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Short communication

# NEGATIVE TEMPERATURE COEFFICIENT OF THE ACTION OF DDT IN A SENSE ORGAN

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DDT induced repetitive spontaneous activity in the afferent nerve fibres of the lateral-line organ of the clawed toad, *Xenopus laevis* The action of DDT increased markedly with lowered temperature This temperature-effect was easily reversible The results demonstrate that DDT has a definite negative temperature coefficient of activity in this sense organ

Lateral-line organ Repetitive activity
DDT Negative temperature coefficient

## 1 INTRODUCTION

In insects, it is well established that the insecticide DDT (2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane), primarily affects sensory neurones, resulting in repetitive activity in the afferent nerve fibres (Roeder and Weiant, 1948, Becht, 1958, Barton Brown and Kerr, 1967)

On the other hand, there is little information about the effect of DDT on sensory structures of vertebrate animals Anderson (1968) reported that sublethal doses of DDT potentiated the response of the lateral line of brook trout to water motion, and that this effect was more pronounced at lower temperatures These results could not be confirmed in rainbow trout (Bahr and Ball, 1971)

Because of the highly specific action of DDT on axonic membranes (Hille, 1968, Narahashi and Haas, 1968), further study of the effects of DDT in the vertebrate sensory nervous system may be of pharmacological interest The lateral-line organ of the clawed toad, *Xenopus laevis*, is ideal for this study It has a simple innervation, is readily accessible, and the sensory hair cells in this organ are comparable to the hair cells in the inner ear of the higher vertebrates (Flock, 1971)

## 2 MATERIALS AND METHODS

The experiments were performed on the clawed toad, *Xenopus laevis* The animals were exposed to DDT concentrations varying from 1 to 4 ppm in aquaria containing 15 l of water Purified DDT was added to the water in an ethanol solvent After 18 hr of exposure to DDT at a temperature of 22–23°C, a piece of skin was removed from the animal and activity was recorded from a single lateral-line organ, which is innervated by two afferent nerve fibres The methods of preparation and recording were similar to those described by Gorner (1963) and Harris and Milne (1966) Temperature control of the preparation was achieved by means of a thermoelectric device

## 3 RESULTS

The lateral line of *Xenopus laevis* shows irregular spontaneous activity in the absence of any mechanical stimulation (Gorner, 1963), and in most preparations two types of nerve impulses, originating from both afferent nerve fibres, could be distinguished (fig 1A) At room temperature (22–23°C) the intervals between consecutive spikes of the same fibre ranged from about 10 msec to more than 200 msec and the mean rate of spontaneous firing varied in different preparations from 10 to 35 impulses per sec The impulse rate depended on the temperature and decreased with a $Q_{10}$ between 2 and 3 as the temperature was lowered (see also Murray, 1956) Typically, there was a lack of activity at temperatures below 5°C and above 30°C

DDT-treatment caused repetitive spontaneous activity in the afferent nerve fibres Single nerve impulses no longer occurred, all spikes were grouped together in short trains (fig 1B) Although there was a notable individual variation, the number of repetitive spikes per train increased with increasing DDT-concentrations A relation also existed between the number of repetitive spikes and the symptoms of poisoning Weak symptoms of poisoning were attended with trains of 2–4 spikes, and more severe symptoms with trains of 3–6 spikes The number of repetitive spikes per train increased also with time and continued to increase in the isolated preparation

The effect of DDT on the spontaneous activity was highly dependent on temperature and became much more pronounced as the temperature of the preparation was lowered Although, upon cooling, the frequency of the trains and the frequency of the spikes within the trains decreased, the number of spikes per train showed a marked increase This is illustrated in fig 1B–E, which shows the spontaneous activity of a DDT-treated lateral-line organ at various temperatures In this preparation, isolated from an animal which was exposed to 3 ppm DDT, repetitive

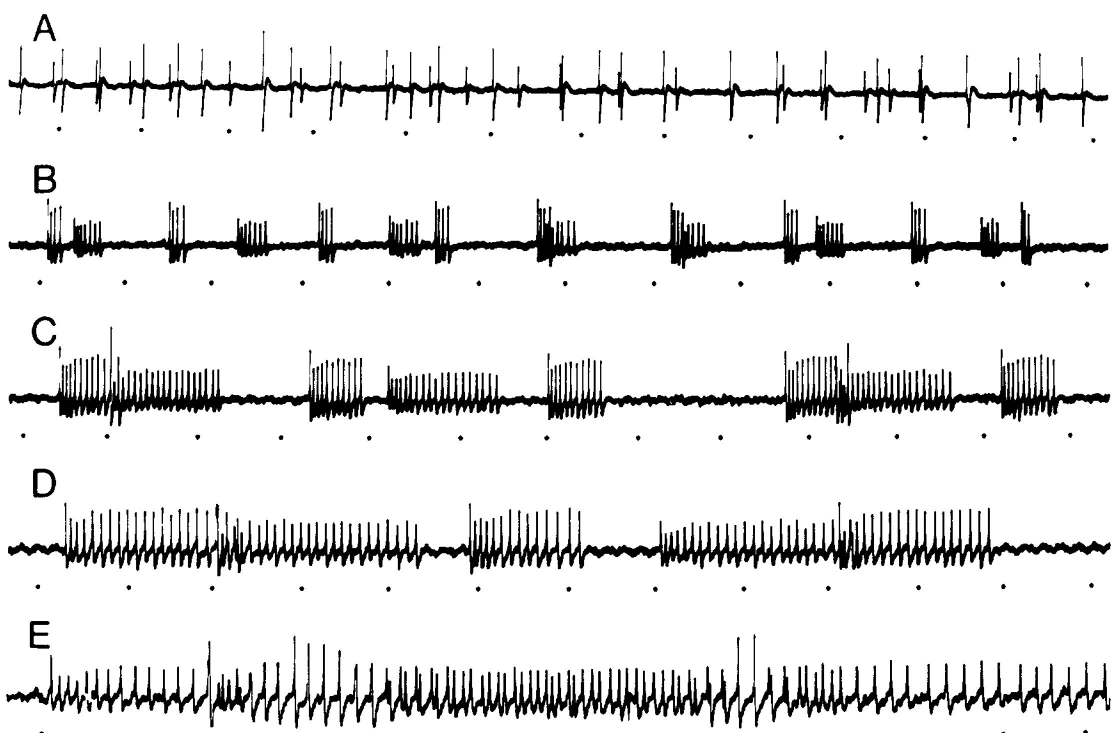


Fig 1 Spontaneous activity from a single lateral-line organ of *Xenopus laevis* (A) Control preparation Two types of nerve impulses can be distinguished Sometimes an extra high spike occurs as both types coincide Temperature 23°C (B) Preparation isolated from an animal which was exposed to 3 ppm DDT for 18 hr Temperature 23°C (C), (D) and (E) Same preparation at a temperature of 19, 16, and 11°C, respectively In (E) two trains of spikes partly coincide Time mark 100 msec

activity increased from trains of 3–7 spikes at a temperature of 23°C (fig 1B) to trains of more than 60 spikes at a temperature of 11°C (fig 1E) Such preparations even showed an increase in mean firing rate with lowered temperature In other cases the effect of temperature was less dramatic, but there was always a marked increase in the number of spikes per train as the temperature of the preparation was lowered Moreover, preparations from animals which were exposed to a DDT concentration of 1 or 2 ppm and did not show repetitive activity at room temperature, but might do so after cooling

Raising the temperature of the preparation caused a decrease in the number of spikes per train, and preparations which were highly repetitive at room temperature eventually showed almost normal spontaneous activity at a temperature of 28°C The effect of temperature was easily reversible and could be repeated more than once in the same preparation

## 4 DISCUSSION

The experiments show that DDT induces repetitive spontaneous activity in the afferent nerve fibres of the lateral-line organ of *Xenopus laevis* Such repetitive activity as reported here is probably responsible for the enhanced reaction of the lateral line in DDT-treated brook trout (Anderson, 1968)

DDT can also induce repetitive discharges in afferent myelinated nerve fibres which are isolated from their end organs (van den Bercken, 1971) The origin of the repetitive activity as described in the present paper is however not located in the lateral-line nerve, since the electrically evoked compound action potentials of this nerve in DDT-treated preparations which were highly repetitive, did not show any sign of repetitivity Moreover, the repetitive firing in isolated nerves needs higher DDT concentrations and does not increase with lowered temperature

The most interesting result is the easily reversible effect of temperature on the DDT-induced repetitive activity As measured by the number of repetitive spikes per train, DDT shows a definite negative temperature coefficient of activity in this sense organ This is of special interest for a better understanding of the mechanism of action of DDT, since this insecticide is known to be more toxic for insects at lower than at higher temperatures, and the symptoms of poisoning can be reversed by changing the temperature (for a survey, see Eaton and Sternburg, 1964) The same is probably true for *Xenopus laevis*, since DDT-treated animals which showed almost no symptoms of poisoning at room temperature, developed sudden and violent convulsions when transferred to water with a temperature of about 12°C

It is tempting to conclude that such a direct effect of temperature on the action of DDT as found in the present study is responsible for the overall negative temperature coefficient of DDT toxicity

A similar temperature-dependent effect of DDT probably occurs in the chordotonal organs of the american cockroach, *Periplaneta americana* (Yamasaki and Ishii, 1954) More recently however this could not be confirmed by Eaton and Sternburg (1964), who reported a positive temperature coefficient of the action of DDT in the afferent nerves of this insect, and concluded that events occurring in the central nervous system are responsible for the overall negative temperature coefficient of DDT toxicity

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