Wales, Australia. By comparing the Doppler shifts of the same signal received at the two sites, the computer processing the data could determine whether a signal could be extraterrestrial or just a TV transmitter, passing satellite, or radar. Says Jill Tarter of the Phoenix team: "We did a search that left no mysteries; all signals were identified." And they were all terrestrial.

Hopes for finding an exception ride on the continued generosity of donors. Packard, Hewlett, and Moore have each promised Phoenix $1 million per year for the next 5 years. That should allow it to search 1000 stars—the original NASA star-by-star search goal.

Will that be enough to bag an alien signal? If there is an antenna like the world's largest—the 300-meter antenna at Arecibo, Puerto—beaming a signal our way from one out of every 1000 sunlike stars, estimates the SETI Institute's Kent Cullers, "then we will succeed soon." In case the galaxy is not so thickly populated by garrulous aliens, the SETI Institute plans to raise a $100 million endowment to extend the search even further, a chore that could tax the optimism of even a SETI searcher.

–Richard A. Kerr

Chewing Up the Fossil Record

Development keeps evolving: New species often improvise on their ancestors' route to adulthood, finding slightly different ways of growing up. But those improvisations can confuse paleontologists struggling to identify new species from an imperfect and hard-to-read fossil record. Witness this tale of a researcher who found a "new" species of lemur—only to have it turn out to be an old species with a previously unrecognized pattern of development.

While rummaging through a museum collection in Madagascar, the world's only natural lemur habitat, paleontologist Laurie Godfrey of the University of Massachusetts, Amherst, discovered a tiny lower jaw with big teeth. And the jaw stood out. "It certainly seemed at first glance that I had found another species," Godfrey recalls.

Bearing a full complement of adult teeth, the mandible closely resembled the lower jaw of a lemur genus known as *Mesopropithecus*, which became extinct approximately 2000 years ago. But adult *Mesopropithecus* mandibles are typically longer and deeper than the one that was in Godfrey's hand. She thought she had gotten hold of a new species, one that was "juvenilized," retaining the light-boned jaw of a youngster into adulthood.

Instead, the jaw actually belonged to a juvenile. Combing through the museum's collection drawers, Godfrey examined the skull of a closely related extinct genus called *Palaeopropithecus*. The skull's sutures had not yet fused, and it lacked the pronounced orbital rims of adults. Instead of a juvenilized adult of a new species, Godfrey inferred that she had the precocious juvenile of *Mesopropithecus*.

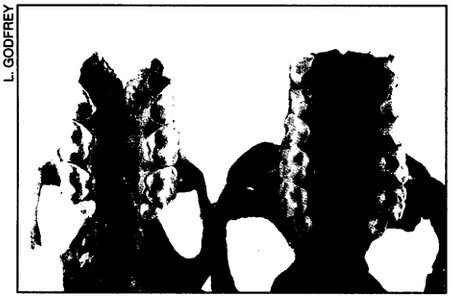
This was a largely overlooked pattern of lemur development—one that persists today, as Godfrey learned when she examined museum specimens of the animal's closest living relatives, the genus *Propithecus* (commonly called the sifaka). These animals all breed at the same time, and so their babies are born during the same 6-week span during the dry season in the southern hemisphere's winter. As a result, the date a juvenile museum specimen was captured gives a good estimate of age. When Godfrey compared the tooth development of sifakas from infancy through their first birthday, she found that these animals, like *Mesopropithecus*, indeed pack in almost all of their permanent teeth within their first year. All other observed groups of lemurs develop their adult teeth later, as their jaw grows.

Dental precocity occurs among an entire family of lemurs. Paleontologists have unearthed five extinct species from various sites in Madagascar. And Godfrey and her colleagues discovered two new species in the previously unsurveyed northern region known as Ankarana. She and her colleagues also think they've unearthed an explanation for this pattern. All of the early toothed lemurs appear to be leaf-eaters, and youngsters need their adult teeth to survive on tough, dry seeds and leaves. Fruit-eating lemurs, because of their softer diet, manage with their milk teeth longer.

Paleontologist Michael McKinney of the University of Tennessee notes that Godfrey's work "emphasizes the importance of the timing of development" in understanding evolutionary processes. He points out that paleontologists must find ways to establish developmental time courses for other animals, or risk confusing new animals with existing ones that have found new ways of growing old.

–Lisa Seachrist

L. GODFREY



Young jaw, old teeth. This extinct lemur gets its adult teeth at a very early age.

Lisa Seachrist is a free-lance writer in Bethesda, Maryland.

CELL BIOLOGY

Regulating G Protein Signaling

As anyone who has ever slept with a snorer, studied in a college dormitory, or lived next door to a pianist knows, tuning out one's surroundings can be a sanity-preserving skill. This ability isn't just limited to humans. Even the simplest cells can mute their own internal communication lines to tune out the racket of chemical noise made by hormones, neurotransmitters, growth factors, and other cell regulators, allowing them to damp down their responses to such stimuli after prolonged exposure.

Exactly how cells achieve this "desensitization" is unclear, but in a spate of recent studies, researchers in several laboratories have closed in on one volume control for a key intracellular communication line: the "G proteins" that serve as intermediaries carrying signals from numerous hormones and neurotransmitters to the cell interior. Over the past year, the work has uncovered a large and growing family of proteins that seem to regulate the sensitivity of G protein signaling pathways in organisms ranging from yeast and nematodes to rats and even humans.

Heidi Hamm, a biochemist at the University of Illinois, Chicago, who recently helped unravel the molecular structure of G proteins themselves, describes the new proteins—known as the RGS proteins (for Regulators of G protein Signaling)—as "very intriguing." Eva Neer, a biochemist at Brigham and Women's Hospital in Boston, agrees and says the findings may help solve a question that signal-transduction researchers have been puzzling over for years.

G proteins take part in an enormous variety of biological sensing and communication systems, helping control everything from mating in yeast to egg-laying in the nematode *Caenorhabditis elegans* to immune responses and vision and olfaction in mammals. But cell biologists have had trouble figuring how cells manage to make the right responses at the right times. "It's hard to explain the specificity of cellular responses solely on the basis of what's known about G protein action in vitro. The cell has to be contributing something else that modulates responses," says Neer. And she adds, "This is exactly the kind of family one would hope that someone would find."

Although the complete mode of action of the family members hasn't yet been worked out, researchers think they work by binding to one of the three protein subunits that

make up a complete G protein and somehow preventing it from carrying out its normal function in signal transmission. Unveiling the specifics of that process, scientists say, could have both basic and practical results. Pharmacologists estimate that up to 60% of all medicines used today exert their effects through G protein signaling pathways, and uncovering new ways in which these pathways are modulated could help explain—and perhaps counter—the phenomenon of drug tolerance, the need for increasing doses to achieve a constant effect.

Early inklings of the existence of the RGS proteins came from studies of mating in the budding yeast *Saccharomyces cerevisiae*. Cell biologists have known for years that mating is triggered when pheromones secreted by yeast cells bind to receptors on neighboring cells. Associated with the receptor just inside the cell membrane is the G protein, actually a complex of three smaller proteins, the α, β, and γ subunits. Binding of the pheromone activates the G protein, sending the β and γ subunits into the cell interior, where they pass on a signal that causes the one-celled organism to stop growing and prepare for fusion with the suitor. But if mating doesn't soon follow, the jilted cell wastes no time brooding: The G protein pathway turns off, shutting out the idle love notes, and the cell gets on with its normal growth.

Exactly how this shutoff happens wasn't clear, but researchers got a hint in 1982, when they discovered that a mutation in a gene called *SST2* (for "supersensitivity-to-pheromone") prevents yeast cells from recovering from pheromone-induced growth arrest—a result suggesting that the protein normally produced by the gene, Sst2p, helps turn the pathway off. Still, not until last year did researchers begin to understand how Sst2p might do this.

The clue came from experiments by molecular biologist Henrik Dohlman and his colleagues at Yale University School of Medicine. The group suspected, Dohlman says, that Sst2p would have to bind to one of the G protein subunits in order to control pheromone signaling. If it did, then inducing yeast cells to produce extra copies of the G protein might compensate for Sst2p defects in *SST2* mutants. And sure enough, when the researchers genetically engineered yeast cells carrying different defective versions of Sst2p to overexpress *GPA1*, a gene encoding a crucial G protein α subunit, the cells partially recovered from growth arrest. But *SST2* mutations had no effect when the G protein receptor was bypassed by engineering cells to make extra β and γ subunits. Those results, Dohlman says, are an "indication that Sst2p works early, most likely at the level of the G protein or receptor."

It soon became apparent, though, that Sst2p's implications extended far beyond yeast mating, as similar proteins began to crop up in a number of seemingly unrelated cellular systems. One example came late last year from the team of molecular cell biologist Marilyn Farquhar at the University of California, San Diego. Farquhar's group studies how cells regulate the transport of secreted proteins through the membranous subcompartments of the cell to the exterior—a process that a human G protein subunit called $G\alpha_{i3}$ can interrupt. Hoping to identify the exact molecules with which $G\alpha_{i3}$ interacts to regulate protein trafficking, Farquhar and molecular cell biologist Luc De Vries went on a genetic hunting trip, using $G\alpha_{i3}$ as the "bait" in yeast cells engineered to express hundreds of thousands of different human "prey" proteins.

The researchers were intrigued to find, De Vries says, that sections of the novel protein they bagged—which they named GAIP, for G Alpha Interacting Protein—share from half to two-thirds of their amino acids with comparable segments of Sst2p and five other proteins listed in the global GenBank database. That, says De Vries, was when the group realized that GAIP's action "is part of a really important issue that probably goes beyond trafficking."

M. KOELLE

Out of balance. Without EGL-10, *C. elegans* worms can't lay their eggs *(top)*. But worms with too much *(bottom)* lay their eggs more frequently. The middle worm is normal.

A similar realization was surfacing in the laboratory of developmental geneticist Robert Horvitz at the Massachusetts Institute of Technology. Michael Koelle, a molecular geneticist in Horvitz's lab, was studying still another system, exploring how changes in neuronal responses to neurotransmitters such as serotonin affect such behaviors as locomotion and egg-laying in the worm *C. elegans*.

Koelle knew that a likely Gα protein called GOA-1 seemed to inhibit both activities, because other researchers had found that when the corresponding gene (*goa-1*) is deleted, the animals become hyperactive and lay eggs more frequently (*Science*, 17 March 1995, pp. 1596, 1648, and 1652). He recently determined, however, that mutations in another gene, *egl-10*, have the opposite effects, suggesting that the gene's protein product, EGL-10, might suppress GOA-1's inhibitory signals.

But the real "nail in the coffin," Koelle says, came when the researchers aligned EGL-10's amino-acid sequence with other proteins in GenBank and came up with none other than Sst2p as well as seven other proteins, including GAIP and two proteins first identified in humans, GOS8 and BL34. Using portions of the genes for the worm and human proteins as probes, Koelle and Horvitz went on to identify another nine similar proteins in rats. All the proteins in this rapidly growing family—which Horvitz's group and other researchers named RGS—feature a "core domain" of about 120 amino acids, which is anywhere from 30% to 75% identical in the various members.

Work reported just this month with GOS8 and BL34 shows that the resemblance isn't just skin deep. Both proteins had been identified during searches for genes needed to activate immune cells called lymphocytes, GOS8 by biochemist David Siderovski and colleagues at the Amgen Institute in Toronto and BL34 by a team including molecular biologists John Kehrl, Kirk Druey, and Veronica Kang of the U.S. National Institute of Allergy and Infectious Diseases and Ken Blumer of Washington University in St. Louis.

The Kehrl group has now found that the mammalian RGS proteins, like their yeast and worm counterparts, help damp down G protein pathways, in this case the ones mediating activation of human lymphocytes. What's more, both the Kehrl and Siderovski groups have shown that the human genes can even replace *SST2* in yeast cells, an indication of how little the genes have changed during evolution. The message, says Blumer, is that "what we learn in yeast has high predictive value for what may be occurring in mammalian cells."

All these studies, researchers say, are consistent with a model in which RGS proteins bind to Gα proteins in specific G protein pathways, attenuating the molecular signals they send. Still, they point out that almost nothing is known with certainty yet about the proteins, including their molecular structures, how they bind to G protein subunits, or what, in turn, regulates their own action.

One thing that is clear, however, is that the field is moving into a growth phase. Researchers don't know how many RGS proteins they will ultimately find, but they predict that there will be a lot. "Given the fact that G proteins are involved in so many important physiological processes, members of the RGS family are probably going to crop up time and again as being really key regulators of these pathways," Blumer says.

Researchers also predict that the high degree of conservation among the proteins will make the job of answering these questions

easier, because it opens the way to doing many of the studies in simple organisms like yeast and C. *elegans*. Says Henry Bourne, a pharmacologist and longtime G protein researcher at the University of California, San Francisco: "Yeast and worms and people have much the same machinery. That makes it a whole lot faster to figure out what's going on." The cells may be tuning out, but biologists are eagerly tuning in.

–Wade Roush

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INFRARED ASTRONOMY

New Images Wet Researchers' Appetites

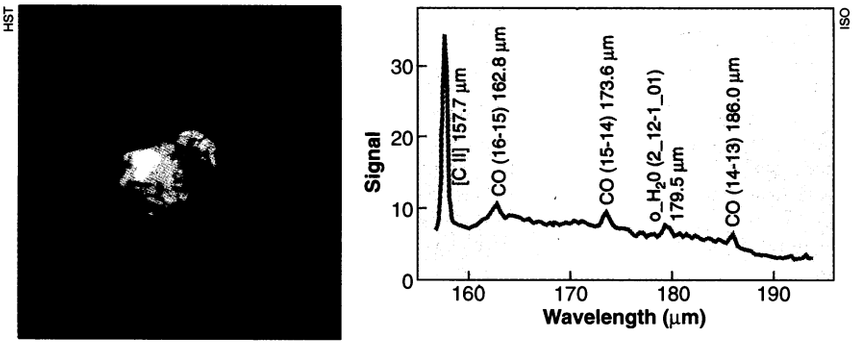
CHILTON, OXFORDSHIRE—In the 3 months since the European Space Agency launched its Infrared Space Observatory (ISO), engineers have been rigorously checking and testing the spacecraft's instruments, communications links, and other systems. But even before the testing was completed, scientists in the project could not resist taking a quick peep at what ISO is capable of—after all, they had waited 12 years since the demise of the only previous infrared observatory to rise above the "fog" of Earth's atmosphere. That glimpse has already provided several surprising observations—including the first-ever detection of water vapor from a source outside our solar system—and has given researchers great hopes for the rest of ISO's 2-year mission. "We see something new almost everywhere we look," said Dietrich Lemke of the Max Planck Institute for Astronomy in Heidelberg, Germany, principal investigator of ISO's imaging photometer, at a press conference last week.

Infrared astronomy is very difficult from the Earth's surface because air itself emits in the infrared, blinding instruments, and water vapor and carbon dioxide in the atmosphere absorb large chunks of the infrared waveband. But astronomers are keen to observe in the infrared because it is the main signal to come from the cooler objects of the universe, such as the interstellar gas clouds from which stars and planets form, the dusty remnants of dying stars, and planets themselves. A 10-month mission in 1983–84 by the U.S.–Dutch–U.K. Infrared Astronomical Satellite provided a map of almost the entire infrared sky, cataloging 250,000 cosmic sources, but astronomers have had to wait until now to get a more detailed look.

Since its launch on 17 November, ISO has chalked up several firsts:

- It has detected particles of ice in space for the first time, as well as frozen carbon dioxide and hydrogen cyanide, in a cloud around a newly forming massive star;
- It has spotted the coolest ever clouds of molecular hydrogen, which are virtually undetectable by other methods. Such clouds may account for some of the unidentified "missing mass" of the universe and are thought to play a key role in star formation;
- It has obtained the first clear and comprehensive spectrum from the atmosphere of Saturn, clearly identifying such molecules as ammonia and phosphine; and
- It has identified hot spots of star formation in the spiral arms of our near neighbor, the Whirlpool Galaxy, and traced the arms right into its nucleus.

But the discovery that is getting astronomers really excited is the detection of water vapor. "It's something of a Holy Grail," says Roger Emery, head of the astrophysics division at Britain's Rutherford Appleton Laboratory (RAL) in Chilton, Oxfordshire, and project scientist on ISO's long-wavelength spectrometer. Water is important in cosmological theories because it can help to cool clouds of interstellar gas and it is one of the essential building blocks of life. So astronomers are keen to know how and in what quantities it is created in space. The signature of water vapor is completely masked to telescopes on the ground by moisture in the atmosphere, so identifying it is a prime goal for ISO. It turned up in a surprising place, however.



A hint of water. ISO spectrum from planetary nebula NGC 2027 (image, from Hubble Space Telescope) shows emission lines for both carbon monoxide and water vapor.

One of the sources ISO looked at during its validation phase was a planetary nebula called NGC 2027, the debris ejected from a dying star. The spectrum ISO obtained showed strong emission lines characteristic of carbon monoxide, implying that a lot of carbon was ejected from the star. Theorists have predicted that there would be little water in such carbon-rich debris, because the carbon would mop up all available oxygen before water had a chance to form. But ISO scientists found an emission line for water in the spectrum of NGC 2027. "All the ingredients [for life] are available in one cloud, ready for the next generation of stars and planets," says astronomer Helen Walker, who coordinates user support for ISO at RAL. If an astronomer had made an observation proposal to look for water in NGC 2027, she says, it would not have been accepted: "It's so unlikely."

"This is going to be very important," says astronomer Ian Furniss of University College London. Many models of interstellar clouds suffer from an excess of energy, so if water vapor is common, its cooling properties could play a key role. "We will understand the energetics of these regions very much better," says Furniss. "I'm very excited. It will fire up a lot of new theories."

ISO scientists are now trying to confirm the water vapor finding in NGC 2027 using a different one of the observatory's four instruments—the short wavelength spectrometer (SWS). "We've made a quick scan and not seen anything yet," says Thijs de Graauw, principal investigator for the SWS at the Netherlands' Institute for Space Research, adding, "we're now making a more detailed scan." Emery is confident that soon ISO will be finding water all over the sky. "We expect to find stronger sources," he says. "This shows that a key element of life is detectable."

–Daniel Clery