SUMMARY AND NEW OBSERVATIONS

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I The skeletal and muscular systems:

1 A detailed description which is hitherto not available and is very essential as a basis for the study of musculature, is given of the axial and appendicular skeleton of the common Indian pond turtle, *Lissemys punctata*.

2 A somewhat complete account of the cranial and cervical musculature of Lissemys and of the familiar Indian tortoise, *Testudo elegans* is given and discussed. A great degree of specialization not met with in the other reptilian groups and certain fundamental differences that strike a contrast between these two chelonians have been noted.

3 In Lissemys a bony transverse bar, the juguloquadrate bar, formed by the jugal in front, the quadrate behind the quadrato-jugal in the middle, divide the *adductor mandibulae externus* into an upper *temporalis* and a lower *masseter* muscle in the same manner as the zygomatic arch of the mammalian skull enables the formation of the *temporalis* and the *masseter* muscles in the mammals. The bony transverse bar of the skull

though present in Testudo does not divide the primitive adductor mandibulae externus into an upper temporalis and lower masseter, as in Lissemys.

4 In Lissemys the intermandibularis is a specially organised muscle which aids in the lowering and raising of the floor of the mouth. The hypoglossum cartilage, absent in other reptilian groups has special muscles to facilitate its movements as well as that of the tongue. These have been termed hypoglosso-glossus and hypoglosso-hyoideus. A well-developed constrictor colli keeps the neck compact and aids in its active movements. In Testudo the intermandibularis, geniohyoideus, genioglossus, hypoglossus, hypoglosso-glossus and the hypoglosso-hyoideus muscles which are chiefly responsible for the throat movements and the movements of the tongue, are present. The genioglossus is a single muscle unlike the one in Lissemys which consists of two, the genioglossus externus and genioglossus internus.

5 The constrictor colli in Testudo forms a more or less complete muscular envelope round the whole of the neck unlike in Lissemys where it is restricted only to the anterior half of the neck.

6 The spinalis cervico-capitis in Testudo consists of five parts instead of four in Lissemys. The presence

of an additional part in Testudo is perhaps to support the neck which has undergone a severe bend at this position.

7 The semispinalis and the longissimus cervicis which in Lissemys exists as a complicated system of muscles linked up with each other for a characteristically varied and powerful muscular action, occur in Testudo as simple muscles showing the primitive segmental arrangement.

8 The rectus cervicis in Lissemys extending from the coracoid to the hyoid, shows a transverse tendinous intersection more or less in its middle and is divided anteriorly into three bellies, two of which are represented in the mammals as the omohyoid having a tendinous intersection and the sternothyroid, while the third one to the oesophagus is specially developed so as to facilitate the retraction of the oesophagus along with the head and neck, into the body shell. In Testudo the rectus cervicis remains as a single muscle even anterior to the tendinous intersection unlike in Lissemys where the muscle is divided anteriorly into three parts.

9 In Lissemys the retrachens capitis collique, the longest muscle in the Chelonia, is a composite muscle, formed by the sterno-cleido-mastoid derived from the

primitive *rectus capitis cervico-plastralis* anteriorly and the *pubo-ischio-femoralis* posteriorly. The *retrachens capitis collique* in Testudo is also a composite muscle but formed by the *sterno-cleido-mastoid* derived from the primitive *rectus capitis cervico-plastralis* and the *longus colli* series of muscles.

10 The epaxial and the hypaxial muscles of the neck show the primitive segmental arrangement. The *longissimus* of each segment is divided into three parts which show an interwoven arrangement that is greatly responsible for the compactness, strength and the intervertebral movements of the neck. In the posterior part of the neck at the level of the anterior thoracic vertebrae, the epaxial and hypaxial muscles are ill-developed or absent due to the presence of the carapace which considerably reduces the intervertebral movements.

11 The muscles of the eye are six in number in Lissemys while the one or more muscles of the nictitating membrane which are present in crocodilia, other Chelonia and Aves are absent. The *tensor nasalis* muscle acts as the dilator of the nostrils in Lissemys but is absent in Testudo.

12 The action of the various muscles concerned in the

principal movements of the head and neck, viz., protraction and retraction, flexion, flexion and lateral rotation, extension or elevation, extension and lateral rotation, and lateral flexion, has been indicated. In the Testudo the same movements are present but in a considerably limited extent.

13 The muscles of the trunk and tail, in the four common chelonians namely Lissemys punctata, Trionyx gangeticus, Geomyda trijuga and Testudo elegans have been described and the following are some of the salient findings.

14 The carapace in Testudo and to a lesser extent in Geomyda having acquired the shape of a dome and the neck having undergone an unextendable bend, unlike in Lissemys and Trionyx, a great reduction in the spinalis-semispinalis system of muscles inevitably resulted.

15 In the evolution of the Chelonia, the lung acquired a striated muscle bag probably derived from the intercostal muscles, which is retained in Lissemys and to a lesser extent in Geomyda, but is reduced to a mere membrane in the others.

16 The diaphragmaticus muscle which is well-developed in Lissemys and Trionyx is reduced to a mere membrane in Testudo and to a slightly lesser extent in Geomyda.

17 The _retrachens capitis collique_ is a highly modified and composite muscle in Chelonia and it is suggested that it is formed by the _sterno-cleido-mastoid_ anteriorly and the _longus colli_ series of the trunk and the _pubo-ischio-femoralis_ posteriorly in Lissemys, while in the others by the _sterno-cleido-mastoid_ and the _longus colli_ series only.

18 The _flexor caudae superficialis_ of the tail, it is suggested, corresponds to the _ilio-caudalis_ and that the hitherto unidentified tail muscle in Testudo to the _ischio-caudalis_ of other reptiles.

19 From the present study it is evident that, of the four chelonians studied, Lissemys is the most primitive and Testudo the most modified, with Geomyda occupying an intermediate position, while Trionyx is closer to Lissemys than to the others.

20 The muscles of the limbs in Lissemys are described in detail. Their changes in origin, insertion and disposition as a result of the peculiarities in the skeleton, have been noted and discussed.

II Some physiological aspects of the skeletal and muscular systems of Lissemys;

1 From the study of the water content of the long

bone and carapace in young and adult Lissemys, it is found that the water content of the carapace is nearly half that of the long bone with the percentage of the total solids correspondingly higher, in a full grown turtle and that with increase in age the water content gets diminished.

2 Since the fluctuations in the protein content of the long bone as growth proceeds, are very slight it is concluded that the protein content of the carapace is not built up at the expense of that of the long bone.

3 It is concluded that the long bones are a store house of calcium and that considerable amount of calcium is transported to the carapace from the long bones in building up the carapace.

4 A study of the gross chemical composition of the thigh muscle in freshwater and terrestrial chelonians has led to the conclusion that the freshwater ones are secondarily adapted to a life in water.

5 A higher iron content in the muscle of the more active chelonians is noted.

6 A higher phosphorus content in the muscle of the land forms possessing a heavier body shell, is noted.

III A The respiratory system and the mechanism of respiration in Lissemys, Trionyx, Geomyda and Testudo:

1 On the fusion of the ribs and the formation of the body shell in the evolution of the early Chelonia resulting in the inability of the body wall to perform the respiratory movements, the inner muscle sheath came to be formed probably from the intercostal muscles. This acquisition of a muscular lung working as a pair of bellows must have given the early chelonians their survival value.

2 The study of the flank cavity muscles reveals a general degeneration of some of these muscles in Testudo and Trionyx. In Both these forms the inner muscle sheath which is so well preserved in Lissemys is reduced to a mere membrane and the condition in Geomyda shows a stage of transition. Again, in Geomyda the diaphragmaticus part of the outer muscle sheath, shows a transitional stage between the one in Lissemys and Trionyx on the one hand and Testudo on the other.

3 In the nature of the flank cavity muscles therefore, Lissemys and Geomyda are to be regarded as more primitive than Trionyx and Testudo with Geomyda as an intermediate form between Lissemys and the other two.

Some evidence in support of this is available from the recent work of Williams et al (1952) who on the basis of their studies on the plastron in Testudinata and Trionychidae have suggested that Lissemydinae are a primitive group.

4 The probable cause for the loss of the inner muscle sheath of the lung of the higher Chelonia and the degeneration of the diaphragmaticus in the terrestrial forms like Testudo could be the evolution in these animals of larger lungs on which the muscle bag was more of a hindrance to their full expansion; and in the mean-time the acquisition of a better physiological equipment for fixing a greater amount of oxygen store in the body for gradual and slow utilization.

5 Respiration in the Chelonia in general is effected by the action of the flank cavity muscles (McCutcheon,1943) and probably by the movements of the neck and the limbs too (Wolf,1933).

6 In a primitive chelonian like Lissemys with smaller lungs and lesser oxyphoric capacity of the blood, the inner muscle sheath on the lung should be acting as a pair of bellows in effecting expiration and inspiration. The movements of the flank cavity muscles,and the neck and limbs should also be helpful in the process.

7 Among the higher forms like Trionyx and Eretmochelys in which there is no muscle sheath on the lung, the lungs are considerably larger and their blood possess a higher oxyphoric capacity. Amongst them the less active forms like Testudo, the oxyphoric capacity is considerably less than the more active ones like Trionyx and Eretmochelys.

III B <u>A comparative study of the morphology of the reptilian lung:</u>

1 A study of the structure of the lung in the various reptiles representing the reptilian orders Lacertilia, Ophidia, Chelonia and Crocodilia, has brought to light considerable structural variations of the lung as a result of the radiation in the reptiles.

2 Among the orders of reptiles, the lacertilian lung as found in Calotes is a simple type with a short bronchus which leads into a central pulmonary chamber which through its lateral chambers give rise to the lung tissue. There is a small posterior saccular chamber.

3 The chelonian lung appears relatively large in size. It has essentially the same structure as that of the lizard but is more elaborated with little or no

saccular portion of the lung. Each lateral chamber leading from the central space is split up into numerous alveoli. The alveoli are larger in size commensurate with the larger size of the lung.

4 The great peculiarity of the ophidian lung is its long posterior saccular chamber. It is an obvious adaptation to store up a large amount of air. It also serves to inflate the body to stiffen it in taking short leaps when greatly terrified. It is also suggested that the saccular part of the lung enables the ground snakes to detect vibrations of sound from the ground.

5 The crocodilian lung is even more specialised than that of the chelonian in as much as there are more numerous alveoli in each lateral chamber. Due to the greater subdivisions of the pulmonary surface, the alveoli are much smaller.

IV <u>The circulatory system of Lissemys with notes on the composition of blood of a few other chelonians and some snakes:</u>

1 The circulatory system of Lissemys is described in detail.

2 The presence of large venous sinuses in turtles similar to the ones present in diving mammals as an adaptation for the diving habit is discussed.

3 The density, water content, total solids, glucose, fat, non-protein-nitrogen, Calcium, haemoglobin, iron, R.B.C.count and cell volume of whole blood and total proteins, albumen, globulin, fibrinogen, and calcium of the plasma of chelonians and snakes have been estimated and the significances in the variations discussed.

4 The variation in the concentration of plasma proteins indicates two lines of evolution namely, ureotelic terrestrialism and uricotelic terrestrialism. It is suggested that those evolving along the former consist of amphibians and aquatic chelonians and mammals; and along the latter comprising the lizards, snakes and birds, while the terrestrial chelonians (tortoises) have taken an intermediate course.

5 With the loss of the muscular sheath on the lung as found in Lissemys, the oxyphoric capacity of the blood has increased in chelonians like Testudo, Trionyx and Eretmochelys.

6 The problem of the much delayed clotting of the blood of some snakes has been discussed and an explanation for this phenomenon is offered. It is suggested that the slow rate of thromboplastin production, together

with a low fibrinogen content and too high calcium content of the blood is responsible for the increase in the clotting time of the snake blood. It is also suggested that this property of blood in snakes has been acquired as a result of the body of these animals being too elongated horizontally.

7 It is indicated that the property of the blood of Lissemys readily laking with oxalate is due to the greater permeability of the red blood cells to oxalate which brings about the binding of the calcium in the cell membrane.

V <u>The water content of the tissues in the chelonians, Lissemys and Testudo, the snakes Naja and Natrix, the lizard Calotes and the crocodile Crocodilus:</u>

1 The water content of the tissues of representative reptiles living under different environments have been estimated and the effect on the water content of the tissues when an amphibious chelonian Lissemys is kept out of water for two to three months, has been studied. The significance in the variations is discussed.

2 In Lissemys, when kept out of water, it was observed that the conservation of water in the body is acheived by

the formation of metabolic water through the break down of fat.

VI Reflections on chelonian evolution:

1 Certain morphological and physiological aspects of chelonian evolution is discussed.

2 It is emphasised that an abbreviation and broadening of the trunk in the chelonians and an opposite tendency of elongation and narrowing in the snakes have been major features in the evolution of these animals resulting in certain very significant and characteristic structural changes in the body.

3 The investigations on bone, blood and muscle are suggestive of some of the physiological aspects of the evolution of the Chelonia which have already been mentioned.