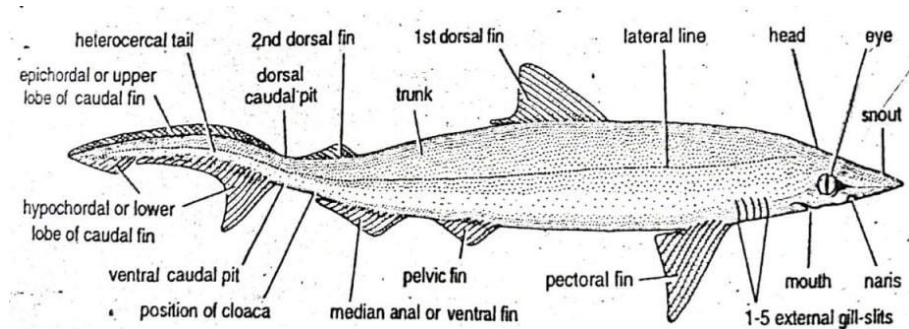


**M.Sc. I Sem: Comparative Anatomy of Vertebrates (ZOPALT1) CC-I
(Lab. Exercises)**

Ex. 1 Identification, Classification and study of distinguish features of the representative examples of different classes of vertebrates: *Scoliodon*, *Catla*, *Rana*, *Varanus*, *Columba*, *Oryctolagus*.

Scoliodon



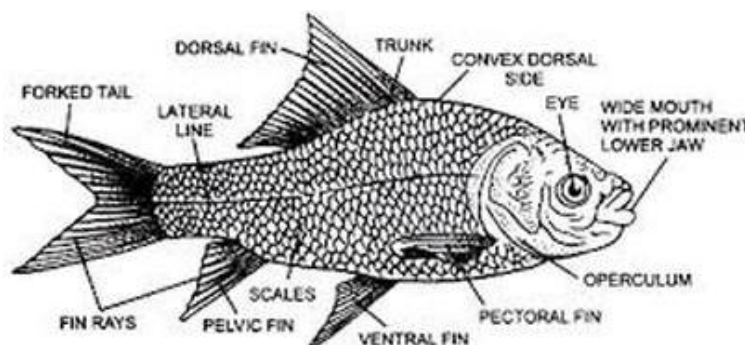
Classification :

Phylum..... Chordata **Superclass.....** Pisces **Class.....** Chondrichthyes **Order.....** Pleurotremata
Family...Scyllidae Genus..... *Scoliodon* (Dogfish)

Comments:

- (1) Commonly called dogfish or dogshark..
- (2) Spindle-shaped body, about 60 cm long, is regionated into head, trunk and tail.
- (3) Dorsal and lateral sides of body are pigmented dark grey or slaty grey, while the ventral side is white.
- (4) Head is dorso-ventrally compressed and flattened into snout. It contains ventrally situated slit-like mouth, obliquely situated nostrils and laterally situated protuberant eyes. A little behind eyes there are five pairs of lateral gill-clefts.
- (5) Trunk bears paired fins. A pair of anterior pectoral fins and a pair of posterior pelvic fins.
- (6) Heterocercal tail turned upwards and caudal fin.
- (7) A pair of pigmented lateral lines extends from head to tail.
- (8) *Scoliodon* exhibits sexual dimorphism. Males are easily recognized by having a pair of intromittent organs, called as claspers. Cloaca is found between 2 pelvic fins.

Catla



Classification: Phylum Chordata **Super-class** Pisces **Class** Osteichthes

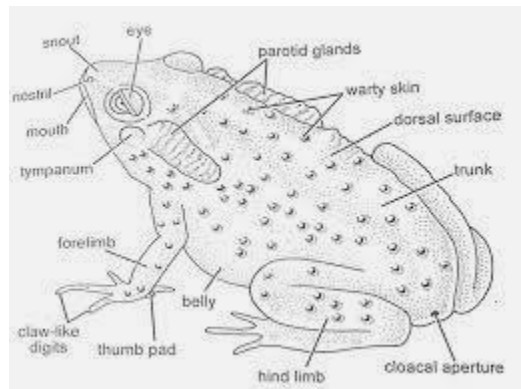
Order Cypriniformes **Family** Cyprinidae **Genus** *Catla*

-Characters:

- It is strong and broad fish
- Reared in association with other major carps
- One of the major carp which gains weight very soon and develops faster than rohu
- It is surface feeder and feeds on plankton voraciously
- Dorsal surface is more elevated than ventral surface
- Colour of dorsal and ventral surfaces vary slightly
- Widened mouth is tilted upside and lower lip rather thick with continuous transverse folds
- Operculum is large
- Eyes are large and black
- Barbles absent
- Dorsal fin advances of pelvic fins
- Fins are black in colour and fin rays are strong
- Caudal fin well forked
- Lateral line almost clear
- Large regular cycloid scales
- Suitable for cultivation in confined waters

Fin formula : D 18-19(3/15-16), P 19, V 9, A 8, C 19, LL 43, Ltr. 7 ½

Bufo



Classification: Phylum Chordata **Class** Amphibia **Order** **Genus** *Catla*

Comments:

1. Geographical distribution: *Bufo* has world-wide distribution. They are abundantly found in India, United States and Pacific State of Alaska. Miocene.
2. *Bufo* is terrestrial, nocturnal, hiding under logs and stones or in burrows in day. It enters water only to breed and spawn.
- (3) Commonly called as true toad.
- (4) It differs from frog in having rough, dry and warty skin with more poison glands than mucous glands. The skin is more or less of protective nature than respiratory.
- (5) Body divided into head and trunk. Head contains mouth large eyes, nostrils and tympanum.

(6) Behind eyes there is a pair of large parotid poison glands. The parotid glands of the toad secrete two toxic substances, bufotalus and bufogus. These toxins cause nausea, respiratory and muscular disturbances and also effect heart functioning, if swallowed by man.

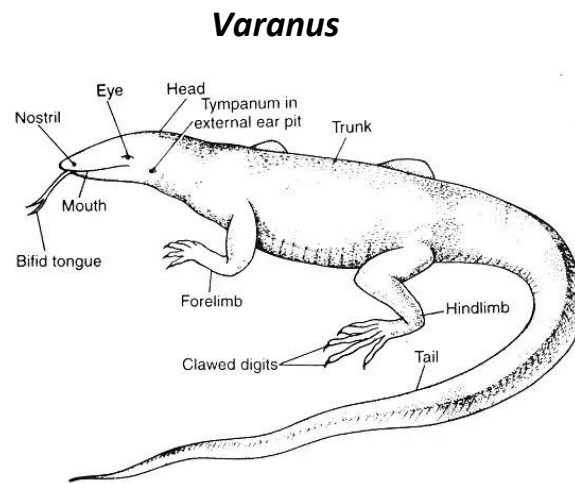
(7) Hind limbs contain 4 claw like digits and thumb pads or adhesive pads.

(8) Forelimbs and Hind limbs are short. Toes provided with horny tips and poorly developed webs.

(9) Maxilliary teeth, sternum absent and ventral parts of pectoral girdle overlap (arciferous). Sacral vertebra has dilated transverse processes. Vertebrae procoelus. Urostyle with double condyle.

(10) Liver is bilobed, Glands of swammerdams absent.

(11) Eggs are pigmented and laid in gelatinous string. Young toads mature in many years.



Classification: Phylum Class Reptilia

Order Genus *Catla*

Comments:

(1) Varanus is distributed in Africa. Southern Asia, South East islands of Australia, India, Sri Lanka and Malaya.

(2) Varanus inhabits dry places under stones and rocks and leads a burrowing life It is most active at night and feeds upon tortoises, squirrels and dead bodies of other animals Monitor lizards are carnivorous and semiaquatic.

(3) Commonly known as Monitor lizard.

(4) Animal measuring 60 to 90 cm in length is divided into head, neck, trunk and tail.

(5) Body is covered with smooth, small scales having large brownish, black and orange patches which act like warning colours.

(6) Head is triangular and contains fixed eyes, nostrils and mouth. External ear opening present just behind head.

(7) Mouth gap wide with a long bifid smooth and protrusible tongue. Teeth large pointed, pleurodont and dilated at base.

(8) Osteoderms absent. Post-orbital arch incomplete.

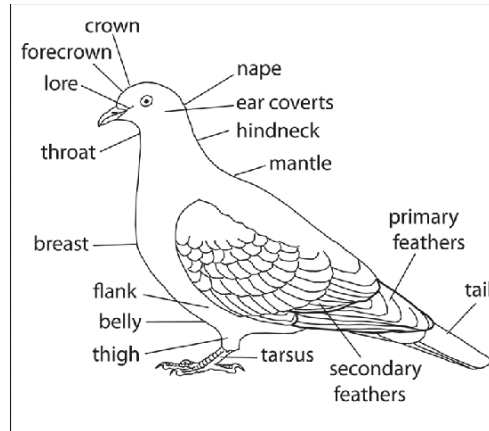
(9) Trunk is large and stout.

(10) Tail is long thickened and serves as storehouse for fat.

(11) Forelimbs and hind limbs are stout, well developed and adapted for swift movement, but they can lift hardly body up from the ground.

(12) Digits are clawed.

Columba



Classification: Phylum Chordata **Class** Aves

Order **Genus** *Catla*

Comments:

(1) *Columba* is commonly found in India, forested zone of the Pacific coast and United States. Eocene to Recent.

(2) *Columba livia* is the most common and familiar bird around man, nesting in buildings, old houses, warehouses, sheds and railway stations. Their flight is swift and strong. Breeding continues throughout the year.

(2) Commonly called as blue-rock pigeon and Kabutar in Hindi.

(3) Body is divisible into head, neck, back and breast and abdomen.

(4) Plumage is grey with glistening metallic green and purple on breast and neck.

(5) Head contains large eyes and slit-like nostrils. It is produced into a short and slender bill or beak. Upper and lower beaks are covered by the horny sheath, called rhamphotheca. At the base of the upper beaks there is a patch of skin called cere.

(6) Beak adapted for seed-eating.

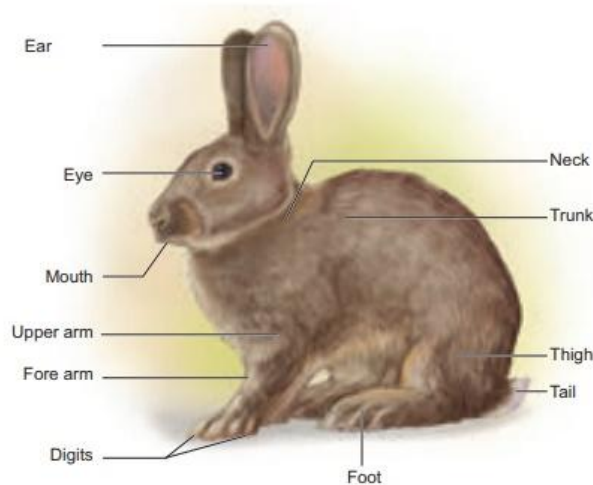
(7) Eyes are large, rounded, with a well-developed nictitating membrane and a rounded pupil. (7) Forelimbs are modified into wings which contain besides skeleton flight feathers called as remiges. Feet are covered with epidermal scutes formed by the fusion of several reptilian epidermal scales.

(8) Hind limbs are modified for bipedal locomotion. Tarsus usually shorter than toes. Wing feathers, tail feathers present. Other structures seen are neck, breast, abdomen and black bars on wings. (9) Eggs white and unmarked.

(9) Pigeons serve as an excellent example for artificial selection of Darwins theory of evolution as various varieties have been produced by man.

(10) Crop large, producing 'pigeon milk' to feed small young.

Oryctolagus



Classification: Phylum Chordata **Class** Mammalia

Order **Genus** *Catla*

Comments

(1) Inhabiting fields, grasslands and woodlands. Gregarious, crepuscular (coming out of burrows for feeding in twilight), coprophagous (eating again their soft stool) for maximum

(2) Commonly called as Rabbit.

(3) Body cat-like and divisible into head, neck, trunk, abdomen and tail.

(4) Head contains long tactile vibrissae or whiskers, external nares, usually shorter eyes and mouth. External ears large having external auditory meatus.

(5) Length 40 cm from mouth to anus.

(6) Fur colour white, black, brown or spotted. (

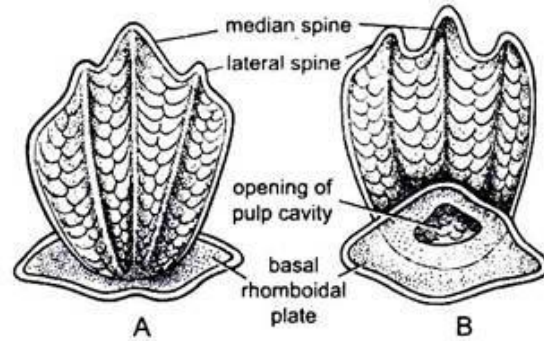
(7) Males have muscular skin-covered penis.

(8) Females have clitoris.

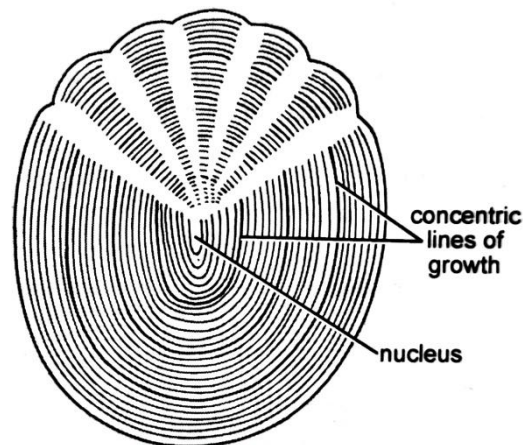
(9) Forelimbs used for digging and hind limbs for leaping. Fast runner (30 to 40 km per hour). Forelimbs contain upper arm, forearm, metacarpus, hand and clawed fingers. Hind limb contains thigh, shank, metatarsus, foot and clawed toes.

Ex. 2 Study of permanent slides showing whole mount of vertebrate scales: Cycloid, Ctenoid, Placoid.

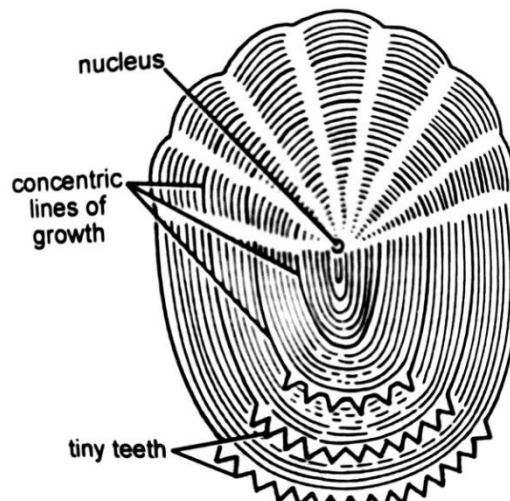
1. **Placoid scales:** Consists of a basal plate and a spine, giving a rough surface to skin. Basal plate is formed of a substance resembling the cement of teeth, secreted by the dermis. The spine develops from the malpighian layer of the epidermis -The outermost covering of spine is made of vitrodentine while inner layer is dentine which encloses pulp cavity. The basal plate has an aperture through which blood vessels and nerves of the dermis enter into the pulp cavity -The placoid scales do not overlap each other -Ecto-mesodermal in origin, resemble teeth in basic structure.



2. Cycloid scales : Thin, transparent, roughly rounded -Shows alternate ridges and grooves
 -Ridges or circuli are concentric rings -Central part is focus -Oblique grooves or radii running from the focus to the margin -Dermal in origin -First appear on the caudal peduncle of the larva and then on the remaining body -Project diagonally in an imbricating pattern, forming a protective covering over the body -The circuli or ridges are less distinctly seen in the posterior part of the scale to which chromatophores are also attached. Bony material is ichthylepdin. **eg.** Carps (Teleosts).



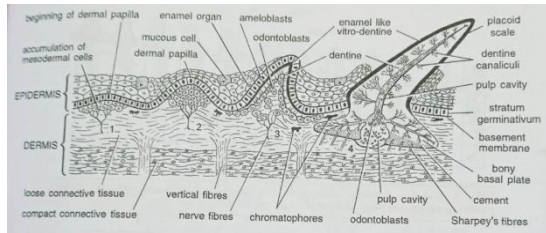
3. Ctenoid scales: Basically similar to the cycloid scale -Has a serrated margin and spines on posterior part **eg.** Perciform fishes (*Anabas, Nandus, Channa*).



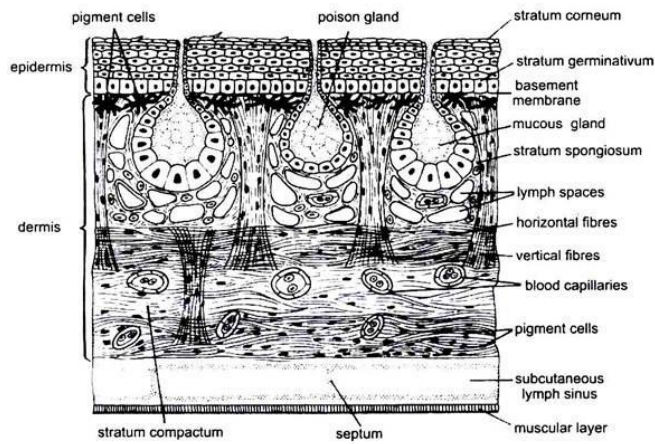
Ex. 3 Comparative study of histological slides of skin in different group of vertebrates:

V.S. of skin of *Scoliodon*, *Rana*, *Uromastix*, *Columba*, *Oryctolagus*.

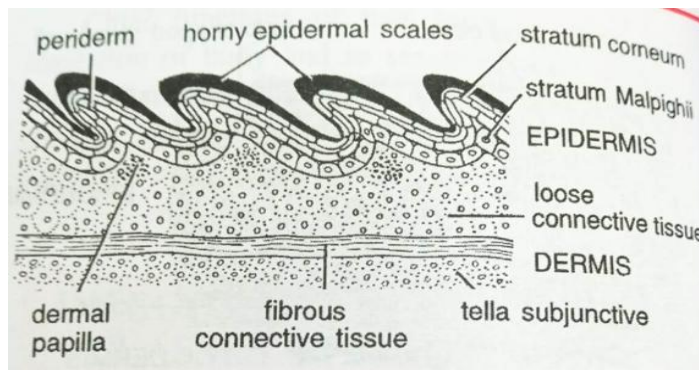
Scoliodon



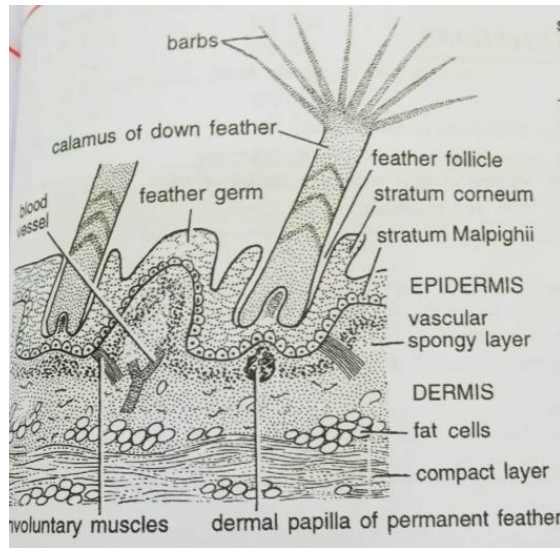
Rana



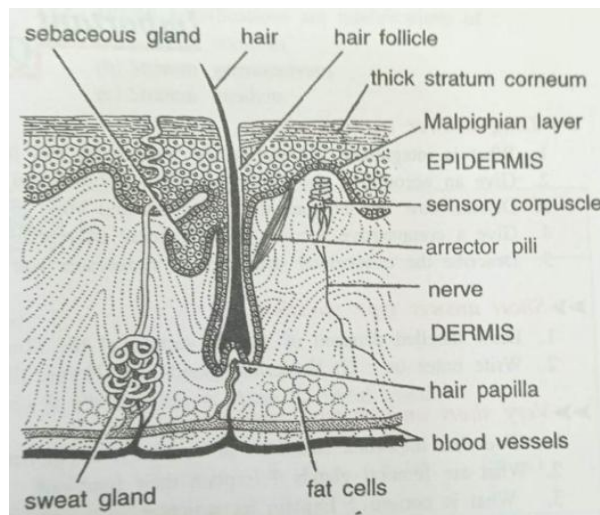
Uromastix



Columba



Oryctolagus.



Characters	FISH -Dogfish (Scoliodon)	AMPHIBIA- Frog (Rana)	REPTILIA- Lizard (Uromastix)	AVES- Pigeon (Columba)	MAMMALIA- Rabbit (Oryctolagus)
A. INTEGUMENT					
1. Skin surface & attachment	Skin hard, rough, rigid, leathery and firmly attached to body.	Skin, thin, moist, slimy, smooth, fitting loosely on body enclosing large sub-cutaneous lymph spaces beneath dermis.	Skin thicker, dry, rough, and loosely folded along the sides of neck and trunk.	Skin, thin, dry, hard, flexible and loosely attached to achieve maximum movement for flight.	Skin thickest, dry. elastic and loosely attached to body. Variously modified.

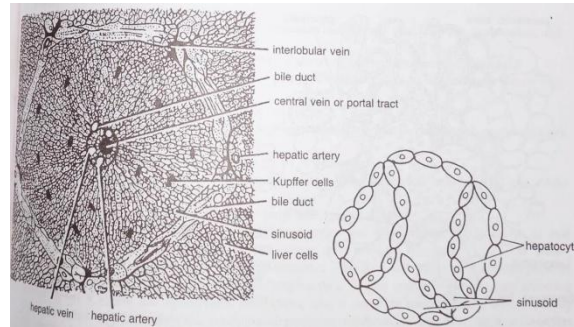
2. Colouration	Colour of Scoliodon is dark, grey dorsally and pale white ventrally. In fishes, greatest colour patterns amongst chordates.	Colour of Rana is greenish with black and brown patches above and lighter pale yellow below.	Body of <i>Uromastix</i> is yellow brown with dark spots above and lighter and paler below. In reptiles, colour patterns for warning or concealment.	Rock pigeon is slaty-grey with green and purple sheen around neck and breast and two black bars on each wing. Birds in general are beautifully coloured.	Colour of rabbit is dusty-brown and protective. Mammals in general are dull coloured.
3. Pigment cells	Pigment containing chromatophores and guanin containing irridophres located in dermis.	Chromatophores located in dermis	Chromatophores located in dermis	Pigment cells found in feathers, they migrate from dermis. feathers.	Pigment granules located in hair and epidermis, pigment cells in dermis.
4. Colour change (Metachrosis)	Body color does not change. Some fishes have protective colouration.	Frog has protective colouration for camouflage and can body colour to match with the surroundings.	<i>Uromastix</i> has no power to change body colour. However, <i>Calotes</i> and <i>Chamaeleons</i> can change body colours.	No capacity for change of body colouration..	Usually, no capcity to change body colouration.
5. Cutaneous respiration	No cutaneous respiration. Not permeable to water.	Skin protective and permeable to water, hence cutaneous respiration present.	No cutaneous respitation. Skin protective and water-proof.	No cutaneous respiration. Skin protective, insulating and water-proof.	No cutaneous respiration. Skin protective, insulating and water-proof.
6. Epidermis	Epidermis stratified , thin and without a cornified stratum corneum, thin cuticle present,	Stratified epidermis with a thin stratum corneum, continuously shed in patches.	Epidermis stratified, relatively thicker stratum corneum periodically shed in bits or in one	Epidermis stratified, relatively thinner, and seasonally shed and	Epidermis greatly stratified. Stratum corneum highly specialized

	no moulting.		piece.	replaced.	with several modifications. No regular moulting.
7. Epidermal glands	Epidermis contains numerous unicellular mucous secreting gobble gland cells. Multicellular poison and luminescent glands also occur in some fishes.	Epidermis is rich in mucous glands. Some amphibians have poison glands like parotid glands of toad.	Lizard have few but no mucous glands. Male lizard has femoral glands on thighs. Some reptiles have scent or musk gland.	No skin glands occur in birds except a single large preen or uropygial gland on tail. No mucous glands present.	Skin richly glandular containing characteristic mammary, sweat and sebaceous glands besides scent glands. No mucous glands present.
8. Dermis	Dermis is typical with connective tissue fibres, blood and lymph vessels and pigment cells. Connective tissue fibres run parallel to surface	Dermis is thin and typical. It consists of an outer loose stratum spongiosum, and an inner compact layer, stratum compactum. Connective tissue fibres are vertical as well as horizontal.	Dermis is thick and typical, containing connective tissue fibres, muscles and nerves, blood capillaries and lymphatic vessels, and pigment cells.	Dermis is mostly thin and typically made of muscle fibres, nerves, blood capillaries and connective tissue. It has no pigment cells.	Dermis is proportionately thicker of all vertebrates, containing intricate fibres, tactile organs, nerves, blood vessels and pigment cells.
9. Dermal scales	Dermal scales are present as placoid scales.	Dermal scales are absent in frog although embedded in the skin of some Gymnophiona.	Dermal scales absent in <i>Uromastix</i> , but some dermal scales, scutes or plates, called osteoderms, occur in some lizards, crocodiles and turtles.	Dermal scales are absent.	Dermal scales or plates absent, occur only in armadillos and whales.
B. Exoskeleton					
1. Parts of exoskeleton	Exoskeleton present and represented by scales.	Exoskeleton completely lacking.	Exoskeleton present and represented by scales, claws, etc.	Exoskeleton present formed by scales, claws, sheaths of beaks and feathers.	Exoskeleton present and formed by scales, claws, hairs, hoofs, horns, nails, outer covering of antlers, etc.

2. Epidermal scales	Epidermal scales are absent.	Both epidermal and dermal scales are absent.	Epidermal scales, thin, small, overlapping and covering whole of the body.	Epidermal scales small, present on lower legs, feet and base of beak only.	Epidermal scales are absent in rabbit but present on the feet and tails of the rats, beavers, etc.
3. Dermal scales	Represented by: Cycloid, ctenoid, ganoid and cosmoid.	No dermal scales	includes dermal scutes and plates crocodiles and turtles.	No dermal scales	No dermal scales
4. Other parts	Hair, feathers, horns and beak absent	Hair, feathers, horns and beak absent	Hair and feathers absent . Grotesque horns (horned toad), rattle (rattle snake) and horny beaks (turtles) present in some.	Hair and horns absent. Feathers (contour, down and filoplume).	Feathers and beaks absent. Hair modified into hair horns (Rhino), scales (<i>Pangolins</i>). Spines (<i>Echidna</i>), quills (porcupine), etc. Claws become nails (primates) or hoofs (ungulates). Horns and antlers present in ungulates.
5. Moulting	Scales do not moult but grow in size with age.	Stratum corneum of frog moulted periodically in small pieces.	Scales shed periodically in small bits.	Feather shed and replaced seasonally.	Horny covering of pronghorn and skin of antlers moulted seasonally.

Ex. 4 Study of available permanent slides of different vertebrate organs: T.S. of mammalian liver, pancreas, testis, ovary, thyroid, duodenum and L.S. of kidney, etc.

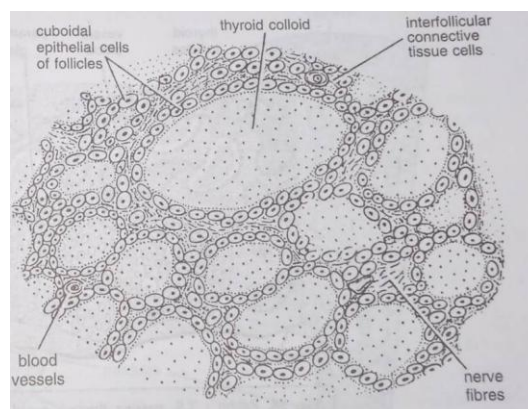
T.S. of mammalian liver



Comments:

- (1) Liver of rabbit is a five-lobed structure. T.S. passing through liver shows hepatic strands ducts, blood vessels and central vein.
- (2) The liver is a solid glandulo-reticular organ made of polyhedral radiating column of cells called as laminae.
- (3) Bile canaliculi lie among the hepatic cells and connect in groups forming bile ductule or portal-tract consisting of bile, duct hepatic artery and hepatic vein.
- (4) Each hepatic lobule is pierced everywhere with a network of sinusoid.
- (5) Conspicuous cells occur at intervals on the walls of the sinuses. These are called as stellate c Kupffer cells. They are highly phagocytic and they ingest erythrocytes and other suspended particles. Kupffer cells could be best seen under high magnification presence of Kupffer cell indicates immune response.

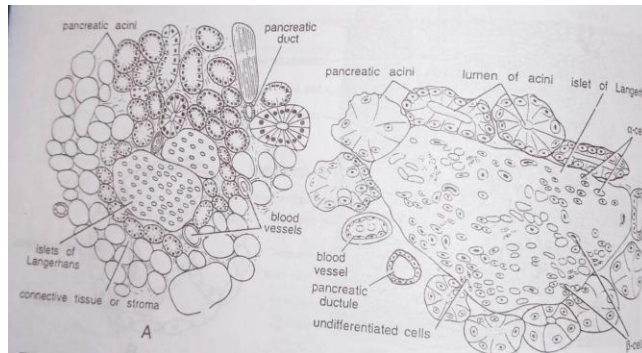
T.S. of mammalian thyroid



Comments:

- (1) It is the most familiar endocrine gland, consisting of right and left lobes connected across to the ventral side by isthmus.
- (2) Thyroid gland comprises of a framework of connective tissue, enclosing numerous rounded oval follicles or vesicles of different sizes and covered by capsule.
- (3) Histologically it consists of a number of rounded thyroid follicles of various sizes, separated by one another by connective tissue strands.
- (4) Thyroid is richly supplied with blood vessels and nerves. It is innervated from the sympathetic nerves.
- (5) Thyroid secretes thyroxin ($C_{15}H_{11}O_4N_4$) which contains an amino acid and 65% of iodine.
- (6) The thyroid is composed of follicular and interfollicular zones. Follicles are surrounded single layered cuboidal epithelial cells. Lumen of each follicle, contains a viscous liquid called thyroid colloid.
- (7) Interfollicular zone contains nerves, blood, vessels and large number of nuclei : nerves, blood vessels and large number of nuclei.

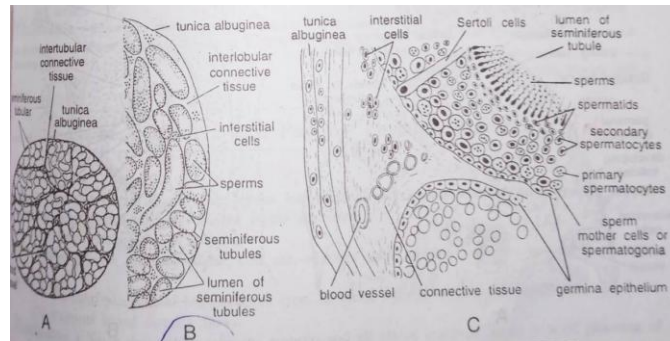
T.S. of mammalian pancreas



Comments:

- (1) Pancreas is a very important digestive gland. T.S. passing through it shows that it is composed of various alveoli or pancreatic acini. It is a compound tubulo-alveolar racemose gland consisting of both exocrine and endocrine parts.
- (2) The mammalian pancreas can be distinguished from that of frog in having distinct lobulations, (alveoli or pancreatic acini and islets of Langerhans.
- (3) Each pancreatic lobe contains 10 to 20 secretory cells or acini which are nucleated. The central part has narrow to wide lumen. The pancreatic duct, large artery and vein are also seen in the section. Several cut blood vessels present in connective tissue.
- (4) Acini and islets of Langerhans are very clearly seen. The wall of each acinus is made up of columnar or pyramidal cells. Each cell contains a central nucleus and coarse granules. Each and acinus has wide lumen.
- (5) The region of islets of Langerhans reveals 3 or 4 kinds of cells-a, B and undifferentiated cells.

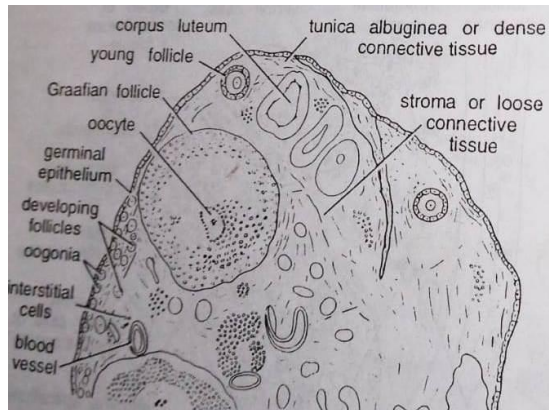
T.S. of mammalian testis



Comments:

- (1) There is a pair of smooth, oval-shaped testes, each enclosed in a thin envelope, called as tunica albuginea.
- (2) Histologically each testis is internally divided into a number of lobules with occasional internal communications and separated by connective tissue.
- (3) Glandular substance of the testis is wholly made up of convoluted seminiferous tubules. Large number of cut seminiferous tubules are seen with varying diameter.
- 4) Section shows tunica albuginea, cells, sperms, seminiferous (B). tubules and lumen of seminiferous tubules
- (5) Interstitial cells which produce a hormone, called as testosterone, which is responsible for the development of male secondary sexual characters.
- (6) Testis is covered by serosa and a fibrous coat or tunica albuginea.
- (7) At the interjunction of two seminiferous tubules, connective tissue, interstitial cells vacuoles a blood vessels are seen.
- (8) In the seminiferous tubules are some nutritive Sertoli cells.
- (9) Seminiferous tubules appear rounded or oval in section. Each tubule is surrounded by a thin basement membrane lined by germinal epithelium.
- (10) From basement membrane to inwards there are several kinds of cells:
 - (i) Spermatogonia lie along periphery of tubule and appear closely packed together,
 - (ii) Primary spermatocytes - They have the largest cells and large nuclei,
 - (iii) Secondary spermatocytes - Smaller cells with deeply stained nuclei
 - (iv) Spermatids- small clusters of cells with condensed nuclei
 - (v) Spermatozoa or sperms lie in the cavity of tubule.
- (11) Sperm has head and tail.
- (12) The nucleus of the sperm lies in the head which is pointed as the acrosome.
- (13) Outer covering tunica albuginea, interstitial cells and blood vessels, etc. are seen in the section.

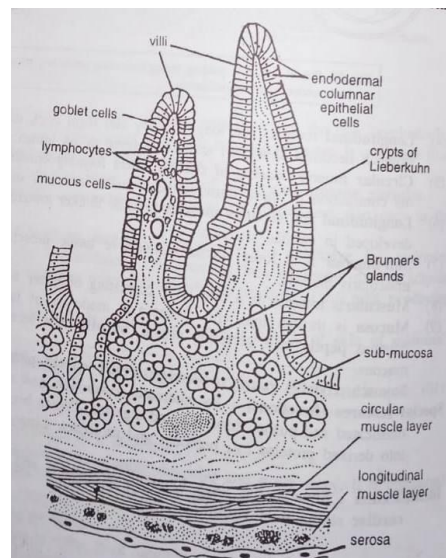
T.S. of mammalian ovary



Comments:

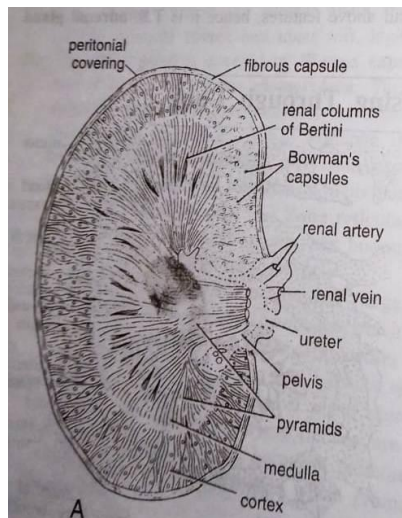
- (1) Outer most layer is of peritoneum which has cubical cells.
- (2) Just beneath peritoneum is germinal epithelium bounded by connective tissue called as tunica albuginea.
- (3) Germinal epithelium gives rise to oogonia, developing follicles and Graafian follicle.
- (4) Section shows young follicles and mature Graafian follicles and corpus luteum.
- (5) Interior of the section shows connective tissues, interstitial cells and blood vessels.
- (6) Detailed structure of Graafian follicle is seen under high magnification. Follicle is surrounded by connective tissue or stroma.
- (7) Fully mature oocyte is surrounded by a thick transparent layer called Zona pellucida surrounded by another layer corona radiata.
- (8) Corona radiata is surrounded by mass of cells called as discus proligerous or cumulus.
- (9) Corona radiata is surrounded by liquor folliculi and then by membrane granulosa. Thick membrane granulosa is covered by thick layer called as theca folliculi.

T.S. of mammalian ileum



Comments:

- (1) The T.S. through ileum shows that it is composed of outer serosa, muscular coat, sub-mucosa, muscularis mucosa and mucosa.
- (2) Serosa forms outer thin layer covering containing squamous epithelial layer.
- (3) Muscular coat consists of outer longitudinal and inner circular fibres.
- (4) Longitudinal muscle layer is comparatively thinner. By their contraction intestinal tube is shortened but its lumen is widened.
- (5) Circular muscle layer is almost double in thickness than the L.M.L. On its (CML) contraction there is increase in the size of the intestine but decrease in the lumen.
- (6) Sub-mucosa is well developed and is composed of loose connective tissue.
- (7) Sub-mucosa is very thin layer consisting of outer longitudinal and inner circular muscle layer.
- (8) Mucosa is thrown into villi or folds composed of single-layered endodermal columnar epithelial cells. From the base of villi upto surface layer there are several tubular simple or branched glands called as crypts of Lieberkuhn. These glands are lined by epithelial cells containing goblet cells.
- (9) Above muscularis mucosa there are several nucleated rounded glands called as Brunner's glands. Villi are composed of tall simple columnar endodermal columnar epithelial cells or absorptive cells and rounded goblet cells. Several nuclei are seen. The inner substance of the villi contains connective tissue, lacteals and nuclei. Along with basal nuclei rounded lymphocyte cells are clearly seen.

L.S. of mammalian kidney**Comments:**

- (1) Kidney is metanephric, compact, bean-shaped, retro-peritoneal, compound, tubular to dorsal body wall. Covered by retroperitoneal covering and fibroin capsule.
- (2) Saggital section of the kidney reveals two distinct portion (i) Cortex and (ii) Medulla. Between the two zones is undefined boundary zone characterized by large blood vessels.
- (3) Cortex has several rounded Bowman's capsules. Medulla is subdivided into conical portions called pyramids.

(4) Cortex and medulla are entirely composed of uriniferous tubules, which have straight direction in the medulla and contorted arrangement in the cortex. Renal artery, renal vein and ureter enter at the hilum.

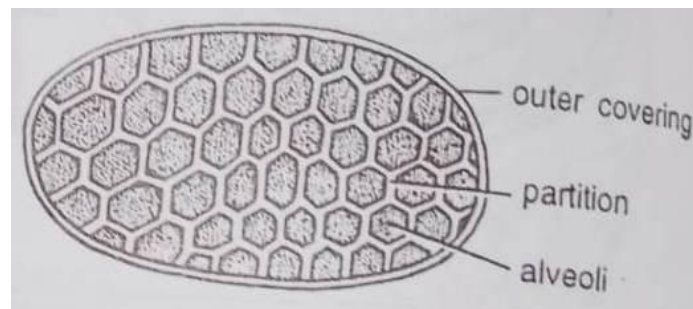
(5) Groups of straight tubules pass from the medulla through the thickness of the cortex forming the medullary rays.

(6) Between the medullary rays are the deep conical downgrowths, called as renal column of Bertini.

7. Uriniferous tubules are lined with large granular ciliated epithelial cells and begin in the cortical part of the organ in dilation as Bowman's capsules, which enclose convoluted tufts of blood capillaries called glomerulus and several nuclei.

8. Capsule is lined by flattened epithelium. Glomerulus is formed by branches of afferent and efferent vessels. Tubule leaves the capsule by neck and it forms proximal convoluted ascending limb, descending limb and loop of Henle. Blood vessels are also seen in the section.

V.S. of reptilian lung



V.S. of Lung of lizard

Comments:

(1) V.S. lung of lizard shows outer serosa enclosing lung alveoli.

(2) Inner lining of lung is raised into number of septa like structures, enclosing air sacs or alveoli.

(3) Lung contains rich blood supply.

(4) Alveoli are separated by septa.

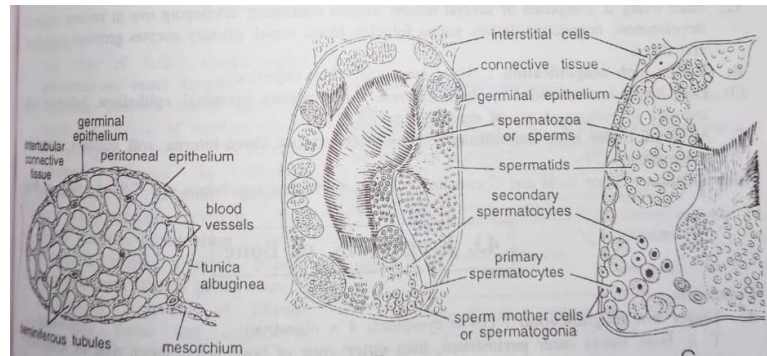
(5) Anterior lung is more sacculated thicker and richly vascularised.

(6) Lung cavity is continuous.

(7) Bronchus entering into lung does not branch into bronchioles but it directly forms alveoli.

(8) In lungs deoxygenated blood is brought by pulmonary artery and oxygenated blood carried away by pulmonary vein.

T.S. of amphibian testis



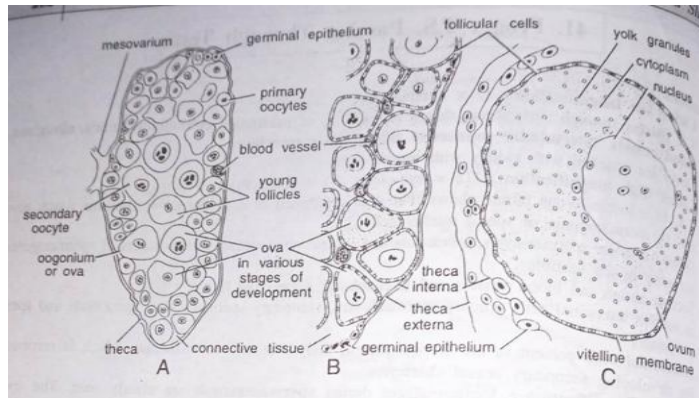
Comments:

- (1) TS passing through testis shows that it is made up of peritoneal epithelium, tunica, albuginea, blood vessels, intertubular connective tissue and mesorchium.
- (2) Testis are attached with kidney with mesorchium.
- (3) T.S. of a seminiferous tubule shows that it is composed of a germinal epithelium which gives rise to spermatogonia or sperm mother cells.
- (4) Other stages are spermatocytes, spermatids and sperms representing various stages of spermatogenesis are seen in the section.
- (5) Section shows cut blood vessels and inter-tubular connective tissue.
- (6) In section interstitial cells, primary spermatocytes, secondary spermatocytes, spermatids and sperms are seen.
7. Interstitial cells present in the section secrete male hormone testosterone, which is responsible for developing secondary sexual characters.

T.S. of amphibian Ovary

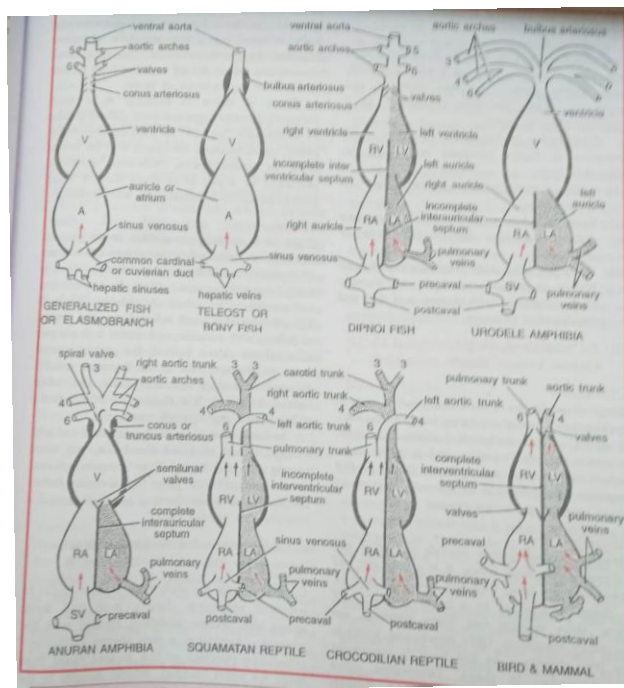
Comments:

- (1) There are two ovaries attached to kidneys by mesovarium.
- (2) Each ovary is composed of several hollow lobules containing developing ova in various stages of development, connective tissues, young follicles, blood vessels, primary oocytes, germinal epithelium and theca.
- (3) Each lobule is surrounded by theca externa, theca interna, germinal epithelium, follicular cells and ova in various stages of development.



Ex.5 Demonstration of brain and heart of different vertebrates through alternative methods of dissection.

a) Comparative study of heart



Characters	FISH Dogfish (<i>Scoliodon</i>)	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
1. Position of heart in body	Heart lies mid-ventrally beneath pharynx in pericardial cavity separated from peritoneal cavity by a partition, called septum transversum , perforated by a pericardio-peritoneal canal .	Heart lies mid-ventrally beneath oesophagus in thoracic cavity. Septum transversum is absent.	Heart lies mid-ventrally above sternum in thoracic cavity. There is no septum transversum .	Heart lies mid-ventrally in thoracic cavity surrounded by lobes of liver.	Heart lies enclosed in a median pericardial cavity of thorax, between the pleural cavities containing lungs.

Characters	FISH Dogfish (<i>Scollodon</i>)	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
2. Pericardium	Heart lies protected within a 2-layered membranous pericardium .	Heart lies enclosed by a thin, transparent, 2-layered sac, the pericardium .	Heart lies protected within a 2-layered, thin, transparent sac, the pericardium .	Heart enclosed by a thin, 2-layered, transparent, membranous sac, the pericardium .	Heart completely surrounded by a 2-layered membranous sac, the pericardium .
3. Size, shape and colour	Small, S-shaped, dorso-ventrally bent and raddish brown.	Small, somewhat conical or triangular and reddish in colour.	Small, roughly triangular and reddish in colour.	Comparatively larger, conical in shape and reddish in colour.	Larger pear-shaped and reddish in colour.
4. Chambers	Consists of a linear series of 4 chambers: sinus venosus, auricle, ventricle and conus, all distinguished externally. But only auricle and ventricle are true chambers, hence 2-chambered .	3- chambered , made of 2 auricles and 1 ventricle. Auricles not demarcated externally. Besides, sinus venosus and truncus arteriosus also present.	3- chambered , made of 2 auricles and one incompletely divided ventricle, all faintly demarcated externally. Sinus venosus also present.	4- chambered , made of 2 auricles and 2 ventricles. Ventri-cles not distinguish- shable externally.	4- chambered , made of 2 auricles and 2 ventricles, all distinguishable externally.
5. Sinus venosus	Triangular, extending transversely over posterior region of ventricle and fused with pericardial wall. Receives venous blood from body by two ducti Cuvieri laterally and two hepatic sinuses posteriorly.	Triangular, dark coloured, attached dorsally over auricles and ventricles. Receives venus blood by 3 venae cavae : two anterior precavals and one posterior postcaval , joining at its angles.	Sinus venosus is large, bilobed, attached transversely to dorsal surface of auricles. Formed by the union of 2 precavals and 1 postcaval .	Sinus venosus absent said to be incorporated into right auricle. Thus 3 caval veins open directly into right auricle.	Sinus venosus absent and merged into right auricle. Their union marked externally by a groove, sulcus terminalis , and internally by a muscular ridge, crista terminalis. 3 venae cavae open directly into right auricle.
6. Sinus-atrial aperture	Sinus opens into posterior end of auricle by a sinuatrial aperture guarded by a pair of membranous valves .	Sinus opens into dorsal wall of auricles by a large, oval, sinu-atrial aperture guarded by a pair of flaplike valves .	Sinus opens into right auricle through an oval aperture with muscular lips and without valves .	Sinus venosus absent. However, opening of postcaval into right auricle guarded by a muscular Eustachian valve .	Sinus venosus absent. However, opening of postcaval into right auricle guarded by a rudimentary Eustachian valve .
7. Atria or auricles	Atrium or auricle somewhat triangular. Undivided internally due to lack of an inter-auricular septum .	Auricles somewhat rectangular. Do not form auricular appendages. Internally divided completely into right and left auricles by an inter-auricular septum .	Two auricles divided <u>completely</u> by an inter-auricular septum . Right auricle gives off a small diverticulum from its dorsal antero-medial surface.	Two auricles divided by an inter-auricular septum . Dorsal anteromedial diverticulum absent.	Two auricles completely separated by an inter-auricular septum . Right auricle without diverticulum.

Characters	FISH Dogfish (<i>Scoliodon</i>)	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
8. Atrial wall	Thin - walled, spongy, moderately muscular.	Thin walled, without processes.	Thin-walled, inner lining forming a network of low muscular ridges.	Comparatively thick-walled with inner surface raised into muscular ridges.	Comparatively thick walled. Inner surface raised into a network of muscular ridges called musculi pectinati .
9. Auricular appendix	Each auricle laterally projects beyond ventricle as ear like auricular appendages .	Absent.	Absent.	Absent.	Each auricle produced behind into a swollen flap, the auricular appendix , slightly covering the ventricle of its side.
10. Pulmonary veins	Absent and therefore do not open into auricle.	A common pulmonary vein opens into left auricle.	A common pulmonary vein opens into left auricle.	Four pulmonary veins open by a common aperture into left auricle.	Two pulmonary veins open by a common opening into left auricle.
11. Auriculo-ventricular aperture & valves	Atrium opens into ventricle through its dorsal wall by a single auriculo-ventricular aperture guarded by a pair of membranous valves.	Both auricles open into ventricle posteriorly through a common large auriculo-ventricular aperture guarded by 2 pairs of flaplike valves.	Both auricles communicate behind with ventricle through separate right and left auriculo-ventricular apertures due to backward extension of interauricular septum into ventricle, each guarded by a valve of one semilunar flap.	There are two separate circular auriculo-ventricular apertures. Right valve is made of a large muscular fold, while left valve is <i>bicuspid</i> , made of two membranous flaps.	There are two separate auriculo-ventricular apertures. Right aperture is guarded by a tricuspid valve made of 3 triangular flaps or cusps, while left bicuspid or mitral valve consists of 2 flaps only.
12. Ventricles	Small, pearshaped, thickwalled undivided chamber lying ventral to sinus and auricle. Interventricular septum not found.	Small, conical, thick-walled undivided chamber lying posterior to auricles. No interventricular septum .	Small, conical thick-walled chamber lying behind auricles. Incompletely divided by a prominent oblique muscular ridge or septum into a larger dorsal part, cavum dorsale , and a smaller ventral part, cavum pulmonale .	Two right and left large, thick-walled ventricles, completely separated by a vertical interventricular septum .	Two large and thick-walled right and left ventricles completely separated by a vertical interventricular septum .
13. Chordae tendineae	Cavity of ventricle traversed by numerous muscular strands, chordae tendineae giving it a spongy texture.	Flaps of auriculo-ventricular valve attached to wall of ventricle by thread like chordae tendineae .	Free edges of auriculo-ventricular valves attached to inner wall ventricle by firm cords, the chordae tendineae .	Flaps of auriculo-ventricular valves attaches to papillary muscles by chordae tendineae .	Free edges of valvular flaps connected to papillary muscles by long, tough connective tissue strands, chordae tendineae .

Characters	FISH Dogfish (<i>Scoliodon</i>)	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
14. Columnae carnae	Absent.	Irregular strands or ridges given from inner wall of ventricle.	Prominent ridges raised from inner surface of wall of verticle.	Bars of muscles traversing cavities of ventricles.	Small irregular muscular ridges projecting from wall of ventricles.
15. Papillary muscles	Absent.	Absent.	Absent.	There are prominent muscular projections from inner wall of ventricles.	These are large, conical, nipple-shaped muscular elevations from inner wall of ventricles.
16. Conus or truncus arteriosus	Conus arteriosus is a stout, undivided, muscular tube given anteriorly by ventricle. Its cavity contains 2 rows of 5 a semilunar valves each, 3 larger and 2 smaller. Spiral valve absent.	Truncus arteriosus is a pear-shaped tube arising anteriorly from right ventral side of ventricle. It's cavity is divided by 3 semilunar valves into a distal chamber, synangium and a proximal chamber, pylangium . Latter is further divided by a spiral valve into cavum pulmocutaneum and cavum aorticum .	Conus or truncus arteriosus absent.	Conus or truncus arteriosus absent.	Conus or truncus arteriosus absent.
17. Aortic arches	Conus leads anteriorly into a ventral aorta which gives off 5 pairs of lateral aortic arches.	Truncus bifurcates anteriorly into right and left trunks each dividing into 3 aortic arches : common carotid, systemic and pulmocutaneous . Ventral aorta absent.	Ventral aorta absent. 3 aortic arches arise directly from ventricle : pulmonary from cavum pulmonale and right and left systemic from cavum dorsale.	Ventral aorta absent. Only 2 aortic arches arise : pulmonary from right ventricle and right systemic leaving left ventricle.	Ventral aorta absent. Only 2 aortic arches present : pulmonary arising from right ventricle and left systemic from left ventricle.
18. Foramen Panizzae	Absent.	Absent.	Present at the point of contact where two systemic arches cross each other.	Absent.	Absent.
19. Working	Heart receives only venous blood from body and sends it to gills only for aeration. Called venous heart with a single circulation .	Heart receives venous as well as oxygenated bloods. It supplies mixed blood to different regions of body. Called transitional heart with a single circulation .	Mixing of venous and oxygenated bloods occurs in incompletely divided ventricle. Hence transitional heart with single circulation and less efficient.	Heart completely 4-chambered without mixing of venous and oxygenated bloods. Hence with double circulation and more efficient.	Heart 4-chambered as in birds. Hence with double circulation , venous blood going to lungs and oxygenated blood to body, and more efficient.

b) Comparative study of Brain

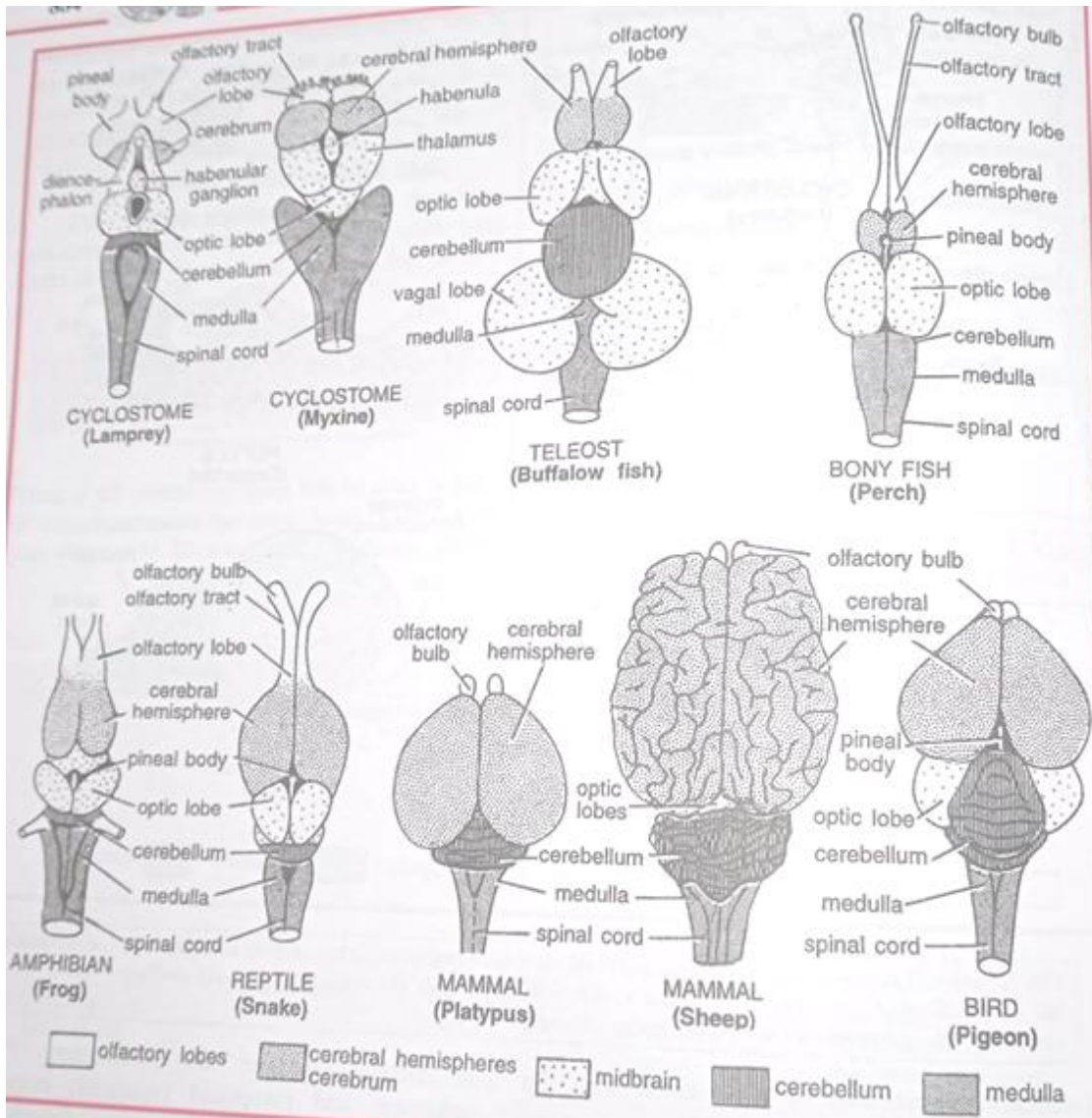


Table 11. Comparative Account of Brain in Fish, Amphibia, Reptilia, Aves and Mammalia.

Characters	FISH Dogfish (<i>Scoliodon</i>)	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
1. Cranium	Brain enclosed within a cartilaginous cranium.	Cranium bony.	Cranium bony.	Cranium bony.	Cranium bony.
2. Size & main parts	Brain simple, elongated, flattened, thrice as long as broad, and made of usual 3 basic parts forebrain, midbrain & hindbrain.	Brain simple, elongated, flattened, nearly 3 times longer than broad. Made of same 3 main parts forebrain, midbrain & hindbrain.	Elongated as in frog, but comparatively larger and broader. Similarly made of forebrain, midbrain and hindbrain.	Brain relatively larger and more complex than in reptiles. A little longer than broad. Made of usual 3 main parts.	Brain relatively largest complex and most advanced. Nearly twice as long as broad. Made of usual 3 main parts.
3. Meninges	Brain protected by a single membrane, meninx primitiva .	Brain protected by 2 membranes : a thin inner piamater and a thick outer duramater .	Brain protected by 2 membranes : piamater and duramater , as in frog.	Brain protected by 2 meninges : pia-archnoid and duramater .	Brain protected by 3 membranes : pia-mater , arachnoid and duramater .

[I] FOREBRAIN

A. OLFACTORY LOBES

4. Position	Attached to anterolateral angles of cerebrum, hence widely separated.	Attached side by side in front of cerebrum, demarcated by slight constrictions.	Attached in front of cerebrum without to constrictions, and side by side.	Attached anteriorly to cerebral hemispheres and largely covered by them.	Attached distinctly to anterior end of cerebrum.
5. Shape and size	Large, bilobed, highly developed. Hence brain called nose brain . Sense of smell highly developed.	Small and spherical due to poor sense of smell in frog.	Small in proportion due to poor sense of smell.	Small, conical due to poor sense of smell.	Small, elongated due to poor sense of smell.
6. Parts	Differentiated into a slender stout olfactory tract or peduncle and a bilobed olfactory bulb .	No differentiation between tract and bulb.	Each drawn out into a narrow, slender peduncle bearing distally a small nodulelike olfactory bulb .	No distinction into olfactory peduncles and olfactory bulbs .	Olfactory tracts remain covered beneath cerebrum. Clubshaped bulbs visible dorsally.
7. Relation with olfactory sac	Olfactory bulb closely applied to large olfactory sac.	Not closely applied to olfactory sac.	Not closely applied to small nasal sac.	Not closely applied to olfactory sac.	Closely applied to nasal sac.
8. Olfactory ventricles	Cavities called rhinocoels spacious.	Rhinocoels small and narrow.	Rhinocoels narrow.	Rhinocoels absent.	Rhinocoels present.

B. CEREBRAL HEMISPHERES

9. Size & shape	Cerebrum large, somewhat rectangular. It has no median groove dividing it into right and left cerebral	A deep median longitudinal fissure divides cerebrum into two long, oval, cerebral hemispheres .	Two oval cerebral hemispheres divided by a mid-longitudinal groove.	Two very large, pyriform cerebral hemispheres separated by a deep sagittal fissure. Cover olfactory	Large, pyriform, greatly developed, separated by deep sagittal fissure. Overlap olfactory lobes in front and
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Characters	FISH Dogfish (<i>Scoliodon</i>)	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
10. Neuropore	hemispheres of higher vertebrates. It bears a small mid-ventral opening, the neuropore , for terminal nerves to emerge out.	Neuropore absent.	Neuropore absent.	lobes in front and diencephalon behind. Neuropore absent.	midbrain behind. Neuropore absent.
11. Surface	Smooth, without folds, fissures and lobes.	Smooth, without folds, fissures and lobes.	Surface smooth. No folds, fissures and lobes.	Relatively smooth, devoid of folds, fissures and lobes.	Surface bears fissures (sylvian, rhinal, etc.) and divided into lobes (frontal, parietal, temporal, hippocampal).
12. Cerebral cortex	Absent. Grey matter forms lining of lateral ventricles.	Shows beginning of cerebral cortex.	Poorly developed.	Relatively poor than in mammals.	Very well developed.
13. Pallium	Roof of cerebrum (pallium) poorly developed.	Pallium developed better than in fish.	Pallium shows an increase over that of amphibians.	Relatively poor than in mammals.	Very well developed.
14. Corpora striata	Ventro-lateral walls of cerebrum (corpora striata) poorly developed.	Developed better than in fish.	Thick, developed.	Thick, very conspicuous.	Comparatively less developed.
15. Corpus callosum	Absent.	Absent.	Absent.	Absent.	Special transverse band of neural tissue present inter-connecting two cerebral hemispheres internally.
16. Lateral ventricles	Also called paracoels , spacious and unbranched.	Paracoels or lateral ventricles unbranched.	Paracoels unbranched.	un- Paracoels branched.	un- Well developed and branched.

C. DIENCEPHALON

17. Shape & Size	It is small, narrow and dorsally covered beneath anterior extension of cerebellum.	It is short, rhomboidal and not covered dorsally by cerebellum.	It is small, rounded and covered dorsally by cerebral hemispheres and optic lobes.	Dorsal surface covered by cerebrum and cerebellum.	It is completely covered dorsally and below backward extension of cerebral hemispheres.
18. Epiphyseal apparatus	From dorsal roof arises a long and slender pineal stalk carrying a small rounded pineal body . No parietal organ.	Pineal stalk is short. In tadpole, it bears a small spherical pineal body . In adult frog, pineal body separates and lies above skull. No parietal organ.	Epiphyseal apparatus includes an anterior parietal organ and a posterior pineal body .	Pineal stalk short and nearly vertical. Pineal body small, spherical and delicate. Parietal organ absent.	Pineal stalk slender and inclined posteriorly. Pineal body small, rounded. No parietal organ present.

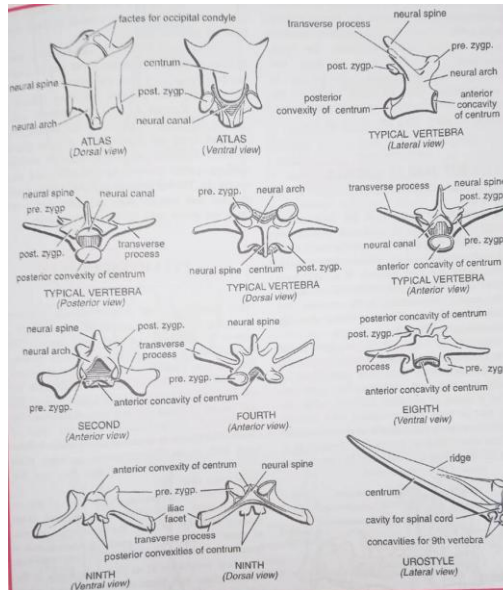
Characters	FISH	AMPHIBIA	REPTILIA	AVES	MAMMALIA
	Dogfish (<i>Scoliodon</i>)	Frog (<i>Rana</i>)	Lizard (<i>Uromastix</i>)	Pigeon (<i>Columba</i>)	Rabbit (<i>Oryctolagus</i>)
19. Infundibulum	It is ventral hollow projection behind optic chiasma . It consists of a large median lobe and 2 lateral smaller inferior lobes , produced behind into a thin-walled saccus vasculosus .	Infundibulum is a large median bilobed projection. Inferior lobes and saccus vasculosus are absent.	A small infundibulum given off ventrally behind optic chiasma . But inferior lobes and saccus vasculosus are not present.	Infundibulum small and without lobi inferiores and sacci vasculosi .	Infundibulum short and without lobi interiores and saccivasculosi .
20. Pituitary body	Median infundibular lobe bears, posteriorly an oval prominent hypophysis , and together form the pituitary body .	Infundibulum bears posteriorly a flattened oval hypophysis and together form pituitary body .	Infundibulum and a posterior hypophysis together constitute pituitary body .	Ventral infundibulum and posterior hypophysis pituitary lacks an intermediate lobe.	Infundibulum and hypophysis form pituitary body also having an intermediate lobe.
21. Corpus albicans	Absent.	Absent.	Absent.	Absent.	Behind pituitary lies a small rounded body, corpus albicans or corpus mammillare .
22. Middle commissure	Cavity or diacoel bounded laterally by optic thalami but middle commissure connecting them lacking.	Optic thalami present but middle commissure absent.	Optic thalami present but middle commissure absent.	Middle commissure absent.	Optic thalami connected across diacoel by a middle commissure .
[II] MIDBRAIN					
23. Optic lobes	Dorsal side consists of two large, hollow optic lobes or corpora bigemina with (optocoels), which remain mostly concealed by cerebellum. Control vision.	Dorsal surface made of 2 large uncovered lateral, rounded and hollow optic lobes or corpora bigemina with optocoels . Inhibit spinal cord reflexes on opposite side of body.	2 medium, oval dorso-lateral hollow optic lobes or corpora bigemina which remain uncovered.	2 optic lobes or corpora bigemina , lateral, very large, spherical, hollow, laterally displaced due to meeting of cerebrum and cerebellum and connected together by a transverse optic commissure .	Optic lobes divided forming 4 small solid spherical bodies, called corpora quadrigemina , mostly covered by cerebral hemispheres, optocoel absent.
24. Crura cerebri	Floor or crura cerebri poorly developed and mostly concealed ventrally by inferior lobes and saccus vasculosus .	These run longitudinally beneath optic lobes connecting cephalon and medulla. Partially covered by pituitary.	Thickened floor forms crura cerebri which are comparatively less developed.	Bands of ventral crura cerebri thickened as in lizard.	Crura cerebri far better developed than in lower vertebrates.

Characters	FISH	AMPHIBIA	REPTILIA	AVES	MAMMALIA
	Dogfish (<i>Scoliodon</i>)	Frog (<i>Rana</i>)	Lizard (<i>Uromastix</i>)	Pigeon (<i>Columba</i>)	Rabbit (<i>Oryctolagus</i>)
[III] HIND BRAIN					
A. CEREBELLUM					
25. Shape & Size	Large, elongated, rhomboidal dorsal structure overlapping midbrain and diencephalon anteriorly and medulla posteriorly.	Small, narrow, dorsal transverse, band just behind optic lobes.	Small, flat, semicircular ridge. Remains uncovered.	Very large elongated antero - posteriorly, covering midbrain in front and medulla behind.	Very large, transversely elongated, partly overlapping medulla behind and midbrain in front.
26. Division	Made of 3 lobes divided by 2 transverse furrows.	It is undivided.	Remains undivided.	Divided into 3 lobes : a large median vermis , and two small lateral flocculi .	Divided into 5 lobes: a median vermis , two lateral lobes each terminating into a flocculus .
27. Surface	Dorsal surface bears irregular folds.	Surface is smooth, without folds.	External surface is smooth.	Surface folded all over.	Surface much folded.
28. Ventricle	Cavity or epicoel extensive.	Cavity small.	Cavity small.	Solid.	Narrow and branched.
29. Arbor vitae	Absent.	Absent.	Absent.	Absent.	White matter looks tree-like, called arbor vitae in grey matter.
30. Pons varolii	Absent.	Absent.	Absent.	Absent.	It is a stout, ventral transverse neural band connecting two lateral sides of cerebellum.
B. MEDULLA OBLONGATA					
31. Shape & Size	Large, hollow (metacoel), triangular gradually tapering behind, partly concealed in front under cerebellum.	Small, conical hollow uncovered.	Small, triangular, hollow and uncovered.	Small, hollow, concealed beneath cerebellum.	Broad, triangular, hollow, tapering and covered partly by cerebellum.
32. Restiform bodies	Medulla bears antero-laterally a pair of irregular, thin-walled, hollow outgrowths, the restiform bodies .	Absent.	Absent.	Absent.	Absent.
33. Ventral flexure	Absent.	Absent.	Medulla and spinal cord meet at a ventral flexure.	Well-marked as in a lizard.	No ventral flexure.
[IV] CRANIAL NERVES					
34. Number	10 pairs.	10 pairs.	12 pairs, XI is spinal accessory and XII is hypoglossal.	12 pairs as in lizard.	12 pairs as in lizard and pigeon.

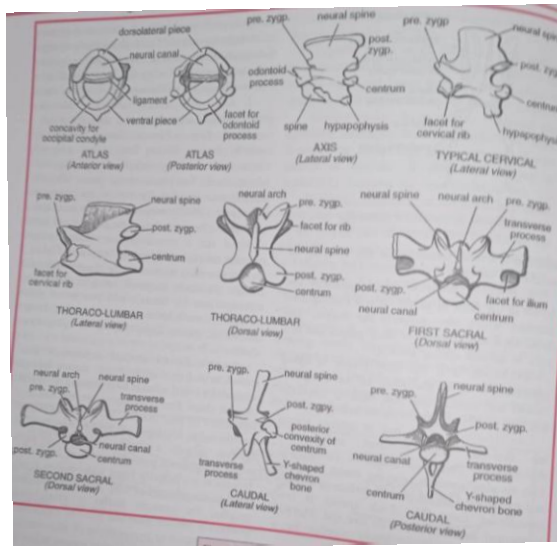
Ex. 6 Comparative study of vertebrae, limbs and girdles of different vertebrate groups.

Vertebrae

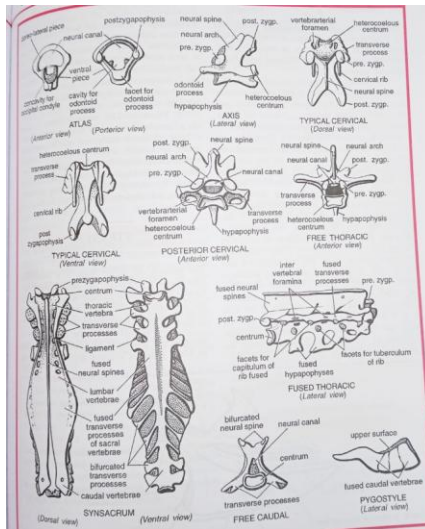
Frog



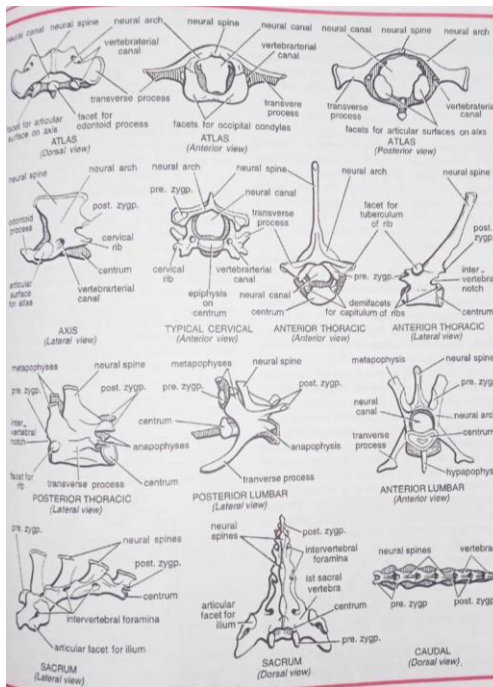
Varanus



Fowl



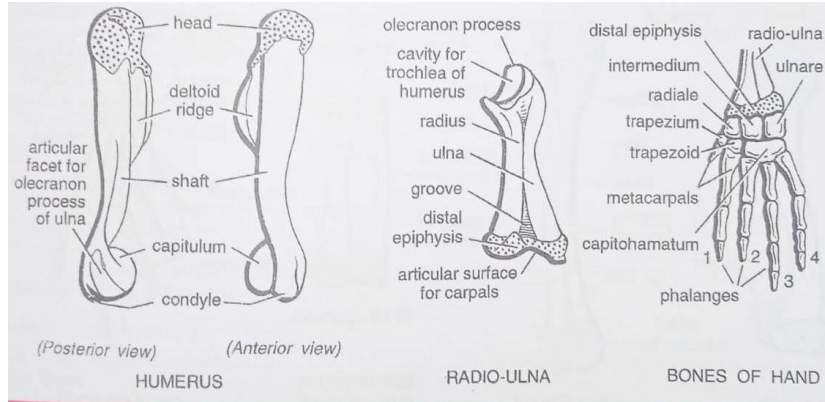
Rabbit



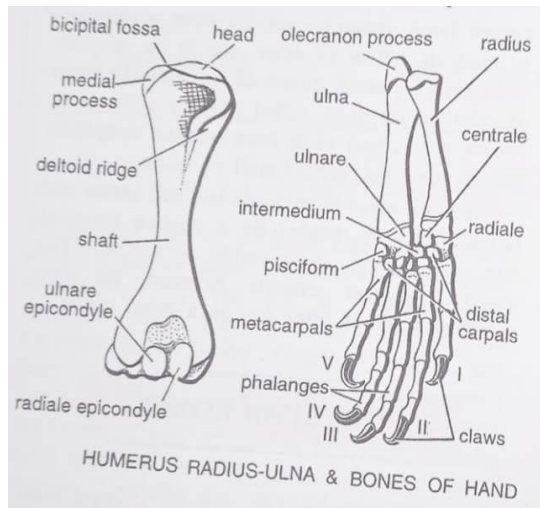
Limb bones

Fore limb

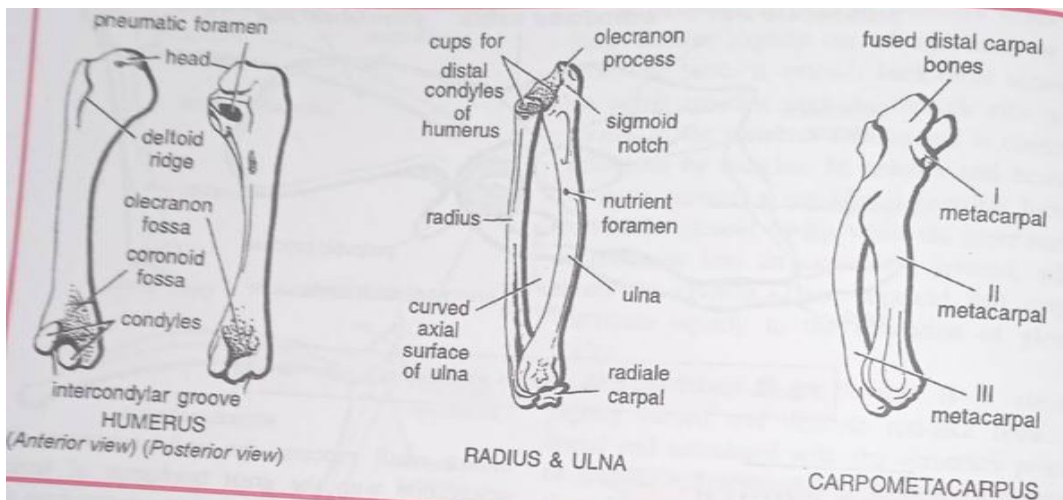
Frog



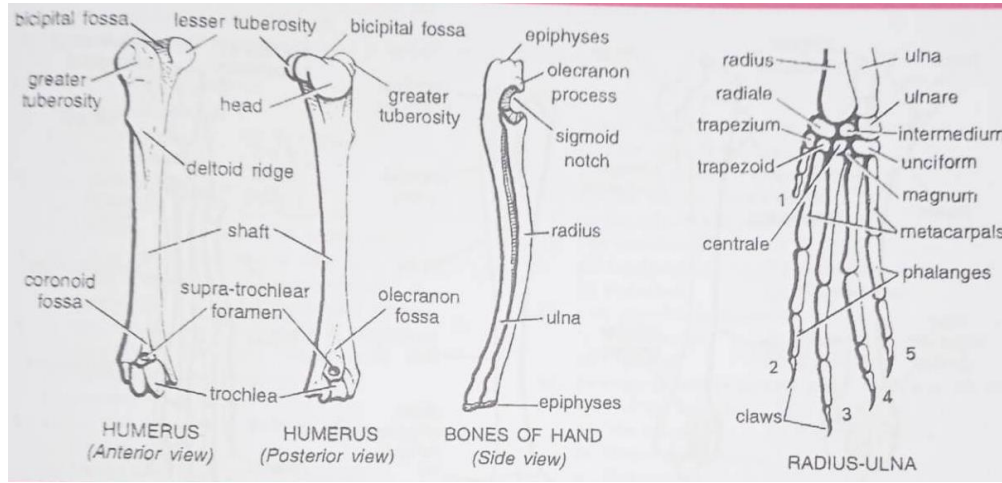
Varanus



Fowl

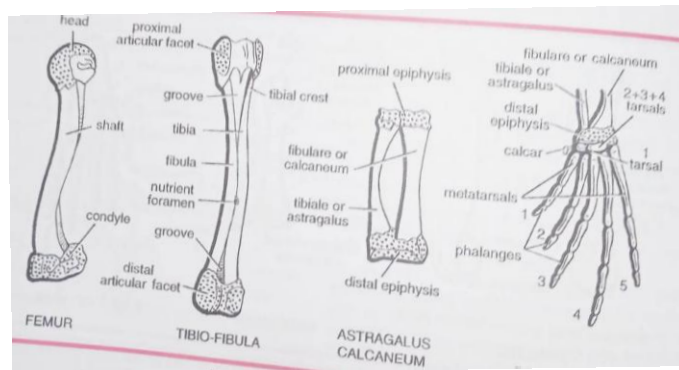


Rabbit

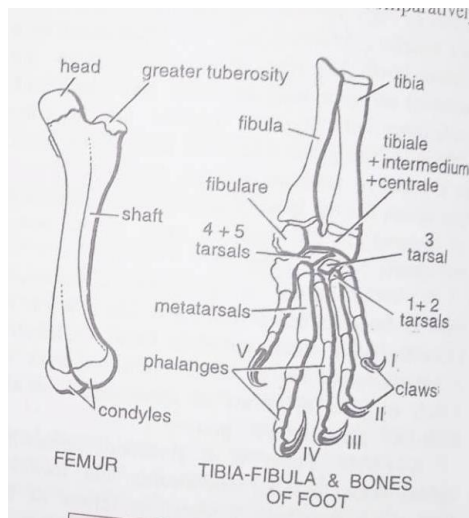


Hind limb

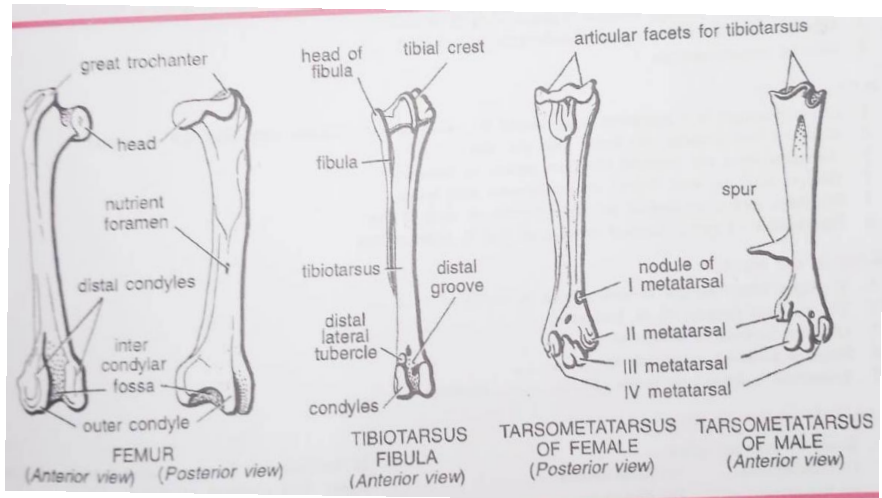
Frog



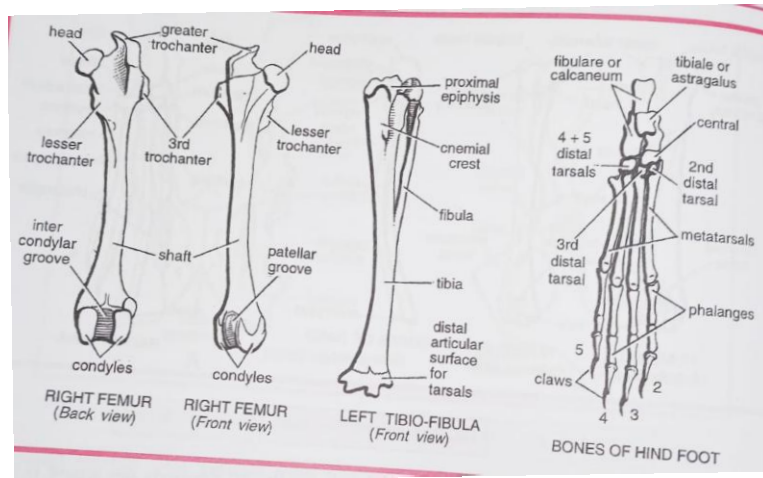
Varanus



Fowl



Rabbit



Bones	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
[I] FORELIMB BONES				
1. Bones	Bones included are : 1. Humerus 2. Radio-ulna 3. Carpals 4. Metacarpals 5. Phalanges	Bones included are : 1. Humerus 2. Radius & ulna 3. Carpals 4. Metacarpals 5. Phalanges	Bones included are : 1. Humerus 2. Radius & ulna 3. Carpals 4. Carpometacarpus 5. Phalanges	Bones included are : 1. Humerus 2. Radius & ulna 3. Carpals 4. Metacarpals 5. Phalanges
2. Humerus	Bone of upper arm. Short and cylindrical. Shaft slightly curved. Proximal end covered by cartilage and swollen into a convex head which fits into glenoid cavity of pectoral girdle. Below head shaft bears a prominent deltoid ridge . Tuberosities absent. Distal end with a round condyle or capitulum and ridges for articulation with radio-ulna.	Bone of upper arm. Shaft elongated, flat with expanded ends. Proximal end bears a small rounded head , a medial process and a deltoid ridge . Distal end pulley-like bearing two epicondyles for articulation with radius and ulna.	Bone of upper arm. Shaft elongated, slightly flat and curved. Proximal end greatly expanded bearing a convex head bordered by two tuberosities , a large pneumatic foramen and a prominent deltoid ridge . Distal end bears two condyles with an epicondylar groove for articulation with radius and ulna.	Bone of upper arm. Shaft rather small but stout and rod-like. Proximal end with a large rounded head , two tuberosities (greater and lesser), a bicipital groove and a slight deltoid ridge . Distal end bears pulley-like trochlea , and fossae perforated by supra-trochlear foramen , for articulation with ulna.
3. Radius & ulna	Bones of forearm. Fused lengthwise to form a short compound bone called radio-ulna . Proximal end concave to receive capitulum of humerus. Ulna projected into a short conical olecranon process forming elbow joint. Distal end flat, broad, covered by cartilage and forming two articular facets for carpals.	Bones of forearm. Separate and elongated. Radius somewhat slender, smaller and distally bears a concave articular facet and a styloid process . Ulna is stouter, bearing proximally an olecranon process and distally a convex articular facet for carpals.	Separate bones of forearm. Radius is shorter, straight and slender. Its proximal end is concave to receive a condyle of humerus, while distal and is knob-like. Ulna is longer, stouter and outwardly curved. Its proximal and is concave and forms olecranon process while distal convex end articulates with carpals. Only 2 free carpals of proximal row, radiale and ulnare , attached to radius and ulna respectively. Distal carpals fused with metacarpals. Pisiform bone absent.	Bones of forearm. Separate, elongated, somewhat curved and tightly bound together. Radius is smaller. Ulna is longer, proximally bearing a prominent olecranon process and a concave sigmoid notch for trochlea of humerus. Distally two bones bear epiphyses and articulate with carpals.
4. Carpals	Bones of wrist. 6 small bones arranged in 2 rows of 3 each. Pisiform bone absent.	9 carpals in wrist arranged in two rows of 3 and 5 with a centrale in between. Pisiform bone present.	8 free carpals in wrist arranged in 3 rows of 3, 1 and 4 respectively. Pisiform bone present.	
5. Metacarpals	5, slender, rod-like elongated bones of hand. But first metacarpal of pollex or thumb is rudimentary.	Manus of palm is supported by 5 elongated metacarpals.	Manus contains a single bone, the carpometacarpus , formed by the fusion of distal carpals and 3 metacarpals. First metacarpal rudimentary while second and third elongated and fused at the two ends.	Manus contains 5 elongated, rod-like metacarpals. However, first metacarpal of thumb or pollex is very much reduced.

Bones	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
6. Phalanges	Short bones of 4 fingers. Pollex or thumb lacking. Phalangeal formula 0, 2, 2, 3, 3. Terminal phalanx clawless.	Short bones of 5 fingers. Phalangeal formula 2, 3, 4, 5, 3. Last phalanx bears a horny claw.	Short bones of 3 clawless fingers. Phalangeal formula 1, 2, 1.	Short bones of 5 clawed fingers. Phalangeal formula 2, 3, 3, 3, 3.

[II] HIND LIMB BONES

	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
1. Bones	Bones included are : 1. Femur 2. Tibio-fibula 3. Tarsals 4. Metatarsals 5. Phalanges	Bones included are : 1. Femur 2. Tibia & fibula 3. Tarsals 4. Metatarsals 5. Phalanges	Bones included are : 1. Femur 2. Tibiotarsus & fibula 3. Tarsometatarsus 4. Phalanges	Bones included are : 1. Femur 2. Tibia & fibula 3. Tarsals 4. Metatarsals 5. Phalanges
2. Femur	Single bone of thigh. Shaft long, slender, slightly curved. Both ends expanded & covered with calcified cartilage. Proximal end bears a rounded head which forms a ball-and-socket joint with acetabular cavity of pelvic girdle. Distal end articulates with tibio-fibula.	Single bone of thigh. Shaft long strong with expanded extremities. Proximal end bears a rounded prominent head for acetabulum and two processes called lesser and greater trochanters . Distal end pulley-like with 2 condyles and one tuberosity for articulation with tibia and fibula respectively.	Single bone of thigh. Shaft long, cylindrical stout, slightly curved and with broad ends. Proximal end with a prominent rounded head for acetabulum, a great trochanter and between them a facet for articulation with antitrochanter of ilium. Distal end pulley-like with two prominent condyles and a groove for tibio-tarsus.	Bone of thigh. Shaft long, strong, cylindrical and expanded at both ends. Proximal end with a distinct rounded head for acetabulum and 3 trochanters (lesser, greater and third). Distal end pulley-like with 3 condyles and a groove for tibio-fibula.
3. Patella	Absent.	Absent.	A small sesamoid bone, patella , present at the knee joint.	Patella present at the knee-joint.
4. Tibia & fibula	Shank has a single compound bone, tibiofibula . Longest bone in the body. Shaft slightly curved with broad and flat two ends covered with cartilage, and a longitudinal median groove. Proximal end of tibial part with a cnemial or tubial crest . Distal end bears facets for astragalus and calcaneum of tarsus.	Shank contains two separate bones. Tibia is stout, slightly curved and proximally bears a small cnemial crest and two concave facets for distal condyles of femur. Fibula is slender whose distal convex end articulates with tarsus.	Shank contains two separate bones. Tibia and proximal tarsals become fused into an elongated, strong, compound tibiotarsus , the longest bone in body. Its proximal end bears a prominent cnemial crest and 2 concave articular facets for distal condyles of femur. Distal pulley like end articulates with tarsus. Fibula is reduced, slender, swollen proximally but gradually tapers distally without reaching up to ankle.	Bones of shank region. Tibia is large, stout and straight. Its proximal end bears a low but sharp cnemial crest and two concave facets for distal femoral condyles. Fibula is small, slender, proximally free but distally fused with tibia forming the compound tibio-fibula which is the longest bone in the body.
5. Tarsals	4 ankle bones or tarsals arranged in 2 rows of 2 bones each. Proximal	Ankle contains 5 tarsal bones, 2 in proximal row and 3 in distal row.	No free tarsal bones. Proximal tarsals fused into tibiotarsus while	Ankle contains 6 tarsal bones. Proximal row includes 2 large bones

Bones	AMPHIBIA Frog (<i>Rana</i>)	REPTILIA Lizard (<i>Uromastix</i>)	AVES Pigeon (<i>Columba</i>)	MAMMALIA Rabbit (<i>Oryctolagus</i>)
6. Metatarsals	tarsals elongated but united at the two ends. Outer calcaneum or fibulare is thick and stout. Inner astragalus or tibiale is thin and curved. Sole of foot contains 5 elongated, rod-like metatarsals corresponding to 5 toes.	Foot carries 5 elongated rod-like metatarsals each supporting a toe.	distal tarsals fused with tarso-metatarsus. Distal tarsals and 2, 3, and 4 metatarsals of foot fuse into a single stout straight and compound bone, tarsometatarsus . Its proximal end bears 2 concavities for tibio-tarsus. Distal end bears 3 pulleys, each representing one metatarsal. First metatarsal rudimentary.	called astragalus and calcaneum. A single middle bone is called centrale or navicular. Distal row contains 3 tarsal bones. Foot carries 4 elongated metatarsals, one for each toe. First metatarsal absent as there is no hallux or first toe.
7. Phalanges	There are 5 clawless toes. Phalangeal formula 2, 2, 3, 4, 3.	5 clawed toes present. Phalangeal formula 2, 3, 4, 5, 3.	4 clawed toes. Fifth toe absent. Phalangeal formula 2, 3, 4, 5.	4 clawed toes as hallux absent. Phalangeal formula 3, 3, 3, 3.

Comparative Account of Girdles of Vertebrates

A. Pectoral Girdles						
Characters	Cartilagenous Fish Dogfish (<i>Scoliodon</i>)	Bony fish Rohu (<i>Labeo</i>)	Amphibia Frog (<i>Rana</i>)	Reptilia Lizard (<i>Uromastix</i>)	Aves Pigeon (<i>Columba</i>)	Mammalia Rabbit (<i>Oryctolagus</i>)
1. Condition	Cartilagenous, not well developed		Bony as well as cartilagenous, well developed	Bony as well as cartilagenous, well developed	Bony, well developed for flight	Largely bony, well adapted for running and burrowing
2. Position	Embedded in lateral and ventral body wall, posterior to gills, support pectoral fins		Embedded in thoracic body wall around heart which it protects, supports forelimbs	Embedded in ventro-lateral thoracic wall, supports forelimbs	Lies at the antero-dorsal sides of trunk, supports wings	Lies along the antero-lateral sides of trunk, supports forelimbs
3. Shape and Division	U-shaped, consists of right and left		Like an inverted arch, made	Like an inverted arch, made of	Made of two roughly V-shaped halves	Made of two somewhat triangular

	halves firmly fused mid-ventrally		of two identical halves united mid-ventrally	two similar halves united mid-ventrally	widely apart from each other	halves completely separate from one another
4. Attachment	Not attached dorsally to vertebral column or ventrally to sternum which is absent		Both halves united mid-ventrally with sternum	Both halves meeting ventrally with a T-shaped interclavicles and a rhomboidal sternal plate	Two halves are firmly connected with sternum through a V-shaped furcula made by two clavicles and one interclavicle	Two halves do not unite with sternum or vertebral column
5. Parts or Bones	Each half is made of scapular and coracoids portions		Each half consists of scapular and coracoids portions	Each half includes scapular and coracoids parts	Each half includes scapular and coracoids parts	Each half includes a large scapula-coracoid bone
6. Scapula	It is dorsal, rod like and tapering		Scapula is lateral, stout, flat and broader at the two ends	Scapula is lateral, stout, oblong and broader dorsally but narrower ventrally	Scapula is lateral is elongated, sabre like, dorsal conneted with underlying ribs by muscles and with coracoids by ligaments	Scapula or scapulocoracoid is lateral, large, flat and triangular with broad base dorsal and narrow apex ventral
7. Scapular processes	None		None	Scapula gives out an anterior ossified process, mesoscapula	Scapula bears near anterior end a scapular tubercle. Anterior end also gives out an acromian process.	Outer surface of scapula bears a prominent vertical ridge or spine. It terminates below into a free acromian process posteriorly giving off a mecomian process.

8. Supra – scapula	Absent		Suprascapula is broad, rectangular, flat, calcified cartilage, attached dorsally with scapula and covering the first four vertebrae.	It is a thin, flat, calcified cartilaginous plate attached dorsally with scapula. It does not cover vertebral column.	Absent	Very much reduced like a thin strip of calcified cartilage along the dorsal edge of scapula.
9. Coracoid	Poorly developed, ventral, flat, support the floor of pericardial cavity		Coracoid bone is broad and dumb-bell shaped. A rodlike precoracoid cartilage is separated from it anteriorly by a wide gap, coracoids foramen. Two coracoids meet midventrally through an x-shaped cartilage, the epicoracoid.	Coracoid is large, flat and fenestrated. Divided by two large gaps into procoracoid, mesocoracoid and coracoids proper. An irregular cartilaginous epicoracoid covers the gaps or fenestry anteriorly.	Coracoid is stout, straight and rod like. Lower end articulates with coracoids groove of sternum. Upper end forms a hook like acrocoracoid process. Epicoracoid absent.	Coracoid vestigial, represented by a small hook-like coracoids process from scapula above glenoid cavity. Epicoracoid absent.
10. Glenoid cavity	Absent		Formed posteriorly at the junction of scapula and coracoids to receive the head of humerus.	Formed posterior-laterally jointly by scapula and coracoids bones.	Formed posterior-laterally jointly by scapula and coracoids bones.	Formed posterior-ventrally at the apex of scapula exclusively.
11. Clavicles	Well developed		On either side it is a	Small, slender and	Long, slender, rod like	Slender, slightly curved

	and placed ventrally.		slender rod like, transverse bone attached in front of precoracoid cartilage.	curved bones separated medially from each other by interclavicles.	bones, attached dorsally to scapula and coracoids and ventrally fused with interclavicles.	bony rod. Inner end attached to manubrium of sternum while outer end with acromian process of scapula.
12. Interclavicle	Absent		Absent	T-shaped, interclavicles present between clavicles and two halves of pectoral girdle.	Both clavicles fused with a laterally compressed sc or hypocleidium, forming a V-shaped composite bone, the furcula.	Absent but present in prototherians.
13. Foramen triosseum	Absent		Absent	Absent	Present, formed by the dorsal end of clavicle, acromian process of scapula and acrocoracoid process of coracoids. Through this tendon of pectoralis minor muscle passes to be inserted dorsally upon head of humerus.	Absent
B. Pelvic Girdles						
Characters	Cartilaginous Fish Dogfish (<i>Scoliodon</i>)	Bony fish Rohu (<i>Labeo</i>)	Amphibia Frog (<i>Rana</i>)	Reptilia Lizard (<i>Uromastix</i>)	Aves Pigeon (<i>Columba</i>)	Mammalia Rabbit (<i>Oryctolagus</i>)
1. Condition	Simple, cartilaginous		Bony as well as	Bony, solid and strong.	Bony, large, light,	Bony, large, stout, well

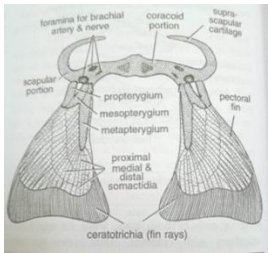
	, transverse, rod-like, called ischio-pubic bar.		cartilaginous, well developed.	Well developed for tetrapod locomotion.	pneumatic. Well adapted for flight and bipedal locomotion.	adapted for fast running.
2. Position	Embedded in ventral abdominal wall in front of cloaca, supports pelvic.		Occupies posterior region of trunk and gives support to pelvic region and hind limbs.	Occupies pelvic region of trunk and supports hind limbs	Occupies pelvic region and gives support to legs.	Occupies pelvic region and supports hind limbs
3. Shape and halves	Horizontal, transverse, rod-like, not divided into halves		V-shaped, made of two similar halves, called ossa innominata, united posteriorly into a median disc.	Made of two similar triradiate structures of ossa innominata, meeting mid ventrally but not uniting with each other	Made of two similar triradiate structures of ossa innominata, completely separated as an adaptation for laying eggs.	Two identical triradiate halves or ossa innominata are firmly united mid-ventrally at a pubic symphysis.
4. Attachment with vertebral column	Not attached to vertebral column.		Two limbs run parallel with vertebral column while median disc supports last vertebra or urostyle	Only iliac bones attached with the first sacral vertebra.	Firmly fused with synsacrum as an adaptation for bipedal locomotion	Ilia firmly articulate with sacrum
5. Bones	Not determined into separate bones		Each half or os innominatum made of three bones- ilium, ischium and pubis	Each half or os innominatum made of three bones- ilium, ischium and pubis	Each half or os innominatum made of three bones- ilium, ischium and pubis	Besides three usual bones, a fourth bone, called cotyloid, also found
6. Joints	Absent		Joints of bones	Joints of bones	Joints of bones not	Joints of bones distinct

			distinct	distinct	distinct	
7. Ilium	Represented by a small blunt iliac process with a foramen		Forms anterior long arm resting on transverse process of 9 th vertebra. Forms a dorsal vertical blade or iliac crest. Posteriorly both ilia united with median disc forming iliac symphysis	Ilium rod like and stout. Its tip articulating with the notch of transverse process of first sacral vertebra. Iliac of both sides separated without any iliac symphysis. Forms a small preacetabular process.	Ilium large plate like, wholly attached to synsacrum. Differentiated into pre and postacetabular parts. No iliac symphysis.	Ilium large, raised into a dorsoanterior iliac crest. Distal part broad and articulates with flask of sacrum. No iliac symphysis present.
8. Antitrochanter process	Absent		Absent	Absent	Ilium forms a small antitrochanter process on posterior border of acetabulum	Absent
9. Ischium	No distinct from pubis		Ischium small and meeting with its fellow at a median vertical ischiatic symphysis in postero-dorsal part of disc.	Ischium flat, oblong, meeting with fellow at a mid-ventral ischiatic symphysis from which project a small cartilaginous preischium in front and a hypoischium behind.	Broad, plate like bone behind acetabulum. No ischiatic symphysis, no hypoischium, etc.	Ischium is postero-dorsal, small and flat. Posterior most thickened part called ischial tuberosity. Ischial symphysis absent.
10. Ilio-ischiatic foramen	Absent		Absent	Absent	A large oval ilio-ischiatic foramen separates ischium anteriorly from	Absent

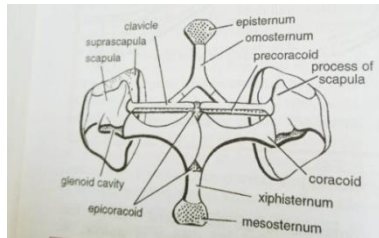
					postacetabular ilium	
11. Pubis	Not distinct from ischium		Both pubes are small, triangular, made of calcified cartilage, and fuse at a mid-ventral pubic symphysis in the disc. Epipubis absent.	Long slender bone directed antero-ventrally meeting its fellow at a pubic symphysis having a small knob like anterior cartilage, the epipubis.	Pubis is a thin, slender bone running backwards and parallel to ventral edge of ischium, no pubic symphysis.	Pubis is small slender, ventro-medial and meets its fellow at a mid-ventral pubic symphysis. Epipubis absent.
12. Obturator foramen	Absent		Absent	A small obturator foramen pierces pubis near acetabulum.	Ischium and pubis separated by a notch in pigeon and by an oval foramen in fowl.	A large obturator foramen separates pubis from ischium.
13. Prepubis	Absent		Absent	Middle of pubis produced into a small rod-like outwardly directed prepubis.	Prepubis absent in pigeon. In fowl, pubis projects in front of acetabulum as a prepubic process.	Absent
14. Acetabulum	Absent		Present on either lateral side of disc. Formed by all the three bones as a prominent cup like depression into which fits the head of femur.	Present laterally as a concave depression at the junction of ilium, ischium and pubis and receives the head of femur.	All the three bones unite to form a deep lateral acetabular cavity perforated basally and covered by a membrane.	Acetabulum is not perforated basally and formed by ilium, ischium and cotyloid bones. Pubis does not participate.

15. Cotyloid bone	Absent		Absent	Absent	Absent	Present
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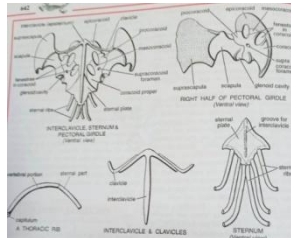
Pectoral Girdles



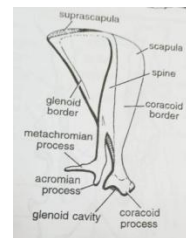
Scoliodon



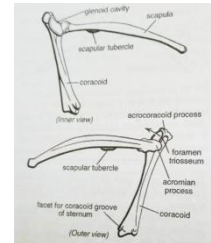
Frog



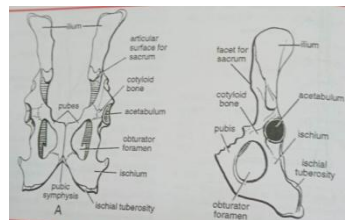
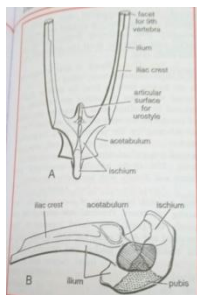
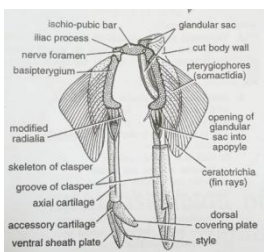
Varanus



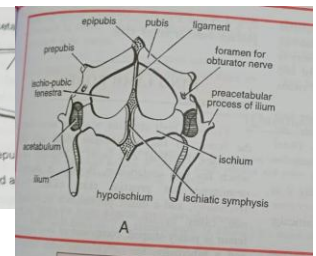
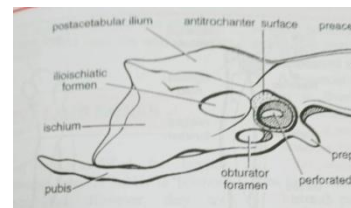
Fowl



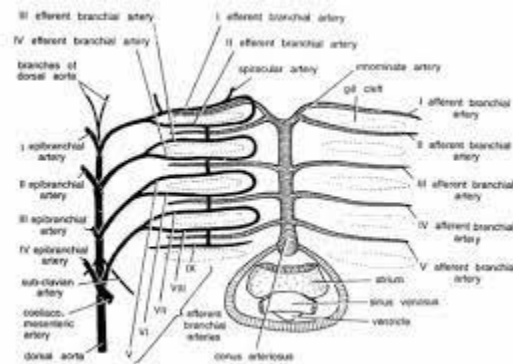
Rabbit



Pelvic Girdles



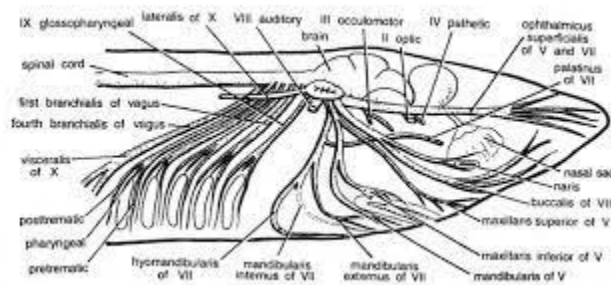
Ex. 7 Study of afferent and efferent arteries of fish.



- **Afferent branchial arteries:**
- There are four pairs of afferent vessels.
- 1st pair is formed by the bifurcation of ventral aorta.
- 2nd pair is having separate origin, but 3rd and 4th have a common origin.
- These arteries arise from the ventral aorta which supply deoxygenated blood to the gills for oxygenation.

- **Efferent branchial arteries:**
- These arteries arise from the gills and supply oxygenated blood to all body parts.
- The oxygenated blood from the gills is collected by 09 efferent blood vessels on each side.
- First 08 join in pairs while 9th is connected with 4th pairs of efferent vessels by a longitudinal connective.

Ex. 8 Study of cranial nerves of fish.



- -Cranial nerves originate from cranium/brain. These are generally 10 pairs but ‘O’ nerves associated with olfactory nerves have also been identified.
- -Following are the cranial nerves of a teleost fish:
- -‘O’ nerve: It originates from cerebral hemisphere, near olfactory lobe and innervates olfactory sac (sensory nerve).
- I- Olfactory nerve: It originates from olfactory lobe and ends in the olfactory rosette/sac.
- -It is a specially sensory nerve and carries smell impulses to the brain.
- -II- Optic nerve: It arises from optic tectum, both optic nerves cross each other and supplies the retina of the eye. It is special sensory nerve carrying visual impulses to brain.
- -III- Oculomotor nerve: It originates from the ventral side of mid brain/optic lobe. This nerve supplies to the superior, inferior, anterior recti and inferior oblique muscles of the eye. It is a motor nerve which controls the movement of eye ball.
- -IV- Trochlear nerve: It originates from the dorso-lateral side of the mid brain, between optic lobes and cerebellum.
- -It supplies the superior oblique muscles of the eye ball (motor nerve).
- -V- Trigeminal nerve: It originates from the lateral side of medulla and innervates the upper lower jaws and the snout. It divides into three branches:

- (a) Ophthalmicus: It has two branches:
 - (i) Ophthalmicus profundus: It supplies olfactory capsule and dorsal skin of snout.
 - (ii) Ophthalmicus superficialis: It supplies skin of snout.
- (b) Maxillaris: It also has two branches:
 - (i) Maxillaris superior: It supplies skin of upper jaw.
 - (ii) Maxillaris inferior: It innervates posterior part of upper lip.
- (c) Mandibularis: It innervates muscles of lower jaw.
- -Trigeminal nerve is mixed somatic sensory and motor in functions. It shows thermal and tactile sensibility of skin on anterior portion of head.
- -VI- Abducens nerve: It arises from ventral side of medulla, and innervates posterior and external rectus muscles of eyes. It is motor in nature.
- -VII- Facial nerve: It also originates from side of medulla, forming trigemino-facial complex, it is divided into four branches:
 - (a) Ophthalmicus superficialis: It innervates the supra orbital canal of the lateral line system.
 - (b) Ramus buccalis: It supplies the skin of snout and maxillary barbules, and infra orbital lateral line canal.
 - (c) Ramus palatinus: It supplies roof of the buccal cavity and pharyngeal cavity.
 - (d) Ramus hyomandibularis: It is divided into three branches:
 - (i) Mandibularis externus: It innervates mandibular canal (lower jaw, lower lip and mandibular teeth).
 - (ii) Mandibularis internus: It supplies the mucous membrane of buccal floor.
 - (iii) ramus hyoideus: It innervates muscles of hyoid arch. It is a mixed nerve, special and somatic sensory visceral and motor functions.
- -VIII- Auditory nerve: It originates from lateral side of medulla, supplies internal ear. It is special sensory in nature. It has two branches:
 - (a) Vestibular branch: To supply utriculus and ampullae.
 - (b) Saccular branch: To supply sacculus and lagena.
- -IX- Glossopharyngeal nerve: It originates from ventro-lateral side of medulla and innervates the first gill slits and pharynx. It is a mixed nerve and supplies taste buds of

pharynx and muscles of first gill slit through pre-trematic branch and to muscles of pharynx and a part of lateral line system through post-tramatic branch.

- -X- Vagus: It takes its origin from the medulla. It is a mixed nerve. It has three branches:
- (a) Branchialis: -These are three in number. Each innervates the pharynx and then divides into pre-trematic and post-trematic branch to supply muscles of remaining three gills.
- (b) Visceralis: It supplies various visceral organs.
- (c) Lateralis: It innervates lateral line canal.