CHAPTER X

Summary and Conclusion

The present investigations dealt with the functional anatomy of the feeding apparatus and the enzymatic profile of the jaw and locomotory muscles of *E. conicus*, *D. nasutus* and *D. tristis*.

The studies were carried out in relation to:

1. Food-getting and feeding behaviour.
2. Osteology of the skull, vertebrae and the ligaments associated.
4. Structure and disposition of the locomotory muscles.
5. Locomotor performance and morphological variables.
6. Histochemical studies on the metabolites, some related enzymes and neuromuscular junctions of the jaw and locomotory muscles.

The dietary items of *E. conicus*, *D. nasutus* and *D. tristis* consist of five broad taxonomic assemblages: they are rodents, birds, lizards, frogs and insects. Index of Relative Importance values (IRI) show that each species of snake has its own highest IRI value for
different group of prey items. *E. conicus* has highest IRI value for rodents. *D. tristis* and *D. nasutus* have highest value for lizards. These snakes show least preference to invertebrate food items. IRI values reveal that single food items are very important in diet of these snakes and they have spectacular trophic relationship between other animal groups.

*E. conicus* is a ground dweller, sit-and-wait forager, rodent specialist, nocturnally active and kills its prey by constriction before swallowing. *D. nasutus* and *D. tristis* are active snakes, the faster 'runners' among the snakes and utilize great speed to pursue prey.

The body colour of *E. conicus D. nasutus* and *D. tristis* resemble the colour tone of the niche they inhabit. Aposematic behaviour and cryptic colouration appears to be the best defensive strategy against predation.

The skull of *E. conicus* is very solidly constructed. The solid nature of the skull is an adaptation to engulf large sized prey items. *D. nasutus* has higher linear measurements of osteological characters. The arrangement of quadrate bone is differed in these snakes. In *E. conicus* it is vertically placed which gives a squarish structure to the skull. In *D. nasutus* and *D. tristis* the quadrate is more posteriorly placed and gives an angular arrangement. The quadrato-mandibular ligament is well developed in *D. nasutus* which allows lateral expansion of jaws.

The number and size of the teeth differed in each group. In
$D.\ tristis$ teeth have more or less even length. This arrangement helps in experiencing the force of jaw closure approximately equal to each individual tooth. In $E.\ conicus$ and $D.\ nasutus$ teeth project beyond the even teeth. This permits the force of jaw-closure to be locally concentrated upon these teeth.

The vertebrae of these snakes have more or less similar pattern. In $D.\ nasutus$, the length of the vertebra is higher than $E.\ conicus$ and $D.\ tristis$. The length of zygantrum and zygosphene in $E.\ conicus$ is greater than $D.\ nasutus$ and $D.\ tristis$. This gives strong articulation between vertebrae which helps in constricting prey during feeding. In $E.\ conicus$, the tip of the rib contains a small bony piece which is attached by ligament to the rib. This helps in anchoring the rib to the substratum during rectilinear progression.

Based on functions, muscles operating the feeding apparatus are grouped into abductors, adductors, protractors of the upper jaw, retractors of the upper jaw and protractors of lower jaw and retractors of upper jaw. The pattern of disposition of the jaw muscles are more or less similar in the three snakes. The muscles of hyoid has no role in the protraction and retraction of the tongue.

The jaw-muscles operate with the help of different lever systems for getting maximum efficiency. The abduction involves a first-class lever and the adduction involves a simple third-class lever system. In protraction and retraction of upper jaw some muscles operate with a complex first-class lever and some others with a
simple second-class lever system. In the protraction of the lower jaw a simple second class lever system is used.

Quantitative myological studies reveal that, the abductor and adductor muscles of *D. nasutus* exert a greater amount of effective force of abduction and adduction per gram weight of muscle. The indices to the effective forces of protraction and retraction of by the upper and lower jaw muscles show that *E. conicus* exerts higher effective force of protraction and retraction per gram weight of muscle than *D. nasutus* and *D. tristis*.

The epaxial muscles of *D. nasutus* and *D. tristis* have higher segmental length and tendon length than *E. conicus*. These muscles provide the forces necessary for lateral flexion of the vertebral column in *D. nasutus* and *D. tristis*. The long proportional length of contractile tissue of the muscle segments in *E. conicus* increases the power of constriction. Among the hypaxial muscles of these snakes, the costocutaneous muscle of *E. conicus* are well developed to perform rectilinear mode of locomotion. The locomotory muscles of *E. conicus*, *D. nasutus* and *D. tristis* contain parallel-fibred arrangements.

*D. tristis* is the fastest 'runner' among the snakes studied. It has the highest burst speed (3.01 ms⁻¹) and mid-distance speed of (2.21 ms⁻¹). *D. nasutus* is also a fast runner (burst speed 4.53 ms⁻¹ and mid-distance speed 3.17 ms⁻¹). *E. conicus* has the minimum speed (burst speed 54.53 ms⁻¹ and mid-distance speed 46.09 ms⁻¹).

In rectilinear progression the dorsal part of body progresses
at a fairly constant velocity with minimal accelerational changes and the ventral side moves by jerks. It decreases the speed of locomotion. In lateral undulation force is directed posterio-laterally. For lateral undulation the animal requires capacity for forming variably sized bends and body must be slender, elongate and relatively light weighed.

The morphological characters and mechanical properties of the skin have importance in snake locomotion. Localized differences in skin thickness, weight and scale size help their particular mode of locomotion. During locomotion skin functions as an exotendon for transmitting locomotor forces and also provides re-enforcement to resist the pressure encountered during vertebral flexions.

Based on the staining intensity for SDH, all the jaw-muscles studied contain three types of fibres viz. type I with high intensity of staining, intermediate type with an intermediate staining and type II with very low staining. The abductor and adductor muscles of *D. nasutus* and *D. tristis* contain higher amount of glycogen, LDH, αGPDH, phosphorylase and acid-stabile ATPase. This provides the physiological basis for the production of greater amount of effective force of abduction and adduction per gram weight of muscle. The protractor and retractor muscles of *E. conicus* are loaded with higher percentage of glycogen, LDH, Phosphorylase, αGPDH and acid-stabile ATPase than *D. nasutus* and *D. tristis*. This enables to produce higher effective force of protraction and retraction per gram weight of muscle which help to ingest prey items.
The presence of high frequency of nerve endings in abductor and adductor muscles of *D. nasutus* and *D. tristis* revealed that the muscles perform fast actions: have more neuromuscular junctions to meet the specific needs of muscular activity.

The histochemical study of metabolites and related enzymes in the locomotory muscles revealed that there occur differences in glycolytic and oxidative metabolism in different locomotory muscles. The epaxial muscles of *D. tristis* and *D. nasutus* contain higher percentage of glycogen. LDH, phosphorylase, αGPDH and acid-stabile ATPase loaded fibres. In *E. conicus* the epaxial muscles contain greater amount of fat loaded fibres and the related metabolic enzymes. Among the hypaxial muscles, M. retractor costae biceps, M. levator costae, M. supracostalis dorsalis, M. costocutaneous superior and M. costocutaneous inferior of *E. conicus* contain higher percentage of glycogen and the related enzymes than *D. tristis* and *D. nasutus*. The positive correlation of speed with glycogen, phosphorylase, LDH, αGPDH and acid-stabile ATPase reveal that they are mainly responsible for the production metabolic energy during fast movement. The negative correlation of speed with fat, SDH and alkali-stable ATPase suggest that these are involved in the production of energy for sustained activity.

The locomotory muscles of these snakes contain type I intermediate type and type II fibres. The type II fibres have greater diameter than type I and intermediate type fibres.
The tropic action of nerves influences the contractile properties of muscles. The histochemical studies on acetylcholinesterase and nerve endings revealed that muscles involved in fast action have high frequency of nerve endings. The epaxial muscles of *D. nasutus* and *D. tristis* and the costocutaneous muscles of *E. conicus* have high frequency of nerve ending. This facilitate a well ordered sequence of muscle contractions during locomotion.

The functional anatomy and enzymatic profile of the jaw and locomotory muscles of *E. conicus*, *D. nasutus* and *D. tristis* are adapted to their specific mode of feeding and locomotory behaviour. The knowledge of fibre type composition and metabolic specializations add depth to the understanding of the snakes metabolism and its relationships to their behavioural as well as physiological capacities. Even though the three snakes belong to two different families, they share many features in common as an adaptation to their particular way of life. Even slight changes in their behaviour are however well reflected as variations in the structural and physiological organization of their body set-up. The novelty of the work is that for the first time it gives an insight into the correlation between structure and function in relation to the feeding and locomotion in the three snakes studied. The present work will help to bridge the gap of information in functional anatomy and muscle physiology of snakes especially in locomotor physiology.