

AN ABDOMINAL RECEPTOR OF THE AMERICAN COCKROACH, *PERIPLANETA AMERICANA* (L.) AND ITS RESPONSE TO AIRBORNE SOUND

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Abstract—A receptor sensitive to substratum vibration and high-intensity airborne sound has been found in the lateral folds of abdominal segments 2 to 6 of *Periplaneta americana*. The electrophysiological results reveal the presence of two sensory units that differ in the amplitude of their output and the degree of sensitivity to airborne sound. The histological study revealed the presence of rigid spines in the lateral fold. These spines are probably an integral part of the entire sensory structure.

INTRODUCTION

THE perception of airborne sounds and substratum vibrations by the American cockroach, *Periplaneta americana*, has been clearly demonstrated to be associated with the cerci (PUMPHREY and RAWDON-SMITH, 1936) and subgenual organs (AUTRUM and SCHNEIDER, 1948) respectively and represents the known major sound-sensing systems in the American cockroach (DETHIER, 1963). Recently, an entirely different organ has been located in the lateral folds of abdominal segments 2 to 6 which responds to both airborne sound and substratum vibration. This paper reports the preliminary electrophysiological and histological studies on the organ *in situ*.

MATERIALS AND METHODS

American cockroaches reared under controlled laboratory conditions and maintained on Purina Lab Chow were used in these experiments. An isolated abdomen of an adult cockroach was cut longitudinally along the sternum to one side of the nerve cord. The abdomen was opened and pinned out on a wax dissecting tray and several drops of aerated physiological saline (YAMASAKI and NARAHASHI, 1960) placed on the opened preparation. A small piece of paper towelling was placed beneath the abdomen to absorb excess fluid so that the lateral and segmental folds could be kept relatively free of liquid. Keeping the lateral fold free of liquid proved to be the most difficult part of the procedure even when excess saline was removed.

Since the receptor studied is present in the lateral portion of abdominal segments 2 to 6, the final stages of the dissection will be described for segment 3 and applies equally to the remaining segments. Names of muscles and alphabetic-numerical designations of nerves used in this description are those given by SHANKLAND (1965).

After removing fat body, gut, and tracheae, the medial and lateral internal muscles were removed and nerve 3A was cut distally to branches A2 and A3 in order to provide a section of nerve 3A of adequate length for monitoring nervous activity. This section of nerve contains only active sensory neurons of branch A3, which innervates the lateral area. The entire sternum was then removed by making a second longitudinal cut on the opposite side of the original lateral incision. The removal of the entire sternum restores the 'normal' geometry of the lateral fold and provides adequate open space in which to work.

Electrolytically etched tungsten wire electrodes (HUBEL, 1957) were used with standard electrophysiological instrumentation to record afferent impulses from the receptor. Permanent records of the response displayed by the oscilloscope were obtained photographically by a manually operated Polaroid Land camera, Model 110B. A Grass Model S4 stimulator was used to simultaneously trigger the oscilloscope trace and to produce a click by activating a small speaker positioned near the lateral fold with a 1 msec pulse. The speaker was a modified Telex Monoset (Telex, Electro-Acoustic Division, St. Paul, Minn.) which had one ear-piece replaced by a small paper cone tapering to a 5 mm orifice.

Click intensity in decibels (dB—re 0.0002 dyn/cm²) was measured by positioning the speaker cone orifice the same distance used for stimulating the receptor from the microphone of a General Radio Model 1551-C sound level meter.

Since the sound level of a click produced by a single 1 msec pulse could not be accurately measured by the meter, a series of clicks produced by 400 1 msec pulses/sec was used to obtain a more accurate dB measurement. The dB value thus obtained was considered to represent the value of a click produced by a single 1 msec pulse for a set voltage. By varying the voltage of the stimulator, clicks of different intensities could be obtained.

For the histological study, abdomens of teneral males were fixed in Bouin's fluid for 24 hr. The specimens were dehydrated through graded ethyl alcohol solutions and eventually infiltrated via xylene with melted paraffin, m.p. 50–54°C, under vacuum. Transverse serial sections were cut 10 μ thick and stained according to standard histological techniques with Mallory's triple stain.

RESULTS AND DISCUSSION

Electrophysiological study

Absolute threshold values for the receptor varied among preparations because of possible individual variation in sensitivity and also because of liquid, either blood or saline, which entered the lateral fold and acted as a stimulus damp. At threshold the typical response from the more sensitive unit (Fig. 1A) was a single small spike with a latency of 3 to 4 msec following the click, although several preparations gave a minimum of two small spikes. As the click intensity was increased, the number of small spikes increased and the latency of response decreased. Figs. 1(A) and (B) are oscilloscope photographs of the response of a single preparation to the indicated click intensities and show the increase in repetitive firing and decrease in response time with increased click intensity.

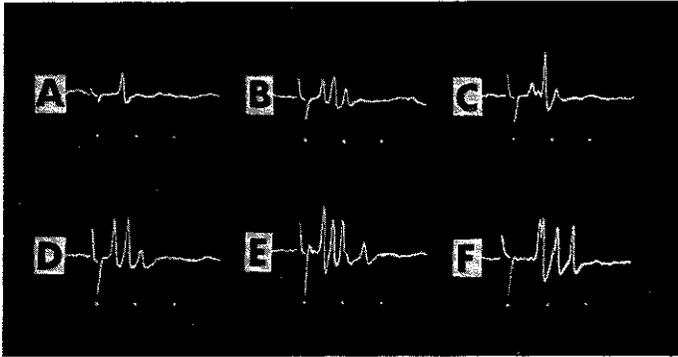


FIG. 1. Response of American cockroach abdominal lateral receptor to clicks of increasing intensity. The click intensities used were: (A), 79 dB; (B), 84 dB; (C), 85 dB; (D), 86 dB; (E), 93 dB; (F), about 90 dB. Responses in (A)–(E) are all from one preparation and (F) represents a different preparation. White dots below trace represent 5 msec intervals. All traces were intensified with white drawing ink for reproduction purposes.

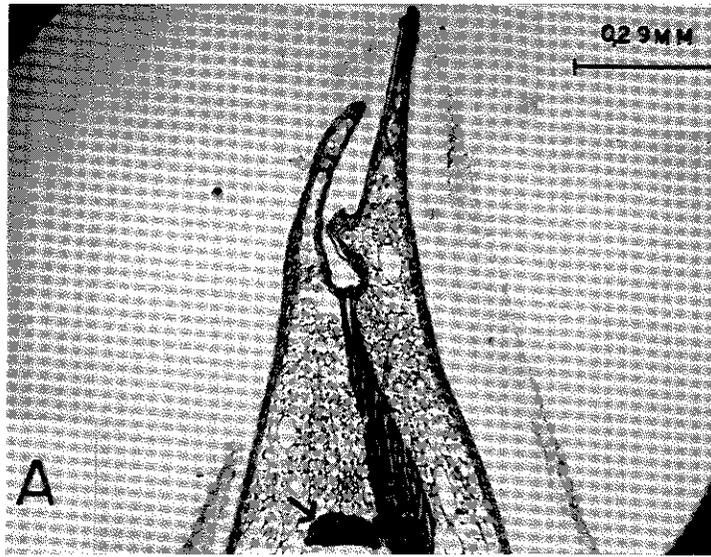


FIG. 2. (A) Transverse section of lateral area of abdominal segment 3. The muscle indicated with arrow is the posterior intersegmental sterno-tergal muscle, and the muscle attached to the lateral fold is homologous to the anterior intersegmental sterno-tergal muscle of SHANKLAND (1965). (B) Enlarged view of lateral fold of same section used in (A). Note presence of rigid spines in lumen of lateral fold.

With an additional increase in click intensity a new, larger spike appeared (Fig. 1C). This larger spike from the less sensitive unit followed the same pattern of response observed with the small spike, that is, as the click intensity increased the repetitive firing increased and the latency of response decreased (Figs. 1C-E). In Figs. 1(C)-(E), the small spikes are not visible because they are in phase with the larger spikes. In Fig. 1(F), which is the response from a different preparation, the different-sized spikes are partly out of phase and can be recognized. The responses represented in Figs. 1(A)-(E) are typical for all preparations studied once threshold was reached. The observed discharge patterns, spike size differences, and different levels of sensitivity with varying intensities of sound are very similar to the responses of a noctuid moth tympanic organ stimulated with clicks (ROEDER and TREAT, 1957).

The receptor also responded with a burst of large and small spikes when an air-stream was directed at the lateral fold and when the cuticle was scratched with a fine glass rod. When the wax in the dissecting tray was gently tapped with a hard object to induce substratum vibration, the receptor responded similarly to Fig. 1(E). This means of stimulation was regularly employed to determine the vitality of a preparation before click stimulation was initiated.

Histological study

The gross anatomy of the lateral area is shown in Fig. 2(A). The muscle attached to the lateral fold is homologous with SHANKLAND's (1965) anterior intersegmental sterno-tergal muscle. However, he describes this muscle as originating on the sternum and not on the lateral fold as Fig. 2(A) indicates. The small, crescent-shaped piece of muscle (arrow, Fig. 2A) visible at the distal portion of the anterior intersegmental sterno-tergal muscle is the posterior intersegmental sterno-tergal muscle.

The lateral fold is shown in greater detail in Fig. 2(B) and reveals the cuticular layers and the general shape of the rigid spines that are found in the lateral fold. These spines appear to be acellular and are irregularly spaced throughout the entire length of the fold. The entire endocuticle in the region below the spines and extending half-way around the fold stains a bright blue with Mallory's triple stain; the entire exocuticle and remaining endocuticle beyond the lateral fold stain an orange to orange-red. This suggests a change in the chemical nature of the endocuticular region below the spines.

A group of nerve cells is present on the lateral fold about 50 μ posterior to the attachment of the anterior intersegmental sterno-tergal muscle. This cell cluster has displaced the hypodermal cells and appears to be directly attached to the ventral endocuticular area of the fold. It is somewhat fan-shaped in three dimensions with the axons merging to form a branch of nerve A3, which is attached ventrally by connective tissue. It is probable that these cells represent the entire neural element of the receptor. However, it has not yet been possible to identify the cellular components which are responsible for the two different-sized spikes observed electrophysically. The entire neural element is quite similar in appearance to the

subgenual organ of the American cockroach depicted by AUTRUM and SCHNEIDER (1948), although it has not been determined whether the receptor described here is chordotonal in nature.

The results of these preliminary electrophysiological and histological experiments have clearly established the presence of a sensory organ in the abdomen of the American cockroach. This organ appears to be a vibration receptor since substratum vibration produced by tapping on the dissecting tray causes the receptor to respond. Also, airborne sounds of high intensity are required to evoke a response, and liquid in the lateral fold acts as a stimulus damp, possibly by preventing the spines from moving.

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