

Comparative Anatomy : Evaluation and fate of kidney

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Urinary system is devoted to quite different functions: namely, to the elimination of waste products, primarily ammonia, and to the regulation of water and electrolyte balance. Anatomically, the urinary system includes the kidneys and the ducts that carry away their product urine.

Structure of the Mammalian Kidney:

The vertebrate kidneys are a pair of compact masses of tubules situated dorsal to the abdominal cavity.

The mammalian kidney have the two regions: an outer **cortex** surrounding a deeper **medulla**, urine produced by the kidney enters the **minor** and then the **major calyx**, which joins the **renal pelvis**, a common chamber leading to the **urinary bladder** via the **ureter**. Elimination of urine from the body occurs through the **urethra**. Within the kidney, the functional unit that forms **uriniferous tubule**. The uriniferous tubule consists of two parts: the **nephron (nephric tubule)** and the **collecting tubule** into which the nephron empties, **The renal artery**, one of the major branches from the dorsal aorta, delivers blood to the kidneys. Through a series of subsequent branches, it eventually forms tiny capillary beds known as **glomeruli**, each being associated with a **renal capsule (Bowman's capsule)** constituting the first part of the nephron. Collectively, the glomerulus and renal capsule form the **renal corpuscle**. An ultrafiltrate without blood cells and proteins is forced through the capillary walls and collects in the renal capsule before it passes through the **proximal** convoluted tubule, **intermediate** tubule, and **distal** convoluted tubule of the nephron, eventually entering the collecting tubules.

During transit, the composition of the fluid is altered and water is removed.

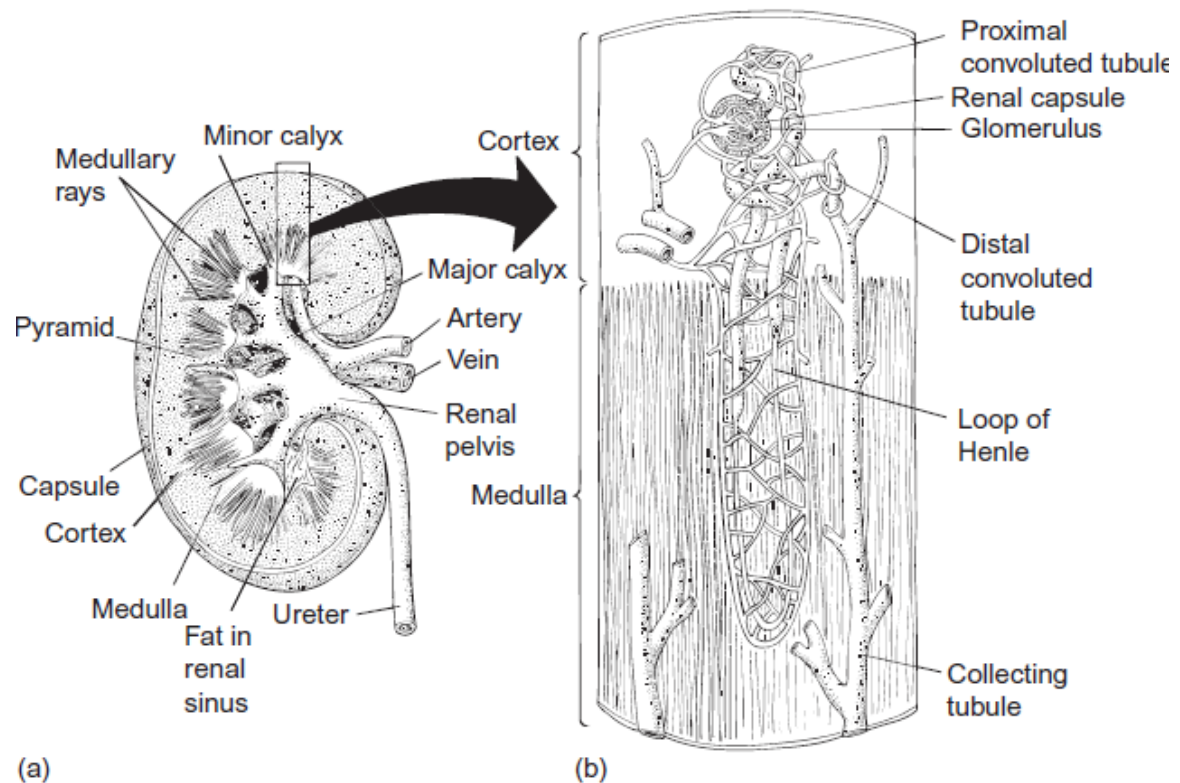
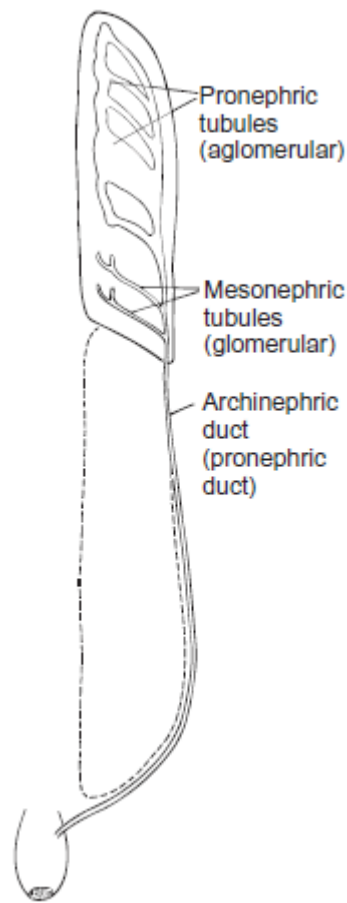


FIGURE 14.1 Structure of the mammalian kidney.

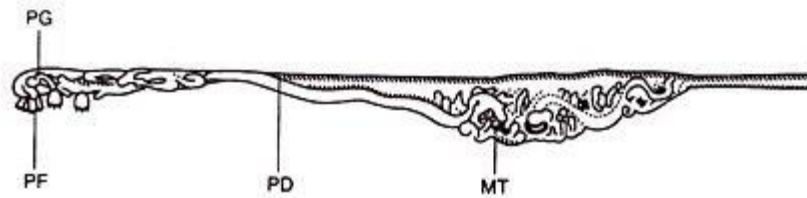
Fishes

In the hagfish pronephric tubules arise in the anterior part of the nephric ridge during embryonic development. These tubules unite successively with one another, forming the urinary or pronephric duct. Anterior tubules lack glomeruli but open to the coelom via peritoneal funnels, whereas posterior tubules are associated with glomeruli but lack connection to the coelom. **In the adult,** anterior aglomerular tubules together with several persisting posterior glomerular tubules become the compact pronephros. Although the adult pronephros may contribute to formation of coelomic fluid, the mesonephros is considered to be the functional adult kidney of hagfishes. Each paired mesonephros consists of 30 to 35 large glomerular tubules arranged segmentally along the excretory duct (pronephric duct).



Structure of the hagfish kidney.

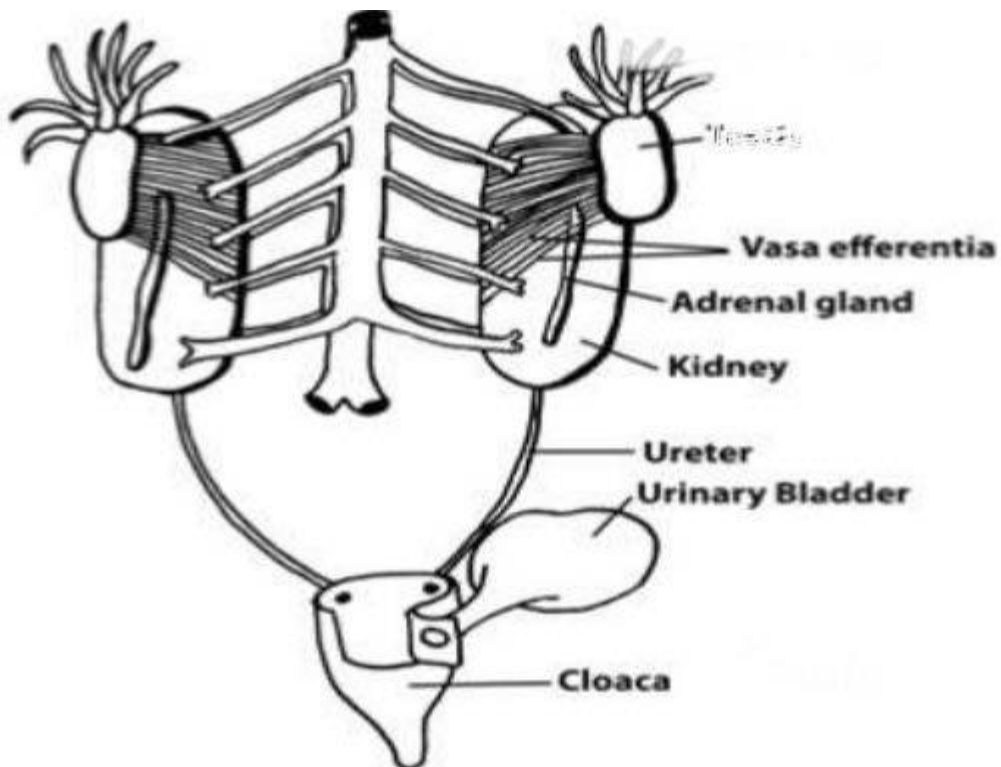
In lampreys: the early larval kidneys are pronephric tubule, consisting of three to eight coiled tubules called a vascular glomus services several tubules. Each pronephric tubule opens to the coelom through a peritoneal funnel and empties into a pronephric duct. The pronephros is the sole excretory organ of the young larva. Later in larval life, it is joined by additional mesonephric tubules posteriorly. Upon metamorphosis, additional tubules are yielding an opisthonephros that becomes the functional adult kidney .**In a few teleost species**, the pronephros persists as the functional adult kidney.



Kidney of larval lamprey; PD :pronephric duct: PF peritoneal funnel: PG: a pronephric glomus: MT: mesonephric tubule

Tetrapoda

Among amphibians having active, free-living larvae, a pronephros may develop and become functional for a time. **in adult Amphibians** have two kidneys, just like humans, and those kidneys filter wastes out of the blood and combine them with water to form **urine**. **Urine** then travels from the kidneys via the ureters to the bladder, and then out through the cloaca.



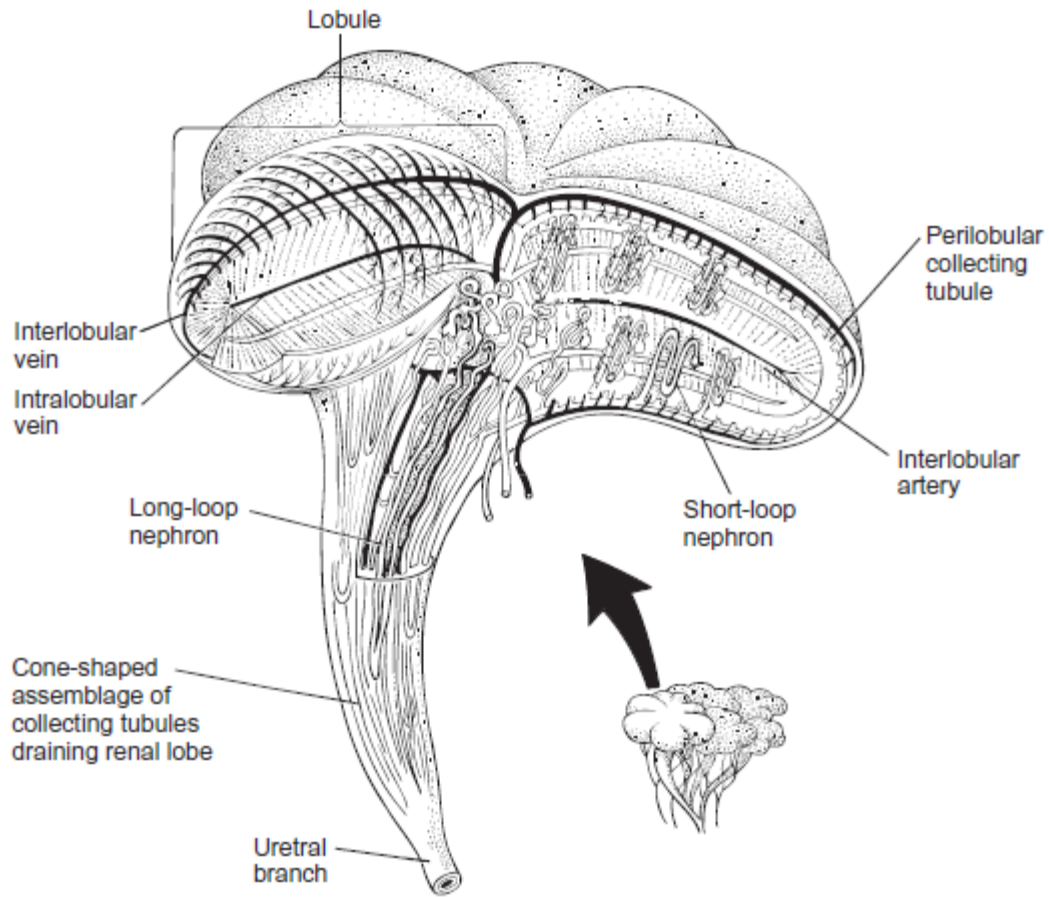
Excretory system of Amphibians

Reptiles

Urinary system is formed by the *kidneys*, including their *nephrons* (= nephric tubules) and collecting ducts. The collecting ducts drain products from the nephrons into ureters that themselves drain to the cloaca. A urinary bladder that opens in the floor of the cloaca may or may not be present depending upon species. The kidneys arise as paired structures from embryonic mesoderm. Three basic types of kidney structure (as well as some composite types) may form from these long, strip-like. Pronephros, Mesonephros, Metanephros, all appear in the reptilian. In theory, the Pronephros forms first, is more cranial in location, and its tubules connect to a pronephric duct that drains to the cloaca. Mesonephros forms next and is just caudal to Pronephros. The Metanephros forms last, is most caudally located and its nephric tubules drain into ureters which connect to the cloaca.

Birds

The kidneys contain some nephrons with short, distinct loop segments, Although analogous to the loops of Henle in mammals, these short avian loops evolved independently. These avian kidneys exhibit a modest ability to produce concentrated urine. Their product is about two to four times more concentrated than their blood. However, the nephrons of most birds do not have loops. In the absence of a loop, the avian nephron is similar to the nephron of reptiles.



Bird kidney. A section of the kidney

Kidney Function and Structure

the kidney performs two fundamental physiological functions, **excretion** and **osmoregulation**. Both are related to maintaining a constant internal environment in the face.

Nephron structure can be quite different from one taxonomic group to the next and may appear at first to have no obvious correlation with the phylogenetic position of the taxon.

In hagfishes, the nephron is quite simple. A short tubule connects the renal capsule to the excretory duct.

In lampreys and freshwater bony fishes, the nephron is more differentiated. It includes a renal capsule, proximal and distal tubules usually joined by an intermediate segment, and a collecting tubule. However, the nephron of saltwater teleosts is usually reduced because the distal tubule is lost, and in some, the renal capsule is lost..

Excretion: Removing the Products of Nitrogen Metabolism

Carbon dioxide and water are end products of carbohydrate and fat metabolism, and both are easily eliminated. But metabolism of proteins and nucleic acids produces nitrogen, usually in the reduced form of ammonia (NH₃). Because ammonia is highly toxic, it must be removed from the body quickly, sequestered, or converted into a nontoxic form to prevent accumulation in tissues.

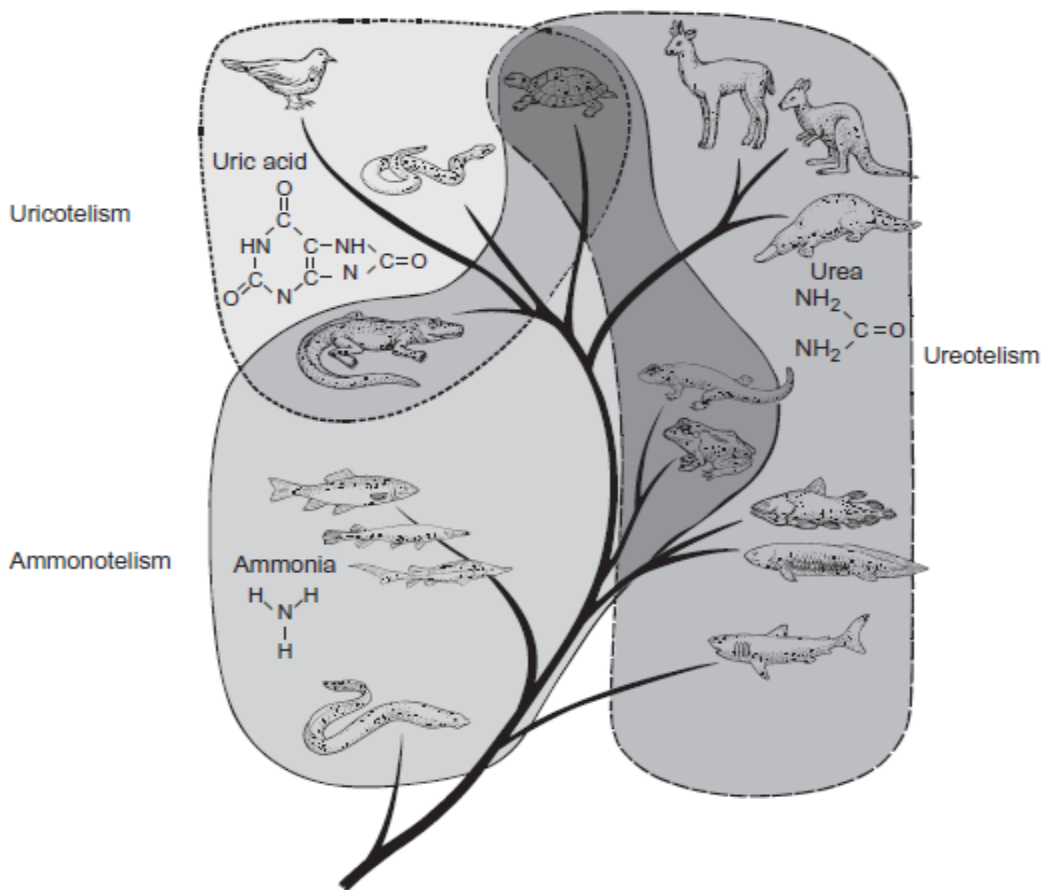
Three routes of eliminating ammonia, sometimes in combination, exist in vertebrates: Direct excretion of ammonia is **ammonotelism**, Excretion of nitrogen in the form of uric acid is called **uricotelism**, The third route is **ureotelism**, excretion of nitrogen in the form of urea .

Ammonotelism is common in animals living in water. **Ammonia** is soluble in water, and a great deal of water is required to flush it from body tissues. . For vertebrates living in an aqueous medium, water is plentiful. Thus, ammonia is eliminated through the gill epithelium, skin, However, in terrestrial vertebrates, water is often scarce, so water conservation becomes more critical. Because amniotes have lost gills, the gill epithelium is no longer a major route for ammonia excretion. Given these terrestrial constraints, ammonia is converted into urea or uric acid, both being nontoxic forms that address the immediate problem of ammonia toxicity. Furthermore, less water is required to excrete urea or uric acid, so water is conserved as well.

In advanced tetrapods, two evolutionary routes have been followed in addressing the related problems of water economy and nitrogen elimination.

Birds and most living reptiles primarily depend on uricotelism. Uric acid, only slightly soluble in water, is formed in the kidneys and transported via the ureters to the cloaca.

Mammals have followed a different evolutionary route in dealing with nitrogen elimination. They depend largely on ureotelism, the conversion of ammonia into urea. Mammalian kidneys accumulate urea and excrete it as a concentrated urine, thus also detoxifying ammonia and conserving water .



Mechanisms of eliminating nitrogenous wastes.

Water Balance

Most vertebrates require physiological vigilance to maintain internal balance because the external world constantly intrudes. Some groups, such as **reptiles**, control water loss with a thick integument that reduces the permeability of their skin to water. In addition, the kidneys, the cloaca, and even the urinary bladder are **water conservers**, meaning that they recover water before nitrogen is eliminated from the body.

In freshwater fishes, the osmotic problem results from a net tendency for an *inward* flux of water. Relative to fresh water, the body of the fish is **hyperosmotic**, meaning that its body fluids are osmotically more concentrated (hence *hyper-*) than the surrounding water. Because fresh water is relatively dilute and the body is relatively salty

For most saltwater fishes, the osmotic problem is just the reverse. There is a tendency for a net *outward* flux of water from the body tissues, dehydrating them. Relative to salt water, the bodies of most marine fishes are **hyposmotic** meaning that the body is osmotically less concentrated (hence *hypo-*) than seawater. Water tends to be drawn from the body, and dehydration of the body will result if this condition is not controlled physiologically. In this respect, To aid in water conservation, the kidneys are designed to excrete very little water, thus reducing water loss. To address the problem of excess salt, the gills and sometimes special glands become partners with the kidneys in the business of osmoregulation.

Water Elimination

Water elimination is a problem for hyperosmotic vertebrates living in fresh water. The vertebrate mechanism of urine formation seems especially well suited to address such a problem. The kidneys of most insects and some other invertebrate animals are **secretion kidneys**. vertebrate kidneys, like the kidneys of most crustaceans, annelids, and molluscs, are **filtration kidneys**. **In humans**, each day the kidneys form about 170 liters (45 gallons) of glomerular filtrate in their 2 million renal capsules. This is four to five times the total volume of water in the body.

In freshwater fishes and aquatic amphibians, the kidneys characteristically have large, well-developed glomeruli. Consequently, relatively large volumes of glomerular filtrate are produced. The prominent distal tubule absorbs solutes (salts, amino acids, etc.) from the filtrate to retain these in the body, but it absorbs only a third to a half of the filtered water. In this instance, a large proportion of the water is eliminated in the urine. Thus, the kidney is designed to produce large amounts of dilute urine and address the main osmotic problem of excess water in freshwater vertebrates.

Salt Balance

Marine reptiles and birds that eat salty foods or drink seawater to replace lost fluids also ingest high levels of salt. Because their kidneys cannot handle this excess salt, it is excreted by special **salt glands**. In response to a salt load, salt glands intermittently produce a highly concentrated secretion containing Na₊ and Cl₋ primarily. **In reptiles**, these salt glands can be specialized nasal glands (in some marine lizards), orbital glands (in some marine turtles), sublingual

glands (in sea snakes), or glands on the tongue's surface (in Asiatic saltwater crocodiles and North American crocodiles).

In marine birds, paired nasal salt glands are present. These large, specialized glands are usually located within shallow depressions on the dorsal surface of the skull and release their concentrated secretion into the nasal cavity .

Marine mammals lack specialized salt glands. Their kidneys produce urine that is much more concentrated than seawater, so most salt is eliminated through the kidneys. **Many terrestrial** mammals have sweat glands in the integument primarily serving thermoregulation, but they also eliminate some salt.

In fresh water, the problem is totally different. Salt tends to be lost to the environment. Freshwater fishes absorb salts through their gills. **In aquatic amphibians**, the skin aids in the regulation of salt balance.

Water Conservation

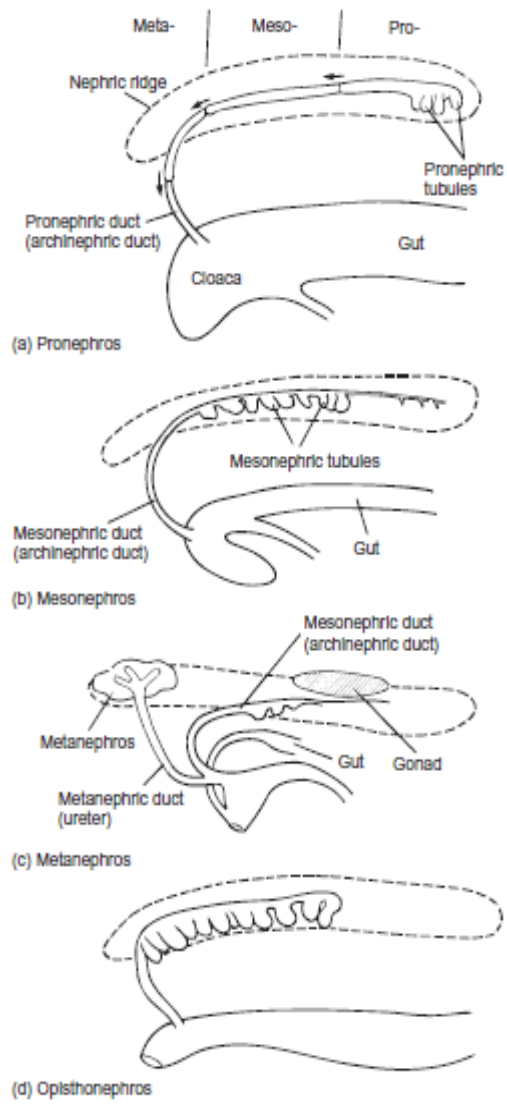
Terrestrial vertebrates have alternative adaptations to conserve water. In mammals, and to a lesser extent in birds, water conservation is based on modification of the loop of Henle. The loop creates an environment around the tubules that encourages the absorption of water before it can be excreted from the body. Consequently, urine becomes concentrated, and kidney design serves water conservation.

In the mammalian kidney, the relationship between tubule design and water conservation is complex. The first step in urine formation is formation of glomerular filtrate. Circulating blood cells. Second, most of the sodium ions, nutrients, and water are reabsorbed in the proximal tubule. Absorption is facilitated by the large surface area of proximal tubule cells and depends on active transport of sodium. Usable proteins that were part of the glomerular

filtrate are also absorbed in the proximal tubule. Third, the filtrate enters the intermediate tubule of the loop of Henle.

Osmoconformers

In hagfishes, unlike in the hyposmotic body fluids of most marine fishes, concentrations of Na₊ and Cl₋ in blood and extracellular fluid are elevated, so they are close to those of seawater. Hagfish tissues tolerate these relatively high levels of solutes. Because the hagfish is in osmotic equilibrium with its environment, the nephron does not need to excrete large volumes of urine. Consequently, the nephron is reduced to little more than a renal capsule connected to the archinephric duct by a short, thin-walled duct (figure 14.10a). The well-developed renal corpuscle is quite large. Because water elimination is not a problem for the hagfish, the well-developed renal corpuscle probably functions in regulating divalent ions such as Ca²⁺ and SO₄²⁻.



Embryonic origin of the kidneys