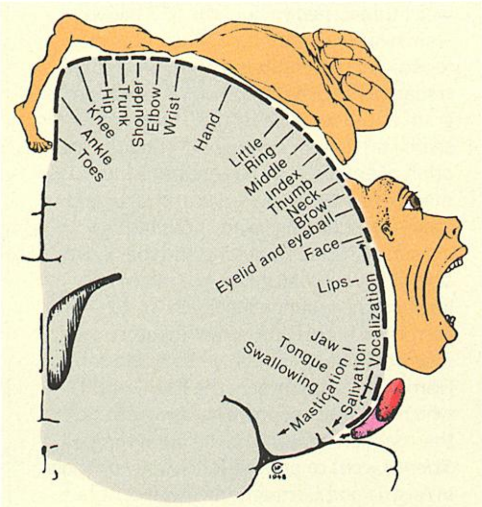
the animal's movements conclude.

The research, reported by Michael Graziano and colleagues at Princeton University in New Jersey in the 30 May issue of *Neuron*, might mean that the "map of motor cortex will have to be redrawn," says neuroscientist Larry Abbott of Brandeis



Goodbye, homunculus? This textbook depiction of the primary motor cortex's responsibilities might need to be refined.

University in Waltham, Massachusetts. "It will be a much more deep map than just this picture of a body."

The Princeton team uncovered the new map by electrically stimulating neurons in the primary motor cortex of monkeys, as other researchers had done, but in these experiments they used longer durations. A 50-millisecond stimulation—the same duration used in 1950 and earlier to trace the motor homunculus—causes brief muscle twitches. But Graziano and his team then tested how the neurons respond to pulses lasting a half-second or so, about as long as neurons in this part of the brain are active during natural movements.

The results were "pretty spectacular," says Abbott, who's seen the team's videos of monkeys responding to the stimulation. Rather than just twitching a muscle, the monkeys carried out coordinated, well-timed, determined movements. For instance, stimulation to one spot in the primary motor cortex caused a monkey to clench its fingers, move its hand near its face, and open its mouth. It didn't matter where the monkey's hand started out—every stimulation of the same cortical spot caused the monkey to assume the same final position. Of 324 stimulation sites in two monkeys, some 86% evoked a distinct posture.

The team found some evidence for a rough body-centered map of the motor cortex that matches the traditional motor homunculus. Certain regions often directed the hand and arm, whereas others largely caused movements of the legs or face. But the researchers found a more systematic pattern superimposed on the brain region, this one of locations in space. Zapping certain spots made the monkey reach its hand down and to one side, say, whereas nearby neurons led the hand to a slightly higher position or slightly closer to the middle of the body.

And in yet another blow to textbook descriptions of the motor system, the researchers found that their newfound neural map of space extended from the primary motor cortex to the nearby premotor area—a region that in other respects works quite independently.

Neuroscientists are both intrigued and mystified by these findings. "The challenge is to figure out just what this tells us about the organization of the cortex," says cognitive neuroscientist Larry Snyder of Washington University in St. Louis, Missouri.

One possibility, suggests neuroscientist Peter Strick of the University of Pittsburgh, is that two systems coexist in the primary motor cortex. Brief stimulation might directly activate spinal cord neurons in a way that matches the traditional view of the motor homunculus, whereas longer pulses might pull in more complicated neural circuits. But as difficult as it might turn out to be for neuroscientists to agree on what the primary motor cortex is doing, the textbook illustrators are going to have the even tougher job of depicting it.

–LAURA HELMUTH

COSMOLOGY

Best Big Bang Pictures Show New Wrinkles

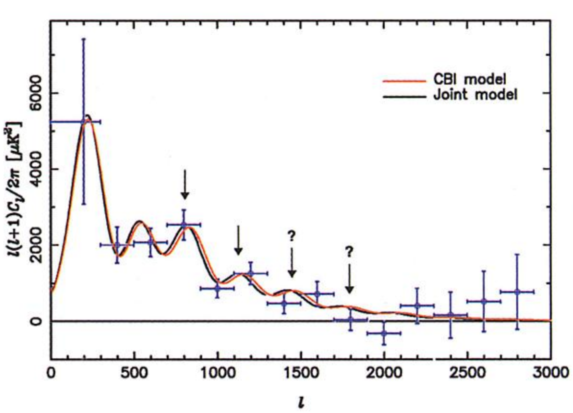
ARLINGTON, VIRGINIA—The data were so hot that bootlegged versions had been circulating for months. Even so, their official release here on 23 May has set cosmologists abuzz. The measurements, taken by the Cosmic Background Imager (CBI), a telescope in the Atacama Desert of Chile, give scientists their sharpest view yet of the infant universe.

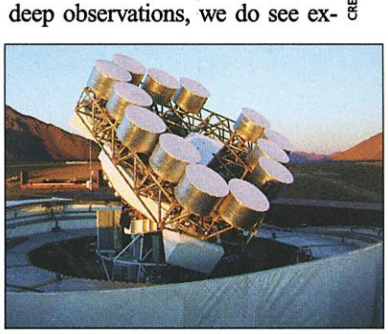
"The instrument is extremely exciting," says Max Tegmark, a cosmologist at the University of Pennsylvania in Philadelphia. CBI is sensitive to very small features in the cosmic microwave background that other microwave background observatories such as DASI, BOOMERANG, and even the new Microwave Anisotropy Probe (MAP) satellite can't see. "This is the one experiment that is not going to get eclipsed by MAP," Tegmark says. Indeed, Tegmark was so eager to get his hands on the CBI researchers' data that he used a digital camera to snap a photo of one of their overheads at a lecture—a photo that quickly made the rounds of the cosmological community.

The new CBI results show details of a surface that existed about 300,000 years after the big bang, when the universe was a roiling ball of plasma. Theory says that plasma was ringing with sound waves, which caused ripples in the cosmic microwave background. This "acoustic" model predicts that these still-visible ripples should be of characteristic sizes, just as a musical instrument produces sound waves of characteristic frequencies.

Last April, BOOMERANG and DASI released observations revealing the first and second "peaks" in the microwave background spectrum—akin to hearing the fundamental and first overtone of a musical instrument—and gave hints of a third peak (*Science*, 19 January 2001, p. 414). CBI, with its extra sensitivity to higher overtones, appears to have spotted the third and fourth peaks and might even have glimpsed the fifth and sixth peaks as well. Comparing the data with theoretical models gives scientists an independent measure of the budget of matter and energy in the universe. "The CBI data allows us to have a completely new test" of cosmological models—and the models are passing the test, says Alan Guth, a cosmologist at the Massachusetts Institute of Technology. For example, the "volume" of the overtones is diminishing, as the acoustic model predicts. "You see it starting to damp out as it should," says John Carlstrom, a cosmologist at the University of Chicago who is associated with the CBI team.

Even though the peaks are getting smaller, the CBI team has noticed that there is more "volume" at small scales than the acoustic model can account for. "In these deep observations, we do see ex-





Ripple effect. Extra "peaks" in the distribution of cosmic background radiation, seen by CBI (*right*), might shed light on the universe's history and composition.

CREDITS: (TOP) FROM W. PENFIELD AND T. RASMUSSEN, *THE CEREBRAL CORTEX OF MAN* (MACMILLAN, 1950); (BOTTOM) CBI/CALTECH/NSF cess power over what the theory predicts," says Anthony Readhead, leader of the CBI team. "If it's real, then we think it's a very exciting result." Readhead says that the unexpected excess might be due to the so-called Sunyaev-Zel'dovich effect, in which photons from the early universe scatter off electrons in hot gas in clusters of galaxies closer to Earth, distorting the cosmic background radiation.

If the observations hold up, a more detailed analysis of the excess "volume" at small scales might enable cosmologists to map the formation of galaxies and galaxy clusters in the early universe. "These are really signposts of the structural evolution of the universe," says Carlstrom.

CBI's fine-grained photos should also complement data taken from galaxy surveys. "Traditionally, microwave background has been on superlarge scales, while surveys of galaxy clusters have dealt with very small scales," says Tegmark. But with big galaxy surveys, such as the Sloan Digital Sky Survey, and small angular-scale measurements of the microwave background, the measurements are beginning to overlap, allowing scientists to compare them directly. "This will be particularly fun," Tegmark says.

–CHARLES SEIFE

AGRICULTURE

Organic Farms Reap Many Benefits

The bountiful crop yields of the green revolution have fed millions, yet they pose an environmental tradeoff: rich harvests in exchange for polluting pesticides and fertilizers. Organic farmers have long touted their methods as a more benign way to nourish the world. But few rigorous studies have looked at the long-term yields and environmental effects of organic farming. Outside of Europe, organic farms remain a niche operation relying on premium prices to survive.

Now a report on page 1694 brings encouraging news for organic fans. A team led by agronomists Paul Mäder of the Research Institute of Organic Agriculture in Frick, Switzerland, and David Dubois of the Swiss Federal Research Station for Agroecology and Agriculture in Zürich reports the results of the longest and most comprehensive study to date comparing organic and conventional farming, measuring many aspects of crops and soil over 21 years. The bottom line: Organic farms can be nearly as productive as regular farms for some crops, and they leave soils healthier. The study also conclusively demonstrates that for most crops, organic plots are more energy efficient per unit crop.

"This study is as complete a picture as we have from anywhere," says Phil Robertson, an agricultural ecologist at Michigan State University, East Lansing. Agrees soil scientist John Reganold of Washington State University, Pullman: "This gives more credibility to organic systems."

The 1.5-hectare trial, started in 1978 near Basel, Switzerland, compares four farming systems. One group of plots mimics conventional farming, treated with chemical pesticides and herbicides and soluble nitrogen for fertilizer. Another models an "integrated" approach that includes manure with conventional techniques. The organic plots use only manure and mechanical weeding, along with plant extracts to control pests. The fourth system is a much less common practice called biodynamic farming that adds unique treatments, such as a variety of herbs added to compost manure.

Green thumb. Organic farms, which used mechanical weeding rather than herbicides, hosted more kinds of beneficial insects.

Over 2 decades, the average crop yield was about 20% lower in both kinds of organic fields, a finding on par with previous studies. The best-performing organic crop was winter wheat, which stacked up at about 90% of the conventional harvest. Potatoes fared the worst with about 38% lower yields, mainly due to potato blight and potassium deficiency. The yields are all the more impressive given that the organic plants received less than half the nutrients given to conventional plots. "To add that much less fertilizer and still get 80% of the conventional yields is outstanding," says Reganold.

Because no synthetic fertilizer had to be produced or applied, growing organic crops also required less energy than conventional crops—up to 56% less energy per unit yield. The team also found evidence that nutrient-cycling microbes are more plentiful and efficient in organic soil, making more nutrients available to plants. According to a microbial diversity assay (which measures the range of bacterial metabolites as a proxy), biodynamic soil ranked higher than organic, which in turn outranked soils in conventional fields.

More microbes are known to improve soil structure, and Mäder's team found another benefit: higher yields in organic plots with maximum microbes. But Robertson questions whether the greater microbial diversity is simply a product of more diverse organic materials in the soil, for example, from the added manure. And microbiologist Kate Scow of the University of California, Davis, notes that the diversity assay looks at an "incredibly narrow" range of ecological niches and that other studies have been contradictory.

Soils did appear to be healthier in organic plots, with 40% more roots colonized by fungi that assist with plant nutrition. Earthworms were up to three times more abundant, and there were twice as many spiders and other pest-eating arthropods. Mäder thinks that these environmental benefits and higher energy efficiency help justify the existing government subsidies for organic farmers in Europe: "I think our research could stimulate governments to encourage this by showing long-term benefits."

But the study doesn't address other concerns about organic farming, Robertson adds, for example, whether organic farms can be economically viable on a large scale or in other economic conditions, such as in the United States, where such farms are not subsidized. Also uncertain are questions of groundwater pollution and atmospheric emissions of nitrogen forms. But if such concerns can be addressed, as indicated by a few other large trials, then perhaps the next revolution might be a bit greener.

–ERIK STOKSTAD

SEQUENCING

Chimps and Fungi Make Genome "Top Six"

Although the relevance of honey bees, chickens, and sea urchins to biomedicine might seem a stretch, the National Human Genome Research Institute (NHGRI) announced last week that deciphering the genomes of these species is a top priority. These organisms, in addition to the chimp, a protozoan called *Tetrahymena thermophila*, and several fungi, will be next in

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