ANIMAL DIVERSITY: CHORDATA PART-II
CODE: ZOL4B04T
[TAXONOMY, DIVERSITY, STRUCTURAL ANATOMY AND ADAPTATIONS OF CHORDATES – AVES AND MAMMALS]

Prepared By
Jamshiya Jaithun C
Assistant Professor
Department Of Zoology

CPA COLLEGE OF GLOBAL STUDIES , PUTHANATHANI

FOURTH SEMESTER B. SC. ZOOLOGY PROGRAMME

ZOOLOGY CORE COURSE-IV (THEORY)

ANIMAL DIVERSITY: CHORDATA PART-II

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[TAXONOMY, DIVERSITY, STRUCTURAL ANATOMY AND ADAPTATIONS OF CHORDATES – AVES AND MAMMALS]

[54 hours] [3 hours per week] [3 credits]

COURSE OUTCOMES [COs]

COs Course Outcome Statements

1. CO1 Describe the classification of class Aves down to orders, salient features of each order with suitable examples (11 hrs)
2. CO2 Describe the external characters and functional systems of *Columba livia* (14 hrs)
3. CO3 Enumerate the salient features and classification of class Mammalia down to orders with suitable examples (11 hrs)
4. CO4 Elucidate the external characters and functional systems of *Oryctolagus cuniculus*
5. (14 hrs)
6. CO5 Compare the circulatory, excretory and nervous systems of vertebrates (4 hrs)

Question paper pattern for external examination

[Module 1-2: Short answer 5x2=10 marks, Paragraph 3x5=15 marks, Essay 1x10= 10 marks
Module 3-4: Short answer 5x2=10 marks, Paragraph 3x5=15 marks, Essay 1x10=10 marks
Module 5: Short answer 2x2=4 marks, Paragraph 1x5=5 marks]

CLASS: AVES [25 hrs]

MODULE 1. Classification of Aves [11 hrs]

Classification of class Aves down to the orders specified; mention at least one example for each order.

Subclass **Archaeornithes [2 hrs]**

1. Order Archaeopterygiformes e.g. *Archaeopteryx lithographica* – a brief account on its discovery and evolutionary significance.

Subclass **Neornithes [2 hrs]**

Super order **Palaeognathae** [=Ratitae]

2. Order Casuariiformes e.g. *Casuarius* (Cassowary)
3. Order Dinornithiformes [=Apterygiformes] e.g. *Apteryx* (Kiwi)
4. Order Rheiformes e.g. *Rhea*
5. Order Struthioniformes e.g. *Struthio* (Ostrich)
6. Super order **Neognathae** [=Carinatae] **[7 hrs]**
7. Order Galliformes [pheasants, quail, turkeys, grouse] e.g. *Pavo cristatus*
8. Order Anseriformes [screamers, water fowls] e.g. *Anas poecilorhyncha*
9. Order Passeriformes [perching birds] e.g. *Passer domesticus*
10. Order Piciformes [woodpeckers, barbets, honeyguides] e.g. *Dinopium*
11. Order Coraciiformes [kingfishers & allies] e.g. *Alcedo atthis*
12. Order Apodiformes [swifts, humming birds] e.g. *Apus nipalensis*
13. Order Strigiformes [owls] e.g. *Bubo*
14. Order Cuculiformes [cuckoos, roadrunners, turacos] e.g. *Eudynamys*

15. Order Psittaciformes [parrots, lories, cockatoos] e.g. *Psittacula krameri*
16. Order Gruiformes [cranes, rails, coots, bustards] e.g. *Ardeotis nigriceps*
17. Order Charadriiformes [plovers, gulls, terns, auks, sand pipers] e.g. *Tringa*
18. Order Columbiformes [pigeons, doves, dodoes, sand grouse] e.g. *Columba*
19. Order Falconiformes [diurnal birds of prey – falcons, hawks] e.g. *Mylvus*
20. Order Ciconiiformes [herons, storks, ibis, spoon bills] e.g. *Ardeola grayii*
21. Order Pelecaniformes [pelicans, cormorants] e.g. *Pelecanus*
22. Order Sphenisciformes [Impennae] e.g. *Aptenodytes* (penguin)
23. Order Phoenicopteriformes [flamingos] e.g. *Phoenicopterus*

Recent Extinctions: Passenger Pigeon [*Ectopistes migratorius*), Dodo [*Raphus cucullatus*], Pink-headed Duck [*Rhodonessa caryophyllacea*], Elephant Bird [*Aepyornis*].
Rediscovery of Jerdon's Courser [*Cursorius bitorquatus*] & Forest Owlet [*Athene blewitti*].

MODULE 2. Type: ***Columba livia*** (Rock Pigeon) **[14 hrs]**
[External characters, integumentary system (structure of feather in detail – exclude development of feather), skeletal system (skull excluded), digestive system, respiratory system, circulatory system, excretory system, sense organs and reproductive system].

CLASS: MAMMALIA [25 hrs]

MODULE 3. **Classification of Mammalia [11 hrs]**
Classification of class Mammalia down to the orders cited with examples specified.
Subclass Prototheria [2 hr]
Infraclass **Ornithodelphia** [egg-laying mammals]

1. Order Monotremata e.g. *Ornithorhynchus* [Platypus], *Tachyglossus* [= *Echidna*]

Subclass Theria [2 hr]
Infraclass **Metatheria** [marsupials]
2. Order Marsupialia e.g. *Didelphis* [Opossum], *Macropus* [Kangaroo]
Infraclass **Eutheria** [true placental mammals] **[7 hrs]**
3. Order Edentata e.g. *Bradypus* (Sloth), *Dasypus* (Armadillo) *Myrmecophaga* (Spiny ant-eater)
4. Order Pholidota e.g. *Manis* (Pangolin/ Scaly ant-eater)
5. Order Lagomorpha [rabbits and hares] e.g. *Lepus nigricollis*(Indian Hare)
6. Order Rodentia e.g. *Funambulus, Ratufa*(Giant squirrel)
7. Order Soricimorpha [shrews, moles] e.g. *Suncusmurinus, Crocidura*
8. Order Erinaceomorpha e.g. *Paraechinus micropus* (Indian Hedgehog)
9. Order Chrysochloridea e.g. Golden mole of South Africa
10. Order Dermoptera [colugos] e.g.*Cynocephalusvolans* (flying lemur)
11. Order Chiroptera e.g. *Pteropus, Pipistrellus, Kerivoula picta (Painted bat)*
12. Order Primates e.g. *Loris, Macaca, Gorilla, Pongo*, *Hylobates, Homo*
13. Order Carnivora e.g. *Phoca* (Seal), *Odobenus* (Walrus), *Panthera sp.*, *Viverriculaindica* (Civet), *Lutrogale* (Otter),*Cuon alpinus* (Wild dog).

14. Order Cetacea e.g. *Physeter* (Sperm whale), *Delphinus* (Dolphins), *Phocaena* (Porpoise), *Balaenoptera* (Baleen whale]
15. Order Artiodactyla e.g. *Sus scrofa cristatus* (Wild Boar), *Bos gaurus* (Gaur), *Giraffa* (Giraffe), *Hemitragus* [Tahr], *Rusa*
(=*Cervus) unicolor* (Sambar deer), *Axis axis* (Spotted
deer), *Moschiola* (Mouse deer), *Antilope cervicapra*
(Blackbuck).
16. Order Perissodactyla e.g. *Equus caballus* (Horse), *Rhinoceros*
17. Order Sirenia e.g. *Trichechus* (Manatee), *Dugong*
18. Order Proboscidea e.g. *Elephas maximus indicus* [Indian elephant], *Elephas maximus borneensis* [Borneo pigmy elephant], *Loxodonta africana* [African savanna elephant] and *Loxodonta cyclotis* [African forest elephant].
19. Order Hyracoidea e.g. Hyrax (Coney)
20. Order Tubulidentata e.g. *Aardvark*

MODULE 4. Type*:* ***Oryctolagus cuniculus*** (European Rabbit) **[14 hrs]**
[External features, integumentary system, skeletal system (dentition in detail –skull excluded), digestive system, respiratory system, circulatory system (exclude arterial and venous systems), excretory system, sense organs and reproductive system].

MODULE 5. Comparative Anatomy [4 hrs]
Compare the circulatory, excretory and nervous systems of vertebrates.

CLASS AVES

Salient features :

Warm-blooded , ovi-parous , bipedal , feathered , winged and toothless vertebrates , tetralocular heart , elaborate respiratory mechanism , high body temperature , and great powers for flight .

- Epidermal feathers and scales (only on shank and foot)
- Jaws : toothless beak or bill , covered by *rhamphotheca*
- Forelimbs modified as wings
- 3 digits in fore-limbs and never more than 4 in hind limb
- Oil gland (preen gland)
- Pneumatic bones
- Monocondylian skull and diapsid skull
- Heterocoelous vertebrae
- Karge and keeled sternum
- Double headed ribs
- Carpo-metacarpus and tarso-metatarsus
- Pectoral girdle : wish bone / furcula _ V shaped
- 4 chambered heart
- Right aortic arch present . left is absent in adult
- Sound producing organ : syrinx
- Metanephric kidney and uricotelic
- Right ovary and right oviduct absent in the adult
- Poorly developed olfactory organs
- Eyes : pecten and sclerotic plates
- Eggs : cleidoc , amniote and macrolecithal

TYPE STUDY : *COLUMBA LIVIA* : BLUE ROCK PIGEON

EXTERNAL FEATURES

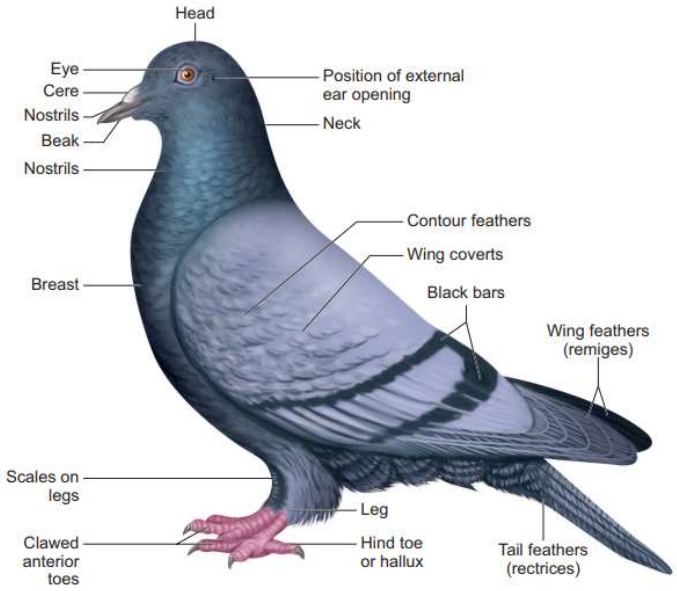


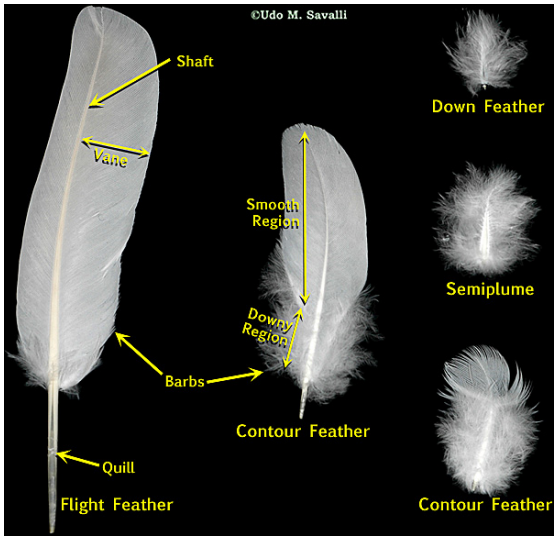
Figure 4.26 Columba livia – Common Rock Pigeon-External Features

- 4 divisions : head , neck , trunk and tail
- Head
  - Toothless jaws
  - Cere : patch of naked , swollen and sensitive skin at the base of upper beak
  - External nostrils
  - Eyes guarded by eye-lids (3)
  - Auditory apertures : covered by auricular feathers
- Trunk
  - Paired forelimbs :3 divisions : brachium , ante-brachium and manus , pentadactyl , modified as wings, feathers on wings : remiges , 3 digits
  - Hind-limb : 3 divisions : femur , crus and pes ;4 toes ; pes is adapted for walking and perching ; clawed
- Tail
  - Uropygium
  - feathers ; rectrices
  - Contains oil gland
  - Cloacal aperture : between trunk and tail
  - Rudder in flight and balancing while walking and perching

EXOSKELETON

- Epidermal derivative
- Includes : Feathers , scales on feet and toes , claws at the tips of toes and rhamphotheca

Feathers



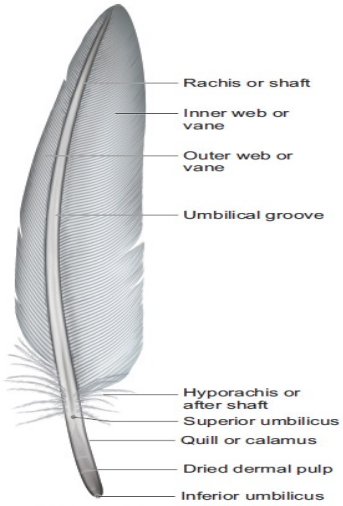
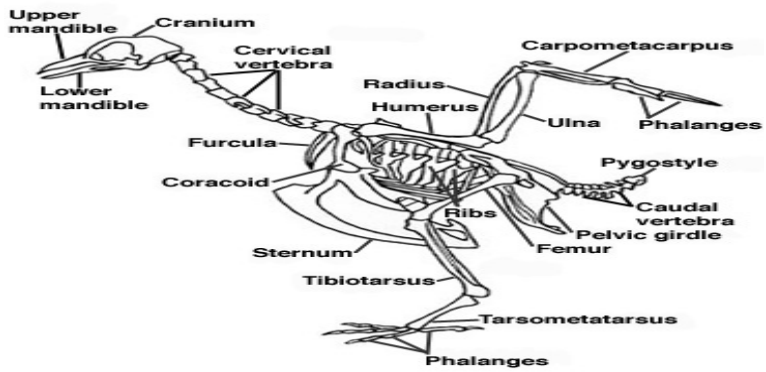


Figure 4.28 Quill Feather

- Plumage : complete feathery covering of the whole body of a bird
- Modified reptilian scales
- **Structure of a typical feather :**
  - Quill feather or penna : feather with well developed central axis and expanded blade
  - Central axis : shaft
  - Flat blade ; vane or vexillum
  - Shaft has 2 regions : quill and rachis
  - Quill : hollow , swollen basal part ; partially buried in the feather follicle
  - Rachis : narrow , solid and cylindrical terminal part that supports vane
  - Basal tip of quill has opening : inferior umbilicus : for nourishment
  - Umbilical groove : rachis forms the longitudinal axis of the vane
  - Barbs: numerous thin plate like and bilaterally arranged tranverse branches arising from rachis
  - Barbs bear barbules
  - Proximal barbules : have curved ridges called flanges
  - Distal barbules bear minute hooklets : barbicels
  - Exhibit inter locking mechanism
  - 2 types of vanes ; plumaceous (loose) and pennaceous (well-knit)
- Kinds of feathers:
  1. flight feathers : rectrices and remiges
  2. covering feathers : contour , coverts , down feather , filoplumes and semiplumes

ENDOSKELETON



Prepared By : Jamshiya Jaithun C
CPA College Of Global Studies ,Puthanathani

1. Axial skeleton : skull , vertebral column , hyoid apparatus , ribs and sternum
2. Appendicular skeleton : limbs and girdles

HYOID APPARATUS

- Arrow shaped , with body and anterior cornua and long posterior cornua
- Body is composed of 3 pieces : entoglassal , basihyal and urohyal

VERTEBRAL COLUMN

- Neck region : free and mobile
- Trunk : rigid and compact
- Tail : fused and free vertebrae
- Heterocoelous centrum
- Epiphyses absent
- 42 vertebrae :
  - Cervical ; 14
  - Thoracic : 5
  - Lumbar : 6
  - Sacral : 2
  - Caudal : 15
- Structure : typical
- Cervical vertebrae other than 1 and 2 is a typical one
- Heterocoelous centrum : flexible and mobile ; allows 180^{0}
- centrum encloses neural canal
- neural arch , neural spine and transverse processes are highly reduced
- transverse foramen : opening at base of transverse processes
- pre-and post-zygapophyses

FORE-LIMB AND PECTORAL GIRDLES

- Humerus : strong and stout shaft and basal head and distal condyles
- Radius : short , slender and straight
- Ulna : long , stout and curved ; bears olecranon process
- 5 carpals
- 3 metacarpals
- Carpo-metacarpal joint : wrist joint
- Phalangal formula : 1,2,1,0,0
- Modification : reduced flexibility ; radius and ulna do not move upon each other ; 3 fingers ; carpo-metacarpus
- **Pectoral girdle** : firmly connected to sternum
  - 3 bones : coracoids , scapula and clavicle
  - Glenoid cavity : shoulder joint
  - Ventrally , clavicle meet and fuse to form V shaped furcula : inter clavicle
  - Sternum : breast bone : specialised for attachment of flight muscles ; broad , flat and boat shaped ; body is called metasternum and bears thin and sharp ridge : keel

HIND-LIMB AND PELVIC GIRDLE

- Thigh : femur ; bears head and trochanter and condyles
- Shank : tibio-tarsus and slender fibuls
- Knee cap ; patella
- Separate tarsals are absent in adultsankle joint : intertarsal joint
- 4 metatarsals
- Phalangal formula : 2 , 3, 4, 5, 0
- Bears claws
- **Pelvic girdle**
  - Composite bone : *os innominatum*
  - Innominatum is formed by fusion of 3 bones ; ilium , ischium and pubis
  - Acetabulum and head of femur articulates to form hip joint
  - Ischia and pubis does not forms symphyses

Flight muscles

1. Pectoral muscles , 2 types ,

a) pectoralis major : largest ; powerful and depressor muscle and brings down –stroke of the wing

b) Pectoralis minor : elevator muscle and brings upstroke of the wing

2. Accessory muscles : bring rotator movements
3. Tensor muscles : outstretching of the wings and folding of wings

DIGESTIVE SYSTEM

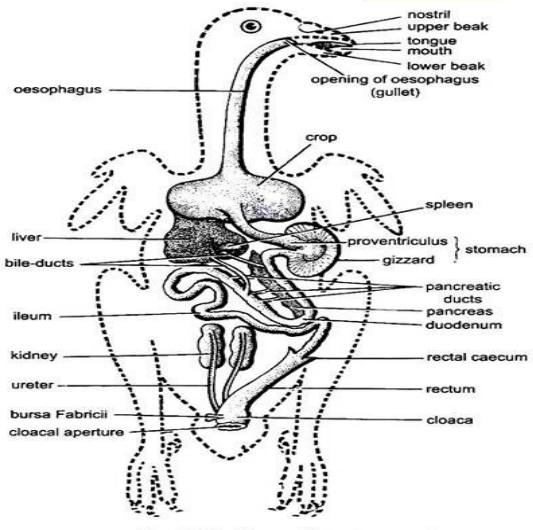


Fig. 26.28. Pigeon. Alimentary canal.

- Consists of alimentary canal and glands
- Toothless horny beak
- Buccal cavity : mucous glands and scanty taste buds
- Buccal glands are mucous secreting .
- No salivary glands
- Oesophagus enlarges to elastic sac : crop

- Crop : function : temporary storage of food , softening and moistening of food
- Pigeon's milk : crop glands become active under prolactin and secretes fluid called crop milk
- Stomach has 2 divisions : proventriculus (secretory) and gizzard (gastric mill)
- Small intestine : duodenum and ileum
- Rectum represents large intestine
- Rectal caeca acts as centres for water absortion
- Cloaca : 3 divisions : coprodeum , urodeum and proctodeum
- **Glands**
  - Buccal glands : enzyme free mucus
  - Gastric glands :HCl and pepsin
  - Tubular glands
  - Intestinal glands
  - Liver : bile
  - Pancreas : heterocrine
  - Caecal glands

RESPIRATORY SYSTEM

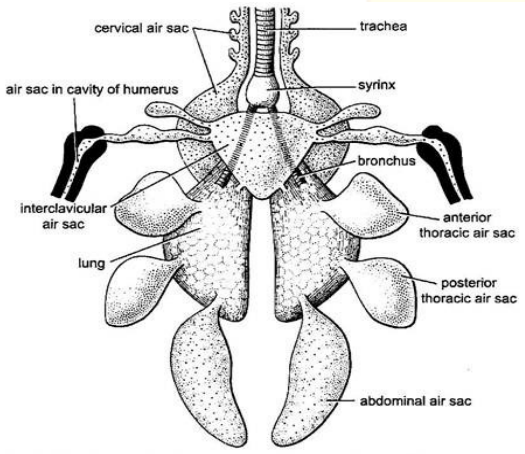


Fig. 26.33. Pigeon. Respiratory system (lungs and air sacs) in ventral view.

- Complex
- 2 unique features
  - Small , compact , non-elastic and non-distensible lungs
  - Air sacs
- Air passage
- External nostrils → nasal canal → internal nostril (1) → pharynx → larynx → trachea → syrinx → 2 bronchi → lungs

- **Lungs :**
  - Small , non-elastic ; without alveoli
  - Covered within pleura
  - *Bronchial intercom*

- Bronchus : divides and further divides into many branches like primary , vestibule , mesobronchus , secondary , endobronchi , ectobronchi , tertiary bronchi and finally into bronchioles

- **Air sacs** :
  - thin-walled , non-muscular , non-vascular , non-elastic sac which opens by ostia
  - 9 types : 4 inspiratory air sacs and 5 expiratory air sacs
  - **Double respiration** : within lungs , renewal of air and exchange of gases takes 0place twice during every respiratory cycle

CIRCULATORY SYSTEM

- Enclosed in pericardium ; with pericardial fluid
- Tetralocular
- Sinus venosus , conus arteriosus and ventral aorta absent
- Atrium separated by interauricular septum atrium and ventricle separated by auriculo - ventricular septum ; and ventricle by interventricular septum
- Right half : deoxygenated blood ; left half : oxygenated blood
- R auricle receives : 3 large veins : R and L pre-caval veins and single post-caval vein
- L auriculo-ventricular valve : bicuspid and R monocuspid valve
- Ventricles : thick walled with trabeculae and chordae tendinae
- From R V : pulmonary trunk ; from L V : R systemic trunk with 3 semi lunar valves
- Left systemic trunk absent
- Arterial system : pulmonary arch and carotico-systemic arch
- Venous system : pulmonary , venous system , and hepatic portal system
- Renal portal system absent
- Venous system is peculiar in :
  - each lung is drained by 2 pulmonary veins
  - Caval veins open directly to L A
  - Sinus venosus absent
  - Renal portal system not well developed

SENSE ORGANS

Tactile : Beak : rhamphotheca

Herbst's corpuscles in the dermis of skin

Gustatory organs : few taste buds on dorsal tongue

Olfactory : nasal chambers at the base of beak: anterior part of chamber lined by schneiderian membrane innervated by olfactoreceptor cells

Visual organs (eyes)

- Eyeballs are large and biconvex ; guarded by upper and lower and nictitating membrane
- Eye glands : harderian and lacrimal glands
- 8 sets of extrinsic eye muscles

- Eyeball is hollow and fluid filled
- Wall is formed of : sclerotic , choroid and retinal layers
- **Sclerotic** : horny and non-vascular
- Cornea : exposed outer part
- Cornea is covered by transparent conjunctiva
- Sclerotic plates
- **Choroid** : vascular and pigmented layer : consisting iris and pupil
- **retina**: transparent and non-vascular : with rods and cones
- Have lateral and monocular vision : area centralis
- Also have Forward and binocular vision : area centralis
- Blind spot
- Yellow spot
- Biconvex crystalline lens within capsule
- Lens : 2 chambers : aqueous chamber and vitreous chamber
- Pecten : strongly pigmented , highly vascular fan like structure projecting into vitreous chamber

Stato-acoustic organ

- Hearing and balancing organ
- 2 portions : middle and inner ear ; external lobe is absent

External ear opening ⟶ auditory meatus ⟶ tympanic membrane ⟶ tympanic cavity

(middle ear) ⟶ plectrum ⟶ fenestra ovalis /fenestra rotunda ⟶ membranous labyrinth (inner ear)

- Cochlea : hearing in function ; have 3 chambers ;
  i. Scala vestibuli : perilymph : fenestra ovalis
  ii. Scala media : endolymph
  iii. Scala tympani : perilymph : fenestra rotunda
- Scala vestibuli separated from scala media by reissner's membrane
- Scala tympani separated from scala Media by basilar membrane (comprises organ of corti ; sensory in action with hair cells)

EXCRETORY SYSTEM

- Metanephric kidney
- Kidney : flat and trilobed ,tubular gland with numerous nephrons
- Nephrons join and form urinary duct
- Duct opens to urodaeum
- Urinary bladder is absent
- Uricotelic
- Excretory waste : guano
- Wolffian duct : vas deferens

- Mullerian duct : oviduct

MALE GENITAL ORGANS

- Pair of testes attached to kidney by mesorchium
- Testis is a tubular gland formed of numerous seminiferous tubules
- From testis , leads off a number of vasa efferentia
- Vasa effrentia joins vas deferens
- Epididymis ; initial coiled part of vas deferens
- Vas deferens opens to urodaeum
- Copulatory organ is absent

FEMALE GENITAL ORGANS

- Right ovary and oviduct absent
- Only left ovary and oviduct is present
- Left ovary suspended by mesovarium
- Ovary has numerous ovarian follicles
- Functional oviduct : long , broad and convoluted muscular tube ; suspended b y mesotubularium
- Oviduct opens to body cavity by oviduccal funnel having a wide opening : ostium tubae
- Glandular part of oviduccal funnel : magnum : secretes albumen
- Tubular portion : isthmus : secretes shell membranes
- Isthmus expands to a wide uterus
- Uterus opens to vagina which opens to urodaeum

CLASSIFICATION OF CLASS AVES

SUBCLASS I. ARCHAEORNITHES

(Gr., archios = ancient + Ornithos = bird)

- Extinct Jurassic birds of Mesozoic age, about 155 million years ago.
- Wings with little power of flight.
- Teeth embedded in sockets were present in both jaws.
- Tail long with more than 13 (18-20) caudalvertebrae bearing rectrices arranged in two lateral rows.
- Pygostyle was absent.
- Vertebrae were amphicoelous.
- Thoracic ribs without uncinate process.
- Abdominal ribs present.
- Sternum without keel.
- Three carpals and metacarpals were free,and three clawed digits.

1. ORDER ARCHAEOPTERYGIFORMES

- Examples: *Archaeopteryx lithographica and Archaeornis siemensi* found in the Upper Jurassic limestone of Solenhofen in Bavaria.
- Each was about the size of a crow.

ARCHAEOPTERYX

Kingdom : Animalia

Phylum : Chordata

Class :Aves

Order : Archaeopterygiformes

- Archaeopteryx is a primitive fossil bird, which lived in the last Jurassic, some 140-150 million years ago.

Discovery

- It's fossils were first discovered by Andreas Wagner in 1861 from the upper Jurassic lithographic lime stone of beds of Bavaria in Germany. Wagner named it Gryphosaurus.
- A second and a more complete fossil specimen was obtained in 1877 from near around the same locality. It was namedArchaeornis seimensi.
- In 1956, a third fossil specimen was also discovered.
- On a detailed study all the three fossil specimens were found to belong to the same species, and the name Archaeopteryx lithographica was accepted on the basis of the law of priority.

Evolutionary significance

- Archaeopteryx is an interesting combination of reptilian and avian features.
- It is neither a true reptile nor a true bird, but is intermediate between reptiles and birds.

Reptilian Features

- Toothed jaws, with peg-like, homodont and thecodont teeth.
- Non-pneumatic (solid) bones.
- Long, terminally tapering tail, supported by free posteriorly tapering caudal vertebrae, as in Lizards.
- Amphicoelous vertebral centra, as in Sphenodon.
- Free or unfused trunk, sacral and caudal vertebrae.
- Absence of pygostyle.
- Presence of free cervical and abdominal ribs, as in Sphenodon and crocodilians.
- Single-headed ribs, without uncinate processes.
- Presence of mandibular foramen, as in crocodiles.
- Clawed digits and free carpals and metacarpals, without carpometacarpus.
- Reptilian number of phalanges in the fore-limb.
- Small, poorly developed and keelless sternum.
- Elongated and backwardly directed pubis.
- Small cerebellum.

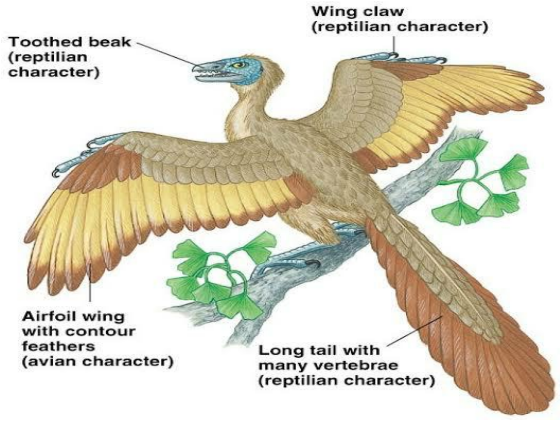
Avian Features

- Presence of contour feathers over the body, remiges on fore-limb and rectrices on tail.
- Fore-limb is modified as a wing with three fingers.
- Elongated hind-limb, with four clawed digits.
- Backwardly directed hallux.
- Avian number of phalanges in the hind-limb.
- Presence of tarsometatarsus in the foot.
- V-shaped furcula in the pectoral girdle.
- Large skull, with rounded cranium, large orbits and fusion of skull bones.
- Elongated jaws, forming beak.
- Sclerotic plates and pecten in eyes.
- Warm-bloodedness.

Archaeopteryx is a connecting link that bridges the evolutionary gap between reptiles and birds.

It's reptilian features reveal that birds evolved from arboreal bipedal reptiles.

Archaeopteryx is an unfinished bird and not the direct or immediate ancestor of true modern birds.



SUB-CLASS II. NEORNITHES

(Gr., neos = modern + ornithos = birds)

- Living as well as extinct birds.
- Wings usually well developed used for flight with a few exceptions.
- Tail is short, ends in a pygostyle.
- rectrices are arranged in a semicircle around the Pygostyle.
- Teeth are absent except in few fossil oirds.
- Vertebrae are heterocoelous in living forms
- Caudal vertebrae are 13 0r less.
- Few caudal vertebrae free and rest fused into a pygostyle.
- The sternum is well developed and usually provided with a keel or carina.
- The metacarpals are fused with the distal carpals to form a carpo-metacarpus.
- Except in one case, not more than two digits of the hand bear claws.
- In nearly all cases claws are absent in the hand.
- Thoracic ribs with uncinate processed
- Abdominal ribs are absent.
- subclass is divisible into four superorders

SUPER-ORDER I. ODONTOGNATHA (toothed jaws)

(Gr., odontos = teeth)

- Extinct upper Cretaceous birds.
- Teeth present on jaws, advantageous for catching fish.
- Brain is of avian type rather reptilian

SUPER-ORDER I. PALAEOGNATHAE / RATITAE

(Gr., palaios = old + gnathos = jaw; L., ratis = raft)

- Large sized, fiightless, walking or running birds.
- Wings are reduced or absent.
- Feathers without interlocking mechanism.
- Tail feathers irregularly arranged,or absent.

- Teeth are absent.
- Except Tinamus and Kiwi, oil gland is Lacking.
- Skull is palaeognathous
- Syrinx absent
- Quadrate is single headed.
- Sternum devoid of keel
- Uncinate processes in ribs are absent or vestigial.
- Tail vertebrae are free.
- Pygostyle small or absent
- Coracoid and seapula are small and fused at an obtuse angle.
- Clavicles are small or absent.
- Except Rhea and Emu, ilium and ischium are not united posteriorly.
- Pectoral muscles not well developed
- Penis in male is large and erectile and female possesses a clitoris.
- Youngs are precocious.
- Ratites are not found in India.

2. ORDER STRUTHIONIFORMES

(Gr., struthio = ostrich + form)

- Large flightless terrestrial birds.
- Feathers without aftershaft.
- Head, neck and legs sparsely feathered.
- Head is comparatively small and the neck is very long and flexible.
- The beak is short and broad.
- Only two toes (3rd and 4th) on each foot.
- Pubic symphysis present.
- Examples: *Struthio camelus* (True ostriches of Africa and Western Asia).

Example : *Struthio* (Ostrich)

- Camel bird
- Inhabitant of arid and semi arid zones of African , Arabian and Syrian deserts
- Largest animal & egg is the largest animal egg
- Flightless , but can run fast

- Body : large and massive ; with a featherless head ,short and flat beak
- Long and naked neck
- Rudiment wings
- Long and strong legs
- Wings are used as balancers while running
- Broad foot , heavily padded
- Head , neck and foot are featherless
- Feathers : plume-like without aftershaft
- Male has retractile penis ,; female has clitoris
- Habitually swallow grit and gravel
- Omnivore
- *Gregarious* and *polygamous*
- Desert adaptations:
    1. Long and strong legs for taking fast strides on sand
    2. 2 toes : easy running
    3. Broad and heavily padded and hoof like foot: easy walking and running on sand
    4. Ability to stretch out wings : balancing
    5. Ability for flapping wings: increase speed
    6. High water tolerance
    7. Cryptic coloration : to escape
    8. Habit of crouching low on sand : defence
    9. Thick and very hard egg

3. ORDER CASUARIIFORMES

(NL. *casuarius* = genus of cassowary + form)

- Large flightless terrestrial birds.
- Head is sparsely feathered, while neck and body densely feathered. Head bears a comb-like structure.
- Feathers with aftershaft nearly equal to shaft.
- Wings small or rudimentary.
- Three toes with typical claws on each foot.
- Examples: *Dromaeus* (Emus of New Zealand), *Casuarius* (Cassowaries of Australia and New Guinea)

Example : Cassowary (*Casuarius)*

- Third largest; similar to Emus

- Inhabit dense rain-forests
- Body : more than 2 m tall
- Neck :long
- Rudiment wings
- Long and stout legs ; three-toed foot
- Tail feathers are absent
- Body is covered by glossy black and hairy feathers
- Neck is bare, and brilliantly colored with scarlet , yellow and blue
- Head : blue colored
- Head bears black shield with green sides on the top
- Habitually swallow grit and gravel
- Fast runners ; swimmers
- Inner toe is armed with a long , spike like claw : offensive weapon
- Monogamous
- Male : incubates egg and take care of brood

ORDER DINORNITHIFORMES (extinct)

- giant flightless, terrestrial, extinct bird (extinct about 700 years ago)
- Feathers with large aftershaft
- Wings almost absent.
- The beaks were short.
- Legs massive bearing 4 toes.
- Examples: *Dinornis maximus* (Moas of New Zealand).

4. ORDER APTERYGIFORMES

(Gr., a = not + pteryx = Wing + form

- Flightless terrestrial birds.
- Feathers fluppy hair-like without aftershafts.
- Wings are rudimentary or degenerate.
- The beak is long and slender with nostrils at the tip of the maxilla.
- The eyes are small
- The neck and legs are comparatively short.
- Eggs are relatively largest of all the living birds.
- Nocturnal, feeding on worms and insects.
- Examples:*Apteryx* (Kiwis of New Zealand)

Example : *Apteryx* (kiwi)

- Smallest living flightless bird
- Native of New Zealand
- Body is covered by long , hair-like drooping feathers
- Short neck and wings and tail are rudimentary
- Short and stout legs
- Foot ends in 3 long strong and clawed toes
- Claws are sharp : defence
- Long and slender beak ; downwardly curved with nostrils at its upper lip
- Nocturnal carnivores
- Poor vision but keen sense of smell
- Monogamous
- Male incubate egg

5. ORDER RHEIFORMES

(Gr., Rhea = mother of Zeus+form)

- Flightless terrestrial and swift-running birds.
- Head, neck and thighs are feathered.
- Wings are better developed.
- Legs bear 3 toes with heavy and typical claws.
- Ischia form a ventral symphysis.
- Examples: *Rhea americana* (American ostrich found in South America).

Example : Rhea

- American ostrich
- Fast running flightless bird
- Similar to ostriches
- Body is brownish yellow above and white below
- Head and neck are feathered and not naked
- Well developed tail feathers are absent
- Rudiment wings: used as saila to assist twisting and turning body while running
- Wing's vigorous flapping : increases speed
- Hindlimbs : powerful , 3 toed , clawed
- Clavicle absent
- Pubic symphysis and syrinx present

- High power of vision
- Omnivores
- Male incubates egg and take care of broods

SUPER-ORDER NEOGNATHA

(Carina = A keel)

- Modern, Usually small, flying birds
- Wings well developed.
- Feathers having interlocking
- Rectrices are present and regularly arranged
- Pterylae are regular, while irregular in ratites
- Oil gland is present
- Skull is neognathus
- Quadrate is double-headed.
- Sternum with a well developed keel
- Ribs with uncinate processes.
- Pygostyle present.
- Scapula and coracoid unite at a right angle
- Ilium and ischium are posteriorly
- Pectoral muscles well developed

6. ORDER PELECANIIFORMES

(, pelicanus = pelican + form)

- Aquatic fish-eating and colonial nesters.
- Nostrils are vestigial or absent.
- Presence of a pouch on the throat.
- Four toed webbed feet.
- Beaks are long with wide gapes for catching and swallowing the struggling prey.
- Examples: It includes pelicans, darters, gannets, and cormorants

Example : Pelican (*Pelicanus): Neerpakshi*

- Large , web-footed , gregarious birds
- Large wing spreads

- Long bill
- Pouch in upper throat where they store fishes
- Huge body , well developed beak and short legs
- Fully webbed feet
- great powers of flight
- Upper part of bill : long , flat and boat shaped , terminating in a hook
- Large and broad wings
- Short , square and soft tail
- Oil obtained from it's fat : treat *rheumatism*

7. ORDER CICONIIFORMES

(L, ciconia = a stork + form)

- Long snake-like neck and long-legged birds.
- Feathers are decorative.
- Beaks abruptly decurved at middle in flamingos.
- Toes are without web.
- Young born naked.
- Food comprises fish and other aquatic animals
- Examples: It includes marshy wading Birds Ardea

Example : *Ardeola grayii*

- Indian pond heron
- Small heron
- Appear stocky with a short neck , short thick bill and buff-brown back
- In summer , adults have long neck feathers ; have a dark reddish brown back which contrsst yellowish head , neck and breast
- Transformed in flight , looking very white due to brilliant white wings
- Breeding habitat : marshy wetlands
- Usually , solitary foragers

8. ORDER ANSERIFORMES

(L,anser = goose + form)

- Beak or bill, is broad, covered with soft cornified epidermis.
- Margins of the beak containing many transverse horny ridges (lamellae).

- Tongue is fleshy.
- Legs are short and feet are webbed.
- Tail is usually short, consisting of many feathers.
- Examples: Aquatic birds such as *Anas* (Wild duck)

Example *: Anas poecilorhyncha* (spot –billed duck)

- Large dabbling duck
- Non-migratory breeding duck
- Name is derived from red spot at the base of bill
- When in water : recognized by white tertials that form a stripe on the side ; and in flight : by green speculum with a broad white band at the base
- Grey ducks with paler head and neck and black bill tipped bright yellow
- Wings are whitish with black flight feathers below and from above a white-bordered green
- Male does not have a eclipse plumage
- Legs and feet are bright orange to coral red

9. ORDER FALCONIFORMES

(L, falco = falcon+ form)

- Beak is short and curved at the tip.
- Mandibles are sharp edged.
- Feet usually with sharp curved claws adapted for grasping and holding the prey.
- Diurnal and strong fliers.
- Examples: Diurnal birds of prey – falcons, Vultures, Kites, and hawks

Example : *Milvus (* pariah kite) chakkiparunthu

- Medium sized bird of prey
- Smaller size , less forked tail
- Dark plumage without any rufous
- Upper plumage is brown but the head and neck tend to be paler
- Patch behind eye appears darker
- Outer flight feathers black and feathers have dark cross bars and are mottled at the base
- Beak is sharply pointed and hooked
- Lower parts of body : pale brown , lighter towards chin
- Gregarious
- Cere and gape are yellow
- Bill is black
- Legs are yellow and claws are black
- Shrill whistle followed by a rapid whinnying call
- Attracted to smoke and fires

10. ORDER GALLIFORMES

(L, gallus = a cock + form)

- Terrestrial game birds with short and powerful flight.
- Beak is short.
- Feathers with aftershaft.
- Feet usually massive adapted for scratching and running.
- Graminivorous.
- Examples: Game bird like *Pavo cristatus* (Peacock)

Example : *Pavo cristatus* (Peacock)

- Indian peafowl
- Sexual dimorphism : exquisite train and plumage
- Male :Brightly coloured , with predominantly blue fan-like crest of spatula-tipped wire-like feathers and is best known for the long train made up of elongated upper tail covert feathers ; bear colourful eyespots
- During courtship , stiff feathers are raised into a fan
- Capable of flight
- Long , strong , greyish brown legs : running
- Females are brown , grey and cream colored ; but are also crested;lacks elongated feathers
- Loud calls make them easy to detect

- Diurnal
- Cock is polygamous
- Male performs attractive nuptial dance

11. ORDER GRUIFORMES

(L., grus = crane+ form)

- Small, medium and large-sized birds.
- Flightless or weak fliers or strong fliers
- Feathers with aftershaft.
- Legs long and beaks heavy
- Examples: Crane-like wading birds, *Choriotis (*bustard)

Example : *Ardeotis Nigriceps* (Indian Bustard)

- Found on Indian Sub continent
- Large bird with horizontal body and long bare legs
- Heaviest of flying bird
- Looks like ostrich
- Head bears a black cap contrasting with pale head and neck
- Body is brownish with a black patch spotted in white
- Male is deep sandy colored ; and during breeding season has a black breast band
- Crown of head : black
- Female : smaller , head and neck are not pure white , poorly developed breast band
- Males have a well developed gular pouch inflated during display
- Omnivorous
- Protected under Wildlife Protection Act 1972

12. ORDER CHARADRIIFORMES

(NL., *charadrius* = genus of plovers + form)

- Shore dwelling aquatic birds
- Fore- and hind-limbs are slender and enormously elongated.
- Toes usually webbed.
- Beaks mud probing.
- Feathers are dense and firm.
- Examples : plovers , gulls terns ,*Tringa glariola*

EXAMPLE :*Tringa*

•

13. ORDER COLUMBIFORMES

(L., *columba* = dove + form)

- Skin thick and soft.
- Beak usually short and slender
- Tarsus usually shorter than toes
- Crop large producing "pigeon milk to feed young ones.
- Graminivorous and frugivorous.

Example: *Columba livia* (Blue rock pigeon)

- Jungle pigeon/blue-rock pigeon
- Gregarious and granivorous
- Monogamous
- 4 divisions : head , neck , trunk and tail
- Head
  - Tootless jaws
  - Cere : patch of naked , swollen and sensitive skin at the base of upper beak
  - External nostrils
  - Eyes guarded by eye-lids (3)
  - Auditory apertures : covered by auricular feathers
- Trunk
  - Paired forelimbs :3 divisions : modified as wings, feathers on wings : remiges , 3 digits
  - Hind-limb : 3 divisions : 4 toes ; adapted for walking and perching ; clawed
- Tail
  - Uropygium
  - feathers ; rectrices
  - Contains oil gland
- Flight adaptations
  - Streamlined and smooth surfaced body: minimise resistance
  - Airy feathers : reduce weight
  - Pneumatic bones : reduce weight
  - Internal air sacs : weight reduction
  - Fusion and reduction of bones :makes strong to resist air current

- Wings ,powerful breast muscles
- Keeled sternum: muscle attachment
- Large tail feathers: steering
- High metabolisms : max. Energy

14. ORDER CUCULIFORMES

(L, *cuculus* = cuckoo+ form)

- Toes 2 in front and 2 behind, out hind toe reversible.
- Feet not adapted for grasping
- Tail long and beak moderate.
- Many cuckoos are parasitic, the female laying eggs in nest of other birds :*brood parasitism*

Example : *Eudynamis scolopaceous* (Koel) : kakkakuyil


- Nomadic local migrant
- Male is glistening metallic black with yellowish green bill and crimson eyes
- Female : dark brown above , with white spots and bands on tails and wings
- Flight : quick and swift , with rapid wing-beats
- Food : berries , fruits , rarely insects , snails
- Become noisy during breeding season
- *Brood parasites*

15. ORDER PSITTACIFORMES

(L.psitacus = parrot + form)

- Feathers are green, blue, yellow or red
- Beak stout, narrow, sharp-edged and hooked at the tip.
- Upper jaw is movably articulated with the skull.
- Feet zygodactylus, i.e, two toes in front and two toes behind.
- Outer toe is not reversible.

Example : *Psittacula krameri* (Green Parrot)

- Common parakeet; parakeet means long tail

- Grass green body and short , heavy and deeply hooked red bill
- Male : has a rose pink and black collar
- Feet : adapted for grasping , holding & climbing
- Have 4 toes : 2 facing front and 2 facing back
- Herbivorous
- Non-migratory
- Captive individuals can be taught to speak

16. ORDER STRIGIFORMES

(Gr., strix = Owl+ form)

- Head large and rounded.
- Eyes large and directed forwards. Each in a disc of radial feathers.
- Retina contains principally the rods.
- Ear opening large, often with flap-like cover.
- Beak short, feet with sharp claws adapted for grasping.
- Nocturnal and predators.

Example: *Bubo bubo (*Great horned owl)

- Genus bubo contains 20 species
- Eagle –owl
- One of the largest species of owl and most widely distributed
- Has distinctive ear tufts , with upper parts mottled with darker blackish colouring and tawny
- Barred wings and tail
- Under parts are variably hued buff , streaked with darker colouring
- Facial disc: not very visible
- Eyes are orange
- Nocturnal predator

17. ORDER APODIFORMES (MICROPODIFORMES)

- Usually small birds.
- Legs are very short and feet very Small
- Wings very long formed of long distal segments.
- Beak is small and weak or slender with long tubular tongue.
- Examples: Swifts (*Apus)* are insectivorous Humming birds (*Trochilus*).

Example : *Apus nipalensis (Nepal* house swift)

- Capable of flying long distances by alternately shutting off hemispheres of their brain-in –flight
- Medium sized dark swift
- Nests in building and cave crevices
- Darker throat
- Longer and pointed wings
- Long , sharply forked tail
- White plumage patches
- Gives a high-pitched , twittering trill
- Contrasting small white throat

18. ORDER PASSERIFORMES (Perching Birds)

- Perching birds / singing birds
- Largest order of birds
- Most are omnivores
- 3 toes forward and one (hallux) backwards : helps them for perching
- Most species have 12 tail feathers
- Have complex set of 4 muscles in their syrinx

Example : *Passer domesticus (* house sparrow) : Angadi Kuruvi

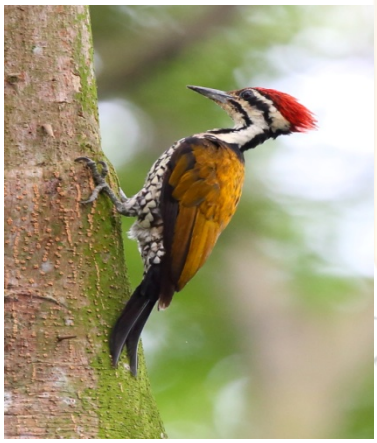
- Resident bird found throughout Indian subcontinent
- Lives almost as a commensal of man
- Exhibit sexual dimorphism
- Male: crown is grey and sides of neck and back are chestnut
- Males have white cheek
- Wings are rufous , with a white shoulder patch
- Female : greyish brown above and plain brownish white below
- Beak is conical

- Smalle yes
- Feet: adapted for perching
- Omnivorous, but chiefly granivorous
- Pets of granary
- Helps in pest control
- Both incubate eggs

19. ORDER PICIFORMES

- Includes wood peckers , barbets and honeyguides
- Most are insectivorous , barbets : eat fruit and honeyguides : can even digest beeswax
- 2 toes forward and two back arrangement : zygodactylous
- Woodpeckers : 3 toed
- Many members have stout, sturdy beaks
- Males and females of a species looks alike
- Combinations of black and white with accents of red and yellow plumage are common
- Do not have down feathers, only true feathers
- Communication in woodpeckers and barbets: drumming

Example :*Dinopium* (Wood Pecker)



20. ORDER PHOENICOPTERIFORMES

- Only existing family : Flamingos
- Water birds
- There are 6 species
- Large
- Very long legged
- Long neck
- Filter –feeding bills

Example : *Phoenicopterus* (Flamingos)

- 3-5 fet tall
- Long leg and neck
- Bent bills
- Young flamingo: greyish red plumage ,but adults : Plumage can be pink , white or red (due to feeding)
- Flamingo name derived from Spanish : meaning :' flame coloured'

- Usually stand on one leg , other being tucked beneath body
- Capable flyers
- Filter feeders
- Noisy birds

21. SUPER - ORDER SPHENISCIFORMES (IMPENNAE)

- Flightless marine birds , inhabiting polar and circum-polar regions
- Single order : *Sphenisciformes*
- Fore limbs : flipper –like swimming paddles
- Short legs , placed far back to the body
- Webbed toes
- Reduced scale-like feathers
- Bill : covered with horny plates

Example :*Aptenodytes* (Penguins)

- Primitive , flightless and gregarious birds
- Antarctic continent of southern hemisphere
- Oval body
- Cryptic coloration of sea birds , black / bluish above and white below
- Wings are devoid of quill feathers , but covered with scale like feathers
- Paddle like flippers for swimming and diving
- Legs are short and far back in the body
- Erect stand on land
- Toes : webbed : used for steering
- Plumage covers entire body
- Expert swimmers
- Young ones are fed with half digested food regurgitated by parents
- Curious example for birds migration by swimming
- **Aquatic adaptations**:
  1. Modification of wings : resistant paddle: for swimming and diving
  2. Strongly webbed feet
  3. Presence of solid bones
  4. Absence of air sacs inside bones
  5. Short and closely and heavily packed plumage which holds very little air
  6. Sleek and streamlined body: reduce resistance

RECENT EXTINCTIONS

1. **PASSENGER PIGEON (*Ectopistes migratorius)***
   - Extinct North American pigeon
   - Once abundant in Mississippi valley
   - Around 3-5 billion passenger pigeon lived in the early 19th century , but was ruthlessly massacred for flrsh and sport by the pleasure-hunting and trigger-happy man
   - They fell an easy prey to man because **:**Crowded nesting habit & communal flights in large flocks
   - Last living Martha died in 1914
2. **DODO (*Raphus cucullatus*)**
   - Dodo was a flightless relative of pigeon and doves ,which once inhabited the islands of Mauritius and reunion
   - Dodo is perhaps the first bird known it have been exterminated by man in the modern times
   - It is a large ,approximately three -feet tall, with down grey feathers and a white plume for a tail. The dodo had tiny wings and its sternum -an area with strong wing muscles for flying birds- was correspondingly small
   - Awkwardly looking sluggish ,swan -like ,fearless and Mauritian pigeon that adopted a terrestrial habit
   - Stout and 4 – toes legs
   - The bird fell an easy prey to man ,its egg became the favourite target of pigs, rats and other animals ,

dodo
Dodo (*Raphus cucullatus*).
Encyclopædia Britannica, Inc./Christine McCabe

introduced to Mauritius

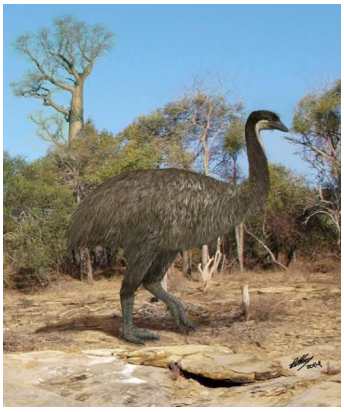
   - Live dodo used to be exhibited in Europe between 1600 and 1640, and India between 1628 and 1634
   - But now , there remain only head and foot on oxford , a foot in the London natural history museum and head in Copenhagen
   - Although the flesh of dodo is known to be unpalatable ,the bird wad mercilessly massacred by sailors for food
   - Pig and rats , introduced to Mauritius in the 16thcentury are said to have eaten its egg in large numbers

3. PINK-HEADED DUCK (*Rhodonessa caryophyllacea)*

- Was a resident of Northern & N-E India with reports from Orissa , West Bengal , Bihar , Assam & Manipur
- The pink-headed duck (*Rhodonessa caryophyllacea*) is a large diving duck that was once found in parts of the Gangetic plains of India, Bangladesh and in the riverine swamps of Myanmar but feared extinct since the 1950s.
- Numerous searches have failed to provide any proof of continued existence.
- It has been suggested that it may exist in the inaccessible swamp regions of northern Myanmar and some sight reports from that region have led to its status being declared as "Critically Endangered" rather than extinct.
- The genus placement has been disputed and while some have suggested that it is close to the red-crested pochard (*Netta rufina*), others have placed it in a separate genus of its own.
- It is unique in the pink colouration of the head combined with a dark body.
- A prominent wing patch and the long slender neck are features shared with the common Indian spot-billed duck.
- The eggs have also been held as particularly peculiar in being nearly spherical

4. ELEPHANT BIRD (*Aepyornis)*

- Is a genus of Aepyornithid
- One of the three genera of ratite birds endemic to Madagascar until their extinction around AD 1000
- Flightless
- Keelless sternum
- Closest living relative : new Zealand kiwis
- It is widely believed that the extinction of *Aepyornis* was the result of human activity.
- The birds were initially widespread, occurring from the northern to the southern tip of Madagascar.
- One theory states that humans hunted the elephant birds to extinction in a very short time for such a large landmass
- There is indeed evidence that they were killed.
- However, their eggs may have been the most vulnerable point in their life cycle. A recent archaeological study found fragments of eggshells among the remains of human fires, suggesting that the eggs regularly provided meals for entire families.
- The exact time period when they died out is also not certain.
- There is archaeological evidence of *Aepyornis* from a radiocarbon-dated bone at 1880 with signs of butchering, and on the basis of radiocarbon dating of shells
- It has also been suggested that the extinction was a secondary effect of human impact due to transfer of hyperdiseases from human commensals, such as chickens and guinea fowl.



REDISCOVERY OF :

1. JERDON'S COURSER

- **Rarest bird**
- Resident bird of Godavari valley in AP
- First discovered by J.C.Jerdon in 1848
- Last authentic record : 1900
- Missing for about 89 years
- Rediscovered : 1986 by Bharat Bhushan from dry scrub jungles in AP . Area is declared as part of wildlife sanctuary
- Upper part of body : pinkish/ sandy brown
- Crown and hind-neck are dark brown
- White chin and throat
- Tail : white with black

FOREST OWLET

- Decribed as 'mystery bird of India'
- Remained unrecorded for 100 years
- First reported : 1873
- Last confirmed repport : 1884
- Rediscovered : 1997 in Maharashtra by Dr. Pamila
- Size:29cm
- Head and back of neck : earthy brown and white spots in hind collar
- Dark bad on throat
- Sweet call
- Exhibit Cannibalism

TYPE
RABBIT *(Oryctolagus cuniculus) : Class : Mammalia*
EXTERNAL FEATURES

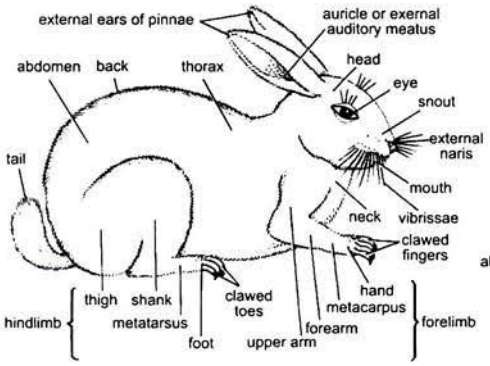


Fig. 29.2. Rabbit. External features in side view.

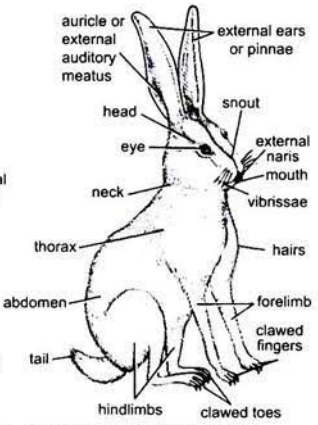


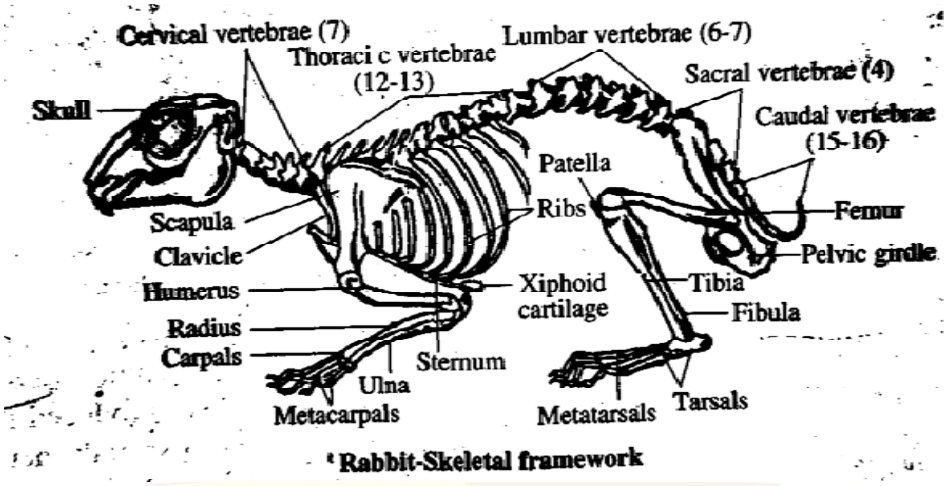
Fig. 29.3. Hare. External features.

- Fur covered body
- 4 divisions :

1. **Head**
   - Slightly depressed and elongated
   - Blunt snout
   - Anterior : mouth bounded by upper and lower lip
   - Upper lift has a cleft which exposes incisors :cleft lip
   - Tactile hairs : *vibrissae*
   - Oblique external nostrils above mouth
   - Lateral eyes with eyelids with eyelashes ;and *nictitating membrane*
   - Behind eyes : flexible ear *pinnae*
2. **Neck**
3. **Trunk**
   - 2 portions: thorax & abdomen
   - Abdomen of female bears 4/5 pairs of teats
   - Behind root of tail : anus
   - Infront of anus ,ventrally : *Urinogenital opening (*male :at tip of penis)
   - Area between anus and urinogenital opening : *perinaeum*
   - Trunk bears *pentadactyl* forelimbs and hindlimbs
   - Forelimbs :3 divisions : *brachium ,ante-brachium & manus (carpus , metacarpus & 5 digits*)
   - Forelimbs : used for digging
   - Hindlimb : used for leaping
   - Hindlimbs ; 3 divisions : *femur , crus & pes (tarsal , metatarsal & 4 digits)*
   - Locomotion is *plantigrade* : entire palm and foot touching the ground

1. **Tail**
   - Short and covered with fluffy fur
   - Peculiar movements serve as warning signal

SKELETAL SYSTEM

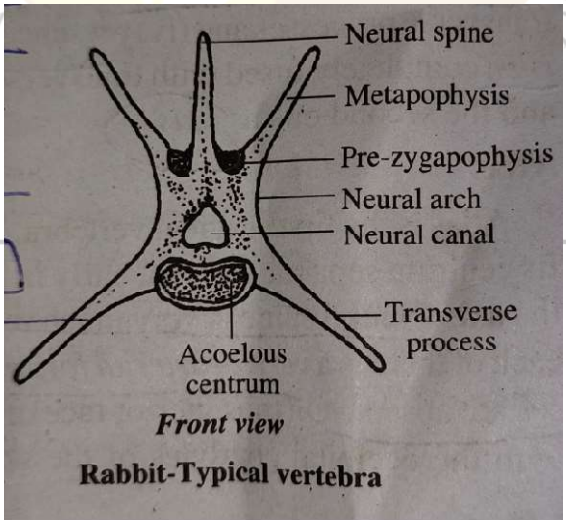


- 2 divisions :
  1. Axial : skull , vertebral column , ribs and sternum
  2. Appendicular : limbs and limb girdles

Vertebral column

- 44-47 vertebrae:
  - *Cervical :* 7
  - *Thoracic :* 12/13
  - *Lumbar:*6/7
  - *Sacral :* 4
  - *Caudal :* 15/16
- Acoelous
- *Intervertebral discs* : thin pads of fibro cartilage between adjascent centra

Typical vertebra



- Lumbar vertebra : typical vertebra
- *Acoelous* centrum
- Fused to each end of centrum : *epiphysis*
- Produced fom centrum : *neural arch* ; encloses *neural canal*

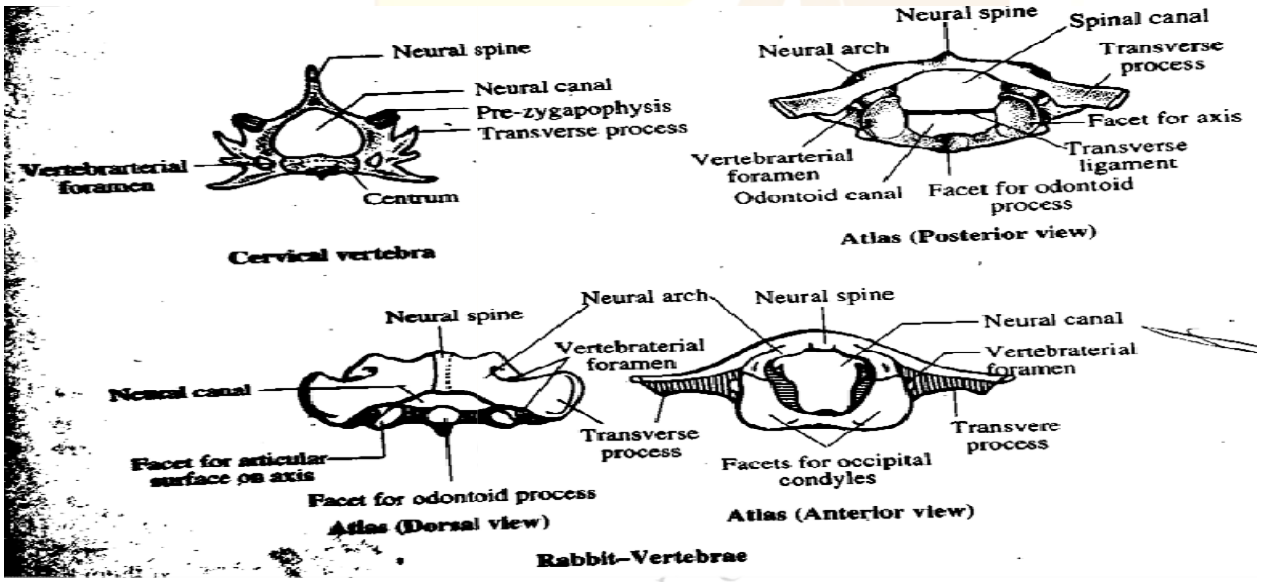
- *Intervertebral notches* of adjascent vertebrae come close to form : *intervertebral foramina* (for the passage of spinal nerves)
- Neural arch bears median *neural spine* , a pair of lateral *transverse processes* and paired *pre* and *post-zygapophysis*

Cervical vertebrae (7)

- Reduced centrum
- Short transverse processes and neural spine
- *Vertebarterial foramina*
- Pair of m uch reduced *double-headed bony ribs*
- First vertebra: *atlas* and second *: axis*

Atlas

- First cervical
- Ring shaped , without a proper centrum
- Reduced neural spine
- Flat *transverse processes*
- *Zygapophyses* absent
- Occipital facets ; for the articulation of *occipital condyles* of skull
- Neural canal is partitioned into : *spinal canal* and *odontoid canal*



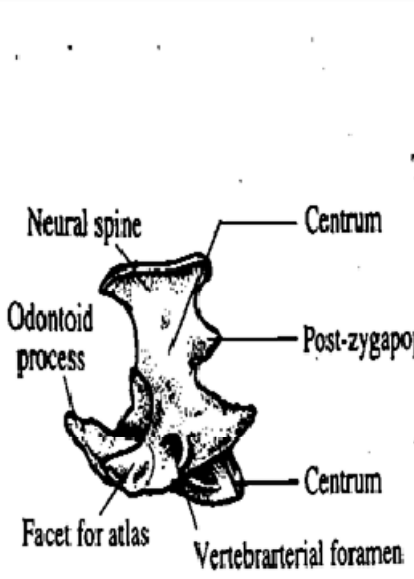
Axis

- Second cervical vertebra
- Broad centrum
- Peg-like forward process produced from centrum : *odontoid process* which articulates with atlas
- Atlas : odontoid articulation : pivot for rotation of head
- Long and compressed neural spine
- Small and backwardly directed transverse processes
- *Pre-zygapophysis* absent
- *Post-zygapophysis* present

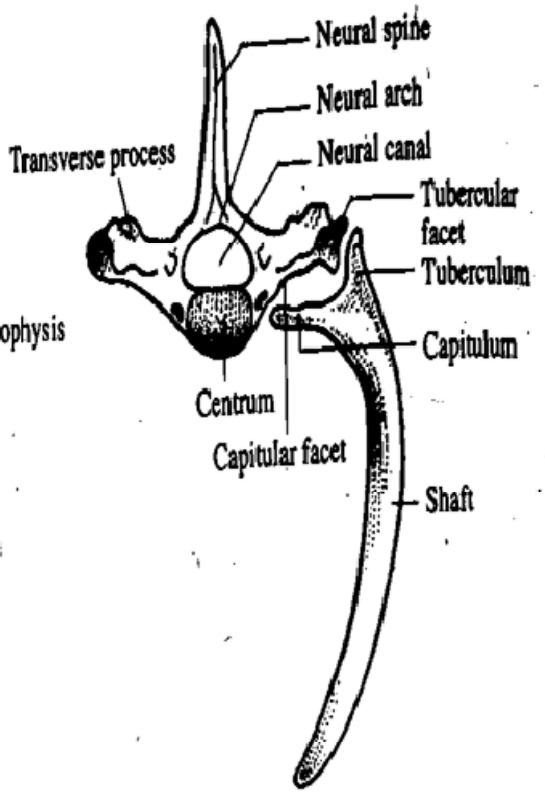
Thoracic vertebrae(12/13)

- Similar to typical

- No *mammillary processes*
- Elongated neural spine
- Short and stout tranverse processes
- Thoracic vertebrae is articulated to double headed ribs



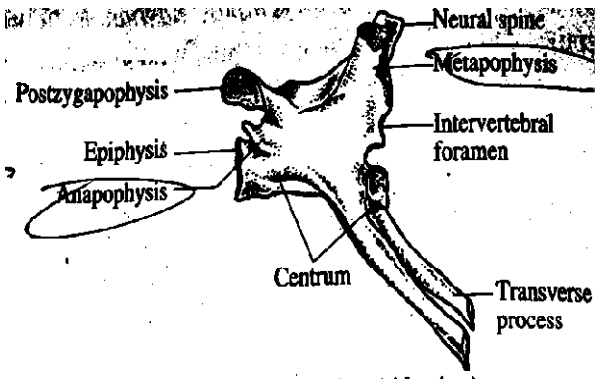
Rabbit-Axis (Lateral view)



Rabbit-Thoracic vertebra with rib

Lumbar (6/7)

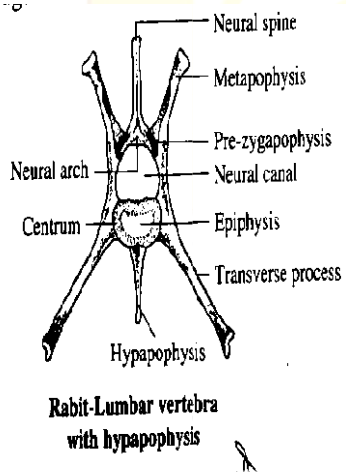
- Largest
- Represent typical vertebrae
- *Hypapophysis*



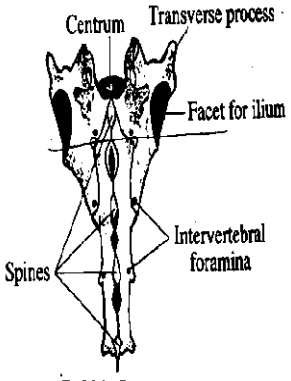
Rabbit - Lumbar vertebra (side view)

Sacral (4)

- Fused to form a plate : *sacrum*
- Wedged between ilia of the pelvic girdles
- First sacral vertebra forms facets for articulation with ilia to form *ilio-sacral joint*



Rabit-Lumbar vertebra with hypapophysis



Rabbit-Sacrum

- Long spine
- Small tubercle-like *zygapophyses* on the upper side

Caudal (15/16)

- Bony pieces without prominent neural spine and transverse process
- Few have neural arches , spines and zygapophysis
- Decrease in size

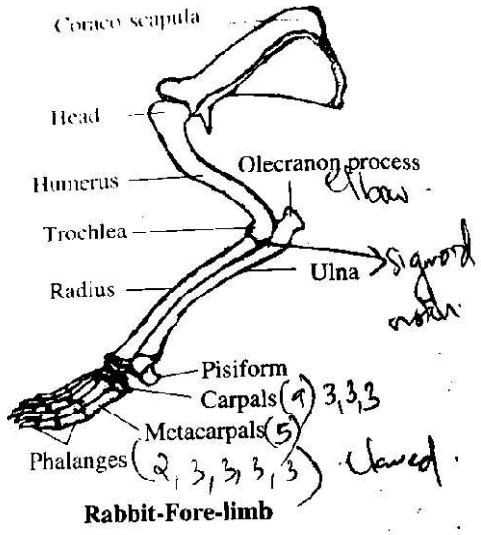
Ribs

- Ribs + sternum = thoracic framework
- 12 pairs of ribs
- 2 parts : *shaft* (articulate with sternum)and *head*(articulate with vertebra)
- First 8 pairs : double headed : with *tuberculum* & *capitulum*
- Last 4 pairs : single heaed (no tuberculum)
- First 7 pairs : direct/true ribs
- 8^{th} and 9^{th} : fused with 7^{th} : so called *indirect ribs*
- Last 3 pairs : *floating ribs*

Sternum

- Breast bone
- Long ,narrow and segmented
- Segments: *sternebrae*
- 3 parts: *pre sternum*, *mesosternum* & *metasternum*

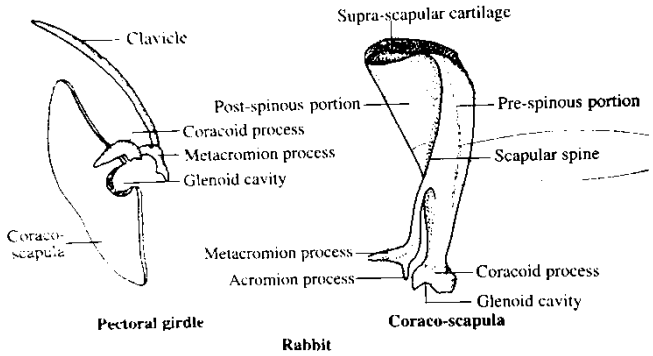
Fore-limb



Rabbit-Fore-limb

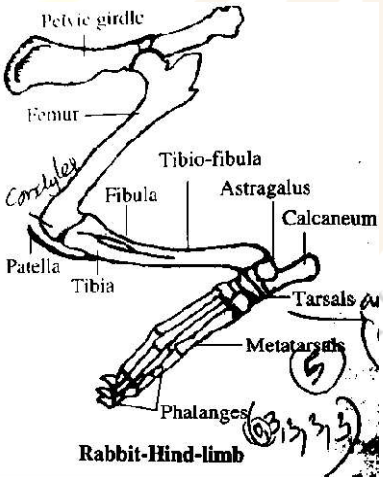
- Short and in *plantigrade position*
- clawed
- Pentadactyl : 5 divisions:
    1. *Humerus* : upper arm
    2. *Radius and ulna* : fore-arm
    3. *Carpus* (wrist): 9 *carpals*
    4. *Metacarpus* (palm): 5 *metacarpals*
    5. *Phalanges* : finger ;2,3,3,3,3
- Humerus has 2 parts : *shaft* and 2 extremities(*head* and 2 other prominences)
- Head of humerus fits into *glenoid cavity* of pectoral girdle to form : *shoulder joint*

Pectoral girdle



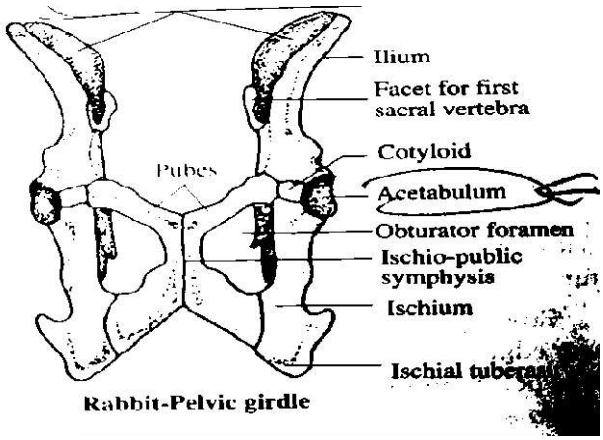
- Reduction & loss of bones happens
- Each side , 2 bones :
  - *coraco-scapula* (shoulder blade)
    - thin and flat
    - bears *glenoid cavity*
    - *scapular spine :* ridge in outer side of scapula
  - *clavicle (*collar bone)

Hind-limb



- *Pentadactyl* ; 5 divisions :
  1. *Femur* : thigh
- Two parts : *shaft* and two extremities
- Distal extremity bears *condyles*
- *Patella* : knee cap
  2. *Tibia* and *fibula* : shank
- Tibia articulates with the condyles of femur to form *knee joint*
  3. Tarsus (ankle): 6 *tarsals*
  4. Metatarsus(sole) : 5 *metatarsals*
  5. Phalanges: toes: 0,3,3,3,3

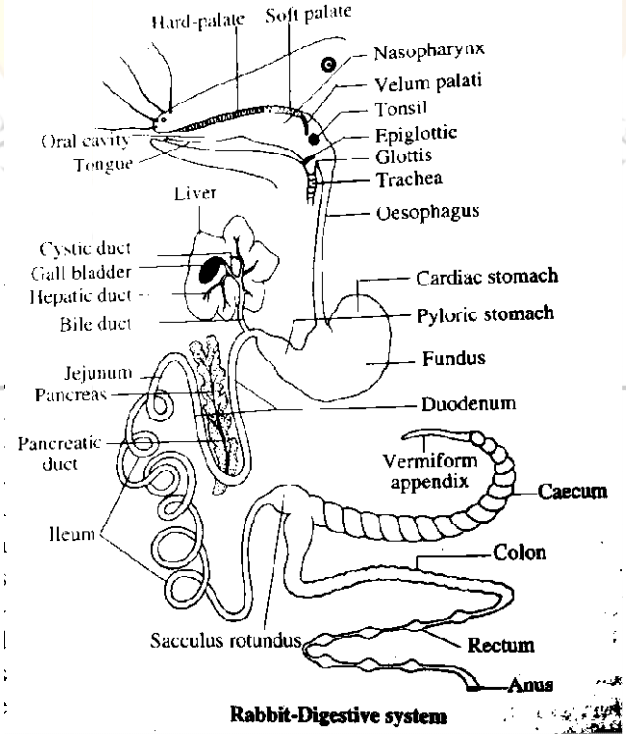
Pelvic girdle



Rabbit-Pelvic girdle

- On each side : compound bone : *os innominatum*
- Formed of ;
    1. *Ilium* : large and broad ; with articulation for sacrum
    2. *Ischium* : broad
    3. *Pubis*
- Junction of 3 bones: *acetabulum* where the head of femur fits to form hip joint
- *Pubo-ischiatic symphysis*: where pubis and Ischia of 2 sides meet

DIGESTIVE SYSTEM



Rabbit-Digestive system

- Consists of;
    1. Alimentary canal : mouth ,buccal cavity ,pharynx , oesophagus , stomach , intestines and anus
    2. Glands :salivary , gastric , intestinal glands ,liver & pancreas

Mouth and buccal cavity

- Terminal ; guarded by lips
- Buccal cavity : spacious & separated from nasal canal by palates ; so can retain food in stomach while breathing
- Palate : anterior hard palate and posterior soft palate
- Hard palate : ridges called *palata ridge* : prevent escape of food from oral cavity
- Anterior end of hard palate : *naso-palatine openings* ; which leads to canals
- Each canal leads to *nasal chamber* which lodges *jacabson's organ* :for recognition of nature of food
- *Uvula :* free pendulous flap from posterior ridge of soft palate
- Behind soft palate : *internal nostrils*
- Buccal floor bears tongue joined by *frenulum*
- Tongue bears lingual papillae with *taste buds*

Dentition

- *Thecodont:*teeth are set in sockets of jaw bone
- *Heterodont* : different types of teeth with different function and structure :I , PM & M .
- *Diastema* : toothless gap between I and PM .Canines are totally absent
- *Lophodont* :PM and M have broad crowns with sharp transverse ridges
- *Diphyodont* : 2 sets of teeth appear in life(milk and permanent dentition)

Dental formula $\left\{\frac{2.0.3.3}{1.0.2.3}\right\}$ **x 2 = 28**

Pharynx

- 2 portions ; *oro-pharynx* and *naso-pharynx*
- *Glottis* is covered by cartilaginous lid : *epiglottis*

Oesophagus

- Narrow tube
- Opens to stomach
- Wall Contains involuntary muscles and mucus secreting cells

Stomach

- Spacious chamber
- 3 divisions : *cardiac , fundus & pyloric*
- Opening of oesophagus to cardiac stomach : guarded by *cardiac sphincter*
- Opening of Pyloric stomach to intestine : guarded by *pyloric sphincter*
- Mucous membrane of stomach : has numerous folds with deep pits : *gastric pits* , into which glands open

Intestine

- 2 divisions :
    1. Small intestine
- 3 divisions : *duodenum , jejunum and ileum*
- *Bile duct* and *pancreatic duct* opens to duodenum
- Jejunum has *brunner's glands* (mucus)

- Ileum, dilates terminally to *sacculus rotundus* with a valve *ileo-caecal valve* which directs fresh food to caecum ,preventing it from entering colon
- Internal lining of ileum has *villi* and *peyer's patches*(lymphatic bodies)

2. Large intestine

- 2 portions : *colon & rectum*
- Junction between colon and ileum has *ileo-colic sphincter*
- It has *haustra* and *taeniae*
- Rectum is beaded due to presence of fecal pellets
- Leading from junction between ileum and colon : *caecum / blind gut* with *spiral valve* inside
- Caecum terminates in *vermiform appendix*
- Caecum : centre of digestion and absorption of cellulose

Glands :

Salivary glands

- 4 pairs :
  1. *Parotid* : near base of ear lobes
  2. *Infra-orbital* : below and in front of eyes
  3. *Sub-maxillary* : close angles of jaws
  4. *Sub-lingual* : below tongue

Gastric glands

- Stomach wall
  1. *Cardiac glands* : mucus-secreting
  2. *Fundic glands*: 3 types of cells : *chief cells* (gastric enzymes pepsin and lipase) , *parietal cells* (HCl) and *mucus cells*
  3. *Pyloric glands*: mucus

Intestinal glands

- Small intestine wall
- Secretion : *succus entericus*
- 2 kinds of cells : mucin secreting *goblet cells* & enzyme secreting (erepsin , maltase ,lactase , sucrose and lipase) *paneth cells*

Liver

- 5-lobed
- Produces *bile*
- *Gall bladder* is embedded in the right central lobe
- Duct of bladder ; *cystic duct*
- Duct from each lobe : *hepatic duct*
- Hepatic duct and cystic duct unite to form common *bile duct* which opens to duodenum
- Lobe is formed of *liver lobules*
- Hepatic cells : *liver cells*

Pancreas

- *Heterocrine gland*
- Exocrine : *acinar gland : pancreatic juice (* trypsin , amylase and lipase)
- Endocrine *: islets of langerhans* (insulin , glucagon & somatostatin)

Feeding and digestion

- Herbivorous
- 3 major stages: *buccal digestion ,gastric digestion* and *intestinal digestion*

Buccal digestion / oral

- Mechanical : *mastication , insalivation* and *moistening*
- Chemical : *salivary amylase* breaks down carbohydrates in to *dextrins* and *maltose*
- Partly digested food : *bolus*

Gastric digestion

- Mechanical *: churning*
- Chemical : action of gastric juice which contains mucin , HCl and gastric enzymes (*pepsin* and *lipase)*
- HCl : disintegrates food , kills bacteria and activates enzymes
- Pepsin : protein to proteoses and peptones
- Lipase : fats to fatty acid and glycerol(partly)
- Partly digested food in stomach : *chime*

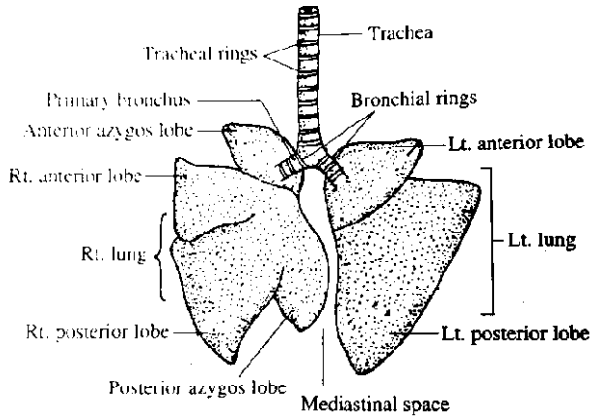
Intestinal digestion

- Enzymatic
- Chyme is acted upon by Bile and pancreatic and intestinal enzymes
- Bile : neutralizes , emulsifies fats and helps intestinal absorption of fat and fat soluble vitamins
- *Trypsin* : proteins to dipeptides
- *Erepsin* : dipeptides to aminoacids
- Amylase: breaks polysaccharides into disaccharides
- *Disaccharases* of intestinal juice : hydrolyse disaccharides into monosaccharides
- Lipase: fats to fatty acid and glycerol

Coprography and cellulose digestion

- Cellulose digestion occurs in : caecum by symbiotic bacteria
- Bacteria produces *: cellulose* and *cellobiase*
- Cellulose : cellulose into cellobiose
- Cellobiase : cellobiose into glucose
- *Refection / pseudorumination / coprophagy* : freshly eaten food passes to caecum ; after cellulose digestion , partly digested food passes out as : soft faeces.This is eaten by animal , which later stays in stomach and intestine for normal digestion .It will not re-enter into caecum ,but passes to large intestine :water reabsorption : faecel pellets are formed

RESPIRATORY SYTEM



Rabbit - Trachea and lungs (Ventral view)

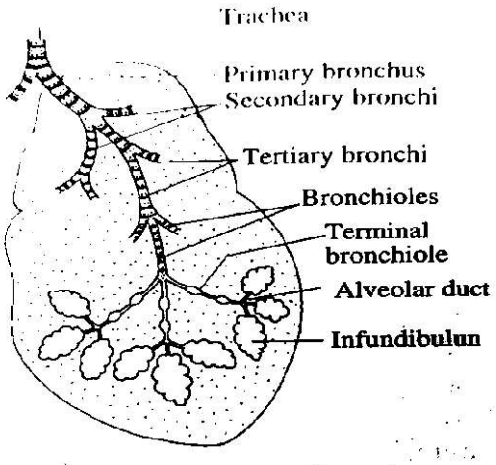
- Includes ;
  1. A pair of lungs
  2. Air tract : external nostrils , nasal cavities , internal nostrils , nasopharynx , larynx , trachea and bonchi

Tract

- External nostrils leads to nasal canal separated by *internasal septum*
- Canal is lined by ciliated , glandular and sensory epithelium
- Glottis is covered by *epiglottis*
- Larynx has 4 cartilages
- Larynx : mechanical valve ; regulation of entry and exit of air
- Larynx leads to trachea
- Trachea : made of incomplete cartilaginous half rings : *tracheal rings*
- Trachea enters thoracic cavity and divides into 2 *bronchi* supported by *bronchial rings*
- Trachea , bronchi and their branches are internally lined by ciliated mucous epithelium

Lungs

- Covered by bony frame work : dorsally: vertebral column; ventrally : sternum and laterally : ribs
- Enclosed within pleural sac , made of pleural membrane which encloses a cavity : *pleural cavity* , filled with *pleural fluid*
- Lungs are lobular organs : right one : 4 lobes and left one : 2 lobes
- Each lobe has large number of blind sacs : *infundibula / artria*
- Each infundibulum ,inturn , is formed of several air pockets / air chambers : *alveoli*
- *Alveoli* : structural units of lungs and centre of gas exchange
- Walls of lungs have a complex system of blood capillaries : *air capillaries*
- Air capillaries are formed by branching and re-branching of bronchus
- Bronchus entering lung : *primary bronchus* ; divides into *secondary bronchi* , which breaks into *tertiary bronchii* ; which inturn breaks into thin-walled terminal *bronchioles* from which alveolar ducts which end in alveoli arises



Rabbit - Structure of lung

Mechanism

- Movements are brought about by ribs (costal) and diaphragm (abdominal) by muscular activity and regulated by medulla oblongata

  1. Inspiration
- External intercostal muscles and muscles of diaphragm contracts
- Ribs are drawn forward and sideward and arched diaphragm becomes straight ; sternum moves forward and downward
- Thoracic cavity expands and lungs dilate and fresh air is drawn into lungs

  2. Expiration :
- External intercostal muscles and muscles of diaphragm relax and internal intercostal muscles contract
- Ribs , sternum & diaphragm return to original position
- Thoracic cavity decreases and lungs get compressed and used air forced out
- Lungs are never completely emptied during expiration : some air remain: *residual air*
- Mammalian lungs are less efficient than avian lungs

CIRCULATORY SYSTEM

- Closed type
- 2 divisions:

  1. Blood vascular system /*cardiovascular system* (blood, heart and blood vessels)

  2. *Lymphatic system* (lymph , lymph channels , lymph vessels , nodes & lymph heart)

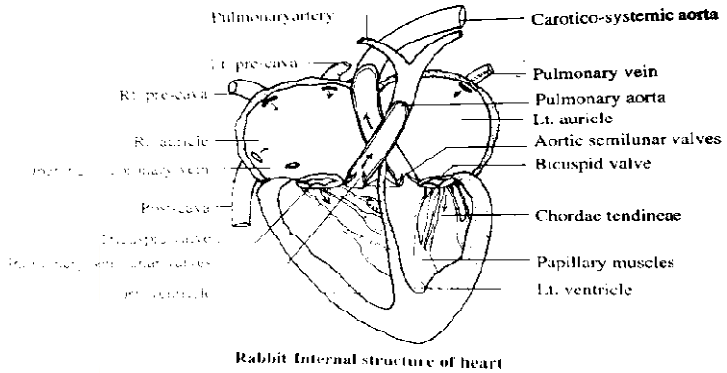
Blood

- Transporting medium
- Fluid part : blood plasma : water , proteins , non-protein compounds , secretion products and wastes
- Solid part : corpuscles / blood cells : RBC, WBC & platelets
- Functions : Transport of nutrients , respiratory gases , metabolic wastes , hormones , enzymes ; defence ; regulation of pH balance , electrolyte balance, water balance

Heart

- Tetralocular : 2 auricles & 2 ventricles
- Enclosed within *pericardium*

- *Double pump*
- *Auriculo-ventricular groove* divides atrium and ventricle portions
- Distinct sinus venosus and arteriosus absent
- Primitive ventral aorta splits up into *pulmonary* and *carotico-systemic trunks*
- 4 chambers
- **Right auricle and ventricle : deoxygenated blood**
- **Left side: oxygenated blood**



Rabbit Internal structure of heart

- *Interauricular septum* : separates auricles
- *Interventricular septum* : separates ventricle
- *Auriculo-ventricular septum* : separates auricle from ventricle
- *Musculi pectinati* : muscular ridges in auricular wall
- Veins to right auricle *:* ***right*** **and** ***left pre-caval veins*** **, a** ***post-caval vein*** **and** ***coronary vein***
- Veins to left auricle : ***right*** **and** ***left pulmonary veins (*****non-valvular)**
- Right Auriculo-ventricular valve : *tricuspid*
- Right Auriculo-ventricular valve : *tricuspid*
- Ventricles : thick walled
- *Columnae carneae* : muscular ridges in ventricles
- *Papillary muscles* : muscular projections in ventricle
- *Chordate tendinae* : prevent valves from flexing
- ***Pulmonary trunk*** : from right ventricle (3 *semilunar valves)*
- ***Carotico-systemic trunk*** : from left ventricle (3 *semilunar valves)*

Working of heart

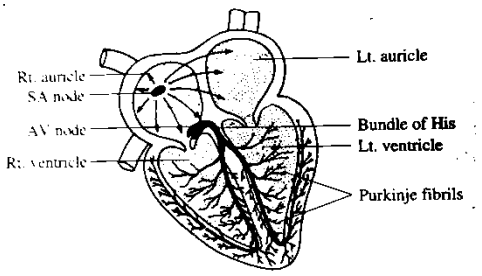
- Regular & rhythmic heart beat
- Contraction : systole ; relaxation : diastole
- Systole : 2 stages : auricular systole and then ventricular systole
- Diastole is combined : simultaneous

Pace maker & regulation

- *Myogenic*
- Regulated : by intrinsic regulatory system
- Regulatory system : *nodal tissue*
- Nodal tissue consists of ,

1. *SA node* : near opening of right pre-cava
2. *AV node* : inter-auricular septum
3. Conducting system : bundle of his , purkinje fibrils

- SA node contains *: pace maker cells* (P cells ;to elicit excitation) & *transitional cells* (T cells ; to transmit)
- SA node : *heart of heart/ pace maker*



Heart - Pace maker and conducting system

Complete double circulation

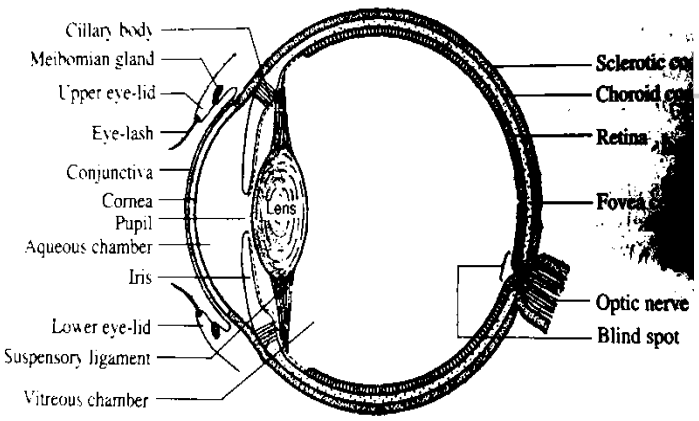
- Includes *pulmonary* and *systemic circulation*
- Heart passes through the heart twice ; gas exchange takes place twice : *double circulation*
- Since heart is 4 –chambered and right and left halves are completely separate from, each other , pulmonary and systemic circulation never mix : *complete double circulation*

SENSE ORGANS

1. *Photoreceptors* : eyes
2. *Stato-acoustic organs* : internal ears
3. *Olfacto receptors* : nasal mucosa
4. *Gustatoreceptors* : taste buds
5. *Cutaneous receptors* (*tangoreceptors* , pain receptors & *thermo receptors*)

EYE (PHOTORECEPTOR)

- Has a fluid filledand spherical eyeball , lodged in the eye socket in orbit
- Guarded by lids and nictitating membrane
- *Conjunctiva* : transparent membrane over eye ball
- Eye muscles : 4 *recti muscles* & 2 *oblique muscles*
- Eye glands : *ciliary*(lubricate eyelid & eyelash), *lacrimal* (tear cleanses and moistens , provides nourishment and kills bacteria) , *Harderian* and *Meibomian glands* (lubricate eyelid & eyelash)



Rabbit-V.S. of eye ball

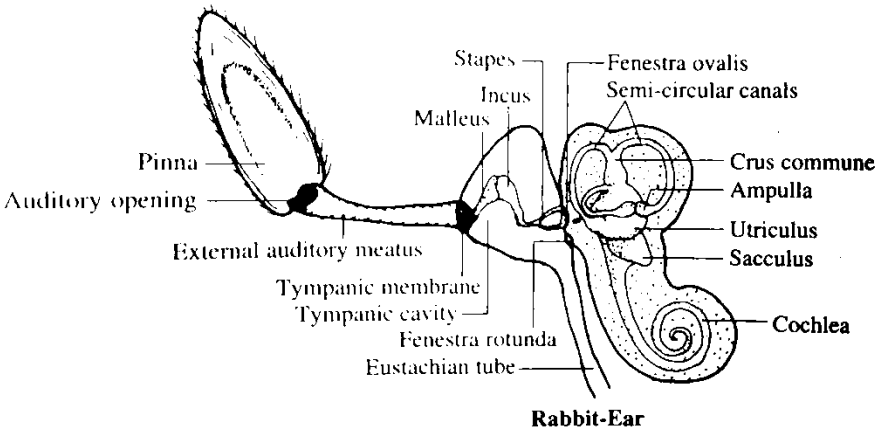
Eyeball structure

- 3 concentric layers :

1. Outer ***sclerotic coat*** : tough fibrous layer
2. Middle ***choroid coat*** : heavily pigmented vascular layer
3. Inner ***retina*** :light-sensitive nervous layer

- Exposed part : *cornea*
- Pigmented vertical curtain : *iris*
- *Pupil* : centre of iris, for the passage of light
- *Ciliary body :* produced from the base of iris is muscular structure
- Iris contains : radial and circular muscles
- Iris divides cavity of eyeball into :
  1. outer *aqeous chamber* : filled with aqeous humour : secreted by ciliary body ; nourishes cornea and lens and maintains intraocular pressure
  2. Inner *Vitreous chamber* : filled with vitreous humour : maintains intraocular pressure
- *Crystalline lens* : solid , transparent and biconvex lens enclosed within lens capsule , suspended by *suspensory ligament* , basally attached to ciliary body
- *Retina :* complex part , consists of outer *pigmented layer* (pigmented cells) and inner *sensory layer* (*photosensitive cells , bipolar neurons & ganglion cell*)
- Photosensitive cells : *rods (scotopic vision)* and *cones (photopic vision)*
- *Yellow spot* :small area near centre of the back of retina where cones are numerous (yellow pigment)
- *Blind spot:* point where rods and cones are almost absent
- *Optic disc:* point where optic nerve joins the retina
- *Monocular vision :* each eye has its own field of vision , never overlaps

EAR (STATO-ACOUSTIC ORGAN)



Rabbit-Ear

- Hearing and balancing organ

- 3 parts :

1. External :

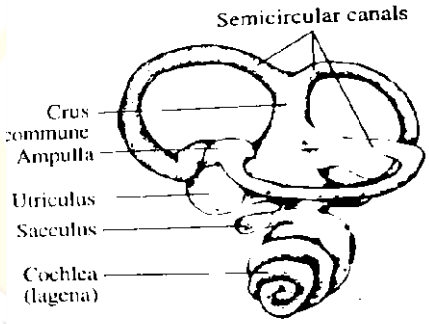
- Reception & transmission of sound waves
- Two parts : *pinna* & external *auditory meatus*
- *Pinna* : movable external ear flap ; formed of cartilage and voluntary muscles
- *Auditory meatus* : deep passage ,leading from external ear opening to middle ear through tympanic bone

2. Middle :

- Reception & transmission of sound waves
- Situated inside tympanic bulla
- Consists of air-filled tympanic cavity , separated from external auditory canal by *tympanic membrane*
- Communicates with the inner ear through *fenestra ovalis* and *fenestra rotunda*
- Tympanic cavity is bridged by a bony chain : *ossicular chain ;* stretches between tympanic membrane and fenestra ovalis : 3 bones *: ear ossicles : malleus , incus and stapes*

3. Inner :

- Hearing and balancing
- Contains receptors for hearing and balancing
- Membranous bag : *membranous labyrinth*(filled with *endolymph*) enclosed within *bony labyrinth* (filled with *perilymph*)
- Membranous labyrinth : 2 main parts : *semicircular canals & vestibule*



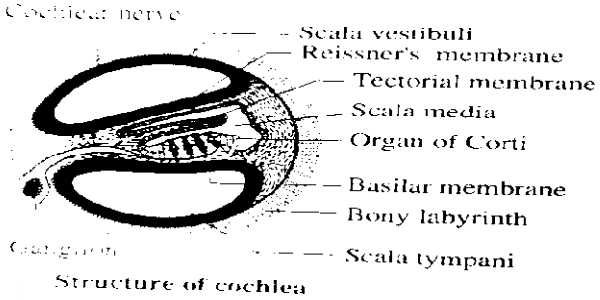
Rabbit-Membranous labyrinth

- Semicircular canals has swollen *ampulla* at distal end
- Vestibule : 3 parts : *utriculus , sacculus & cochlea*
- Semicircular canals , utriculus and sacculus : **balancing**
- *Cochlea* : **hearing** , serves as auditory analyzer of ear
- There are several sensory patches on ampullae (called *cristae*), utriculus(called *maculae*) and sacculus (*maculae*)
- Sensory patches : contains *: sensory hair cells* and supporting cells
- Cristae and maculae are innervated by *auditory nerve*
- Membrane of crista : *cupula*
- Membrane of macula : *otolith membrane*

Structure of Cochlea

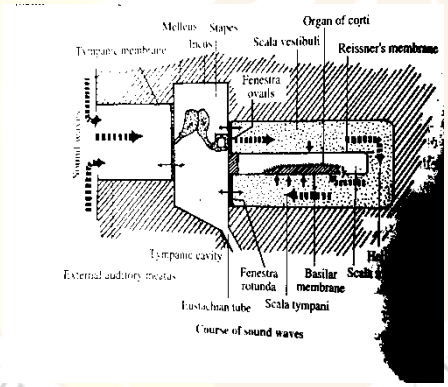
- Complex
- Bony capsule which enclose cochlea : *bony cochlea*

- Bony cochlea consists of *modiolus* and *cochlear canal*
- Has 3 chambers separated by membranes
    1. *Scala vestibule* : *perilymph*: communicates with tympanic cavity through fenestra ovalis
    2. *Scala media* : internal ; filled with *endolymph*
    3. *Scala tympani* : *perilymph* : communicates through fenestra rotunda



Structure of cochlea

- Scala media and scala vestibule : separated by *reissner's membrane*
- Scala media and scala tympani : separated by *basilar membrane*
- Lying over basilar membrane : receptor apparatus : *organ of corti* ; which consists of sensory hair cells and supporting cells
- Organ of corti : sound receptor and elicits nerve impulses



MODULE : 5

COMPARISON OF CIRCULATORY, EXCRETORY AND NERVOUS SYSTEM IN VERTEBRATES

1. CIRCULATORY SYSTEM:

Birds:

- 4 chambered heart
- Complete separation of oxygenated and de oxygenated blood.

Fishes:

- Only one circuit. Pumped through capillaries and gills
- Closed loop circulatory system

Amphibians

- 2system of circulation
- Oxygenation of blood through the skin and the other to take oxygen to rest of the body.
- 3 chambered heart

Reptiles

- Three chambered heart
- The heart have a partial septum between the ventricles
- This allows better separation of oxygenated and de oxygenated blood

Mammals

In mammals 3 kind of circulation ;

- Systemic circuit
- Pulmonary circuit
- Coronary circuit
- Through this circuits blood circulation occurs

2. EXCRETORY SYSTEM

Birds:

- Birds are primarily uricotelic
- Their kidneys extract nitrogenous waste from their blood stream and extract it as uric acid

Fishes:

- Primary excretory organ in fishes, as in other vertebrates, is the kidney.

- In fishes some excretion also takes place in digestive gland and skin, especially in gills

Amphibians :

- Have two kidneys, it filters the waste out of the blood.
- Nitrogenous waste can take one of three forms, ammonia, uric acid and urea.

Reptiles :

- Kidneys unable to produce liquid urine that is more concentrated than their body fluids.
- Excretory product in the form of ammonia

Mammals:

- Waste is filtered from the blood and collected as urine in each kidney.
- Urine leaves the kidneys by urethra, and collects in bladder.

3. NERVOUS SYSTEM

Birds:

- The Central nervous system is made up of a brain, spinal cord and nerves. The brain is in the skull & connected to one end.

Fishes:

- The central nervous system consist spinal cord, medulla oblongata and the brain.
- Brain divided into telencephalon, diancephalon, mesencephalon and cerebellum

Amphibians :

- Have a central brain, a spinal chord and nerves throughout the body
- The amphibian brain is less developed than that of reptiles, birds, and mammals but similar in morphology.

Reptiles :

- Nervous system contains brain, a spinal chord and sense organs.

Mammals:

- The nervous system is comprised of two major parts, and divisions ; namely central nervous system and the peripheral nervous system.
- Central nervous system includes brain and spinal cord.

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