Matured tissues of root are the possible source of growth substances as reported by Thurman and Street[11]. Strictly enough, the buds and roots are developing only in association with lateral root scars. The lenticels are formed in association with lateral roots after the plantation of root cuttings from the same region where the buds and roots develop. The developing primordia pierce out through these lenticels.

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1. Cuthbertson, E. G., *Aust. J. Exp. Agric. Anim. Husb.*, 1972, **12**, 528.
2. Mann, H. and Cavers, P. B., *Can. J. Bot.*, 1979, **57**, 1783.
3. Leopold, A. C., *Auxins and Plant Growth*, University of California Press, Berkeley, 1955.
4. Booth, A. and Satchuthananthavale, R. M., *New Phytol.*, 1974, **73**, 453.
5. Khan, M. I., *Pak. J. Bot.*, 1973, **5**, 71.
6. Peterson, R. L., *The Development and Function of Roots*, ed. by J. G. Torrey and D. T. Clarkson, Academic Press, London, 1975.
7. Prasad, T. K., Mehta, P. M., Dave, Y. S. and Suma, T. K., *Indian J. Exp. Biol.*, 1980, **18**, 1524.
8. Fuente, R. K. D. and Leopold, A. C., *Plant Physiol.*, 1966, **41**, 1481.
9. Goldsmith, M. M., *Ann. Rev. Plant Physiol.*, 1977, **28**, 439.
10. Wangermann, E., *New Phytol.*, 1974, **73**, 623.
11. Thurman, D. A. and Street, H. E., *J. Exp. Bot.*, 1960, **11**, 188.

STUDIES ON THE RETROCEREBRAL ENDOCRINE AND NEUROHAEMAL ORGANS OF THE ADULT *SERINETHA AUGUR* (FABR.) (HETEROPTERA : COREIDAE)

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ABSTRACT

The retrocerebral endocrine system of the adult *Serinetha augur* consists of a pair of corpora cardiaca (CC) and a single corpus allatum (CA) situated below the brain and dorsal to the gut. The posterior parts of the corpora cardiaca appear to have fused with the anterior part of the corpus allatum forming a complex organ. The brain of this insect has two groups of median neurosecretory cells (MNC) in its pars intercerebralis and one group of lateral neurosecretory cells (LNC) in its lateral side of the protocerebrum. The cephalic aorta (AO) in sections seems to have the axons of the median neurosecretory cells of the brain, the former being connected with the latter by NCC–I through the median neurosecretory pathways. The axons of the lateral neurosecretory cells appear to terminate in corpora cardiaca which are linked with the LNC by NCC II through the lateral neurosecretory pathways. The corpus cardiacum, consisting of some smaller chromophobic and some larger chromophilic cells, reveals the presence of neurosecretory materials synthesized in LNC as evidenced by its intense reaction with AF. Similarly the neurosecretory materials produced by MNC are identified in the wall of the cephalic aorta indicating its role as neurohaemal organ. It is inferred from these observations that the corpus cardiacum and the cephalic aorta function as neurohaemal organs in the adult *S. augur*.

INTRODUCTION

STUDIES on the neurosecretory system and retrocerebral endocrine glands of insects have revealed that corpus cardiacum acts as a neurohaemal organ in several insects[1–5]. This gland is a neurohaemal organ has not been established for many insects including those of Hemiptera.

Further, Johansson[6] has reported for *Oncopeltus fasciatus* that the aorta acts as neurohaemal organ as evidenced by the deposition of neurosecretory material (NSM) in this structure. Subsequently this conception of accepting aorta as the neurohaemal organ in hemipteran insects was supported by various authors[7–14]. This structure has also been shown to be the neurohaemal organ in the dipteran insect *Calliphora erythrocephala*[15,16] and *Sarcophaga ruficornis*[14]. These observations are further supported by the presence of axons of the neurosecretory cells of the brain in the aorta of *Periplaneta americana*[17] and the lygaeid bug, *Metochus uniguttatus*[18] and *Leptocorisa acuta*[19], Although a great deal of work has been done on the retrocerebral endocrine glands of *O. fasciatus*[8,19,20,21] the retrocerebral complex and the neurohaemal nature of corpus cadiacum especially in hemipteran insects have not been studied extensively.

The present paper deals with the neurohaemal nature of the corpus cardiacum and the aorta and the neurosecretory pathways in the adult *Serinetha augur*, a heteropteran bug of the family, coreidae.

Materials and Methods

Laboratory colonies of *S. augur*, fed on *Croton sparsiflorus* and maintained at $28 \pm 2°$ C with RH 80 ± 4 % were used in the present histological investigations. The brains with the retrocerebral endocrine glands were dissected out under insect ringer solution and were fixed in Bouin's fluid. They were lightly stained with dilute alcoholic eosin to facilitate orientation during embedding. Paraffin sections were cut at 6μ–8μ thickness and were stained with Aldehyde fuchsin (AF)[22] and chrome haematoxylin phloxine (CHP)[23]. These stainings clearly demonstrate the neurosecretory colloids.

Observations

The median neurosecretory pathway and nervi corporis cardiaci-I (NCC-I)

The axons of the median neurosecretory cells run forward for a short distance, decussate with those of the opposite side, diverge and traverse the protocerebrum as nervi corporis cardiaci-I (NCC-I). The NCC-I, after running for a short distance, by-pass the corpus cardiacum and enters the dorsal aorta from the lateral aspect (Fig. 1). There seems to be no axonal connection between the NCC-I and the corpora cardiaca. The axons of the neurosecretory cells after entering the aorta give off a number of secondary axons containing the neurosecretory materials in the form of granules (Fig. 4).

The lateral neurosecretory pathways and the nervi corporis cardiaci-II (NCC-II)

The axons of the lateral neurosecretory cells converge to form the lateral neurosecretory pathways and they emerge out of the tritocerebral part of the brain, as the nervi corporis cardiaci II and enter the corpus cardiacum (Fig. 1).

The associated neurosecretory pathways (ANSP)

The neurosecretory materials which ooze out from the neurosecretory cells and their axonal pathways form two associated neurosecretory pathways (ANSP) along the main nervous channels (Fig. 6).

Corpora cardiaca (CC)

A pair of these conical glandular organs is situated ventrolateral to the gut. The posterior portions of the CC are fused with each other as well as with the corpus allatum situated below the former (Fig. 1).

The corpus cardiacum is composed of two types of cells, namely the larger chromophilic cells and the smaller chromophilic cells, the fomer being numerous in comparison with the latter. The smaller cells stain less intensely with CHP and AF than the larger cells. The neurosecretory materials (NSM) identified in the intercellular spaces of the central part of this gland exhibit an almost identical staining reaction as shown by the lateral neurosecretory cells of the brain (Fig. 5).

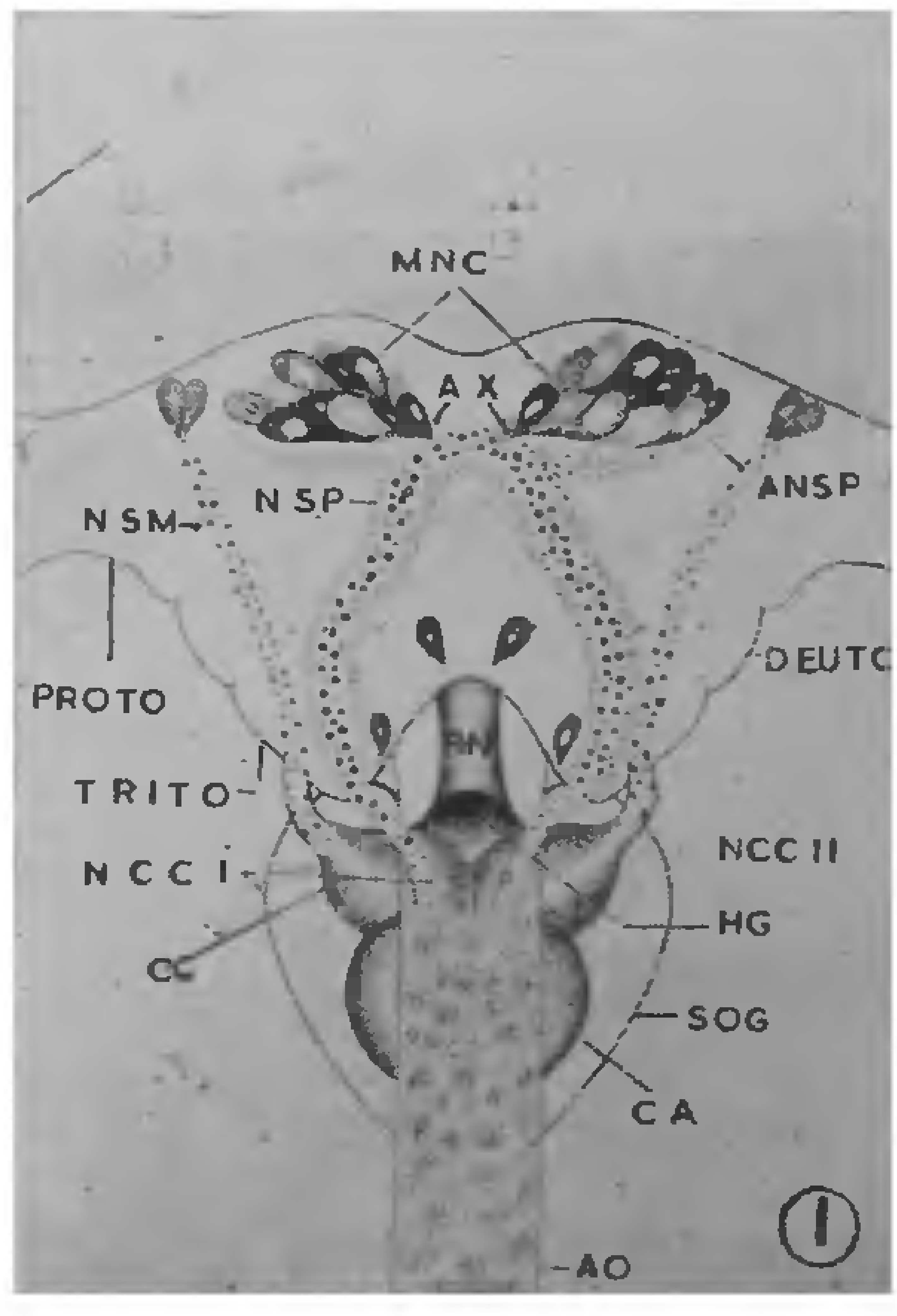


FIG. 1. Schematic diagram of the neuroendocrine system of the adult *Serinetha augur* showing the neurosecretory pathways. Aorta (AO), Axons (AX), Associated neurosecretory pathways (ANSP), Corpora cardiaca (CC), Corpus allatum (CA), Deutocerebrum (DEUTO), Hypocerebral ganglion (HG), Median neurosecretory cells (MNC), Neurosecretory pathway (NSP), Nervi corporis cardiaci-I and nervi corporis cardiaci-II (NCC-I and NCC-II), Neurosecretory material (NSM), Protocerebrum (PROTO), Recurrent nerve (RN), Suboesophageal ganglion (SOG), Tritocerebrum (TRITO).

Corpus allatum (CA)

Corpus allatum is a single globular gland lying posterior to the corpora cardiaca with which it is fused forming a complex organ (Fig. 1). The size of the gland varies in different individuals depending on the developmental stages of their ovaries. The nervus corporis allati (NCA-I) is not clear in histological sections since the gland forms a complex structure with the corpora cardiaca. On the other hand, NCA-II is quite conspicuous (Fig. 4).

The cells of this gland are of two types the smaller ones being situated at the peripheral zone and the larger ones at the central zone (Fig. 3). Each cell has a scanty amount of cytoplasm reacting moderately with CHP and AF, indicating the presence of the secretory materials (Fig. 3). This gland, in addition to these secretory materials, shows the presence of other secretory substances identical to those produced by the medial neurosecretory cells (Fig. 3).

The neurosecretory cells of suboesophageal ganglion

Two large neurosecretory cells are identified on the posterior side of the suboesophageal ganglion (SOG). These cells have large concentric nuclei each with a diameter of 11·25 to 13·5 μ. The cytoplasm of these few cells stains deeply with AF and has a deep purple colour similar to that of the A cells of the medial group (Fig. 7). The axons of these cells are packed with moderate amount of NSM in mature individuals.

Aorta (AO)

The aorta which runs dorsal to the retrocerebral endocrine organs appears to be a neurohaemal organ. The floor of this vessel is thin and is intimately fused with the dorsal part of the corpora cardiaca (CC) and corpus allatum (CA) (Fig. 2). The wall of the aorta contains CHP positive neurosecretory materials similar to those of the neurosecretory cells of the brain (Fig. 4).

Discussion

Nervi Corporis Cardiaci (NCC-I and NCC-II)

Anatomical studies on the retrocerebral endocrine organs of hemipteran insects have revealed the existence of certain variations in the organisation of NCC-I and NCC-II. Thus, Benwitz[24] has reported that the NCC-I and NCC-II are fused together to form a common nerve on either side of the brain in *Corixa puncrata*. Awasthi[13] and Tiwari *et al.*[25] have identified two distinct nerves NCC-I and NCC-II in the corpora cardiaca of *Nezara viridula* and *Leptocorisa varicornis*, respectively. The presence of a third nerve NCC-III, has been recorded for *Oncopeltus fasciatus*[6], *Ranatra elongata*[9] and *Belostoma indica*[10]. The present observations repoted for *S. augur* have shown that the nervi corporis cardiaci I and II are distinct nerves, the former terminating on the lateral aspect of the aorta and latter entering into the corpus cardiacum. Thus, the distribution of NCC-I and II of this insect appears to be similar to that of *N. viridula*[12] and *L. varicornis*.[25]

Retrocerebral complex

Corpus cardicum

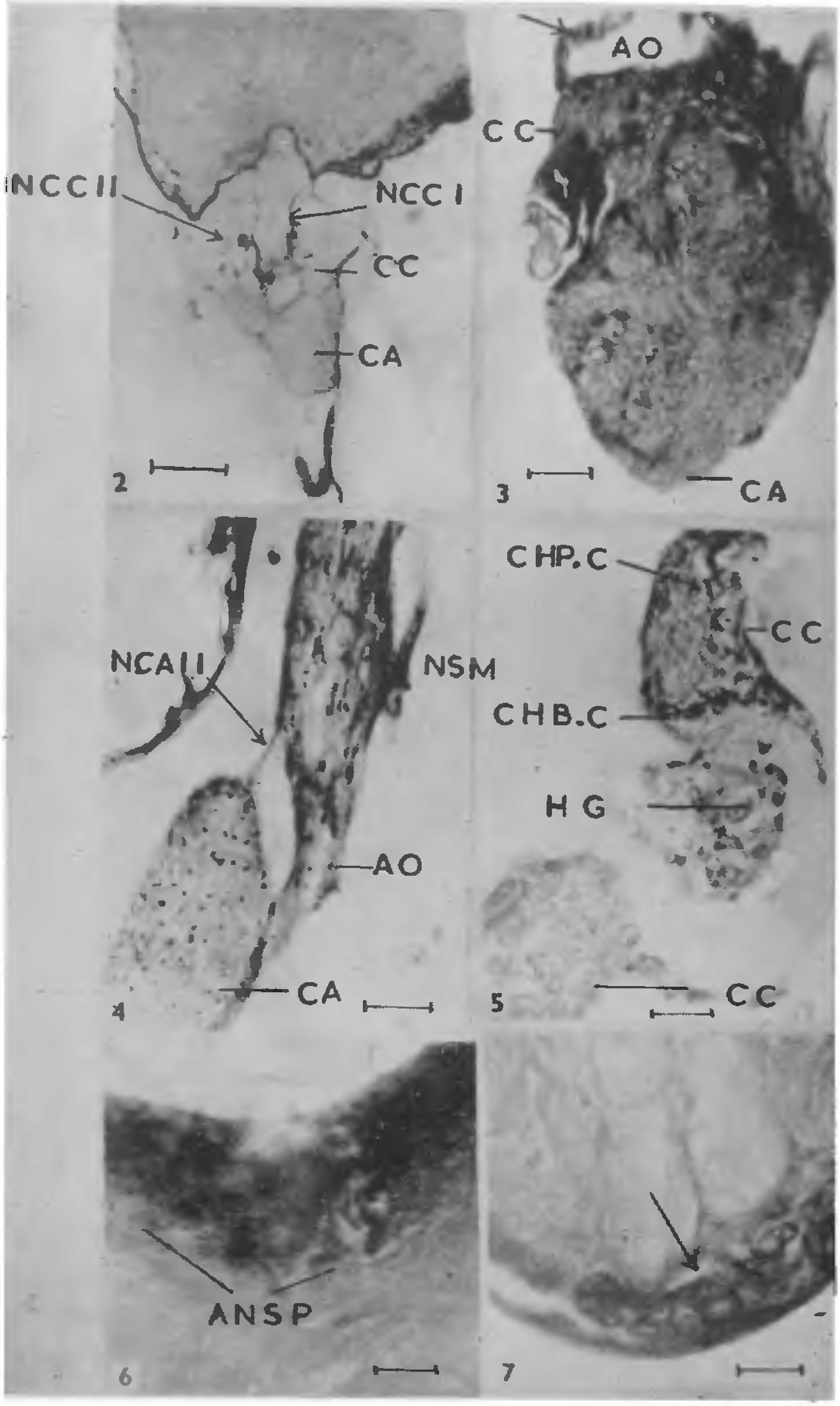
The present anatomical observations on the retrocerebral endocrine system of *S. augur* indicate that its general organization is identical to that of *Dysdercus koengii*[8] and *Nezara viridula*[12]. However, it exhibits certain histophysiological differences as follows:

The corpora cardiaca of this insect have been shown to be composed of two types of cells, the smaller chromophobic cells and the larger chromophilic cells. These cells are found to have been distributed at random, as it has been reported for *Dysdercus koengii*[8] and *Nezara viridulla*[12]. The chromophilic cells of the dorpora cardiaca of *S. augur* are characterized by their larger nuclei and nucleoli with their cytoplasm reacting intensely with CHP and AF. On the other hand, the chromophobic cells have smaller nuclei and nucleoli with their cytoplasm feebly stained with CHP and AF. The chromophilic cells of the corpora cardiaca of *S. augur*, based on their cytological features and staining reactions, seem to be involved in secreting their own substances (intrinsic secretion). Similarly the corpora cardiaca of hemipteran insects[26] and the insects of other orders have been shown to function as neurohaemal organ for extrinsic as well as intrinsic secretions[27].

Awasthi[28], while working with *Labedura riparia* has identified in the corpora cardiaca of this insect the presence of intrinsic secretion as well as the neurosecretion elaborated by the lateral neurosecretory cells. The present observations on the corpora cardiaca of *S. augur* have revealed the existence of the secretory products identical with those of the lateral neurosecretory cells of the brain in their staining properties. In the light of these observations, it may be inferred that the corpora cardiaca of this insect seem to be a neurohaemal organ for both intrinsic and extrinsic secretions as it has been reported for *L. riparia*[28].

Corpus allatum and aorta

It has been shown that the corpus allatum of *S. augur* is composed of two types of cells, the smaller ones being situated at the peripheral zone and the larger ones at the central zone. These cells are found to



FIGS. 2–7. Fig. 2. Transverse section of the retrocerebral endocrine organs showing the corpora cardiaca (CC) and Corpus allatum (CA). Note the nervi corporis - cardiaci-I and II (NCC-I and

NCC-II) terminating in Aorta and corpus cardiacum respectively. Bouins, 6 μ Chrom alum haematoxylin phloxine (CHP), scale : 90 μ. Fig. 3. Transverse section of the corpus allatum (CA) and Cardiacum complex (CC) with Aorta (AO) on its dorsal side. Note the deposition of A-cell like material in the corpus allatum (Arrow) and the accumulation of neurosecretory material in the wall of the Aorta (Arrow). Bouins, 6 μ, Aldehyde fuchsin (AF), scale : 18 μ. Fig. 4. Longitudinal section of the corpus allatum (CA) and aorta (AO) showing nervi corporis allati-II (NCA-II) and the deposition of neurosecretory material (NSM) in the wall of the aorta. Bouins, 6 μ, chrome haematoxylin phloxin (CHP), scale: 27 μ. Fig. 5. Transverse section of the corpora cardiaca (CC) and the hypocerebral ganglion (HG) showing the chromophilic (CHP. C.) and chromophobic cells (CHB.C) in the corpora cardiaca. Baouins, chrome haematoxylin phloxin (CHP), scale : 40μ. Fig. 6. Transvers section of the protocerebral part of the brain showing associate neurosecretory pathways (ANSP) formed by oozed neurosecretory material from the neurosecretory cells and their axons. Bouins, 6 μ, Aldehyde fuchsin (AF), scale : 18 μ. Fig. 7. Transverse section of the suboesophageal ganglion showing two large neurosecretory cells similar to A-type cells with the neurosecretory materials in their cytoplasm. Bouins 6 μ, Aldehyde fuchsin (AF), scale : 40 μ.

have cell boundaries as it has been reported for *Rhodnius prolixus*[29], *Adelophocoris lineolatus*[4], *Dysdercus koengii*[8], *Leptocorisa varicornis*[25], *Leptocorisa acuta*[14]. On the other hand, the cells of the corpus allatum of *Iphita limbata* have been shown to be syncytial[30].

Further it was reported earlier for *S. augur* that some of the secretory materials localized in the corpus allatum exhibit a similar staining property as shown by the secretory materials of the medial neurosecretory cells, indicating that the corpus allatum seems to store some of the secretory substances, synthesized by the A cells. The anatomical observations reported for his insect have also shown that the floor of the aorta twith its thin layer is fused with the dorsal part of the corpus allatum, containing AF positive neurosecretory materials similar to those of the medial neurosecretory cells of the brain. It is evident from these findings that the aorta functions as a neurohaemal organ for these medial neurosecretory cells of the brain. The blood vessel has also been shown to be the neurohaemal organ for insects such as *Calliphora erythrocephala*[15,16], *Sarcophaga ruficornis*[12], *Periplaneta americana*[17], *Metochus uniguttatus*[13] and *Leptocorisa acuta*[18]. The close association of the aorta with the corpus allatum in *S. augur* enables one to suggest that the secretory materials identified in the corpus allatum of this insect seem to have been derived by the process of diffusion from this aorta, as it acts as neurohaemal organ for the medial neurosecretory cells of the brain. This inference gains support from the observations of Awasthi[12] and Faruqui[19] who have reported the existence of the neurosecretory substance produced by A-cells in the corpora allata of *Nezara viridula* and *Leptocorisa acuta* respectively.

On the other hand, Tiwari *et al.*[26] have reported the absence of this material in the corpus allatum of *Leptocorisa varicornis* in spite of its intimate association with the aorta. However, they have pointed out that there is every possibility for the exchange of neurosecretory materials between the two.

Sub-oesophageal ganglion

The suboesophageal ganglion of *S. augur* has been shown to be composed of two neurosecretory cells on its posterior side. These cells are found to react intensely with AF, similar to A type of the medial group indicating the presence of neurosecretory materials in their cytoplasm. These secretory substances seem to get transferred into the haemolymph, probably by the process of diffusion, as these cells have no separate neurosecretory pathways. Similar cells have also been identified in the suboesophageal ganglion of *Hylys dentatus*[11], *Oncopeltus fasciatus*[21], *Nezara viridula* and *Metochus uniguttatus*[12].

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1. Cazal, P., *Bull. Boll. Fr. Flg. (Suppl.)*, 1948, **32**, 1
2. Wigglesworth, V. B., *Publ. Staz. Zool. Napoli. (Suppl.)*, 1954, **24**, 41.
3. Junqua, C., *Bull. Biol.*, 1956, **90**, 154.
4. Ewen, A. B., *J. Morphol.*, 1962a, **111**, 255.
5. Gupta, D. P., *J. Zool.*, 1970, **162**, 401.
6. Johansson, A. S., *Nytt. Mag. Zool.*, 1958, **7**, 1.
7. Seshan, K. and Ittycheriah, P. I., *Science*, 1966, **153**, 427.
8. Dogra, G. S., *J. Insect. Physiol.*, 1967a, **13**, 1895.

9. Dogra, G. S., *J. Morphol.*, 1967*b*, **11**, 223.
10. —, *Acta Anat.*, 1969, **72**, 429.
11. Srivastava, R. C., *Ann. Entomol. Soc. Amer.*, 1970, **63**, 1972.
12. Awasthi, V. B., *J. Morphol.*, 1972, **136**, 337.
13. —, *Int. J. Insec. Morphol. Embryol.*, 1973, **2**, 1.
14. Faruqui, S. A., *Zool. Jb. Anat.*, 1974, **92**, 181.
15. Norman, T. C., *Z. Zelforsch*, 1965, **67**, 461.
16. Thomsen, M., *Ibid.*, 1969, **94**, 205.
17. Miller, T. and Thompson, W. W., *J. Insect. Physiol.*, 1968, **14**, 1099.
18. Faruqui, S. A., *Folia Morphol.*, 1975, **22**, 261.
19. Johansson, A. S., *Trans. Amer. Entomol. Soc.*, 1957, **83**, 119.
20. Schreiner, B., *Gen. Comp. Endocrinol.*, 1966, **6**, 388.
21. Unnithan, G. C., Bern, H. A. and Nayar, K. K., *Acta Zool.*, 1971, **52**, 117.
22. Ewen, A. B., *Am. Micro. Soc.*, 1962*b*, **81**, 94.
23. Gomori, G., *Amer. J. Path.*, 1941, **17**, 395.
24. Benwitz, G., *Zool. Jb. Anat.*, 1956, **75**, 311.
25. Tiwari, R. K., Srivastava, K. P. and Harihar, Singh, *Zool. Beit.*, 1975, **21**, 105.
26. Bowers, B. and Johnson, B., *Gen. Comp. Endocrinol.*, 1966, **6**, 213.
27. Awasthi, V. B., *Anat. Anz.*, 1974, **136**, 244.
28. —, *J. Insect. Physiol.*, 1975, **21**, 1713.
29. Wigglesworth, V. B., *Quart. J. Microsc. Sc.*, 1934, **77**, 191.
30. Nayar, K. K., *Curr. Sci.*, 1954, **22**, 241.

NOBEL PRIZE AWARDS FOR 1981

Nobel Prize for Medicine

The 1981 Nobel Prize for Medicine was awarded jointly to Dr. Robert Sperry of the California Institute of Technology for his discoveries concerning 'the functional specialisation of the cerebral hemispheres' and to Prof. Torsten N. Wiesel and Dr. David Hubel for their discoveries concerning 'Information processing in visual system'.

Nobel Prize for Physics

The 1981 Nobel Prize for Physics was awarded jointly to Prof. Kai Stegbahn of Upsala University for his contribution on 'the development of high resolution electron spectroscopy' and to Prof. Nicolaas Bloembergen of the Harvard University and Prof. Arthur Schawlow of Stanford University for their contributions on 'the development of laser spectroscopy'. Prof. Kai Stegbahn got half the award while the other half was shared by Prof. Bloembergen and Prof. Schawlow.

Prof. Bloembergen is a Honorary Fellow of the Indian Academy of Sciences (Bangalore). He was also a Raman Professor and delivered a series of lectures during his visit to India from September to December 1979.

Nobel Prize for Chemistry

The 1981 Nobel Prize for Chemistry was awarded jointly to Prof. Kenichi Fukui of Kyoto University, Japan and to Prof. Roals Hoffmann of Cornell University, New York, for independently developing the theories concerning the course of chemical reactions.