EFFECTS OF VARIOUS POISONS ON *ANOPHELES* HEART RATES

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This note summarizes the general effects of a wide variety of poisonous compounds (mostly insecticides) on the heart rates of intact, freshly fasting *Anopheles* mosquito larvae (*A. quadrimaculatus* Say; LTD strain; Diptera, Culicidae).

Most of the studies were made with unsexed fourth instars of variable ages (2 to 36 hours in the stadium). Heart rates were calculated from continuous recordings from 5 to 20 individuals as previously described (Jones, 1956a). Observation times varied from approximately 20 minutes to not more than 2 hours per larva.

When intact freshly fasting larvae were placed in either p,p'-DDT (10^{-4}, 10^{-5}), methoxychlor (10^{-4}), dieldrin (10^{-4}, 2×10^{-5}), toxaphene (10^{-4}), parathion (10^{-4}), ethyl p-nitrophenyl thionobenzene phosphonate (EPN; 10^{-6}), sodium pentachlorophenate (PCP; 10^{-2} to 10^{-4} molar), or 2,4-dinitrophenol (DNP; 10^{-4} to 10^{-5} molar), the heart rates did *not* decline as did those of controls fasting in distilled water or in 1 percent acetone, but remained approximately constant, essentially like the rates of *normal* larvae feeding in culture water or in distilled water containing fresh food (as in fig. 1, line B). Male and female larvae [1] did not differ in their cardiac responses to either DDT or dieldrin prior to convulsions.

Immersion of larvae in either eserine (10^{-5}, 30 minutes), neutralized atropine (10^{-3}, 30 minutes), or freshly half-saturated ether solution (in a closed dish for 5 to 10 minutes) did not alter the basic cardiac reaction when larvae were then placed in DDT.

[1] Larvae were sexed by examination of the antennal discs as described by Jones ('57).

Cardiac stimulation greatly exceeding a normal feeding rate was found with very high concentrations of DNP (10^{-2} and 5×10^{-3} molar). The acceleration was progressive and occurred without the larvae's becoming hyperactive.

Heart rates of larvae in sodium fluoride (10^{-2}) were normal compared to sodium chloride controls (0.24 molar) for 55 minutes, whereupon they rapidly diminished and the hearts dilated abnormally and stopped beating in 60 to 70 minutes (as in figure 1, line D). In sodium met-

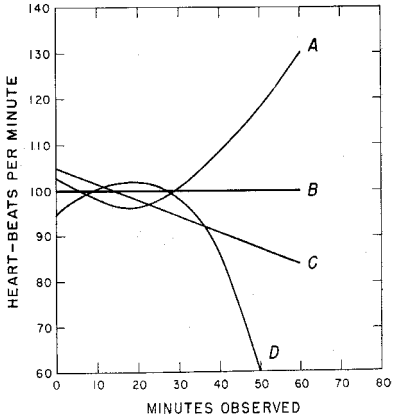

FIG. 1.—Diagram of principal cardiac responses of intact *Anopheles* larvae under normal and abnormal situations.

Line A.—Marked progressive cardiac stimulation. Type of reaction seen with strong DNP.

Line B.—Mild stimulation as found in normal feeding larvae and as occurs during poisoning with DDT, dieldrin, BHC, toxaphene, EPN, weak DNP.

Line C.—Normal cardiac decline. Type seen in larvae fasting in distilled water, 1 percent acetone, phenothiazine, rotenone, pyrethrins.

Line D.—Cardiac depression. Type seen with sodium fluoride. Similar but more rapid with sodium metarsenite.

arsenite (10^{-2}) the rates were like those of saline controls (0.08 molar) for only 15 minutes, then the heart either beat very slowly or beat normally but with very long stops in systole between every three or four normal contractions before final arrest.

Prior to the moribund stage, relatively slight decreases in the heart rate were found with highly concentrated p-chloromercuribenzoate (a powerful sulfhydryl inhibitor; 2×10^{-4} molar), rotenone (about 10^{-4}), phenothiazine (10^{-4}), or pyrethrins (I and II; 10^{-6}).

Mild cardiac stimulation of fasting rates in *Anopheles* larvae has already been reported with such varied treatments as certain concentrations of carbon dioxide and oxygen (Jones, 1956b), sodium, potassium, and calcium chlorides (Jones, 1956c), and a few drugs (*viz.*, eserine and nicotine) (Jones, 1956d). High concentrations of potassium have been reported to give marked cardiac stimulation of approximately the same magnitude as DNP (Jones, 1956c).

The relative indifference of the mosquito heart to many poisons is not peculiar, for this organ is said to be without nerves and is refractive to drugs known markedly to affect cardiac nerves of other insects (Jones, 1954, 1956d). The mosquito heart reacts to many poisons essentially like the cockroach heart (see Krijgsman *et al.*, 1950, Orser and Brown, 1951, Naidu, 1955). This seems surprising since the cockroach has a well-innervated heart (Alexandrowicz, 1926, McIndoo, 1945) which reacts to many drugs in a manner quite unlike that of the mosquito larva (Krijgsman and Krijgsman-Berger, 1951, Naidu, 1955, Jones, 1956d). It is worth noting that the reactions of *Anopheles* and cockroach hearts to DDT (decrease in the roach, mild [2] stimulation in *Anopheles*) are very different from the reactions of the hearts of acutely poisoned dogs and monkeys, for in these mammals DDT is said to sensitize the myocardium to extrinsic epinephrine and intrinsic sympathin and to lead to the onset of ventricular fibrillation (Phillips *et al.*, 1946).

In summary, it has been found that the myogenic heart of the *Anopheles* mosquito larva is only mildly affected by a number of poisonous compounds. Only one toxicant, DNP, led to a truly marked stimulation of the heart rate and produced this effect only in massive doses.

[2] Yamasaki and Ishii (1950) found the heart of *Locusta* was definitely depressed after perfusion with DDT.

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