VII. ORGANOCYGENY
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(A) The alimentary canal and associated glands.

In the beginning, the alimentary canal appears as the invaginations of the ectoderm, first in the anterior region as stomodaenum and then in the posterior region as proctodaenum.

The stomodaenum first makes its appearance in about twenty-six hours. At this time there appears a small shallow pit-like depression in the anterior one third of the embryo (See Fig. 42). By the end of thirty hours, a small cup-like structure develops in this region which is the stomodeal invagination. After thirty-six hours, it forms an elongated dorso-posterior tubular invagination (Fig. 52). The cells of the tubular stomodaenum are continuous with the ectoderm of the embryo. The stomodaenum continues to grow and forms an elongated tube which is oesophagus (Fig. 53). The oesophagus is thickened where it joins the mid-gut and a bulbous crop is developed in that region. In about eighty-four hours, a continuous membrane is seen surrounding completely the yolk mass near the junction of stomodaenum and mid-gut (Fig. 54). At the same time, in the anterior region, a structure consisting of hexagonal cells is formed (Fig. 55). As the development of the embryo proceeds, this region develops into hypopharynx. The hypopharynx is of special interest in the development of the stomodaenum. It is an unusual modification of the stomodaenum which does not occur commonly in insects. The hypopharynx arises by the fusion of the sternites of the three gnathal segments.
It consists of a simple and single lobed structure. The inner wall of the hypopharynx develops chitinous lining which is continuous with the outside ektodermal chitinous layer (Fig. 56). The inner wall of ventral side of the hypopharynx contains longitudinal chitinous rods enclosing narrow tubular spaces between them. These small tube-like spaces appear as minute pores in the transverse section. The inner wall of the dorsal side of the hypopharynx forms a chitinous lining with wavy margins. Just below the hypopharynx, a paired mandibular gland develops from the invaginations in the mandibular segment (Fig. 57). The cells of the mandibular glands are large, deeply stained and vacuolated (Fig. 58). These cells divide mitotically. A short duct is developed from each of these glands which joins and opens in the oral cavity by a common duct.

Before thirty-six hours, the mesenteron layer starts differentiating from the median endomesoderm. It arises independently of stomodaeum and proctodaeum (Fig. 58; see also Figs. 62 and 63). It is a thin, delicate and unicellular layer of elongated cells with oval nuclei. The yolk nuclei have migrated to the periphery and formed a continuous syncytial layer surrounding the yolk mass. As the development of the embryo proceeds to the dorsal side, the mesenteron layer also develops towards the dorsal side. After the dorsal closure of the embryo this mesenteric layer encloses the yolk mass completely (Fig. 60). Thus a unicellular layer of the mid-gut is formed. As the mesenteric layer develops, the mesodermal layer also develops along with it. At this stage the yolk mass
is already invested by a very thin, delicate and syncytial layer formed by the peripheral migration of the yolk nuclei. Thus two distinct layers are seen during the process of dorsal closure of the mid-gut. In later stages the yolk nuclei degenerate and the yolk-sac layer is not visible. Thus it is obvious that the mid-gut is endodermal in origin and formed from the median endodermal strand.

The proctodaeum appears at about the thirtieth hour as a shallow invagination near the posterior end of the germ band (Fig. 61). This invagination proceeds in the antero-dorsal direction. The posterior mesenteron rudiment is not formed near the developing region of the invagination. In thirty-six hours, it is quite deep and horizontal (Fig. 62). The proctodeal invagination at this stage is situated on the tenth abdominal segment. During the shortening of the embryo the invagination becomes U-shaped (Fig. 63). The mid-gut forms a S-shaped curvature with the proctodaeum. A transverse section passing through this region shows three conspicuous protrusions of the inner wall (Fig. 64). Their precise function remains to be ascertained. An account of the malpighian tubules has been treated separately (See infra vide).

**Malpighian tubules**

Six malpighian tubules arise as outgrowths of the proctodeal wall at a distance of 0.02 mm. from its junction with the mid-gut in the seventy-second hour, when the mid-gut development is complete (Figs. 65 and 66). Each tubule arises separately and no common vesicle connects them to the alimentary canal.
The area where the malpighian tubules originate becomes slightly pale from the rest of the proctodeal wall. No indication of the interstitial ring of endodermal cells at the junction of mid-gut and hind-gut has been observed. This supports the concept of the ectodermal origin of the malpighian tubules. Of the six malpighian tubules, two pairs lie ventrally, while the third pair is dorsal in position. The cavities of the malpighian tubules are continuous with the proctodeal cavity. As the tubules develop they become enveloped by a nucleated sheath which forms the musculature. The nuclei of the sheath are elongated (Fig. 67). The mesodermal cells continue to grow along with the proctodeal invagination. At the seventy-eighth hour, the alimentary canal becomes S-shaped. The two ventral pairs of the malpighian tubules grow towards the posterior side while the third dorsal pair turns towards the anterior side. The diameter of the tubule is 0.03 m.m. and there are six cells in the transverse section of the tubule. In the eighty-four hours, however, the diameter of the tubule and number of cells in cross section remain constant. In the ninety-six hours, the elongation of the malpighian tubules takes place. The diameter of the tubule is slowly reduced and five cells are seen in the cross section of the tubule. The cells of the tubules are lined internally by chitin in the proximal part of the malpighian tubules (Fig. 68). At the hundred and eighth hour, there is no decrease in the diameter of the tubules but the number of the cells as seen in the transverse section of the tubule are constant. There is further
increase in length of the tubules. In the hundred and twenty hours, the diameter of the tubules is reduced to 0.02 mm, but the number of the cells is found to be still constant in the cross-section. The tubules, however, are increased in length. As the embryo advances in age the diameter and the number of the cells in cross section of the tubule remain constant.

From these observations, it is clear that the cell division, rearrangement and their enlargement result in increase in the length of the tubules. Table 2 gives the details of the observations made on the embryonic growth of the malpighian tubules.

78 0.030 6 0.010 The alimentary canal becomes S-shaped and the two ventral pairs of malpighian tubules grow towards the posterior end while the mid-ventral pair turns to the posterior side. The tubules are elongated.

(B) The nervous system.

The nervous system is formed as a result of differentiation of specialized cells of the ectoderm. These cells are the neuroblasts. The differentiation of the neuroblasts takes place during the development of the embryo in about twenty-four hours. The neuroblasts become differentiated by their large size, nuclei and cytoplasm staining lighter than the adjoining cells. Two to four such neuroblasts are seen in the transverse section of the embryo at this stage (Fig. 69). Neuroblasts enlarge and are withdrawn inside, forming a continuous layer, while the smaller cells of the ectoderm constitute the dermato-blasts (Fig. 70). The ectoderm at this period presents a pair of thickenings along the sides of the mid-ventral line. Thus along the entire length of the embryo two continuous cords of

(Cont. p. 47)
Table 2.

Observations recorded on the malpighian tubules during the embryonic development of *D. indicus*. Over six sections were examined for each stage and no variations were noticed.

<table>
<thead>
<tr>
<th>Age of embryos (hrs.)</th>
<th>Diameter of tubules (m.m.)</th>
<th>Number of cells in transverse section</th>
<th>Thickness of cells (m.m.)</th>
<th>Mode of development</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>0.030</td>
<td>6</td>
<td>0.010</td>
<td>The six malpighian tubules make their appearance as outgrowths of the proctodaeum near the junction of the proctodaeum with mid-gut.</td>
</tr>
<tr>
<td>84</td>
<td>0.030</td>
<td>6</td>
<td>0.010</td>
<td>The alimentary canal becomes S-shaped and the two ventral pairs of malpighian tubules grow towards the posterior side while the third dorsal pair turns towards the anterior side. The tubules are elongated.</td>
</tr>
<tr>
<td>96</td>
<td>0.025</td>
<td>5</td>
<td>0.015</td>
<td>The diameter of the tubule and number of cells remain constant. The tubules are increased in length.</td>
</tr>
<tr>
<td>108</td>
<td>0.025</td>
<td>4</td>
<td>0.015</td>
<td>The diameter of the tubule is gradually decreased. The number of cells in cross section is reduced. The cells are enlarged and lined internally by chitin.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The diameter remains same but the number of cells in cross section is reduced. The tubules are increased in length.</td>
</tr>
</tbody>
</table>
The number of cells remains the same. The diameter of the tubule is decreased. The cells are enlarged. There is increase in length of the tubules.

The diameter and number of cells in cross section are constant. The cells are enlarged. Tubules are increased in length.
the neuroblasts are seen. These are the lateral cords. Neuroblasts of the lateral cords give rise to the nerve cells which are smaller and deeply stained.

During the subsequent development, the two lateral cords enlarge on either side of the mid-ventral line of the embryo. Due to their enlargement a neural groove appears between them (Fig. 71).

Above the neural groove, in addition to the lateral cords, a narrow median cord can be seen. The cells of the median nerve cord are narrow and columnar. In this region there is no differentiation of dermatoblasts. The cells of the median cord constitute a part of the nerve ganglion between the unfused halves of either side of the ganglion (Fig. 72).

As these changes are taking place the embryo becomes divided into definitive segments in the head, thorax and abdominal region. This results in a segmental arrangement of ganglia (Fig. 73). In the head region three centres which contribute to the brain formation can be seen. These are the protocerebral, deutocerebral and tritocerebral ganglia. The protocerebral and deutocerebral ganglia arise pre-oraly while the tritocerebral ones arise in between the mandibular and deutocerebral ganglia.

During the subsequent development the nerve cords become separated from the ectoderm. The ganglia become well consolidated and the two from either side come very close to fuse together giving rise to the segmental ganglion. Lateral nerves arise from the segmental ganglion in each segment (Fig. 74).
Anterior and posterior ganglionic commissures can be seen in the horizontal section (Fig. 75). In the intersegmental regions, although the lateral cords lie close to one another, they retain their individuality and constitute the paired longitudinal connectives between the preceding and succeeding ganglia (See Figs. 75 and 76).

The sub-oesophageal ganglion is formed by the fusion of three ganglia of the gnathal segments: mandibular, maxillary and labial. These three ganglia of the respective segments and separate from the ectoderm, draw closer together, fuse to develop sub-oesophageal ganglion. The formation of the sub-oesophageal ganglion can be seen in the longitudinal section (Fig. 77). The sub-oesophageal commissure is formed from the ganglion itself.

All the three thoracic i.e. pro-, meso- and meta-thoracic ganglia remain separate throughout the development. But in the abdomen the last three segmental ganglia fuse together and only eight abdominal ganglia are seen in the later stages (Fig. 75). Thus, the original number ten is reduced to eight.

Brain formation takes place by the differentiation of neuroblasts and dermatoblasts. There is no noticeable difference between the neuroblasts of brain and those of ventral nerve cord. All the three i.e. protocerebral, deutocerebral and tritocerebral ganglia become differentiated when the ventral nerve cord ganglia are specialised. The protocerebral is the largest of the three ganglia and occupies a position at the base of the antenna. The tritocerebral ganglion is the smallest
of the three and is in continuation with the deutocerebral ganglion in front and mandibular ganglion behind. The ganglia of the brain retain their connections with the ecto-dermal wall for a longer time and their subsequent separation is brought about very late in the embryonic life (Fig. 79). The circum-oesophageal connective develops from the tritocerebral ganglion of either side and connects the brain with the sub-oesophageal ganglion (Fig. 80).

In the later development the head ganglia subsequently become massive and eventually separate from the ectoderm. The protocerebral and deutocerebral ganglia after their separation from ectoderm are widely separated from each other. As the consolidation of the head capsule takes place protocerebral ganglia occupy most of the head capsule. The two protocerebral lobes increase enormously in size, so that the two lobes lie close together. A well defined supra-oesophageal commissure is seen connecting the two lobes of brain. This commissure is formed by the respective ganglia. A deep mid-dorsal ectodermal groove can be seen at this time (Fig. 81).

At about the forty-eighth hour, a small portion of the lateral ectoderm forming the optic ganglion anlage sinks below the general level of the protocerebral lobe on either side (See Fig. 79). In the fifty-four hours, this region separates from the adjoining tissue (Fig. 82). Thus the optic ganglion arises by an invagination on either side. During the subsequent development the dermatogen layer separates from neurogen portion of the brain. The optic ganglion thus formed contains neuroblasts which arrange themselves to form mitotically
dividing two to three cell rows. Rapid divisions result in the formation of small crowded ganglion cells distinguished from the peripheral cells. These small ganglionic cells form nerve fibres which become continuous with the protocerebral lobes. When this differentiation is taking place some of the peripheral cells of the optic ganglion underlying the stemmata give out optic nerve fibres.

The stomogastric nervous system.

The stomogastric nervous system arises from the median three evaginations in the dorsal stomodeal wall before the eighty-fourth hour (See Fig. 55). In the evaginated portion the cells of the stomodeum lose their epithelial nature to become the large ganglion cells which form neuropyle over the stomodeum (Fig. 83). Of the three evaginations the first evagination is situated close to the labrum and gives rise to the frontal ganglion. The frontal ganglion separates from the stomodeal wall in the further development and becomes conspicuous. The second evagination gives rise to an elongate discrete hypocerebral ganglion. The small ventricular ganglion is formed from the third evagination of the stomodeal wall. The recurrent nerve is formed from the frontal ganglion by the cells which extend posteriorly along the dorsal wall of the stomodeum. As the development of the head advances the frontal ganglion shifts to lie well in front of the brain (See Fig. 56).

Neurilemma.

Neurilemma is a very delicately thin cellular membrane.
which invests the ventral nerve cord, brain and the stomo-

gastric nervous system. Median cord of the intersegmental

region participates in the formation of the neurilemma of the

ganglia of the ventral nerve cord (Fig. 84). The cells are

elongated with spherical nuclei. The neurilemma of the brain

and stomagastric nervous system is derived from their peri-
hedral cells.

(C) The tracheal System.

The tracheal system consists of invaginations as well as

invaginations of the body wall of the embryo. The invagina-
tions develop and form tracheal anastomosis in the body while

the invaginations will give rise to the tracheal gills. At

about the seventy-eighth hour, when the development of the

appendages is well progressed, paired invaginations of the ecto-
derm appear. No invagination appears in the head and prothoracic

region of the embryo. There are two, meso- and meta-thoracic

ectodermal invaginations in the thoracic region. In the

abdomen the first nine abdominal segments bear such ectodermal

invaginations. The last abdominal segment does not bear any

tracheal invagination. Thus, all the eleven pairs of tracheal

invaginations arise on the lateral ectoderm.

At first the invaginations arise as shallow in-pushings

of the ectodermal wall but soon they penetrate and end blindly

to form cup-like structures (Fig. 85). The ectodermal cells

of the invaginations are deeply stained and can be easily

distinguished. As the development of the embryo proceeds the

tracheal invaginations turn towards the dorsal side (Fig. 86).
The invaginations continue to grow to dorsal side to reach the dorso-lateral position and their apertures become gradually smaller in size to get ultimately plugged by the surrounding ectodermal wall. Thus a closed tracheal system is formed. Each invagination gives rise to anterior and posterior diverticulae near the dorso-lateral position. The posterior diverticula of the previous segment grows posteriorly while the anterior diverticula of the next segment grows towards the anterior side. Both the diverticulae meet each other in all the respective segments and form a dorso-lateral tracheal trunk on either side (Fig. 87). Further development of the tracheal branches is due to progressive formation of diverticulae. As the embryo grows the cells of the tracheae also increase by multiplication. But the number of cells does not appear to increase in the transverse sections. Hence, the tracheal tubes appear to grow by cell division and rearrangement.

At about the hundred and fourteenth hour, cuticular lining is secreted by the cells of the tracheal tubes and wavy bands of the cuticular intima are seen longitudinally running along the length of the embryo (Fig. 88). The gas appears during the hundred and twenty hours in the dorso-lateral tracheal trunks in the anterior region of the embryo. The entire system is filled up with the gas within less than half an hour.

Each of the appendages of the first nine segments are supplied by a fine tracheal tube and therefore is called as an abdominal gill (Fig. 89).
(D) **The tentorium.**

Paired ectodermal tubular ingrowths appear on the third day at the bases of the antennae just anterior to the mandibles and at the posterior angles of the first maxillae (Fig. 90). Because these invaginations are tubular a transverse canal is formed across the floor of the head capsule (Fig. 91). Later, these invaginations cross to form a X-shaped body. Chitinization of the tentorium takes place on the fourth day. Tentorium supports the brain and helps for attachment of cephalic muscles.

(E) **The oenocytes.**

At the forty-second hour, certain cells beneath the lateral ectoderm become much enlarged in the abdominal region (See Fig. 72). Their non-vacuolated cytoplasm is weakly stained. Oenocytes measure on an average 8 μ in diameter. Their nuclei are large, spherical and deeply stained. The chromatin material is sparse and granular. Oenocytes appear in metamerically arranged groups along the sides of the first nine abdominal segments. Their regular arrangement is lost and become distributed as free cells in the thorax and abdominal region as the embryo advances in age. Some of them move in the abdominal appendages (See Fig. 89). The oenocytes become more round, as the embryo advances in age (Fig. 92). Oenocytes have not been observed in dividing state at any stage of the development. Their nuclei become densely packed with dark staining granules which appear identical with the chromatin granules when the embryonic cuticle is formed. Their role in such activities has been already well established.
(F) The sense organs (stemmata).

The embryo of *D. indicus* has on each side of the head six functional lateral ocelli or stemmata. They are dorso-lateral in position. Six ectodermal invaginations appear on either side in the sixty-sixth hour. Each of these invaginations forms a cup-like structure (Fig. 93). From this cup-like structure the respective parts of the stemma are differentiated.

Each ocellus has the form of a cellular sac beneath the lenticular cornea (Fig. 94). The lumen of the cellular sac is a narrow cleft through long axis of the ocellus. The cells of the distal part of the ocellular sac turn inward from the epidermis and form a pigmented iris from which the secondary retinal cells continue towards the deeper part of the ocellus. The retinal cells include vertical median cells. Both sets of the retinal cells contain rhabdoms at their free ends, those of the vertical cells forming two rows at the bottom of the sac. The convergent peripheral retinal cells are directed towards one another in the lateral wall of the ocellus beyond the vertical rhabdom. The tapering proximal ends of the retinal cells come together to form ocellar nerve.

(G) The mesoderm and coelomic sacs.

(1) The Mesoderm.

During the process of gastrulation a gastular tube with a distinct lengthwise lumen is formed along the germ band. The walls of the gastrular tube are made up of columnar epithelial cells. The dorso-ventral flattening of the gastrular tube
gives rise to the lower layer or the endomesoderm. The cells of the endomesoderm are polyhedral with granular cytoplasm. The nuclei of the cells are large and spherical. The endomesoderm becomes conspicuous by the rapid division of cells. The cells begin to spread out laterally except for certain regions of the head lobes (Fig. 93). The endomesoderm spreads unevenly to present an irregular appearance in the thoracic region (Fig. 96), while in the other regions the cells have migrated laterally to form a uniform band of two layered cells.

At about the twenty-fourth hour, the mesodermal cells accumulate to form three to four layers in the segmental region at the lateral edges of the germ band (Fig. 97). These are the future somites.

Three arbitrary divisions of the segmental mesoderm have been considered viz. median, sub-somitic and somitic. The median mesoderm lies above the future nerve cord and below the endoderm layer. This is the only part of the mesoderm which does not undergo segmentation. The sub-somitic is that portion which lies between the somitic and median strip. The somitic mesoderm lies laterally. The somitic and sub-somitic mesoderm are histologically indistinct.

Intersegmentally, the somitic mesoderm becomes severed so that the adjacent somites are no longer connected. Thus when the segmentation is complete mesoderm is not seen in the intersegmental regions.

The intrasegmental mesoderm connects the somites of a respective segment. The germ band expands laterally to cover the ventral side of the yolk surface.
At the caudal end mesoderm is more conspicuous as compared with the anterior region of the head lobes (Fig. 9b). This is due to the progressive differentiation that takes place posteriorly and hence the caudal region becomes segmented at a later stage.

Paired somites occur in the labral, antennary, intercalary, three gnathal, thoracic and abdominal segments.

In a typical thoracic or abdominal segment, the segmentation of the lateral mesoderm is facilitated by deepening of the intersegmental furrows and thus somites come to lie in the ectodermal pockets.

In the thirty-six hours, the stomodeal invagination further penetrates through the endomesoderm so that the mesoderm becomes separated into pre-oral from the endomesodermal layer. The migration of the pre-oral mesoderm from post-oral position has not been observed during this study.

(2) The coelomic sacs.

The segmentation of the mesoderm is soon followed by the development of the coelomic sacs as small cavities in the lateral mesoderm on either side. The coelomic sacs are roughly spherical which later become increasingly elongated.

The mesoderm cells of the coelomic cavities lying next to the ectoderm constitute the somatic mesoderm while the inner layer forms the splanchnic or visceral mesoderm. Along the mid-ventral line the layer of splanchnic mesoderm pulls slightly away from the ventral nerve cord forming the epineural sinus (See Fig. 71).
When the coelomic cavities are well developed they are separated from each other in the intersegmental regions by stout septa (Fig. 99), which in later stages become thin and very much reduced. During the subsequent development these septa disappear and a communication is established between the cavities of the successive segments in the intersegmental regions. In this way coelomic cavities form a pair of continuous tubes running on either side. In L. indicus coelomic sacs are found in labral, antennary, intercalary, mandibular, first maxillary, labial, all the three thoracic and nine abdominal segments.

The labral coelomic sacs - This is the first pair of coelomic sacs belonging to the labral segment. It appears at about the thirtieth hour. Labral rudiments have not appeared at this stage and the coelomic sacs are situated medially in line with the succeeding somites (Fig. 100).

Labral rudiments make their appearance along with the gnathal and thoracic appendages. A pair of hollow labral rudiments occur as medial ectodermal outgrowths. They are separated by a deep and narrow cleft. Later, the coelomic sacs lie within the cavity of the labral rudiments. The stomodenal invagination and deepening of the median cleft cause the sacs to approach each other.

In thirty-six hours, the prominent labral rudiments project from the protocephalon. The labral coelomic sacs are round and formed of a single layer of cubical epithelium. Posteriorly, the sacs are continuous with the pre-oral mesoderm which stretches backwards on either side of the stomodaeum.
to join post-oral mesoderm in front of the antennary coelomic sacs.

The labral rudiments fuse at the base and the coelomic sacs come to lie within a single cavity (Fig. 101).

At the end of the second day, the epithelium of the coelomic sac breaks down and gives rise to the stomodeal splanchnic musculature.

The labral coelomic sacs differ from the typical coelomic sacs in their shape, location and histological uniformity.

The antennary coelomic sacs - These form the second pair of protocephalic segment. They appear in thirty hours. In the forty-eight hours, the antennary rudiments together with their coelomic sacs occupy pre-oral position.

The intercalary coelomic sacs - This is the third pair of coelomic sacs. Intercalary coelomic sacs are oval and lie rather medially behind the antennary coelomic sacs. As the intercalary sacs maintain their contact with the ventral side of the stomodaeum, concurrently, the antennary rudiments migrate anteriorly. In the forty-second hour, these coelomic sacs break-down and the cells form loose masses which extend on either side of the stomodaeum. The disintegrated loose cells enlarge to become oval. They give rise to the sub-oesophageal body (Fig. 102).

The mandibular coelomic sacs - These form the fourth pair of oval coelomic sacs.

The first maxillary coelomic sacs - This is the fifth
pair of oval coelomic sacs.

The labial coelomic sacs - These oval sacs are situated in the last gnathal segment.

The thoracic and abdominal coelomic sacs - In thirty-six hours, three thoracic and nine abdominal coelomic sacs are found. Histologically they resemble each other. They are elongate and oval in the transverse section (Figs.103 and 104); but the coelomic sacs of the seventh, eighth and ninth segments are seen as attached to the splanchnic walls of the eighth abdominal coelomic sacs.

(H) The circulatory system:

The lateral walls of the embryo approach each other during the dorsal closure of the embryo. Amnion forms the provisional dorsal body wall. Meanwhile, the mesoderm becomes differentiated into a mesenteric layer of the elongated epithelial cells. During the development of these structures cardioblasts are differentiated (Fig.105). These cardioblasts arise from the walls of the coelomic sacs at the point where the splanchnic and somatic layers meet. Cardioblasts are large cells with spherical nuclei and granular cytoplasm.

The cardioblasts of each side then push towards the mid-dorsal line where they become crescent-shaped (Fig.106). These cardioblasts come closer so as to form dorsal and lateral walls of the heart. During the dorsal closure of the body wall, the mesodermal cells proliferate from the
lateral walls and a thin plate, which at first appears like a cord, connects the cardioblasts lying on either side. This cord of mesoderm forms the dorsal diaphragm (Fig. 107).

The cephalic aorta is formed by the fusion of the coelomic sacs of the antennary segment. The aorta extends posteriorly and finally joins with the heart. Thus, a straight vascular tube is formed extending from the antennary segment to the caudal region.

The ventral diaphragm forms from the strands of the muscle fibres extending mesally towards the mid-line along the ventral surface just above the nerve cord.

During development the heart tissue remains loosely connected by a mesentry with the splanchnic mesoderm which invests the mid-gut. This can be seen in the posterior region of the embryo. The lumen of the heart is continuous with a narrow circum-intestinal blood sinus surrounding the proctodaeum (Fig. 108).

Blood cells arise from the mesoderm which forms a sort of bridge between the segmental mesodermal mass (see Fig. 71). The blood cells are seen scattered everywhere in the body cavity. They are large with spherical nuclei and vacuolated cytoplasm.

(I) The muscular system

The muscular system is mesodermal in origin. The myoblasts become arranged into columns to form muscles and the muscle striations are clearly seen in the sections of later stages.
There are several pairs of muscles in the head which stain deeply. Mesoderm which is in association with the antennal segment gives rise to the flexor and extensor muscles of the antennae. Even though the mesodermal mass penetrates inside the antennal cavities it does not form any definite muscles of the antennae prior to hatching of the larva.

The dorsal wall of the hypopharynx is provided with the strong dilator muscles arising on the clypeal region of the cranium (See Fig. 37).

Mandibles are hinged to the lateral angles of the head by dorsal and ventral articulations so that they move in a horizontal plane with the help of great flexor and extensor muscles of the mandibles.

The muscles of the maxillae are attached to the cross bars of the tentorium. The myoblasts migrate along with the tentorial invaginations of the maxillary segment. The labial muscles arise from sub-somatic mesoderm. Most of the larger and stronger muscles are attached to the tentorium and they extend to the inner side of the head wall.

Muscles of the thorax and abdomen develop from the somitic and sub-somatic mesoderm. The somitic mesodermal mass splits into three masses and gives rise to median dorsal and dorso-lateral bands of muscle fibres while the third, elongated mass extends dorso-ventrally and gives rise to transverse muscle bands. The mesoderm cells i.e.
myoblasts become arranged into columns of elongated cells. The terminal cell being inserted on the adjacent intersegmental epidermis. The transverse muscles are formed by elongation of myoblasts along with the epidermis from one place to their other place of insertion. The ventral longitudinal muscle band develops from the most lateral portion of the sub-somatic mesoderm (Fig. 105). The oblique muscles arise from the clumps of sub-somatic mesoderm cells lying dorso-laterally to the nerve cord. In prothorax, certain muscles are specially adopted for the movement of the head. The two depressors develop from the somitic mesoderm cells. The myoblasts which occupy the cavities of the thoracic appendages give rise to the intrinsic musculature of the leg.

The muscles of the fore-gut are derived from the pre-oral mesoderm. The pre-oral mesodermal mass surrounds the stomodeal invagination from all sides. This mass grows as the stomodaenum increases in length and ultimately gives rise to the musculature of the fore-gut.

The splanchnic mesoderm which differentiates after the formation of the coelomic cavities, becomes associated with the developing wall of the mid-gut. This splanchnic mesoderm forms a very thin cover surrounding the mid-gut.

The musculature of the proctodaeum is mostly derived from the mesodermal mass of the last abdominal segment which surrounds the proctodeal invagination.

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The germ nuclei can be differentiated in the early development of *D. indicus*. Four cleavage nuclei pass through the oösome i.e. germ tract plasm (Fig. 7). These cleavage nuclei are the germ nuclei. The cytoplasmic granules (i.e. germ cell determinants) disappear during the development. The germ nuclei are of large size (20μ). When the thin unicellular layer is formed, the germ cells lie at the posterior end of the egg (See Fig. 23). The germ cells are easily marked out at this stage by their large size and enlarged spherical nuclei. But they do not project outside conspicuously as noticed in the development of some other coleopteran families such as Chrysomelidae and Curculionidae. During the process of gastrulation these cells lie in the posterior region of the germ band. At the time of formation of embryonic envelopes they are found in the endomesoderm and especially in the mesoderm near the posterior amniotic fold (See Fig. 33). As the development of the embryo proceeds these cells move to the posterior part of the abdomen (See Fig. 62). These can now be referred to as the "germ glands." When the proctodeal invagination is quite deep these cells are seen lying in its front in the eighth segment (See Fig. 63). From this position they are taken to the dorsal side at the time of the dorsal closure of the embryo. The germ glands or gonads now lie in the fifth abdominal segment. Two groups of gonads are seen suspended in the body cavity from the dorsal side and above
the alimentary canal (Fig. 109). The gonads are invested by a very thin mesodermal sheath. Sexual differentiation is not recognisable during the embryonic life. The freshly hatched larvae also do not show sexual dimorphism.