Meister has been working on vision-related research for more than 15 years. Vision shows remarkable parallels not only across taxonomic classes, such as mammals and amphibians, he says; there are even features that seem to be common to all vertebrates. "Each visual system [the eye, the optic nerve, the connections to the brain]," he explains, "has evolved to solve the particular tasks required by its owner. But as regards the retina, it is actually remarkably similar in all these animals. The same basic types of neurons, the same three-layer structure, the same kinds of connections, and generally the same principles of processing.

"Here is why I think that's the case," he continues. "The retina is essentially the interface between the animal and images from the natural world. It must convert an optical image into neural signals, adjust the gain [increase in signal power expressed as a ratio of output to input] to deal with different conditions of illumination, and then somehow compress the information so it can be transmitted to the brain. All these tasks are pretty much driven by visual images from the natural world, and those are the same whether you're a monkey or a rabbit." Though the researchers have not done experiments on a human retina, "You can see effects in human vision that look like this," Meister says. "They go under the rubric of 'pattern adaptation.'" ~DONALD N. S. UNGER

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Retinal Revival

Markus Meister's research may someday help restore vision after retinal degeneration. One form, macular degeneration (the macula is the center of the retina, at the back of the eye), is a leading cause of blindness. It affects more than an estimated 25 million people worldwide, including nearly a third of those older than 75. As the U.S. elderly population swells during the next two decades, the number of Americans affected is expected to double.

Although macular degeneration is not a central focus of Meister's work, he says that, "down the line, understanding how the retina encodes visual information will be essential to building a 'retinal prosthesis' that could emulate the retina's function."

Currently, he's participating in two projects to develop such a treatment, one at Massachusetts Eye and Ear Infirmary, the other at MIT and Massachusetts General Hospital. "One scheme," he explains, "is to make a chip that will stimulate the optic nerve fibers with electrical pulses that would otherwise have been produced by the retina. The more we understand how the real retina processes images, the better we will know how to control such an artificial retina. The other scheme is built on a form of gene therapy—less technical wizardry involved, but it may work sooner."

ANIMAL COLOR LINES

Clues on the Wing

Vladimir A. Lukhtanov saw *Agrodiaetus* butterflies of several species flying together, and even though they all looked much the same in most respects—all an inch to an inch and a half wide, with the same sort of spots, and, upon examination, same-shaped genitalia—the males of different species had wings of different color. Why?

Lukhtanov is an entomologist at St. Petersburg State University in Russia, where one of his students was Nikolai P. Kandul. Kandul came to Harvard and completed a doctorate in organismic and evolutionary biology this year, working in the laboratory of Hessel professor of biology Naomi E. Pierce. With Kandul as link, collaborating teams—consisting of Lukhtanov and one other from St. Petersburg, and Kandul, Pierce, and two others from Harvard—analyzed the *Agrodiaetus* butterflies that Lukhtanov had seen.

The researchers built a phylogeny, or family tree, of 15 species. They were relatively young species and genetically very closely related. Kandul and his colleagues believe that the species formed in a process called "reinforcement." Reinforcement occurs when natural selection strengthens behavioral discrimination to avoid costly interspecies matings that tend to produce weedy, sterile hybrids. The evolutionary process of reinforcement can eventuate in speciation, providing a direct link between Darwin's theory of natural selection and the origin of new species.

"The phenomenon of reinforcement," says Kandul, "is one of the very few mechanisms that has natural selection playing a role in speciation. It might be

***Agrodiaetus damon* male**

***Agrodiaetus damon* female**

NIKOLAI KANDUL

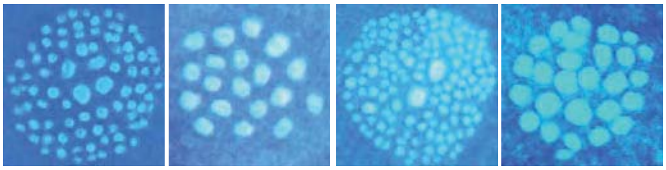
Male butterflies of various *Agrodiaetus* species display a range of wing color to the human eye. Tests by researchers using ultraviolet light confirm that butterflies see similar differences.

NIKOLAI KANDUL AND VLADIMIR LUKHTANOV

widespread, but it is hard to find good evidence of it." The joint study of *Agrodiaetus* butterflies, reported in *Nature*, details a probable instance, rarely demonstrable in nature, of the reinforcement model of evolution at work.

For one species of butterfly to become two, two branches of the species must stop breeding with each other, as though Cantabrigians decided to stop breeding with other Americans. Two branches of the species may be separated geographically —by a mountain range, for instance. (The genus *Agrodiaetus* lives from Spain to Central Asia, sometimes amid mountain ranges.) After hundreds of generations, the butterflies may find that they are no longer *able* to interbreed and have become clearly distinct species. But what if a *nascent* species that has developed some random genetic difference while living in isolation comes round the mountain and finds itself in seductive proximity to one or more other developing species? They must all take vows of reproductive isolation if they are to successfully branch into different species. Biologists can get excited by these *Agrodiaetus* butterflies because they appear to show in their colorful wings how reproductive isolation can be aided.

The collaborators discovered that separated species of *Agrodiaetus* butterfly living in isolation tend to look alike. In species living together, on the other hand, the males of each species look strikingly



NIKOLAI KANDUL

These photographs show pairs of chromosomes in four *Agrodiaetus* species. "Usually butterfly species from the same genus have very similar numbers of chromosomes," says Nikolai Kandul. "This group is fascinating because every species has a different number, and the range in number in the genus is huge." These differences in chromosome number probably drive speciation, says Kandul. The more a breeding pair differs in their number of chromosomes, the less successful their union will be.

different: their wings may be silver, brown, or blue. (All females are brown.) The males' divergent wing colors allow females, which breed only once, to identify a same-species mate and avoid producing hybrids through interbreeding. Natural selection acts through reinforcement against maladaptive hybrids and favors colorful wings as ways of distinguishing species. It promotes the evolution of differences between nascent species and thus speciation. Thus do those colorful wings drive a wedge between species.

~CHRISTOPHER REED

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NEW RELEASE: ASIA 4.0

Overseas Insourcing

Since the 1950s, the United States has led the world in science and technology, training an unrivaled pool of physicists, engineers, biologists, and chemists. Graduates from American universities have given the nation's industries an edge in the race for technological innovation and helped ensure U.S. dominance in the global economy.

But the country's leadership edge in science and technology is shrinking, according to a recent report by Ascherman professor of economics Richard B. Freeman, director of the Labor Studies Program at the National Bureau of Economic Research. Freeman spent the past three years investigating how a weak domestic job market in science and engineering, combined with the globalization of high-tech work, is affecting America's supply of scientists and engineers and, by extension, the U.S. economy. He documents a dramatic shift in the distribution of scientific capital—including specialists, skilled workers, and research facilities—away from America's shores toward newer high-tech centers in Europe and, more significantly, Asia.

Freeman believes this trend could soon threaten American technological competitiveness, especially as large developing countries like China and India harness their growing scientific and engineering expertise to their enormous, low-wage labor forces. The outsourcing of technical jobs, he warns, foreshadows the displacements American workers will likely face in coming years.

The source of America's vulnerability, Freeman argues, lies in numbers. In 1970 more than half of the world's science and engineering doctorates came from American universities, but now other countries have caught up. In 2001 the European Union (EU) granted 40 percent more science and engineering Ph.D.s than the United States, and by 2010 will produce nearly twice as many. China's gains are even more striking. In 1975 the number of Chinese doctorates was negligible; but by 2003, the country had graduated 13,000 Ph.D.s—70 percent of them in science and engineering. China is expected to surpass the United States in numbers of science and engineering doctorates by 2010. At the college level, statistics show a waning interest among U.S. students in science-related careers; in 2000, only 17 percent of all bachelor degrees in the United States were in natural sciences and engineering, compared to a world average of 27 percent and a Chinese average of 52 percent.