to Amato and the Italian Parliament depends on the current government lasting until next spring's legislative elections. The perpetual crises of Italian politics could bring the government down at any time, leaving the new minister's reforms stillborn. But if Veronesi does hang on, many researchers have high expectations for what he might accomplish. "In a year, one can do many things," says Silvio Garattini, scientific director of the Mario Negri Institute for Pharmacological Research in Milan.

–MICHAEL BALTER