XII. THE CIRCULATORY SYSTEM

In _C. trachypterus_ the development of the organs which constitute the blood vascular system can be considered under the following heads:

(1) The dorsal vessel
(2) The cephalic aorta.
(3) The pericardial cells and pericardial septum and
(4) The blood cells and blood sinuses

(1) The dorsal vessel:

The anlagen of the dorsal blood vessel appear in an early stage of development at about 168 hours. These cells, known as cardioblasts, develop on the dorso-lateral borders of the coelomic sacs slightly below the point from where the provisional dorsal closure and the splanchnic layer take their origin (Plate XVIII, Fig. 62). They begin to differentiate from the adjoining mesodermal cells as large rounded bodies whose nuclei are poorer in chromatin content. The cardioblasts are first distinguishable in the segmental regions from the second maxillary to the fifth or sixth abdominal segments. Later they extend in the intersegmental
portions also and are seen in transverse sections throughout the whole of thoracic and abdominal region. When the lateral body wall of the developing embryo begins to move mid-dorsally to affect the definitive dorsal closure, these cells are also carried along with it towards the developing dorsum of the embryo. That much of development occurs before blastokinesis.

Soon after the completion of blastokinesis the process leading to the dorsal closure is accelerated and the cardioblasts reach the mid-dorsal part beneath the hypodermis (Plate XVIII, Fig. 63). These cells now appear distinctly crescent-shaped with their convex sides direct towards the body-wall and concave sides face each other. The cardioblasts of the opposite sides still lie apposed to each other but concurrently with the union of the lateral parts of the embryo to form the dorsal wall, the two horns of the crescentic cardioblasts unite enclosing a space, called the mid-dorsal longitudinal sinus, which forms the lumen of the tubular heart. The heart so formed contains a few blood cells. Dorsally it remains attached for sometimes to the hypodermis, ventrally with the pericardial (dorsal) diaphragm and laterally with the somatic mesoderm. This can be seen in a transverse section of the embryo one day after blastokinesis (Plate XVIII,
The process of narrowing down of the mid-dorsal sinus starts from the posterior end and proceeds anteriorly where it gets connected to the posterior part of the cephalic aorta situated in the head region. By about three days after blastokinesis the heart is separated from the hypodermis and runs from the second maxillary to the tenth abdominal segment.

All workers are generally agreed on the mesodermal origin of the cardioblasts (Johannsen and Butt, 1941). According to them, the origin of heart rudiments was first investigated by Korotneff (1883, 1885) in the mole cricket (*Gryllotalpa vulgaris*) and since then the same view has been subscribed by later workers. Further, the cardioblasts in three genera, *Donacia*, *Chrysomela* and *Formica* are reported to be rounded and not crescentic. Roonwal (1937, 1939) maintained a similar mode of origin of these cells in *L. migratoria*.

(2) The Cephalic aorta:

It is generally accepted by all workers that the dorsal aorta is formed from the median walls of the antennal coelomic sacs and not from the cardioblasts. Johannsen and Butt (1941) describe that in *Apis, Pieris, Forficula, Butlermis, Carausius*.
and in other orthoptera the aorta originates from the antennal coelomic sacs and this appears to be the normal method of its formation. Roonwal (1937) confirms their description in *Locusta migratoria*. In the present material the development of the aorta is essentially similar to what has been described by Roonwal (1937).

In *C. trachypterus* the formation of the cephalic aorta is initiated at about 144 hours of development. It is formed from the inner walls of the dorso-rostral and dorso-anal pouches of the antennary coelomic sacs. The formation of these coelomic pouches has already been described earlier in connection with the coelomic sacs. For descriptive convenience it is proposed to describe the development of the anterior and posterior parts of the cephalic aorta separately as detailed below.

(i) The anterior aorta:

As mentioned above the anterior portion of the aorta develops from the dorso-rostral pouches of the antennary coelomic sacs at the age of 144 hours. These parts of the sacs extend anteriorly in the cephalic region over the stomodaeum. The cells constituting the inner walls of the coelomic sacs also elongate in the direction of the extension of the coelomic pouches at the age of 168 hours (Plate XIV,
Fig. 51). As development progresses the extended parts which appear tubular begin to bend towards each other and ultimately fuse to form a dorso-ventrally flattened sinus or the blood distributing apparatus. This process is completed at the age of 192 hours (Plate XV, Fig. 53).

The anterior cephalic aorta so formed encloses the frontal ganglion of the stomatogastric nervous system which lies over the dorsal wall of the stomodaeum. The dorso-lateral walls extend further outwards in the form of two thin strips which meet the body wall in the cyclopeal region. Like the dorso-lateral walls their counter parts, the ventro-lateral portions also bend outwards but they do not extend up to the body-wall and their terminal ends develop into fatty tissue. The outer walls of the coelomic pouches are also converted into fat body.

The anterior cephalic aorta so formed supplies the blood to the anterior portion of the head. In sections of a newly hatched hopper it is tubular and no muscles seem to have appeared. Soon after its formation it becomes continuous with the posterior aorta.

(ii) The posterior aorta:

It develops from the dorso-anal portion of the antennary coelomic sacs at the same age at which the
anterior cephalic aorta appears. The two coelomic pouches lie at a distance on either side of the stomodaeum. Their median walls begin to thicken at about 168 hours (Plate XIV, Fig. 52), at the level of the pharyngeal ganglia which subsequently gets enclosed within the aorta. The median walls acquire a certain amount of thickness and then begin to curve inwards on either side so as to form a trough-like structure which ultimately fuse together to form the aorta proper. This happens soon after the completion of blastokinesis. The coelomic walls enclose between them a portion of the epineural sinus and the lateral walls of the dorso-anal pouches of the antennary coelomic sacs are converted into fat body. The cephalic aorta so formed becomes continuous with the anterior portion of the heart in the second maxillary segment.

(3) The pericardial cells and the pericardial septum:

As the name indicates the pericardial cells develop near the heart after it has come into existence. On the ventro-lateral sides of the heart are seen some rounded loose cells, sometimes two or more joining together to form a string which can be easily differentiated by their size and shape from the adjoining fat cells. These pericardial cells appear a day after blastokinesis and are found in the space bounded from below by the dorsal diaphragm and laterally by the
somatic mesoderm (Plate XVIII, Fig. 64; Plate XIX, Fig. 65). They first make their appearance in the thoracic and fourth or fifth abdominal segments but soon spread over up to the eighth abdominal segment. They originate from the part of the somatic mesoderm which is delimited by the dorsal diaphragm. In this region the mesodermal cells begin to loosen and give rise to both the pericardial cells and the fat cells (Plate XIX, Fig. 66). Some of the former cells are seen adhering to the lateral and ventro-lateral parts of the dorsal vessel. They persist throughout the embryonic life and are also seen in a freshly hatched hopper.

The pericardial septum (Dorsal diaphragm) is a thin delicate membrane found below the heart and extends laterally to join the mesodermal layer from which it takes its origin. Later it develops fan-shaped muscles fibres through which it is attached to the lateral body-wall in the segmental regions. In the intersegmental regions, however, such muscle fibres are not discernible. It provides support to the newly formed dorsal blood vessel throughout its length (Plate XVIII, Fig. 64).

A similar septum known as ventral diaphragm develops below the alimentary canal about one day after blastokinesis. It is formed from the somatic mesoderm and extends transversely between the developing alimentary canal and the nerve cord
(Plate XIII, Fig. 47). The cells of the somatic mesoderm thin out rapidly so as to form this membrane which extends up to the level of the oblique muscles.

(4) **The blood cells and blood sinuses:**

The blood cells arise from the median mesoderm which lies over the developing ganglia of the ventral nerve cord. The cells of this part of the mesoderm are generally arranged in a single layer but at some places it becomes two layered. Blood cells first appear at the age of 120 hours when the provisional dorsal closure is fully formed and encloses an epineural sinus. Prior to the liberation of these cells the median mesoderm loses its regular arrangement and begins to release individual cells into the epineural sinus (Plate, V, Fig. 22).

In the beginning these cells are of various forms such as oblong, rounded and spherical but ultimately all of them assume a more or less spherical form. Besides the epineural sinus isolated blood cells are also seen in the pericardial chamber, the lateral blood sinuses, the circum-intestinal blood sinus and also in other places of the body cavity. Though few blood cells lie in close proximity of the heart but there is no evidence to regard them as having a common
origin with the cardioblasts.

Earlier workers have described the origin of blood cells from a variety of sources like the yolk cells, the cells of serosa, walls of the heart, from undifferentiated mesodermal cells, the sub-oesophageal body cells, the entoderm and even from the ectoderm (Johannsen and Butt, 1941). Roonwal (1937) while admitting the origin of the blood cells in *Locusta migratoria* from the mesodermal strand does not hold this region alone responsible for their production. In his opinion since loose mesodermal cells are met with in a variety of places so it is not possible to assign their origin to a single area. Observations on *C. trachypterus* are in complete accord with this view.

During development two types of sinuses appear in *C. trachypterus* of which the first pair is known as the lateral blood sinus. It appears at about 120 hours stage when the provisional dorsal closure has been fully laid down and the splanchnic mesoderm begins to extend along the provisional dorsal closure towards the mid-dorsal line. The dorso-lateral edges of the somatic mesoderm now separate from the lateral ectoderm so as to form two spindle-shaped lateral blood sinuses. The spaces so formed are bounded dorsally by the provisional dorsal closure and ventrally by the somatic mesoderm. Some isolated blood cells are also seen in these
sinuses. When the lateral body-wall begins to grow upwards to effect the definitive dorsal closure these lateral blood sinuses are also carried along with it reaching the mid-dorsal part of the developing embryonic body. These changes occur about 12 hours after blastokinesis. Another 12 hours later the sinuses of either side fuse into one large mid-dorsal sinus which forms the lumen of the heart after the cardioblasts of the opposite side unite to form the dorsal vessel (Plate XVIII, Fig. 64).

Another sinus which develops around the intestine, whence known as circum-intestinal blood sinus, is a transitory structure and is represented by a narrow space bounded internally by the splanchnic mesoderm and externally by a thin mesentry whose origin could not be established with certainty (Plate XIII, Fig. 49). Observations under high magnification reveal that this mesentry is in such a close contact with the splanchnic layer that it is difficult to detect the sinus at some places. This may be due to fixation and subsequent processing during which the two layers tend to collapse. About two days after blastokinesis this mesentry degenerates and the sinus disappears.

Boonwal (1937) described two paired lateral blood sinuses and one unpaired circum-intestinal blood sinus in Locusta migratoria. His first pair of lateral blood sinuses
is formed before blastokinesis by the provisional dorsal closure and the somatic mesoderm. This sinus disintegrates during blastokinesis and in its place develops a second pair of lateral blood sinus formed by the amnion and the splanchnic mesoderm. Roonwal's first pair of lateral blood sinus corresponds to the paired lateral sinus of *C. trachypterus* while the second pair does not develop in the present grasshopper since amnion does not participate in the formation of the provisional dorsal closure as reported by Roonwal (1937). He further claims that the heart does not open directly into the circum-intestinal blood sinus but merely abuts the mid-dorsal wall of the later. This condition is seen throughout the length of the heart excepting the distal meso-thoracic region where it is connected with the circum-intestinal blood sinus by means of a short-lived connecting tube.

Observations on *C. trachypterus* are in accord with these findings but a connecting sinus between the heart and the circum-intestinal blood vessel, as reported by Roonwal, has not been observed in this insect. It is quite likely that this structure, being a transitory one, might have been missed by the present writer.