

SHORT COMMUNICATION

OCTOPAMINE IN A NEUROHAEMAL AREA WITHIN THE
ANTENNAL HEART OF THE AMERICAN COCKROACH

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A great deal of research suggests that octopamine functions as a neuromodulator, neurotransmitter and neurohormone in insects (Orchard, 1982; Evans, 1985; Hoyle, 1985). Especially high concentrations of this biogenic amine have been reported for neurohaemal tissue such as the corpora cardiaca and the neurohaemal organs of the medial nervous system (Evans, 1985). In the presented paper, octopamine is shown to occur in another neurohaemal area located within the antennal heart of the cockroach, *Periplaneta americana*.

The antennal heart is a circulatory organ consisting of two ampullae that are attached to the frontal cuticle, medial to the bases of the antennae (Fig. 1A). The ampullae are interconnected by a transverse muscle which functions as a dilator, expanding the lumina of both ampullae simultaneously upon contraction; the elasticity of the ampullae walls returns them to their original shape during relaxation of this muscle (Pawlowa, 1895; Pass, 1985). Within the walls of the ampullae numerous interstitial neurosecretory terminals can be found which are clearly neurohaemal releasing sites (Beattie, 1976; Pass, Agricola, Birkenbeil & Penzlin, 1988). Neuroanatomical investigations employing cobalt iontophoresis revealed that these terminals originate from neurones in the suboesophageal ganglion. Among other neurones unpaired cells were stained which strongly resemble, in their morphology and location, the well-known dorsal unpaired median (DUM) neurones (Pass *et al.* 1988). As all individually investigated DUM neurones are octopaminergic (Evans, 1985; Orchard & Lange, 1985), a search was made for the presence of octopamine in the antennal heart.

Key words: octopamine, neurohaemal organ, circulatory organ, antenna, sensory system, *Periplaneta americana*.

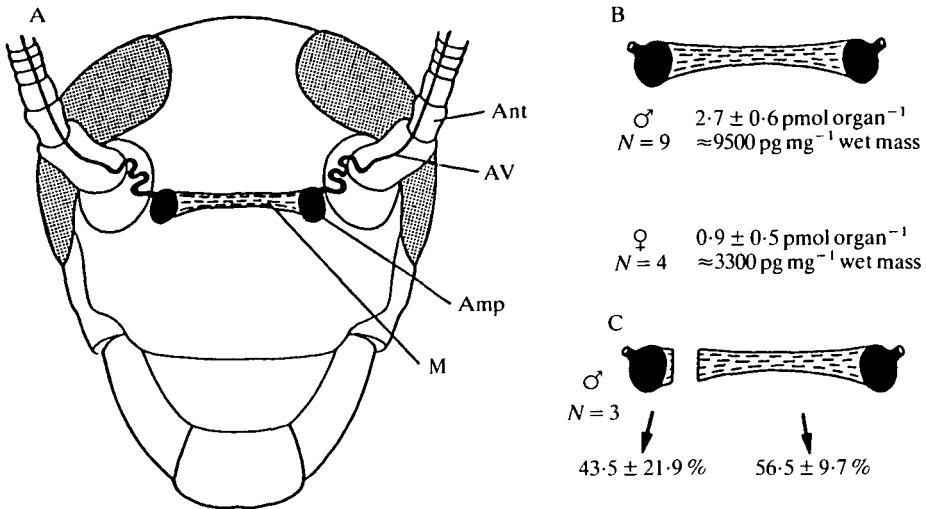


Fig. 1. Antennal heart of *Periplaneta americana*. (A) Representation of the morphology of the organ and its location in the head; Amp, ampulla; Ant, antenna; AV, antennal vessel; M, dilator muscle of ampullae. Octopamine contents, determined by a radioenzymatic assay, are given for (B) the whole organ of both sexes and (C) the isolated ampulla and the ampulla plus dilator muscle (10 or 20 organs were pooled for each assay; antennal heart wet mass was estimated from volume and assuming a specific mass of 1 g cm^{-3}).

For determination of octopamine, antennal hearts were dissected from the head and immediately frozen. Octopamine was identified by dansylation with thin-layer microchromatography (Neuhoff, 1973) and in a radioenzymatic assay (Molinoff, Landsberg & Axelrod, 1969) using high-performance liquid chromatography to check the reaction product.

Microchromatograms of dansylated antennal heart extracts demonstrated, besides an extraordinarily high amino acid content (especially of proline), a fluorescent spot that proved to be identical to synthetic octopamine which was used as a reference. The presence of octopamine was confirmed in the radioenzymatic assay. There was a dramatic difference between sexes: male antennal hearts contained about three times more octopamine per organ than female ones (Fig. 1B). To determine the distribution of octopamine within this organ, one ampulla was isolated so that little muscle remained. The octopamine content of the single ampulla was determined and compared with that of the other ampulla plus dilator muscle (Fig. 1C). More than 40% of the octopamine content of the whole organ was measured in the isolated ampulla, indicating that octopamine is stored in the neurohaemal areas located there. The concentration of this substance in the antennal heart is much higher than that in various parts of the nervous system (Evans, 1985) and in muscle with octopaminergic innervation (Orchard & Lange, 1985). This lends more support to the assumption that octopamine is released from the neurohaemal area of the antennal heart into the haemolymph than to the alternative supposition that octopamine acts as a local mediator for the extrusion of another neurohormonal substance.

The neurohaemal role of the antennal heart is of special interest from a functional point of view. Octopamine and/or other substances released from this organ are pumped into the antennae. These appendages are especially long in the cockroach and circulation takes a considerable time (about 10 min, estimated from observation of haemocyte flow). The target sites for the released substances can therefore be expected to be within the antennae. Since the antennae contain only numerous sensory neurones, plus epidermal cells and a few tracheae, the obvious targets are the receptors. In *Periplaneta americana* more than 90% of the antennal sensory neurones are sensitive to chemical stimuli (Schaller, 1978), which play an invaluable role in the behaviour of these animals. Males differ from females in their sensory equipment and have twice as many sensory neurones. This is the only significant distinction between the antennae of the sexes and could be related to the difference in their octopamine contents. With respect to a hormonal control of insect chemoreceptors, evidence is accumulating for long-term changes in their sensitivity (Blaney, Schoonhoven & Simmonds, 1986). Little is known about the chemical identity and the origin of these hormones, but biogenic amines may be involved as they have such long-lasting modulatory effects in nervous systems (Kupfermann, 1979). In particular, octopamine has been observed to enhance responsiveness to olfactory and various other sensory stimuli upon injection into the central nervous system (Mercer & Menzel, 1982; Sombati & Hoyle, 1984; Kinnammon, Klaassen, Kammer & Claassen, 1984) or into the haemocoel (Linn & Roelofs, 1986).

Another target site for the substances released from the antennal heart neurohaemal area could be the transporting epithelium in the proximal section of the antennal vessel (Beattie, 1976; Pass, 1985). It probably has an iono- and/or osmoregulatory function for the haemolymph within the antennae, which may be of importance to antennal sensory functions.

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