# Building Matter From a Dozen Blocks

The zoo of fundamental particles that make up ordinary matter appears to have a limited capacity after all. Last week, five separate teams of researchers reported evidence that, taken together, limits to three the number of families of fundamental particles known as quarks and leptons that can exist.

"The evidence is very impressive," says Jonathan M. Dorfan of the Stanford (Calif.) Linear Accelerator Center. According to the so-called standard model of particle physics, each family is represented by a particular type of neutrino — a massless particle that interacts only feebly with matter. "The likelihood of having a fourth generation characterized by a massless neutrino looks particularly bleak," Dorfan says.

The findings, reported by the Mark II detector team at the Stanford Linear Collider and by the four detector groups at the Large Electron-Positron (LEP) collider in Geneva, Switzerland, mark a milestone in attempts to understand the structure of matter. They confirm earlier astrophysical calculations that had constrained the number of massless or light neutrinos to four or fewer — a conclusion based on the apparent abundance of helium in the universe.

The results also show that the standard model works quite well. That model assumes ordinary matter consists of two types of particles, quarks and leptons, and that the forces between them are carried by particles known as bosons. There are three types of leptons (electrons, muons and tau particles), each associated with a different type of neutrino, and there are three pairs of quarks (one pair in each family), which combine to make up protons, neutrons and other heavy particles.

The latest experimental results come from observations of the decay of Z° particles — massive particles created in collisions between high-energy electrons and positrons (the antimatter counterpart of electrons). The new particles promptly decay into leptons or pairs of quarks, which decay further, producing a spray of debris.

By examining how the Z° decays into other particles, physicists can tally the number of types of neutrinos that take part in the decay process. The number of neutrino types affects the form of the bell-shaped curve that represents the number of Z° particles produced plotted against the collision energy. Any extra families of fundamental particles would widen the curve and lower the height of its peak.

All five research groups produced data consistent with the existence of only three types of massless neutrinos, and hence, three families of fundamental particles. But that doesn't eliminate the possibility of finding new particles — for example, those associated with heavy neutrinos (if such particles exist). However, the chances of finding a massive neutrino now appear slim, several physicists suggest.

For the next two years, researchers, especially those using LEP, intend to focus on a search for the Higgs boson, postulated more than 30 years ago as a way to explain why different particles have the particular masses they do. If the Higgs boson exists, it would show up only rarely in Z° decays, perhaps once in a million events. So far, LEP has produced 11,000 Z° particles and Stanford has produced 500.

"It's a very rare event, so you need a lot of data," says George A. Snow of the University of Maryland at College Park, who works with one of the LEP detectors. "But something wild may happen that lets us find the Higgs particle sooner." Variations on the Higgs model suggest the possibility of several different types of Higgs particles, which may show up more readily in Z° decay data.

"There's still physics to do," Dorfan says. Although one crucial question has been settled, many more remain, including the basic one of why there are exactly three families of fundamental particles making up ordinary matter. — *I. Peterson*

# Scientists give the nod to more sleep time

Now you don't have to feel guilty when you hit the sleep button to quiet the early-morning blast of your clock radio. New research suggests healthy people who sleep an extra hour or two are more wakeful during the day and perform better on tests measuring reaction time and vigilance.

This finding supports the theory that many people live with a chronic "sleep debt," which builds during the work week and is relieved in part by lazy weekends. The research, described in the October SLEEP, shows that extra sleep can yield a performance boost, especially for people more sleep-deprived than most.

At Henry Ford Hospital's Sleep Disorders and Research Center in Detroit, Timothy Roehrs, Thomas Roth and their colleagues studied healthy men aged 21 to 35 who had regular bedtimes and normal sleep patterns. At the study's start, they gave volunteers the Multiple Sleep Latency Test (MSLT). Administered four times a day, the test assesses daytime wakefulness by measuring how quickly subjects fall asleep when instructed to nap in a dark room. The researchers used MSLT scores to identify 12 men who were sleepier than average and 12 who were more wakeful than average.

They then had the 24 subjects spend one eight-hour night in the sleep laboratory, sending them to bed at 11:30 p.m. and waking them at 7:30 a.m. For the next six nights, participants went to bed two hours earlier. The men slept in the laboratory on nights 1, 3 and 6 of this phase.

On each day following a night in the sleep lab, the researchers gave study participants the MSLT, waking them 90 seconds after they fell asleep to prevent the naps from adding to total sleep time. On the same days, the men took tests that measure reaction time and sustained vigilance — abilities needed for such tasks as driving a car or monitoring nuclear power-plant equipment.

The scientists found that when the men spent 10 hours in bed, they typically slept for nine hours and showed more alertness during the day. The 12 who were the sleepiest at the study's start, nodding off after six minutes or less during the initial MSLT naps, improved the most.

By the last day of the sleep-extension part of the study, the average score for this subgroup had risen to 10 minutes. The normally alert subjects — who appeared less sleep-deprived to begin with — improved slightly, taking at least 16 minutes to fall asleep during the initial MSLT and an average of 18 minutes on the last day. Both groups scored higher on attention and vigilance tests after spending 10 hours in bed.

The researchers say their study dispels the notion that too much sleep is detrimental to performance. "Most people will benefit from spending more time in bed," says Roth. "Ideally, you should sleep until you're slept out," Roehrs adds. But getting more sleep in today's fast-paced world may not be easy, they note.

James A. Horne, a sleep researcher at Loughborough University in Leicestershire, England, contends the benefits seen in this study are "marginal" and may not be worth the trouble for most individuals. "They are talking about two hours' extra time in bed for a small improvement in reaction time," he says. Horne disputes the theory that most people are sleep-deprived, arguing that people tend to sleep in on weekends not out of biological need but because sleeping late is a pleasant experience.

— *K.A. Fackelmann*