Chap. 8: Summary

The objectives of present studies are to study the anatomy and histology of internal structures like nervous system, reproductive systems and venom gland of *Heterometrus xanthopus* (Pocock) (Scorpionidae) and *Orthochirus bicolor* (Pocock) (Buthidae) and also to give the comparative account of anatomy and histology of above mentioned aspects in *H. xanthopus* and *O. bicolor*.

The scorpions selected for present study were regularly collected from eastern portion of Pune (Maharashtra, India) and surrounding region. Collected specimens were brought to the laboratory, anaesthetised with chloroform, dissected in scorpion Ringer’s solution. The camera lucida diagrams of anatomical systems under studies were drawn. Histological slides of organs under study were made by paraffin embedding method (Godkar P.B and Godkar D.P., 2003). These permanent slides were studied and photographed under higher magnifications.

The nervous system of both the species of scorpions consists of a large anterior cephalothoracic mass together with a long ventral nerve cord. The cephalothoracic mass consists anterio-dorsal supra-oesophageal ganglion and posterio-ventral sub-oesophageal ganglion, both laterally connected by circum-oesophageal connectives. The supra-oesophageal ganglion is divided into protocerebrum and tritocerebrum. Two pairs of nerves originate from protocerebrum called median optic nerves and lateral optic nerves. The protocerebrum contains paired median optic nerve centers, lateral optic nerve centers Both median and lateral optic centers send tracts to the central body through optic commissure. The protocerebrum also consist of globuli cell regions. The tritocerebrum of cephalothoracic mass consists of cheliceral ganglion. It is located in the circum pharyngeal region at the base of paired cheliceral nerve.

The sub-oesophageal ganglion of *H. xanthopus* is slightly elongated, but ovoid in *O. bicolor*. The sub-oesophageal ganglion of both the species give a pair of pedipalpal nerves, accessory pedipalpal nerves, four pairs of ambulatory nerves, four pair of vagus nerves and paired nerves of ventral nerve cord. Histologically, it consist of major nerve centers, includes pedipalpal nerve centres, ambulatory nerve centres, and vagus nerve centers and ventral nerve cord nerve centers.

The ventral nerve cord of both the species is formed by a set of seven ganglia. Out of these, three ganglia are found in mesosoma and four in the metasoma. Each ganglion is fusion of two symmetric hemiganglion, joined together by paired nerves called connectives. Two pairs of nerves arise from each of the first six ganglia and five
pairs of nerves arise from the seventh ganglia. Histologically, bilateral symmetrical groups of nerve cells are observed. In the first six ganglia, the major nerve fiber tracts run the central neuropile of each ganglion, where as the cell bodies called ganglion cells are located in the distal half of the ganglion, connected to centrally located neuropile and also to each other via commissural and longitudinal tracts. In addition the seventh ganglion also consists of the large nerve fibers originate from posterior portion of the seventh ganglion and extend in fifth metasomal segment, the cell bodies of these fibers are located in the distal border of the 7th ganglion.

The male reproductive organs of both the species under study consist of paired testes, each of which is formed by two longitudinal tubes united by four transverse tubes, thus forming three loops in each testis. In H. xanthopus three paired loops of testes extending from 3rd to 6th mesosomal segments while in O. bicolor three paired loops of testes extending from 3rd to 5th mesosomal segments. The testis anteriorly continues as vas deference and open into organ known as vesicula seminalis, attached to paraxial organ. In H. xanthopus the paraxial organ is lamelliform, while in O. bicolor it is flagelliform with cylindrical glands, dorsal and ventral annex glands. All open in gonopore.

Histologically, the testis show outer extremely thin layer of circular muscles covers basement membrane and germinal epithelium. The cells of germinal epithelium are flat and each with large distinct nucleus. Germinal epithelium is divided by septa into different lobules. The lobules consist of various stages of development such as spermatogonia, spermatids and spermatozoa and mature sperms found in bunches. In H. xanthopus the lobules of the testics are distinct and separated from one another by connective tissue septa. While in O. bicolor the lobules are present but there is no distinct border between them. The border of lobule is fused with one another. The mature sperm of H. xanthopus measure about 47µm in length, while the mature sperms of O. measure about 35.7µm in length.

Female reproductive system of H. xanthopus consists of three longitudinal tubes, interconnected by four transverse tubes. It forms six loops, three on each side. These constitute ovariuterus of scorpion H. xanthopus, present in 3rd mesosoma to 6th mesosoma. While female reproductive system of O. bicolor consists of three longitudinal tubes, interconnected by five transverse tubes. It forms eight loops, four on each side. These constitute ovariuterus of scorpion O. bicolor, present in 3rd mesosoma to 5th mesosoma. In both the species under study, from the anterior angle of each lateral longitudinal ovariuterus tube, the oviducts proceed anteriorly, forming the receptacle
seminalis. The receptacle seminalis open into a genital chamber, which opens to the exterior through the gonopore.

The ovariuterus of both the species is formed by two layers of cells that surrounding irregular lumen. The outer layer formed of irregularly polygonal cells and the inner layer formed of long and thin columnar cells. The inner layer is called germinal epithelium. The ovum of *H. xanthopus* measures about 28 µm in diameter, while the ovum of *O. bicolor* measures about 14.28 µm in diameter. The development of oocyte is similar in their early stages.

*H. xanthopus* is katoikogenic scorpion, the oocyte develop in specialized diverticulum that branch from the female ovariuterus. The developing cells situated at the tip of diverticuli undergo development; the embryo in diverticulum attains elongated shape. In later stages of development, specialized feeding apparatus developed in embryo. It helps the embryo to absorb maternal nutrient. This feeding apparatus is called “bottle and teat”. It is a connection between the stomodeum of embryo and appendix. The appendix is very closely associated with the hepatopancreas of the mother; it receives and transports nutrients from the hepatopancreas to the embryo.

The unknown cellular structure attached to the inner lining of diverticulum adjacent to the mouth of embryo. It was noticed that this structure appear to develop during embryonic development in the month of December and remains persistent up to the month of April and disappear in late stage of development before parturition. During development, the basic pattern of anterior to posterior development is maintained in *H. xanthopus*. Development of prosoma and mesosoma take place in early period where early two eye spots, paired pedipalps, paired chelicerae and four pairs of legs are seen to developed. In lateral stage of development, metasomal segments become distinct but short as compare to the mesosoma. The slit like mouth portion appears in the anterior portion. The gestation period of *H. xanthopus* is June to April (about 11 months).

The embryonic development of *O. bicolor* is comparatively different than that of *H. xanthopus*. The *O. bicolor* is apoikogenic scorpions. The ova develop in ovarian follicles, which are attached directly to the ovariuterus, as the ovum increases in size, however, it pushed towards the outside and appears as an initial outgrowth on ovariuterus. The cleavage of the yolky ovum of *O. bicolor* is discoid. The subsequent divisions producing a multicellular body called germ disc or the blastoderm. The blastoderm differentiates into an epiblast and hypoblast. The hypoblast produces a mesoblast. The serosa forms first from the blastoderm. The germ disc undergoes further development. The embryo grows around the yolk and become 10 segmented and
development of coelomic cavity at the site of mesoderm, hepatopancreas formed below the developing alimentary canal. The growth zones of developing embryo proliferate and embryo attains 18-segmented stage. These segments may be anterior cheliceral and pedipalpal segment, four ambulatory segments, seven mesosomal segments and remaining five posterior metasomal segments. The cellular lining of columnar epithelial cells also appeared between the proximal portion of developing embryo and yolk mass. The gestation period of *O. bicolor* is about June to November (5-6 months).

Anatomically, the poison vesicle of *H. xanthopus* is covered by smooth cuticle, while the poison vesicle of *O. bicolor* is covered by very hard and thick cuticle. In both the cases the cuticle is made of three layers: the outer epicuticle, middle homogeneous layer of exocuticle and innermost endocuticle. The cuticle encloses the connective tissue layer and compressor muscles. The compressor muscles of the *H. xanthopus* consist of thick bundles, while the compressor muscles of *O. bicolor* are comparatively thin. The venom glands of both the cases are fully extended in vesicle, broader at middle and narrowed at both the ends. The venom glands of both the cases, encloses a lumen surrounded by folded secretory epithelium. There are one large fold and four small folds in *H. xanthopus* and four larger folds in *O. bicolor*.

Histologically, the venom glands of both the species, encloses a lumen, surrounded by extensive folding of secretory epithelium. The epithelium cells arranged on basement membrane and connective tissue layers. There are two types of epithelial cells. One type is goblet cells and other columnar epithelial cells. These goblet cells and columnar cells are numerous in *H. xanthopus* and are compactly arranged on the both the sides of connective tissue. In *O. bicolor* the venom glands consist of very few goblet cells and columnar cells. These cells are not compactly arranged on the both the sides of the connective tissue.

No previous attempts have been attributed on the studies of anatomy and histology of nervous system, reproductive systems and venom gland of *H. x* and *O. b*. These are now finding in relation to above mentioned aspects, for species under study.

Following are the significant findings noted in the present study:

1) In the Nervous system of *H. xanthopus* the protocerebrum is situated much anterior to the sub-oesophageal ganglion.

2) The paired telsonic nerves of *O. bicolor* cross each other at the posterior half of the fifth metasomal segment. The nerves again run posteriorly, run parallel to each other and enter in to the vesicle. At the base of vesicle, around the dorso-ventral muscular
strand, the telsonic nerves form thick ramification by dividing into fine branches and form a ring like structure.

3) Male reproductive system of *O. bicolor* consists of more complex structures like presence of vesicula seminalis, cylindrical glands, dorsal annex gland and ventral annex gland along with flagelliform paraxial organs.

4) *H. xanthopus* is katoikogenic scorpion. In later stages of development of embryo, a special oral feeding apparatus called “bottle and teat” develops in between stomodeum of embryo and appendix. While *O. bicolor* is an apoikogenic scorpion and embryos are nourished on yolk present in the follicle itself through the cellular lining of columnar epithelial cells developed between anterior portion of embryo and yolk.

5) In *H. xanthopus* the **unknown cellular structure** appears during embryonic development, attached to the anterior ventral inner lining of diverticulum adjacent to the stomodeum of embryo.

6) The venom glands of *H. xanthopus* are covered by much thick compressor muscle bundles than *O. bicolor*. The venom glands of *H. xanthopus* consist of numerous goblet cells and columnar cells than *O. bicolor*. 