gressing three amino acids at a time down the chain. It repeats this process 5000 times and freezes in place any arrangement that occurs 70% of the time until, lo and behold, substructures, sheets, for example, emerge. The hierarchical nature of proteins suggests that this approach will eventually yield an entire protein, although Rose has not yet demonstrated this. Even so, he is eager to match up the latest version of the program, Toddler LINUS, against other prediction tools. "We signed up [for CASP2] on the first day it was announced," Rose says.

He will know how LINUS fared by the end of the year: Participants in CASP2 will compare their results at another Asilomar meeting in December. But he and fellow protein predictors may not have to wait quite that long to get a sense of the competition. Moult has set up a Web site (http://iris5.carb.nist.gov:8000) with a set of examples that will enable those with ab initio programs to check how their programs compare with others in deciding which structures are the right ones.

In addition, a center for assessing predictions, based at Lawrence Livermore National Laboratory, is distributing the CASP2 test protein sequences and collecting predictions. Funded by the Department of Energy, this center will continue these activities even after December, to provide predictors with a continuous source of new test sequences.

Other steps are also being taken to encourage collective action by the community. Hubbard and his colleagues have written a computer program called Graphical Language for Assembly of Secondary Structure (GLASS) to visualize the results of all these computational efforts. "[GLASS] allows you to read in a lot of information from different types of predictions and it generates a 3D image," Hubbard explains. The scientist can look at the image and several variations on that image, superimpose related, known structures, and determine, for example, whether atoms that should be on the molecule's surface are buried. In this way, a researcher can use all the prediction tools and perhaps be better able to come up with the correct structure answer, Hubbard adds.

Although this kind of cobbling together of techniques may not be what the predictors had once envisioned—many had hoped for the fame and recognition of having solved the protein-prediction problem by themselves—many think it will ultimately be the most successful approach. "Everyone has these daydreams of being the Einstein of protein folding," says UCLA's Fischer. "But everyone realizes that we're just nibbling at the edges. Collectively, the *group* is ultimately going to solve the problem."

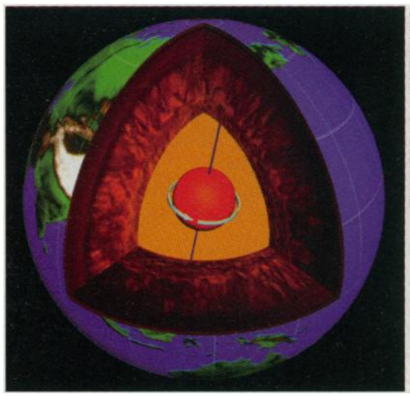
–Elizabeth Pennisi

GEOPHYSICS

Earth's Core Spins at Its Own Rate

Geophysicists with ever sharper seismological tools are constantly probing beneath the surface of the Earth, but the planet's deep interior remains its most remote frontier. So when a team of seismologists announced last week that Earth's solid-iron inner core spins faster than the rest of the planet, gaining almost a tenth of a turn during the past 3 decades, it sent a tremor of excitement through the community of deep Earth researchers. A week later, scientists were still digesting the news, but one thing was certain: Geophysicists at last had direct measurements to help guide their explorations of the frontier.

"It's an exciting result," says planetary physicist David Stevenson of the California Institute of Technology. Theoreticians aren't startled that the inner core rotates faster than the rest of the planet, he says, "but the surprising thing is that its rotation rate [perhaps as fast as once in 400 years] is as big as it is." The most important implication of this result, says Stevenson, is the additional constraint it will provide on models of Earth's magnetic field, which is generated in the molten-iron outer core. The new rotation rate offers modelers their first direct measure of what's going on in the core. It could, for example, provide a measure of the strength of the field in the core, a property only guessed at until now.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Spin control. Earth's solid-iron inner core rotates around its axis faster than the rest of the planet.

Indeed, it was a model prediction last year that prompted Xiaodong Song and Paul Richards of Columbia University's Lamont-Doherty Earth Observatory to search for some sign of inner-core rotation; they reported on the results of that search in the 18 July issue of *Nature*. If the rotation rate were anywhere near as high as predicted, the team reasoned, they would see some change in recent decades in the speed at which seismic waves pass through the inner core. They based this assumption on two previously known properties of the inner core. First, for several years seismologists have been showing how the crystalline iron of the inner core has a "grain" much like a piece of wood (*Science*, 31 March 1995, p. 1910). This grain, presumably caused by an alignment of iron crystals, is revealed by the fact that seismic waves traveling along the grain, roughly north-south, move a little faster than those traveling across the grain parallel to Earth's equatorial plane.

Second, researchers have recently shown that this grain, or anisotropy, is not quite lined up with the north-south rotation axis of Earth and the inner core. This means that if the inner core rotates at a different speed from that of the rocky mantle, the orientation of the anisotropy—and of the "fast track" for seismic waves—would change over time, circling around the high latitudes like a searchlight. Anyone monitoring seismic wave velocities along a particular route through the inner core from one polar region to the other should see those velocities change over time, as the fast track becomes more aligned or less aligned with that particular route.

That is just what Song and Richards saw when they compared the travel times of seismic waves that passed through the inner core with those that didn't. For example, waves passing just outside the inner core from earthquakes in the South Sandwich Islands off the southern tip of South America arrived in College, Alaska, just as fast in 1967 as they did in 1995. But waves passing through the inner core made the trip 0.3 seconds faster in 1995 than in 1967. Song and Richards concluded that the inner core's fast path had been swinging into alignment with the South Sandwich–Alaska route at a rate of 1.1 degrees per year.

"I think they're right about the inner core rotating," says Kenneth Creager of the University of Washington, who has worked on inner-core anisotropy. And to everyone's pleasant surprise, the rotation found by Song and Richards is "roughly the same" as seen in one model last year, says Gary Glatzmaier of Los Alamos National Laboratory, who developed the model with Paul Roberts of the University of California, Los Angeles. Their model's inner-core rotation rate is within a factor of three or so of the observed rate and in the same eastward direction, suggesting that the properties of Earth's interior assumed in building the model "may not be that bad," says Glatzmaier.

If Glatzmaier and Roberts's model works anything like the real Earth, the inner core is being dragged eastward ahead of the rest of the solid planet by the powerful magnetic drag of two intense jets in the outer core, jets analogous to the jet streams in the atmosphere. In the model, these jets are part of the geodynamo created by the outer core's churning, conductive liquid iron, which generates the magnetic field. Reflecting the truly frontier nature of the inner core, "we don't know what the magnetic field's magnitude is in that region," notes Stevenson. A comparison of the model's inner-core rotation rate with the observed rate would seem to confirm the model's prediction that the field at the inner core is 100 gauss—200 times stronger than at the surface.

Still, "there are a lot of uncertainties in the modeling and the seismology," says Glatzmaier. "So a big question remains—is Earth doing the same thing as our model?" As far as the inner core goes, says Creager, it's too soon to tell for sure. The core is rotating faster than the rest of the planet, "but I think it's premature to say [just] how fast." The new preliminary estimate could have been thrown off by variations in the strength of the anisotropy from place to place in the inner core, he says: "It's becoming clear that the inner core is a little more complicated than we gave it credit for."

–Richard A. Kerr

For more information, see the Lamont-Doherty World Wide Web page on inner core rotation: http://www.ldeo.columbia.edu/song/pr.html

PLANET HUNTING

'Hot Jupiters' Leave Theorists in the Cold

CAPRI, ITALY—It has been just 10 months since a pair of Swiss astronomers first identified a planet orbiting a sunlike star other than our own, but the tally of so-called "exoplanets" has now passed the total of nine familiar planets of our solar system. That mark came earlier this month at the Fifth International Conference on Bioastronomy on this island off the southern Italian coast, where astronomers reported several new sightings, including the first evidence of another multiplanet system around a sunlike star. And with the total steadily growing, researchers are beginning to identify tentative groupings of planet types, one of which, says Geoff Marcy of San Francisco State University, is "a class of planets that is completely unlike the planets in our solar system."

Exoplanets cannot be seen directly, but betray their existence by the gravitational pull they exert on their parent stars—which wobble toward and away from us. By measuring these regular variations in the star's velocity, astronomers can deduce the orbital period of the planet and put a lower limit on its mass. Soon after Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland announced their discovery of a massive planet orbiting a star known as 51 Pegasi (*Science*, 20 October 1995, p. 375), Marcy and his colleague Paul Butler discovered two more: one around 47 Ursae Majoris and another at 70 Virginis (*Science*, 26 January, p. 449). Now at least 10 exoplanets are known to be orbiting sunlike stars, and some general trends are beginning to emerge.

The first is that planets less massive than five times the mass of Jupiter tend to have circular orbits, while larger stellar companions—more than nine Jupiter masses—reside in elliptical orbits. "This might provide us with a clear distinction between true planets and brown dwarfs," says Mayor. Brown dwarfs are "failed stars" which are not massive enough to ignite hydrogen fusion in their cores. Mayor announced at Capri his discovery of three new brown dwarf companions, and he and others suggested that the companions of 70 Virginis and HD 114762 should be reclassified as brown dwarfs.

Within the group of less massive companions in circular orbits, astronomers have been surprised to find a completely new class of planets, which they dubbed "hot Jupiters." These giant planets are termed hot because their orbits are between 10 and 20 times closer to their parent stars than the Earth is to the sun, and their orbital periods—or "years"—are only a few days long. The original exoplanet, around 51 Pegasi, belongs to this class, and three more have since been discovered orbiting 55 Cancri, Tau Bootis, and Upsilon Andromedae, Marcy and Butler's most recent find. "55 Cancri and Tau Bootis are close cousins of 51 Pegasi, while Upsilon Andromedae is a real twin," says Marcy. Within a couple of months Mayor expects to announce four new members of this class, based on observations that are currently being analyzed.

Theorists are completely puzzled by these findings—current models cannot account for giant planets forming so close to their parent stars. Some conclude that the hot Jupiters must have formed at much larger distances and subsequently migrated inward as they were slowed down by friction with a remnant circumstellar disk of gas and dust (*Nature*, 18 April 1996, p. 606).

But Mayor is not so sure. If orbital decay is the culprit, something is needed to halt this process after the planet has traversed nearly 99% of its original distance to the star, he says, for that is where all the hot Jupiters are being found. Some theorists, including Jack Lissauer of the State University of New York, Stony Brook, are working on new models to explain the existence of the hot Jupiters. Lissauer thinks his computer simulation might be able to form the planets at their current positions, but says he has to do more calculations before giving details about his hypothesis.

Next year, Marcy and Butler will use the 10-meter Keck telescope in Hawaii for their planet-hunting program, while Mayor and Queloz will have moved to a dedicated telescope at the European Southern Observatory in Chile. With these better telescopes, more sensitive detectors, and more observing time, the two groups expect to discover full-fledged planetary systems instead of single planets. The Capri meeting provided a possible taste of things to come when Butler announced that he and Marcy had detected a second planet orbiting 55 Cancri. Also, a few weeks before the Capri meeting, George Gatewood of the Allegheny Observatory in Pittsburgh announced his discovery of two planets in orbit around a nearby star called Lalande 21185 using a different detection technique. Most astronomers have few doubts that exoplanets will soon vastly outnumber Earth and our eight nearby companions.

–Govert Schilling

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.

PLANETS DISCOVERED AROUND OTHER SUNLIKE STARS

Star	Distance to star (Earth-Sun = 1)	Orbital period	Lower limit on mass (Jupiter = 1)	Notes
51 Pegasi	0.05	4.3 days	0.5	First exoplanet, "hot Jupiter"
47 Ursae Majoris	2.1	1103 days	2.4	
70 Virginis	ecc. orbit	116.7 days	6.6	Possible brown dwarf
55 Cancri	0.11	14.76 days	0.8	"Hot Jupiter"
55 Cancri	>5	unknown	>5	
HD 114762	ecc. orbit	84.01 days	10	Possible brown dwarf
Tau Bootis	0.0047	3.31 days	3.7	"Hot Jupiter"
Upsilon Andromedae	0.054	4.61 days	0.6	"Hot Jupiter"
Lalande 21185	2.2	5.8 years	0.9	Astrometric detection
Lalande 21185	11	30 years	1.1	Astrometric detection (uncertain)