Qatar Univ. Sci. Bull. (1983), 3: 169 - 179

DEVELOPMENTAL ANATOMY OF THE CENTRAL NERVOUS SYSTEM OF THE COTTON LEAF WORM, SPODOPTERA LITTORALIS BOISD.

By

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ABSTRACT

The central nervous system, C.N.S., of the cotton leaf worm, *Spodoptera littoralis* (B.) develops from a median row of embryonic neuroblasts which divide repeatedly to form a double ganglionic chain. The two chains fuse together laterally giving rise to the larval C.N.S. which is differentiated into a brain, a frontal, a suboesophageal, three thoracic and seven abdominal ganglia.

During the pupation period, the larval C.N.S. undergoes marked changes leading to the formation of the C.N.S. of adult moths. These changes involve fusion of certain parts of the system and degeneration of others. The brain and suboesophageal ganglion fuse together forming a large brain mass which is pierced by the oesophageal passage. The first thoracic ganglion remains unchanged. The second and third thoracic ganglia, as well as the first abdominal ganglion, also fuse together producing the large second thoracic ganglion of adult moths. The fifth and sixth abdominal ganglia are completely degenerated.

Thus, the fully-developed C.N.S. of adult moths consists of a brain, a frontal, two thoracic and four abdominal ganglia.

INTRODUCTION

Most of the investigators who have studied the development of the C.N.S. of insects noticed that the total number of ganglionic bodies varied considerably in the larval and adult stages of the different groups of insects (Snodgrass, 1935; Johansen and Butt, 1941; *et al,* 1958.; Menees, 1961; Banhawy and Anwar, 1970 and Wigglesworth, 1972). These observations varied according to the representative species studied. Besides, the anatomical and histological changes occurring in the elements of the C.N.S. which accompanies development of larval to adult stages, have not received due attention.

The aim of the present investigation is to clarify the anatomical and histological alterations that take place in the C.N.S. of the cotton leaf worm, *Spodoptera littoralis* (B.) through its development from embryonic to adult stages.

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MATERIAL AND METHODS

Pure strains of *Spodoptera littoralis* (B.) were obtained from the Faculty of Agriculture, Assiut University, A.R.E. These strains were allowed to breed several times under suitable laboratory conditions before using them as material for the present study.

Embryonic and post-embryonic stages including larvae, pupae and adult moths were also studied in the present investigation.

Materials were fixed in the appropriate fixatives for suitable periods which depended largely on the type of the fixative and developmental stages, of the insect, studied.

Paraffin sections varying from 5-10 μ in thickness were stained in haematoxylin-eosin, Mallory's triple and Heidenhain's stains (Pantin, 1962).

The size of the ganglionic bodies were determined be sectioning the whole C.N.S. at 10 μ thickness, in an accurate serial manner, and then multiplying this thickness by the number of sections encountered in the different parts of the ganglion.

OBSERVATIONS

A. Embryonic stages:

Eggs of *Spodoptera littoralis* examined shortly after fertilization showed that some of the cuboidal cells of the germinal layer were detached from the underlaying yolk mass at a certain region of the egg. These cells divide repeatedly giving rise to a thick row of cells, the neuroblasts (Fig. 1-a & b; Pl. I, figs. 1 & 2). Each cell possesses a prominent rounded nucleus containing numerous chromatin particles. Neuroblasts were underlined by a narrow transverse cavity, the neutral groove.

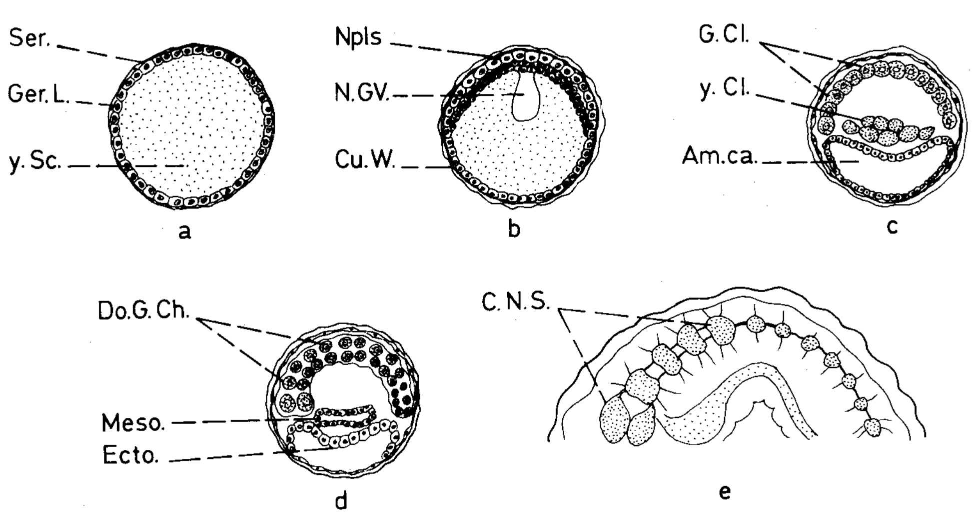

Figure 1 (a, b, c, d and e) : The embryonic development of the C.N.S.

The neuroblasts undergo further development before egg laying, leading to the formation of a curved strand of cells identified as ganglionic cells (Fig. 1-c; PL. I, fig. 3). These cells split longitudinally producing a double row of ganglionic cells, which divide repeatedly and result in the formation of definite ganglinoic bodies. These bodies fuse laterally together producing a single row of small ganglionic bodies connected together by two short longitudinal connectives (Fig. 1-d; PL. I. fig. 4).

B. Larval stages:

The C.N.S. of the larval stages of *Spodoptera littoralis* lies along the median line of the ventral side of the body, being formed of a double chain of longitudinal connectives carrying a number of ganglionic bodies. These are differentiated into a brain, a frontal, a suboesophageal, three thoracic and seven abdominal ganglia. The corpora allata-cardiaca complex is attached to the median region of the anterior part of the brain (fore-brain) by a short thick nerve (Fig. 2).

C. Pupal stages:

Certain changes have been noticed to take place in the different parts of the C.N.S. of the larval stages during pupation which accompanies their development into adult stage In the late larval stages, particularly the prepupal ones, some parts of the C.N.S. increase in size, approach each other and presumably undergo fusion during the pupal stges. On the other hand, certain parts become markedly decreased in size, and are assumed to undergo complete degeneration during the pupal stages (Table, 1). On careful examination of that table, the brain appears to acquire a comparatively large size in the prepupal (late larval) stage, whereas the suboesophageal ganglion appears rather smaller in size in these stages as compared to that in the previous ones. This ganglion was observed later to show complete fusion with the brain forming a relatively large ganglionic body or brain mass. Consequently, the circum oesophageal connectives are no longer demonstrated in moth stage, and the oesophagus appears piercing the brain mass. This phenomenon is clearly shown in the histological preparations illustrated in figures 5 & 6 on Plate II.

The frontal ganglion does not show any apparent morphological variations other than those of the larval stages.

As regards the thoracic ganglia, the first one becomes rather increased in length accompanying the insect development, and it persists in the adult stages as the first thoracic ganglion. The second thoracic ganglion undergoes marked elongation during the prepupal stage and thus it becomes to lie closer to the third thoracic ganglion. The latter appears larger in size, as compared to that of the early larval stages. It is also observed that the first abdominal ganglion is clearly enlarged during the middle and late larval stages, and consequently the distance between the third thoracic ganglion and the first abdominal ganglion is markedly shortened in the prepupal stage. During the pupal stage, the first abdominal ganglion appears to fuse with the third thoracic ganglion and which, in turn, is fused with the second thoracic ganglion. So, a single ganglionic mass, namely the second thoracic ganglion is formed in the adult stage (PL. II, figs. 7 & 8).

The second, third and fourth abdominal ganglia of the late larval stages becomes more enlarged than before. These ganglia persist in the adult stages forming the first, second and third abdominal ganglia. On the other hand, the fifth and sixth abdominal ganglia diminish gradually until they completely degenerate in the pupal stages. The seventh abdominal ganglion becomes more elongated and the longitudinal connectives, extending between it and the sixth ganglion, also increased in length. This ganglion represents the last abdominal ganglion of the adult stages (Table, 1).

Table (1)
Measurements of the different parts of the central nervous system of *Spodoptera littoralis* during the larval stages (in microns).

C.N.S. \ Stages	Early	Median	Late (Prepupal)
Br.	175	245	260 ***
Con.	50	63	60
So G.	126	175	135 ***
Con.	35	56	75
T_1. G.	95	160	190 **
Con.	140	385	420
T_2. G.	95	150	160 ***
Con.	165	700	420
T_3. G.	95	190	200 ***
Con.	40	70	63
A_1. G.	70	175	175 ***
Con.	130	420	245
A_2. G.	65	90	140 **
Con.	165	630	595
A_3. G.	65	175	180 **
Con.	200	805	580
$A_{.4}$. G.	75	80	182 **
Con.	170	420	700
A_5. G.	60	70	70 *
Con.	165	245	140
A_6 G.	50	100	70 *
Con.	35	60	420
A_7. G.	100	190	210 **

* Degenerated ** Persisted *** Fused

Br.: Brain, so. G: Suboesophageal ganglion, T_1.G.; T_2.G, T_3.G: First, second, third thoracic ganglia,
A_1.G, A_2.G, etc....: First, second, etc... abdominal ganglia Con. Connective

D. Moth stages

As a result of the changes which have taken place in the C.N.S. during the pupal stages, that of adult moths is formed of a brain, a frontal, two thoracic and four abdominal ganglia. The corpora allata-cardiaca complex shows a bilobed structure which is attached to the anterior part of the brain (fore-brain) by a pair of short and thick nerves. (Fig. 3)

In the moth stages, the longitudinal connectives of the thoracic region are double-stranded, but it becomes single-stranded in the abdominal region.

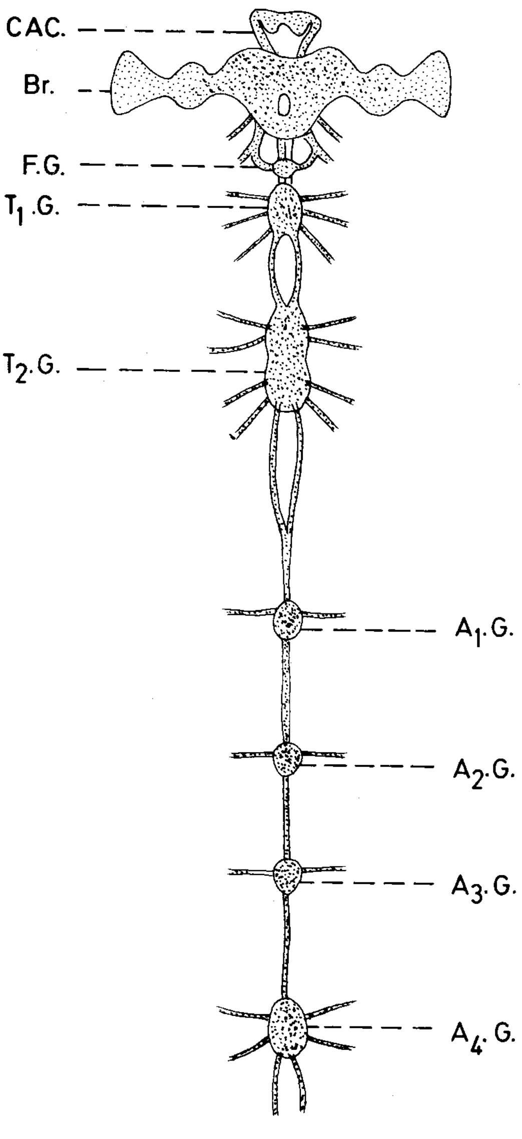

Figure 2 Larval central nervous system.

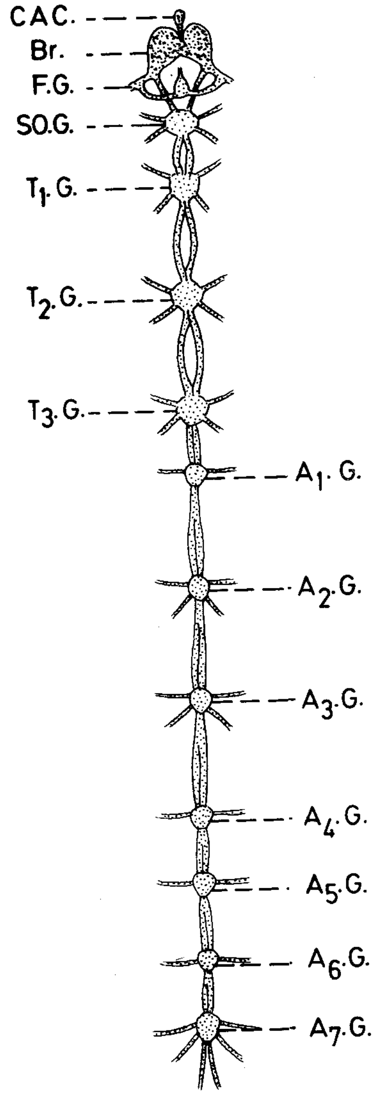

Figure 3 Adult central nervous system.

RESULTS AND DISCUSSION

In the cotton leaf worm, *Spodoptera littoralis,* Hassan *et al* (1958) reported the presence of twelve ganglionic bodies in the larval stages including a brain, a suboesophageal, three thoracic and seven abdominal ganglia. These findings were accepted by Allan (1964) who also noticed that the abdominal ganglia were reduced to five in the adult stages of the insect and according to which, ten ganglia are found in the moth stages of *Spodoptera littoralis.*

The data obtained from the present investigation indicates the existence of thirteen ganglionic bodies in the larval stages of *Spodoptera littoralis.* These comprise a brain, a frontal, a suboesophagel, three thoracic and seven abdominal ganglia. It is clear that the frontal ganglion was overlooked by Hassan *et al* (1958) and Allam (1964). The total number of ganglia are reduced to eight in the adult moth stages and not to five as was previously reported by Allam (1964). These include: a brain, a frontal, two thoracic and four abdominal ganglia. This reduction in the number of ganglionic bodies occurred as a result of certain developmental changes whioch have taken place during the pupal stages. These changes involved fusion between some parts as well as degeneration of others. The brain was fused with the suboesophageal ganglion to form the large brain mass of the adults. The frontal and the first thoracic ganglia persisted, but the second and third thoracic ganglia as well as the first abdominal ganglion were fused together to produce the large second thoracic ganglion of the months. The second, third and fourth abdominal ganglia remained unchanged, whereas the fifth and sixth ones degenerated and disappeared during pupation. The seventh abdominal ganglion persisted during pupation to form the last (fourth) abdominal ganglion of the moth stages. Thus, it is clear that only four abdominal ganglia exist in adult moths and not five, as was previously mentioned by Hassan *et al* (1958) and Allam (1964) Most of the present observations have not been reported elsewhere, in lepidopterian insects.

However, similar findings have been listed for other groups of *Arthropoda* regarding fusion of ganglia accompanying development. In most Crustacean species, as in the crayfish (Astacus sp.), the right and left halves of the ventral nerve cord undergo partial fusion during their embryonic development, so that the ganglia appear single instead of double. A further ganglionic fusion was observed, where the ganglia of the last three cephalic and first two thoracic segments have fused to form a large complex suboesophageal ganglion (Marshall and Williams, 1972).

In chelicerates, the ventral nerve chain consists primarily of twelve separate ganglia, one per segment. These ganglia tend to show some degree of anterior concentration and fusion with the suboesophageal mass which consists basically of five ganglia (Borradaile *et al,* 1961 and Marshall and Williams, 1972). According to these authors, the scorpion shows the least degree of concentration; only the anterior four opisthosomic ganglia are fused together in the prosoma, while seven ganglia are retained in the opisthosoma, the seventh one consists of two ganglia fused together.

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ABBREVIATIONS

A_1.G., A_2.G., etc....	:	First, second, etc...abdominal ganglia.
Am. Ca.	:	Amniotic cavity.
Br.	:	Brain
CAC.	:	Corpora allata-cardiaca complex.
Cu. W.	:	Cuticular wall.
Do. g.ch.	:	Double ganglionic chain.
Ecto.	:	Ectoderm.
F.b.	:	Fore-brain.
F.G.	:	Frontal ganglion.
G.Cl.	:	Germinal layer.
Lon. Con.	:	Longitudinal connective.
Meso.	:	Mesoderm.
Nbls.	:	Neuroblasts.
NC.	:	Nerve cells.
N. Gv.	:	Neural groove.
Os.	:	Oesophageal passage.
Ser.	:	Serosa.
So. G.	:	Suboesophageal ganglion.
T_1G., T_2 G., etc..	:	First, second, etc.. thoracic ganglia.
Y.Cl.	:	Yolk cells.
Y.Sc.	:	Yolk sac.

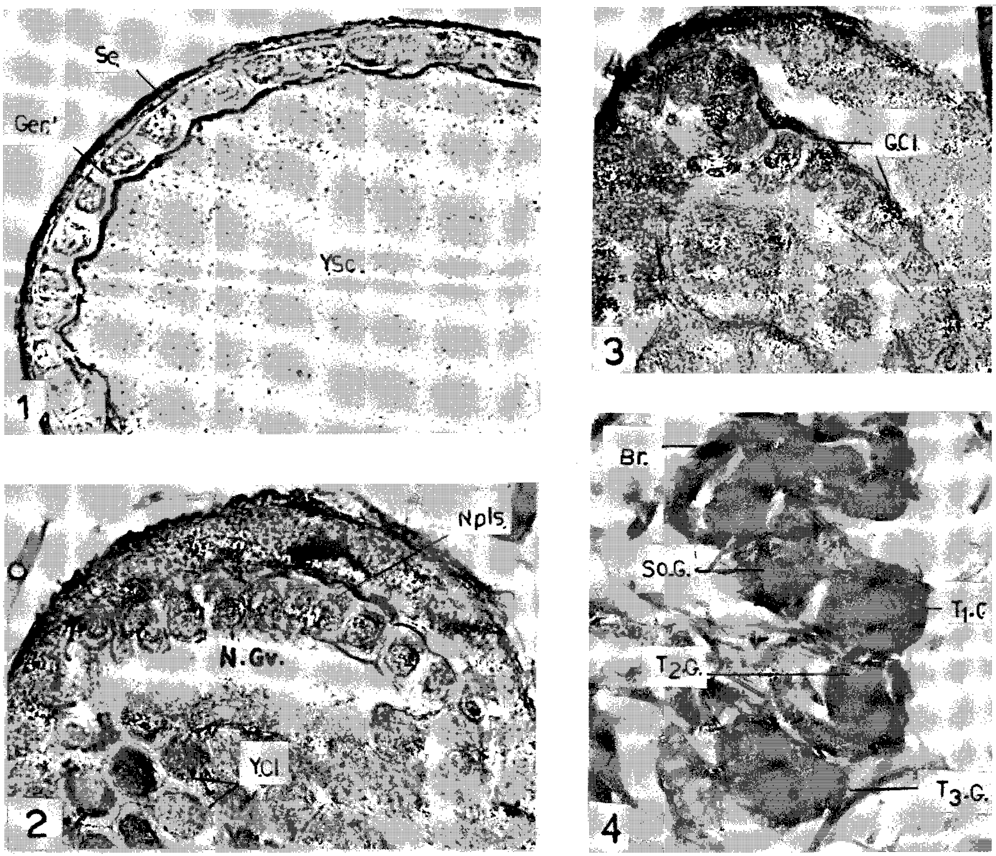

PLATE 1:

Figure 1 T.S. of a part of an unfertilized egg.

Figure 2 T.S. of a part of an unfertilized egg.

Figure 3 T.S. an advanced developmental stage of a fertilized egg.

Figure 4 Sagittal section through a part of an early larval C.N.S. before egg laying.

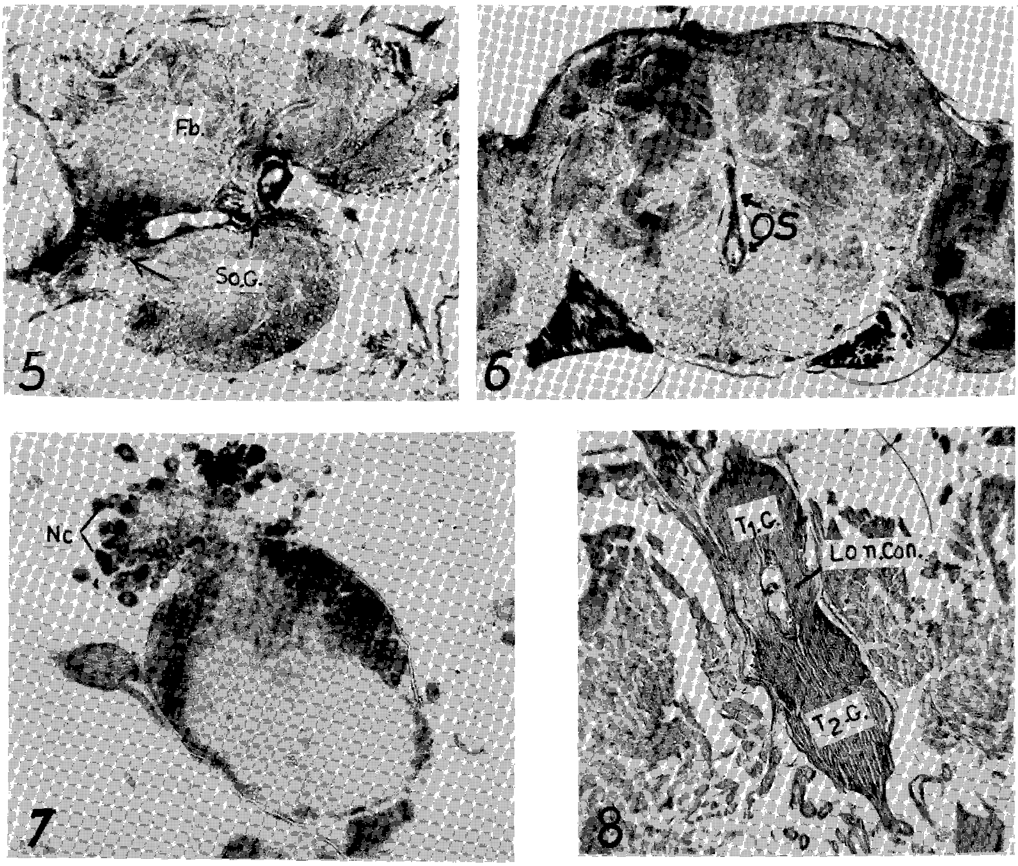

PLATE II:

Figure 5 T.S. of the brain of the median pupal stage during the process of fusion between the fore-brain (F.b) and the suboesophageal ganglion (S.G.).

Figure 6 Surgical section through the brain of adult stage.

Figure 7 Sagittal section through the second thoracic ganglion during its formation in the median pupal stage.

Figure 8 Sagittal section through the first and second thoracic ganglia after their final development in the late pupal stage.

دراسة تشريحية لتطور الجهاز العصبي
في دودة ورق القطن (سبودوبترا ليتورالس)

محمود أحمد البنهاوي ، إبراهيم محمد أنور

على الرغم من الأهمية الواضحة للجهاز العصبي في دودة ورق القطن نظراً للنشاطات الافرازية لمكونات من الخلايا العصبية وارتباط ذلك بالنشاط العام للحشرة ، الا أن ذلك لم يلق اهتماماً يذكر من الباحثين . وفي دراسة مورفولوجية عامة للمؤلفين الحاليين لهذا الجهاز في هذه الحشرة تبين وجود اختلاف واضح في مكونات هذا الجهاز عما سبق وذكره الباحثون السابقون .

وقد استدعى ذلك اجراء دراسة تشريحية وهستولوجية مفصلة لهذا الجهاز في أطوار النمو المتتالية للحشرة بدءا من المراحل الجنينية حتى الاطوار البالغة . وقد تبين ان يرقة الحشرة تحتوي على ثلاث عشرة عقدة عصبية ، واثناء النمو يندمج بعضها مع البعض ، كما يتخلل ويختفي بعضها الاخر ويظل بقيتها دون تغير . وبذلك يتكون هذا الجهاز في الحشرة الكاملة من ثمان عقد عصبية فقط .

ومن أهم ما لوحظ كذلك وجود عقدة عصبية لم يفطن احد لوجودها من قبل ، في هذه الحشرة ، وهي العقدة الجبهية ، وكذلك اندماج العقدة تحت المريئية مع المخ مما ينتج عنه تكوين عقدة عصبية مركبة كبيرة الحجم يخترقها المرىء وهو ما لم يتم وصفه من قبل ايضاً في دودة ورق القطن .