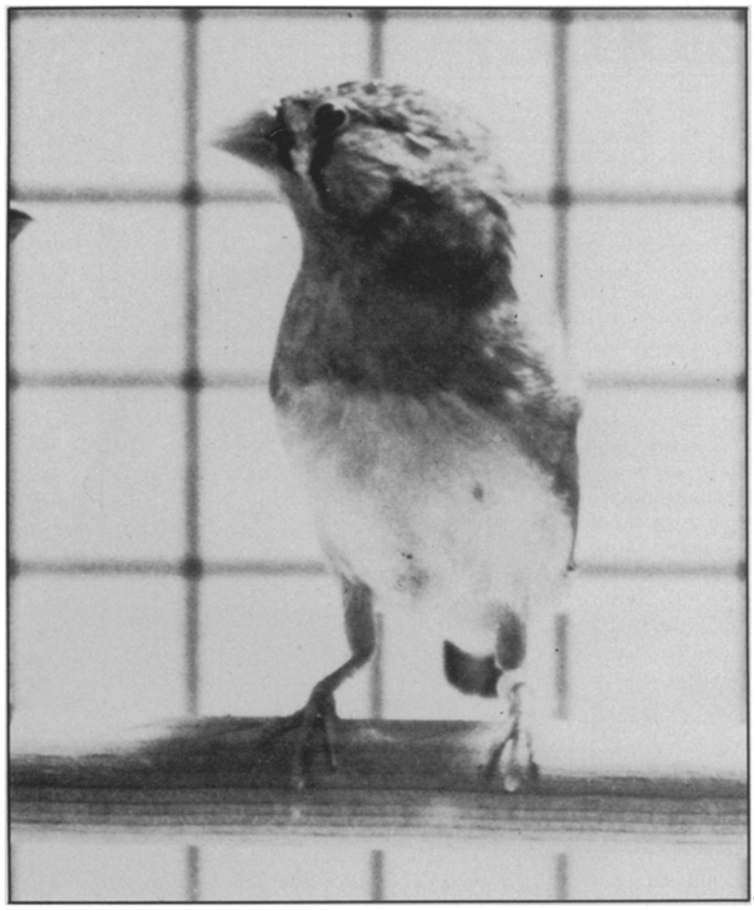
A SONG FOR THE FEMALE FINCH

Hormone treatments at two stages of life alter development of the song regions in a bird's brain and allow the female bird to sing like a male

BY JULIE ANN MILLER



Gurney

With erect posture and fluffed feathers, hormone-treated female courts and sings.

No melody pours forth from the female zebra finch to answer her mate's soft song. Sexual differentiation, it seems, conspires to make her songless. Not only does she have a smaller sound-producing organ and lack the hormones that trigger the male's sweet, simple tune, but she also is short of the specific brain cells that direct the song's rendition.

The brains of zebra finches are among the best examples currently available to link behavioral and anatomical sex differences. The male birds, but not the females, sing a short, rather quiet courtship song accompanied by feather erection and other stereotyped behaviors. Several interconnected brain areas known to be involved in the control of song (SN: 8/7/76, p. 94) are dramatically and consistently larger in the males than in females, Fernando Nottebohm and Arthur P. Arnold at Rockefeller University have shown. Investigators, convinced of sex differences in bird brain organization, are now seeking the developmental events responsible for shaping the features characteristic of each sex.

Hormones at two stages of the bird's development participate in a zebra finch's song capabilities, Mark Gurney of California Institute of Technology reported at the recent meeting in Atlanta of the Society for Neuroscience. Earlier work by Arnold had shown that male sex hormones (androgens) can reinstate singing and other sexual behaviors in castrated males. But females do not sing even when injected with androgens. This difference suggests that although the adult bird needs androgens to produce a song, some event earlier in development already has distinguished the males from the females.

One turning point in song system development comes at about the time of hatching, Gurney and Mark Konishi found. They implanted pellets containing hormones into newly hatched zebra finch chicks. The hormones had no effect on the song system of the male birds, but they did alter the development of those brain areas in the female bird. In two brain areas, one called the nucleus robustus archistriatalis (RA) and the other the caudal nucleus of the hyperstriatum ventrale (HVc), the male sex hormone metabolite dihydrotestosterone increases the volumes somewhat, and the female sex hormone estradiol increases them dramatically over the volumes in untreated females. Testosterone normally produced in a male bird probably acts both as dihydrotestosterone and as estradiol.

The time at which these brain areas are sensitive to estradiol is limited. Estradiol implanted in female adults has no effect on the anatomy of those brain areas, Gurney reports.

Still, there is more to the zebra finch song than early exposure to hormone. Although females given hormones at hatching develop enlarged song centers in the brain, they remain songless. Gurney and Konishi suspected that such females, like castrated males, might need a dose of male sex hormone to produce a song. The scientists implanted pellets containing androgen into adult females that had received estradiol at hatching. Isolated in a soundproof chamber, each bird soon began to warble an unstable song. After five days of hormone treatment, the distinct song elements developed and within a month the female was singing a highly stereotyped song. "The song quality, its tempo, structure and elements, are as good as a male adult's," Gurney says. Those female birds also display distinctly male courtship behavior.

These behavior changes are clearly reflected in the bird's brain. The same song areas that were dramatically enlarged by estradiol were enlarged further by adult exposure to androgen. The final volume in the RA, for instance, was more than 7 times that of an untreated female, more than 1.5 times that of a female only treated with estradiol at hatching and approximately the same volume as in an adult male. In female birds not exposed to estradiol at hatching, testosterone did not induce the anatomical changes in the RA or HVc regions nor did it prompt the birds to sing. "The estrogen renders HVc [and RA] competent to respond to androgen in adulthood," Gurney says.

Gurney and Konishi are now more closely examining how the hormones affect the volumes of the brain areas. They have evidence that each hormone controls a separate developmental event; estradiol influences the size of the cells and testosterone influences the number. They are also looking at hormonal effects on the architecture of the brain cells.

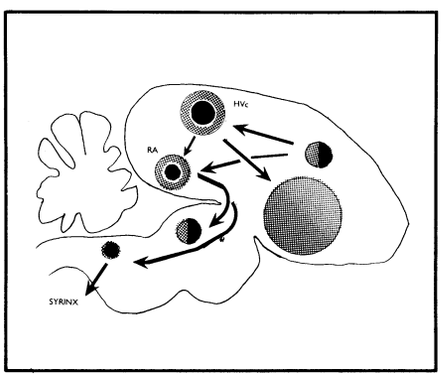
Support for the idea that sensitivity to androgens is an important aspect of sexual differentiation comes also from the work of Arnold, now at the University of California at Los Angeles. Arnold finds that nerve cells in many of the song-control regions accumulate the hormone testosterone or its metabolites. Because accumulation of a hormone is considered a prerequisite for many of its effects, Arnold believes androgens act at many levels in the male zebra finch brain to shape singing behavior.

Sex difference in number and size of hormone target cells was described by Arnold and Albert Saltiel in the Aug. 17 SCIENCE. In some areas of zebra finch brain, such as HVc, a greater proportion of the cells accumulate testosterone in males than in females. In RA, no difference is observed in the number of target cells, but the cells in males that accumulate testosterone are larger than those in females. Therefore, by adulthood the zebra finch sexes differ in several ways in the brain cells that can respond to sex hormones.

The workings of the song-controlling brain regions have been explored further by Arnold. With a microelectrode, he can electrically stimulate cells in the RA or HVc and measure a response in the muscles of the syrinx, the organ responsible for bird sound production. Even though song areas in the female brain are smaller and may look different than those of the male, at least for one area the wiring seems to be the same between the sexes. Arnold finds that stimulation of the female HVc, like that of the male, can produce muscle contractions in the syrinx. But some sex difference remains — the level and duration of the electrical stimulation required to produce a muscle response is generally greater in females.

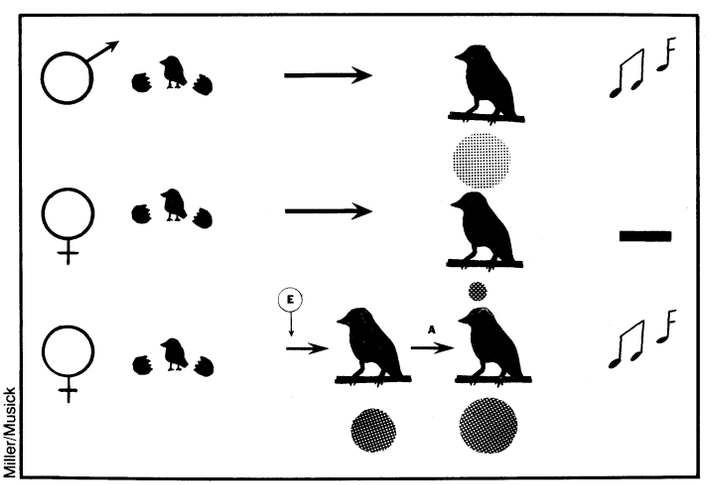
By using specific staining and marking techniques, Arnold and colleagues also are identifying microscopically the cells involved in sexual differentiation. So far they have found a sexual difference in the topographical distribution of two chemicals — the enzyme that breaks down the neurotransmitter acetylcholine and the catecholamines thought to be neurotransmitters in the brain.

The recent findings by Arnold, Gurney and Konishi add strong support for a model set forth 20 years ago. The "organizational hypothesis" says that the neural circuits underlying sexual behaviors are permanently arranged by hormones in the newborn. Now the evidence is clear that there are sex differences in aspects of neural organization, and the scientists have begun to identify the developmental events that lead to such differences as those that underlie the male zebra finch's exclusive song. □



after Arnold

Several of the brain regions believed to control bird song are larger in the male's brain than in the female's. The black disks represent the relative size of the female regions; the shaded disks represent male's. No size determinations have been made on areas shown by half disks and the largest song region in the male brain, called area X, cannot be seen at all in the female brain.



Miller/Musick

Male birds sing, females do not. But females treated with estradiol just after hatching and with androgen at adulthood do sing and exhibit other male behavior. The shaded disks represent the relative size of one brain region involved in song production.

. . . Agent Orange

identify health effects from the controversial herbicide are planned or underway. For instance, a General Accounting Office study released last month says that the Air Force is developing a health-effects study of its servicemen who participated in the aerial spraying of Agent Orange as part of operation "Ranch Hand" in Vietnam. The GAO report adds that the Veterans Administration is also working up a list of veterans who have been treated for herbicide-related problems; as of last September, it had identified 4,800 who had requested such treatment. Those listed will eventually be asked to visit a VA facility to undergo a physical exam, and then be re-examined once a year for the next five.

In its report, "U.S. Ground Troops in South Vietnam Were in Areas Sprayed With Herbicide Orange," the GAO found that contrary to statements issued by the Defense Department, military personnel did enter regions within the first four to six weeks after they had been sprayed. In fact, the report found that between 1966 and 1969, an estimated 16,100 marines were assigned to units that came close to or into regions that had been sprayed with Agent Orange no more than four weeks earlier — 5,900 troops were there on the day of spraying. Although Army troops undoubtedly were exposed also, records are too disorganized and incomplete to ever track down the number, much less the names of those involved, the GAO study found. However, "names and last-known addresses of marines assigned to units close to herbicide orange spraying can be obtained from Marine Corps records," says GAO. Unfortunately, complains Lewis Golinker, a staff attorney for the National Veterans Law Center in Washington, to date that simply has not been done.

Between 1965 and 1970, the Defense Department sprayed 10.65 million gallons of Agent Orange — roughly a 50:50 mix of two potent herbicides, 2,4-D and 2,4,5-T (SN: 3/17/79, p. 166) — in Vietnam. While civilian use of 2,4,5-T is normally restricted to application of one to four pounds of the chemical per acre, undiluted Agent Orange sprays in Vietnam deposited an average 13.8 lbs of 2,4,5-T per acre.

Since 1977 there have been nearly 1,000 health claims registered by veterans who suspect that they suffer illnesses caused by exposure to Agent Orange. But a lack of strong supporting evidence linking the chemical to human-health effects has limited the ability of claimants to win compensation. In fact, the "VA has allowed no compensation claims based solely on herbicide exposure in Vietnam," the GAO says. And it adds that DOD still views Agent Orange as "relatively nontoxic."

The nation's five Agent Orange manufacturers, threatened with a class action suit representing more than 2,000 servicemen, have themselves filed suit against the government claiming the chemical was misused. □