Says Steven Kivelson of the University of California, Los Angeles: "It's really deep, and it's really quantum mechanical."

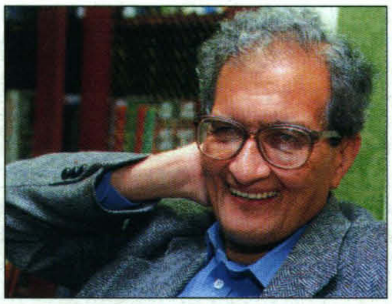
–JAMES GLANZ

Famine Survivor Wins Economics Prize

In 1943, despite a robust economy and an ample harvest, a famine engulfed the Indian state of Bengal and killed up to 3 million people. Last week, a child survivor of that disaster who went on to develop an economic explanation of how starvation could occur amid plenty won the Nobel Prize in economic sciences. In awarding the prize, the Royal Swedish Academy of Sciences cited 64-year-old Amartya Sen for his contributions to the field of welfare economics and for restoring "an ethical dimension to the discussion of vital economic problems."

Sen, who earned a doctorate from Cambridge University in 1959 and recently returned to its Trinity College to teach, has spent the past 3 decades on problems ranging from how government spending choices influence individuals to how researchers should best calculate poverty statistics. But he is perhaps best known for work that offered a fresh look at the economics of famine. Studies of disasters in India, Bangladesh, Ethiopia, and Saharan Africa led Sen in the 1970s to challenge the conventional view that famines are caused solely by food shortages. Instead, he showed that other factors—such as declining wages and rising food prices caused by bad weather or flawed government policies—influence the distribution of food and aggravate famine conditions for the poorest people. "Many past famines have been associated with high inflation, making the groups that fall behind in the inflationary race selected victims of starvation," he wrote in a 1996 paper for the journal *Development*.

"[Sen] achieved something very rare in economics," says a former student, economist Prasanta Pattanaik of the University of California, Riverside, who praised Sen's ability both to develop highly abstract theory and apply it to real world problems. In studying poverty, for example, Sen helped devise measures that do more than just show how many people fall below a nation's poverty line. The new indices, now in wide use, show how far below the line people fall and also identify social factors—such as poor health and limited education—that reduce economic mobility. The approach, described in dozens of books and papers, has provided policy-makers with useful information for devising solutions, including the knowledge that policies designed to help individuals just a few dollars below the line may do little for those deeper in poverty.



A caring science. Sen has added an "ethical dimension" to economic analysis.

Sen has "pushed people to think about poverty in much broader dimensions" and influenced international development policies, says economist Lyn Squire of the World Bank in Washington, D.C. In particular, he says, "the development community has moved away from looking at poverty with a narrow focus on income and [toward] ways to empower the poor to make choices."

The ethical implications of economic policy have long concerned Sen, who until recently held chairs in both economics and philosophy at Harvard University. "Economic analysis," he argued in a 1990 speech to Italy's Agnelli Foundation, "has something to contribute to substantive ethics in the world in which we live."

–DAVID MALAKOFF

NEUROSCIENCE

Researchers Go Natural in Visual Studies

Artificial stimuli are usually used to probe visual processing, but recent work with natural images is providing some surprising new insights

When you look out your living room window, chances are you will see a scene that's a lot more complex than bars of light or fields of moving dots. But those are the kinds of visual stimuli neuroscientists have used for decades to understand how the brain interprets the visual world. "The idea is that what you learn from these simple stimuli is going to generalize and tell you how [the visual system] would respond to a real scene," says neuroscientist Bruno Olshausen of the University of California (UC), Davis. "But that is just an assumption … that has never been tested"—until now, that is.

Within the past decade, a small cadre of neuroscientists has begun to determine how the visual system responds to "natural scenes," defined as images from the real world, whether they depict jungle foliage or a city street. The work is providing new insights into why visual neurons have evolved the properties they have, what controls the responses of individual neurons, and how our brains process the images we actually see. It turns out, for example, that when the visual system responds to complex natural scenes, interactions between neurons are much more important than had been previously known. Researchers also hope that natural scenes will help them understand the functions of some visual neurons whose activities until now have been a complete mystery.

Here's looking at you. Cats' visual neurons fire more efficiently when they look at movies like *Casablanca* than when exposed to visual "white noise" (*inset*).

Among the first neuroscientists to experiment with natural scenes were computer modelers, in part because it is easier to analyze a model's response to a complex scene than that of a real brain. In one striking example, Robert Barlow and his colleagues at the State University of New York Health Sciences Center in Syracuse used a computer model to ask how a horseshoe crab's eye responds to a

CREDITS: (TOP TO BOTTOM) R. DREW/AP; DAN ET AL., JOURNAL OF NEUROSCIENCE 16, 3351 (1996); ASSOCIATED PRESS PA natural scene. Neuroscientists have characterized the response properties of the crab's visual neurons in such fine detail that they can simulate every neuron in a computer model, and the model will process an image just as the animal's eye would.

Barlow and his colleagues gained a "crab's eye" view of the world by mounting little movie cameras on the shells of horseshoe crabs and recording what the animals saw while exploring their natural underwater environment at the Marine Biological Laboratory in Woods Hole, Massachusetts. They then fed the movie into their model to see how it would respond. One clear finding: Objects resembling potential mates sparked the most robust responses from the neurons. "The eye of this animal is tuned to best detect objects that are matelike in terms of size, contrast, and motion," Barlow says. "We would never have learned this had we not [recorded] what the animal sees in its natural habitat."

Other researchers have taken a different modeling approach to explore how the more advanced visual systems of mammals operate. This work began with an analysis of what sets natural images apart from artificial stimuli. Natural scenes tend to have smooth transitions in space and time. "If one point [in a natural image] is white," notes UC Berkeley neurophysiologist Yang Dan, "the next point will probably be white also. If there is a wall, the next moment the wall is still likely to be there." That regularity, which is true for all natural scenes, can be described mathematically. In contrast, artificial stimuli have more abrupt changes. In some cases, these are even random—the visual equivalent of white noise.

The regularity of natural scenes means that, as far as the brain is concerned, some of the information coming from them is redundant. Theorists, including Olshausen, David Field of Cornell University in Ithaca, New York, and Joseph Atick of Rockefeller University in New York City, have used computer models to predict the properties of visual neurons that would minimize this redundancy and encode information from a natural scene most efficiently. Their models have come up with neural properties like those of actual neurons in the visual system.

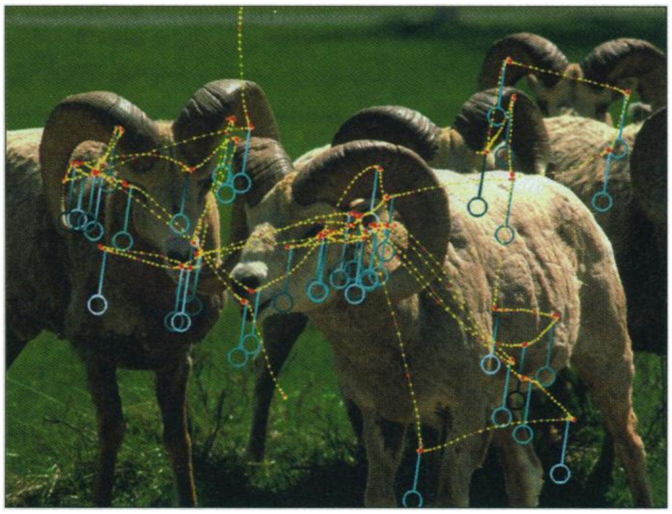
For example, in the late 1980s, Atick, then at the Institute for Advanced Study in Princeton, New Jersey, used information theory—a type of mathematical analysis used by communications engineers—to ask how early levels of the visual system might process natural scenes efficiently. The answer: The neurons could remove redundancy by converting the signal into one in which each element varies independently of the elements that precede or follow. In engineering parlance, such a signal is known as a "white" signal.

Atick then used a computer model to ask how neurons would whiten a signal. It predicted very closely the response properties of neurons in the retina and the lateral geniculate nucleus (LGN), the brain area that first receives visual signals before they enter the visual cortex. These properties cause the neurons to respond most strongly to contrast changes in either space or time and diminish their responses when there is no change in contrast.

In 1995 Dan, then a postdoc with Clay Reid at Rockefeller University, took the next step. She recorded directly the response of LGN neurons to natural scenes to see whether they do indeed whiten incoming visual signals as predicted by the model. Dan did her experiment on anesthetized cats whose eyes were trained on movies rented from a video store and found the expected randomness in the neurons' responses. "From the signal at any moment, you can't predict what is going to happen at the next moment," she says.

But did those responses depend on the characteristics of the natural scene, she wondered, or did the LGN neurons "just want to fire white?" To answer that question, she showed the animals visual white noise: checkerboard patterns that changed randomly from one moment to the next. The signal that came out was "definitely not white," she says. Rather than being unpredictable, the neuronal firing patterns were filled with negative correlations. "If at one moment there is a high firing rate," says Dan, "it is more likely that in the next moment you will have a low firing rate." That confirmed that LGN neurons don't simply whiten all the signals but transform them in a way that appears specialized to handle natural scenes.

Olshausen and Field did a computer-modeling analysis similar to Atick's for the primary visual cortex, the visual area that receives information from the LGN, and their model evolved response properties just like those of primary visual cortex neurons. Field and Olshausen haven't yet verified the results with actual recordings, but their results, along with Dan's and Atick's, indicate how neurons have evolved to process visual information efficiently. The work, says Olshausen, illustrates "the importance of considering what the system was designed to do" when trying to understand it. Or as neuroscientist Bill Geisler of the University of Texas, Austin, puts it: "If you want to understand the functioning of the visual system, it makes sense to look at its functioning in the environment in which it evolved."



Visual tracks. The yellow dots trace the eye movements of a monkey viewing a natural scene. The green circles show the patches of the image that fall in the receptive field of a neuron as the eye moves; the brightness of the circles reflects that neuron's activity.

CREDIT: JACK GALLANT/UC BERKELEY

Neuronal mysteries

Researchers hope to put that principle to work to learn more about some of the more complex properties of visual neurons that they've glimpsed but don't yet fully understand. One such property concerns how a neuron's responses might be altered by the activity of other neurons responding to different parts of the same visual scene. These neuronal interactions may be masked in traditional experiments, in which the animals' eyes are fixed at a point on the screen while stimuli are flashed within the small part of the visual scene surveyed by a particular neuron, known as its receptive field. In these experiments, areas that fall within most other neurons' receptive fields generally contain little information. Natural scenes, on the other hand, usually fill the eye's entire field of vision, so areas outside a neuron's receptive field are as crowded with visual information as those within. In addition, subjects freely viewing a complex natural scene flick their eyes from spot to spot, exposing each neuron to a procession of complex image patches.

Researchers knew that these differences would make neurons respond differently to natural scenes than to simple artificial stimuli. But it was not clear just how significant those differences would be, says UC Berkeley neurophysiologist Jack Gallant. Gallant's team has been exploring this question by showing a monkey a natural scene while recording from individual neurons in the animal's visual cortex.

Gallant's team creates "review" movies, which show the sequence of the scene's patches that fell in and around a neuron's receptive field as the animal looked around a natural scene. The team can play these movies back repeatedly to test the consistency of the neuron's responses. Their experiments already point to some intriguing effects that natural scenes have on the firing of individual neurons.

Gallant's team first characterized the responses of a neuron with gratings—a common form of artificial stimulus that looks somewhat like a small patch of corrugated tin roof—and then allowed the monkey to view a natural scene freely. Most of the neurons' responses to the natural scenes were muted compared to their responses to gratings. That was no big surprise, because previous work had shown that features that lie just outside a neuron's receptive field—and natural images are loaded with such information—tend to damp its response. The effect is thought to be caused by the activity of neurons that respond to those features. But additional work indicated that this neuronal interaction is more complicated than simple damping, says Gallant. Parts of the image outside a neuron's receptive field "are sculpting the responses of the neuron. They make the cell respond to fewer things, but the things it responds to, it responds to better." These effects are bigger than researchers had suspected from experiments with artificial stimuli, says Field. "Now that they seem to play a major role in the cell's activity," he adds, "we need a rigorous approach to actually finding out what they are doing."

Researchers hope that experiments with natural scenes will also help them solve the mystery of dormant neurons. "Periodically [you] record from cells that are just silent," says Field. Most often encountered in visual processing areas beyond the primary visual cortex, these inert neurons probably detect features or combinations of features that no one has thought of testing. Field and others hope that recording from the neurons while the animal views natural scenes will reveal features that make the neurons fire, providing clues to their normal roles. "If you use natural images, at least you are in a domain that the animal evolved to deal with," Gallant says.

Among those taking this approach are Dario Ringach and Robert Shapley at New York University. After finding neurons in the primary visual cortex of monkeys that didn't respond to any of the standard stimuli, Ringach tried movies. Where gratings and bars had failed, *Sleeper* and *Goldfinger* brought the neurons to life. "The most striking thing so far," says Shapley, is "that you can actually get responses from cells [that are silent] with the usual battery of tests." The finding means, he says, that you can check back to see what images were on the screen before, during, and after the moment when the neuron fired and look for patterns that may reveal what the neuron responds to.

The technique requires some intuition. For example, if a neuron seems to fire whenever there is red on the screen, Ringach reanalyzes the movie for when red is or isn't in view and checks whether there is any correlation with the neuron's firing.

But the associations may not be that simple: The neurons may be responding to combinations of features, and those combinations may be spread out in space or time. Such associations are unlikely to jump out at a human observer. "The real problem" says Ringach, is to use computer analysis to "tell what the cell is responding to without guessing." To scan all possible sets of events that might have triggered a neuron "isn't in principle impossible," says Shapley; "it just takes a lot of computing time."

Some neuroscientists, such as David Hubel of Harvard University, question whether the effort is worth it. Hubel, who received a Nobel Prize for his work using artificial stimuli to characterize visual neurons, argues that natural scenes are too complicated and too loosely defined to provide useful information about the mechanisms of vision. "It is all very well to say that there is something magic about a natural scene," he says, but it makes more sense to test the visual system instead with "more elaborate artificial scenes" that can be carefully designed and controlled.

"Nothing is magical about natural scenes," responds Gallant. "They are just another tool" to be used in addition to artificial stimuli, because they are useful in revealing adaptations our visual system has made to interpret the natural world. Eventually, Olshausen predicts, more neuroscientists are bound to find uses for this tool: "This is just the beginning. Five years from now, there will be entire sessions of the annual neuroscience meeting talking about natural images." —MARCIA BARINAGA

ECOLOGY

The Great DOE Land Rush?

The department is considering selling off land around its national labs that has been undisturbed for decades; these zones have become protected havens for wildlife and valuable locations for ecological research

Since its creation in 1948, Oak Ridge National Laboratory (ORNL) in Tennessee has buffered itself from civilization with a natural security system: a tract of wilderness covered with oak, hickory, and pine forests. Ecologists have had a field day in Oak Ridge's 14,000-hectare protected zone—home to peregrine falcons, cerulean warblers, and 18 other rare animal species—and in similar swaths of wilderness surrounding six other Department of Energy (DOE) national laboratories. These zones have yielded data on everything from biological invaders to soil carbon levels that inform the climate change debate. "This land is incredibly valuable," says ecologist James Ehleringer of the University of Utah, Salt Lake City.

But these ecological havens are fraying at the edges. As part of an effort to cope with post–Cold War budget cuts, DOE has been quietly divesting itself of wilderness parcels no longer deemed essential to safeguarding the nation's weapons labs. So far, three labs have given up more than 1200 hectares (ha) of buffer zone to local governments and the U.S. Bureau of Land Management, which in turn have sold much of this land to developers for house lots, landfills, and commercial construction. Another 5200 ha may soon be put on the auction block. Scientists acknowledge that they have been slow to take up the cause. "These are federal reservations, and many researchers consider them inviolate," says James MacMahon, an ecologist at Utah State University in Logan. "I don't think it's on anyone's radar."

But the deals are setting off alarms among environmental groups. The Nature Conservancy (TNC), for instance, plans to complete a biodiversity database this month that documents roughly 1500 species, including rare or endangered animals and plants, in ORNL's buffer zone. This and other grassroots efforts are gelling into a campaign to persuade DOE to set aside as much of the buffer zones as possible for wildlife and research. "DOE should take stock of what it has before making any decisions" on land use, says Curt Soper of TNC in Seattle.

The disputes involve lands originally valued for their emptiness. Early ecological studies done in the buffer zones tracked the fate of radioactive waste dumped or leaked by the secretive labs, says Steve Hildebrand, ORNL's environmental sciences director. Then in the 1950s, outside researchers began discovering the lands as valuable spots to study broad ecosystem questions. "Scien-