tractive" as a result of the changes wrought by *transformer*. Ferveur, who is now at the University of Paris at Orsay, is investigating those possibilities.

Other researchers are also interested in following up on the Greenspan group's work. It provides useful clues to researchers studying genes that affect courtship in fruit flies, says Barbara Taylor, who studies *fruitless* at Oregon State University. "It suggests a place [in the brain] to look for changes in *fruitless* that we might not have looked at [otherwise]," she says.

And what does it say about sexual orientation in higher animals, including humans? Greenspan cautions that care must be taken in drawing parallels to humans from studies of fruit flies. "There isn't a lot of indication that the organization of a fly brain is relevant to a noninsect brain," says Greenspan, so the details of the conversion to bisexuality in flies are probably not applicable to humans.

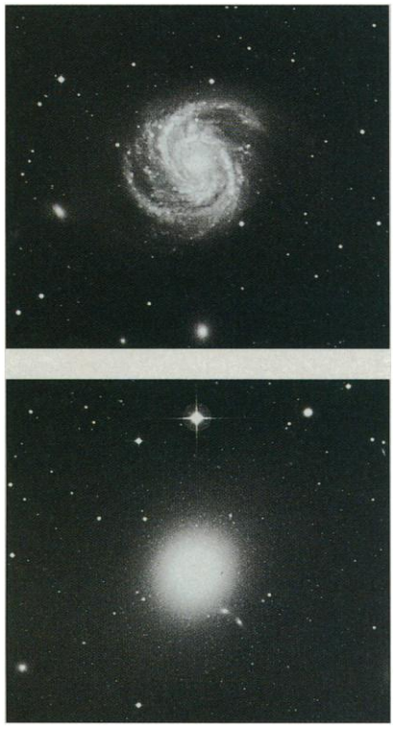
But, says Dean Hamer, a researcher at the National Institutes of Health who is searching for a gene linked to homosexuality, the fly study does support "the general principle that the brain is the locus of sexual behavior, and that the brain is wired differently in males and females, under a program of genetic control, and that variations in that [wiring] can cause variations in sexuality. We think that general rule holds in humans as well."

–Marcia Barinaga

ASTRONOMY

Galaxy Experts Train Electronic Stand-Ins

University of Alabama astronomer Ronald Buta does a job few of his colleagues in the field care to do. Like a naturalist classifying a butterfly collection, Buta pores over thousands of galaxies imaged in telescope surveys and assigns each one a number that indicates whether it is a spiral galaxy, an elliptical galaxy, or something in between. Perhaps fewer than a dozen scientists in the world are formally trained in this deceptively simple task, which Buta calls "very tedious and time-consuming." Still, he feels it's a vital job. "Buried in the morphology of galaxies is information about how they formed and how they evolved," he says. Now Buta and his fellow classifiers may be getting some help from electronic apprentices, as he and other astronomers report on page 859 of this issue of *Science*.



Shapely galaxies. Neural networks can learn to tell a spiral *(top)* from an elliptical.

PHOTOS BY ROYAL OBSERVATORY/PHOTO RESEARCHERS

Buta was one of "six hotshots who understand galaxy morphology," as another astronomer describes them, who were enlisted to teach their classification skills to the brain-inspired computer programs known as artificial neural networks. When these electronic pupils were then left free to classify galaxies on their own, the networks did their teachers proud. "A computer algorithm can replicate the expert [who trained it] as well as another expert can," says Ofer Lahav of the Institute of Astronomy in Cambridge, United Kingdom, who recruited Buta and the other classifiers for the unusual experiment.

The work reported in this issue isn't the only attempt to automate galaxy classification: Stephen Odewahn, a University of Minnesota astronomer, is leading a similar project in training neural networks, for example. That's all to the good, because Buta and other human classifiers will need all the help they can get to cope with the flood of data that's expected from efforts like the Sloan Digital Sky Survey, which by itself is expected to image more than a million galaxies. "We're going to be overwhelmed with data," says Lahav, who devised the networks with his colleagues Avi Naim, Laerte Sodre, and Michael Storrie-Lombardi.

If ways can be found to analyze such masses of information, it could be very valuable. Studies of galaxy morphology have hinted, for instance, that elliptical-shaped galaxies are more common in regions packed with other galaxies, suggesting that a region's density somehow influences galactic shape. And some astronomers peering back in time by looking into the far reaches of the universe wonder whether spiral galaxies were more prevalent early in cosmic history than they are now. But pursuing such questions means classifying a deluge of galaxy images. And as Odewahn puts it, "You can't get Harold Corwin [a co-author of the *Science* paper] to look at a half-million images. We need an automated way of extracting type."

In spite of this need, classifying the shape of galaxies might seem an unpromising target for automation, because it is more art than science. In 1936, the pioneering astronomer Edwin Hubble suggested a classification scheme that placed elliptical galaxies at one end of a sequence and spirals similar to the Milky Way at the other. Over the years, Hubble's scheme was refined to take into account characteristics including the size of a galaxy's central bulge and the dimensions of a spiral galaxy's arms. But exactly where a galaxy's shape fits in the scheme comes down to a matter of expert—and therefore subjective—judgment.

Fortunately for astronomers, neural networks are good at replicating human skills that can't easily be quantified, because instead of being rigidly programmed from the start, they learn from experience. The networks designed by Lahav and his colleagues classify each galaxy based on more than a dozen morphological features, but the weights they assign to each feature can change in the course of their training. Each galaxy expert trained a network on anywhere from 300 to 600 galaxy images by giving it the "correct" answer for each image. As the networks analyzed more and more images, they modified the weights assigned to each feature in order to produce answers as close as possible to the "correct" ones.

Once the training was finished, the researchers staged a competition between the electronic apprentices and their teachers. Each neural network classified 100 to 200 galaxies on its own, and its judgments were then compared with those of the expert who had trained it. The networks didn't exactly replicate their tutors' choices—but then again, the experts didn't always agree among themselves. In short, says Lahav, a neural network could match, say, Buta's classification of a galaxy as well as any other of the world's top classifiers could.

"There's still a role for the experts," says Buta, who notes that a neural network may fail to flag those galaxies with unusual features that, in the past, have proven so informative to astronomers. "Sometimes it's the exception to a rule that reveals the rule," he says. Still, Buta welcomes electronic apprentices for their speed and endurance. They "will provide a huge database on morphology that no human could find the time to do," he says. Adds Odewahn, "Edwin Hubble would have been doing it this way if he could have."

–John Travis