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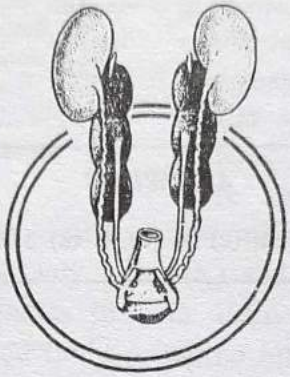

Urinogenital System in Vertebrates

Urinary system of vertebrates includes *kidneys* and their ducts, while reproductive system includes male and female *gonads* and their ducts. Kidneys excrete harmful metabolic nitrogenous wastes and regulate the composition of body fluids, while reproductive organs perpetuate the species. Thus, kidneys and gonads remain functionally unrelated. However, the two systems are intimately related morphologically in vertebrates because the male urinary ducts are also used for discharging gametes. For this reason, it is more convenient to treat and describe the two systems together as the *urogenital* or *urinogenital system*.

Vertebrate Kidneys and Ducts

1. Basic structure and origin. Vertebrate kidneys are a pair of compact organs, lying dorsal to coelom in trunk region, one on either side of dorsal aorta. They are all built in accordance with a basic pattern. Each kidney is composed of a large number of units called *uriniferous tubules* or *nephrons*. Their number, complexity and arrangement differ in different groups of vertebrates.

Kidney tubules arise in the embryo in a linear series from a special part of mesoderm called *mesomere* or *nephrotome* (Figs. 1, 5 & 6). It is the ribbon-like intermediate mesoderm, running between segmental mesoderm (epimere) and lateral plate mesoderm (hypomere) on either side along the entire trunk from heart to cloaca. A uriniferous tubule is differentiated into three parts : *peritoneal funnel, tubule* and *Malpighian body*.

(a) Peritoneal funnel. Near the free end of a uriniferous tubule is a funnel-like ciliated structure called *peritoneal funnel*. It opens into coelom (splanchnocoel) by a wide aperture, the *coelomostome* or *nephrostome*, for draining wastes from coelomic fluid. Nephrostomes are usually confined to embryos and larvae and considered vestiges of a hypothetical primitive kidney.

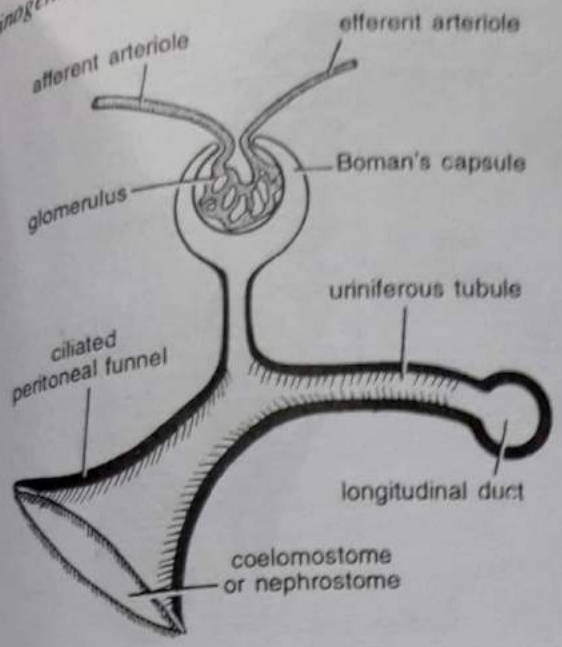

Fig. 1. Structure of an embryonic kidney tubule.

(b) ***Malpighian body.*** A tubule begins as a blind, cup-like, hollow, double-walled *Bowman's capsule*. It encloses a tuft of blood capillaries, called *glomerulus*. It is supplied blood by a branch of renal artery, called *afferent glomercular arteriole*. An *efferent glomerular arteriole* emerges out of glomerulus to join the capillary network surrounding the tubule.

Bowman's capsule and enclosed glomerulus together form a *renal corpuscle* or *Malpighian body*. Encapsulated glomeruli are termed *internal glomeruli* which are common. Those without a capsule and suspended freely in coelomic cavity are called *external glomeruli* (embryos and larvae). Capsules without glomeruli are termed *aglomerular*, such as found in embryos, larvae and some fishes.

(c) ***Tubule.*** Malpighian bodies filter water, salts and other substances from blood. During passage through tubules more substances are secreted into filtrate, while some are reabsorbed. All the tubules of embryonic kidney are convoluted ductules that conduct the final filtrate to a *longitudinal duct* which opens behind into embryonic cloaca.

2. Archinephros. *Archinephros* is the name given to the hypothetical primitive kidney of ancestral vertebrates (Fig. 2). It may be regarded

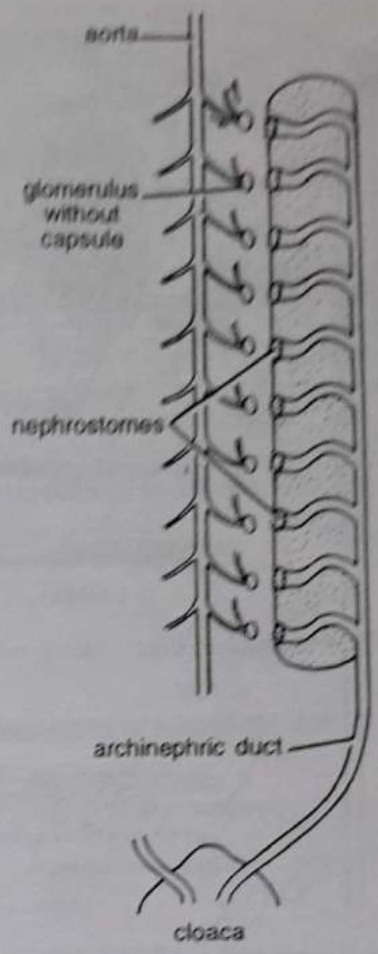

Fig. 2. Hypothetical primitive ancestral vertebrate kidney or archinephros.

as a complete kidney or *holonephros* as it extended the entire length of coelom. Its tubules were segmentally arranged, one nephron 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 *Wolffian* or *archinephric duct* opening behind into cloaca.

Such a hypothetical archinephros is found today in the larvae of certain cyclostomes (*Myxine*), but not in any adult vertebrate. It is supposed to have given rise to all the kidneys of later vertebrates during the course of evolution. Modern vertebrates exhibit three different kinds of adult kidneys : *pronephros*, *mesonephros* and *metanephros*. It is supposed that these represent the sequence or three successive stages of

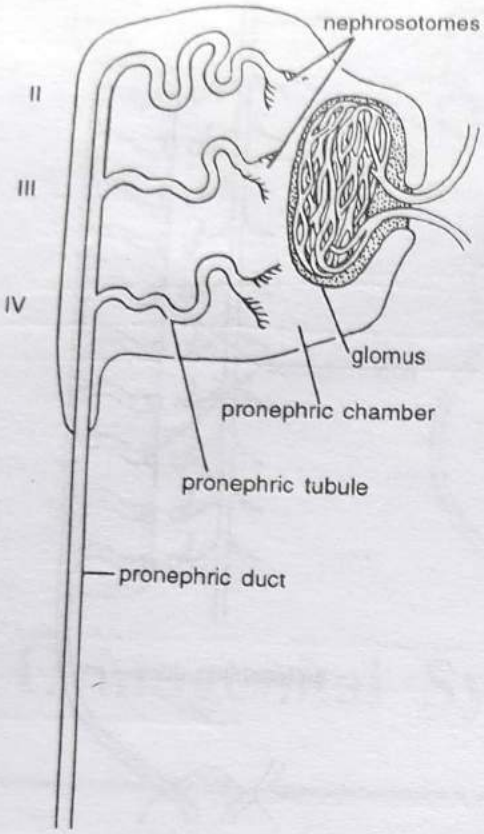

Fig. 3. Encapsulated pronephric kidney of 15 mm. frog larva.

development of the ancestral archinephros, and all the three are never functional at the same time.

3. Pronephros. In the embryos of all vertebrates, the first kidney tubules appear dorsal to the anterior end of coelom, on either side. These are called *pronephros* as they are first to appear (Fig. 3). Pronephros is also termed *head kidney* due to its anterior position immediately behind the head. A pronephros 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 and about a dozen in chick embryo. Each tubule opens into coelom by a funnel or nephrostome. 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*. Glomus and tubules become surrounded by a large *pronephric*

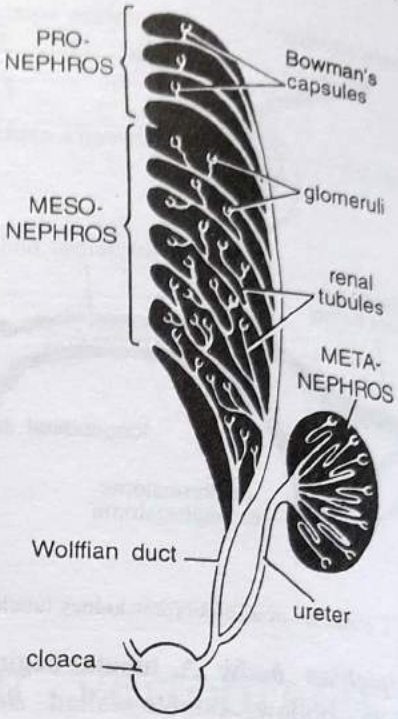

Fig. 4. Diagrammatic plan of pronephros, mesonephros and metanephros in vertebrates.

chamber derived from pericardial or pleuroperitoneal cavity. Originally each tubule has its individual external aperture, but secondarily, all tubules of a pronephros open into a common *pronephric duct*, leading posteriorly into the embryonic cloaca.

Pronephros is functional, if at all, only in embryonic or larval stage. It is mostly transitory and soon replaced by the next stage or mesonephros. However, a pronephros is retained throughout life in adult cyclostomes and a few teleost fishes, but it is nonurinary and mostly lymphoidal in function.

4. Mesonephros. In the embryo, a mesonephros develops from the middle part of intermediate mesoderm, posterior to each pronephros soon after its degeneration (Fig. 4). At first, the new mesonephric tubules join the existing pronephric duct and are segmentally disposed. Later on the tubules multiply by budding so that their segmental arrangement is disturbed due to increased number of tubules per segment. Tubules of pronephros and mesonephros develop similarly

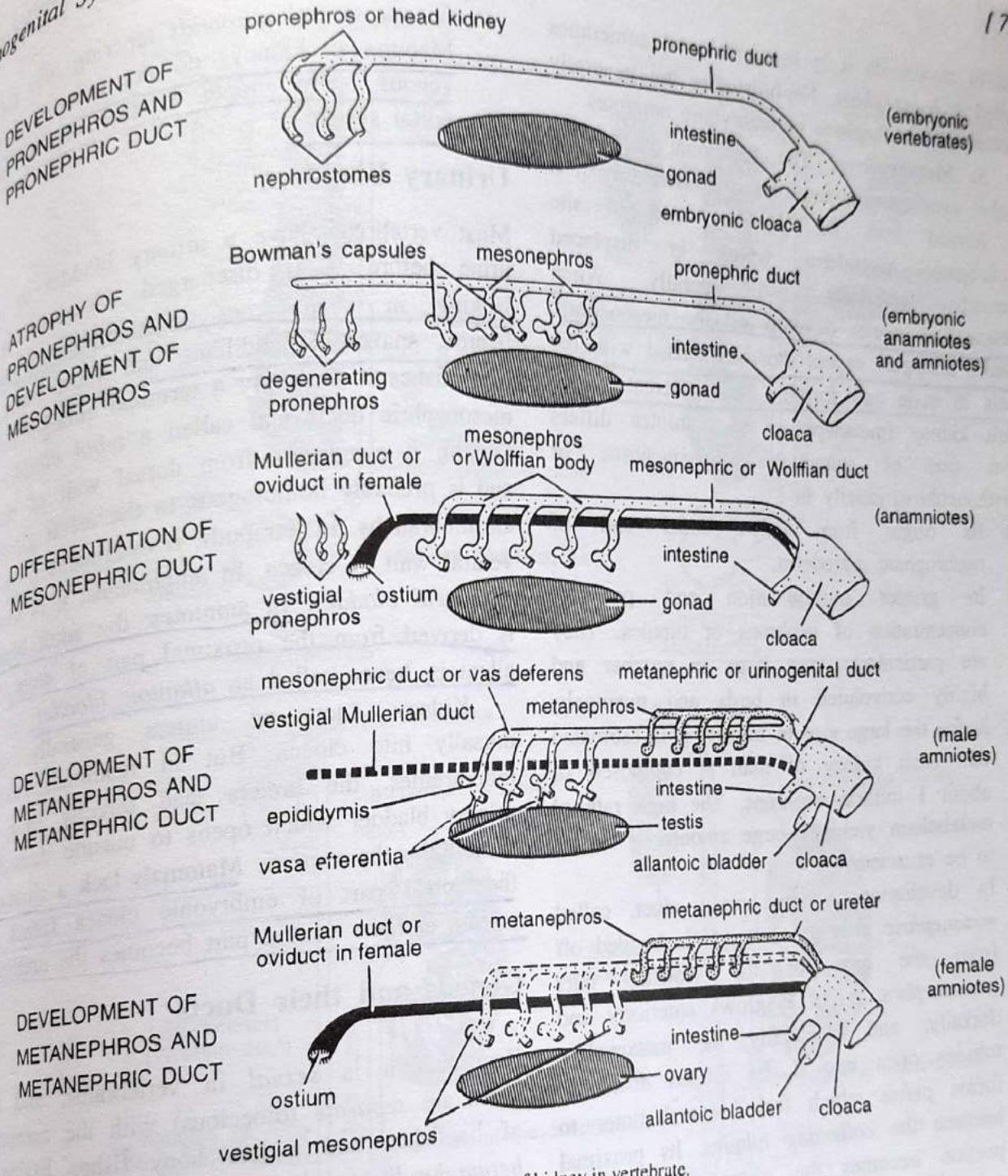

Fig. 5. Evolution of kidney in vertebrate.

and are homologous. However, mesonephros is functionally better than pronephros because mesonephric tubules are more numerous, longer and develop internal glomeruli enclosed in capsules forming Malpighian bodies. Thus, they remove liquid wastes directly from glomerular blood rather than indirectly from coelomic fluid as in case of a pronephros. The mesonephros is also termed *Wolffian body*. With disappearance of pronephros, the old pronephric duct becomes the *Wolffian* or *mesonephric duct*.

In amniotes (reptiles, birds and mammals), mesonephros is functional only in the embryos, replaced by metanephros in the adults. In fishes and amphibians, mesonephros is functional both in embryos as well as adults. In sharks and caecilians, tubules extend posteriorly throughout the length of coelom. Such a kidney is sometimes called a *posterior kidney* or *opisthonephros*. Whereas in adult anurans, urodeles and embryonic amniotes, the mesonephros does not extend posteriorly. Mesonephric kidney is not metameric,

but in myxinoids it is segmental and sometimes called a *holonephros*. Nephrostomes are generally lacking in mesonephros of embryonic amniotes.

5. Metanephros. The functional kidney of higher vertebrates or amniotes is a *metanephros*. It is formed from the posterior end of the nephrogenic mesoderm which is displaced somewhat anteriorly and laterally. When metanephric tubules develop, all the mesonephric tubules disappear except those associated with the testis in male and forming vasa efferentia. The adult kidney (metanephros) of amniotes differs from that of anamniotes (mesonephros or opisthonephros) chiefly in :

(1) Its origin from only caudal end of nephrogenic mesoderm.

(2) In greater multiplication and posterior concentration of nephrons or tubules. They are particularly very large in number and highly convoluted in birds and mammals, hence the large size of kidney. It is estimated that each kidney of man is composed of about 1 million nephrons. The high rate of metabolism yields a large amount of wastes to be excreted.

(3) In developing a new urinary duct, called *metanephric duct* or *ureter*. It is budded off from the base of the Wolffian duct (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 the *metanephric duct* or *ureter* that empties into cloaca or urinary bladder in mammals.

(4) The mammalian metanephros shows greatest organization of all, with several additional features. A thin, U-shaped *loop of Henle* forms between proximal and distal convolutions of a metanephric tubule. Such loops are absent in reptiles and rudimentary in birds. Kidney shows an outer *cortex* with concentration of renal corpuscles, and an inner *medulla* having collecting tubules and loops of Henle, which are aggregated into one or several *pyramids* tapering into pelvis. Mammalian kidneys do not receive afferent venous blood supply as there is no renal portal system.

Urinary Bladders

Most vertebrates have a urinary bladder to store urine before it is discharged. However, it is lacking in cyclostomes, elasmobranchs, some lizards, snakes, crocodilians and most birds. In most fishes it is simply a terminal enlargement of mesonephric ducts and called a *tubal bladder*. In Dipnoi, it evaginates from dorsal wall of cloaca and is probably homologous to the rectal gland of elasmobranchs. In tetrapods, it evaginates from the ventral wall of cloaca. In amphibians, it is termed a *cloacal bladder*. In amniotes, the adult bladder is derived from the proximal part of embryonic allantois, hence called an *allantoic bladder*.

Kidney ducts or ureters generally open dorsally into cloaca. But in mammals, except monotremes, the ureters lead directly into the urinary bladder which opens to outside through a short tube, the *urethra*. Mammals lack a cloaca as the dorsal part of embryonic cloaca forms the rectum and the ventral part becomes the urethra.

Gonads and their Ducts

Reproduction is *sexual* in vertebrates, and the sexes are *separate* (dioecious) with the exception of hagfishes and a few bony fishes having a *hermaphrodite* gonad. Reproductive glands or gonads of males are called *testes* which produce the male gametes called *sperm*. Female gonads are called *ovaries* which produce *ova*. In the embryo, gonads originate as a pair of thick elevated folds or *genital ridges* of coelomic epithelium from the roof of coelom, one on either side of the dorsal mesentery. Genital ridges are much longer than the functional adult gonads, suggesting that in the ancestral vertebrates the gonads extended the whole length of the pleuroperitoneal cavity. The functional adult gonad is derived from the middle or *gonal* part of genital ridge, while its anterior *progonal* and posterior *epigonal* parts remain

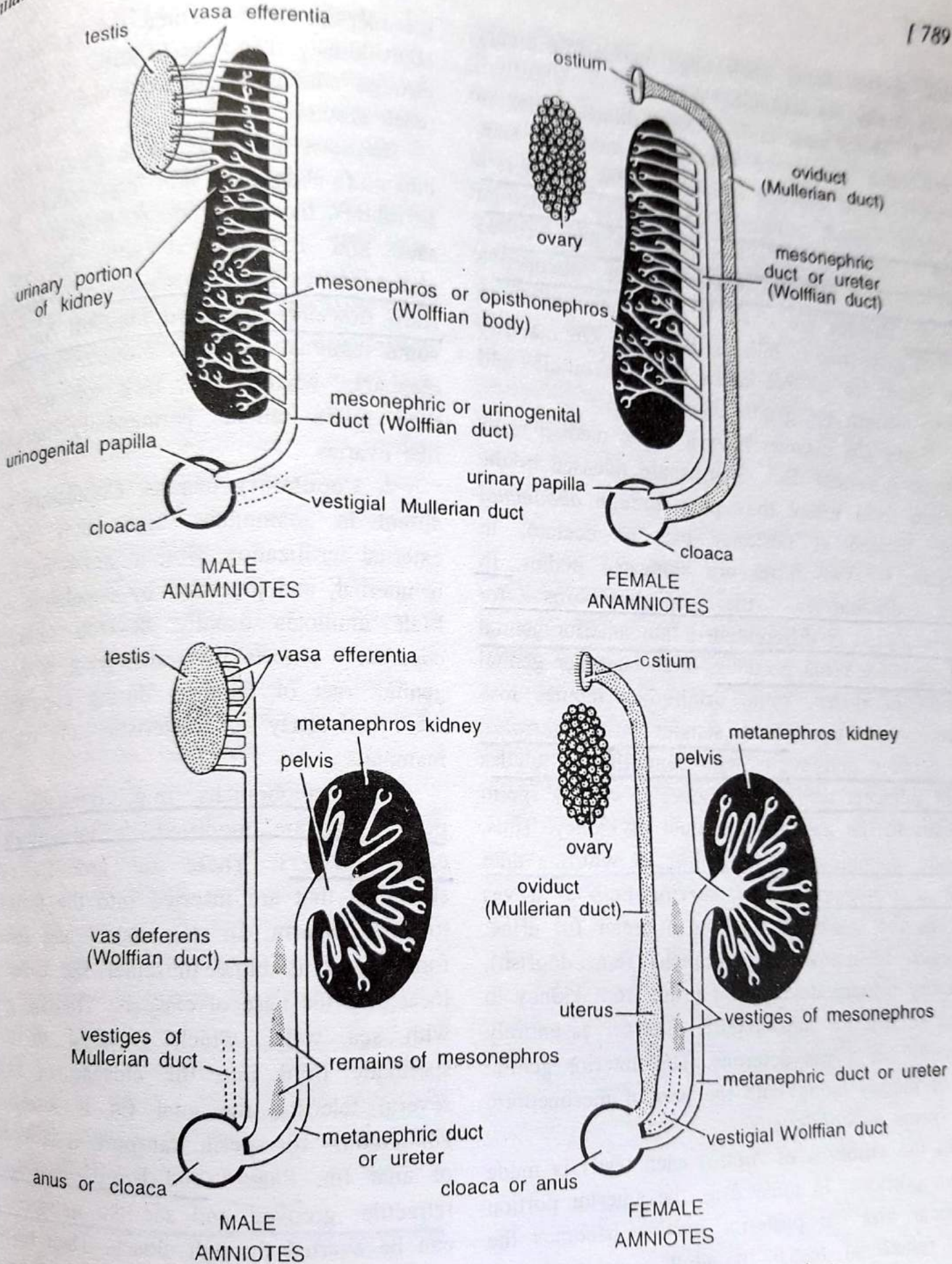

Fig. 6. Schematic representation of evolution of urinogenital organs and their ducts in vertebrates.

...enile. Gonads ... fishes), or degeneration of one juvenile gonad ... and lizards,