HISTOLOGY AND DEVELOPMENT OF ARGAS (ARGAS) HERMANNI
(IXODOIDEA: ARGASIDAE) SALIVARY GLANDS

By

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The anatomy and histology of Argas (Argas) hermanni salivary glands were studied during nymphal and adult development. The paired salivary glands consist of 2 alveolar types. Type I alveoli consist of several cells forming a striated peripheral zone around a clear central cell. These alveoli do not exhibit significant histological changes during development or after feeding but their size decreases after feeding and increases during the postfeeding period. The activity of this type is probably related to osmoregulation and fluid transport by the glands. Type II alveoli consist of 7 cell types and subtypes containing globules of various staining reactions,

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ABSTRACT

The anatomy and histology of Argas (Argas) hermanni salivary glands were studied during nymphal and adult development. The paired salivary glands consist of 2 alveolar types. Type I alveoli consist of several cells forming a striated peripheral zone around a clear central cell. These alveoli do not exhibit significant histological changes during development or after feeding but their size decreases after feeding and increases during the postfeeding period. The activity of this type is probably related to osmoregulation and fluid transport by the glands. Type II alveoli consist of 7 cell types and subtypes containing globules of various staining reactions.
Histology and development of Argas salivary glands

sizes, and/or shape. The alveolar size decreases after feeding and increases during the postfeeding period. After feeding, cell types a1, a2 and b do not exhibit great changes, while types c, d, e1 and e2 lose most or all of their secretary globules. Type a1 cells probably store a precursor material to replace a certain cell type(s) depleted during feeding. Vacuoles in type a2 and b cells may represent soluble metabolites or extracellular spaces after apocrine secretion of some globules. The globule chemical structure probably changes before feeding in type d and during feeding in type e1 and e2 cells. Cells depleted during feeding are replaced by new cells and/or new globules are synthesized in depleted cells during the postfeeding period.

INTRODUCTION

Tick salivary glands are considered to be one of the most suitable sites for multiplication of micro-organisms transmitted during tick feeding and causing diseases of man and animals. In this study, we investigate the anatomy and histology of Argas (Argas) hermanni Audouin salivary glands during nymphal and adult development.

MATERIALS AND METHODS

An A. hermanni colony, originating from ticks collected from a domestic pigeon (Columbia livia) house in Suez, Egypt, was maintained in an incubator at 28±1°C and 75% RH and domestic pigeon were used as hosts.

The salivary glands of unfed first- (N1) and second- instar (N2) nymphs, 2 weeks (2WN) and 6 weeks (6WN) postmoultng, of adult males and females, 1 month (1M) and 2 months (2M) postmoultng, and of fed N1 (FN1), N2 (FN2), males and females within 2 hr postfeeding were investigated. The dissected tick was flooded with 0.7% saline solution to which a drop of methylene blue was added to obviate the anatomy of the glands and their relationship with the other organs.

For histological examination, the dorsal cuticle was removed and the tick was fixed in Zenker-formol fixative. After dehydration in an ascending series of ethyl alcohol and double embedding in celloidin-paraplast, serial sections, 5-7 μm thick, were prepared and stained with Harries, haematoxylin and eosin. Surface areas of nuclei, cells and alveoli (referred to hereafter as size) were calculated as described by Marzouk et al. (1987). The means and standard errors were calculated for the size of each cell and alveolar type in all examined stages, and the data were compared using Student's t-test. When no significant difference was observed (P>0.05) between the nuclear dimension of a certain cell type within a certain stage, the mean and standard error was calculated for all the nuclei in that stage.

RESULTS

Anatomy

The paired salivary glands are anatomically similar in males, females and nymphs. They lie in the ventrolateral aspect of the body cavity and extend from near the capitular foramen anteriorly to the level of the third leg coxa posteriorly. Each gland consists of a translucent, grapelike cluster of alveoli. Methylene blue obviates 2 types of alveoli; type I stain deeply and form a narrow mass extending along the medial side of the anterior two thirds of the gland (Fig. 1) and type II stain light blue and constitute the rest of the gland.

The 2 main ducts traverse the entire length of the gland, emerge from the anterior end of each gland, pass through the capitular foramen on both sides of the pharynx and open posterolaterally into the salivarium. Type I alveoli open into short alveolar ducts which connect directly with the main duct (Fig. 2). Type II alveoli open into short alveolar ducts, 2 or more of which usually unite into one common lobular duct that connects with the main duct (Fig. 3).

Histology

The salivary duct and type I and II alveolar structure is similar in all the examined unfed stages.

Salivary ducts: The main duct wall consists of a 1-cell-thick epithelial layer lined with a cuticle possessing spiral thickenings (Fig. 2). The boundaries between the cells are indiscernible and their vesicular nuclei are rounded or oval. The lobular and alveolar ducts are narrower but structurally similar to the main duct (Fig. 3). The ducts in 6WN1, 2WN2, 6WN2, 1M and 2M adults may contain fine grayish purple granules while after feeding purple granules may be observed.

Type I alveoli: Each alveolus consists of several cells with indiscernible boundaries, resting on a delicate basement membrane (Fig. 4). These cells form a peripheral zone with striations almost perpendicular to the alveolar boundary where numerous very fine granules occur. In this zone, there are 6-9 small, vesicular, rounded to oval nuclei, with chromatin lumps adhering to the nuclear membrane. Only one large oval, vesicular, nucleus with coarse chromatin granules adhering to the nuclear membrane occurs in the central clear zone.
Type II alveoli: These alveoli have a circular or oval outline and consist of 5-12 cells surrounding a central lumen and lying on a fine basement membrane. These cells appear mostly triangular in outline with the triangle base at the alveolar periphery. Between the basal parts of these cells lie small interstitial cells with numerous fine processes extending to the alveolar lumen (Fig. 5). The cuticular lining of the alveolar ducts extends into the alveolus to form a valve-like structure at the alveolar base (Fig. 6). Except for the interstitial cells, the cells in these alveoli contain secretory globules. According to the staining reaction, size and/or shape of these globules, 5 main cell types are distinguished.

Type a cells: These cells are close to the alveolar duct and contain round, bright red, globules (Figs. 7, 8). Two subtypes may be distinguished, type $a_1$ with small globules, 0.4-1.5 um in diameter, and type $a_2$ with large, more or less rounded globules, 1.8-3.8 um in diameter. The nuclei are vesicular, rounded, and usually lie near the basal part of the cells.

Type b cells: These cells are usually near the alveolar duct. They are packed with cup-shaped purple globules (Figs. 7, 8). 1.0-4.6 um in diameter. The nuclei are rounded, compact and eccentric.

Type c cells: These cells usually lie away from the alveolar duct. They are triangular or oval, and contain rounded globules, 1.5-3.0 um in diameter. The globules possess a translucent peripheral zone, which may be colourless, purple or bluish purple, and a deep purplish blue central core, 0.4-1.5 um in diameter (Fig. 9). The globules are sometimes so closely packed together that their boundaries become indiscernible. The nuclei are rounded, compact and basally located.

Type d cells: When more than one of these cells are present in one alveolus, one may occur near the alveolar duct and the others among the other cell types. They contain more or less rounded globules, 2.3-6.1 um in diameter, which do not stain with haematoxylin or eosin (Figs. 8, 9). The globule contents appear homogeneous and the interglobular spaces contain a finely granular, weakly basophilic cytoplast. The nuclei are rounded, vesicular, and basally located.

Type e cells: These cells lie usually away from the alveolar duct. They contain blue or bluish-purple globules. Two subtypes may be distinguished according to the globule size (Figs. 7, 9). In type $e_1$, the globules are small, more or less rounded, measuring 1.0-3.8 um in diameter. In type $e_2$, globules are large, usually with an irregular outline, measuring 2.0-3.0 x 7.6-8.0 um in their largest dimensions. The nuclei in both subtypes are rounded, vesicular, and may be centrally or basically located.

Developmental changes in the salivary glands:

The salivary gland length is ca 0.694 mm in unfed $N_1$, 0.930 mm in unfed $N_2$ and 1.256 mm in unfed adults, the increase in gland length during growth from one stage to the following one being about X1.3.

Type I alveoli: These alveoli do not show significant histological changes but exhibit a distinct pattern of change in size during nymphal and adult development (Table 1). During the starvation period, no change (P>0.05) occurs in their dimensions, but after feeding their size decreases (P<0.01). However, the alveoli are larger (P<0.001) in unfed $N_2$ than in unfed $N_1$, and larger (P<0.01) in unfed adults than in unfed $N_2$. The alveolar size is similar (P>0.05) in males and females.

The stratified zone thickness remains unchanged (P>0.05) during nymphal development, but is greater (P<0.01) in adults than in nymphs (Table 2). Both the large and small nuclei do not exhibit a significant change (P>0.05) in size throughout nymphal and adult development (Table 2).

Table 1

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mean dimensions of alveoli (um) + S.E. (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type I</td>
</tr>
<tr>
<td>First-instar nymphs:</td>
<td></td>
</tr>
<tr>
<td>2-week-unfed</td>
<td>20.8±3.7x33.6±23.7&lt;sub&gt;a&lt;/sub&gt;</td>
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<tr>
<td>6-week-unfed</td>
<td>21.6±2.4x28.7±23.5a&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Fed</td>
<td>21.2±3.9x25.6±23.8&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>Type II</td>
</tr>
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<td>38.4±5.8x74.5±52.1&lt;sub&gt;ab&lt;/sub&gt;</td>
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<td>6-week-unfed</td>
<td>37.5±5.9x34.9±23.5&lt;sub&gt;b&lt;/sub&gt;</td>
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<tr>
<td>Fed</td>
<td>29.9±3.8x37.8±41.8&lt;sub&gt;bc&lt;/sub&gt;</td>
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<tr>
<td>Second-instar nymphs:</td>
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</tr>
<tr>
<td>6-week-unfed</td>
<td>26.2±4.1x35.6±23.4&lt;sub&gt;ab&lt;/sub&gt;</td>
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<tr>
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</tr>
<tr>
<td>Males:</td>
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</tr>
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</tr>
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<td>Fed</td>
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<tr>
<td>Females:</td>
<td></td>
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</tr>
<tr>
<td>2-month-unfed</td>
<td>30.0±4.0x36.5±32.6&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>Fed</td>
<td>28.1±4.9x39.1±32.6&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

* Figures followed by similar letters are not significantly different (P>0.05); those followed by different letters are statistically different (P<0.05 - P<0.001).
Fig. 2: L. S. in *A. hermanni* salivary gland showing type I alveolus opening into an alveolar duct (AD) connecting directly with the main salivary duct (MD) which is lined with cuticle possessing spiral thickenings (X 551).

Fig. 3: Section in *A. hermanni* salivary gland showing main (MD), lobular (LD) and alveolar (AD) ducts (X 551).

Fig. 4: Section in *A. hermanni* type I alveoli showing the large (LN) and small (SN) nuclei and the central (CZ) and peripheral (PZ) zones (X 1377).
Fig. 2: L. S. in *A. hermanni* salivary gland showing type I alveolus opening into an alveolar duct (AD) connecting directly with the main salivary duct (MD) which is lined with cuticle possessing spiral thickenings (X 551).

Fig. 3: Section in *A. hermanni* salivary gland showing main (MD), lobular (LD) and alveolar (AD) ducts (X 551).

Fig. 4: Section in *A. hermanni* type I alveoli showing the large (LN) and small (SN) nuclei and the central (CZ) and peripheral (PZ) zones (X 1377).
Figs. 5-9: Sections in type II alveoli in unfed *A. hermanni* (X 1385) showing (5) interstitial cell (arrow) (osmic acid) (6) valve-like structure (arrow) at the junction with the alveolar duct, (7) cells type a_1, a_2, b and e_2, (8) cells type a_2, b and d, and (9) cells type c, d, e_1 and e_2.

Fig. 10: Section in *A. hermanni* type II alveolus after feeding showing vacuoles in type a_2 and d cells (X 1385).
**Figures followed by similar letters are not significantly different (P<0.05); those followed by different letters are statistically different (P<0.05).**

### Type a1 cells
Type a1 cells do not change (P>0.05) in size during N1 starvation period but decrease (P<0.01) in size after N1 feeds (Table 3). No change (P>0.05) occurs in cells size during N1 postfeeding period and in 2WN2. However, these cells enlarge (P<0.01) in 6WN2 (Table 4), do not change (P>0.05) in size after N2 feeds or in 1M males (Table 5), and enlarge in 2 M males. Type a1 cells are larger (P<0.01) in 1M females than in fed N2 but do not change is size in 2 M females (Table 6). In both males and females, no change (P>0.05) occurs in cell size after feeding. Also, no change in shape or average type a1 cell number in each alveolus, or in secretory globule appearance occurs throughout nymphal and adult development. The mean diameter of their nuclei is 6.1±0.02 urn (range 5.8-6.4 urn).

### Type a2 cells
Type a2 cells increase (P<0.01) in size only during N1 prefeeding period (Table 3) and no change (P>0.05) in size occurs after N1, N2 and adults feed (Tables 3-6). However, these cells are larger (P<0.01) in 1M females than in N2 (Tables 4,6). In all stages, the average number of these cells in each alveolus remains unchanged after feeding. Also, their globules do not exhibit a change in appearance before or after feeding but a large vacuole may appear in these cells after feeding (Fig. 10). The mean diameter of their nuclei is 5.9±0.01 urn (range 5.8-6.0 urn).

### Type b cells
Type b cells do not change significantly (P>0.05) in size during development within each stage (Tables 3-6). However, they are larger (P<0.01) in N2 than in N1 and in females than in N2, but their size is similar (P>0.05) in males and N2. Although no change in average cell number per alveolus or in globule appearance occurs after nymphs and adults feed, a vacuole may appear in some of these cells (Fig. 10). The mean diameter of their nuclei is 5.3±1.03 urn (range 4.0-6.1 urn).

### Type c cells
Type c cells vary greatly in size within each stage examined. However, their mean size does not change during N1 and N2 starvation period (Tables 3, 4), but they are larger (P<0.01) in N2 than in N1. Their size is similar (P>0.05) in 1 M adults and N2 but is greater in 2M than in 1M adults (Tables 5, 6). After nymphs and adults feed, only one type c cell may be observed in a few alveoli. However, in N1 and N2, the discernible type c cells do not exhibit a significant change (P>0.05) in size (Tables 3, 4), while in adults they decrease (P<0.01) in size after feeding (Tables 5,6). In all fed stages, the globules in the discernible cells do not change in appearance. The mean diameter of their nuclei is 6.6±1.2 urn (range 4.0-8.1 urn).

### Type d cells
Type d cells do not change (P>0.05) in size during the nymphal and adult starvation period (Tables 3-6). In unfed N1, N2 and males, their size is similar (P>0.05) but is smaller (P<0.01) than in females. After nymphs and adults feed, a few smaller (P<0.05) cells of this type are discernible in only few alveoli.

While in 2WN1, the globule content appears nearly colourless and homogeneous, weakly basophilic granules may appear inside and between the globules in some cells in 6WN1, 2WN2, and 1M and 2M adults (Fig. 11). However, in fed ticks the few discernible cells do not contain such granules but may contain a large vacuole. The mean diameter of their nuclei is 5.3±1.03 urn (range 4.1 - 5.9 urn).

### Type e1 cells
Type e1 cells do not change (P>0.05) in size and their globules do not exhibit marked changes in appearance during the starvation period of any of the examined stages (Tables 3-6). Also, these cells are similar in size (P>0.05) in all unfed stages. However, after nymphal and adult feeding they decrease (P<0.01) in size. A vacuole or coarse granules may replace most of the globules (Figs. 12, 13) and only 1 or 2 cells of this type may be observed in most alveoli. The mean nuclear diameter of this type is 4.7±1.03 urn (4.1-6.2 urn).

### Type e2 cells
Type e2 cells do not change (P>0.05) in size during the starvation period in all stages (Tables 3-6). However, those in N2 are larger (P<0.01) than those in N2, similar (P>0.05) in size to those in males, and smaller (P<0.01) than those in females.

In 2WN1, type e2 cells contain only globules, while in 6WN1, coarse granules may replace most of the globules in some cells, and may occur inside the globules in others (Fig. 14). After feeding, the granules replace most or all of the globules in numerous cells. Other type e2 cells may contain only few typical globules and a large vacuole (Fig. 12) or empty-looking globules (Fig. 15). However, all these cells as well as those containing typical globules are similar in size to those in unfed N1.

In 2WN2 and in 1M adults, most type e2 cells contain typical globules, while a few cells contain the empty-looking globules or coarse granules inside and between the globules. Such cells are not observed in 6WN2 and 2M adults in which all type e2 cells contain only typical globules. However, the globules may stain differently in the same or different cells in unfed N2 and adults, being light purple or bluish purple (Fig. 16).

After N2 and adults feed, many type e2 cells similar to those observed in fed N1 are observed with no change (P>0.05) in cell size after feeding (Tables 4-6). However, in all examined stages, only 1-3 cells may be observed in each alveolus. The mean nuclear diameter in this type is 6.9±1.07 urn (range 6.1 - 10.1 urn).

In both nymphs and adults, many small cells measuring 10.1 ± 1.27 x 16.3±1.97 urn in their largest dimensions (range
Figs. 11.17: Sections in *A. hermanni* type II alveoli (X 1385) in (11) 6WN₁ showing type d cells with basophilic granules inside the globules, (12) N₂ after feeding showing a vacuole in type e₁ and e₂ cells, (13) N₁ after feeding showing a vacuole (arrow) and granules in type e₁ cells, (14) 6WN₁ showing coarse granules in type e₂ cells, (15) N₁ after feeding showing empty - looking globules in a type e₂ cell (arrow), (16) 2WN₁ showing globules with different shades of purple in type e₂ cell (arrow), and (17) N₁ after feeding showing cells lacking the globules (arrows).
Table 3
Changes in dimensions of the cell types in the granular salivary alveoli during development of *Argas hermanni* first-instar nymph.

<table>
<thead>
<tr>
<th>Stage</th>
<th>a1</th>
<th>a2</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e1</th>
<th>e2</th>
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<tbody>
<tr>
<td>2-week-unfed</td>
<td>14.7±1.03x21.0±4.15 a*</td>
<td>14.1±1.77x21.4±2.98 c</td>
<td>15.0±3.57x21.3±2.79 e</td>
<td>11.2±4.33x19.4±5.54 f</td>
<td>16.4±2.07x21.4±5.53 g</td>
<td>16.7±2.00x22.0±4.15 i</td>
<td>18.0±2.97x24.4±2.34 k</td>
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<tr>
<td></td>
<td>(14.0-16.0x16.0-26.0)</td>
<td>(10.0-20.0x18.0-26.0)</td>
<td>(6.0-20.0x12.0-36.0)</td>
<td>(14.0-20.0x16.0-30.0)</td>
<td>(12.0-22.0x16.0-30.0)</td>
<td>(12.0-22.0x20.0-28.0)</td>
<td></td>
</tr>
<tr>
<td>6-week-unfed</td>
<td>14.7±1.78x21.7±2.48 a</td>
<td>17.8±3.49x23.5±3.54 d</td>
<td>14.6±2.23x22.9±3.44 e</td>
<td>12.2±2.16x19.6±4.16 f</td>
<td>17.6±2.85x21.4±3.40 g</td>
<td>14.8±3.20x22.5±6.82 i</td>
<td>18.7±4.00x22.4±3.84 k</td>
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<td>(10.0-16.0x14.0-30.0)</td>
<td>(12.0-24.0x20.0-30.0)</td>
<td>(6.0-13.0x10.0-28.0)</td>
<td>(12.0-22.0x16.0-26.0)</td>
<td>(10.0-20.0x20.0-30.0)</td>
<td>(14.0-24.0x18.0-30.0)</td>
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<tr>
<td>Fed</td>
<td>11.4±1.70x16.6±1.97 b</td>
<td>17.7±2.61x23.3±2.94 c</td>
<td>13.5±2.54x20.2±2.89 e</td>
<td>12.7±3.99x19.1±3.90 f**</td>
<td>15.8±2.11x18.5±2.79 g**</td>
<td>13.7±3.02x20.7±3.02 j</td>
<td>19.7±1.59x23.3±2.48 k</td>
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<td>(8.0-14.0x14.0-20.0)</td>
<td>(10.0-20.0x16.0-26.0)</td>
<td>(6.0-20.0x10.0-28.0)</td>
<td>(12.0-18.0x16.0-22.0)</td>
<td>(6.0-18.0x16.0-28.0)</td>
<td>(18.0-22.0x20.0-28.0)</td>
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</tr>
</tbody>
</table>

*Figures followed by similar letters in the same column are not significantly different (P>0.05); those followed by different letters are statistically different. (P<0.05-P<0.01).

**Only few cells are discernible.

Table 4
Changes in dimensions of the cell types in the granular salivary alveoli during development of *Argas hermanni* second-instar nymph.

<table>
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<tr>
<th>Stage</th>
<th>a1</th>
<th>a2</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e1</th>
<th>e2</th>
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<tr>
<td>2-week-unfed</td>
<td>11.7±2.09x17.1±3.20 a*</td>
<td>18.1±2.96x25.9±4.35 c</td>
<td>17.3±3.35x24.7±3.58 d</td>
<td>13.5±4.22x19.0±5.60 e</td>
<td>16.0±3.58x20.0±3.80 f</td>
<td>16.9±2.66x22.5±4.1 h</td>
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<td>(8.0-14.0x12.0-24.0)</td>
<td>(14.0-26.0x20.0-34.0)</td>
<td>(12.0-24.0x16.0-32.0)</td>
<td>(8.0-20.0x10.0-26.0)</td>
<td>(10.020.0x14.0-26.0)</td>
<td>(12.0-20.0x16.0-30.0)</td>
<td>(16.0-26.0x24.0-32.0)</td>
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<td>16.4±2.07x23.6±2.49 c</td>
<td>17.1±2.52x22.9±3.65 d</td>
<td>15.2±2.76x20.9±5.91 e</td>
<td>15.0±2.76x20.0±1.79 f</td>
<td>14.4±2.55x22.4±2.95 h</td>
<td>23.3±4.50x26.6±4.48 j</td>
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<td>(12.0-20.0x14.0-22.0)</td>
<td>(14.0-20.0x18.0-30.0)</td>
<td>(10.0-21.0x14.0-30.0)</td>
<td>(8.0-30.0x12.0-32.0)</td>
<td>(12.0-18.0x18.0-22.0)</td>
<td>(16.0-20.0x18.0-24.0)</td>
<td>(18.0-30.0x20.0-32.0)</td>
</tr>
<tr>
<td>Fed</td>
<td>13.0±2.16x18.6±1.65 b</td>
<td>16.5±3.50x25.5±4.10 c</td>
<td>16.3±2.69x22.5±3.81 d</td>
<td>15.4±2.55x19.1±5.88 e**</td>
<td>13.3±2.46x17.8±2.48 g**</td>
<td>13.7±1.73x18.9±2.69 i</td>
<td>20.3±2.50x25.6±3.74 j</td>
</tr>
<tr>
<td></td>
<td>(10.0-16.0x16.0-22.0)</td>
<td>(10.0-24.0x26.0-32.0)</td>
<td>(10.0-22.0x26.0-30.0)</td>
<td>(6.0-24.0x12.0-28.0)</td>
<td>(12.0-20.0x14.0-22.0)</td>
<td>(12.0-16.0x16.0-22.0)</td>
<td>(16.0-24.0x20.0-30.0)</td>
</tr>
</tbody>
</table>

*Figures followed by similar letters in the same column are not significantly different (P>0.05); those followed by different letters are statistically different. (P<0.05-P<0.01).

**Only few cells are discernible.
### Table 5
Changes in dimensions of the cell types in the granular salivary alveoli during development of male *Argas hermanni*.

<table>
<thead>
<tr>
<th>Stage</th>
<th>a₁ (μm) ± SE (range)</th>
<th>a₂ (μm) ± SE (range)</th>
<th>b (μm) ± SE (range)</th>
<th>c (μm) ± SE (range)</th>
<th>d (μm) ± SE (range)</th>
<th>e₁ (μm) ± SE (range)</th>
<th>e₂ (μm) ± SE (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-month-unfed</td>
<td>15.5±2.84×19.1±2.25 a*</td>
<td>16.6±2.63×23.1±3.88 c</td>
<td>16.2±2.74×22.0±1.63 d</td>
<td>12.0±2.00×19.5±4.20 e</td>
<td>15.7±2.43×19.4±1.90 f</td>
<td>14.4±3.57×21.4±3.64 h</td>
<td>18.6±2.12×26.6±2.95 j</td>
</tr>
<tr>
<td>2-month-unfed</td>
<td>15.3±2.10×22.7±2.30 b</td>
<td>15.4±3.67×25.9±4.05 c</td>
<td>15.7±2.15×24.5±5.46 d</td>
<td>15.4±1.77×22.4±2.87 f</td>
<td>16.3±4.59×20.0±3.02 f</td>
<td>16.8±3.90×20.0±3.02 f</td>
<td>21.5±2.98×26.5±3.82</td>
</tr>
<tr>
<td></td>
<td>(10.0-20.0×18.0-30.0)</td>
<td>(12.0-24.0×20.0-34.0)</td>
<td>(10.0-24.0×12.0-32.0)</td>
<td>(10.0-22.0×16.0-24.0)</td>
<td>(14.0-22.0×18.0-24.0)</td>
<td>(18.0-28.0×22.0-32.0)</td>
<td></td>
</tr>
<tr>
<td>Fed</td>
<td>15.3±3.50×20.4±3.20 b</td>
<td>15.4±3.87×23.2±3.76 d</td>
<td>15.3±3.50×20.4±3.20 b</td>
<td>15.4±3.87×23.2±3.76 d</td>
<td>15.4±3.87×23.2±3.76 d</td>
<td>15.4±3.87×23.2±3.76 d</td>
<td>18.9±2.66×28.6±5.74 j</td>
</tr>
</tbody>
</table>

* Figures followed by similar letters in the same column are not significantly different (P>0.05); those followed by different letters are statistically different. (P<0.05-P<0.01).

** Only few cells are discernible.

### Table 6
Changes in dimensions of the cell types in the granular salivary alveoli during development of female *Argas hermanni*.

<table>
<thead>
<tr>
<th>Stage</th>
<th>a₁ (μm) ± SE (range)</th>
<th>a₂ (μm) ± SE (range)</th>
<th>b (μm) ± SE (range)</th>
<th>c (μm) ± SE (range)</th>
<th>d (μm) ± SE (range)</th>
<th>e₁ (μm) ± SE (range)</th>
<th>e₂ (μm) ± SE (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-month-unfed</td>
<td>14.9±2.80×23.7±4.07 a*</td>
<td>20.0±4.81×29.0±4.92 b</td>
<td>17.2±2.15×29.2±7.68 c</td>
<td>12.6±2.99×18.9±4.87 d</td>
<td>23.0±3.21×28.3±4.83 f</td>
<td>18.7±3.93×26.0±2.53 h</td>
<td>23.3±5.24×30.4±4.72 j</td>
</tr>
<tr>
<td></td>
<td>(12.0-20.0×20.0-32.0)</td>
<td>(12.0-30.0×22.0-36.0)</td>
<td>(12.0-22.0×18.0-46.0)</td>
<td>(8.0-20.0×12.0-30.0)</td>
<td>(18.0-28.0×22.0-38.0)</td>
<td>(12.0-22.0×22.0-28.0)</td>
<td>(20.0-38.0×22.0-40.0)</td>
</tr>
<tr>
<td>2-month-unfed</td>
<td>13.2±2.71×24.2±4.14 a</td>
<td>17.1±2.43×25.2±4.58 b</td>
<td>17.6±2.95×26.0±3.65 c</td>
<td>15.7±3.80×14.6±3.6 e</td>
<td>25.0±3.21×25.7±3.3 f</td>
<td>16.0±4.90×24.0±1.63 h</td>
<td>22.3±4.83×29.3±4.65</td>
</tr>
<tr>
<td></td>
<td>(10.0-18.0×18.0-30.0)</td>
<td>(14.0-20.0×20.0-32.0)</td>
<td>(14.0-22.0×20.0-30.0)</td>
<td>(10.0-22.0×20.0-30.0)</td>
<td>(16.0-26.0×18.0-30.0)</td>
<td>(10.0-20.0×22.0-26.0)</td>
<td>(16.0-30.0×24.0-36.0)</td>
</tr>
<tr>
<td>Fed</td>
<td>13.8±2.73×20.7±5.13 a</td>
<td>16.8±2.48×26.4±3.56 b</td>
<td>17.1±3.02×26.4±3.4 c</td>
<td>13.8±2.49×21.7±2.8 d**</td>
<td>15.7±3.45×21.7±2.4 g**</td>
<td>14.7±2.34×20.5±2.96 i</td>
<td>22.9±2.61×28.5±4.01 j</td>
</tr>
<tr>
<td></td>
<td>(8.0-18.0×14.0-30.0)</td>
<td>(12.0-20.0×22.0-32.0)</td>
<td>(12.0-22.0×22.0-34.0)</td>
<td>(8.0-21.0×10.0-30.0)</td>
<td>(12.0-20.16.0-28.0)</td>
<td>(10.0-18.0×18.0-28.0)</td>
<td>(17.0-24.0×18.0-38.0)</td>
</tr>
</tbody>
</table>

* Figures followed by similar letters in the same column are not significantly different (P>0.05); those followed by different letters are statistically different. (P<0.05-P<0.01).

** Only few cells are discernible.
Histology and development of Argas salivary glands

8.0 - 12.1 x 14.2 - 18.0 um) are observed after feeding (Fig. 17). These cells are devoid of globules, their cytoplasm is basophilic, and the nucleus occupies most of the cell; these cells may be type c, d, e1 or e2 cells exhausted during feeding.

DISCUSSION

The general structure of A. hermanni salivary glands and ducts conform to that of other argasid ticks (Roshdy, 1966; 1972; Balashov, 1968; Sonenshine and Gregson, 1970; Guirgis, 1971; Chinery, 1974; El Shoura 1985). The cuticular spiral thickening probably aid dilation and collapse due to pharyngeal movements and flow of the saliva in the duct similar to that in F. microplus (Megaw and Beadle, 1979) and Amblyomma americanum (Krolak et al., 1982).

Type I alveoli in A. hermanni are histologically similar to those of other argasid (Balashov, 1968; Sonenshine and Gregson, 1970; Chinery, 1974; Rosshdy, 1972; Rosshdy and Coons, 1975) and ixodid species (Till, 1961; Balashov, 1968; Chinery, 1965; Coons and Rosshdy, 1973; Megaw and Beadle; 1979; Meredith and Kaufman, 1973; Binnington, 1978; Binnington et al., 1983). Kirkland (1971) considered this type in Haemaphysalis leporispalustris to be unicellular. On the other hand, in A. arboreus a central cell with a clear cytoplasm was described to be connected directly with the alveolar duct (Rosshdy and Coons, 1975). In Am. americanum, the central cell made contact with the duct lumen through an opening of a "constrictor cell" which was considered to store fluid prior to secretion (Krolak et al., 1982). The peripheral cells, with their basal membrane infoldings, were considered to resemble the avian salt cells (Bloss, 1968) and to be associated with osmoregulation and fluid transport by the salivary glands (Sauer et al., 1974; Hsu and Sauer, 1975; Needham and Sauer, 1975; Binnington, 1978).

Type I alveoli in A. hermanni probably participate in fluid secretion during the feeding process, since they decrease in size after feeding, but with no discernible structural changes. Guirgis (1962) and Khalil (1972) did not observe postfeeding changes in A. arboreus type I alveoli but Chinery (1974) observed histological changes in A. persicus alveoli. Similarly, while El Shoura (1985) reported no postfeeding ultrastructural changes Dhzaharov (1965) reported extensive changes in Ornithororos moubata alveoli. Also, while type I alveoli in B. microplus (Binnington, 1978) and Haem. leporispalustris (Kirkland, 1971) showed no postfeeding histological or ultrastructural changes, those in H. asiaticum (Dzhaharov, 1965), Am. americanum (Barker et al., 1984 and Haem. longicornis (Yanagawa et al., 1987) exhibited extensive changes.

The increase in type I alveolar size in unfed N2 and adult A. hermanni is probably associated with the general growth of the tick body as well as storage of secretory material. In adults, the increase in alveolar size is associated with elongation of the membrane infoldings which probably contributes to the functional efficiency of these alveoli.

In A. hermanni, 7 cell types and subtypes are observed, a number greater than that previously described in other argasids. This difference may be attributed to variation among the species or the use of different fixatives and staining techniques. Also cells containing globules of different sizes and exhibiting the same staining reaction were considered to be of the same type. In support of the latter assumptions, Robinson and Davidson (1913) described only one type in A. persicus alveoli, while Chinery (1974) observed 2 types and Rosshdy (1972) observed 3 types. Chinery (1974) considered cells with granules of 3 different sizes, but staining (with haematoxylin-eosin) more or less similarly, as well as others containing colloid-like masses to belong to a single cell type. This author suggested that these cells represented different stages in salivary secretion elaboration. On the other hand, Rosshdy (1972) considered these cells to belong to 3 distinct types as they showed different staining reactions with Mallory triple and Giemsa stains. Histochemical studies in A. hermanni are underway to ascertain the chemical characteristics of the 7 cell types and subtypes.

The interstitial cells in A. hermanni type II alveoli were observed in many tick species. In O. moubata (El Shoura, 1985), these cells developed during feeding to form extensively branched canaliculi similar to those of transporting epithelial cells and were considered responsible for elimination of excess water in the blood meal (Meredith and Kaufman, 1973; Coons and Rosshdy, 1979, 1981; Binnington, 1978; Megaw and Beadle, 1979). However, Coons and Rosshdy (1973) suggested that these cells may have a supportive function or may differentiate into new secretory cells.

A. hermanni type II alveoli do not exhibit a significant change in size during the starvation period except in females in which they increase in size, probably owing to increased storage of secretory material. The postfeeding decrease in size is probably associated with loss of the globules of many cells. Guirgis (1971) and Khalil (1972) observed numerous globule-free cells of greatly reduced size after A. arboreus fed. In contrast to these findings, Chinery (1967) reported no change in granule appearance or staining properties during or after A. persicus feeding.

Type II alveoli in A. hermanni increase in size in unfed N2 and females. This is probably due to globule restoration in cells depleted during feeding, and/or formation of new cells. In nymphal A. arboreus, Khalil (1972) observed formation of new globules 3 days after feeding in 2 cell types which lost their globules during feeding. These cells reached a maximum size 5 days after moulting to the following stage. Globule formation may take place in the Golgi cisternae and adjacent rough endoplasmic reticulum as described in A. arboreus (Coons and Rosshdy, 1981) and O. moubata (El Shoura, 1985). Delay of alveolar growth in A. hermanni males may be related to the male sexual activity since the gonads develop considerably in male-producing nymphs (Balashov, 1968); argasid males are engaged in mating shortly after moulting which probably divert the greatest part of the body anabolic activity to the gonads.

Type a1 cells do not exhibit a significant change throughout development except for the decrease in size after the N1 feeds. It may be presumed that this type store a precursor secretory material to replace a certain cell type(s) depleted during feeding. Further investigations are required to verify this assumption.

In 6WN2 and females only, type a2 cells change in size during development. Also, type b cells increase in size is limited to unfed N2 and females. Both type do not exhibit a change after feeding except for the presence of a vacuole in some cells. These vacuoles may represent soluble metabolic products which are washed out during fixation and dehydration, or they may represent extracellular spaces surrounded by a thin membrane similar to those formed in some cells after A. arboreus feeding owing to apocrine
secretion (Coons and Roshdy, 1981). Such assumptions require further investigation.

Changes in type c and d cells strongly suggest that most of these cells release all of their globules during nymphal and adult feeding and some release part of their globules during adult feeding. Basophilic granules appearing inside and between the globules in type d cells in unfed ticks and cells may represent globule degradation globule staining properties in type e 2 cells may represent these cells release all of their globules during nymphal and released during feeding.

Changes in type e 1 cells suggest that the globules change into coarse granules while most of the cells release all or most of their content during feeding. However, changes in type e 1 cells may represent globule degradation into coarse granules during the starvation period as well as during feeding when most of these cells release all of their secretory content. Some cells may release these granules afterwards which appear in the salivary duct lumen in unfed ticks. Difference in the globule staining properties in type e 2 cells may represent different steps in the synthesis or degradation of their contents.

Replacement by new cells or replenishment of depleted type c, d, e 1 and e 2 cells with new globules occurs during the nymphal postfeeding period. In type c and e 2 cells, secretory material storage probably continues during the prolonged starvation period.

Cell types c, d, e 1 and e 2 in A. hermanni may release their globules by apocrine or merocrine secretion. During A. arbores (Coons and Roshdy, 1981) and O. moubata (El Shoura, 1985) feeding, the granules of some cell types are released by an apocrine secretion while those of other types are released by exocytosis. Merocrine and apocrine secretions are of significant adaptive value for the rapid and repeated feeding of argasid ticks since cells remain sufficiently intact to synthesize new granules for the next feeding.

During the different phases of development, no change in size of nuclei in type I and type II alveoli. This may reflect a continuous cell activity throughout A. hermanni development.

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REFERENCES


Histology and development of Argas salivary glands


