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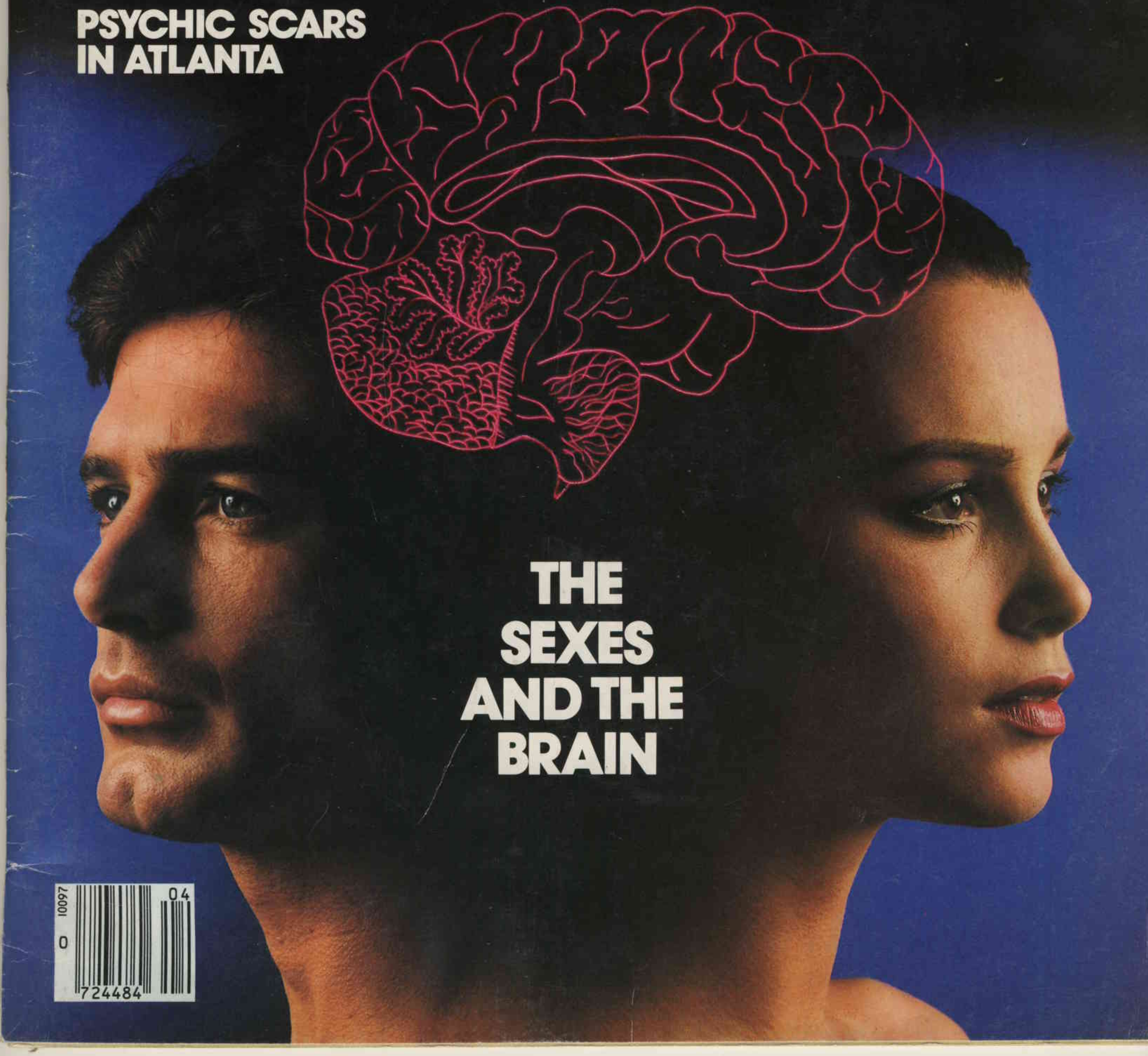
PSYCHIC SCARS IN ATLANTA



THE SEXES AND THE BRAIN

THE BRAIN: HIS AND HERS

Men and women think differently. Science is finding out why

by PAMELA WEINTRAUB

Are the brains of men and women different? If so, do men and women differ in abilities, talents, and deficiencies? A scientific answer to these questions could affect society and culture, and variously shock, intrigue, delight, depress, and reassure people of both sexes. Now an answer is coming into sight: Yes, male and female brains do differ.

That men and women think and behave differently is a widely held assumption. Generations of writers have lavished their attention on these differences, proclaiming, for example, that aggressiveness and promiscuity are natural to the male, that domesticity is the legacy of the female. Today's feminists acknowledge some differences, but hotly dispute the notion that they are innate. They stress that it is society, not nature, that gives men the drive to dominate and keeps women from achieving careers and power. But proof that behavioral and intellectual differences between the sexes are partly rooted in the structure of the brain, that women are inherently superior in some areas of endeavor and men in others would in no way undermine legitimate demands for social equality. Instead the result could be a better, more realistic relationship between the sexes.

A cross section of the brain seen from the front. It is composed largely of the cerebrum, which is covered by the cerebral cortex. Top: artist's view of male and female stereotypes

The evidence suggesting differences between male and female brains comes from research in behavior, biochemistry, anatomy, and neuropsychology. The most recent study deals with the long-established fact that skill in mathematics is far more common among men than women. Feminists—and many scientists—blame sexual stereotyping. But psychologists Camilla Benbow and Julian Stanley, at Johns Hopkins University, challenged that interpretation after testing 9,927 seventh and eighth graders with high IQs. As Benbow told DISCOVER reporter John Bucher, of the students who scored 500 or better on the math part of the Scholastic Aptitude Test, boys outnumbered girls by more than two to one. In other words, the psychologists argue, male superiority in math is so pronounced that, to some extent, it must be inborn.

This finding follows several recent studies proving that male and female brains, at least in animals, are physically different. From the hypothalamus, the center for sexual drive, to the cerebral cortex, the seat of thought, scientists have found consistent variations between the sexes. The causes of these differences, they say, are the sex hormones—the male androgens and female estrogens and progesterones that are secreted by the sex glands and carried through the blood stream to distant parts of the body, where they control everything from menstruation to the growth of facial hair.

Basic to all the studies of gender and the brain are the facts of sex determination. When a child is conceived, each parent contributes a sex chromosome, either an X or a Y (so-called for their shapes). When two X's combine, the fetus develops ovaries and becomes a girl. An X and a Y produce a boy; the Y chromosome makes a protein that coats the cells programmed to become ovaries, directing them to become testicles instead. The testicles then pump out two androgens, one that absorbs what would have become a uterus, and another, testosterone, that causes a penis to develop.

Though scientists have not yet been able to pinpoint any physiological differences between the brains of men and women, they think that the development of the brain parallels that of the genitals. If the fetus is a boy, they say, the testosterone that produces the penis also masculinizes tissue in the hypothalamus and other nearby structures deep within the brain. New data suggest that if the fetus is a girl, estrogen secreted by the ovaries feminizes brain tissue in the surrounding cerebral cortex. Scientists cannot dissect living human brains, but they have found ingenious ways to test their theories. The major approaches:

HUMAN BEHAVIOR

To shed light on the sexuality of the brain, endocrinologist Julianne Imperato-McGinley of Cornell Medical College in New York City studied 38 men in an isolated part of the Dominican Republic who, because of a genetic disorder, started life as girls. They stayed indoors playing with dolls and learning to cook while boys fought and shouted outside. At the age of eleven, when the breasts of normal girls began to enlarge, the children studied by Imperato-McGinley showed no change. But at twelve, most of them began to feel stirrings of sexual desire for girls. At puberty, their voices deepened, their testicles descended, and their clitorises enlarged to become penises.

These children came from a group of families carrying a rare mutant gene that deprived them of an enzyme needed to make testosterone work in the skin of their genitals. For this reason, their external genitals looked female at birth. But at puberty their bodies were able to use testosterone without the enzyme, and it became obvious that they were males—as chromosome tests confirmed. All but two are now living with women. They have male musculature and, although they cannot sire children, they can have sexual intercourse. They have assumed masculine roles in their society. "To the world," says Imperato-McGinley, "they looked like girls when they were younger. But their bodies were actually flooded with testosterone." She concludes that they were able to adjust easily because hidden in the girl's body was a male brain, virilized by testosterone before birth and activated by another rush of testosterone during adolescence.

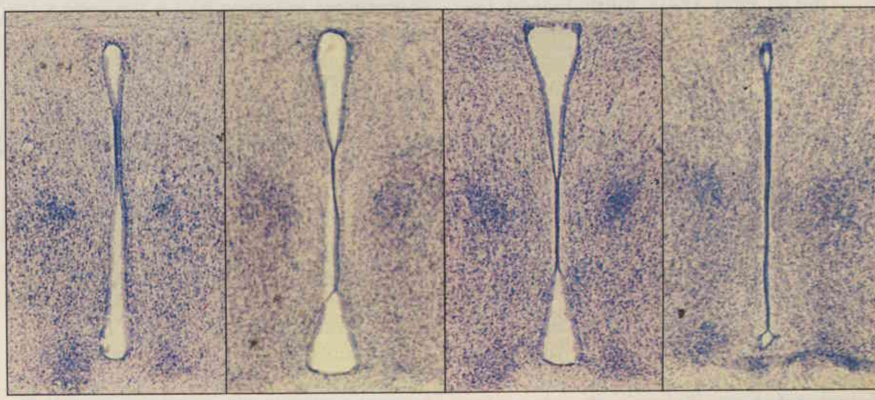
Although Imperato-McGinley suggests that brain structure determines behavior, another scientist thinks that the reverse may also be true: Anne Petersen, director of the Adolescent Laboratory at the Michael Reese Hospital and Medical Center in Chicago, says that cultural experiences can masculinize or feminize the brain. In a recent study, Petersen found that boys who excel in athletics also excel in spatial reasoning—a skill controlled by the right hemisphere of the cerebral cortex, and defined as the ability to understand maps and mazes or objects rotating in space. Says Petersen, "An athlete must be constantly aware of his own body and a whole constellation of other bodies in space." A daily game of basketball might, through some still mysterious mechanism, stimulate the secretion of hormones that prime a player's brain for success in basketball. The same brain structures would be used to deal with spatial problems. "Women are far less athletic than men," says Petersen, "and also less adept at spatial reasoning. Part of the problem may be their lack of involvement in sports. Perhaps some women just never develop the area of the brain specialized for spatial control."

Like Petersen, endocrinologist Anke Ehrhardt thinks that society plays an important part in shaping gender behavior. Nevertheless, she says, "certain types of sexual behavior are influenced by the sex hormones." Leafing through the clutter of papers and books that cover her desk at New York City's Columbia Presbyterian Medical Center, Ehrhardt cites cases of girls whose adrenal glands, because of an enzyme defect, produced abnormally large amounts of androgens while they were still in the womb. "We find that they are extremely tomboyish," she says. "They are career oriented, and spend little time with dolls. And we've just learned that boys exposed before birth to drugs that contain high doses of feminizing hormones engage in less roughhousing than other boys."

ANIMAL BEHAVIOR

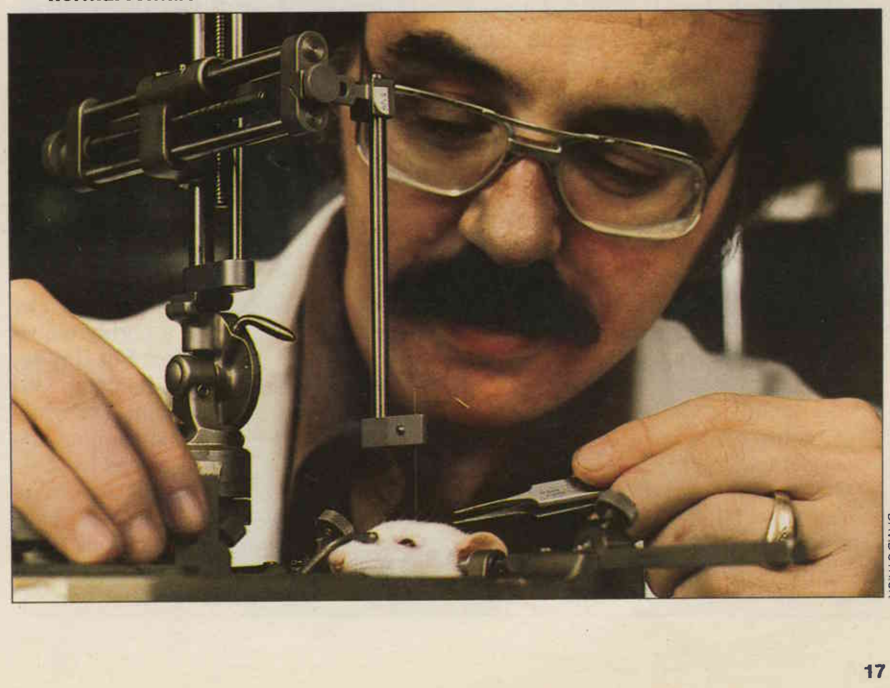
Ehrhardt admits that labeling the pursuit of a career masculine and playing with dolls feminine seems like stereotyping. To substantiate her evidence, she has compared her results with those obtained from studies of animals, whose gender behavior is rigid and easily defined.

Animal physiologists first made the connection between hormones and behavior in 1849, when the German scientist Arnold Berthold castrated roosters and found that they stopped fighting with other roosters and lost interest in attracting hens. When he transplanted the testicles into the abdominal cavities of the castrated birds, the roosters became aggressive again. Observing that the transplanted testicles did not devel-



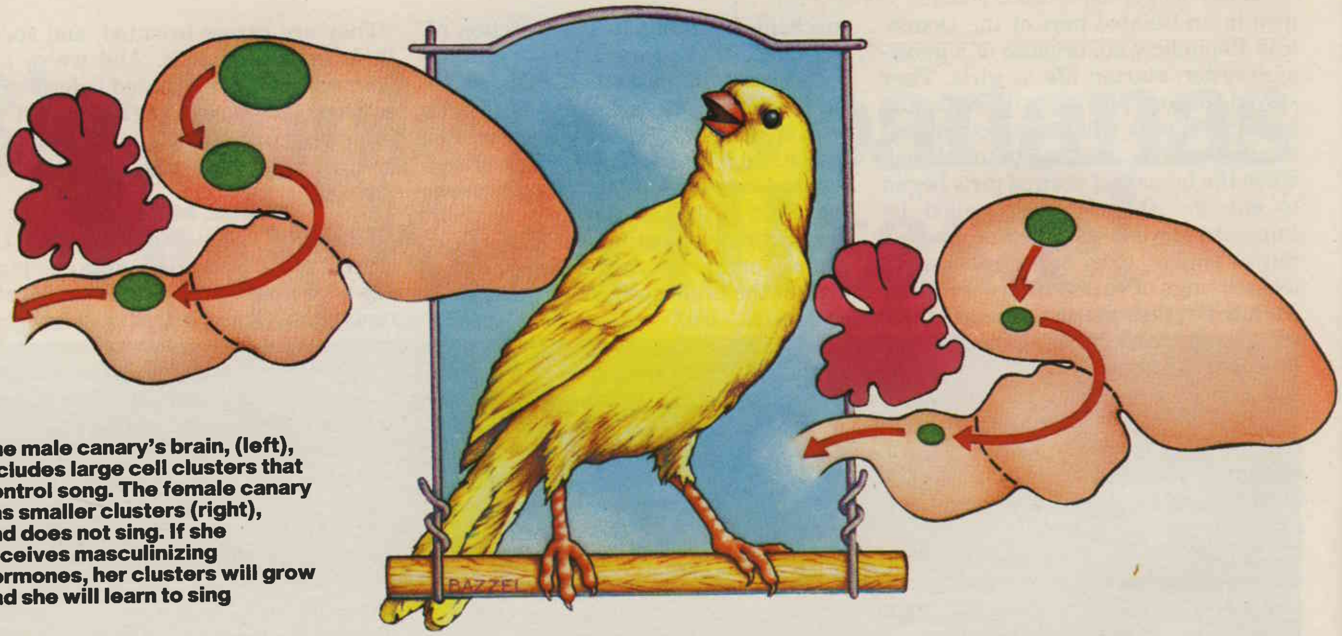
ROGER GORSKI

normal female **normal male** **masculinized female** **castrated male**



DAVID STRICK

U.C.L.A.'s Roger Gorski injects hormones into the brain of a rat. Above are slides of cell clusters in the hypothalamus of the rat brain. Endocrinologist Gorski has found that he can change the size of the cluster by administering hormones to the rat soon after birth



The male canary's brain, (left), includes large cell clusters that control song. The female canary has smaller clusters (right), and does not sing. If she receives masculinizing hormones, her clusters will grow and she will learn to sing

op connections with the rooster's nervous system but did develop connections with its circulatory system, he speculated that their influence on behavior came from a blood-borne substance, which was later identified as a hormone.

In 1916, Frank Lillie, a Canadian physiologist, noticed that the freemartin, a genetically female (X-X) cow that looks and acts like a male, always had a male twin. He speculated that the freemartin's gonads were masculinized in the womb by hormones secreted by the testicles of the twin.

Fascinated by this finding, scientists began using testosterone to make "freemartin" guinea pigs, rats, monkeys, and dogs. This set the stage for the landmark experiment conducted at the University of Kansas in 1959 by physiologists William Young and Robert Goy.

"We injected pregnant guinea pigs with huge amounts of testosterone," explains Goy. "This produced a brood of offspring in which those that were genetically female had male genitalia as well as ovaries." When the females were 90 days old, the researchers removed their ovaries and injected some of them with still more testosterone. The injected females began to act like males, mounting other females and trying to dominate the group. Says Goy, "We realized that we had changed the sex of the guinea pig's brain."

The researchers concluded that hormones affect behavior in two ways. Before birth, hormones imprint a code on the brain, "just as light can stamp an image on film," Goy says. "Later, throughout life, other hormones activate the code, much as a developer brings out an image on film. Whether the animal behaves like a male or a female depends on the code."

Goy has spent the past two decades proving that theory for a whole range of species, including the rhesus monkey. Now at the Primate Research Center at the University of Wisconsin in Madison, he has found that masculinized monkeys display sexual behavior that ranges from female to male in direct proportion to the amount of testosterone they are given while in the womb and throughout life. "It doesn't much matter whether it's rough-and-tumble play, mounting peers, or attempting to dominate the group," he says. "It's all related to the duration of treatment."

Perhaps more important, Goy has found that by varying the treatment he can produce monkeys that are physically female but behave like males. This is proof, he says, "that these animals behave like boys because of masculinizing hormones, not because of a male appearance that causes the other animals to treat them like boys."

Like the human brain, the brain of the rhesus monkey has a highly elaborate and convoluted cortex. But Goy believes that monkeys can be compared with people only up to a point. For while primitive drives may be similar, he says, human beings are guided by their culture to a greater degree than monkeys. "Nevertheless," he adds, "there are instances when people seem to be less bound by culture. Then they begin to look very much like our monkeys."

BIOCHEMISTRY

Other scientists have substantiated this evidence with hard biochemical data. To learn where sex hormones operate, neurobiologist Donald Pfaff of New York City's Rockefeller University injected various animals with radioactive hormones and removed their brains. He cut each brain into paper-thin sections, then placed each section on film sensitive to radioactivity. He thus made maps showing that the hormones collected at specific places, now called receptor sites, similarly located in the brains of species ranging from fish to rats to the rhesus monkey.

The primary site for hormone action, Pfaff saw, was the hypothalamus, a primitive structure at the base of the brain stem. That made sense, because the hypothalamus is the center for sex drive and copulatory behavior. "But the most intriguing thing," says Pfaff, "may be the receptors found in the amygdala [a part of the brain above each ear]. During the 1960s, surgeons found that when they destroyed the amygdala, patients with fits of aggression became completely passive. So we now suspect that sex hormones may control aggression, even fear." Neurologist Bruce McEwen, also of Rockefeller, recently found estrogen receptors in the cerebral cortex of the rat—receptors that disappear three weeks after birth. The cortex controls thought and cognition, but McEwen does not know the significance of these receptors.

The receptors are located at the same sites in both sexes, but because each sex has its own characteristic mix of hormones, male and female brains function differently. To unravel the secret of hormone operation, McEwen has been analyzing the chemistry of the rat brain. He has discovered that receptor sites are hormone-specific; a testosterone site, for example, is insensitive to estrogen. Perhaps more important, he has learned that once hormones pair up with receptors, they mold the structure of the brain by directing nerve cells to manufacture proteins. Early in life, the proteins build nerve cells, creating permanent structures that may exist in the brain of one sex but not the other. Later in life, the proteins produce the chemicals that enable one nerve cell to communicate with another, and precipitate various kinds of sexual behavior.

McEwen and Pfaff have not dissected human brains, but they feel justified in applying some of their findings to people. For, as Pfaff explains, evolution is a conservationist. "As new species evolved, nature didn't throw away old parts of the brain," he says. "Rather, new systems were added. Everyone has a fish brain deep inside. Outside the fish brain there is a reptilian brain, depressingly similar to the way it would look in a lizard. Wrapped around the reptilian brain there is a mammalian brain, and then, finally, the cerebral cortex in such animals as monkeys and human beings." McEwen thinks that the receptors in the hypothalamus probably have similar effects in people and rats. "The difference," he says, "is that human beings can override their primitive drives with nerve impulses from the powerful cerebral cortex."

ANATOMY

Anatomical evidence that sex hormones change the structure of the brain came recently from Roger Gorski, a neuroendocrinologist at the University of California at Los Angeles. Examining the hypothalamus in rats, he found a large cluster of nerve cells in the males and a small cluster in females. By giving a female testosterone shortly after birth, he created a large cluster of cells in her hypothalamus that resembled that in the male. If he castrated a male after birth, its cell cluster shrank. Gorski has no idea what the cell structure signifies, but he does know that it varies with changes in sexual behavior.

The anatomical differences do not stop there. Fernando Nottebohm, of Rockefeller, has discovered a large brain-cell cluster in the male canary and a small one in the female. These cells are not in the spinal cord or the hypothalamus but in the forebrain—the songbird equivalent of the cerebral cortex, the part that controls thought and cognition.

The function that Nottebohm studied was song. Only the male songbird can sing, and the more intricate the song the more females he attracts. That takes brainwork, says Nottebohm. "The canary puts songs together just as the artist creates. A large collection of syllables can be combined in infinite ways to form a repertoire in which each song is unique."

Until Nottebohm discovered the large cluster of male brain cells that control the muscles of the syrinx, the singing organ, he had assumed that male and female brains were anatomically identical. He found that if he gave female canaries testosterone before they hatched and again during adulthood, they could learn to sing. When he studied the brains of the singing females, he found that their cell clusters had grown. Says Nottebohm, "The intriguing thing is that the size of the repertoire was more or less proportional to the size of the cell clusters."

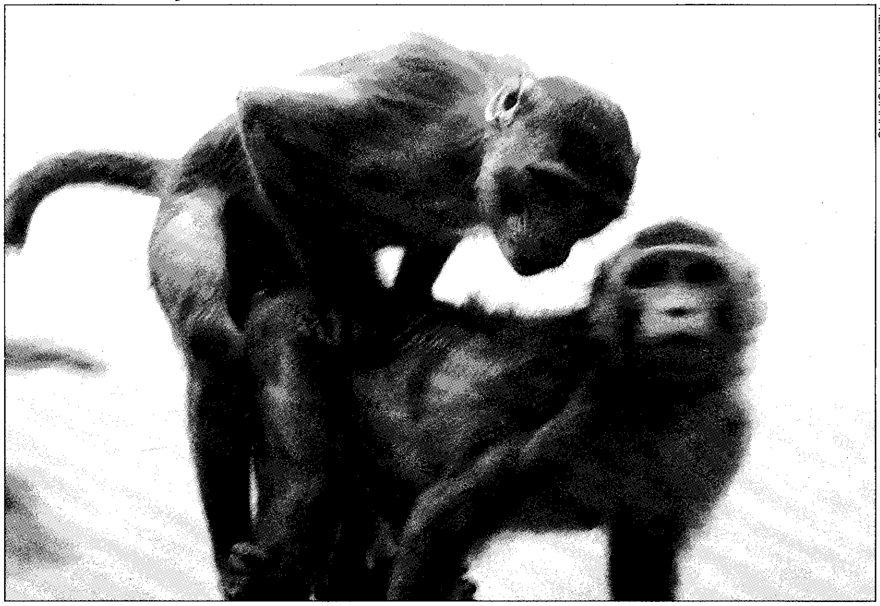
Scientists studying mammals have also discovered anatomical differences between the sexes in the thinking part of the brain—in this case, the cerebral cortex of the rat. Marian Diamond, of the University of California at Berkeley, discovered that in the male rat the right hemisphere of the cortex was thicker than the left—and that in the female the left was thicker than the right. But if she castrated the male rat at birth or removed the ovaries from the female, she could alter the pattern. Administering female hormones to males and male hormones to females also affected the width of the cortex. Says Diamond, "Hormones present during pregnancy, hormones present in the birth-control pill, all affect the dimensions of the cortex."

Jerre Levy, a neuropsychologist at the University of Chicago, is encouraged by Diamond's findings because they provide strong anatomical evidence for her theory: the cortex is different in men and women, largely because of hormones that early in life alter the organization of the two hemispheres.

Levy is responsible for much of what is known about the human brain's laterality—the separation of the roles performed by the right and left hemispheres. Levy began her work in this field in the 1960s, when she was studying "split brain" patients, epileptics whose hemispheres had been surgically separated as a means of controlling violent seizures. The researchers found that the hemispheres could operate independently of each other, somewhat like two minds in a single head. The right hemisphere specialized in the perception of spatial relationships, like those in mazes and solid geometry, and the left controlled language and rote memory.

Levy has found that these abilities vary with gender. In test after test, men excelled in spatial reasoning and women did better with language. Fascinated by the discrepancy, she decided to test laterality in normal people and based

A female monkey treated with testosterone mounts a male


ALEXANDER TSIARAS

her experiments on a well known fact: light and sound perceived by the eye and ear on one side of the head travel to the hemisphere on the other side for processing.

She discovered that the right ear and eye are more sensitive in women, the left in men. She concluded that the right hemisphere dominates the masculine brain, and the left the feminine.

Levy points to the work of neuropsychologist Deborah Waber, of Harvard Medical School, who found that children reaching puberty earlier than normal have brains that are less lateralized—that is, their left and right hemispheres seem to share more tasks. Because girls generally reach puberty two years before boys, these findings have caused speculation that the bundle of nerve connections, the corpus callosum, between the two hemispheres of the female brain have less time to lateralize, or draw apart, during puberty. If that is true, says Levy, it could help to explain female intuition, as well as male superiority in mechanics and math. The two intimately connected hemispheres of the female brain would communicate more rapidly—an advantage in integrating all the detail and nuance in an intricate situation, but according to Levy a disadvantage "when it comes to homing in on just a few relevant details." With less interference from the left hemisphere, Levy says, a man could "use his right hemisphere more precisely in deciphering a map or finding a three-dimensional object in a two-dimensional representation."

All this brings Levy back to hormones. She thinks that the estrogen that changes the size of the cortex in Marian Diamond's rats may also change the size and organization of the human cortex. Her new tests are designed to study the organization of the cerebral cortex in people with hormonal abnormalities—girls who produce an excess of androgen and boys who are exposed to large amounts of estrogen before birth.

Levy has ambitious plans for future research, including scans of living brains and tests of babies whose mothers have undergone stress during pregnancy. Much remains to be done, for though the existence of physical differences between male and female brains now seems beyond dispute, the consequences are unclear. Talent in math, for example, is obviously not confined to men, nor talent in languages to women; the subtleties seem infinite. Already the new findings promise to color the modern view of the world. But the implications can easily be misconstrued.

Gunther Dörner, an East German hormone researcher, has claimed that he can put an end to male homosexuality by injecting pregnant women with testosterone. Dörner bases his theory on studies done by two American researchers, who subjected pregnant rats to stress by confining them in small cages under bright lights. They found that the rats' male offspring had low levels of testosterone during certain critical periods, and exhibited homosexual behavior. Dörner concluded that stress on pregnant females alters sexual preference patterns in the brains of their male offspring, and that this finding applies to human beings as well. His suggested antidote: testosterone.

His conclusions appall the American researchers, who agree that mothers under stress produce male offspring with abnormal behavior, but argue that Dörner has gone too far. Dörner's work is supported by the East German government, which is notorious in its aversion to homosexuality, and American scientists fear that he may get a chance to put his ideas into practice on human beings.

Another example of misinterpretation is the article that appeared in *Commentary* magazine in December, citing the "latest" in brain research as an argument against equal rights for women. This angers Anne Petersen. "A lot of people have been making a lot of political hoopla about our work," she says. "They've used it to say that the women's movement will fail, that women are inherently unequal. Our research shows nothing of this sort, of course. There are things that men do better, and things that women do better. It's very important to differentiate between the inferences and the scientific findings."


THOMAS ENGLAND

Jerre Levy holds a model of the human brain

These findings could influence fields ranging from philosophy, psychiatry, and the arts to education, law, and medicine. If women are indeed at a disadvantage in mastering math, there could be different methods of teaching, or acceptance of the fact that math is not important for certain jobs. For example, tests of mathematical competence have been used as criteria for admission to law school, where math is barely used; tests of spatial ability have been used to screen people for all types of nontechnical pursuits. If scientists can prove that such tests discriminate unnecessarily against women, hiring policies could be changed. Eventually, psychiatrists and lawyers may have to assess their male and female clients in a new light. And brain surgeons may have to consider the sex of a patient before operating. For if the two hemispheres of the brain are more intimately connected in women than in men, then women may be able to control a function like speech with either hemisphere. Surgeons could feel confident that a woman would recover the ability to talk, even if her normal speech center were destroyed; they might proceed with an operation that they would hesitate to perform on a man.

Investigators have made amazing progress in their work on the sexes and the brain, but they have really just begun. They will have to link hundreds of findings from widely diverse areas of brain science before they can provide a complete explanation for the shared, but different, humanity of men and women. ■