B.Sc. III Sem: Comparative Anatomy and Physiology (CC- V)

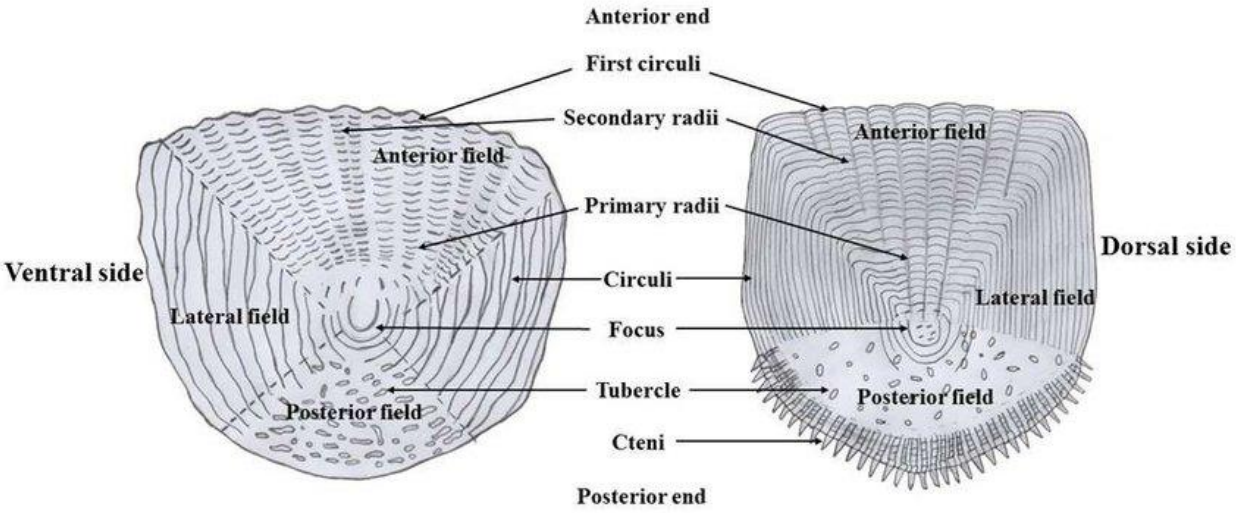
(Lab. Exercises)

Ex. 1 Temporary mount of external scales in fishes (cycloid, placoid, ganoid, ctenoid).

Aim: Preperation of temporary mounts of fish scales (cycloid and ctenoid).

Procedure:

1. Take out the cycloid (*Labeo*) and ctenoid (*Anabas*)scales from preserved fishes and keep them in watch glass.
2. Wash the scales 2-3 times with water to remove preservative and dust.
3. Stain the material with 70% aqueous eosin for 10 minutes.
4. Wash the material with water to remove excess stain.
5. Mount the material in glycerine and cover with glass cover slip.
6. Observe the mount under compound microscope.



Observation:

Cycoid scale

-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. **eg.** Carps (Teleosts).

Ctenoid scale

-Basically similar to the cycloid scale

-Has a serrated margin and spines on posterior part

eg. Perciform fishes (*Anabas, Nandus*).

Aim: Preparation of temporary mount of Placoid scales (isolated and in-situ).

Principle: Placoid scales are found in the skin of cartilaginous fishes. A piece of skin when gently boiled in 4% KOH solution, it becomes transparent and placoid scales are visible clearly; and when boiled at high temperature for some more time, skin is dissolved and placoid scales are settled on the bottom. Both isolated and in-situ stages can be stained for the observation.

Requirements: Pieces of skin of *Scoliodon*, 4% of KOH solution, Eosin stain, sprit lamp, test tube and test tube holder, etc.

Procedure: 1. Take the piece of skin (4-5 sq.mm) avoiding muscles attached to these.

2. First gently boil the pieces in 4% KOH up to the transparency. Take out 1-2 transparent pieces in watch glass containing distilled water.

3. Then further boil the remaining pieces until their complete dissolution.

4. Discard the KOH, and take out the isolated placoid scales with the help of brush and dispersed in the same watch glass containing transparent pieces of the skin.

5. Wash both types of materials 3-4 times with distilled water to remove KOH.

6. Now stain the materials with eosin and mount in glycerine.

7. Observe both types of scales under microscope.

Observation:

a) Isolated placoid scales: It consists of a basal plate and a spine, giving arough surface to skin.

-It is ecto-mesodermal in origin and homologous to tooth.

-Placoid scales do not overlap to each other.

-Basal plate is formed of a cement like substances secreted by dermis.

-Spine develops from epidermis, composed of outer vitrodentine and inner dentine which encloses pulp cavity.

-The basal plate has an aperture through which blood vessles and nerves of the dermis enter into the pulp cavity.

b) Placoid scales in-situ: Placoid scales are arranged in linear fashion on the skin.

-Basal plate is embedded in the dermis while spine is projected out.

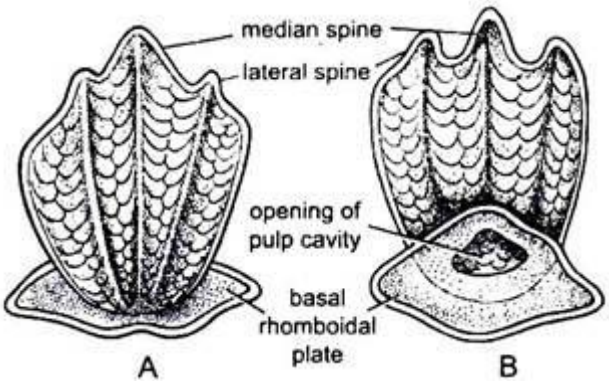
-They give rough surface to the skin and protective in nature.

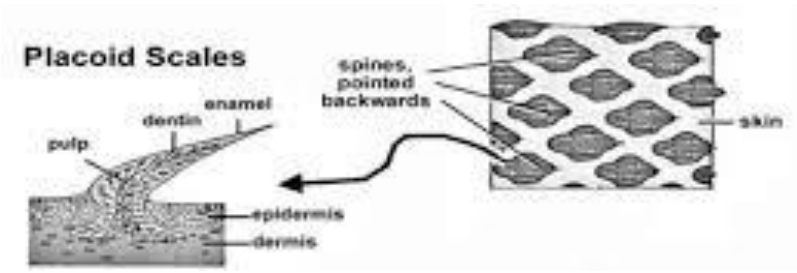
Precautions: 1. Boil the material gently to avoid bubbling of KOH solution.

2. Keep the mouth of test tube towards the wall.

3. Dorsal surface of skin should be upside.

4. Wash the placoid scales carefully, otherwise they will be washed off.





Ex. 2 Comparative study of brain with the help of models and charts.

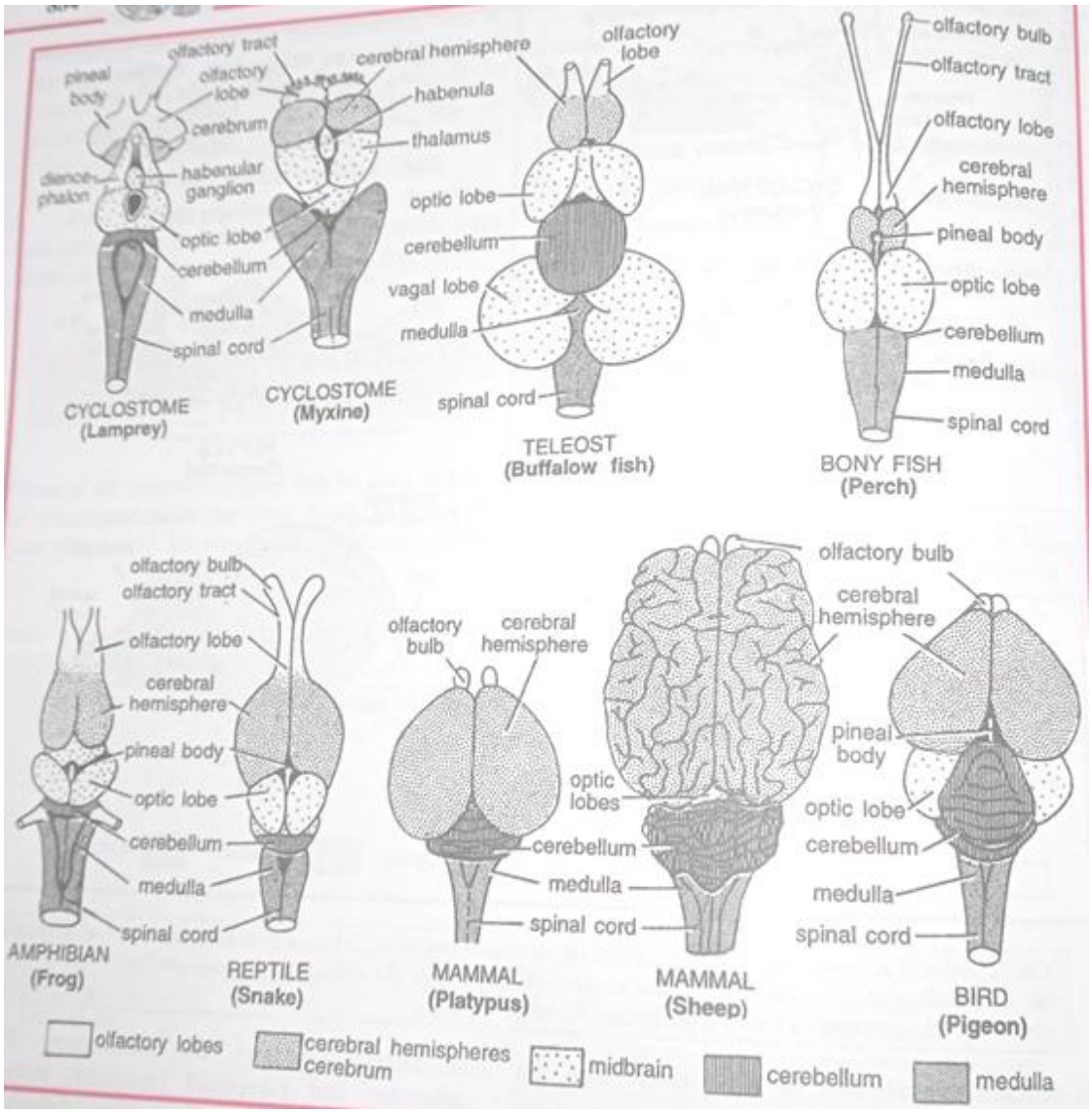


Table 11. Comparative Account of Brain in Vertebrates

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
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 borad, 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

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
	hemispheres of higher vertebrates.			lobes in front and diencephalon behind.	midbrain behind.
10. Neuropore	It bears a small mid-ventral opening, the **neuropore**, for terminal nerves to emerge out.	Neuropore absent.	Neuropore absent.	Neuropore absent.	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, well developed.	Thick, very conspicuous.	Comparatively less developed.
15. Corpus callosum	Absent.	Absent.	Absent.	Absent.	Special transverse band of neural tissue present interconnecting two cerebral hemispheres internally.
16. Lateral ventricles	Also called **paracoels**, spacious and unbranched.	**Paracoels** or lateral ventricles unbranched.	**Paracoels** unbranched.	**Paracoels** unbranched.	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 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 Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
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** form **pituitary** which 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 mammilare.**
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 almost 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 diencephalon 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.

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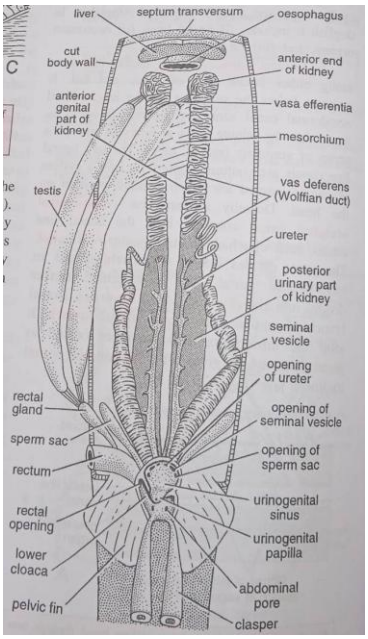
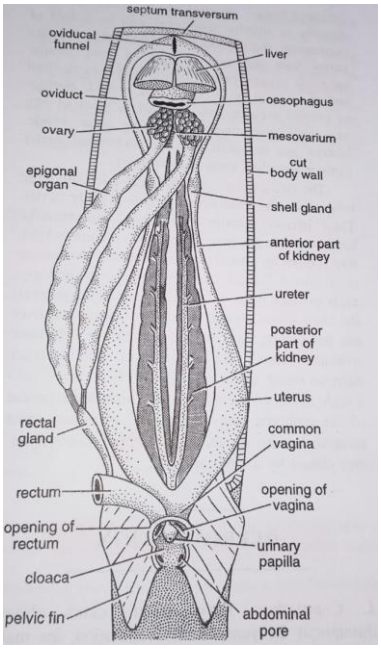
			[III] HIND BRAIN		
			A. CEREBELLUM		
25. Shape & Size	Large, elongated, rhomboidal dorsal structure overlapping midbrain and diencephalon anteriorly and medulla posteriorly.	Small, narrow, dorsal transverse, band just behind optic lobes.	Small, flat, semicircular ridge. Remains uncovered.	Very large 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 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. 3 Comparative study of urinogenital system with the help of models and charts.

Scoliodon

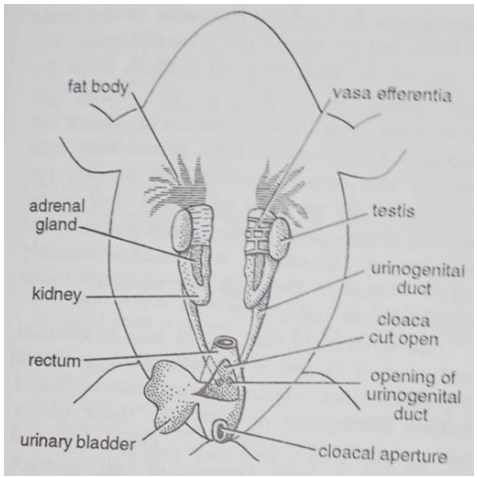


Male

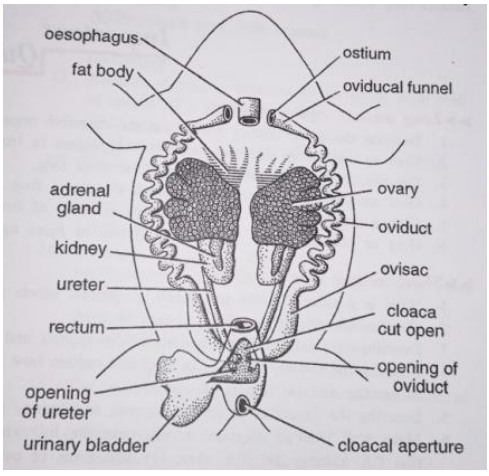


Female

Frog

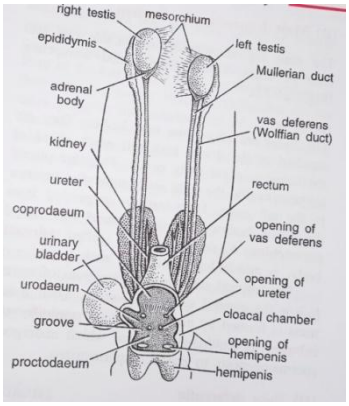


Male

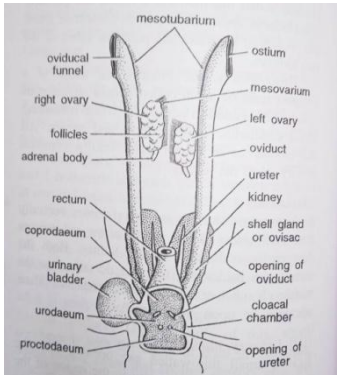


Female

Uromastix

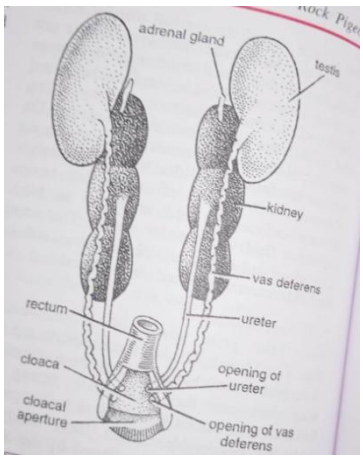


Male

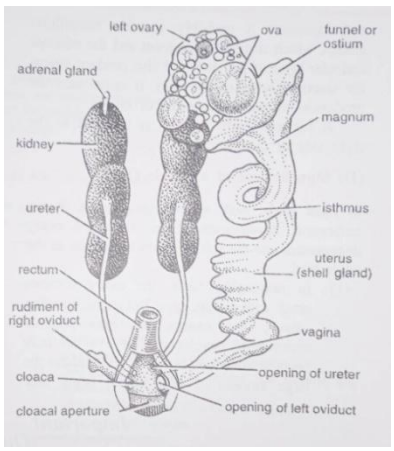


Female

Pigeon

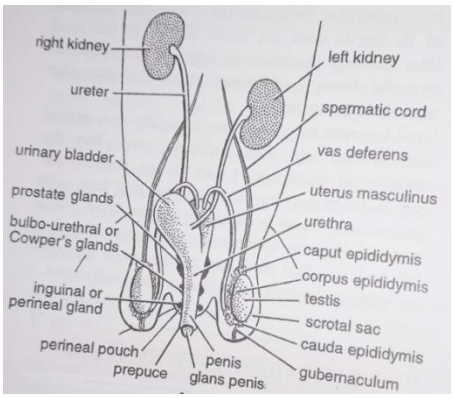


Male

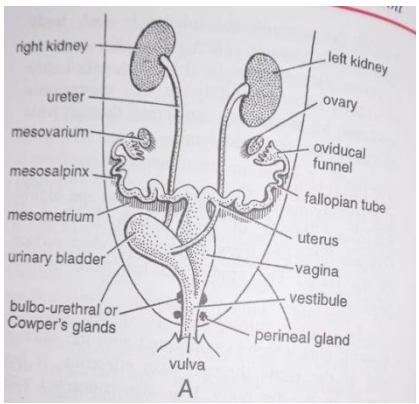


Female

Rabbit



Male



Female

Table 12. Comparative Account of [illegible]

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
[I] URINARY AND EXCRETORY SYSTEM					
1. Excretory organs	Include a pair of kidneys, a pair of **urinary ducts**, and a **urinogenital sinus**. No bladder.	Include a pair of **kidneys**, a pair of **ureters** a **urinary bladder** and **cloaca**.	Include a pair of **kidneys**, paired **ureters**, a **urinary bladder** and **cloaca**. No bladder.	Include a pair of **kidneys**, a pair of **ureters** and **cloaca**.	Include a pair of **kidneys**, paired **ureters**, a **bladder** and **urethra**.
2. Kidneys	Adult kidneys greatly elongated antero-posteriorly, ribbon-like flat, and attached to dorsal abdominal wall. Each kidney has 2 distinct parts. Anterior narrow part is **non-excretory,** genital in male but non-genital in female. Posterior broader part is functional kindey and called **opisthonephros**.	Adult kidneys are elongated, oval, flat and attached dorsally one on either side of vertebral column in posterior abdominal cavity. They are not differentiated into parts and are **mesonephric**.	Adult kidneys are small, irregular, attached dorsally and lie in pelvic region at the base of tail. Each kidney is **bilobed**. Anterior broad lobes remains free while posterior narrow lobes become united forming a V-shaped structure. Kidneys are **metamephric**.	Adult kidneys are small, flat, dorsally attached in pelvic region, embedded in hollows of pelvis. Each kidney is **trilobed**, made of anterior, middle and posterior lobes. Kidneys are **metanephric**.	Adult kidneys are small, beanshaped and attached much anteriorly and asymmetrically in anterior abdominal cavity. Kidneys are **metanephric** and not divided into lobes.
3. Histology of kidneys	Covered ventrally by **peritoneum**, not differentiated into **cortex** and **medulla** and made of a compact mass of coiled **uriniferous tubules**.	Same as in fishes.	Same as in fishes and amphibians.	Kidney covered ventrally by **peritoneum**, differentiated into **cortex** and **medulla** and contains a very large number of **uriniferous tubules.**	Each kidney covered ventrally by **peritoneum**, differentiated into an outer **cortex** and inner **medulla**, and made of much convoluted **uriniferous tubules.**
4. Uriniferous tubules	Have a special urea absorbing segment. Loop of Henle absent.	Lack a urea-absorbing segment and loop of Henle.	Lack urea-absorbing segment and loop of Henle.	Lack urea absorbing segment, but water absorbing loop of Henle present.	Absorb urea through glomerular filteration and tubular reabosrption and also have water absorbing loop of Henle.
5. Peritoneal funnels	Nephrostomes present.	Nephrostomes present.	Nephrostomes absent.	Nephrostomes absent.	Nephrostomes absent.
6. Ureters	Kidney ducts or mesonephric ureters of both sides run over ventral surface of kidney and open into a urinogenital sinus, which leads into cloaca. Ureters open separately in male but by a	Mesonephric ureters arise and run along outer side of kidneys and open behind by separate apertures directly into cloaca. A urinogenital sinus is absent.	Metanephric kidney ducts or ureters run ventrally over kidneys and open dorsally and separately into middle chamber of cloaca, called **urodaeum**. Urinogenital sinus absent.	As in reptiles, ureters are metanephric. They run ventrally over kidneys and open behind separately into urodaeum through its roof. Without pelvis.	Metanephric ducts (ureters) arise from inner middle concavity or hilus of kidney and open dorso-laterally into urinary bladder. Cloaca absent. Ureters begin from a wide funnel-like cavity in kidney, called **pelvis**.

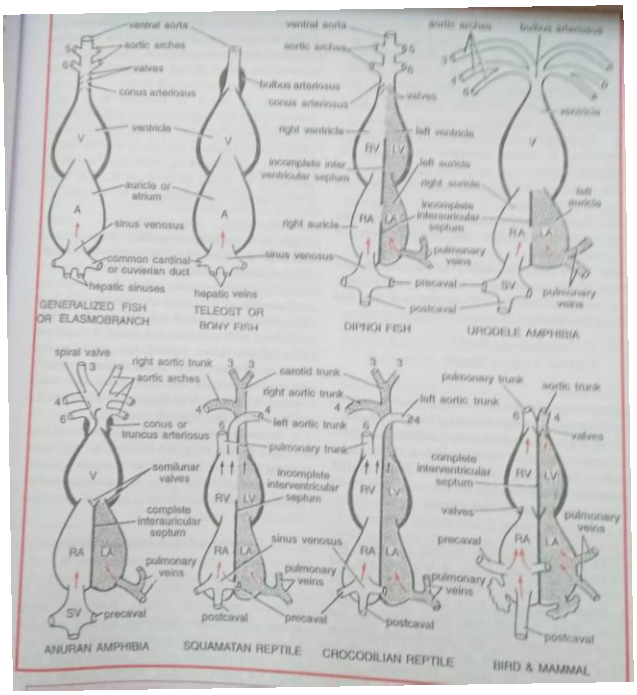
Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
	common aperture on a urinary papilla in female.				
7. **Urinary bladder**	Absent.	A large thin-walled membranous elastic bilobed urinary bladder opens ventrally into cloaca by a sphinctered aperture.	Small, thin-walled, inelastic, undivided sac opening ventrally into coprodaeum of cloaca.	Absent.	Large, median, pear-shaped, muscular sac. Its neck, called **urethra**, opens at the tip of penis in male and into vestibule of female which opens to outside through vulva.
8. **Nature of excretion**	Predominantly ammonotelic because excrete more ammonia than anything else.	**Ureotelic**, excreting predominantly urea along with water.	**Uricotelic**, excreting semisolid uric acid and urates which are not much soluble in water.	Like reptiles, birds are also **uricotelic** excreting mainly uric acid and urates in a semi-solid state.	**Urecotelic** since chief excretory product in urine is urea dissolved in water.
		[II] MALE REPRODUCTIVE SYSTEM			
1. **Sexual dimorphism**	Found, as in male fish inner portions of pelvic fins form **claspers** for transferring spermatozoa during copulation.	Not distinct. However, in male frog, base of first inner finger forms a thick **nuptial pad** during breeding season to clasp female in amplexus.	Poorly developed, shown by the swellings of hemipenes midventrally behind cloaca in male, and by more conspicuous **preanofemoral pores** in male.	Sexual dimorphism is absent in pigeon.	Sexual dimorphism is well marked due to presence of **penis** and **scrotal sac** containing testes only in male.
2. **Male reproductive organs**	Include a pair of testes, vasa efferentia, paired vasa deferentia, epididymes, seminal vesicles, urogenital sinus, sperm sacs and pelvic claspers.	Include two testes, several vasa efferentia, two urinogenital ducts and cloaca.	Include one pair each of testes, vasa deferentia and copulatory sacs, and cloaca.	Include 2 testes, 2 vasa deferentia, 2 seminal vesicles and cloaca.	Include 2 testes, 2 epididymes, 2 vasa deferentia, urethra, penis and some accessory glands.
3. **Testes**	Very long, cylindrical, attached mid-dorsally to abdominal wall by a double peritoneal fold or **mesorchium**.	Ovoid or rod-like, light yellow, attached to antero-ventral surface of kidneys by **mesorchium**.	Oval, white, bodies, attached much ahead of kidneys to dorsal abdominal wall by **mesorchium**. Right testis somewhat anterior to left one.	Oval, white bodies attached by **mesorchium** antero-ventrally to kidneys. Right testis slightly smaller.	Small, oval, white bodies. Remain inside abdominal cavity in young. But descend outside abdomen in **scrotal sac** during breeding season in adult.

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
12. **Copulatory organs**	Copulatory apparatus includes a pair of **siphons** for flushing spermatozoa with sea water, and a pair of grooved **pelvic claspers** for transferring spermatozoa into cloaca of female during copulation.	Copulatory apparatus absent. Fertilization external, in water, where ova and spermatozoa are shed during amplexus.	A pair of eversible vascular **copulatory sacs** present midventrally at the base of tail. During copulation they become everted through cloaca as cylindrical **hemipenes** to convey spermatozoa into cloaca of female.	Copulatory apparatus absent. During copulation male bird rides on back of female, their cloacae are closely apposed and transfer of sperms effected quickly.	It includes small erectile cylindrical **penis** in front of anus of male. It serves to transmit sperms into vagina of female during copulation.
13. **Accessory sex glands**	Do not occur.	Do not occur.	Tubular preanofemoral glands produce a horny secretion which forms temporary spines for grasping female during mating.	Do not occur.	Male has one pair each of prostate, Cowper's perenial and rectal glands. Their secretions either attract the female or contribute to semen.
	[III] FEMALE REPRODUCTIVE SYSTEM				
1. **Female reproductive organs**	Include a pair each of ovaries, oviducts, shell glands, uteri and epigonal organs and a single rectal gland, a vagina and a cloaca.	Include a pair of ovaries, a pair of oviducts and a cloaca.	Include paired ovaries oviducts, vaginae, shell glands and a cloaca.	Include only left ovary, left oviduct including uterus, shell gland and vagina, and a cloaca.	Include paired ovaries, oviducts, uteri and single vestibule, vagina, clitoris and some accessory glands.
2. **Ovaries**	Ovaries are paired, irregular, small, lobulated bodies attached just behind liver to dorsal abdominal wall by a double peritoneal fold called **mesovarium**.	Ovaries are a pair of large irregular, multilobed, hollow, blackish bodies attached near kidneys to dorsal abdominal wall by **mesovarium**.	Ovaries are small, paired, white, void bodies suspended by **mesovaria** well ahead of kidneys. Right ovary is attached somewhat anterior to the left one.	Left ovary is a large irregular white body attached ventral to anterior lobe of left kidney by **mesovarium**. Its surface has numerous **egg follicles** or **sacs** each with a developing ovum.	Two ovaries are small, oval, white bodies attached symmetrically and dorsally behind kidneys by **mesovaria**.
3. **Epigonal organs and rectal glands**	Ovaries are connected by elongated epigonal organs posteriorly to a rectal gland of unknown function.	Epigonal organs and rectal gland absent.	No epigonal organs and no rectal gland.	Both epigonal organs and rectal gland lacking.	There are no epigonal organs and rectal gland.
4. **Oviducts**	Oviducts or **Mullerian ducts** are a pair of large but straight ducts, opening posteriorly into cloaca. Their	Oviducts are very long and much coiled glandular tubes opening behind into cloaca. Their anterior ends	Oviducts are 2 long, wide, thin walled, much plaited tubes opening behind separately into urodaeum. Anterior	Left oviduct is a long and wide tube with thick walls opening behind into urodaeum of cloaca. It opens anteriorly	Two oviducts are large, coiled tubes meeting behind into vagina, and called **Fallopian tubes**. Anterior end of

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
	narrow anterior ends form **oviducal funnels** which meet mid-dorsally just behind septum transversum and open into abdominal cavity by a single **slit-like opening**.	form separate **oviducal funnels** with separate openings or **ostia**, at the bases of lungs.	broad end of each forms a large **oviducal funnel** with a large externally directed ciliated opening or **ostium**, much ahead of ovaries.	near let ovary by a large **oviducal funnel** with a wide fimbriated **ostium** facing inwards.	each opens near ovary by a small **oviducal funnel** with fimbriated **ostium**.
5. Shell glands	A little distance behind funnel, oviduct forms a small enlargement or **shell gland**. It secretes a thin membrane over descending fertilized eggs.	Shell glands are absent.	While passing over kidney, each oviduct forms a slight dilation or **shell gland** into which fertilized eggs are covered by shells.	Behind ostium, left oviduct is divided into several parts : magnum, is thymus, uterus and vagina. Uterus secretes the hard calcareous egg shell.	No shell glands present in oviducts.
6. Uterus	In the region of kidney, each oviduct forms a wide **uterus** inside which the embryos develop.	Before entering cloaca, each oviduct expands into a thin-walled **ovisac**, erroneously called **uterus** which is absent.	Uteri are absent.	Uterus demarcated as states above but **true uterus** for development of embryos absent.	Fallopian tubes are followed by much wider, longer convoluted, vascular and muscular **uteri** where embryos develop.
7. Vagina & vestibule	Two uteri unite posteriorly into a common median vegina opening into cloaca. Vestibule absent.	Vagina absent. So called uteri or ovisacs open directly into cloaca. Vestibule absent.	Short terminal part of each oviduct, called **vagina**, opens dorsally into urodaeum. Vestibule lacking.	The last part of single left oviduct, called **vagina**, also opens in the roof of urodaeum. There is no vestibule.	Both uteri meet into a common long, wide and median **vagina**. It opens with urethra into common **urinogenital sinus** or **vestibule.**
8. Vulva	Vulva absent. Instead cloaca opens to outside through a large median shallow groove.	No vulva present. Cloaca opens directly to exterior through a small circular cloacal aperture.	No vulva. Cloaca opens through a transverse slitlike a perture.	No vulva. Cloaca opens midventrally by a transverse cloacal aperture.	Vestibule opens to outside ventral to anus, through a longitudinal slit-like aperture called **vulva.**
9. Special glands	No special glands associated with female genital tract.	No glands as in fish.	No glands as in fish and amphibians.	No special glands as in fish, amphibians and reptiles.	Special female sex glands include Cowper's, perineal and rectal glands.
10. Milk glands	Absent.	Absent.	Absent.	So-called pigeon's milk, fed to young ones, is secreted by crop glands.	Mammary glands secrete milk and open on 4 or 5 pairs of ventral teats or nipples in female rabbit.

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
			[IV] LIFE HISTORY		
1. Breading season	Throughout the year.	During rainy season from July to September.	During March & April in northern India.	All the year round. Particularly during spring and summer.	All the year round specially from January to June.
2. Fertilization	Internal, inside oviduct, after copulation in water.	External, in water, where ova and sperms are shed during mating.	Internal, inside oviduct, after some courtship preceding copulation on land.	Internal, inside oviduct, after much courtship preceding copulation on land.	Internal, inside oviduct, after mating without courtship on land.
3. Eggs	3 to 7 small and uniformly white eggs retained inside uteri. **(Ovovi-viparous).**	Innumerable small eggs, half black and half white, laid in water in a common jelly forming a **spawn (Ovi-parous).**	10 to 15 large, dirty white shelled eggs laid in a burrow **(Oviparous).**	Usually 2 large oval white shelled eggs laid in a crude nest. **(Oviparous).**	Miscroscopic eggs retained inside uteri. **(Viviparous).**
4. Incubation	No	No	No	Both parents incubate eggs in turns.	No
5. Development	Uterine, 3 to 7 young ones develop in each uterus at a time and nourished through a **yolk sac placenta.** There is no **metamorphosis.**	Development occ-urs in water and includes an aquatic tadpole larval stage which undergoes metamorphosis to become terrestrial adult.	Development out-side body in eggs on land. There is no metamorphosis. Newly hatched young are similar to adult parents.	Development in shelled eggs outside body and without metamorphosis. Newly hatched young are naked and helpless and fed on pigeon's milk to grow and become fit to fly in about 3 weeks.	Development inside uteri. Gestation period lasts for 30 days. New born young blind, naked and fed on milk by mother before they become fit to leave the burrow in about 4 weeks.

Ex. 4 Comparative study of heart with the help of models and charts.



Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
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 trans-versum is absent.	Heart lies mid-ventrally above sternum in thoracic cavity. There is no septum trans-versum.	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.
2. Pericardium	Heart lies protected within a 2-layered membranous **peri-cardium.**	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, mem-branous sac, the **pericardium**.	Heart completely surrounded by a 2-layered mem-branous 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 lar-ger, 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 ex-ternally. But only auricle and ventricle are true chambers, hence *2-chambered*.	3- **chambered,** made of 2 auricles and 1 ventricle. Auricles not demarcated exter-nally. Besides, sinus venosus and truncus arteriosus also present.	3- **chambered**, made of 2 auricles and one incompletely divi-ded ventricle, all faintly demarcated ex-ternally. Sinus venosus also present.	4- **chambered**, made of 2 auricles and 2 ventricles. Ventri-cles not distingui- shable externally.	4- **chambered**, made of 2 auricles and 2 ventricles, all distinguishable ex-ternally.
5. Sinus venosus	Triangular, ex-tending 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 trans-versely 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 **Eust-achian valve**.	Sinus venosus absent. However, opening of postcaval into right auricle guarded by a rudimentary **Eust-achian valve**.
7. Atria or auricles	Atrium or auricle somewhat trian-gular. Undivided internally due to lack of an **inter-auricular** septum.	Auricles somewhat rectangular. Do not form auricular appendages. Inter-nally divided completely into right and left auricles by an **inter-auricular septum**.	Two auricles divided completely 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 sep-arated by an **inter auricular septum**. Right auricle without diver-ticulum.

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
8. Atrial wall	Thin - walled, spongy, moderately muscular.	Thin walled, without muscular 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 *bicuspid*, 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 spongly 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 (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
14. Columnae carneae	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.

Ex. 5 Mount of weberian ossicles of fish.

Aim: Temporary mounting of Weberian Osscles of *Wallago*:

Procedure:

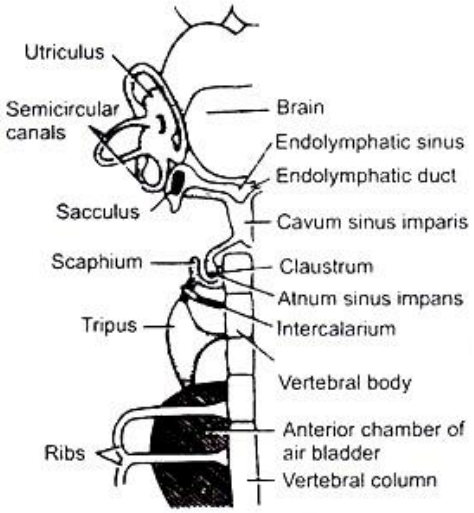
-Take either a preserved or freshly-killed fish remove the skin and muscles of the posterior region of the operculum.

-Trace out the air bladder and locate a triangular piece of bone attached to its anterior end. This tranangular bone is tripus, a part of weberianossicles.

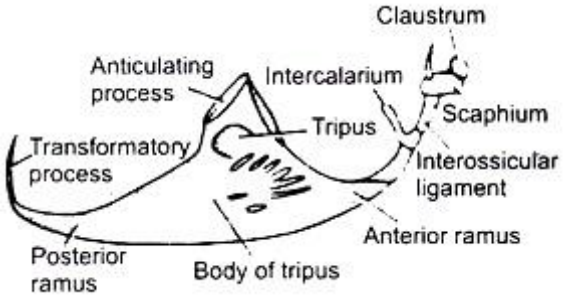
-Go on tracing it anteriorly and trace all the related ossicles.

-Take them out together and place in a watch glass containing water.

-Wash the material and mount in glycerine.



Observation: Weberian ossicles are made of a chain of bony structures and are characteristic of order Cypriniforms. These are four bony pieces, claustrum, scaphium, intercalarium and tripus together referred to as Weberian osicles.



The claustrum is the smallest enterior most piece which articulates with neutral arch of first vertebra. The scaphium is a broad and compressed bony piece which is followed by intercalarium and tripus. Tripus is the largest bony ossicle having three processes, the anterior process is connected to interossicular ligament, medium process is attached to the junction of 2nd and 3rd vertebrae. The posterior process is curved and is connected with the anterior chamber wall of the air or swim bladder. Sound waves are said to travel to the internal ear through these ossicles.

Ex. 6 Study of axial and appendicular skeleton of vertebrates.

Skull

Scoliodon

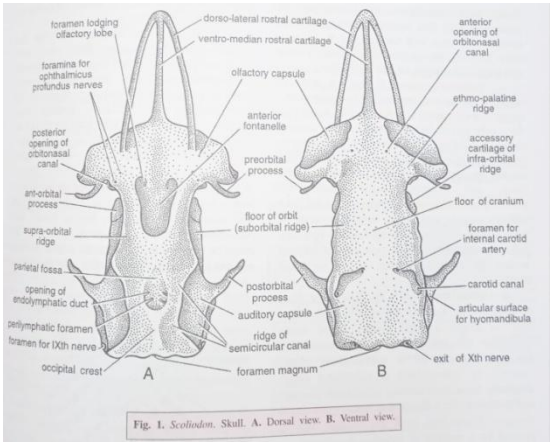
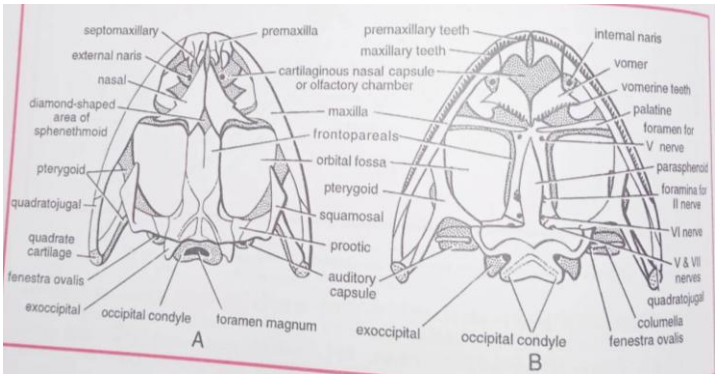
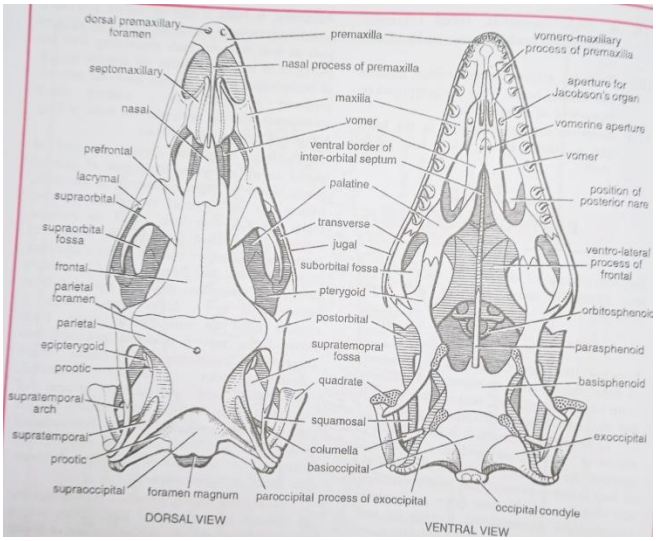


Fig. 1. *Scoliodon*. Skull. A. Dorsal view. B. Ventral view.

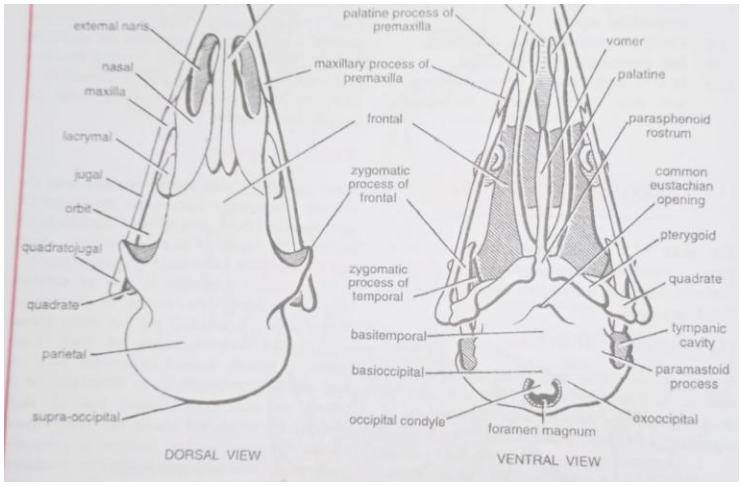
Frog



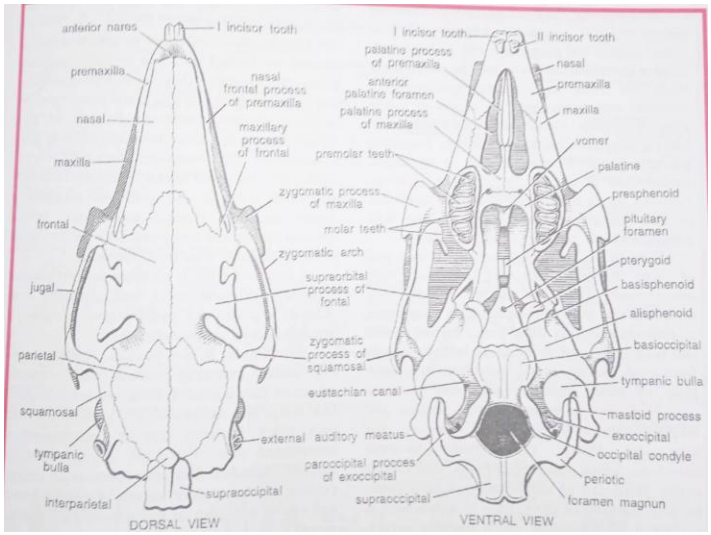
Varanus



Fowl


external naris
nasal
maxilla
lacrymal
jugal
orbit
quadratojugal
quadrate
parietal
supra-occipital
DORSAL VIEW
palatine process of premaxilla
maxillary process of premaxilla
frontal
zygomatic process of frontal
zygomatic process of temporal
basitemporal
basioccipital
occipital condyle
vomer
palatine
parasphenoid rostrum
common eustachian opening
pterygoid
quadrate
tympanic cavity
paramastoid process
exoccipital
foramen magnum
VENTRAL VIEW

Rabbit

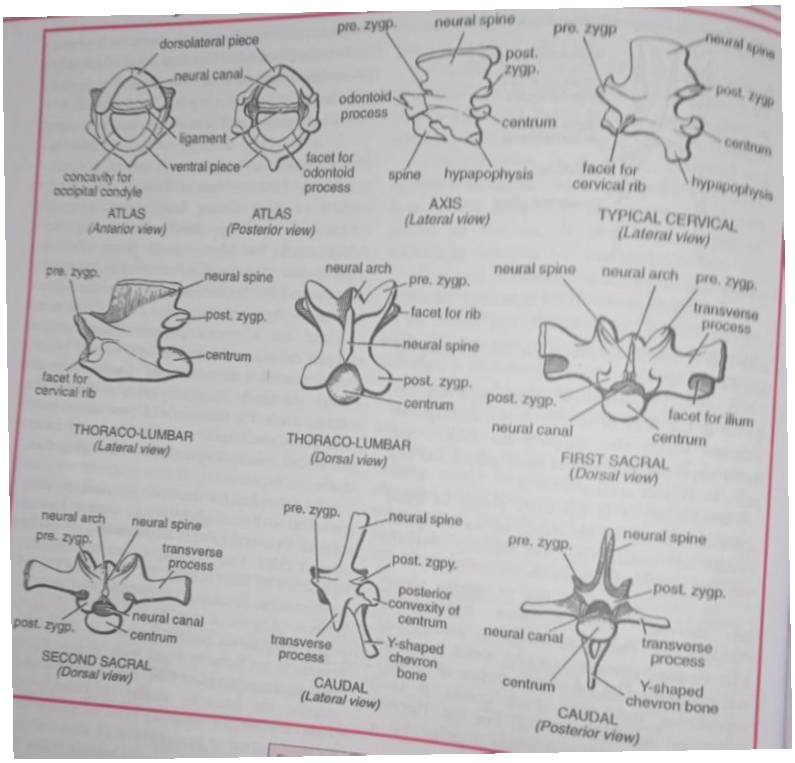

anterior nares
premaxilla
nasal
maxilla
frontal
jugal
parietal
squamosal
tympanic bulla
interparietal
I incisor tooth
nasal frontal process of premaxilla
maxillary process of frontal
zygomatic process of maxilla
zygomatic arch
supraorbital process of frontal
zygomatic process of squamosal
external auditory meatus
supraoccipital
DORSAL VIEW
I incisor tooth
II incisor tooth
palatine process of premaxilla
anterior palatine foramen
palatine process of maxilla
premolar teeth
molar teeth
nasal
premaxilla
maxilla
vomer
palatine
presphenoid
pituitary foramen
pterygoid
basisphenoid
alisphenoid
basioccipital
tympanic bulla
eustachian canal
mastoid process
exoccipital
occipital condyle
paroccipital process of exoccipital
periotic
supraoccipital
foramen magnun
VENTRAL VIEW

Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
1. Form of skull	Elongated and dorso - ventrally flattened.	Broad traingular and dorso-ventrally flattened.	Elongated and dorso -ventrally flattened.	Elongated and convex dorsally.	Elongated and convex dorsally.
2. Weight and pneumacity	Heavier & solid.	Light in weight.	Heavier & solid.	Very light & pneumatic, in adaptation to flight.	Light, some bones spongy.
3. Skull surface	Smooth, without sutures.	Surface rough, sutures distinct.	Surface rough, sutures disinct.	Surface smooth, sutures disappear.	Surface rough, sutures distinct.
4. Ossification	Wholly cartilaginous. Chondrocranium retained throughout life.	Poorly ossified. Much cartilaginous chondrocranium persists.	Extensively ossified except in nasoethmoidal region.	Well ossified neurocranium.	Completely ossified neurocranium.
5. Occipital condyles	Dicondylic	Dicondylic.	Monocondylic	Monocondylic	Dicondylic
6. Beak or snout	3 anterior cartilages-2 dorso-lateral & 1 ventro-median, form a snout a rostrum.	Beak absent.	Beak absent.	Premaxillae, maxillae & dentaries form an elongated beak.	No beak present.
7. Number of bones	Entire neurocranium made of a single piece of cartilage. Bones absent.	Bones fewer. Basisphenoid, alishpenoid, orbitosphenoid, presphenoid, supraorbital, postorbital, etc.	Large no. of bones. Alisphenoids, orbitosphenoids, presphenoid, etc. absent. Prefrontal, supraorbital, post-orbital, epipterygoid present.	Fewer and thin dermal bones. Alisphenoids, orbitosphenoids & presphenoids present.	Perfrontal, postfrontal, parasphenoid, quadratojugal, etc. absent. Alisphenoids, orbitosphenoids present.
8. Cranium	Small & flat.	Small & narrow due to small size of brain.	Cranium small.	Large, rounded dome-like.	Large rounded dome-like.
9. Roof of cranium	Brain completely covered by cartilaginous roof. No dermal bones. Bears anterior fontanelle or parietal fossa.	Cranial roof made by a pair of fused frontparietal bones. No parietal foramen.	Cranial roof formed by two frontals and two fused parietals bearing a median parietal foramen.	Both frontals and parietals become completely merged into one without sutures and parietal foramen.	Cranial roof formed by distinct paired frontals and parietals and an interparietal. No parietal foramen.
10. Floor of cranium	Cranial floor flat, cartilaginous without bones.	Cranial floor occupied by a dagger - shaped parasphenoid.	Cranial floor consists of a basisphenoid and much reduced parasphenoid.	Cranial floor contains a large basitemporal and a reduced parasphenoid.	Cranial floor made by basisphenoid and presphenoid.
11. Foramen magnum	Posteriorly directed.	Posteriorly directed.	Posteriorly directed.	Ventrally directed.	Ventrally directed.
12. Occipital bones	Occipital region cartilaginous, without bones.	Includes two exoccipitals.	4 bones-suprao-ccipital, 2 exocc-ipitals and basi-occipita - firmly fused together.	Usual 4 bones firmly fused together.	Usual 4 bones fused together into a single bone. Each exoccipital forms a paroccipital process.

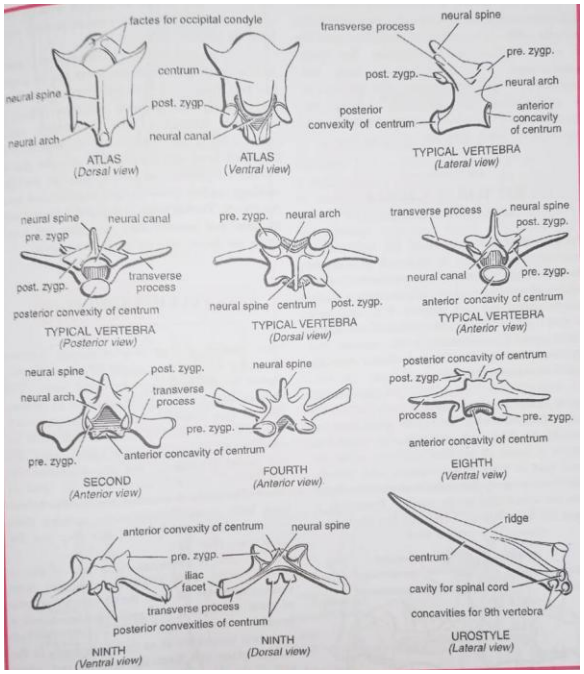
Characters	FISH Dogfish (*Scoliodon*)	AMPHIBIA Frog (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
13. Interorbital septum	Septum absent. Cranium extends forwards. Skull platybasic.	Septum absent. Cranium reaches forwards. Skull platybasic.	Septum thin. Cranium does not extended in front. Skull tropibasic.	Septum thin., Cranium does not exteed in front. Skull tropibasic.	Septum present. Cranium does not reach forwards. Skull tropibasic.
14. Otic bones	Absent.	Single bone, prootic.	3 bones. Epiotic fused with exoccipital, opisthotic with supraoccipital, while prootic is free.	Auditory capsule mainly formed by prootic.	3 otic bones- prootic, epitoic & opisthotic- fused into a periotic bone.
15. Tympanic bone	Absent.	Ring-like or annular. No bulla.	Annular. No bulla.	Annular. No bulla.	Flask-shaped, forming tympanic bulla with periotic.
16. Secondary palate	Absent.	Absent.	Absent.	Incomplete, formed by palatines and pterygoids.	Complete, formed by palantines, maxillae and premaxillae.
17. Ear ossicles	None. Hyomandibular persists.	Hyomandibular forms a single ear ossicle, columella.	Hyomandibular becomes columella.	Hyomandibular becomes columella.	3 ear ossicles. Malleus from articular, incus from quadrate, and stapes from hyomandibular.
18. Nasals	Absent.	2, separate, large, triangular.	2, small, slender, fused.	2 separate, large; Y-shaped.	2, separate, long, narrow.
19. Sphenethmoid	Absent.	Present.	Absent.	Absent.	Absent.
20. Lacrimal	Absent.	Absent.	Small, perforated.	Large, perforated	Small, unperforated.
21. Upper jaw bones	Formed by palatopterygo-quadrate cartilage mandibular arch.	Formed by premaxilla, maxilla and quadratojugal bones and quadrate cartilage.	Upper jaw bones are premaxilla, maxilla, jugal, pterygoid and quadrate.	Include premaxilla, maxilla, jugal, quadratojugal palatine, pterygoid and quadrate.	Include premaxilla, maxilla, jugal, pterygoid and palatine.
22. Lower jaw bones	Formed by Meckel's cartilage of mandibular arch	Formed by Meckel's cartilage and 3 bones- mento-meckelion, dentary and angulosplenial.	Formed by articular, angular, supra-angular, coronoid, splenial and dentary surrounding an axial Meckel's cartilage.	Include articular, angular, supra-angular, splenial and dentary surrounding a Meckel's cartilage.	Include a single membrane bone, dentary.
23. Jaw suspensorium	Hyostylic. Both jaws suspended from cranium through hyomandibular.	Autostylic. Upper jaw fused with cranium. Lower jaw articulates with quadrate.	Autostylic. Upper jaw intimately fused. Articulation between articular of lower jaw and quadrate.	Autostylic. Upper jaw fused with cranium. Articular articulates with quadrate.	Craniostylic. Upper jaw fused. Dentary articulates with squamosal of skull.
24. Quadrate	Absent	Represented by cartilage.	Small, thick, rod-like, fixed.	Stout, Y-shaped, movable.	Modified into incus of middle ear.
25. Teeth	Not attached to jaw cartilages but to skin. Homologous with placoid scales.	Homodont and acrodont. Present on premaxillae, maxillae and vomers.	Homodont and pleurodont. Found on premaxillae, maxillae and dentaries.	Teeth absent.	Heterodont and thecodont. Present on premaxillae, maxillae and dentaries.

Vertebrae

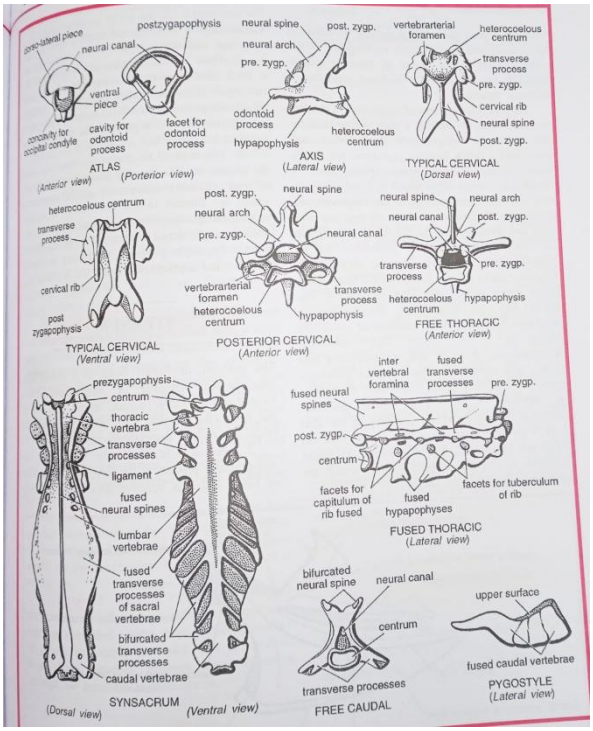
Frog



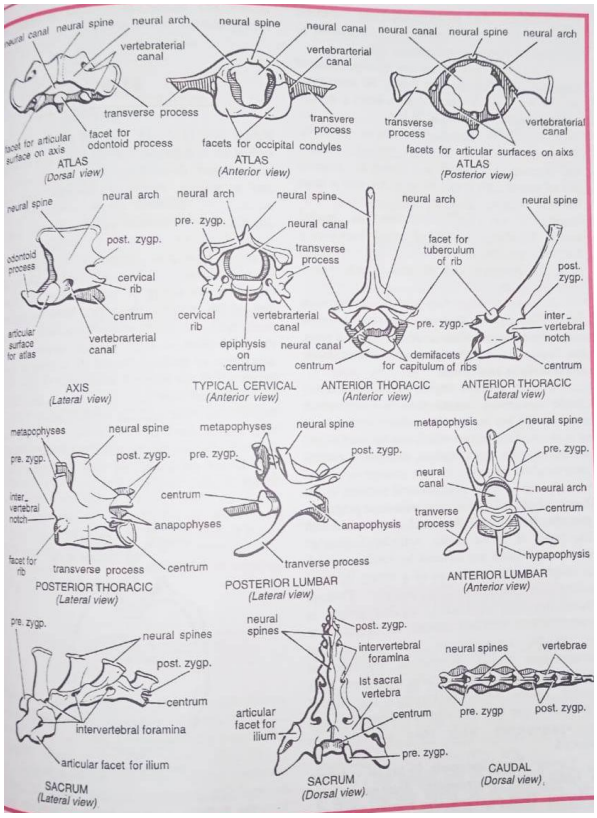
Varanus



Fowl


dorso-lateral piece
neural canal
postzygapophysis
ventral piece
concavity for occipital condyle
cavity for odontoid process
facet for odontoid process
ATLAS
(Anterior view)
(Porterior view)
neural spine
post. zygp.
neural arch
pre. zygp.
odontoid process
hypapophysis
heterocoelous centrum
AXIS
(Lateral view)
vertebrarterial foramen
heterocoelous centrum
transverse process
pre. zygp.
cervical rib
neural spine
post. zygp.
TYPICAL CERVICAL
(Dorsal view)
heterocoelous centrum
transverse process
cervical rib
post zygapophysis
TYPICAL CERVICAL
(Ventral view)
post. zygp.
neural spine
neural arch
pre. zygp.
neural canal
vertebrarterial foramen
heterocoelous centrum
transverse process
hypapophysis
POSTERIOR CERVICAL
(Anterior view)
neural spine
neural arch
post. zygp.
neural canal
pre. zygp.
transverse process
heterocoelous centrum
hypapophysis
FREE THORACIC
(Anterior view)
prezygapophysis
centrum
thoracic vertebra
transverse processes
ligament
fused neural spines
lumbar vertebrae
fused transverse processes of sacral vertebrae
bifurcated transverse processes
caudal vertebrae
SYNSACRUM
(Dorsal view)
(Ventral view)
inter vertebral foramina
fused transverse processes
pre. zygp.
fused neural spines
post. zygp.
centrum
facets for capitulum of rib fused
fused hypapophyses
facets for tuberculum of rib
FUSED THORACIC
(Lateral view)
bifurcated neural spine
neural canal
centrum
transverse processes
FREE CAUDAL
upper surface
fused caudal vertebrae
PYGOSTYLE
(Lateral view)

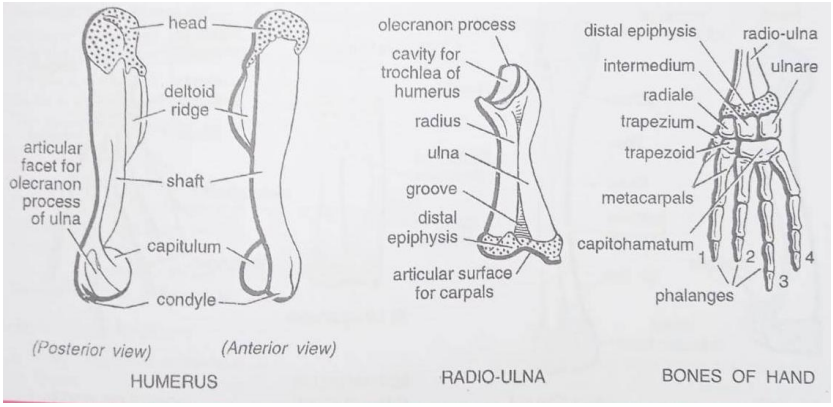
Rabbit


neural canal
neural spine
neural arch
vertebrarterial canal
transverse process
facet for articular surface on axis
facet for odontoid process
ATLAS
(Dorsal view)
neural spine
vertebrarterial canal
transvere process
facets for occipital condyles
ATLAS
(Anterior view)
neural canal
neural canal
neural spine
neural arch
transverse process
vertebrarterial canal
facets for articular surfaces on aixs
ATLAS
(Posterior view)
neural spine
neural arch
post. zygp.
odontoid process
cervical rib
centrum
articular surface for atlas
vertebrarterial canal
AXIS
(Lateral view)
neural arch
neural spine
pre. zygp.
neural canal
transverse process
cervical rib
vertebrarterial canal
epiphysis on centrum
neural canal
centrum
TYPICAL CERVICAL
(Anterior view)
neural arch
facet for tuberculum of rib
pre. zygp.
demifacets for capitulum of ribs
ANTERIOR THORACIC
(Anterior view)
neural spine
post. zygp.
inter-vertebral notch
centrum
ANTERIOR THORACIC
(Lateral view)
metapophyses
neural spine
pre. zygp.
post. zygp.
inter-vertebral notch
anapophyses
facet for rib
transverse process
centrum
POSTERIOR THORACIC
(Lateral view)
metapophyses
neural spine
pre. zygp.
post. zygp.
centrum
anapophysis
tranverse process
POSTERIOR LUMBAR
(Lateral view)
metapophysis
neural spine
pre. zygp.
neural canal
neural arch
centrum
tranverse process
hypapophysis
ANTERIOR LUMBAR
(Anterior view)
pre. zygp.
neural spines
post. zygp.
centrum
intervertebral foramina
articular facet for ilium
SACRUM
(Lateral view)
neural spines
post. zygp.
intervertebral foramina
1st sacral vertebra
articular facet for ilium
centrum
pre. zygp.
SACRUM
(Dorsal view)
neural spines
vertebrae
pre. zygp
post. zygp.
CAUDAL
(Dorsal view)

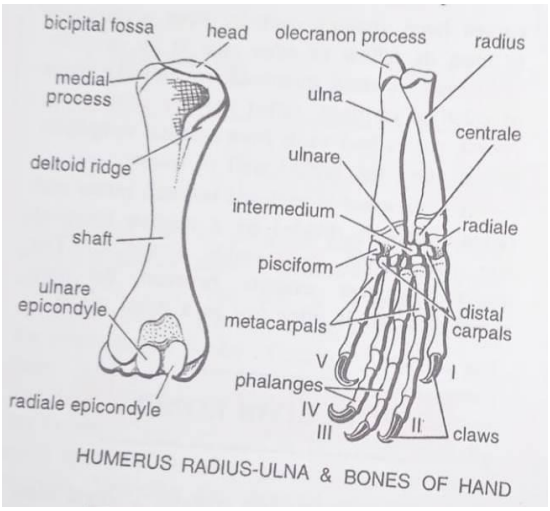
Limb bones

Bones of fore limb

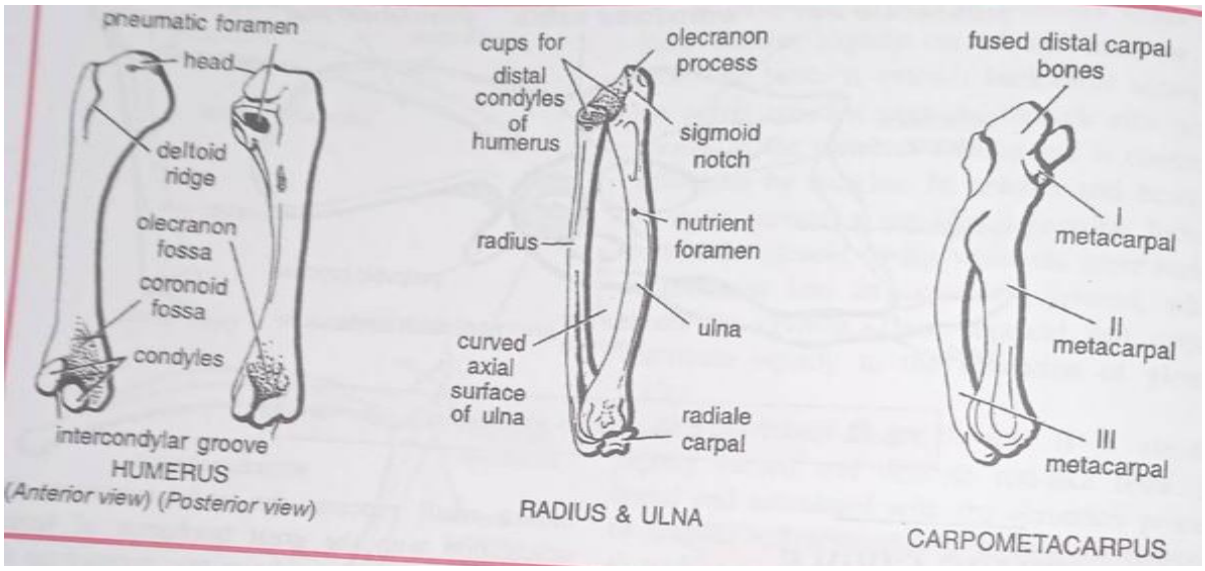
Frog



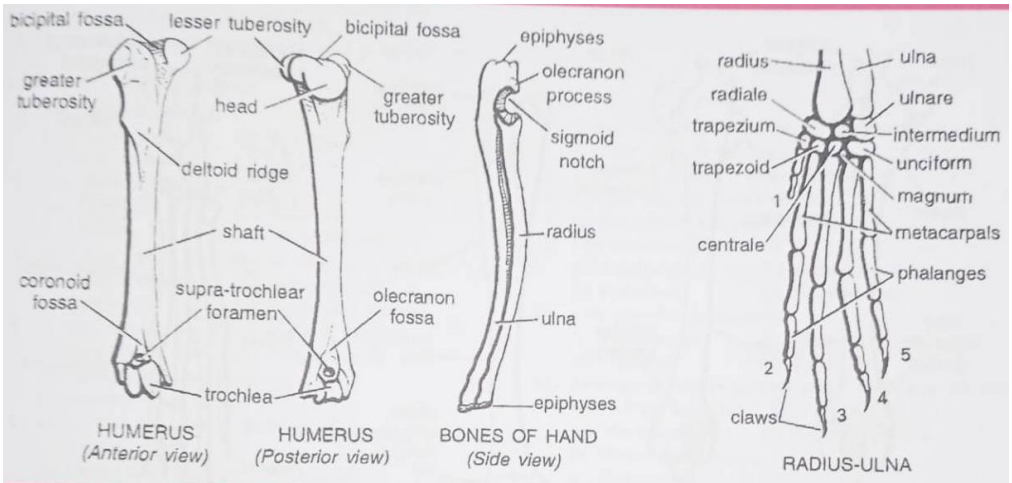
Varanus



Fowl

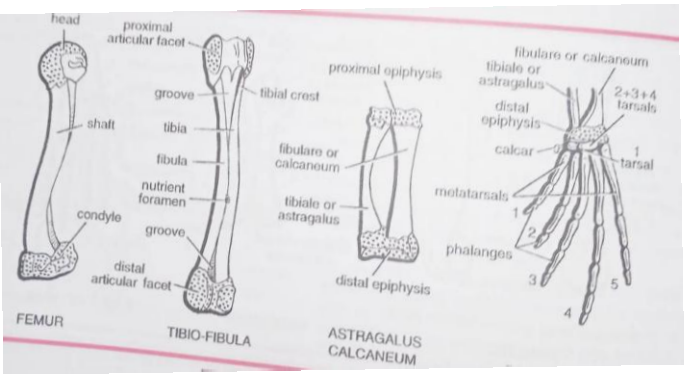

pneumatic foramen
head
deltoid ridge
olecranon fossa
coronoid fossa
condyles
intercondylar groove
HUMERUS
(Anterior view) (Posterior view)
cups for distal condyles of humerus
olecranon process
sigmoid notch
nutrient foramen
radius
ulna
curved axial surface of ulna
radiale carpal
RADIUS & ULNA
fused distal carpal bones
I metacarpal
II metacarpal
III metacarpal
CARPOMETACARPUS

Rabbit

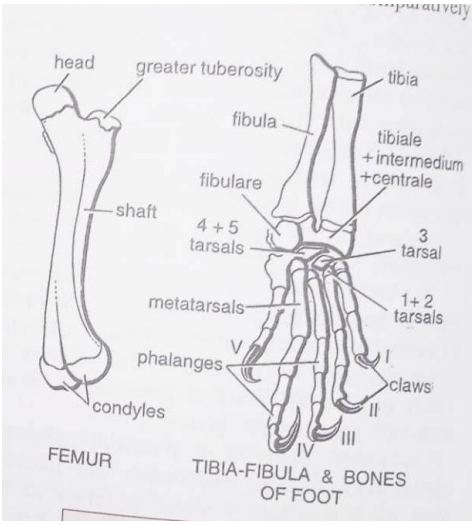

bicipital fossa
lesser tuberosity
greater tuberosity
deltoid ridge
shaft
coronoid fossa
supra-trochlear foramen
trochlea
HUMERUS
(Anterior view)
bicipital fossa
head
greater tuberosity
olecranon fossa
HUMERUS
(Posterior view)
epiphyses
olecranon process
sigmoid notch
radius
ulna
epiphyses
BONES OF HAND
(Side view)
radius
ulna
radiale
ulnare
trapezium
intermedium
trapezoid
unciform
1
magnum
centrale
metacarpals
phalanges
2
5
4
3
claws
RADIUS-ULNA

Bones of hind limb

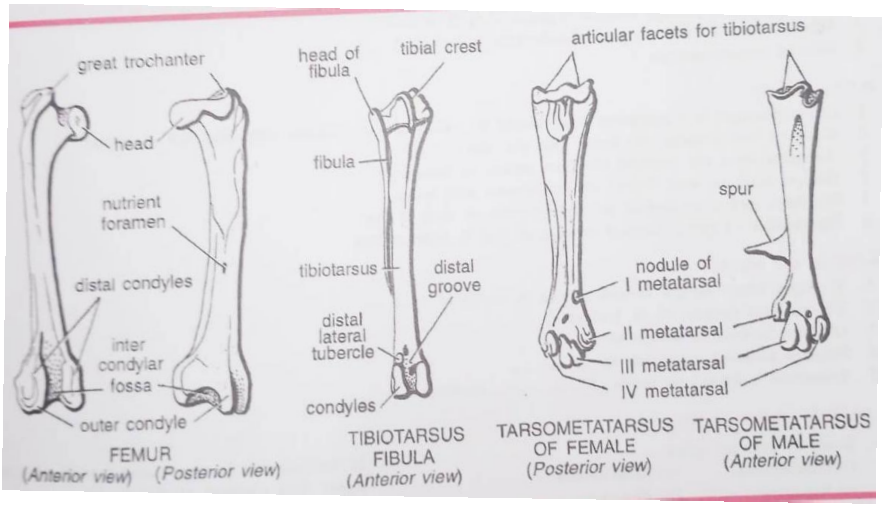
Frog



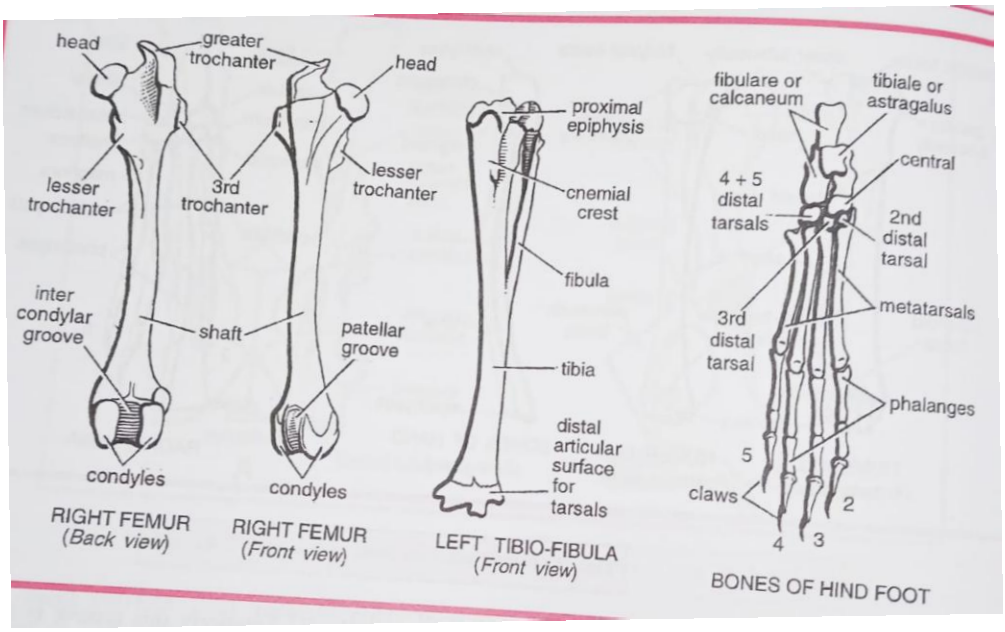
Varanus



Fowl



Rabbit


head
greater trochanter
lesser trochanter
3rd trochanter
inter condylar groove
shaft
condyles
RIGHT FEMUR
(Back view)
head
lesser trochanter
patellar groove
condyles
RIGHT FEMUR
(Front view)
proximal epiphysis
cnemial crest
fibula
tibia
distal articular surface for tarsals
LEFT TIBIO-FIBULA
(Front view)
fibulare or calcaneum
tibiale or astragalus
central
4 + 5 distal tarsals
2nd distal tarsal
3rd distal tarsal
metatarsals
phalanges
5
claws
2
4
3
BONES OF HIND FOOT

Bones	AMPHIBIA Frog *(Rana)*	REPTILIA Lizard *(Uromastix)*	AVES Pigeon *(Columba)*	MAMMALIA Rabbit *(Oryctolagus)*
	[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.	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. **Pisciform** bone absent.	9 carpals in wrist arranged in two rows of 3 and 5 with a centrale in between. **Pisciform** bone present.	Only 2 free carpals of proximal row, **radiale** and **ulnare**, attached to radius an ulna respectively. Distal carpals fused with metacarpals. **Pisciform** bone absent.	8 carpals in wrist arranged in 3 rows of 3, 1 and 4 respectively, **Pisciform** 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 (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
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		
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 respecively.	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 distrinct 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, slightlly 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 **cnemal 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 (*Rana*)	REPTILIA Lizard (*Uromastix*)	AVES Pigeon (*Columba*)	MAMMALIA Rabbit (*Oryctolagus*)
	tarsals elongated but united at the two ends. Outer **calcaneum** or fibulare is thick and stout. Inner **astragalus** or tibiale is thin and curved.		distal tarsals fused with tarso-metatarsus.	called astragalus and calcaneum. A single middle bone is called centrale or navicular. Distal row contains 3 tarsal bones.
6. Metatarsals	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 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.	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 (*Scoliodon*)**	**Bony fish Rohu (*Labeo*)**	**Amphibia Frog (*Rana*)**	**Reptilia Lizard (*Uromastix*)**	**Aves Pigeon (*Columba*)**	**Mammalia Rabbit (*Oryctolagus***
1. Condition	Cartilagenous, not well developed		Bony as well as cartilaginous, well developed	Bony as well as cartilaginous, well developed	Bony , well developed for flight	Largely bony, well adapted for running and burrowing
2. Position	Embeded in lateral and ventral body wall, posterior to gills, support pectoral fins		Embeded in thoracic body wall around heart which it protects, supports forelimbs	Embeded inventor-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 steral 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 mecromian 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 slike. Ower 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 glenid cavity. Epicoracoid absent.
10. Glenoid cavity	Absent		Formed posteriorly at the junction of scapula and coracoids to torecieve 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 compresseddi sc or hypocliedium, 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	**Cartilagenous Fish Dogfish (*Scoliodon*)**	**Bony fish Rohu (*Labeo*)**	**Amphibia Frog (*Rana*)**	**Reptilia Lizard (*Uromastix*)**	**Aves Pigeon (*Columba*)**	**Mammalia Rabbit (*Oryctolagus***
1. Condition	Simple, cartilaginous		Bony as well as	Bony, solid and strong.	Bony, large, light,	Bony, large, stout, well

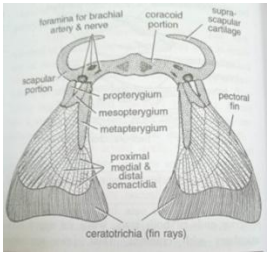
	, transverse, rod- like, called ischio-pubic bar.		cartilaginous, well developed.	Well developed for tetrapod locomotion.	pneumatic. Well adapted for flight and bipedal locomotion.	adapted for fast running.
2. Position	Embeded in ventral abdominal wall in front of cloaca, supports pelvic.		Occupies posterior 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

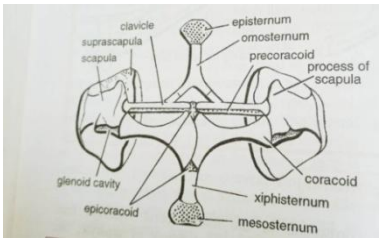
			distinct	distinct	distinct	
7. Ilium	Represented by a small blunt iliac process with a foramen		Forms anterior long arm resting on transverse process of 9^{th} vertebra. Forms a dorsal vertical blade or iliaccrest. Posteriorly both ilia united wuth median disc forming iliac symphysis	Ilium rod like and stout. Its tip articulating with the notch of transverse process of first sacral vertebra. Ilia of both sides separated without any iliac symphysis. Forms a small preacetabular process.	Ilium large plate like, wholly attached to synsaccrum. 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 broder of acetabulum	Bsent
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 ats 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

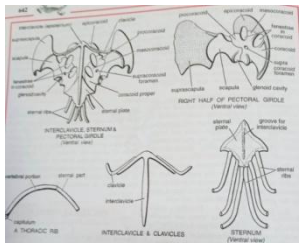
					postacetabular ilium	
11. Pubis	Not distinct hrom ischium		Both pubes are small, triangular, made of calcified cartilage, and fuse at a mid-ventral pubic symphysis in the disc. Epipubis absent.	Long slender bone directed anterio-ventrally meeting its fellow at a pubic symphysis having a small knob like 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 nad meets its fellow at a mid-ventral pubic symphysis. Epipubis absent.
12. Obturator foramen	Absent		Absent	A small obturator foramenpierc is 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 aprominent 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.

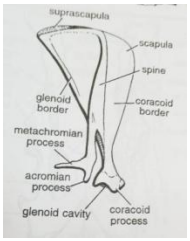
15. Cotyloid bone	Absent		Absent	Absent	Absent	Present

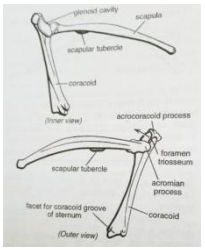
Pectoral Girdles





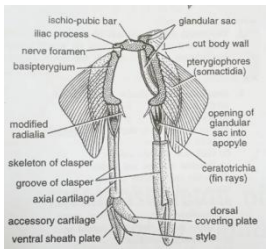


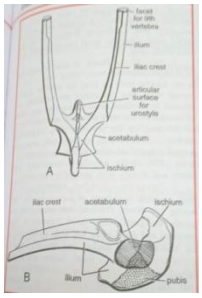


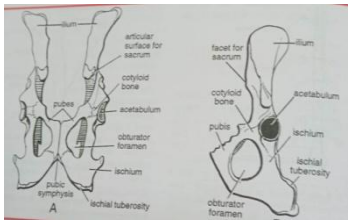


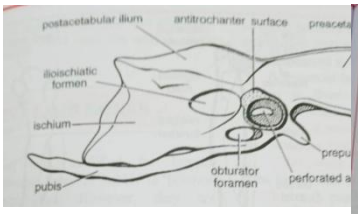
Scoliodon **Frog** **Varanus** **Fowl** **Rabbit**

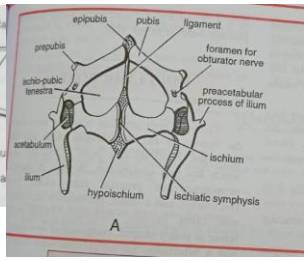
Pelvic Girdles











Ex. 7 Qualitative analysis of nutrients: Carbohydrate, Proteins, Lipids.
Iodine test for Starch:

Object: Determination of starch in a given unknown solution

Principle: Large polysaccharide molecules adsorb the smaller iodine molecules on their surface forming a Starch-Iodine complex of blue colour. On heating, this complex is dissociated but on cooling, it reappears again.

Requirements: Iodine solution, starch solution (1 %), test tubes, test tube holder, sprit lamp.

Procedure: Take 1% of starch solution in a test tube and add one drop of iodine solution. Mix both the solutions.

Observation: A deep blue colour appears.

Result: The given unknown solution is starch.

Precautions:
1. Test should not be carried out in alkaline medium.
2. Excess of iodine should not be added.
3. Use the clean glass wares.
4. Prepare the reagents carefully.

Benedict's test for Glucose/Reducing Carbohydrates:

Object: Determination of glucose in a given unknown solution

Principle: Copper sulphate hydrolyses to form cupric hydroxide which is reduced to cuprous oxide on heating with glucose.

$$CuSO_4 \xrightarrow{H_2O} Cu(OH)_2$$

(Cupric Hydroxide- Blue)

$$Cu(OH)_2 \xrightarrow[\text{Glucose}]{+2H^+} Cu_2O$$

(Cuprous oxide- Red)

Requirements: Benedict's reagent, Glucose solution (1%), test tubes, test tube holders, sprit lamp.
Procedure: Take one ml of glucose solution in a test tube and add two ml of Benedict's reagent. Mix both the solutions and boil for two minutes.

Observation: Yellowish green to brick red colour appears.

Result: The given unknown solution is glucose.

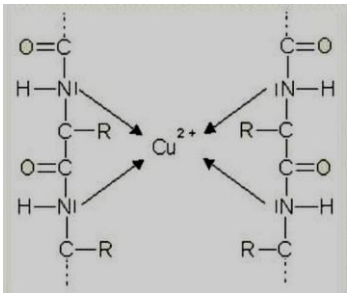
Precautions:
1. Take the solutions in correct proportion and follow the procedure strictly to get approximate quantity of glucose.
2. Use freshly prepared glucose solution
3. Use the clean glass wares
4. Prepare the reagents carefully

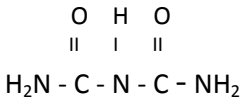
Benedict's reagent: Crystalline Copper Sulphate- 17.30 gm, Sodium citrate- 173.0 gm, Anhydrous Sodium Carbonate – 100.0 gm. Make the final volume of the reagent 1000 ml by distilled water.

Biuret Test for Protein:

Object: Determination of protein in a given unknown solution

Principle: This is really a test for peptide linkages. Since all proteins contain peptide linkages, they respond to this test. A violet coloured Biuret compound is formed.





Requirements: Sodium Hydroxide (40 %), Copper sulphate (0.5 %), Solution of egg albumin/BSA, test tubes, test tube holder, sprit lamp, etc.

Procedure: Take two ml of protein solution in a test tube. Add two ml of NaOH solution. Mix both the solutions and add $CuSO_4$ solution drop wise, with mixing after each addition.

Observation: Purple violet colour is appeared or a ring of violet colour appears at the junction of sample and $CuSO_4$ solution (Ring test).

Result: Given unknown solution is Protein.

Precautions:
1. Addition of excess of $CuSO_4$ solution should be avoided otherwise the blue colour of cupric hydroxide will mask the violet colour.
2. Test should not be carried out with magnesium sulphate or ammonium sulphate
3. Use the clean glass wares
4. Prepare the reagents carefully

Tests for lipids:

I. Solubility Test:

Object: Determination of lipid in a given unknown solution:

Principle: The test is based on the property of solubility of lipids in organic solvents (Ether, Chloroform, Benzene, Carbon Tetrachloride, etc.), semi solubility in alcohol and insolubility in water.
Requirements: Ether, alcohol, water, olive oil, pipettes, test tubes, test tube holders, sprit lamp

Procedure: Take three ml of each water, alcohol and ether in separate test tubes marked A, B and C. Add one to two drops of olive oil into each test tube. Shake vigorously and allow to stand .

Observations:

Test Tube- A: The oil is not miscible. The oil and water separate quickly and oil floats on water.

Test Tube- B: Oil is semi miscible and sinks to bottom. On heating oil is dissolve.

Test Tube- C: Oil is miscible and a clear solution is formed.

Result: The given unknown solution is oil.

Precautions:
1. Reagents should be handled with care.
2. Use only clean glass wares.
3. There should be keen observation of the results.

II. Grease Spot Test or Transluscent Test:

Object: Determination of lipid in a given unknown solution

Principle : All the lipids are greasy in nature hence leave a transparent spot on paper.

Requirements: Olive oil, Ether, white paper, test tube

Procedure: Take three ml of ether in a test tube. Dissolve five drops of oil in it. Put a drop of this solution on a filter paper and let it dry.

Observations: ether evaporates leaving a transluscent spot on the filter paper.

Result: Transluscent spot indicates the greasy character of oil, hence given solution is lipid.

Precautions:
1. Mix the oil with ether properly.
2. Do not put excess solution on the paper

III. Emulsification Test:

Object: Determination of lipid in a given unknown solution

Principle: When oil and water, which are immiscible, are shaken together, the oil is broken up into very tiny droplets which are dispersed in water. This is known as an oil-in-water emulsion. The water molecules, due to their high surface tension, have a tendency to come together and form a separate layer. This is why the oil and water emulsion is unstable.

In the presence of substances that lower the surface tension of water eg. Sodium Carbonate, Soap, Bile salts, etc, the tendency of water molecules to coalesce is decreased and the emulsion becomes stable. Since bile salts cause the greatest decrease in surface tension, they are the best emulsifying agents.

Requirements: Sodium Carbonate solution (0.5 %), Soap solution (Dilute), Bile salts solution (5%), olive oil, test tubes.

Procedure : Take five ml of each water, sodium carbonate solution, soap solution and bile salts solution in separate test tubes marked A, B, C and D. Add five drops of oil in each test tube. Shake vigorously and allow to stand.

Observations:

Test tube- A: Oil and water separate quickly indicating that the emulsion is unstable.

Test tube- B: Oil and sodium carbonate separate after some time indicating that the emulsion is more stable.

Test tube- C: Separation of oil and soap takes still longer time indicating that the emulsion is fairly stable

Test tube- D: No separation of oil and bile salts indicating that the emulsion is the most stable.

Result: The given unknown solution is lipid.

Precautions:
1. Mix the solutions properly
2. Keen observation is must

Ex. 8 Estimation of haemoglobin.

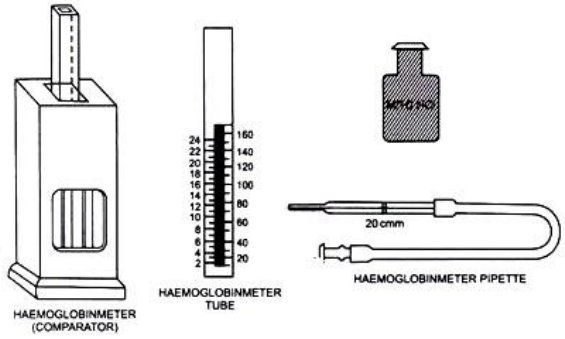
Aim: To estimate the gm percentage of haemoglobin contents in the blood.

Principle: When blood is treated with diluted acid/base, a brown coloured haematin compound is produced. Then this brown coloured solution is diluted with distilled water until the colour matches with standard hlass rods colour fitted in haemometer. In human, the normal vaue of Hb is about 14 gm%. This valuedepends on the age, sex, RBCs count, climatic conditions, etc.

Requirements: Haemoglobinometer, N/10 HCl, distilled water, fresh blood, pricking needle, etc.

Haemoglobinometer/Haemometer: Haemometer consists of two vertical shield tubes containing a standard suspension of the acid haematin. A graduated tube with a glass rod/stirrer of same diameter is also provided which can fit in between vertical tubes. Colour of all the tubes is matched against a white background.

Hb pipette: It is a glass tube, having only one mark of 20cmm, and a rubber tube is fitted with it to suck the blood.



Procedure:

1. Clean the graduated tubes and Hb pipette well.
2. Take out 1ml N/10 HCl in graduated glass tube.
3. Prick the finger with a sterilized needle.
4. Suck the blood in pipette up to 20cmm mark. Wipe out blood adhered to the tip of pipette.
5. Transfer this blood into graduated tube containing N/10 HCl and rinse 2 to 3 times in the same tube.
6. Mix the solutions with glass stirrer and allow to stand for 2-3 minutes.
7. A brown colour of haematin is developed.
8. Dilute this brown colour with distilled water or N/10 HCl dropwise until the colour matches with that of standard tubes.
9. Note the amount of sample in agraduated tube as it is equal to the gm% Hb per 100 ml of blood.

Result: Blood sample contains…….Hb.

Precautions:

1. Clean the glass tubes and rod carefully before use.
2. Fill the micropipette up to 20 cmm mark avoiding air bubbles.
3. Match the colour of tubes carefully against a white background.

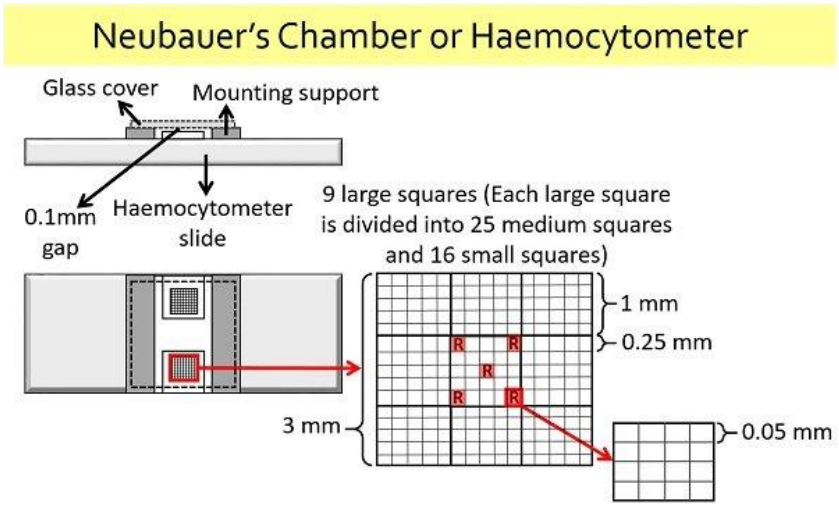
Ex. 9 Counting of different types of blood cells (RBCs and WBCs) using haemocytometer.

RBCs counting

Aim: To estimate the total number of RBCs in human blood.

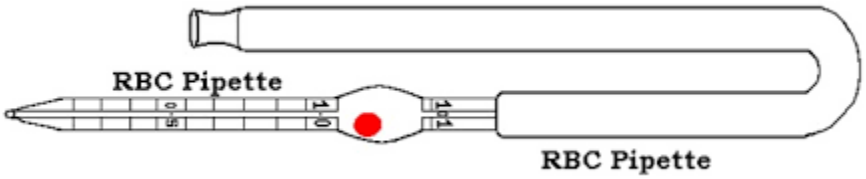
Requirements: Haemocytometer, RBC pipette, Hayem's solution, sterilized pricking needle, microscope, etc.

Haemocytometer: It consists of a special glass slide containing two counting chambers (Neubauer's haemocytometer). It is 3 inches long nd 1.5 inch wide.It has 4 parallel channels extending across the width of the slide, forming 5 plateforms. Central pateform consists of 2 counting chambers.
Each counting chamber is 9 sq.mm in size and is divided into 9 small squares, of 1sq.mm each. Central small square is again divided into 25 smaller squares , of 1/25 sq.mm each. Each smaller square is further divided into 16 smallest squares, of 1/25x16 sq.mm each. Thus there are total 400 smallest squares in central small square.



RBC pipette:

1. It consists of capillary tube, central bulb with red bead and 03 graduation marks (0.5 cmm, 1.0 cmm and 101 cmm).
2. For sucking the blood and diluting fluid, a rubber tube is fixed to the broad end.
3. Red bead inside the bulb is for mixing of blood with Hayem's solution.



Procedure: 1. Sterilize tip of ring finger of left hand with sprit.
2. Prick the finger with sterilized needle, so that blood flows freely. Do not squeeze the finger.
3. Then suck the blood in the clean and dry RBC pipette up to 0.5 cmm mark.
4. Wipe outthe blood adheres to the tip of pipette.
5. Now immediately suck in the Hayem's solution up to the 101 cmm mark of the RBC pipette. Hayem's solution prevents the haemolysis, rouleaxue formation and cogulation of blood.
6. Held the RBC pipette horizontly and rotate several times. Blood is mixed with Hayem's solution with the help of red bead.
7. Discard 1 to 2 drops of the sample.
8. Now quickly transfer the sample in the counting chambers under the coverslip.
9. When counting chambers are properly flooded, keep the slide for few minutes on a horizontal place, so tah RBCs are settled down the bottom of chambers.

10. Transfer the slide gently and place it under the microscope. Start the counting RBCs in counting chambers.

Counting of RBCs: Count the RBCs in 05 different smaller squares (1st, 5th. 13th, 21st and 25th). Avoid the counting of RBCs which are on the triple lines.

Calculation:

$$\text{No. of RBCs/cmm of blood} = \frac{\text{Total no. of RBCs counted x dilution (200) x Total no. of smallest squares (400)}}{\text{No. of smallest squares counted (80) x Height of blood film (0.1 mm)}}$$

Results: No. of RBCs /cmm of blood is…….

Precations: 1. Use clean and dry haemocytometer and pipette.

2. Use rectified sprit to sterilize needle and finger tips.

3. Dilution fluid should not exceed the 101 cmm mark.

4. Mix the Hayem's solution and blood properly to get uniformly distributed RBCs.

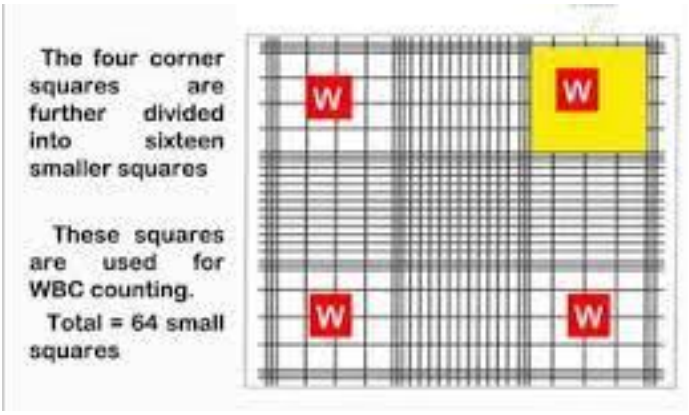
5. Do not overflow the counting chamber.

WBCs counting

Aim: To estimate the total number of WBCs (TLC) in human blood.

Requirements: Haemocytometer, WBC pipette, WBCs diluting fluids, sterilized pricking needle, microscope, etc.

Haemocytometer: Each counting chamber contains 09 small squares, of 1 sq.mm each. 04 small squares, one on each corner, are used to count the WBCs. Each small square is divided into 16 smallest squares.

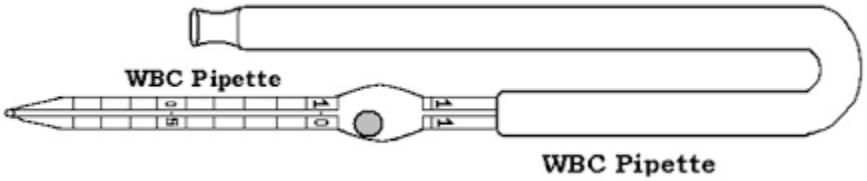


WBC pipette:

1. It consists of capillary tube, central bulb with white bead and 03 graduation marks (0.5 cmm, 1.0 cmm and 11 cmm).

2. For sucking the blood and diluting fluid, a rubber tube is fixed to the broad end.

3. White bead inside the bulb is for mixing of blood with diluting and staining fluid.



Procedure:

1. Sterilize tip of ring finger of left hand with sprit.
2. Prick the finger with sterilized needle, so that blood flows freely. Do not squeeze the finger.
3. Then suck the blood in the clean and dry WBC pipette up to 0.5 cmm mark.
4. Wipe out the blood adheres to the tip of pipette.
5. Now immediately suck in the diluting fluid up to the 11 cmm mark of the WBC pipette (dilution 20 times) and mix the blood with diluting fluid.
6. Discard 1 to 2 drops of the sample.
8. Now quickly transfer the sample in the counting chambers under the coverslip.
9. After settling the WBCs, start the counting.

Counting of WBCs: Count the WBCs in 04 corner small squares (1st,3rd. 7th and 9th).

$$\text{No. of WBCs/cmm of blood} = \frac{\text{Total no. of WBCs counted x dilution (20)}}{\text{No. of small squares counted x Height of blood film (0.1 mm)}}$$

Results: No. of WBCs /cmm of blood is…….

Precations: 1. Use clean and dry haemocytometer and pipette.
2. Use rectified sprit to sterilize needle and finger tips.
3. Dilution fluid should not exceed the 11 cmm mark.
4. Mix thediluting fluid and blood properly to get uniformly distributed WSBCs.
5. Do not overflow the counting chamber.

Ex. 10 Study of action of salivary amylase.

Object : To demonstrate the salivary amylase activity on starch

Principle: Saliva contains starch digesting enzyme Ptylin which digests the starch into maltose and glucose. Presence of starch and glucose is observed by iodine and Benedict's test respectively.

Requirements: Saliva, Starch solution (1 %), iodine solution, Benedict's reagent, test tubes, test tube holders, sprit lamp.

Procedure: Wash the mouth with sterilized water to avoid acidic contents present in the mouth. Collect the saliva in a test tube avoiding bubbles. Take three test tubes a and prepare the sample as follows :

-I Test tube: Take 0.5 ml of starch solution

-II Test tube: Take 0.5 ml of starch solution + 1.0 ml of saliva and keep for five minutes at room temperature

-III Test tube: Same as that of II test tube sample

-Perform the iodine test in I and II test tubes, Sample + Iodine solution---- Deep blue colour

-First test tube shows positive iodine test (Presence of starch)

-Second test tube gives negative iodine test- sample remains colourless, showing the absence of starch because Ptylin digested the starch.

-Perform Benedict's test in third test tube, showing positive result (Presence of glucose)

Sample + Benedict's reagent.....$\xrightarrow{\text{Boil}}$.....Brick red colour precipitate

Result: Presence of glucose shows that ptylin has digested the starch into glucose which gives the positive Benedict's test

Precautions:

1. Clean the test tubes properly

2. Prepare the reagents carefully

3. During boiling, keep the mouth of test tube away from body or towards the wall

Ex. 11 Rate of oxygen uptake in fish.

Aim: Estimation of rate of oxygen consumption in fish.
Principle: Fish are gill breathers. They consume dissolved oxygen present in the water. A fish is kept in air tight container for a definite time. The difference between initial DO contents in water and DO after a time interval is the amount of oxygen consumed by the fish per hour.
Requirements: Live fish, reagents, glassware and other accessories required for the estimation of DO, air tight container.
Method:
-Take an air tight container filled with well aerated water.
-Estimate the initial DO content in the water following modified Winkler's method.
-Now keep a live fish in the water and close the mouth air tight.
-After one or two hour of incubation of fish, again estimate the final DO contents in the water.
-Now calculate the difference in between initial and final DO contents in water.
Calculation:

Oxygen consumption rate by fish (mg/hour) = Initial DO – Final DO

Result: The oxygen consumed by the fish is ---------mg/hour.

Precautions:

1. Estimate the DO content in water accurately.
2. Handle the fish with utmost care to avoid injury.
3. Keep the mouth of container air tight.

4. Wash the glassware properly.

Ex. 12 Effect of temperature on opercular movement of fish.

Aim: To determine the effect of temperature on the ventilation rate of fish.

Materials required: Medium size fishes in small container, timer, thermometer, crushed ice, normal and hot water, etc.

Background: Counting of opercular movement is a way to calculate respiration rate in fishes. Fish breaths by taking in water through mouth and forcing it over the gills, when the mouth closes. This time oxygen-carbon dioxide exchange occurs between blood of gills and incoming water. Operculum opens to exhale the carbon dioxide rich water. By counting operculum movement we can get an idea of a fish response to an ecological change. Respiration rate will typically increase as dissolved oxygen concentration in water decreases.

Procedure:

Carefully a fish was taken out from the tank and placed it in the beaker filled with tap water at room temperature.

The temperature of water in beaker is recorded by thermometer. Fish was allowed to calm down for 5-10 minutes.

Counting of respiration was done by looking at the opening and closing of operculum or mouth for 1 minute. The counting was recorded two more times.

The same procedure was followed for cold and hot water.

Observation table:

Water temp. (^{o}C)	Opercula movement per minute			Mean value of opercular movement
27	Observation 1	Observation 2	Observation 3	
30				
40				

*Plot a graph by taking water temperature at x- axis and opercular movement at y-axis.

Inference: The opercular movement of fish is ……

Precautions:

1. Handle the fish carefully
2. Slowly add cold and hot water in the aquarium
3. Record the water temperature acurately
4. Count the opercular movement with utmost care.

Ex. 13 Group discussion or Seminar presentation on one or two related topics from the list.