vous system goes haywire, with some neurons failing to develop and others becoming misdirected. Because the floor plate sits next to the notochord, known to influence various events in development, researchers tested its effects on floor-plate formation.

By either removing bits of notochord from chick embryos or grafting in extra pieces, researchers found that with extra notochord tissue, a second floor plate appears; without part of the notochord, part of the floor plate was missing (*Science*, 16 November 1990, p. 985, and 15 November 1996, p. 1115). Scientists were even able to identify the notochord's molecular messenger: a powerful protein called Sonic hedgehog, which in culture can cause certain cells to develop characteristics of the floor plate.

But Le Douarin's work indicates that this classic hierarchy is too simple. In very early chick embryos, her team replaced a group of notochord precursor cells with the corresponding cells from a quail embryo. Chick and quail cells are readily distinguishable, making it easy to track the fate of the transplanted cells. A few days later, the team found that the resulting chimera had formed a notochord and a floor plate—both made of quail cells. If the notochord were directing the floor plate to form, says Le Douarin, the floor plate would have been of chick cells.

Genetic data also support the floor plate's independence from the notochord's signal. Zebrafish mutants missing a notochord can develop floor plates, and distinct notochord and floor plate cells can be detected in very early zebrafish embryos, says developmental geneticist Marnie Halpern of the Carnegie Institution of Washington.

To Le Douarin, these results mean that the precursors of both the notochord and the floor plate are present in the very early embryo and move together through the developing neural tube. She suggests that previous experiments may have been misinterpreted, and that when the notochord was removed, the floor plate predecessors came along.

But Columbia University developmental biologist Tom Jessell, who did some of the earlier experiments, disagrees. He says previous work shows that the floor plate may be a team project, of notochord precursor and other cells, but the commands still originate from the notochord. The chimera experiments don't indicate when the floor-plate cells begin to differentiate, he says. He argues that the notochord's production of Sonic hedgehog is crucial, noting that in Sonic hedgehog knockout experiments, the notochord degenerates and a floor plate does not form.

Le Douarin is not surprised by the reluctance to revise what seemed an orderly chain of command. "Everybody assumed that they knew what was right," she says, "but all assumptions are subject to revision."

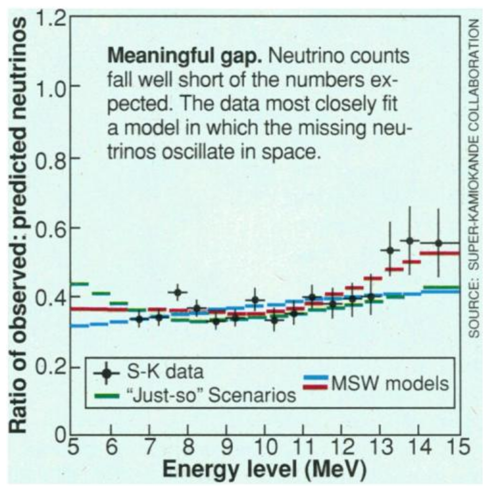
–Gretchen Vogel

PARTICLE PHYSICS

Heavy News on Solar Neutrinos

TAKAYAMA, JAPAN—The recent announcement by a team of Japanese and American physicists that they have found evidence of mass in neutrinos from the atmosphere stole the show at an international conference here (*Science*, 12 June, p. 1689). Almost lost in the excitement was a hint that the same may be true for another kind of neutrino also being captured by the thousands at the Super-Kamiokande collaboration's 50,000-ton water-filled detector, which is located in a mine 1 kilometer underground. A report of a deviation in the expected number of neutrinos generated by the sun at certain energy levels suggests that, like the atmospheric neutrinos, solar neutrinos can change their identity while in flight. That feat would require these ephemeral subatomic particles to have at least a smidgen of mass.

"We don't want to say anything too strongly about [the evidence] yet," says Yoichiro Suzuki of the University of Tokyo, who heads the collaboration's solar neutrino analysis team. "We need more data." But to some onlookers, the small variations in solar neutrino counts by energy reported by the team look like the signature of neutrino oscillations, or identity shifting. "It is the first time the effect has been observed within one experiment," says John Bahcall, a neutrino expert at the Institute for Advanced Study in Princeton, New Jersey. Previous attempts have cobbled together results from different experiments, he explains.



Meaningful gap. Neutrino counts fall well short of the numbers expected. The data most closely fit a model in which the missing neutrinos oscillate in space.

The first clues that neutrinos might have mass came from experiments in the 1960s that picked up only between one-third and one-half the expected number of neutrinos streaming from the sun. Because neutrinos come in three types, or flavors, and the detectors were sensitive only to a subset of flavors and energy ranges, some researchers speculated that the missing neutrinos had converted, or oscillated, to a type that could not be detected. But the laws of quantum mechanics state that a particle must have mass to oscillate. That suggested a flaw in the Standard Model, the established theory of particles and forces that has served as the basis of modern physics, which posits zero mass for neutrinos.

There are at least two theories to explain where the oscillations are taking place. In one, dubbed the "just-so" scenario, solar neutrinos oscillate in a vacuum. In that picture, the number that change into an undetectable form should depend on the neutrinos' energy and the distance they travel from the sun to the detector on Earth. The theory gets its name from the fact that calculations of where particle oscillation is likely to peak required that the oscillation length be nearly equal to Earth's orbital radius. In the other, called MSW for the initials of its three inventors, the oscillations get a kick whenever the neutrinos interact with matter, whether in the sun or on Earth.

In the MSW scenario, the number of neutrinos detected should fluctuate from day to night, when Earth's rotation places the planet's entire mass between the sun and the detector. The effect should be largest for neutrinos that travel straight through Earth's dense core. The just-so picture predicts no day-night effect, but it does predict a slight variation in neutrino counts by energy and by season, as Earth's distance from the sun varies.

Earlier neutrino detectors couldn't gather enough data to test these predictions. But since it started operating in April 1996, Super-Kamiokande has recorded evidence of some 7000 electron neutrinos, more than three times the number spotted by every other neutrino detector combined.

So far, researchers have not found any day-night effect, and there appears to be no enhancement of the oscillation effect for neutrinos coming through Earth's core. The new results don't doom the MSW theory, however: Under certain parameters, the effect might not be seen for neutrinos flowing through Earth. On the other hand, Super-Kamiokande did see a small deviation from the expected spectrum curve at particularly high energies and a very slight seasonal variation in the number of high-energy neutrinos, support for the idea that oscillations can take place in empty space.

Neutrino researchers agree that more evidence is needed to make a definitive case for solar oscillations. But Bahcall and others say that the new data from Super-Kamiokande represent "real progress" in solving a decades-old puzzle.

–Dennis Normile