CHAPTER FIVE
Urogenital System

Genital system keep the species, on other hand, the **urinary system** is devoted to quite different function: namely, to the elimination of waste products, primarily amonia and to the regulation of water and electrolyte balance. Although urinary and reproductive systems functions are quite different, most textbooks treat both systems together and considered them as a single system, the **urogenital system**. The reasons of grouping these two systems together, in spite of their variation in function, are: **i.** their proximity to each other; **ii.** both may use common pathways or ducts; **iii.** initially and even in most classes the excretory ducts of both systems enter a common cavity, the cloaca **iv.** originally, urinary and reproductive organs arise from the same or adjacent tissues, the mesoderm which extends along the posterior wall of the abdominal cavity, thus they maintain in close anatomical association throughout the organism's life. According to the priority in importance for the life of the organism, the urinary system begins to develop firstly and after a certain degree of function already exists within the developing urinary system, does the genital system appear.

Anatomically, the urinary system includes the primary organs, the **kidneys** and the **ducts** that carry away their product, urine. The genital system includes the primary sex organs, the **gonads** (testes, sing. testis and ovaries sing. ovary) and their **ducts** that carry away the products they form, sperm or eggs.

Urinary or Excretory System

Some of the products of metabolism cannot be utilized as sources of energy. They are called end products of metabolism, or **waste**, and must be eliminated. Among the waste products of metabolism are **carbon dioxide**, **urea**, **ammonia**, **uric acid**, **creatinine**, various **pigments** and **inorganic salts**. Carbon dioxide is eliminated, for the most part, through the gills in aquatic forms, through the skin and lungs in amphibian and through the lungs in terrestrial vertebrates. The remaining substances are excreted almost entirely through what are called the **excretory** or **urinary organs**. In certain fishes nitrogenous and other wastes may be excreted in considerable quantity by way of gills. In human small amounts may be eliminated through the sweat glands. Most excretory substances are in solution in water called urine. Water itself is not considered to be a waste product, but any excess is eliminated along with substances dissolved in it. The organs which in vertebrates eliminate the urine are called **kidneys**. All parts of the excretory system in vertebrates except certain structures near the terminal duct openings are mesodermal in origin and derived from embryonic mesoderm.

To understand urinary system we must know what is the meaning of the following organs and how formed:
Mesoderm, mesomere, nephric ridge, renal tubules (nephrons), archinephros, pronephros, glomerulus pl. glomeruli, external glomerulus, nephostome, mesonephros, internal glomerulus, metanephros, vertebrates' developmental stages which bear each type of kidney (location). Supplement structures for kidney or extrarenal excretion and types of urinary bladders.

Embryonic development of nephric or renal tubules (nephrons)

The kidneys form within the intermediate mesoderm (mesomere) (Fig.1) located in the dorsal and posterior body wall of the embryo.

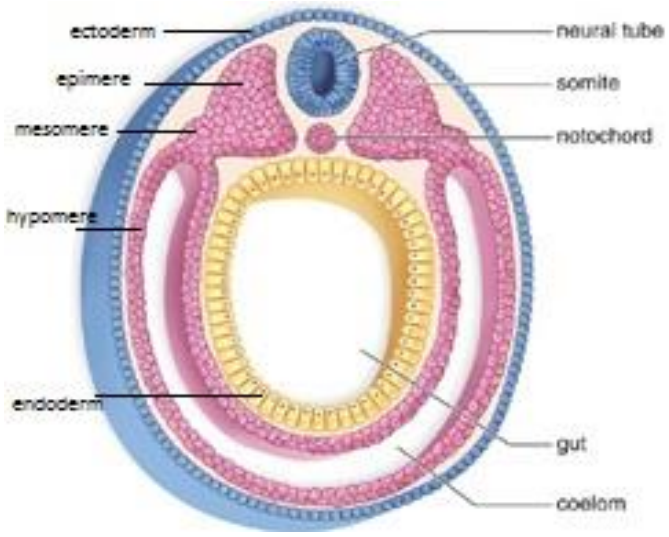

FIGURE 1: Vertebrate embryo, cross section, showing 3 germ layers: ectoderm, mesoderm and endoderm, with 3 parts of mesoderm: epimere, mesomere and hypomere.

Kidney organization

Although, in a wide view, the complete series of tubules, which are derived from mesomere, may be regarded as constituting a single kidney, in living vertebrates it does not develop at once, but in three stages or phases which are termed the **pronephros**, **mesonephros** and **metanephros** respectively. Tubules forming these three types of kidneys arise in one of three regions of **nephric ridges**, protruded part of intermediate mesoderm: anterior region (pro-), middle region (meso-) or posterior region (meta-), note the Fig. 2 with following details.

(a). Tubules forming pronephros arise in the anterior part of the nephric ridge, these tubules produce a **pronephric duct** that grows posteriorly in the nephric ridge and empties into the cloaca. The pronephros is the first kidney arises during embryonic development.

(b). Tubules of the mesonephros arise in the middle of the nephric ridge and tap into the existing pronephric duct, now appropriately renamed the **mesonephric duct**. The mesonephros is usually the embryonic and transient kidney.

(c). Metanephros, type of kidney, sprouting from the mesonephric duct in form of diverticulum called uretic diverticulum which later on called the **ureter**. Uretic diverticulum grows into the posterior section of the nephric ridge where it stimulates differentiation of tubules that form the metanephros. In males, the mesonephric duct remain and usually takes over the task of sperm transport and is called the **vas deferens**. In the female, the mesonephric duct degenerates.

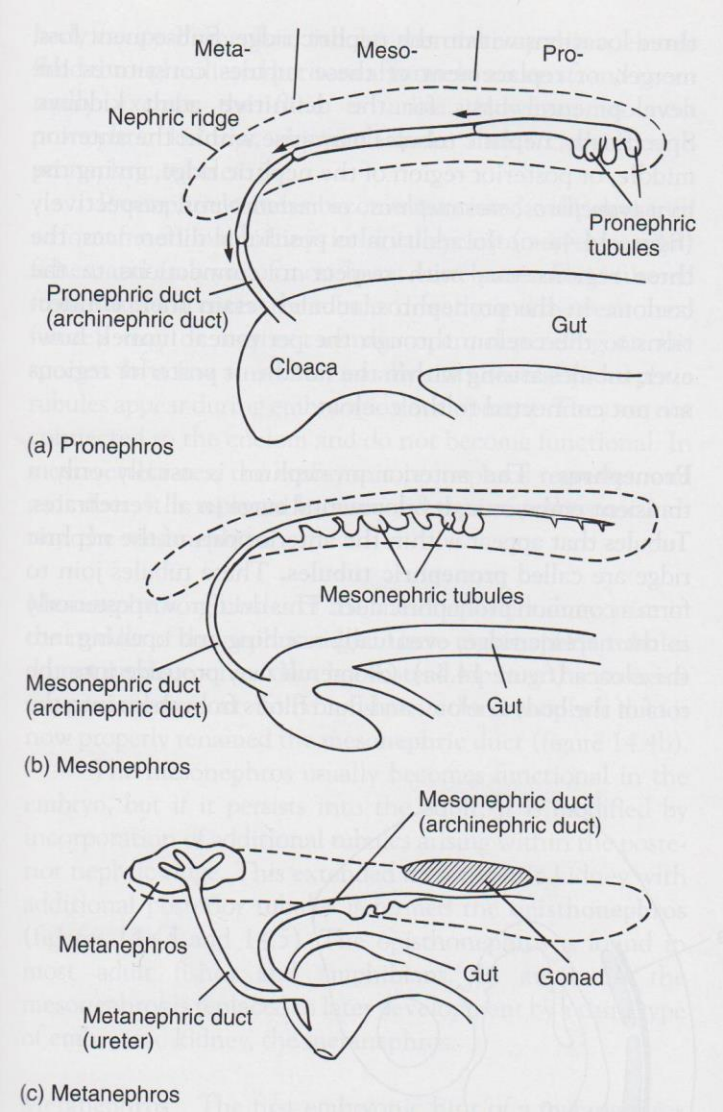

FIGURE 2: Development of the main 3 types of kidneys, of modern vertebrate, from the ribbon of intermediate mesoderm, in succession and antero-posteriorly.

Types of kidneys

Starting from primitive vertebrates till mammals, four types of kidneys are distinguished (Fig.3):

1. Archinephros. It is the name given to the hypothetical primitive kidney of ancestral vertebrates. It may be regarded as a complete kidney or holonephros as it extended the entire length of the coelom. Its ***tubules*** were segmentally arranged, one nephrone for each body segment. Each tubule opened by a peritoneal funnel or ***nephrostome*** into coelom. Near each nephrostome was suspended in coelom an ***external glomerulus*** (without capsule). All the tubules were drained by a common longitudinal ***archinephric duct*** opening behind into cloaca. Such hypothetical archinephros is found today in the **embryo of certain agnathans (*Myxine*), but not in any adult vertebrate.**

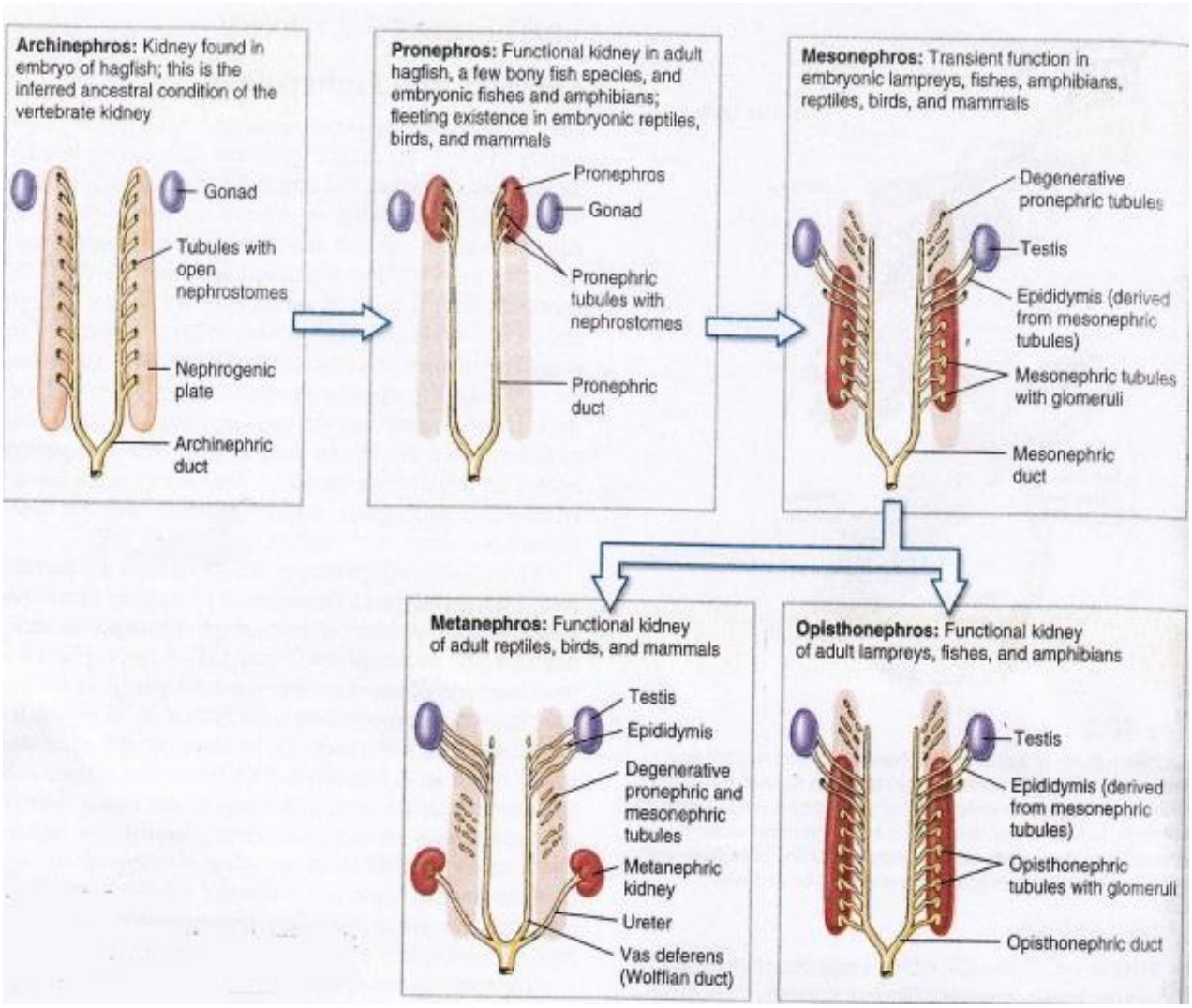

FIGURE 3: Four types of male vertebrate kidneys. Red color, functional structures. Light red color, degenerative or undeveloped parts.

2. Pronephros. This type of kidney is firstly appeared among other types so named pronephros. It is composed of ***pronephric tubules*** which are joined to form a common ***pronephric duct*** which in turn grow posteriorly in the nephric ridge to opens into the cloaca. Also projecting into coelom near each tubule and not connected with it is an ***external*** or ***naked glomerulus*** without capsule. In some cases, glomeruli unite to form a single compound glomerulus, called ***glomus***. Fluid filters from glomeruli into the body cavity, pronephric tubules then take up this coelomic fluid through ***ciliated peritoneal funnels or nephrostome***, act on it, and eventually excrete the fluid as urine. However, in most pronephric kidney, glomeruli make direct contact with pronephric tubules.

Pronephric tubules become associated with glomeruli to form **functional** kidneys in larval agnathans, some adult fishes and embryos of the most primative vertebrates (fishes and amphibians). A pronephrose consists of 3 to 15 tubules segmentally arranged, one opposite each of the anterior mesodermal somites. There are only 3 pronephric tubules in frog embryo, 7 in human embryo. In a few amniotes, usually only several pronephric tubules appear during embryonic development. They are not connected to the coelom and do **not become functional**. In most vertebrates, the embryonic pronephros regresses, and as it does, it is replaced by a second type of embryonic kidneys, the mesonephros.

3. Mesonephros. In the embryo, a mesonepros develops from the middle part of intermediate mesoderm, posterior to each pronephros soon after its degeneration. The ***mesonephric tubules*** do not produce a new duct but they join the preexisting pronephric duct. To be consistent, the pronephric duct is now properly renamed the ***mesonephric duct***. Later on the tubules multiply by budding so that their segmental arrangement is disturbed due to increased number of tubules per segment.

Mesonephros is functionally better than pronephros because mesonephric tubules are more numerous, longer and develop ***internal glomeruli*** enclosed in capsules, each capsule is a modification from the anterior end of mesonephric tubule in a form of double walled cup-shaped structure, lodge glomerulus, and called ***Bowmann's capsule***, this capsule and enclosed glomerulus together form a ***renal corpuscle***. In this case the tubules remove liquid wastes directly from glomerulus blood rather than indirectly from coelomic fluid as in case of a pronephros. The mesonephros usually becomes functional in the embryo, but if persists into the adult, it is modified by incorporation of additional tubules arising within the posterior nephric ridge. This extended mesonephric kidney with additional posterior tubules is termed **opisthonephros**. It is found in most adult fishes and amphibians. In amniotes, the mesonephros is replaced in later development by a

third type of embryonic kidney, the metanephros which retains throughout their life.

4. Metanephros. The ***metanephric duct*** that appears as a uretric diverticulum arising at the base of preexisting mesonephric duct. The uretric diverticulum grows dorsally into the posterior region of the nephric ridge. Here it enlarges and stimulates the growth of ***metanephric tubules*** that come to make up the adult kidney of amniotes, and the metanephric duct is usually called the ***ureter***. The adult kidney (metanephros) of amniotes differs from that of anamniotes (mesonephros or opisthonephros) chiefly in:

i. In greater multiplication and posterior concentration of nephrons or tubules. They are particularly very large in number and highly convoluted in birds and mammals. It is estimated that each kidney of man is composed of about one million nephrons.

ii. Metanephric duct is budded off from mesonephric duct. It grows anteriorly and dorsally, and eventually the metanephric tubules open into it. Its dilated distal tip forms pelvis which forks several times to become the collecting tubules. Its proximal portion becomes metanephric duct or ureter that empties into cloaca or urinary bladder in mammals.

iii. As the kidney evoluted it deviated toward the posterior region of the abdominal cavity, so metanephric kidneys shows more deviation toward posterior region and lie pelvic region.

iv. The mammalian metanephros shows greatest organization of all, with several additional features, as shown in the following discussion.

Mammalian kidney and its functional unit (nephron)

The kidneys lie in the posterior abdominal wall, one on each side of the vertebral column with left kidney being slightly lower than right, embedded in fat, behind the peritoneum. A thin fibrous ***capsule*** covers each kidney. Adrenal glands are at the upper part of each kidney. Below the capsule of the kidney, seen on cut section, is the outer part ***cortex*** and inner part the ***medulla***. The medulla is made up of few medullary ***pyramids***, the inner portion of each pyramid, in the form of a blunt ***papilla***, projects into the outpocketing of the ***pelvis*** known as a ***minor calyx***. Several minor calyces join together to enter ***major calyx***, which in turn open into pelvis. The pelvis leads to ureter (Fig. 4), which empties into bladder, if present, or cloaca.

Nephron (from Greek, nephros, meaning "kidney") is the basic structural and functional unit of the kidney. The nephron is tubule which is closed at one end where it engulfs a tuft of capillaries, called the ***glomerulus***. The glomerulus is a capillary tuft that receives its blood supply from an afferent arteriole of the renal artery that enters the kidney from its hilum region. The glomerulus is surrounded by the close, invaginated, and cup-shaped end of the nephron or ***renal tubule*** forming ***Bowman's capsule***, this capsule with its internal content, glomerulus, they are together called renal or ***Malpighian corpuscle***. In humans, a normal kidney contains 800,000 to 1.5 million renal corpuscles and excretory tubules (nephrons). Bowman's capsule with two layers (Fig.5), the inner one surrounds the glomerulus, called ***visceral layer*** and the outer one is called ***parietal layer***, which is continuous with the next part of the nephron, the ***proximal convoluted tubule***. The two layers enclose a space, where filtered fluid is formed.

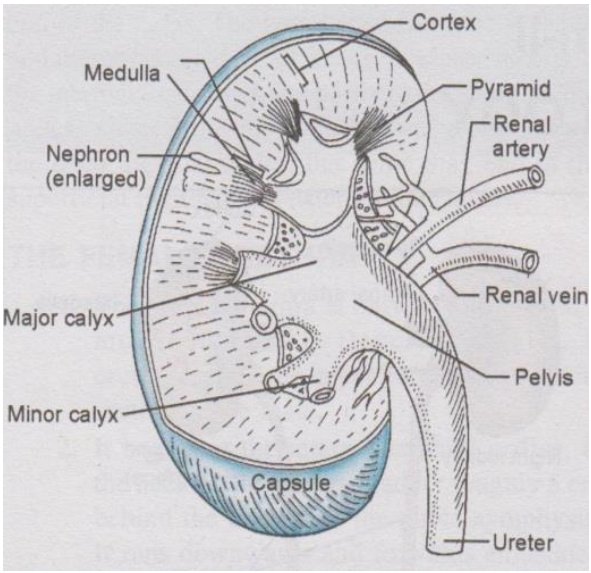

FIGURE 4: Gross structure of the mammalian kidney.

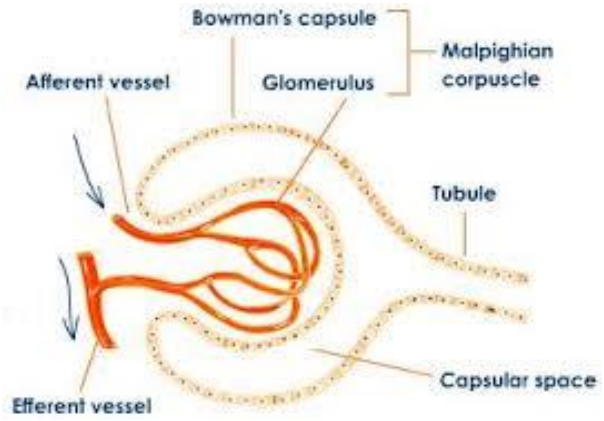

FIGURE 5: Renal or Malpighian corpuscle, composed of tuft of blood capillaries (glomerulus) encircled by Bowman's capsule.

The afferent arteriole carries blood into the glomerular capillaries and capillaries unite to form efferent arteriole which leaves the capillary tuft. Hence the glomerular capillaries are present between two sets of arterioles unlike at other sites where capillaries drain into venules; as a result the hydrostatic pressure is high in glomerular capillaries than elsewhere in the body.

The proximal convoluted tubule (PCT) is highly convoluted and is present in the cortex. It continues as descending limb of ***loop of Henle*** which dips down into the medulla of the kidney then forms the ascending limb of the loop of Henle which ascend to reach the cortex forms the ***distal convoluted tubule*** (DCT), which is present in the cortex of kidney.

The glomeruli are present only in the cortex of the kidney. Those glomeruli which are present in the superficial region of the cortex have short loops of Henle; other glomeruli that are present deep in the cortex at the junction of the cortex with medulla have long loop of Henle (Fig. 6).

The distal convoluted tubule opens into a ***collecting duct***. The kidney tubules are thin tubules consisting of single layer of epithelium. The collecting ducts pass through the cortex and then through the medulla and are ***aggregated into pyramids*** to which they give a striated appearance, in some mammalian kidney the numbers of pyramid may reach 20. The base of each pyramid is positioned at the corticomedullary boundary, and the apex extends toward the renal pelvis to form a papilla. On the tip of each papilla are 10 to 25 small openings that represent the distal ends of the collecting ducts (of Bellini) through which urine from the collecting tubules enters the calyx then to the ureter.

Shapes of metanephric kidneys

The metanephric kidneys of birds are lobed structure and lie against the sacrum and ilium. The metanephros of mammals show marked lobation in the embryo. In many forms this condition is retained throughout life as in cows, so as in some lizards (Fig. 7). In others the lobation is not superficially apparent in the adult and the kidney surface is relatively smooth. The kidneys of snakes, legless lizards, and apodans are elongated, conforming to the slender body.

The kidneys of rabbit and most other mammals are smooth and bean shaped. The pelvis of the rabbit kidney is concaved centrally so has two lateral processes and the single pyramid opened in this invagination (Fig. 8).

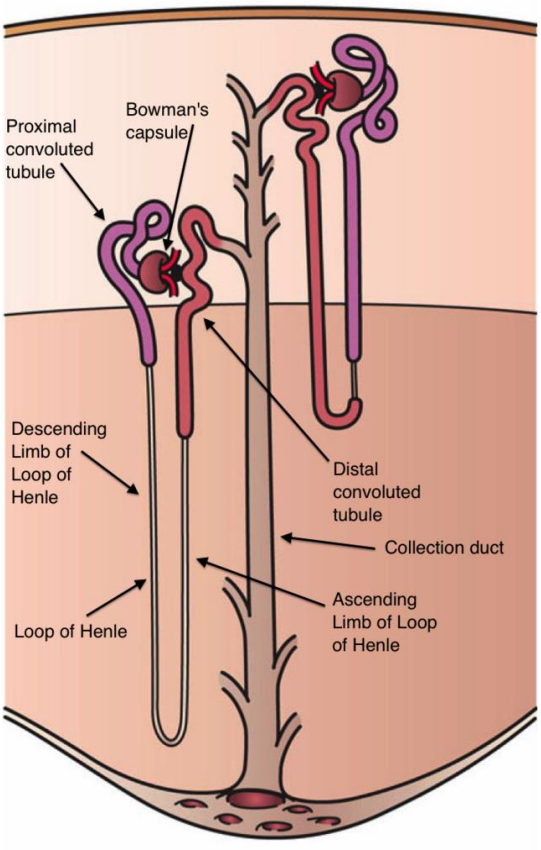

FIGURE 6: Structure of the mammalian nephron.

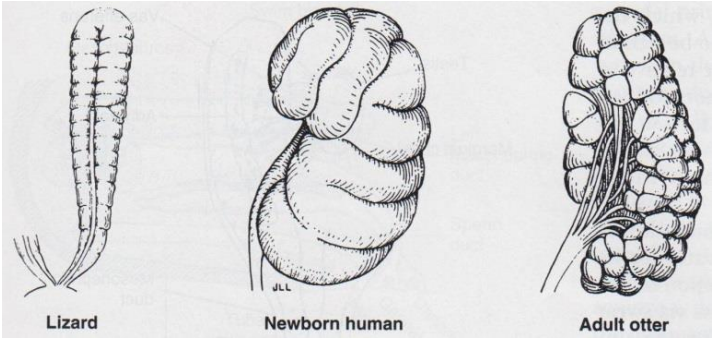

FIGURE 7: Lobulated metanephric kidneys.

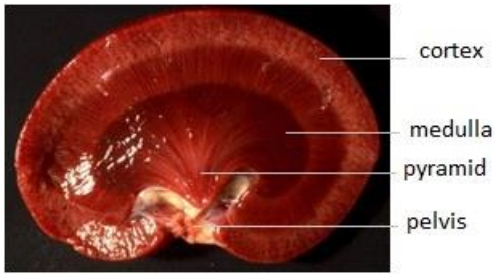

FIGURE 8: Horizontal section through rabbit kidney, which has one pyramid lodged in the concavity of the pelvis.

Extrarenal salt excretion

Craniates that live in an environment laden with salt or that inhabit arid environments and can afford little body water for carrying away accumulated salts have external structures that supplement the kidneys in this role.

i. Marine teleosts have **chloride-excreting glands** on the gills.

ii. Elasmobranchs have **chloride-excreting rectal glands** that utilize little water and empty into caudal end of intestine, hence the rectal glands of bull sharks caught in freshwater are smaller than those caught in salt water.

iii. The salt-excreting glands of lizards are located below the orbits just external to the olfactory capsule, and their ducts empty into the nasal canals. Whitish incrustations of sodium chloride and potassium can be seen at the nostrils.

iv. Those of marine birds are **salt-excreting glands** are large and are located above each orbit. Their long ducts open at the base of the beak just lateral to the nostrils. A groove on the beak extends from this opening to the tip of the beak. Within 15 minutes after these birds have drunk water containing sodium and potassium salts, minute drops of fluid containing these rickle down the groove and drip or are shaken off the beak (Fig. 9).

v. The salt glands of sea turtles open into the orbit, those of sea snakes open into the oral cavity in the fashion of salivary glands.

vi. The mucous coat of hagfishes, which inspired the name slime eels, has been shown to be rich in salt. It may be that integumentary **mucous glands** play a primary role in osmoregulation in those agnathans.

vii. Sweat glands in mammals eliminate salt . In fact, salt lost by this route, unless in excess in the tissues, must be replaced by dietary salts.

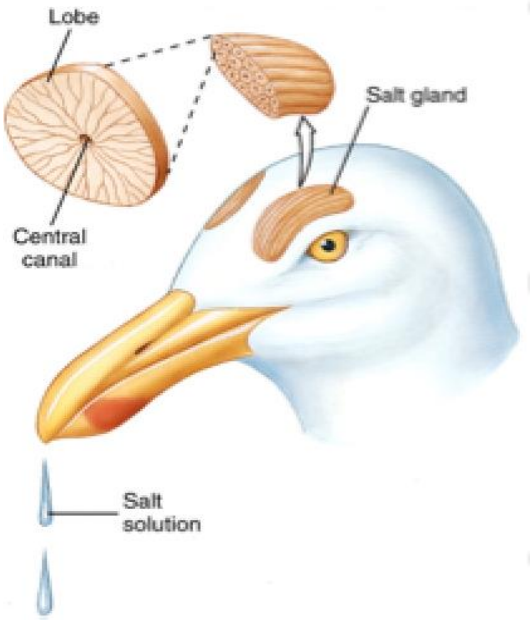

FIGURE 9: Excretion of excess salt from the blood of marine bird through salt glands.

Urinary bladders.

Urinary bladders are, mostly considered as, adaptation to life on land. They serve as reservoirs for water that may be needed later and therefore should not be wasted. It is lacking in agnathans, elasmobranchs, some lizards, snakes, crocodilians and most birds. In most fishes, if present, it is simply a terminal enlargement of mesonephric ducts and called a **tubular bladder**. In dipnoi (lungfishes), it evaginates from dorsal wall of cloaca that has been called a urinary or **cloacal bladder**. In amphibians, it evaginates from the ventral wall of cloaca and also called **cloacal bladder**. In amniotes, the adult bladder is derived from the proximal part of embryonic allantois which is an evagination from the cloaca of the embryo, hence called an **allantoic bladder**. Some freshwater turtles have voluminous bladders, and sometimes, **accessory bladders** that are used by females to carry water for softening and moistening the soil when a nest is being prepared for eggs.

Kidneys ducts or ureters generally open dorsally into cloaca. But in mammals, except, monotremes, the ureter leads directly into the urinary bladder. In first case the cloaca fill with urine and then ascend to urinary bladder.

Reproductive or Genital System

Sexual, or gamic, reproduction is the rule in the phylum Chordata. The sexes of all the selected species, for the comparative study in this textbook, are separate (dioecious). Among vertebrates, hagfishes and few bony fishes are hermaphrodites.

The reproductive system includes the **gonads**; **their products the gametes** (sperm in males and ova in females; and the **ducts** that transport the gametes. Reproductive hormones facilitate sexual behavior and parental care; prepare the reproductive ducts to receive the gametes; support the zygote. The gonads which are male testes (singular, testis) and female ovaries (singular, ovary) , together are considered ***primary sex organs***, while the reproductive ducts, associated glands and intromittent organs are known as ***accessory*** or ***secondary sex organs***. In some species it may be easy for us to distinguish male from female due to their variation in some morphological characters or in color. These two types of variations are called sexual dimorphism and sexual dichromatism respectively and all the morphological features which lead to these two types of sex variation are considered as ***secondary sex characters***, which are not directly concerned with sex. Sexual differences in such secondary sex characters as ornamental plumage, body size and strength, and vocal apparatus are but indirectly related to reproduction. The development, maintenance and function of the accessory sex organs and secondary sex characteristics are controlled, at least in part, by the endocrine secretions of the gonads.

Embryonic development of gonads and gametes

The paired gonads arise from the **genital ridge**, initially a thickening in the splanchnic mesoderm (internal plate of hypomer, see Fig.1). Because the gonad shows neither unique male nor female characters at this early stage, it is termed **undifferentiated gonad**. The undifferentiated gonad shows a series of changes under the influence of i. genes, ii. hormones and even iii. The invasion of germ cells. The gonads of both sexes initially contain **primordial germ cells**, the future sperm or eggs. Surprisingly, germ cells themselves do not arise in the genital ridge nor even in the adjacent mesoderm. In fact they do not arise in the embryo at all. They first debut in remote sites outside the embryo in the extraembryonic endoderm; they undergo a journey that takes them eventually to the undifferentiated gonad. This region of the gonadal primordium thereby becomes **germinal epithelium**. In females, germ cells establish residence in the cortex. In males, arriving germ cells establish residence in the medulla, which develops into seminiferous tubule.

During early differentiation, the gonads have the potential to become either ovaries or testes. Under the influence of genes, hormones, and factors not yet fully identified, these bisexual gonads develop into the gonads of a specific sex. The

gonads enlarge; they generally acquire a dorsal mesentery, the **mesorchium** in case of testes, and the **mesovarium** in ovaries.

Two main primordia for the male and female reproductive or genital ducts in the early bisexual stage embryo

As mentioned now, during embryonic development there is a sexually indifferent stage in which the embryo has the potential to develop either male or female structures. Internally, adjacent to each developing gonad, are two primitive ducts that can give rise to either the male or the female reproductive tracts (ducts). The Wolffian (mesonephric) ducts are more medial. The Müllerian (paramesonephric) ducts are more lateral, but then fuse in the midline more caudally.

In female mammals, the mesonephric duct (**Wolffian duct**) drains the embryonic mesonephros, but it regresses later in development when the metanephros and its ureter become the kidney of the adult. However, a second parallel **Mullerian duct** arises next to the embryonic mesonephric duct before it regresses. The Mullerian duct, rather than the Wollfian duct, forms the oviduct, uterus and vagina. In the female the Wolffian bodies and ducts atrophy (Fig.10). In male mammals, the mesonephric duct becomes the vas deferens. Mesonephric tubules and some of the associated ducts contribute to the epididymis (Fig.11).

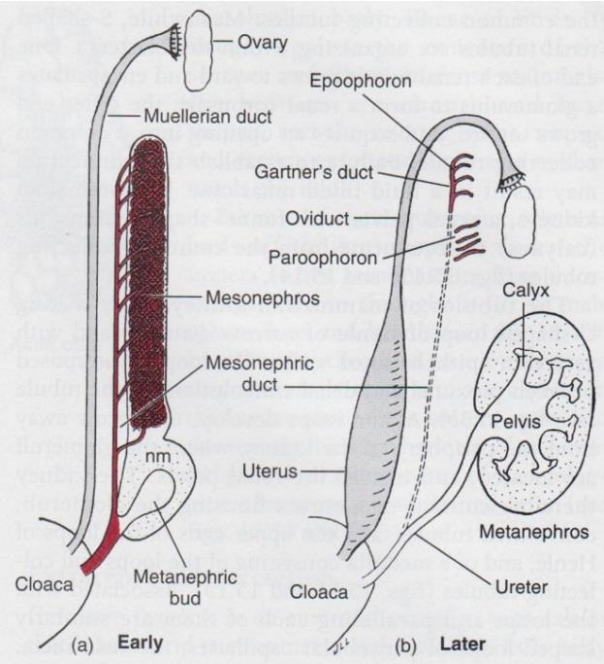

FIGURE 10: Developmental changes in the urinogenital system of early (bisexual) stage mammalian embryo, (a) Early embryo carry both primordial ducts: Wolffian (mesonephric) and Mullerian ducts, (b) In later stage, the Wolffian (mesonephric) ducts atrophy and Mullerian ducts differentiated to female genital ducts.

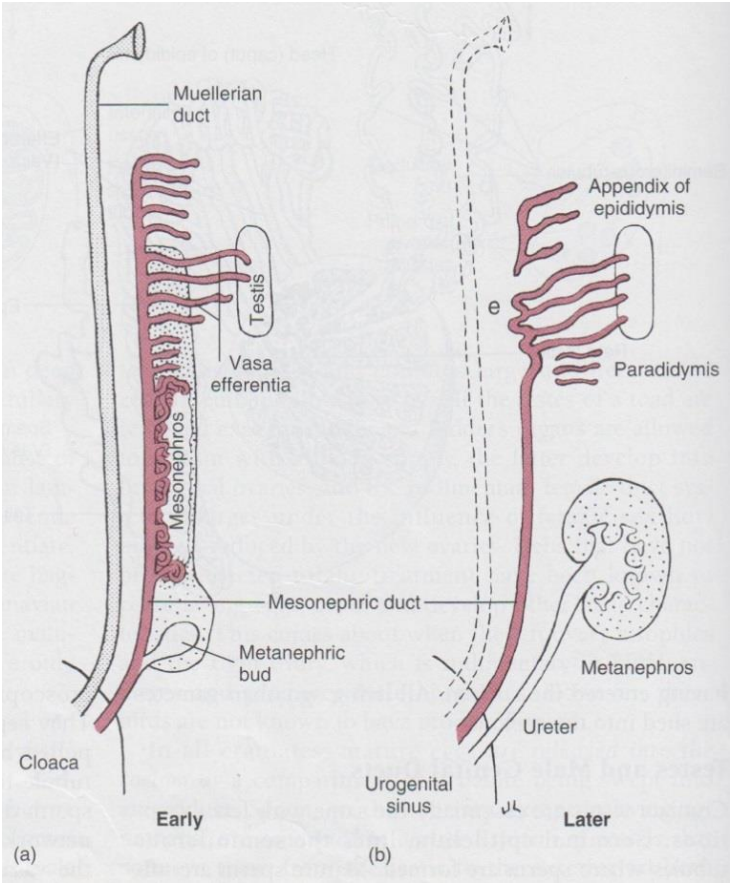

FIGURE 11: Developmental changes in the urinogenital system of early (bisexual) stage mammalian embryo, (a) Early embryo carry both primordial ducts: Wolffian (mesonephric) and Mullerian ducts, (b) In later stage the Mullerian ducts atropy and Wolffian ducts differentiated to male genital ducts.

Testes, male genital ducts, and their relation with mesonephric duct

Craniate testes are essentially the same with few exceptions. Germinal epithelium lines the seminiferous tubules where sperm are formed. Mature sperm are microscopic and abundant. They separate from the lining of the tubules and, propelled by flagellum-like tails, swim the length of the tubule to reach the vasa efferentia, which leads to the sperm duct. In mammals, sperm are first collected in a network of fine channels, the rete testis, before entering the vasa efferentia (Fig. 12). Vasa efferentia are mesonephric tubules that invaded the developing testis instead of becoming associated with glomeruli. The vasa efferentia (usually called efferent ductules in mammals) conducts sperm to the spermatic duct (epididymis and vas deferens).

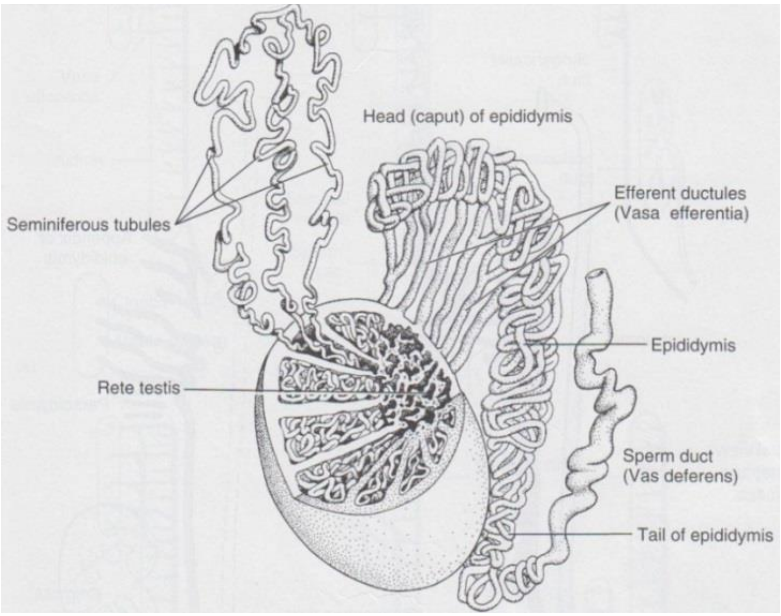

FIGURE 12: Mammalian testis, seminiferous tubules lead to rete testis which in turn enters vasa efferentia, the later lead to spermatic duct (vas deferens).

Locations of testes in mammals

In most vertebrate males, the testes reside within the abdomen; however, the testes of some mammals descend into the **scrotum**, a coelomic pouch suspended outside the body from its posterior end but connected to the abdominal coelom via **inguinal canal**. Other mammals are varied with respect to their testes location. Three states have been detected:

i. In most mammals such as carnivores; perissodactyles; artiodactyles; primates; etc., the testes descend permanently into extra-abdominal skin bags called scrotal sac.

Scrotal sacs are adaptations that maintain mammalian sperm at a temperature cooler than that within the abdominal cavity in which the sperm of most mammals cannot survive.

ii. The testes remain in a transitional state between the abdominal cavity and the scrotal sac, where they lowered into sacs and retracted at will. Passage between the abdominal cavity and scrotal sac, through which testes descend and ascend, is called inguinal canal. This case found in rabbits, rodents and bats.

iii. Some mammals such as monotremes, insectivores, elephants, whales, etc., lack scrotal sac so that their testes remain permanently intra-abdominal like ovaries and testes of other animals other than mammals.

Types of uteri

In mammals, the four main forms of the uterus are: duplex, bipartite, bicornuate and simplex:

Duplex uterus

There are two wholly separate uteri, with one fallopian tube each. Found in marsupials (such as kangaroos, Tasmanian devils, opossums, etc.), rodents (such as mice, rats, and guinea pigs), and lagomorpha (rabbits and hares).

Bipartite uterus

The two uteri are separate for most of their length, but share a single cervix. Found in ruminants (deer, moose, elk etc.), hyraxes, cats, and horses.

Bicornuate uterus

The upper parts of the uterus remain separate, but the lower parts are fused into a single structure. Found in dogs, pigs, elephants, whales, dolphins,[28] and tarsiers, and strepsirrhine primates among others.

Simplex uterus

The entire uterus is fused into a single organ. Found in higher primates (including humans and chimpanzees). Occasionally, some individual females (including humans) may have a bicornuate uterus, a uterine malformation where the two parts of the uterus fail to fuse completely during fetal development. These four different types of uteri are shown in Fig. 13.

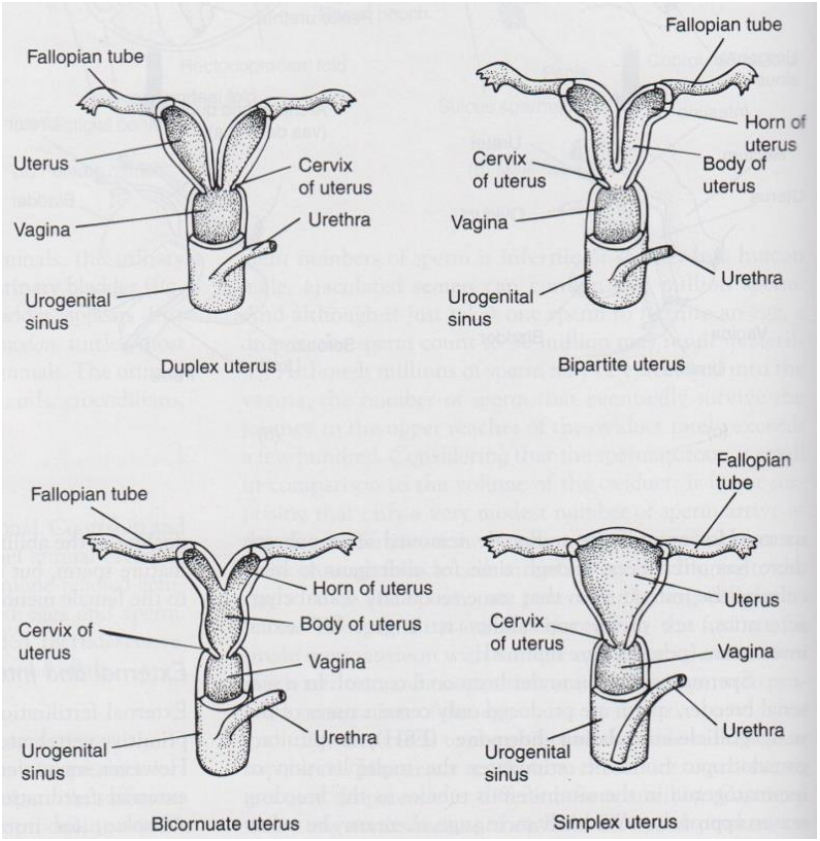

FIGURE 13: Four types of therian mammals uteri.

Fate of cloaca in therian mammals

In mammals that deliver live fetuses: that is marsupials and eutherians, the urorectal fold grows caudad until it reaches the cloacal membrane separating the cloaca from the exterior. This modification completely divides the cloaca into a urogenital sinus and a rectum (Fig.14 a, b and c, female; and a, b and e, male). Rupture of the cloacal membrane at two sites provides two openings to the exterior, an **anus** and a **urogenital aperture.** The embryonic urogenital sinus of both sexes receives the mesonephric ducts, Mullerian ducts and the future urinary bladder (allantois) (Fig.14b).

As development progresses in males, the Mullerian ducts regress, and the urogenital sinus and rectum elongate (compare fig.14b and e). The urogenital sinus eventually becomes continuous with the spongy urethra that has developed in the penis (Fig.14f). The terms urogenital sinus and urethra have now become synonyms when applied to male. By differential growth, the ureters become reoriented to open into the bladder, and the mesonephric ducts (now sperm ducts) continue to empty into the urogenital sinus (Fig.14f). This is the condition in all males.

As development progresses in females, the mesonephric ducts regress, and the Mullerian ducts unite at their caudal ends to form the body of the uterus and the vagina (Fig.14c, gray). The part of the urogenital sinus between the bladder and the entrance of the vagina is now known as the urethra. As a result of these developments, most adult female mammals have two caudal openings to the exterior, a **urogenital aperture** and **anus**.

Female apes, monkeys, humans and some female rodents develop an additional partition in the embryonic cloaca, this one in the urogenital sinus. It divides the urogenital sinus into a urethra and a vagina (Fig.14d). As a result, the embryonic female cloaca in these mammals becomes subdivided into a **urethra, vagina** and rectum, each with its own exit. In monkeys and rodents all three exit directly to the exterior. In apes and humans, the vagina and urethra open separately into the shallow vestibule of the vulva. The urogenital systems of these females have therefore evolved further than those of males.

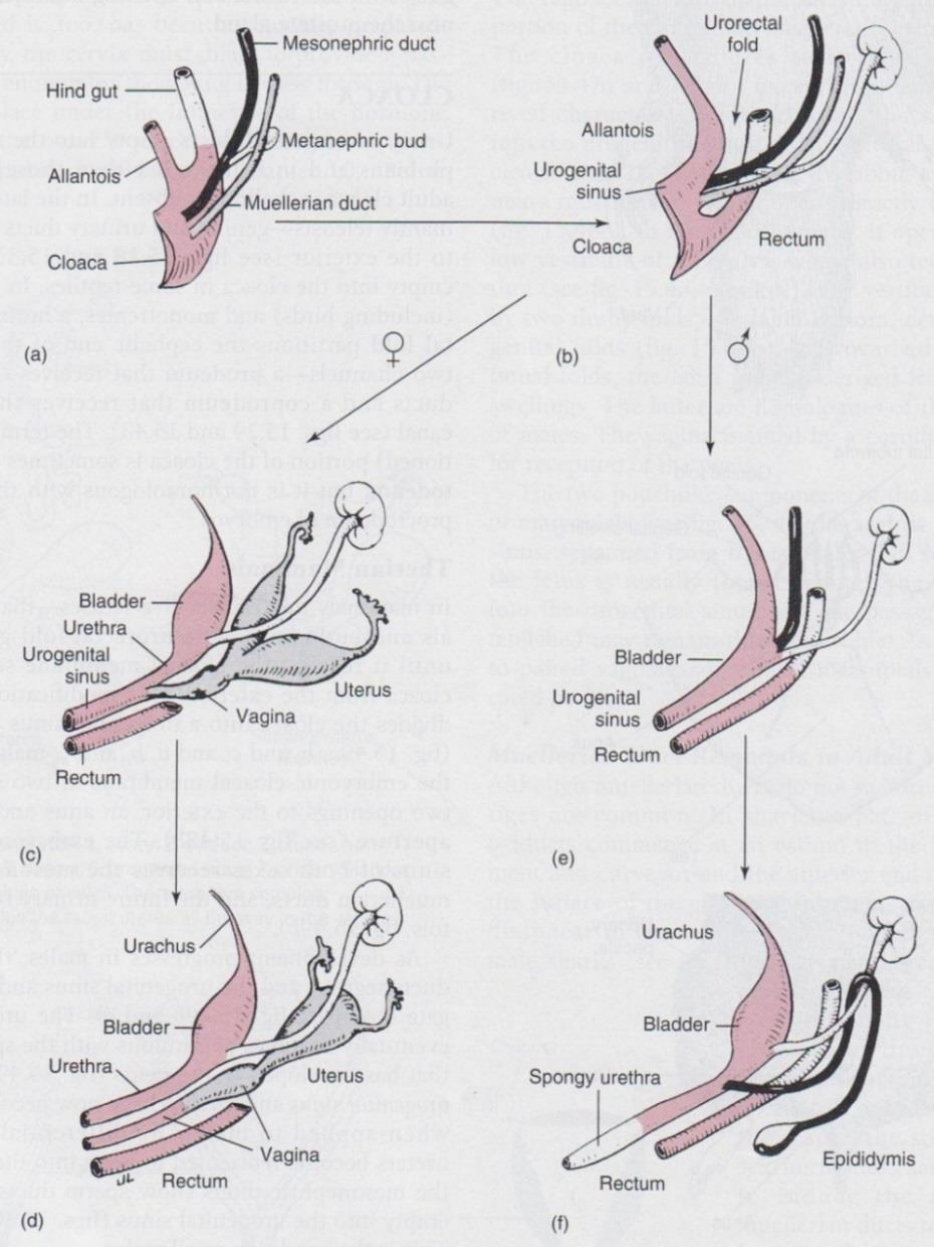

FIGURE 14: Fate of cloaca and allantois in therian mammals.

Comparative Anatomy of the Urogenital System

Amphioxus

The **excretory system** of Amphioxus (*Branchiostoma*) consists of about 90 pairs of true **nephridia**. Each nephridium (Fig.15) consists of an ***excretory tubule*** entirely different from those of vertebrates. They are apparently of ectodermal in origin, have no connection with the coelom and are composed of numerous of flame cells called ***solenocytes***, which collect wastes. A series of such tubules opens into the ***atrium*** or peribranchial space through an ***excretory pore***.

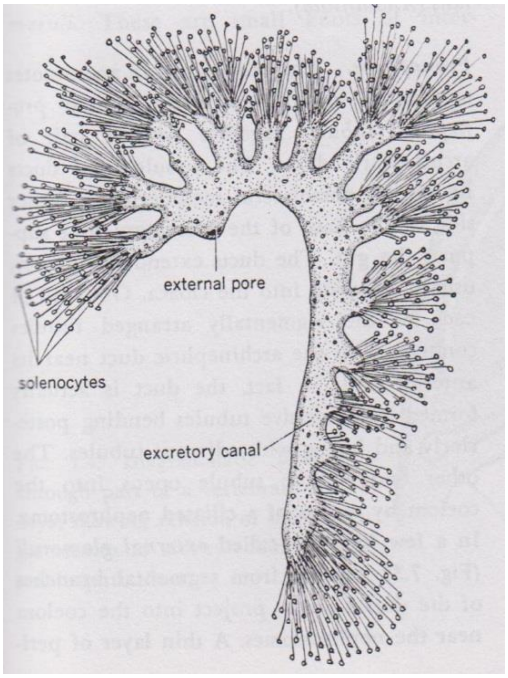

FIGURE 15: *Branciostoma sp.* Nephridium.

The sexes are separate, but they cannot be distinguished morphologically. The **reproductive organs** are similar in both male and female. The gonads are simple, pouch-like metameric organs, located in the ventrolateral sides of the pharyngeal region between **10** to **30** ***gonads*** (***testes*** or ***ovaries*** depending on sex) (Fig.16). They project into the atrium and largely fill its cavity. The sex of the animal will be distinguished by making a cross section through the pharynx. One pair of gonads appears in each section, testes if it is male and ovaries if it is female (Figs. 17 and 18). When the sperm or ova ripe, they force into the ***atrium***, from which they pass directly to the outside through the ***atriopore***. Amphioxus of both sexes lack genital ducts. Although amphioxus is primitive chordate, but possesses anus rather than cloaca because it lacks both urinary and reproductive ducts, hence the exterior body opening is special for intestine so called anus.

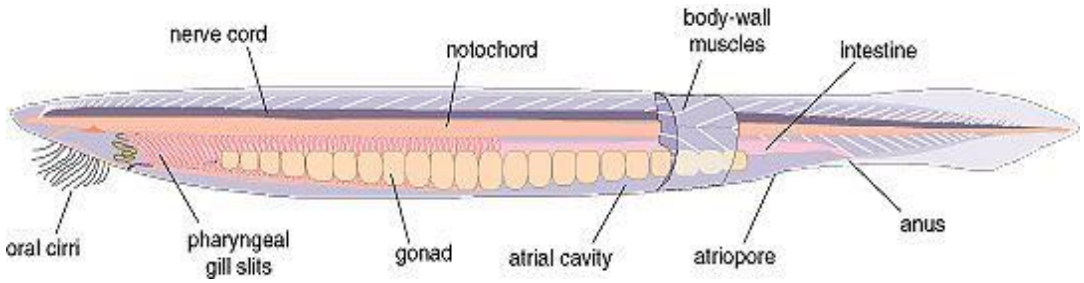

FIGURE 16: Amphioxus, numerous, venterolaterally arranged pairs of gonads surrounded by atrium, where it lacks sexual dichromatism.

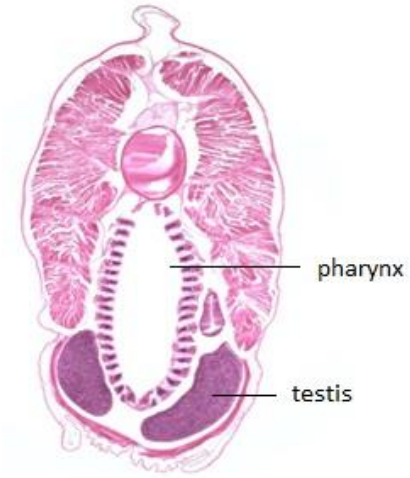

FIGURE 17: Cross section through pharynx of male amphioxus, shows one pair of testes on its both ventrolateral side.

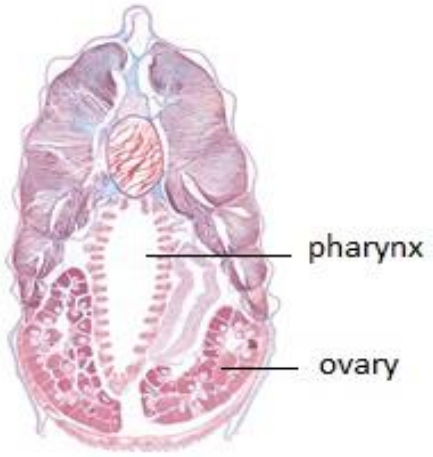

FIGURE 18: Cross section through pharynx of female amphioxus, shows one pair of ovaries on its both ventrolateral side.

Frogs

Sexes are separate, sexual dimorphism is present. Males possess ***thumb***, or ***nuptial pads***; ***vocal sacs*** and they are usually ***smaller*** in size.

The urinary or excretory and genital or reproductive systems are not completely separated; hence both systems are described under a common heading urogenital system. In male, the organs of two systems are not separated but in female they are independent structures. The excretory products (urine) as well as a genital (sperm) pass out through common urogenital duct, so this is another reason of describing these two systems together as urogenital system.

Male excretory system composed of two ***mesonephric kidneys*** lie posteriorly, outside abdominal coelom, and attached one on either side of vertebral column. They are elongated, flat and reddish-brown structures with outer edges smooth and

convex but inner edges notched and straight. The ventral surface of each kidney has an elongated narrow yellow adrenal or suprarenal gland which is an important endocrine gland. To the anterior end of each kidney several small finger-like ***fat bodies*** and a testis are attached (Fig.19).

From posterior outer margin of each kidney leaves a ***Wolffian duct***, also called ***urogenital duct***, since it passes out spermatozoa as well as urine. It is a fine, white tube which extends backwards to open into the dorsal wall of the cloaca. The openings of both urogenital ducts are located separately side by side dorsally in cloaca. Ventral to the cloaca, a bilobed, thin-walled delicate sac, the ***urinary bladder*** opens into the cloaca on the ventral surface.

Male genital system (Fig.19) consists of two ***testes***. They are elongated or ovoid, large-yellow bodies attached to latero-ventral surface of each kidney by a double fold of peritoneum, called ***mesorchium*****.** 10-12 narrow tubes, the ***vasa efferentia*** leaves from the inner margin of testis, run through mesorchium and enter the inner margin of kidney to open into the Bidder's canal. The latter is connected to the mesonephric duct (duct of the mesonephros type of kidney). Thus vasa efferentia conduct mature spermatozoa from testis to the kidney duct (mesonephric duct). As mentioned earlier, mesonephric duct, in male frog, is both urinary duct and a vas deferens, hence it is called ***urogenital duct***. The ducts of both sides open into roof of cloaca separately. In some species of frog, the urogenital ducts are enlarged near kidneys or cloaca forming ***seminal vesicle*** for temporary storage of spermatozoa until needed.

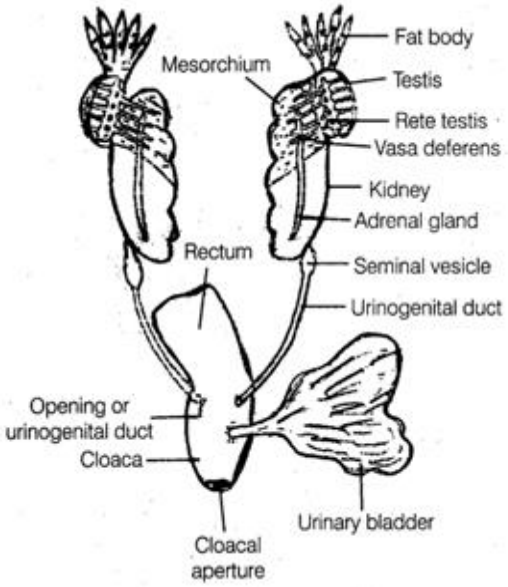

FIGURE 19: Urogenital system of male frog.

Female excretory system (Fig.20) is similar to that of male, except the urinary ducts (mesonephric ducts) and genital ducts (oviducts) are independent.

Female reproductive system is constituted by a pair of ***ovaries***, and a pair of oviducts (Fig.20). The ***ovaries*** are much folded irregular bodies, hollow sacs, greyish or blackish in color one on each side of the coelom. Each ovary is attached to the dorsal abdominal wall by a peritoneal fold called ***mesovarium***. During breeding season, the two ovaries are greatly enlarged, dark in color, contain numerous developing eggs and occupied a considerable space in the coelom.

The ***oviducts*** are long, convoluted tubes, one on each side. Their anterior ends form ciliated funnel-like opening, the ***ostia*** (singular, ostium), or oviduct funnels. These are placed quite anteriorly in the body cavity at the bases of lungs one on either side of esophagus. The posterior ends of the oviducts in most species open independently into ***cloaca***. In certain toads, however, the oviducts unite before entering a cloaca by a common aperture. Just before entering cloaca, each oviduct forms a thin-walled enlargement, the ***ovisac***, sometimes called ***uterus***. The eggs are collected inside ovisacs before being laid.

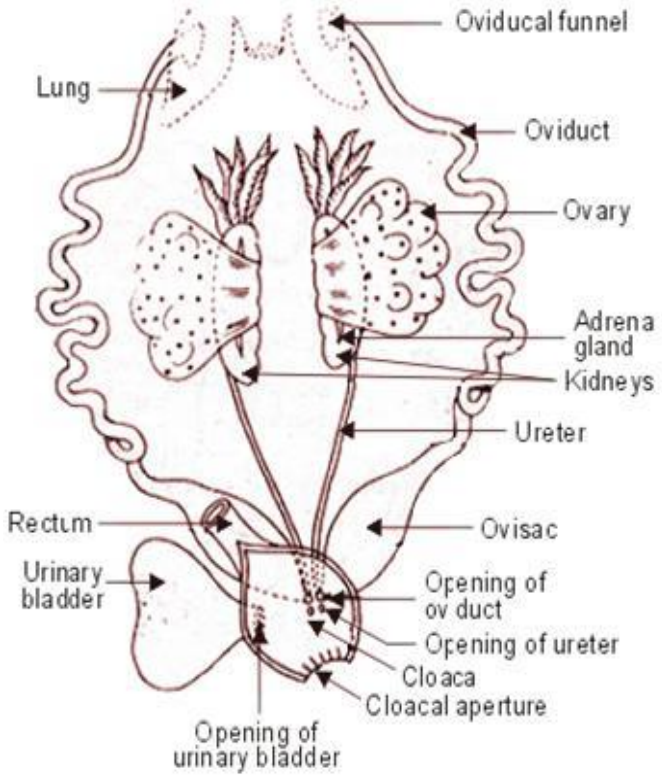

FIGURE 20: Frog urogenital system.

Birds

The excretory and reproductive organs lie in very close contact, so that they are studied together under the urogenital system, although they are functionally quite unrelated. The sexes are separate but sexual dimorphism is not always well marked.

The **excretory (urinary) system** of birds, including pigeon, is situated in the posterior part of the abdominal cavity. It consists of one pair of kidneys and one pair of ureter, in both sexes (Fig.21-22). A urinary bladder is lacking as an adaptation to flight, possibly to reduce body weight. One pair of dark-brown ***kidneys*** lie posteriorly in the body cavity, attached dorsally and lodged in the hollows of pelvis. They are flattened and three-lobed. The ***ureter*** is straight narrow tube leaves the anterior lobe of each kidney and runs backwards along the ventral surface of the other two lobes to opens separately into the dorsal wall or roof of the ***cloaca***. The urine is discharged with feces through cloacal aperture.

Male reproductive (genital) system includes two testes and two genital duct, vasa deferentia (Fig. 21). There is no intromittent or copulatory organ. Each ***testis*** is an oval body, cream white in color, and attached by mesentery to the inner border of the anterior lobe of the corresponding kidney. From its inner border, a ***vas deferens*** emerges to run backwards, lateral to the ureter, as a slightly coiled thin tube, to open separately into the vent (***cloaca***). Just before its opening, it dilates forming a small ***vesicula seminalis***. There are no copulatory organs, copulation being affected by contact of the cloaca of the male with that of the female.

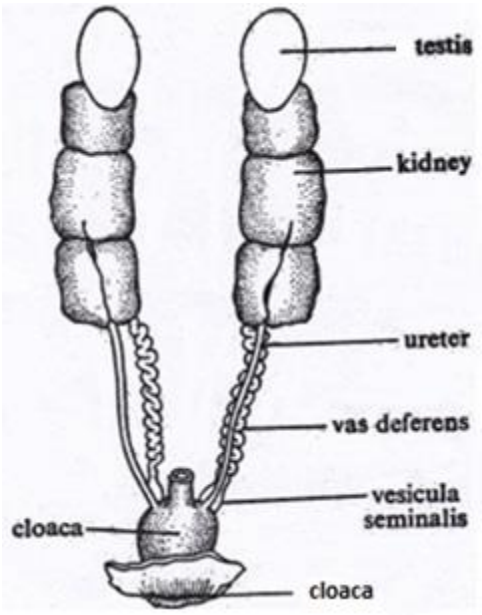

FIGURE 21: Pigeon, male urogenital system.

Female reproductive (genital) system is functional on its left side only (Fig.22). Sometime, however, ***vestiges of right ovary*** and its duct present. The ***left ovary*** has the same relation to the left kidney like that of the left testis in the male. However, the ovary is larger and contains numerous ova of various sizes. The ***left oviduct*** is a wide convoluted tube which opens into the body cavity by a funnel-shaped internal opening, this part followed by many, unclear morphologically, parts secreted albumen and inner and outer shell membranes around the egg cell. The distal dilated part is the ***uterus*** or ***shell gland***, where the hard calcareous shell of the egg is formed. The uterus opens into ***cloaca*** by aperture which lies lateral to that of the left ureter.

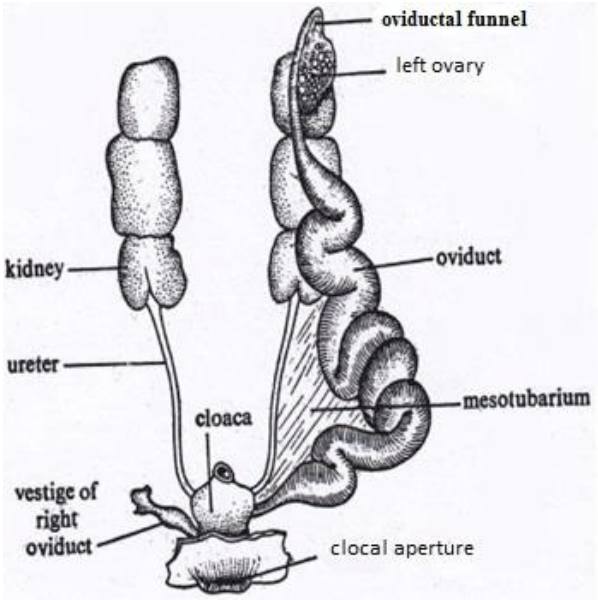

FIGURE 22: Pigeon, female urogenital system.

Rabbit

The urinary (excretory) and genital (reproductive) organs are collectively described as urogenital system. These two systems are closely related and not completely separated. The interdependence of these two systems is restricted to the urethra, which acts as a common passage for both urine and gametes. The sexes are separated and sexual dimorphism is well marked through the external genitalia in both sexes, where, in male, the testes lodged in the scrotum and female has an external urogenital opening located ventral to the anus.

Urinary (excretory) system consists, in both sexes, of a pair of metanephric kidneys, two ureters, urinary bladder and urethra. The two ***kidneys*** are dark red in color, bean-shaped; they are asymmetrically placed in the body cavity, the right lying more anteriorly than the left. Close to each kidney, a small yellowish rounded body, the adrenal gland, is present. It is an endocrine gland has no urinary function. The ***ureters*** are two, each extending from the concavity of its own kidney to open into the dorsal region of the urinary bladder. The ***urinary bladder*** is an ovoid sac

which narrows posteriorly where it receives the genital ducts and extends in the pelvis as a urogenital passage, the ***urethra*** (Fig.23-24).

Male genital (reproductive) system includes a pair of testes, a pair of epididymis, and a pair of vasa deferentia, penis and some accessory glands (Fig.23).

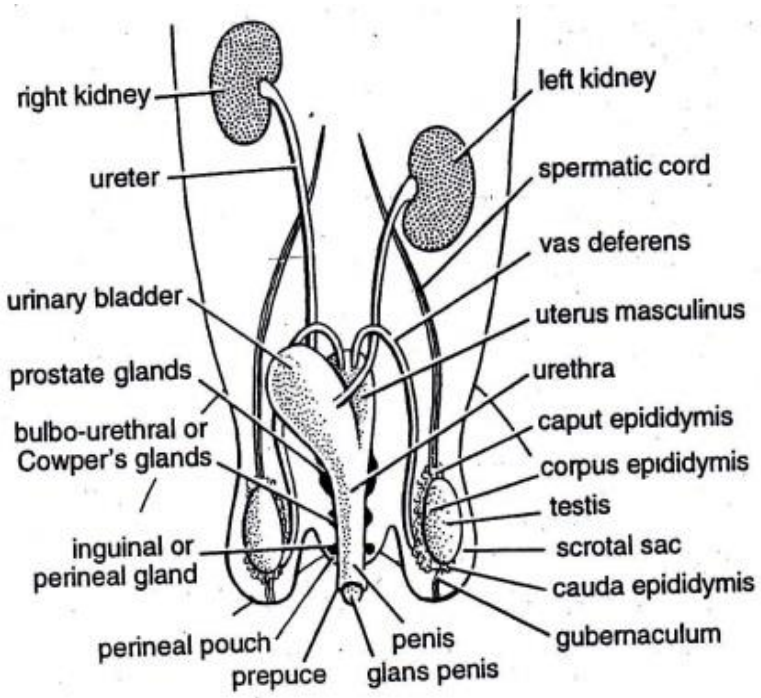

FIGURE 23: Rabbit, male urogenital system.

Testes are white, ovoid, paired bodies lodged in the ***scrotal sac*** which is an externally visible swelling on either side of body cavity, extending a little behind the posterior end of the body. Each testis attached to the scrotum at its posterior end by a band-like tissue, the ***gubernaculum***. The cavity of the scrotum is continuous with the abdominal cavity through the ***inguinal canal***. Each testis remains connected with its original position, the dorsal wall of the abdominal cavity, by a ***spermatic cord***, which extends through inguinal canal and consists of a spermatic artery, vein and nerve all bound in connective tissue.

Along the inner side of each testis lies a compact ridge-like mass, the ***epididymis***. It is an irregular, narrow and highly convoluted tubule of great length. The epididymis has three distinct parts: ***Caput epididymis***, it is the head or anterior part; ***Cauda epididymis,*** it is the tail or posterior part; and ***Corpus epididymis***, it is the narrow body or middle part.

The basal end of epididymis (cauda epididymis) leads into a yellowish-white, muscular tube, the sperm duct or ***vas deferens***. It runs forward along the inner side

of the scrotal sac, traverse the inguinal canal to enter the abdominal cavity. It curves over the ureter, then passes backwards again and opens into a small median sac, the ***uterus masculinus***, which lies dorsal to the neck of the urinary bladder and opens into it. Thus, the two forms the ***urethra*** which is a urogenital canal that extends into the pelvis, ventral to the rectum. The urethra passes through the ***penis*** and opens on its tip.

Male rabbit has several accessory sex glands open into urethra. Their secretions, together with those of epididymis and uterus musculinus, constitute the seminal fluid or semen.

i. Prostate gland. Large gland lies dorsally around the base of uterus masculinus. It opens into urethra by several small ducts. Its whitish alkaline secretion activates the passive spermatozoa.

ii. Cowper's glands. Pair of small bulbourethral glands lie behind the prostate gland at the base of the penis. Their secretion neutralizes acidity for the protection of spermatozoa.

iii. Perineal glands. These are a pair of elongated scent (not genital) glands lying behind the Cowper's glands. They open in the hairless perineal depression on either side of the anus. Their odorous secretion gives the rabbit its characteristic smell.

Female genital (reproductive) system consists of a pair of ovaries, a pair of oviducts, a pair of uteri, vagina, vestibule, clitoris and some accessory sex glands (Fig.24).

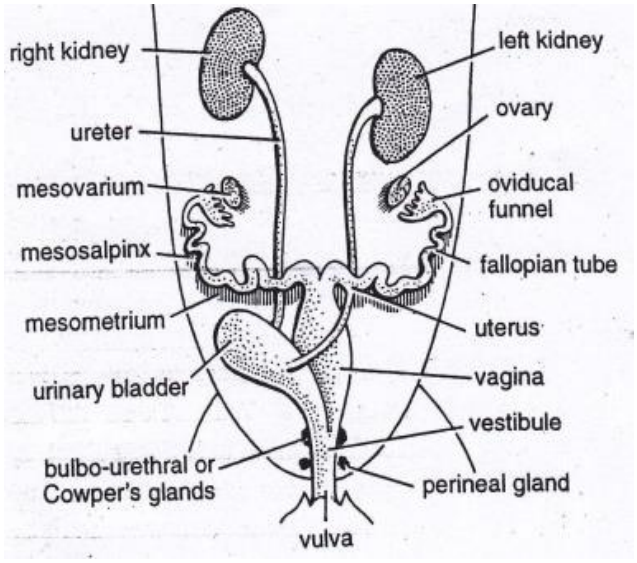

FIGURE 24: Rabbit, female urogenital system.

The two ***ovaries*** are small, whitish, oval bodies. They are abdominal in position, lying posterior and lateral to the kidneys. Each ovary attached to the dorsal abdominal body wall by a mesentery called ***mesovarium***. The two ***oviducts*** open into the coelom close to the outer border of the corresponding ovary of its side by a wide funnel called ***Fallopian funnel*** with an opening called ***ostium***. Funnel leads to the upper part of the oviduct. It is a short, narrow and coiled tube called fallopian tube. Oviduct runs backwards, and then enlarges into the ***uterus*** which unites with its fellow to form the ***vagina***. This extends backwards within the pelvis dorsal to the urinary bladder's neck with which it unites forming the ***vestibule.*** Thus, this is the urogenital canal. It opens into the ***vulva***; the ***clitoris*** had already been noted. ***Cowper's glands*** are as in male, but sometimes absent. ***Perineal glands*** present.