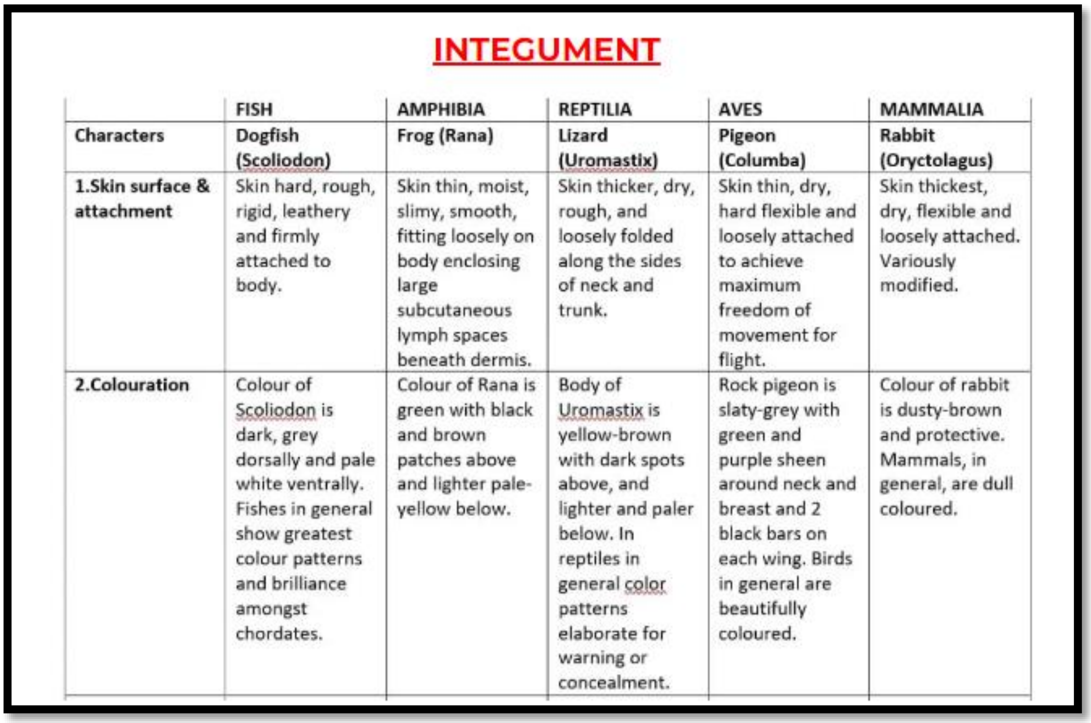
Integumentary system



INTEGUMENT

	FISH	AMPHIBIA	REPTILIA	AVES	MAMMALIA
Characters	**Dogfish (Scoliodon)**	**Frog (Rana)**	**Lizard (Uromastix)**	**Pigeon (Columba)**	**Rabbit (Oryctolagus)**
1.Skin surface & attachment	Skin hard, rough, rigid, leathery and firmly attached to body.	Skin thin, moist, slimy, smooth, fitting loosely on body enclosing large subcutaneous lymph spaces beneath dermis.	Skin thicker, dry, rough, and loosely folded along the sides of neck and trunk.	Skin thin, dry, hard flexible and loosely attached to achieve maximum freedom of movement for flight.	Skin thickest, dry, flexible and loosely attached. Variously modified.
2.Colouration	Colour of Scoliodon is dark, grey dorsally and pale white ventrally. Fishes in general show greatest colour patterns and brilliance amongst chordates.	Colour of Rana is green with black and brown patches above and lighter pale-yellow below.	Body of Uromastix is yellow-brown with dark spots above, and lighter and paler below. In reptiles in general color patterns elaborate for warning or concealment.	Rock pigeon is slaty-grey with green and purple sheen around neck and breast and 2 black bars on each wing. Birds in general are beautifully coloured.	Colour of rabbit is dusty-brown and protective. Mammals, in general, are dull coloured.

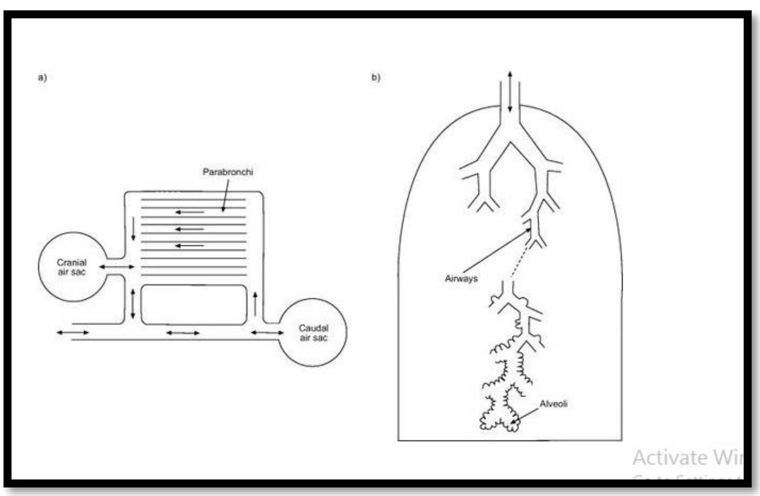
3. Colour change	Body colour does not change. Some fishes have protective colouration.	Frog has protective colouration for camouflage and can change body colour to match with the surroundings.	Uromastix has no power to change colour. However, Calotes and chamaeleons can change body colours	No capacity for change of body colouration in birds in general.	Usually, no capacity to change body colouration.
4. Pigmentation	Pigment containing chromatophores and guanin containing iridophores located in dermis.	Chromatophores located in dermis.	Chromatophores located in dermis.	Pigment cells found in feathers, not in dermis. Colours also due to reflection and refraction of light by feathers.	Pigment granules located in hairs and epidermis, pigment cells in dermis.
5. Cutaneous respiration	Skin protective and sensory. Not permeable to water, hence no cutaneous respiration.	Skin protective and permeable to water hence serves as an organ of respiration.	Skin protective and water-proof, without cutaneous respiration.	Skin protective, insulating and water-proof. No skin respiration.	Skin protective, insulating and water-proof. No cutaneous respiration.
6. Epidermis	Epidermis many layered or stratified, but simple, thin and without a cornified stratum corneum. No moulting.	Many-layered or stratified epidermis with a thin stratum corneum of flat and dead keratinized cells continuously shed in patches.	Epidermis stratified with a relatively thicker stratum corneum periodically shed in bits or in one piece.	Epidermis stratified, relatively thinner, and seasonally shed and replaced.	Epidermis greatly stratified. Stratum corneum highly specialized with several modifications.
7. Epidermal glands	Epidermis contains numerous unicellular mucus- secreting goblet gland cells. Multicellular poison glands and luminescent glands or photophores also occur in some fishes.	Epidermis is rich in multicellular mucous glands. Some amphibians have poison glands like parotid glands of toad.	Lizard has few but no mucous glands. Male lizard has femoral glands on thighs. Some reptiles have scent or musk glands.	No skin glands occur in birds except a single large preen or uropygial gland on tail. No mucous glands present.	Skin richly glandular containing characteristic mammary, sweat and sebaceous glands besides scent glands. No mucous glands present
8. Dermis	Dermis is typical with connective tissue fibres, blood and lymph vessels and pigment cells. But all connective tissue fibres run parallel to surface.	Dermis is thin and typical. It consists of an outer loose layer or stratum spongiosum, and an inner compact layer of collagen fibres called stratum compactum. Connective tissue fibres are vertical as well as horizontal.	Dermis is thick and typical, containing connective tissue fibres, muscle and nerves, blood capillaries and lymphatic vessels, and also pigment cells..	Dermis is mostly thin and typically made of muscle fibres, nerves, blood capillaries and connective tissue. It has no pigment.	Dermis is proportionately thickest of all vertebrates, containing intricate fibres, tactile organs, nerves, blood vessels and pigment cells.

RESPIRATORY SYSTEM IN BIRDS

Respiratory System in Birds Avian Respiration The avian respiratory system delivers oxygen from the air to the tissues and also removes carbon dioxide. In addition, the respiratory system plays an important role in thermoregulation (maintaining normal body temperature). The avian respiratory system is different from that of other vertebrates, with birds having relatively small lungs plus nine air sacs that play an important role in respiration (but are not directly involved in the exchange of gases).

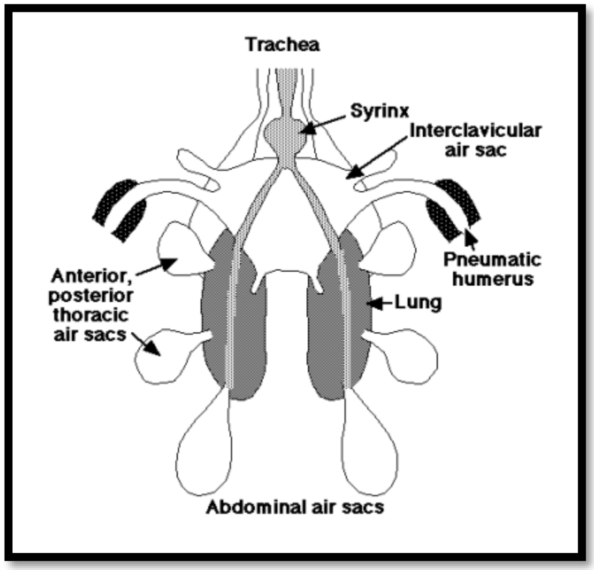
The air sacs permit a unidirectional flow of air through the lungs. Unidirectional flow means that air moving through bird lungs is largely 'fresh' air & has a higher oxygen content. In contrast, air flow is 'bidirectional' in mammals, moving back and forth into and out of the lungs. As a result, air coming into a mammal's lungs is mixed with 'old' air (air that has been in the lungs for a while) & this 'mixed air' has less oxygen. So, in bird lungs, more oxygen is available to diffuse into the blood.

The alveolar lungs of mammals (Rhesus monkey; A) and parabronchial lungs of birds (pigeon; B) are subdivided into large numbers of extremely small alveoli (A, inset) or air capillaries (radiating from the parabronchi; B, inset). The mammalian respiratory system is partitioned homogeneously, so the functions of ventilation and gas exchange are shared by alveoli and much of the lung volume. The avian respiratory system is partitioned heterogeneously, so the functions of ventilation and gas exchange are separate in the air sacs (shaded in gray) and the parabronchial lung, respectively. Air sacs act as bellows to ventilate the tube-like parabronchi (Powell and Hopkins 2004).



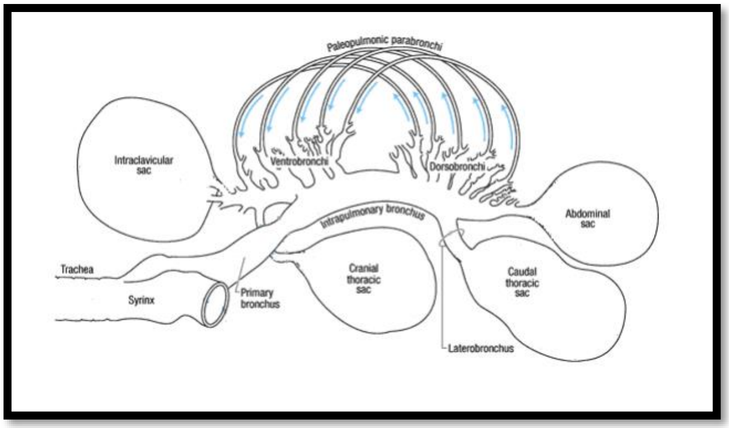
Comparison of the avian 'unidirectional' respiratory system (a) where gases are exchanged between the lungs and the blood in the parabronchi, and the bidirectional respiratory system of mammals (b) where gas exchange occurs in small dead-end sacs called alveoli (From: West et al.

Most birds have 9 air sacs: one interclavicular sac• two cervical sacs• two anterior thoracic sacs• two posterior thoracic sacs• two abdominal sacs• Functionally, these 9 air sacs can be divided into anterior sacs (interclavicular, cervicals, & anterior thoracics) & posterior sacs (posterior thoracics & abdominals). Air sacs have very thin walls with few blood vessels. So, they do not play a direct role in gas exchange. Rather, they act as a 'bellows' to ventilate the lungs (Powell 2000).



The typical bird trachea is 2.7 times longer and 1.29 times wider than that of similarly-sized mammals. The net effect is that tracheal resistance to air flow is similar to that in mammals, but the tracheal dead space volume is about 4.5 times larger. Birds compensate for the larger tracheal dead space by having a relatively larger tidal volume and a lower respiratory frequency, approximately one-third that of mammals. These two factors lessen the impact of the larger tracheal dead space volume on ventilation. Thus, minute tracheal ventilation is only about 1.5 to 1.9 times that of mammals (Ludders 2001).

The trachea bifurcates (or splits) into two primary bronchi at the syrinx. The syrinx is unique to birds & is their 'voicebox' (in mammals, sounds are produced in the larynx). The primary bronchi enter the lungs & are then called mesobronchi. Branching off from the mesobronchi are smaller tubes called dorsobronchi. The dorsobronchi, in turn, lead into the still smaller parabronchi. Parabronchi can be several millimeters long and 0.5 - 2.0 mm in diameter (depending on the size of the bird) (Maina 1989) and their walls contain hundreds of tiny, branching, & anastomosing 'air capillaries' surrounded by a profuse network of blood capillaries (Welty and Baptista 1988). It is within these 'air capillaries' that the exchange of gases (oxygen and carbon dioxide) between the lungs and the blood occurs. After passing through the parabronchi, air moves into the ventrobronchi.



Avian respiratory system showing the bronchi located inside the lungs. Dorsobronchi and ventrobronchi branch off of the primary bronchus; parabronchi extend from the dorsobronchi to the ventrobronchi. Light blue arrows indicate the direction of air flow through the parabronchi. The primary bronchus continues through the lung and opens into the abdominal air sac. Birds exhibit some variation in lung structure and, specifically, in the arrangement of parabronchi. Most birds have two sets of parabronchi, the paleopulmonic ('ancient lung') and neopulmonic ('new lung') parabronchi. However, the neopulmonic region is absent in some birds (e.g., penguins) and poorly developed in others (e.g., storks [Ciconiidae] and ducks [Anatidae]). In songbirds (Passeriformes), pigeons (Columbiformes), and gallinaceous birds (Galliformes), the neopulmonic region of the lung is well-developed (Maina 2008). In these latter groups, the neopulmonic parabronchi contain about 15 to 20% of the gas exchange surface of the lungs (Fedde 1998). Whereas airflow through the paleopulmonic parabronchi is unidirectional, airflow through the neopulmonic parabronchi is bidirectional. Parabronchi can be several millimeters long and 0.5 - 2.0 mm in diameter (depending on the size of the bird) (Maina 1989) and their walls contain hundreds of tiny, branching, and anastomosing air capillaries surrounded by a profuse network of blood capillaries.

Respiratory System in Mammals

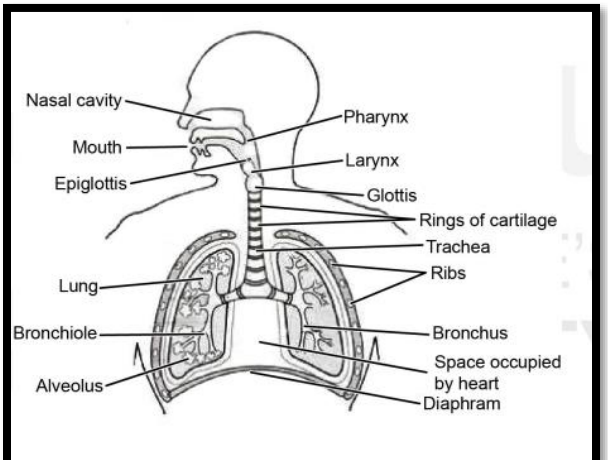


Fig. 4.25: The respiratory system of humans

Mammals have a pair of lungs enclosed in a thoracic cavity. The bony framework of the thoracic cavity is formed of thoracic vertebrae, ribs and sternum. The lungs of the mammals are multi-chambered and usually divided into lobes. Usually the right side has more lobes than the left side. Humans have three right and two left lobes. Figure 4.25 shows the respiratory organs of humans. The air from outside enters through the external nostrils and nasal passages into pharynx. From the pharynx it passes through the glottis into trachea. The trachea is a long tube that traverses the neck and lies ventral to gullet. The anterior part of the trachea is enlarged to form the voice box or larynx. The vocal chords are located inside the larynx and the vibrations of the vocal chords results in the production of the sound. The trachea bifurcates into two primary bronchi. Each primary bronchus enters into lungs and branches into secondary and tertiary bronchi, and finally into bronchioles. Terminal bronchioles lead into thin walled delicate alveolar ducts, the walls of which are evaginated to form clusters of alveoli. The lungs are protected and cushioned by the pleura. The pleura is made of two thin layers of tissue: a) the inner layer (visceral pleura) which wraps around the lungs and is stuck so tightly to the lungs that it cannot be peeled off, and; b) the outer layer (parietal pleura) which lines the inside of the chest wall. The pleura prevent the lungs from separating from the rib cage. The very thin space between the layers is called the pleural cavity. A liquid, called pleural fluid, lubricates the pleural cavity so that the two layers of pleural tissue can slide against each other as the lungs inflate and deflate during respiration.

In mammals buccal cavity plays no role in respiration, and the diaphragm and ribs play an important part. You can see in Figure 4.26, that during inhalation the rib muscles (external intercostal muscles extend between the ribs) and diaphragm contracts causing the raising of the ribs and flattening of the diaphragm increasing the size of the thoracic cavity. The pressure decreases and the air enters into lungs. The entire process constitutes inspiration. Expiration is a passive process, brought about by the relaxation of the intercostals muscles and the diaphragm. The thoracic cavity is brought to its normal size and as a result the air is forced out.

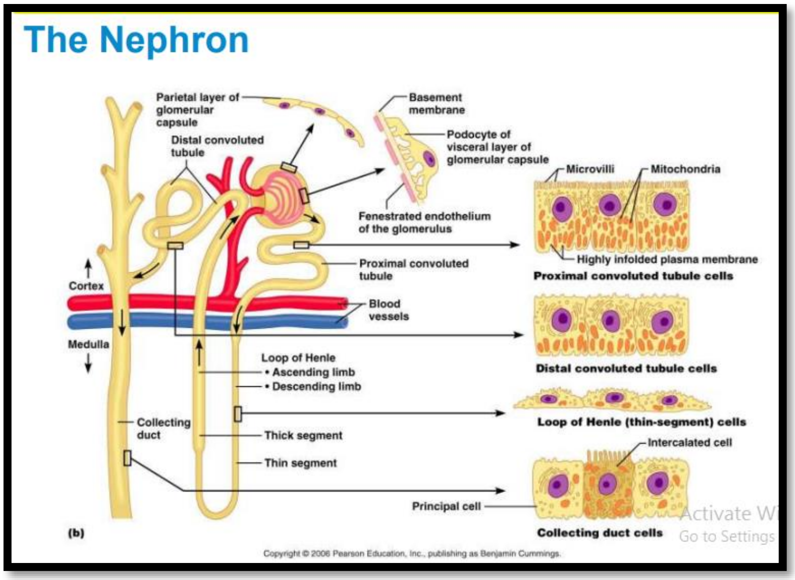
The alveoli are separated by thin wall vascularised, septa that measure 50µm in shrews and bats as they have a high metabolic rate and is as much as 1mm in sirenians (manatees and dugongs) that are more placid. The alveolar surface is covered by certain, Type I alveolar cells where gas exchange

Urinary System

Urogenital System - “Functionally, the urogenital system can be divided into two entirely different components: the urinary system and the genital system. Embryologically, and anatomically, however, they are intimately interwoven. Both develop from a common mesodermal ridge (intermediate mesoderm) along the posterior wall of the abdominal cavity, and initially, the excretory ducts of both systems enter a common cavity, the cloaca. With further development, overlapping of the two systems is particularly evident in the male. The primitive excretory duct first functions as a urinary duct but later is transformed into the main genital duct. Moreover, in the adult, the urinary and the genital organs discharge urine and semen through a common duct, the penile urethra” (“Medical Embryology”, Langman, 1995).

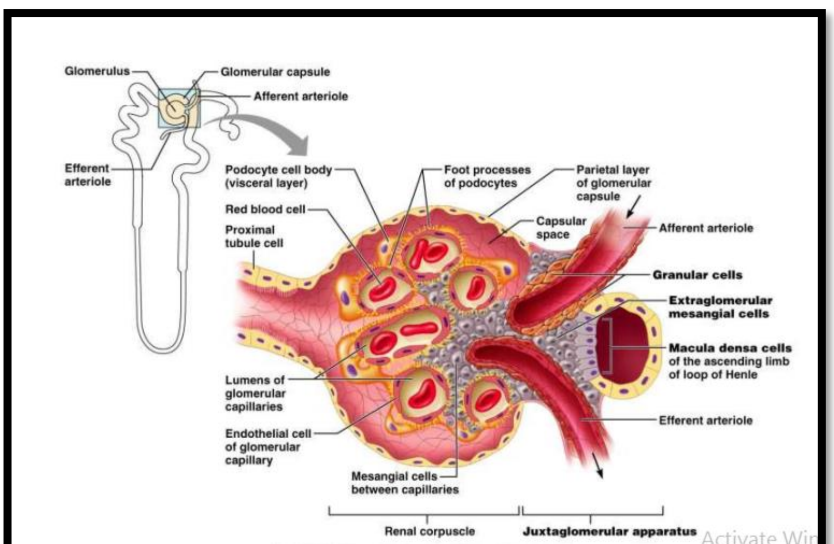
Anatomy of the urinary System kidneys – a pair of bean – shaped organs located♣ retroperitoneally , responsible for blood filtering and urine formation. Renal capsule – a layer of fibrous connective tissue covering♣ the kidneys. Renal cortex – outer region of the kidneys where most♣ enthrones is located . Renal medulla – inner region of the kidneys where some♣ enthrones is located , also where urine is collected to be excreted outward . Renal calyx – duct – like sections of renal medulla for♣ collecting urine from nephrons and direct urine into renal pelvis.

Renal pyramid – connective tissues in the renal medulla binding various structures together . Renal pelvis – central urine collecting area of renal medulla .♣ Hilum – concave notch of kidneys where renal artery, renal vein,♣ ureter , nerves ,and lymphatic vessels converge . Ureter – a tubule that transport urine (mainly by peristalsis) from♣ the kidney to the urinary bladder . Urinary bladder – a spherical storage organ that contains up to♣ 400 ml of urine . Urethra – a tubule that excretes urine out of the urinary bladder to♣ the outside , through the urethral orifice



Juxtaglomerular Apparatus

The JG apparatus is located at the point of contact between the♣ distal convoluted tubule and the afferent and efferent arterioles . In its convolutions , the DCT comes into very close contact♣ with the afferent arterioles . At this point the cells in the afferent arteriols are more♣ numerous, forming a cuff , and are called JG cells these are mechanoreceptors that detect changes in Blood pressure in the afferent arterioles , and secrete renin. The distal convoluted tubule cells contacting these JG cells♣ are called macula densa (chemo or osmoreceptors) that respond to changes in the solute concentration of the filtrate , in the tubule .



Glomerular Filtration a. urine formation begins when waste and water and dissolved♣ materials are filtered out of the glomerular capillary . Urinary excretion = glomcrular filtration + Tubular secretion –♣ tubular reabsorption b. the glomerular capillaries are much more permeable than the♣ capillaries in other tissues . Filtration pressure = Forces favoring filtration (Glomerular♣ capillary hydrostatic pressure & capsular osmotic pressure) – forces opposing filtration (capsular hydrostatic pressure & Glomerular capillary osmotic pressure). Thus, filtration pressure is the net force acting to move material out♣ of glomerulus and into the glomerular capsule .

Succession of kidney in different vertebrate groups and evolution of urino-genital ducts

A uriniferous tubule has the following parts: (i) A ciliated peritoneal funnel near the proximal end of the tubule which opens into the splanchnocoel by a nephrostome or coelomostome (often the peritoneal funnel itself is called a nephrostome). (ii) A convoluted ciliated tubule opening into a longitudinal collecting duct, and a Malpighian body or renal corpuscle.

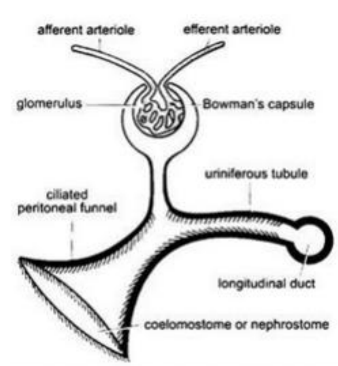


Fig.1) Structure of Embryonic Kidney Tubule

The Malpighian body has a double-walled Bowman's capsule, enclosing a network of interarterial blood capillaries, called glomerulus where filtration of blood takes place. Bowman's capsule and glomerulus together form the Malpighian body or renal corpuscle. An afferent arteriole brings blood into the glomerulus and an efferent arteriole takes blood away from it. Then the efferent arteriole breaks up into capillaries along the entire course of the uriniferous tubule and finally the blood goes to a renal vein.

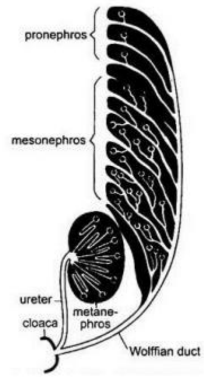
Encapsulated glomerulus is internal glomerulus which is common. The glomerulus without a capsule suspended freely in the coelomic cavity is called external glomerulus which is found in embryos and larvae. Malpighian bodies with glomeruli are lacking in some fishes, embryos and larvae and their kidneys are called aglomerular. In an adult the uriniferous tubules are elongated and coiled, so that their segmental arrangement is lost and they become enclosed in a connective tissue capsule to form a kidney.

Archinephros: The ancestral vertebrates had a pair of kidneys running through the entire length of the coelom. Each had segmentally arranged tubules; one pair per body segment. Each tubule opened separately into the coelom by a peritoneal funnel and nephrostome. Near each funnel was an external glomerulus (without capsule) suspended in coelom. All the tubules of each kidney opened into a common longitudinal duct (Wolffian or archinephric duct) which joined the cloaca. This kidney is called an archinephros or holonephros and its duct is an archinephric duct. Among the living vertebrates an archinephros is found only in the larval Myxine and some apodan amphibians. In present-day vertebrates the uriniferous tubules develop antero-posteriorly in two or three stages in succession, these stages are pronephros, mesonephros and metanephros. These stages have evolved from the original archinephros.

1. **Pronephros:**

   Pronephros is the most primitive and while present in the embryonic development of all vertebrates, is functional in the adult of none. Some larval cyclostomes, however, have a kidney, part of which appears to be homologous to the embryonic pronephros of higher vertebrates. Pronephros develops in the anterior-most part of the nephrotome. There are only 3 to 15 uriniferous tubules in each, one pair to each segment. Near each tubule is a glomerulus projecting into the coelom, which is not connected with the tubule is the external glomerulus. Each tubule opens into coelom by a funnel or nephrostome.

   The uriniferous tubules of each pronephros open into a common pronephric duct which grows back to enter the embryonic cloaca. In some, there is a large pronephric chamber which surrounds the glomus (all glomeruli) and tubules. All glomeruli project into the pronephric chamber where they may unite to form a single compound glomerulus called glomus. Pronephric chamber is derived from pericardial or pleuroperitoneal cavity. All the tubules of a pronephros open into a common pronephric duct opening posteriorly into the embryonic cloaca. A pair of pronephroi appear in all vertebrate embryos but they become functional kidneys only in some cyclostomes and embryos of all anamniotes. In others they degenerate during development but the pronephric ducts persist. Pronephros is replaced by mesonephros. In those vertebrates in which pronephroi become adult kidneys, they are called head kidneys due to its anterior position behind the head.

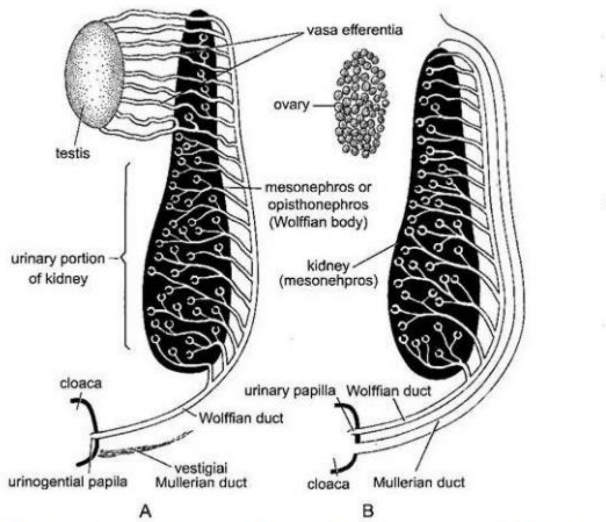


4) A plan of pronephros mesonephros metanephros

2. **Mesonephros:** Mesonephros develops from the middle part of the nephrotome behind the pronephros which degenerates. At first it consists of paired segmental uriniferous or mesonephric tubules, each with a peritoneal funnel opening into the coelom and internal glomerulus enclosed in a Bowman's capsule both are collectively called renal corpuscle. These mesonphric uriniferous tubules join the existing pronephric duct or archinephric duct on each side, which with the disappearance of pronephros is called a mesonephric duct or Wolffian duct.

   Later the mesonephric tubules undergo budding to form hundreds of tubules, so that their segmental arrangement is lost. The mesonephric tubules are coiled or convoluted both proximally and distally and lead into a common longitudinal collecting duct the archinephric duct. This in turn leads to the outside, usually by way of the cloaca. Water, salts and waste products from the blood stream pass into the capsule and then may flow through the tubule to the mesonephric duct (original archinephric duct) and ultimately out of the body. In sharks it functions as a gonadial duct and the kidneys have developed new accessory urinary ducts. The mesonephric tubules have no peritoneal funnels.
   Mesonephroi form the adult functional kidneys in some cyclostomes, fishes, amphibians and the embryos of amniotes in which they degenerate in the adult. The mesonephroi of amniote embryos lack peritoneal funnels, except in monotremes. The mesonephros of anamniotes is not exactly equivalent to that amniote embryos. In anamniotes the mesonephros extends throughout the length of thecoelom behind the pronephros and is formed from the entire nephrotome behind the pronephros and is functional both in embryos as well as in adults.
   While in adults anurans, urodeles and amniote embryos the mesonephros is formed only from the middle part of the nephrotome and it does not extend throughout the length of the coelom. In sharks and caecilians, the kidney is opisthonephros, i.e., mesonephric tubules extend posteriorly throughout the length of the coelom.

The amphibian kidneys, like those of fishes, are of the opisthonephric type. In tailed amphibians the kidneys are rather elongate structures as in elasmobranchs, but in anurans there is a tendency for these structures to be short and compact Renal corpuscles are large to assist in the elimination of water and, thus, prevent excessive dilution of the body fluids. In some amphibians the archinephric duct is both genital and excretory in nature in the male, whereas in others the archinephric duct serves only for the transport of sperms, and the kidney is drained by a new duct, somewhat comparable to the ureter of higher vertebrates.



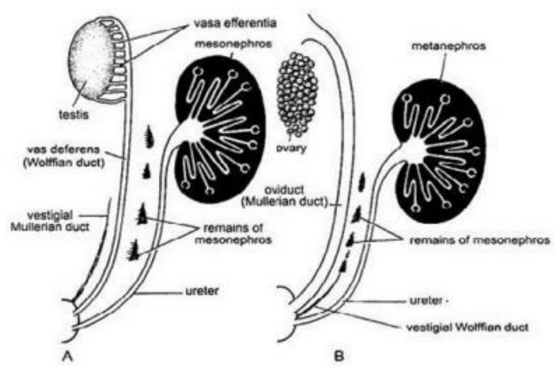
6) Plan of the kidney and genital ducts in anamniotes A. Male B. Female

The kidney of marine fishes, play a major part in maintaining the proper balance with in the body. Salt water tends to dehydrate the body, which is only slightly saline, and it also increases the salt concentration in the body. Freshwater has the opposite effect. Some marine bony fishes have salt-excreting glands on the gills which help to eliminate excessive salt. Most marine fishes, however, other than elasmobranchs, have the renal corpuscles very small so as to reduce water loss. Since the corpuscle is the filter, the smaller it is the less filtrate passes through. The renal corpuscles are much larger in freshwater fishes than in marine species. This means more liquid output, which is necessary to prevent overdilution of the body fluids. Elasmobranchs, unlike most marine fishes, have large renal corpuscles.

3. **Metanephros:** Metanephros is the functional kidney, develops only in amniotes. It is formed from the posteriormost part of the nephrotome behind the embryonic mesonephros which is displaced somewhat anterior and lateral. During embryonic life, however, both pronephros and mesonephros make their appearance. The metanephros fundamentally resembles the mesonephros, but arises more posteriorly in the body, is more compact and contains a few greater number of renal units. Furthermore, the renal tubules, instead of draining into the archinephric duct open

into larger collecting tubules which ultimately lead to a new excretory duct called the ureter.

Metanephric has a double origin, a tubular outgrowth arises from the base of mesonephric duct near the cloaca and it grows anteriorly and dorsally and eventually the metanephric tubules open into it. Its distal end dilates to form the pelvis which divides several times to form collecting tubules, while its proximal part becomes the ureter or metanephric duct. The nephrotome gives rise to metanephric uriniferous tubules of which there are thousands with no segmental arrangement. The metanephric tubules become long and much coiled and have glomeruli enclosed in Bowman’s capsules but they lack peritoneal funnels so that all connection with the coelom is lost. Metanephroi are the functional kidneys of adult amniotes and they have achieved the separation of the urinary function from the genital function which appears to be the trend in the evolution of the urinogenital system. In metanephros, the metanephric tubules are much convoluted, and a thin U-shaped loop of Henle is formed in between proximal and distal convolutions of the tubule.



7) Plan of the kidney and genital ducts in amniotes A. Male B. Female

Urinary Bladder: In most vertebrates there is a bag-like urinary bladder serving as a reservoir for urine. In some fishes the bladder is formed by an enlargement of the terminal parts of mesonephric ducts and is used for temporary storage of urine. In amphibians the urinary bladder is derived as a diverticulum from the ventral wall of the cloaca, and not from the proctodaeum, it is lined with endoderm and is called a cloacal bladder. Urine, thus, first pass from the ducts of the kidneys into the cloacal chamber. From here it is then forced into the bladder for storage. Many reptiles also possess urinary bladder, like that of amphibians, is an outgrowth from the ventral wall of cloaca. It is lacking in crocodilians, snakes and some lizards. The only bird known to possess a bladder is the ostrich. In embryos of amniotes a large bag-like allantois arises from the hindgut.

It serves as an excretory and respiratory organ, in hatching or at birth the allantois is lost but its basal part persists and along with a portion of the cloacal wall it becomes the adult urinary bladder which is endodermal, and is called an allantoic bladder. Generally the kidney ducts (ureters) do not open into the urinary bladder but open dorsally into the cloaca, except in mammals. In mammals, except monotremes, the ureters open directly into the bladder that opens outside through a short, narrow tube the urethra. Cloaca is not found in mammals except monotremes