reinforcing stimulus for the establishment and maintenance of an instrumentally conditioned lever-pressing response. It is also clear that instrumental behavior maintained under these conditions is sensitive to changes in so-called "drive" states, and that it can be brought under the control of both discriminable exteroceptive stimulus conditions and reinforcement schedule contingencies. Future exploitation of this technique will permit an experimental analysis of the reinforcing properties of many pharmacologic agents under varying conditions of behavioral control.

ROBERT CLARK
CHARLES R. SCHUSTER
JOSEPH V. BRADY
Walter Reed Army Institute of Research, Washington, D.C., and *Laboratory of Psychopharmacology, University of Maryland, College Park*

Reference

1. R. M. Chambers, *Am. Psychologist* **9**, 346 (1954); H. W. Coppock and R. M. Chambers, *J. Comp. and Physiol. Psychol.* **47**, 355 (1954); H. W. Coppock, C. P. Headlee, W. R. Hood, *Am. Psychologist* **8**, 337 (1953); J. Olds and M. E. Olds, *Science* **127**, 1175 (1958).

25 January 1961

Suppression of Male Characteristics of Mosquitoes by Thermal Means

Abstract. Dimorphism in *Aedes stimulans*, a northern floodwater mosquito, may be decreased possibly to obliteration by exposing larvae for most of their lives to abnormally high temperature. Determiners for maleness fail to express themselves when larvae are exposed to a temperature of 29°C throughout their lives. Not only are male characteristics eliminated, but normal female ones such as ovaries, spermathecae, and cerci develop. The resultant adult is structurally a female. Forms showing characteristics of both sexes occur when the number of days of exposure to 29°C is lessened.

The sexes of mosquitoes differ in appearance in a number of easily recognizable ways, as has been well summarized by Snodgrass (*1*). Anteriorly, the appendages of the head are distinctive for each sex. The antennae and palpi of males are strikingly more hirsute than their counterparts in females. On the other hand, mouth parts are reduced from the female complement of seven to two functional appendages. Caudally, the male has an elaborate set of copulatory appendages, while the female has none. A pair of flaplike cerci marks the caudal portion of the female externally. Internally, the males have testes, vasa deferentia, seminal vesicles, and a bilobed accessory gland. The female has ovaries, oviducts, spermathecae, and a small saclike accessory gland. Significant changes in these structures have been brought about by treating larvae to abnormally high temperature (*2*).

Table 1. Effect of high-rearing temperature on sexual characteristics of genetically intended males of *Aedes stimulans* in the laboratory. M and F, normal male and female; a.m. and a.f., abnormal male and female; +, present; −, absent.

Imaginal parts	Sex at serial-rearing temperatures of 24° and 29°C						
Days at 24°C:	8	5	4	3	2	1	0
Days at 29°C:	0	3	4	5	6	7	8
Internal parts							
Gonads	M	M	M	M	F	F	F
Tubes to gonads	M	M	M	M	M,F	F	F
Sperms	+	+	+	−	−	−	−
Spermathecae	−	−	−	−	+,−	+	+
Accessory gland	M	M	M	M	M,F	F	F
Caudal parts							
Parameres	M	M	M	a.m.	a.m.	−	−
Phallosome	M	M	M	M	−	−	−
Genitalia position	M	a.m.	a.m.	a.m.	F	F	F
Cerci	−	−	−	a.f.	F	F	F
Cephalic parts							
Antennae	M	M	M	F	F	F	F
Palpi	M	M	a.m.	a.m.	a.m.	a.m.	a.f.
Mouth parts	M	M	M	F	F	F	F

Mosquitoes showing external characteristics of both sexes have been collected in different parts of the world. Such anomalies, called intersexes by Kitzmiller (*3*), number less than 40. Most of them have come from northern latitudes, and in some instances two or more individuals have been collected from the same vicinity at approximately the same time. The facts of location and repetitive occurrence suggest possible genetic or environmental causes for the anomalies. Unfortunately, specimens have been collected so infrequently that little more can be inferred.

Aedes stimulans, a snow-pool mosquito common to Canada and northern latitudes of conterminous United States, has been induced to express marked intersexual tendencies under laboratory conditions. The two sides of the responding genetic males are affected alike, and no unilateral responses have been elicited. When a uniformly mixed population of larvae (Table 1) is separated into two lots immediately after hatching and is exposed in one instance to a continuous temperature of 24°C and in another to one of 29°C, marked differences between the resulting males always occur. Genetically intended males from larvae reared at 24°C develop antennae, palpi, mouth parts, external genitalia, accessory glands, seminal vesicles, vasa deferentia, and testes that are normal in appearance and function. Larvae of genetically intended males when reared at 29°C without exception are like females in all respects except for slight differences in palpi. Internally, the anomalous males have ovaries, oviducts, and spermathecae, and they lack testes, vasa deferentia, seminal vesicles, and bilobed accessory glands. The ovaries have globular egg chambers indistinguishable from those of young genetic females (see *4*).

Abnormally high temperature exerts its modifying effect on larvae of potential males according to the duration of exposure (Table 1). High temperature applied late (last 3 days) in larval life produces no structural defects but prevents rotation of genitalia to the copulatory position. An extension of exposure to high temperature to include the last 6 days of larval life causes a series of changes that produces intersexes. Larvae exposed to 29°C for 7 days or more grow into apparent females, some of which have been inseminated by normal males. Insemination was determined by examining the spermathecae under a compound microscope for the presence of sperms.

Larvae that bear female determiners are unaffected by a temperature of 29°C. They give rise to females that are normal in appearance, copulate readily by the artificial means described by McDaniel and Horsfall (*5*), feed on blood, and develop eggs in a normal manner.

WILLIAM R. HORSFALL
JOHN F. ANDERSON
Department of Entomology, University of Illinois, Urbana

References and Notes

1. R. E. Snodgrass, *Smithsonian Inst. Publs. Misc. Collections* **139**(8), 1 (1959).
2. Funds for support of this work were in part from a grant made by the Graduate College. Reinhart Brust has given much help in this work and our gratitude is expressed to him.
3. J. B. Kitzmiller, *Rev. brasil. malariol. e doenças trop.* **5**, 285 (1953).
4. R. F. Harwood and W. R. Horsfall, *Ann. Entomol. Soc. Am.* **50**, 555 (1957).
5. I. N. McDaniel and W. R. Horsfall, *Science* **125**, 745 (1957).

23 January 1961