Indeed, the work already offers a remarkably clear view of the stages of gene decay. As the *R. prowazekii* genome sequence shows, first genes are interrupted by a stop codon, a sequence of three nucleotides that tells the protein-synthesis machinery that it has reached the end of the gene and should stop. Occasionally, these interrupted genes continue to make incomplete proteins of their own. But as degradation progresses, genes lose the ability to produce proteins and eventually stop being copied into messenger RNA altogether, although they remain identifiable.

The decay is likely the combined result of random mutations and adaptation. Struck by a mutation that disables a gene, individual *Rickettsia* microbes either die or pass the altered genes on to their offspring. Raoult points out that some of the genes lost make enzymes needed to produce amino acids also generated by the host—meaning that the bug can abandon these genes without losing access to the amino acids. "If you don't have some positive benefit from that gene, you lose it," says Nancy Moran, an evolutionary biologist at the University of Arizona in Tucson.

Having painted the outline of *Rickettsia* evolution with broad brush strokes, scientists now hope to focus on the details of how gene inactivation occurs. Moran notes that many of the genes lost perform basic functions such as DNA repair. Thus, it's possible that the loss of, say, one specific DNA repair gene instead of another affects which mutations stick. By clarifying how genes lost may guide the bacterium's evolution, scientists can perhaps grasp how its existing design came to be. **–JENNIFER COUZIN**

Jennifer Couzin is a writer in San Francisco.

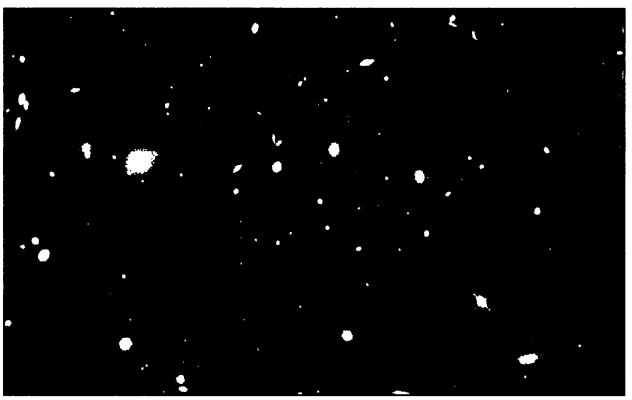
ASTROPHYSICS

Orbiting Observatories Tally Dark Matter

WASHINGTON, D.C.—As galaxy clusters belch x-rays in all directions, they reveal the hidden mass in the universe. At a meeting here celebrating 2 years of observations with the Chandra X-ray Observatory,* astronomers claimed that Chandra observations, along with pictures from the Hubble Space Telescope, enabled them to calculate the amount of dark matter in the cosmos—and seriously damage one theory about its nature.

One of the biggest puzzles in astrophysics is the nature of dark matter, the invisible substance whose gravitational pull holds galaxies together. "It's been about 25 years since we appreciated that dark matter is the dominant form of matter in the universe," says Joel Bregman, an astrophysicist at the University of Michigan, Ann Arbor.

In the past few months, astronomers have measured the amount of dark matter by looking at wiggles in the cosmic background radiation (*Science*, 4 May, p. 823) and by analyzing the distribution of galaxies in space (*Science*, 13 April, p. 188). They've concluded that ordinary matter makes up only about 5% of the mass needed to give space the shape that cosmologists prefer, while dark matter makes up another 25% or so. (The mysterious "dark energy" or "quintessence" seems to make up the remainder.) At the symposium, Steven Allen, an astronomer at the Institute of Astronomy in Cambridge, U.K., presented new evidence that those figures are correct.



Weighty matters. Warped images of galaxies in cluster Abell 2390 helped reveal the mass in intervening space.

With the Chandra satellite, Allen and his colleagues observed the x-rays emitted by gas inside massive galaxy clusters. "For the very first time, we're able to accurately measure the temperature of this gas," Allen says. From the temperature profile and density of the gas, the team figured out how much mass is holding the cluster together. "It's very straightforward," he says.

Meanwhile, pictures from the Hubble Space Telescope and ground-based observatories gave an independent measurement, based on how much the extreme mass of the cluster bends light, a phenomenon called gravitational lensing. The more lensing, the more mass is concentrated in the cluster. Although the two methods are very different, their results agree. "With the optical data and the x-ray data, you get the same answer," says Allen. The values for the amounts of matter and dark matter in the universe match what the cosmic background and galaxy-distribution data imply. "It's the most accurate determination to date of the amount of dark matter in galaxy clusters," he says.

John Arabadjis of the Massachusetts Institute of Technology has used Chandra x-ray data to draw an even stronger conclusion about dark matter. Some theorists postulate that dark matter is self-interacting—that is, particles of it are fairly likely to collide with one another. In that case, the collisions should force the dark matter to spread out more than it would otherwise. This hypothesis seemed to explain the distribution of matter in the centers of dwarf galaxies, but according to Arabadjis, Chandra's x-ray measurements show that dark matter in galaxy clusters doesn't spread out as one would expect if the particles collided easily. Thus, the model that succeeds in dwarf galaxies seems to fail in larger structures. "We can more or less say that self-interacting dark matter is dead now," Bregman says.

Paul Steinhardt of Princeton University is less sure. "The model's been declared dead many times," he says. Steinhardt thinks the study's assumptions are too crude to give definitive answers yet. And even if Arabadjis is right, he says, "there's plenty of room left in the self-interacting picture. But the simplest version might be in trouble." **–CHARLES SEIFE**

GEOLOGY

Swiss Scientists Trace 645-Year-Old Quake

At dinnertime on 18 October 1356, residents of Basel, Switzerland, felt the jolt of an earthquake that toppled churches and castles 200 kilometers away and triggered weeklong fires. The ground seemed to slumber after that. Although a few obscure accounts tell of periodic tremors in the area up to 1721, the nature of the 1356 earthquake—the largest historical seismic event in central Europe—remained a mystery. Now, on page 2070, researchers re-

Ravaged. A 1544 woodcut shows the earthquake that leveled Basel 2 centuries earlier.

CREDITS: (TOP TO BOTTOM) HUBBLE SPACE TELESCOPE; NISEE/ERC

* "Two Years of Science With Chandra," 5–7 September.

port that they have identified an active fault that may explain not only the 1356 earthquake but two earlier ones as well. The finding provides the first indication of how frequently such events shake the upper Rhine graben, the rift valley system to which Basel and its environs belong.

Unlike the San Andreas fault in California, European faults responsible for earthquakes are hard to identify, says Domenico Giardini, director of the Swiss Seismological Service and a co-author of the report. That's because small earthquakes leave little trace on the surface, and major earthquakes are too rare to have left much of a historical record.

With a magnitude estimated at between 6 and 6.5, however, the 1356 quake should have been big enough to leave a visible mark, says Mustapha Meghraoui, a geologist at the University of Strasbourg, France. Meghraoui and colleagues Bertrand Delouis and Matthieu Ferry of the Swiss Federal Institute of Technology in Zürich set out to find it. After poring over aerial and satellite photographs and topographic maps, they zeroed in on a 50-meter-high escarpment that runs for 8 kilometers along the western side of the Birs valley in Reinach, south of the city of Basel. Something had obviously happened there—but was the feature really due to an earthquake, or just to erosion or landslides?

Searching for clues, the researchers visited an archaeological dig in the area. There, in the wall of a trench, they spotted signs of movement along a fault: a sharp contact between a very young sediment and an old sediment. The team crossed the road and started trenching at the base of the scarp, using geophysical evidence such as differences in the electrical resistivity of the ground to pinpoint the most promising sites.

"Before you open the trench, you cannot be 100% certain that you will find the earthquake," says Delouis, a seismologist, who says he followed close behind the digging machine. To date, eight trenches have been opened. Painstaking examination of the wall contents have revealed blocks of sand and clay clearly separated on a steep diagonal—the trace of so-called normal faulting, in which extensional (or pull-apart) forces cause blocks of crust to slide up and down relative to each other along a rupture. In the fourth trench, carbon-14 dating confirmed that three earthquakes had nudged the earth upward a total of 1.8 meters over the past 8500 years.

The new findings suggest that the fault unleashes a 1356-type earthquake every 1500 to 2500 years on average. That may not seem like much to worry about. But averages say little about when the next quake will strike, Meghraoui points out. Besides, he says, the Rhine graben probably harbors other faults capable of rattling the area: "The challenge is to find them and build a realistic seismic hazard assessment."

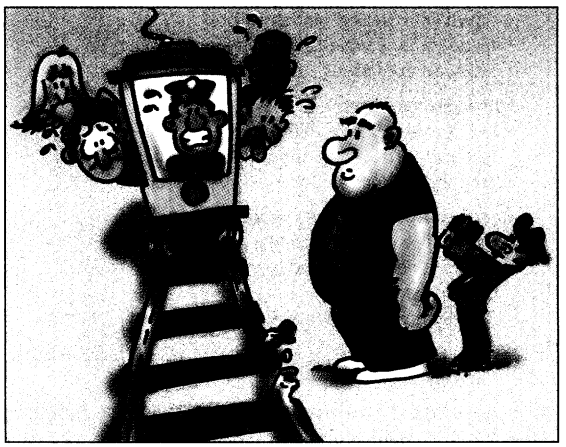
Donat Fäh, a geophysicist with the Swiss Seismological Service, says that data from this and future studies will go into regional earthquake catalogs to help develop building codes, especially for critical facilities such as chemical and nuclear power plants and long-lived features such as artificial lakes. **–GISELLE WEISS**

Giselle Weiss is a writer based in Allschwil, Switzerland.

COGNITIVE NEUROSCIENCE

Moral Reasoning Relies on Emotion

Suppose, in a classical moral dilemma, you see a trolley with five frightened people in it headed for certain disaster. They can be saved from plunging off a cliff if you hit a switch and send the trolley onto another track where, tragically, another person is standing who would be killed by the trolley. What to do? Most people say that it's worth sacrificing one life to save five others.



Right or wrong? Sometimes saving a net four lives just feels wrong.

But suppose the doomed trolley can only be saved if you push a bulky person onto the tracks, where his body would stop the trolley but, alas, he would be killed. Although faced with the same trade-off of five lives for one, most people say it would be wrong to stop the trolley this way. Paradoxes such as this mean job security for philosophers. They've been debating them for decades but have been unable to come up with a logical reason why sometimes

ILLUSTRATION: JOE SUTLIFF

ScienceScope

Patent Fight The Institut Curie in Paris this week said it will formally oppose a European patent for a breast cancer test awarded in January to the biotech firm Myriad Genetics, based in Salt Lake City, Utah. The test detects mutations in the *BRCA1* gene, which are responsible for more than half of all hereditary breast cancers.

Earlier this year, Curie had threatened to file the protest with the European Patent Office in Munich after discovering a mutation in *BRCA1* that is not detected by Myriad's test (*Science*, 8 June, p. 1818). The institute claims that the Myriad patent is too broad and would block the use of other genetically based tests. "Such a monopoly will put the brakes on the development of research," says Curie geneticist Dominique Stoppa-Lyonnet. Myriad executives were not available for comment.

French research minister Roger-Gérard Schwartzenberg has supported the action. Last week he said the government would extend to diagnostic tests an existing law that forces biomedical firms to grant licenses to their products if their patents are "exploited under conditions contrary to the interests of public health."

Cash Prize Hoping to stem the flow of blue-chip graduate students to prestigious U.S. institutions, the University of Toronto will become the first Canadian university to guarantee minimum financial stipends for all doctoral candidates. Starting this fall, the school's roughly 4000 Ph.D. students will each receive at least $11,000 to cover tuition, fees, and living expenses.

The funds will give a boost to students in the oft-neglected social sciences and humanities, who typically must pay their own way, while reducing the need for students to take part-time jobs that could interfere with their studies, says vice provost of students Ian Orchard. The stipends should also help science departments compete with U.S. institutions, Orchard adds. U.S. schools give students an average of $7800 annually—nearly 50% more than under Toronto's former policy, according to a university task force.

Orchard predicts Toronto's move will put pressure on other Canadian universities to sweeten the pot, too. But while University of Alberta provost Douglas Owram applauds Toronto's initiative, he says his school doesn't "have the resources right now" to keep up.

Contributors: David Malakoff, Josh Gewolb, Michael Balter, Wayne Kondro