Model Answers
B.Sc. (Fifth Semester) Examination, 2015
Paper-LZC 501 (Comparative Anatomy of Vertebrates)

Section A

Q. 1- Answer

(i)- (a)	(ii)- (a)	(iii)- (c)	(iv)- (c)	(v)- (d)
(vi)- (a)	(vii)- (a)	(viii)- (d)	(ix)- (b)	(x)- (a)

Section B

2. Jaw suspension means attachment of the lower jaw with the upper jaw or the skull for efficient biting and chewing. There are different ways in which these attachments are attained depending upon the modifications in visceral arches in vertebrates.

Amphistylic: In primitive elasmobranchs there is no modification of visceral arches and they are made of cartilage. Pterygoqadrate makes the upper jaw and meckel's cartilage makes lower jaw and they are highly flexible. Hyoid arch is also unchanged. Lower jaw is attached to both pterygoqadrate and hyoid arch and hence it is called amphistylic.

Autodiastylic: Upper jaw is attached with the skull and lower jaw is directly attached to the upper jaw. The second arch is a branchial arch and does not take part in jaw suspension.

Hyostylic: In modern sharks, lower jaw is attached to pterygoquadrate which is in turn attached to hyomandibular cartilage of the 2^{nd} arch. It is the hyoid arch which braces the jaw by ligament attachment and hence it is called hyostylic.

Methystylic: In bony fishes pterygoquadrate is broken into epipterygoid, metapterygoid and quadrate, which become part of the skull. Meckel's cartilage is modified as articular bone of the lower jaw, through which the lower jaw articulates with quadrate and then with symplectic bone of the hyoid arch to the skull. This is a modified hyostylic jaw suspension that is more advanced.

Autostylic: Pterygoquadrate is modified to form epipterygoid and quadrate, the latter braces the lower jaw with the skull. Hyomandibular of the second arch transforms into columella bone of the middle ear cavity and hence not available for jaw suspension.

Monimostylic: This type of suspension is a modification of autosystylic suspension in which quadrate is immovable and not flexible as in amphibia and many reptiles. Hyomandibular is modified as columella bone of the middle ear cavity.

Holostylic: This type is found in lung fishes and Holocephali. Upper jaw is fused with the skull and the lower jaw is attached directly with it. Hyoid arch does not participate in jaw suspension and is a typical branchial arch. There is no columella bone.

Craniostylic: Found in mammals, in this type of jaw suspension, pterygoquadrate is transformed into alisphenoid and incus, while meckel's cartilage is changed into malleus and not available for jaw suspension. Lower jaw is directly attached to the skull bone called squamosal. Monotremes also possess this type of jaw suspension.

3. The dermis is generally much thicker than the epidermis and lies more deeply. It is made of a fibrous mass of connective tissue (collagen) and is of mesodermal origin. It may directly produce dermal (membrane) bone. The dermis is important in defence against injury and in the maintenance of body heat. Deeper regions of the dermis often contain fatty deposits, smooth muscle, blood vessels and nerves. Chromatophore cells are sometimes epidermal, but

usually dermal in origin. They secrete melanin, which can be passed to the stratum corneum of skin and to hair shafts to produce colour and block harmful sunlight.

Dermal Bone: Once present in some extinct fish - Ostracoderms had a complete head shield, while Placoderms had a broken head shield and body armour. Now dermal bone is present in turtle dermal bone, antlers, and in the dermal armour of armadillo. In antlers the velvet is epidermal in origin and shapes and provides blood to the dermal bone. Once grown, the velvet is shed and only the bone remains. Antlers are found in deer, elk, moose and their relatives, often only in males. They are shed annually.
In most modern vertebrates, dermal bone (membrane bone) is formed from embryonic mesenchyme by intramembranous ossification, and contributes to the skull and skeleton, rather than being manifested externally. An exception is teeth, which are partly derived from dermal bone.

Fish Scales: Fish scales are also called dermal scales since they are derived mainly from the dermis.

1) **Cosmoid Scales:** Found in **Placoderms** (extinct) as plates, and also typical of the Lobe Finned Fishes or **Sarcopterygii**, (Choanichthyes). Extinct fish had scales of enamel, cosmine and bone with pulp cavities. Modern ones, like *Coelocanth* and the lung fish have calcified fibers so this type of scale is almost extinct. No specimens available.

2) **Ganoid Scales:** Made of multi-layered enamel called ganoin over lamellar bone. Primitive (now extinct) species also had a cosmine layer and vascular bone with pulp, but these were lost in modern day examples.

3) **Placoid Scales:** Made of enamel (epidermal) and the dermal derivatives, dentine and bone with a pulp core. They are typical of cartilaginous fishes. Placoid scales are responsible for the rough feeling of dogfish skin.

4) Teleost (bony fish) scales
These are thin scales of dermal bone. They have a thin covering of epidermal tissue over them. It is derived by reduction (loss) of parts of a ganoid scale. There are two types depending on their shape.
4a) Cycloid Scales: A round ended scale.
4b) Ctenoid Scales: A comb shaped end is characteristic of this scale type.

Teeth: Teeth are composed of three main parts. **Enamel,** the hardest substance in the body, covers the tooth surface. It is epidermal in origin. **Ganoin** is a form of enamel. **Dentin** is similar to bone in structure but is harder. It is located beneath the enamel and forms the walls of the third component of teeth, the **pulp cavity**. These are of dermal origin. **Cosmine** is a form of dentin. Dermal bone called **cementum** is also present in mammalian teeth.

Teeth are used to catch and hold prey, to crush hard shells and, in some higher vertebrates, to carry out mechanical digestion of food in the mouth.

Teeth of higher vertebrates are thought to have evolved from bony dermal scales similar to dogfish placoid scales. They have a complex embryonic origin involving both the epidermis and the dermis. Interestingly, their development bears some resemblance to that of hair and feathers. Mesenchyme cells collect in the dermis to form dermal papillae, which are instrumental in the production of dentin and go on to form the pulp of the tooth. Enamel is produced by the epidermis. The tooth in mammals is held in place by cement, which is a non-vascular form of bone.

4. Aortic arches are paired blood vessels that emerge from the ventricle of the heart which are basically similar in number and disposition in different vertebrates during the embryonic stages

Aortic arches in reptiles:

- Reptiles are fully terrestrial vertebrates in which gills disappear altogether and replaced by lungs.
- Only three functional arches (third, fourth & sixth) are present.
- Right systemic arch (fourth) arises from left ventricle carrying oxygenated blood to the carotid arch (third) to be sent into head.
- Left systemic arch (fourth) leads from right ventricle carrying deoxygenated or mixed blood to the body through dorsal aorta.
- Pulmonary trunk (sixth) arises from right ventricle carrying deoxygenated blood to the lungs for purification.
- Generally ductus caroticus & ductus arteriosus are absent but in certain snakes & lizards (**Uromasitx**) the ductus caroticus is present and in some turtle & **Sphenodon**, the ductus arteriosus is present.

Aortic arches in birds & mammals:

- Birds & mammals are warm-blooded because in both the ventricle is completely divided so that there is no mixing of oxygenated & deoxygenated bloods.
- 6 arches develop in embryo, but only 3 arches (third, fourth & sixth) persist in the adult.
- Single systemic aorta, right in birds & left in mammals, emerging from left ventricle and carrying oxygenated blood.
- Systemic aorta unites with the radix aorta to form dorsal aorta.
- Subclavian artery present on the left side in birds & on the right side in mammals.
- Third arch represents carotid arteries, which arise from systemic aorta.
- Sixth arch arises from a single pulmonary trunk taking deoxygenated blood from right ventricle to the lung.
- Embryonic ductus caroticus & ductus arteriosus also disappear

5. Heart in simple terms is a highly muscular pumping organ that pumps blood into arteries and sucks it back through the veins. In vertebrates it has undergone transformation by twisting from a straight tube to a complex multichambered organ, enclosed in membranous pericardium.

Amphibian Heart: Urodeles possess an incomplete septum in atrium and no septum in ventricle. Also there is no spiral valve in the truncus. But urodeles have a pulmonary artery and vein and a single set of semilunar valves in the truncus.

Anurans have a complete septum in atrium but no septum in ventricle. The inner lining of ventricle possesses spongy trabeculae. Truncus arteriosus displays a **spiral valve** or **septum bulbi**, which divides its lumen into a dorsal and a ventral channel and also serves to shunt the oxygenated blood into systemic arches and deoxygenated blood to pulmonary arteries for carrying it to lungs.

Reptilian Heart: There is a complete septum in atrium and an incomplete one in ventricle, with a **foramen of Panizza**, through which two kinds of blood mixes before it is pumped to the body organs. Also, ventral aorta in reptiles divides into two so that the right systemic arch emerges from the left ventricle and the left one emerges from the right ventricle. At the point of their crossing a foramen of Panizza allows the blood to flow from one arch to another. SA node in reptiles migrates near the junction of sinus venosus with atrium and the former is reduced in size.

In crocodiles, both atrium and ventricle are completely partitioned so that there is no mixing of blood in heart but the two systemic arched still have a foramen of Panizza connecting them and hence blood mixes, rendering crocodiles the status of cold blooded animals.

Avian Heart: Birds are endothermic animals for which a complete separation of oxygenated and deoxygenated blood is necessary. So, there is a complete partition in atrium as well as in ventricle and left systemic arch disappears, allowing only oxygenated blood to be pumped to head region and to the rest of body organs. In birds there is single valve between right atrium and ventricle. Sinus venosus has disappeared in birds.

Mammalian Heart: Mammals also have a four chambered heart and only one systemic arch on the left side, allowing no mixing of blood anywhere. There is no sinus venosus in both birds and mammals and pulmonary veins directly enter the right atrium. The SA node is also housed in the atrium now. In mammals sometimes there are extensions of atrial lumen to increase its area. These are called auricles. In monotremes the left atrio-ventricular valve is tricuspid.

6. Excretory organs in protochordates are very different from the higher vertebrates. *Balanoglossus* (Hemichordata) has a glomerulus in the proboscis region to excrete nitrogenous wastes from the blood. *Herdmania* (Urochordata) has a neural organ near the solid nerve ganglion located in between the two siphons. Amphioxus (Cephalochordata) possesses protonephridia that carry hundreds of flame cell-like solenocytes that excrete wastes in the atrial cavity and to the outside.

Kidneys evolved in primitive fresh water vertebrates to excrete excess water that was continuously entering the body by osmosis. Later, kidneys also acquired the function of removing the waste materials from body. In invertebrates and also in hag fishes, body fluids are isotonic to sea water and hence they do not have problem of osmoregulation. Cartilaginous fishes and also coelacanths retain considerable amount of urea in the blood so that blood is isosmolal to sea water and osmotic problems are avoided.

It is believed that kidneys in all modern vertebrates evolved from a hypothetical kidney known as **Archinephros** or **Holonephros,** which extended from anterior to the posterior end of the body, with segmentally arranged glomeruli and nephrostomes. Glomeruli received blood from the dorsal aorta and filtered nitrogenous wastes into the coelom, from where they were collected by the nephrostomes and transported to outside via collecting ducts and archinephric ducts. Such kidneys resemble segmentally arranged nephridia of annelids and can still be observed in the larval hagfishes and apoda.

The English embryologist Balfour suggested that the three types of kidneys found in modern vertebrates, namely, Pronephros, Mesonephros and Metanephros evolved from the anterior, milddle and posterior regions of this archinephros.

Pronephros: Also called the head kidney because of its location in the anterior region of body is still a functional kidney in *Myxine* and some primitive teleosts. It has very few (3-

15) collecting tubules, each with a nephrostome that collect waste materials from a single glomus. Pronephros becomes lymphoid in function in other vertebrates.

Mesonephros: Also called the Wolffian body, mesonephros is the functional kidney of the larvae as well as the adults of fish and amphibian and functional kidney in the embryonic stage of amniotes, i.e. reptiles, birds and mammals. The number of uriniferous tubules increases to thousands and glomeruli are enclosed in a cup-like Bowman's capsule; the latter two together are called Renal corpuscle or malpighian body. In addition, there is also a nephrostome attached to the collecting tubule, which all meet the mesonephric duct that carries the wastes to the outside. Nephrostomes disappear in most of the higher elasmobranchs, teleosts and amphibians. In sharks and urodeles, mesonephros is elongated kidney that extends up to the posterior end of body and hence is called **Opisthonephros**.

Metanephros: Metanephros occurs in the adult reptiles, birds and mammals. Reptilian kidney is elongated, more so in snakes where the body lumen available is narrow and long. Bird kidney is trilobed and mammalian kidney is bean-shaped, with a depressed area at the junction of ureter. Kidney is enclosed in a protective tunic that is made of fibrous and adipose layers. Kidney tissue is divided into an outer cortex that carries renal corpuscles and convoluted tubules and inner medulla which houses collecting ducts and loop of Henle. The number of **nephrons** (uriniferous tubules plus renal corpuscles) runs into millions, thereby increasing the efficiency of kidneys to extraordinary levels. In mammals renal arteries bring blood into the kidneys and renal veins take it away, but reptiles and birds possess a renal portal system.

Uriniferous tubule of mammals carries a loop of Henle that is designed to reabsorb all water from the filtrate by counter current mechanism. Reptiles do not have loop of Henle and birds have a reduced one, both groups being uricotelic do not excrete much water any way.

7. Brain is the anterior end of spinal cord that has enlarged to take care of the sense organs which are located on the anterior end of the body in a bilaterally symmetrical animal that moves ahead in an anterior-posterior axis. This is called **cephalon**, which as it evolves further, divides into three parts, namely,prosencephalon, mesencephalon and rhombencephalon. As the brain develops further by increasing the number of neurons, it further divides into different parts, each one having assigned its own specific function.

Cyclostome Brain: Cyclostome brain is very primitive owing to their parasitic and detritus feeding habits. Cerebral hemispheres are small and smooth. Olfactory lobes are well developed as these animals detect suitability of their hosts by acute sense of smell. For the same reason **thalamus**, which contains olfactory relay centres, is enlarged with a prominent median olfactory area called **habenula**. Optic lobes are small because of primitive or rudimentary eyes. Cerebellus which is related with balance and posture is reduced due to parasitic mode of life. Medulla oblongata is quite well developed and receives six pairs of cranial nerves but there is no pons varolli on the ventral side. Pineal and parietal bodies are present in lampreys but absent in hag fishes.

Fish Brain: Active bony fishes and sharks have well developed brain but bottom dwelling fishes have reduced brain organs. Olfactory lobes are large in sharks and they can detect their injured prey by the smell of blood from a distance of about a kilometer. But in majority of bony fishes optic lobes are reduced. Cerebral hemispheres are quite large but smooth and white. Pineal and parietal bodies are generally reduced in fishes. On the ventral side of diencephalon, there is **saccus vaculosus** posterior to the pituitary that serves as sense organ. Optic lobes are well developed as most fishes are gifted with large eyes but in deep sea fishes they are reduced. Cerebellum is highly enlarged in sharks as well as in active bony fishes and also has lateral extensions called **restiform bodies** or **auricular lobes** which connect medulla with cerebellum. They help in maintenance of balance. Cerebellum is smaller in rays, lung fishes, ganoid fishes and deep sea fishes. Medulla oblongata has no particular variation except in deep sea fishes in which there are large **vagal lobes** on the lateral side which receive impulses from taste buds that are scattered all over the body as pit organs.

Urodele Brain: Urodele brain is primitive and reflects their sluggish nature and under-developed sense organs. Olfactory lobes, optic lobes and cerebellum are reduced and cerebral hemispheres are also small and smooth. Pineal and parietal bodies are present but reduced. There is no saccus vaculosus and corpus striatum is weak.

Anuran Brain: Frogs and toads possess a better developed brain as compared with urodeles. Olfactory lobes are large and fused at base that gives better sense of smell to frog. Cerebral hemispheres are larger with a centralized gray area called **Archipallium** that controls olfactory sense, while the lateral areas are white and are called**paleopallium**. Parietal body is reduced but pineal is well developed and probably a photoreceptor. Ancient amphibians possessed a third eye over the pineal-parietal complex. Optic lobes are well developed but there are no auditory lobes and hence the mesencephalon is called corpora bigemina. Cerebellum is reduced but medulla is enlarged to make the brain a reflex brain or spinal brain.

Reptilian Brain: Brain becomes large by the enlargement of corpus striatum. Cerebral hemispheres are large and oval but the surface is white and smooth except in crocodiles which develop gray matter called **neopallium** similar to mammals. Olfactory lobes are well developed in snakes and lizards which have olfactory sense organs on the tongue, but reduced in turtles and crocodiles. Parietal body is well developed in lizards and in Sphenodon it lies under a lens-like transparent area called the third eye. Pineal body is absent in crocodiles. Optic lobes are well developed in all reptiles and **corpora quadrigemina** is found only in snakes. Cerebellum is reduced in all reptiles owing to their creeping habit.

Bird Brain: Bird brain is characterized by enormous enlargement of cerebral hemispheres, optic lobes and cerebellum. Cerebral hemispheres become enlarged owing to enlargement of **corpus striatum** which is called hyperstriatum but pallium is thin and surface has only white matter. Olfactory lobes are highly reduced, attached to the anterior end of the cerebral hemispheres. Optic lobes are enormous as birds are gifted with the best eye sight in animal kingdom. Parietal body is absent and pineal small in most of the birds. Being bipedal and flying animals, birds need good control over muscles and tendons, which comes from a trilobed highly enlarged cerebellum. The middle lobe of cerebellum is called **vermis** as it has transverse folds and the lateral lobes are called **flocculi**. Birds' brain is instinctive brain that can carry out complex but stereotype functions such as nest building. Spinal cord still has equal control over the body.

Mammalian Brain: Mammalian brain is highly developed and keeps complete control over the body functions. Cerebral hemispheres are enormously enlarged and the surface is folded into depressions (**sulci**) and raised portions (**gyri**) so that large surface area can be accommodated in the small space of the skull. Gray matter has spread to the surface which is called **neopallium**. Two cerebral hemispheres are connected by thick bundles of nerve fibres called **corpus callosum,** which is not found in monotremes and marsupials. Olfactory lobes are highly enlarged, so that mammalian brain is sometimes called nose-brain. Parietal body is absent and pineal is usually present except in animals like *Armadillo*, Sirenia and Edentates. Mammals being active animals, cerebellum is highly enlarged and trilobed and all lobes possess gyri and sulci. Nerve cells form bundles of branching fibres called **Arbor Vitae**. Medulla is short as compared to the large brain but **pons varolli** is enlarged.

8. Stomach is a muscular chamber or a series of chambers that serves for storage of food swallowed, macerating and churning it into pulp by peristalsis and secrete and mix certain digestive juices with it for digestion of nutrients. Primary function of stomach continues to be storage of large quantity of food that has been swallowed.

Cyclostomes. In larval cyclostomes stomach is ciliated which is quite useful in pushing detrivorous diet backwards on which they feed but in adult lampreys stomach is indistinguishable.

Fishes. In most of the fishes stomach continues to be narrow and long to adjust inside the elongated body cavity but in elasmobranchs it is J-shaped and measures about half the length of the entire digestive tract.

Amphibia. Urodeles have straight stomach with hardly any digestive function assigned to it. But in frogs and toads cardiac end is wide and pyloric small.

Reptiles. Snakes and lizards have elongated stomachs that fit inside their elongated abdominal cavity but in turtles the stomach is narrow U-shaped tube. Crocodiles have highly specialized stomach that is highly curved. Except for the tortoises, digestive glands are strongly developed in the stomachs of reptiles.

Birds. Bird stomach is modified greatly into a glandular proventriculus and horny gizzard that is necessary to grind seeds and other types of food that they need to swallow whole in the absence of teeth.

Mammals. In monotremes stomach is sack-like but lacks glands and in ungulates and cetaceans the glands occur in pyloric portion only. Stomach is a large sac meant to accommodate large quantity of food that must be swallowed quickly when available before the arrival of predators and competitors.

Ruminant (cud-chewing) mammals have a complex stomach having four parts, namely, rumen or pounch, reticulum with honey-comb like rough lining, omasum or psalterium and abomasum or rennet. Gastric juice is secreted by the lining of abomasums and pylorus for further digestion. Carnivore stomach is clearly divided into cardiac, fundus and pyloric portions, of which fundus always remains empty and accommodates gases. The so called hourglass stomach is found in primates and rodents in which cardiac and pyloric parts are divided by a constriction.