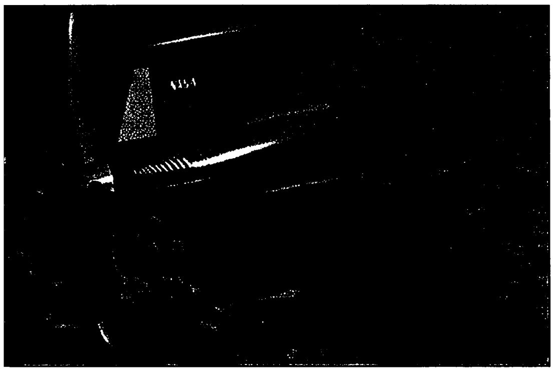


**Soaring plans.** This plane would skim the surface of Mars later this decade under one NASA scenario.

biters and rovers every 2 years over an 8-year period. But that schedule left little margin for error, and the twin 1999 failures raised questions about the soundness of the hardware and software to be used in future missions. The new schedule addresses that problem by alternating orbiter and rover missions. The 2001 orbiter called Odyssey will be followed in 2003 by two small rovers that will land independently. Two years later, a sophisticated reconnaissance spacecraft capable of seeing objects as small as a beach ball will be launched.

The pace of exploration will ratchet up in 2007, with the launch of an Italian communications satellite to provide much-needed data transfer capability. NASA would send a smart lander—perhaps equipped with drills to look for moisture under the surface—and a long-range rover. The plan also calls for a debut that year of a new line of explorers called Scouts that could include balloons or planes.

In 2009, a joint U.S. and Italian orbiter equipped with radar would provide more accurate mapping of the surface. A spacecraft to bring martian soil and rock samples back to Earth wouldn't be launched until 2011 or 2014—6 to 9 years later than planned. That effort would cost between $1 billion and $2 billion, and likely would be done with substantial cooperation with the French space agency CNES. Samples would be returned 2 or 3 years later.

The rationale behind the new approach, says NASA Mars exploration program scientist Jim Garvin, is to seek "the most compelling places from above, before moving to the surface." That approach will allow the agency "to change and adapt over time in response to what we find with each mission," says Scott Hubbard, NASA's Mars program director. It will also provide more data over the long haul. Most researchers seem to agree. "Under the old plan, the fear was we might not know where to get the samples [from], or that, once we got there, we wouldn't have the technology to choose" the best samples, says Steven Squyres, a Cornell University astronomer who is principal investigator of the planned 2003 rover. "This way, we will know a hell of a lot more first."

But that's cold comfort to Carl Agee, chief scientist for astromaterials at NASA's Johnson Space Center in Houston. "We'd like to see a sample return earlier rather than later," he says. "We think the sample return is the biggest payoff."

Some observers think that NASA is being too cautious. "It's a good, but limited, plan," says Louis Friedman, executive director of the Planetary Society, based in Pasadena, California. He believes that NASA would have an easier time getting sufficient funding if it linked the robotic probes to a future human mission. Weiler disagrees, saying that "the program is not driven by human exploration but by science."

Hubbard says NASA intends to spend between $400 million and $450 million annually on the effort during the next 5 years, nearly one-third more than originally planned. In return, he promises, future missions will not only deliver good science but avoid technical snafus through stronger oversight. "This is a program," he says, "not just a collection of projects."

—ANDREW LAWLER

MATERIALS SCIENCE

## Long-Wavelength Lasers Sniff Out New Uses

Just a few weeks after two physicists won the Nobel Prize for figuring out how to make lasers out of semiconductors (*Science*, 20 October, p. 424), researchers at Lucent Technologies' Bell Labs in Murray Hill, New Jersey, announced that they have made those lasers much more useful. A new technique permits the lasers to shine light in regions of the infrared spectrum previously inaccessible to similar devices. The advance may open the door to cheap devices to sniff explosives and other robotic sensors.

Because long wavelengths of light are absorbed by different molecules in different ways, a spectrometer that uses these new light sources would be able to detect faint whiffs of chemicals in the air. "There is a potential here to produce robot laser sensors" tunable over the appropriate region of the spectrum, says Richard Zare, a laser chemist at Stanford University. "They don't exist today."

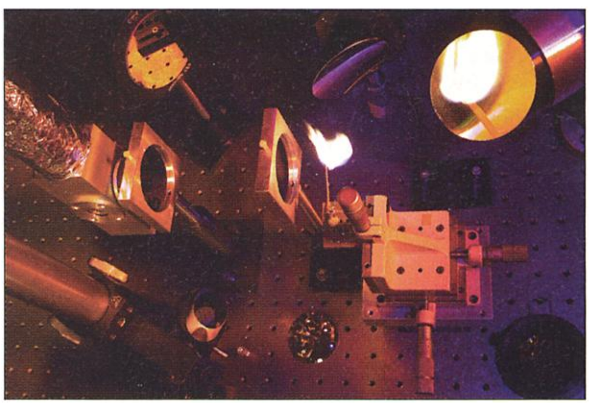
The work, by physicist Federico Capasso and his colleagues at Bell Labs, involves quantum cascade lasers, which are made of many layers of semiconducting materials. Each of these layers is pumped full of electrons and "holes"—spaces for the electrons to nestle in. When an electron settles into a hole, it releases light, which, in turn, induces other electrons to duck into holes, which releases more light, and so forth.

The problem with these lasers is that they can't produce light very deep into the infrared region. They can only generate wavelengths of a few micrometers before running into trouble. For a semiconductor laser to work efficiently, electromagnetic waves must be confined within the "active region" where all the electrons are falling into holes, so the light can induce more electrons to find more holes. Lasers traditionally do this with dielectric waveguides, devices that work rather like fiber-optic cables. Made of materials with different refractive properties sandwiched together, they force light to bounce around inside them.

Unfortunately, the longer the wavelength, the thicker the waveguides have to be—and the harder it gets to deposit the waveguide layers on the chip. "It's fine and dandy until you get to really long wavelengths," says Capasso. "If you wanted to make a dielectric waveguide for a 20-micron laser with conventional dielectrics, you would need a prohibitively thick material, 8 to 10 microns thick."

To address the confinement problem, Capasso and his colleagues have exploited a property of electrons, called surface plasmons, that reside at the interface between a semiconductor and a conductor. Plasmons are waves of electrons that slosh back and forth when excited by, say, an incoming photon. Roughly speaking, a surface plasmon behaves like light trapped at a conductor-insulator interface. This trapping is exactly what the Bell Labs team wants; the light is trapped without the need for bulky waveguides. "You squeeze the light close to the interface," says Capasso.

By building a sandwich of conductors and semiconductors in the chip, the team ensures that the laser light creates a plasmon where the two materials meet. The plasmon



**Fire at will.** Although invisible, the infrared light emitted by a surface plasmon laser packs enough punch to ignite a match.

CREDITS: (TOP TO BOTTOM) JPL/NASA; LUCENT TECHNOLOGIES' BELL LABS waveguide focuses 80% of the light on the laser's active region, compared to about 50% for a traditional waveguide, making the laser much more efficient. The plasmon version is also half the thickness of the traditional 8-micrometer waveguide and still within the capabilities of existing deposition processes.

Best of all, the new technique permits longer wavelength infrared beams. These allow the emitted light to be tuned to make molecules bend, revealing them to a detector as surely as fingerprints pinpoint a criminal. The surface plasmon laser emitted beams of 19-micrometer infrared light—the longest wavelength emitted by a semiconductor laser so far. And Capasso hopes to go even further: "We think we'll be able to do 60 to 80 microns."

Zare hopes that the prototype device might lead to many new applications. "This was a gap where we now have neat light sources," he says. For instance, a laser in that region of the spectrum might be tunable to detect the vibratory motion of various molecules, allowing a robot to detect the molecules' presence. "The applications [include] detecting explosives and chemical and biological agents, looking at disease states, and medical diagnosis," says Zare. Although the lasers still must be kept at temperatures too cold to be widely used, Zare thinks that room-temperature lasers are possible: "I've got lots of hope." –CHARLES SEIFE

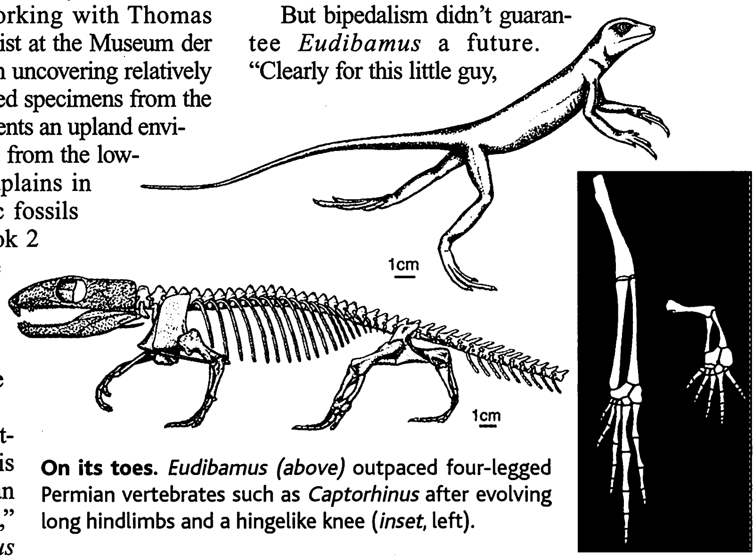
PALEONTOLOGY

## First Upright Vertebrate Lived Fast, Died Young

Early land vertebrates were a cloddish crew. When amphibians first sloshed ashore, some 360 million years ago, they waddled like soldiers crawling under barbed wire. Even after reptiles began to spread into drier landscapes and diversified, these landlubbers still plodded on all fours using the same sprawled stance. Paleontologists thought that the pace didn't pick up until fleet-footed bipedal dinosaurs appeared in the Late Triassic, about 210 million years ago.

Now a fossil discovery shows that at least one reptile was dashing around on two legs in the Early Permian, as much as 80 million years before the first dinosaur. On page 969, Robert Reisz of the University of Toronto in Mississauga, Ontario, Canada, and David Berman of the Carnegie Museum of Natural History in Pittsburgh and their colleagues describe *Eudibamus cursoris*, a 25-centimeter-long herbivore that is the earliest known vertebrate able to run on its hindlimbs. "When I first heard about this fossil, I was just amazed," says Hans-Dieter Sues of the Royal Ontario Museum in Toronto. "I didn't expect a bipedal creature that far back in time." The find suggests that bipedalism may be more common than previously thought—but not necessarily a sure route to evolutionary success.

The 290-million-year-old fossil was discovered by Stuart Sumida of California State University, San Bernardino, in 1993 in a quarry near Gotha, Germany. For about a decade, scientists working with Thomas Martens, a paleontologist at the Museum der Natur Gotha, have been uncovering relatively complete, well-preserved specimens from the quarry. The spot represents an upland environment quite different from the lowland deltas and floodplains in which most Paleozoic fossils have turned up. It took 2 years to prepare the small, delicate specimen. Once the bones were revealed, the group realized that the fossil was unique, too.




**On its toes.** *Eudibamus (above)* outpaced four-legged Permian vertebrates such as *Captorhinus* after evolving long hindlimbs and a hingelike knee (*inset*, left).

CREDITS: (*EUDIBAMUS* AND FEET) D. BERMAN *ET AL.*; (*CAPTORHINUS*) M. J. HEATON AND R. R. REISZ/*JOURNAL OF PALEONTOLOGY* 54, 136 (1980)

"What's really exciting is that this fossil is the first instance of an animal built for speed," Reisz says. *Eudibamus* had hindlimbs that were 64% longer than its forelimbs and 34% longer than its trunk, proportions comparable to those of modern lizards that run on two legs. Feet sporting long digits would have given the animal a substantial stride. "It ran on its toes, especially when it got going," Berman says. "That's what all fast animals do."

Its tail also helped it move quickly, Berman says. Like the tails of modern bipedal lizards (and unlike those of its fellow Permian vertebrates), the tail of *Eudibamus* makes up more than half the length of the creature's body. Muscles attached to such a hefty appendage could have made *Eudibamus*'s hindlimbs powerful enough for two-legged sprinting. The arrangement also kept the animal's center of gravity close to its hip, a necessary feature for balancing a two-legged gait.

*Eudibamus* had also evolved a new kind of knee joint—one that allowed it to run with its feet directly underneath its body. In other vertebrates of the time, the legs jutted outward from the body. That's because one of the paired shinbones (tibia) connected with the underside of the mostly horizontal thigh bone (femur), while the other shinbone (fibula) attached to the end of the femur. By contrast, both shinbones in *Eudibamus* fit onto the end of the femur, forming a hingelike joint that puts all of the leg in one plane, just as in humans and dinosaurs. The result is an energy-efficient posture that allows the bones, not just muscles, to help support the animal's weight.

*Eudibamus* probably wasn't an ideal biped; its limbs might have tended to splay out to the side when it wasn't running. Even so, Reisz and his colleagues speculate, its two-legged posture could have given the animal a crucial edge over four-legged predators. That evolutionary advantage may explain the widespread dispersal of *Eudibamus*—inferred from fragmentary fossils of its relatives—across the northern continent of Laurasia.

But bipedalism didn't guarantee *Eudibamus* a future. "Clearly for this little guy, it didn't make much of a difference," Sues says. "This was a very short-lived evolutionary lineage, as far as we know." Michael Caldwell of the University of Alberta in Edmonton suspects that bipedalism may have evolved many times in vertebrate history before dinosaurs, birds, and primates made the innovation an evolutionary success. In giving lug-necked predators a run for their money, *Eudibamus* may have been just one of any number of creatures darting briefly ahead of their time. –ERIK STOKSTAD

SCIENCE AND COMMERCE

## Digital Music Safeguard May Need Retuning

A hacker-professor says he and his graduate students have cracked the four leading methods proposed for thwarting audio pirates. Ed Felten, a computer scientist at Princeton University, says his achievement shows that so-called digital watermarks—identifying signals hidden inside streams of digital data—cannot protect music from illegal copying. But the music industry begs to disagree.

The charges and countercharges center on a competition sponsored by the Secure Digital Music Initiative (SDMI), a forum of music, technology, and electronics companies that is designing a method to thwart illegal copying of audio files. SDMI champions a protection scheme analogous to the ghostly image of Andrew Jackson that appears next to the Treasury department seal when you hold a new $20 bill up to the light. "A device