Comparative Anatomy: Evaluation and fate of kidney

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Urinarysystemis devoted toquitedifferentfunctions:namely, to theeliminationof 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 oftheMammalianKidney:

The vertebrate kidneys are a pair of compact masses of tubules situated dorsalto the abdominalcavity.

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.** Withinthe kidney, the functionalunitthat forms **uriniferous tubule**Theuriniferous tubule consists of two parts: the **nephron (nephric tubule)** and the **collecting tubule** into which the nephron empties, **The renal artery,** oneofthemajorbranches fromthedorsalaorta, delivers blood to thekidneys. 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 capsuleform the **renalcorpuscle** . Anultrafiltratewithoutblood 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** convolutedtubuleofthenephron,eventuallyenteringthecollectingtubules.

Duringtransit,thecompositionofthefluidisalteredandwaterisremoved.

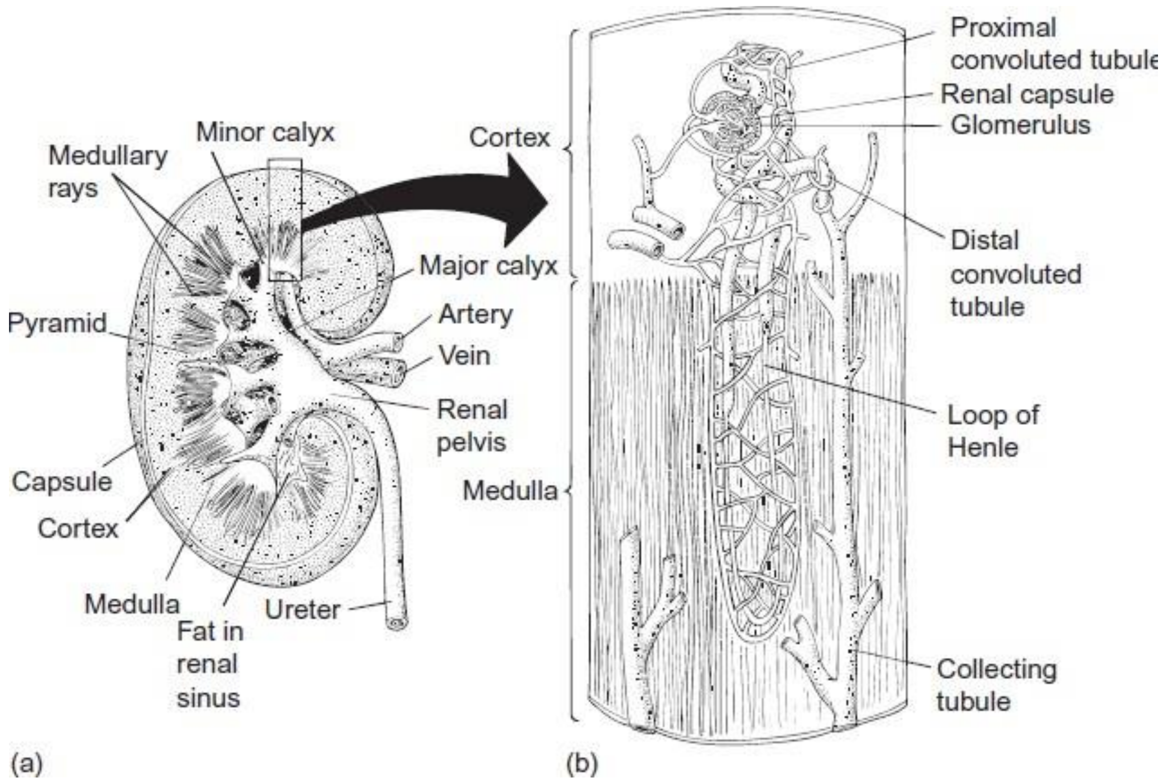
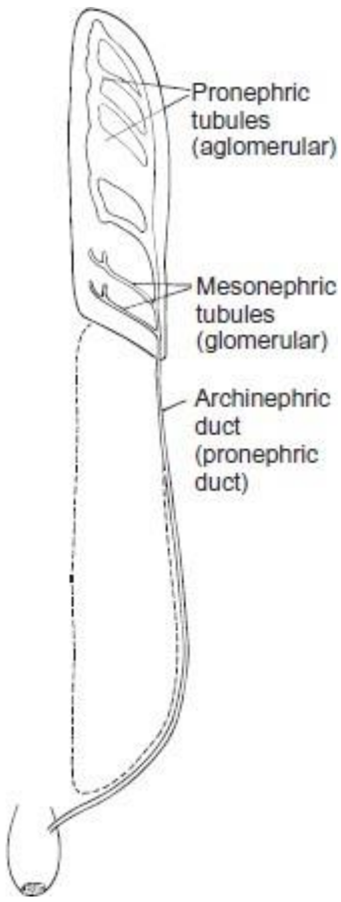


FIGURE14.1Structureofthemammaliankidney.

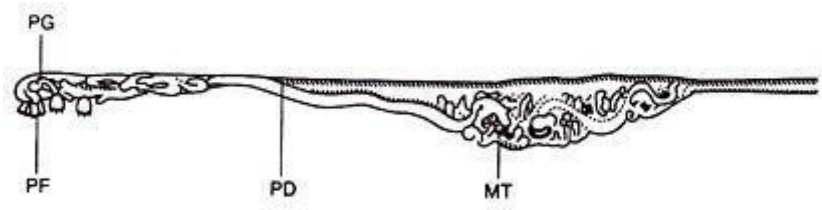
Fishes

In the hagfish pronephric tubules arise in the anterior part of the nephric ridge during embryonic development. These tubules unite successively with one another, formingtheurinaryorpronephric duct. Anteriortubules lackglomeruli 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 mesonephrosconsistsof30to 35large glomerulartubules arranged segmentally along the excretory duct (pronephric duct) .



Structureofthehagfishkidney.

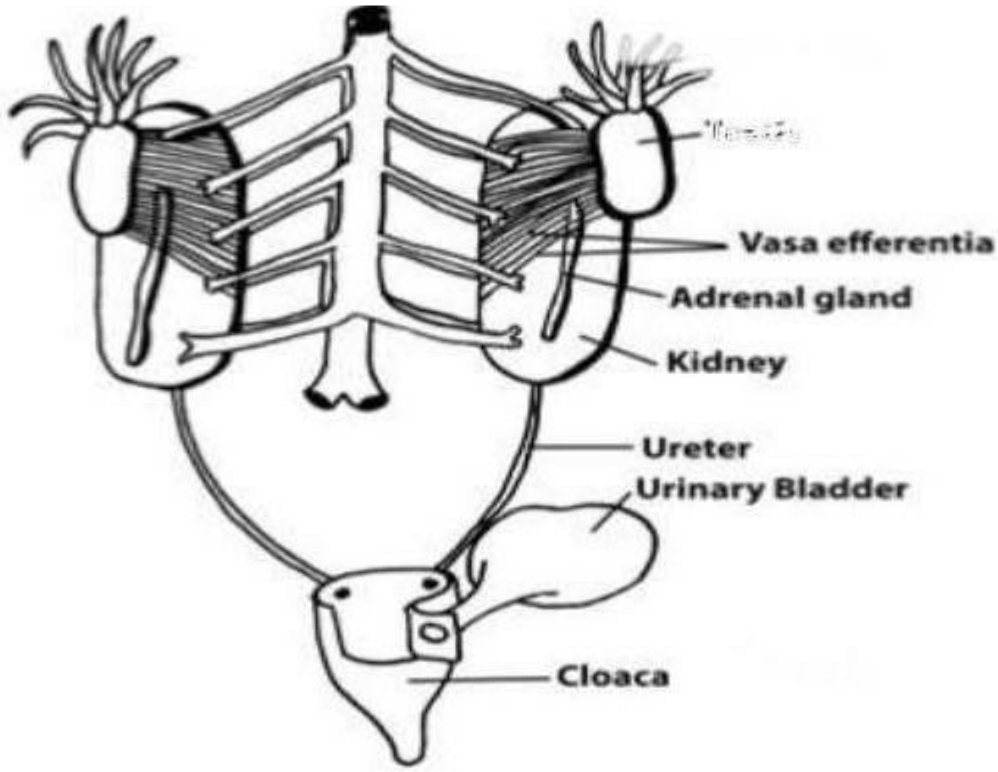
Inlampreys: the early larval kidneys arepronephric tubule, consisting of three to eight coiled tubules called a vascular glomus services several tubules. Each pronephric tubule opens to the coelom through a peritoneal funnel and empties into a pronephric duct. The pronephros is the sole excretory organ 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.



Kidneyoflarvallamprey;PD :pronephric duct:PF peritonealfunnel:PG: a pronephricglomus: 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 watertoform**urine**. **Urine** then travelsfrom the kidneys via the ureters to thebladder, and then out through the cloaca.



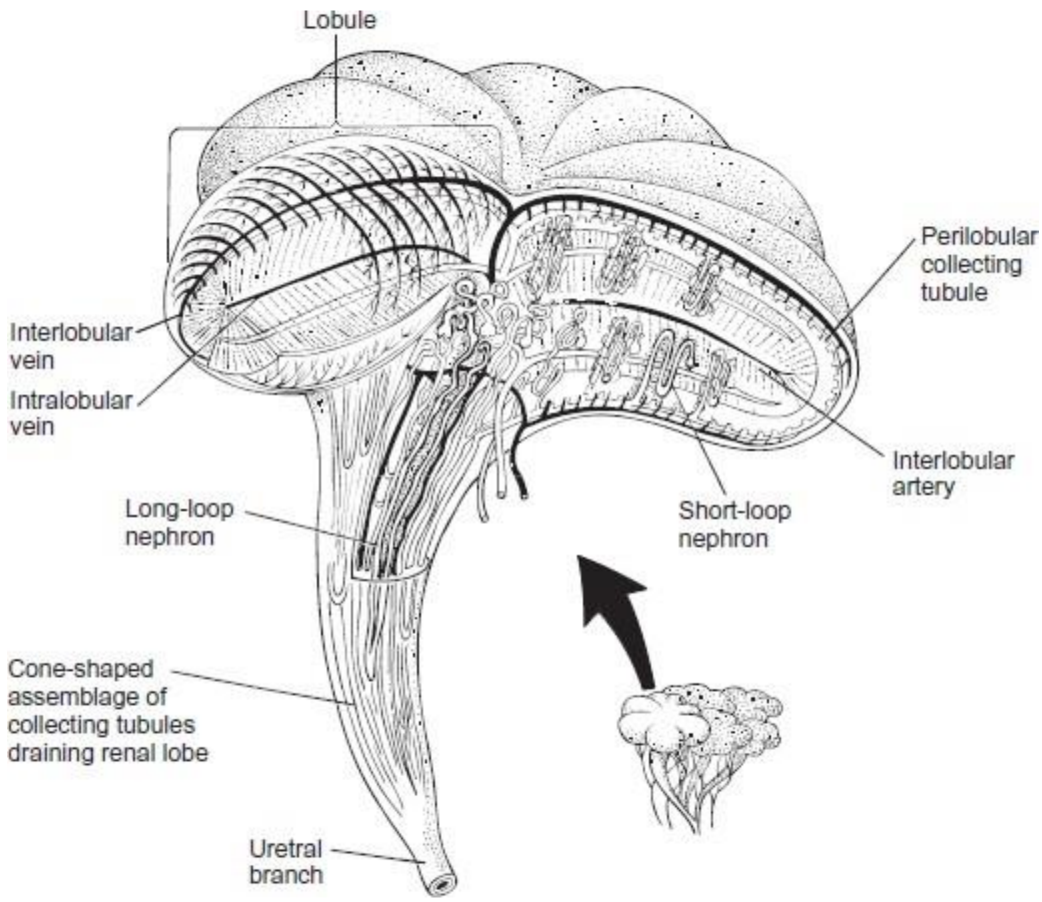
ExcretorysystemofAmphibians

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 to 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 Thekidneys ariseas paired structures fromembryonic mesoderm. Three basic types of kidney structure (as well as some composite types) may form from these long, strip- like. Pronephros, Mesonephros, Metanephros, allappear inthereptilian. In theory, thePronephrosforms first, is morecranial 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 Metanephrosforms 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. Theseaviankidneys exhibitamodestabilityto produce concentrated urine. Their product is about two to four times moreconcentrated thantheirblood. However, thenephrons ofmostbirdsdo nothaveloops. Inthe absenceof a loop, the avian nephron is similar to the nephron of reptiles .



Birdkidney. Asectionofthekidney Kidney

Function and Structure

thekidneyperforms two fundamentalphysiologicalfunctions, **excretion**and **osmoregulation.** Both are related to maintaining a constant internal environment in the face.

Nephronstructurecanbequitedifferentfromonetaxonomic group tothenext and may appear at first to have no obvious correlation with the phylogenetic position of the taxon.

Inhagfishes,thenephronis quitesimple. Ashorttubuleconnects therenal capsule to the excretory duct.

Inlampreys andfreshwaterbonyfishes,thenephronis moredifferentiated. It includes a renalcapsule, proximal and distaltubules usually joined by an intermediate segment, and a collecting tubule. However, the nephron of saltwater teleosts is usually reduced because the distaltubule is lost, and in some, the renal capsule is lost..

Excretion:RemovingtheProductsofNitrogen Metabolism

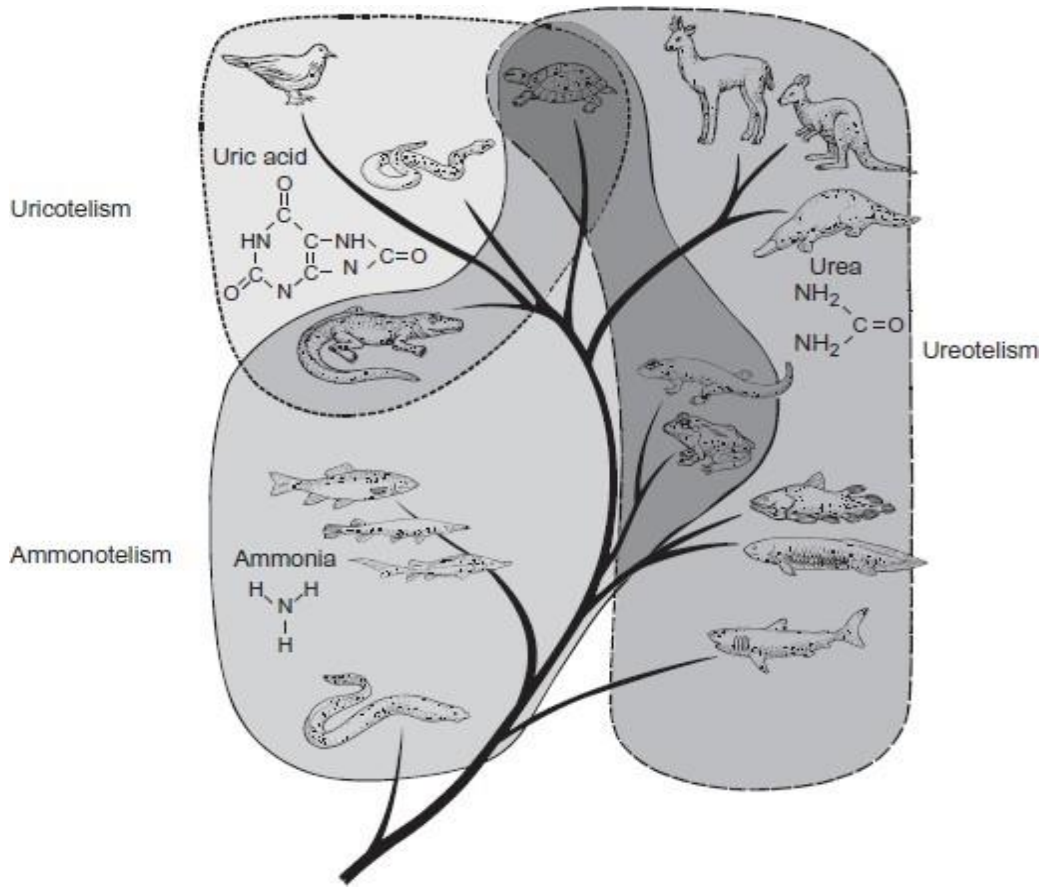
Carbondioxideand waterareend productsofcarbohydrateand fatmetabolism, and both are easily eliminated. But metabolismof proteins and nucleic acids produces nitrogen, usually in the reduced form of ammonia (NH3). Because ammonia is highly toxic, it must be removed fromthe body quickly, sequestered, orconverted into a nontoxic form to prevent accumulation in tissues.
Three routes of eliminating ammonia, sometimes in combination, exist in vertebrates:Directexcretionofammonia is**ammonotelism,** Excretionofnitrogen in the formof uric acid is called **uricotelism,** The third route is **ureotelism,** excretion of nitrogen in the form of urea **.**

Ammonotelismiscommoninanimals living inwater. **Ammonia** is soluble in water, and a great dealof water is required to flush it frombody tissues. .For vertebrates living inanaqueous medium, water is plentiful. Thus, ammonia is eliminated throughthegillepithelium,skin,However, interrestrialvertebrates, water is often scarce, so water conservation becomes morecritical. Because amniotes have lost gills, the gill epithelium is no longer a major route for ammonia excretion. Given these terrestrialconstraints, ammonia is converted into urea or uric acid, bothbeing nontoxic forms that address the immediate problemof 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 andmostliving reptilesprimarilydependonuricotelism.Uric acid, only slightlysoluble inwater, is formed inthekidneys and transported viatheureters to the cloaca.

Mammals havefollowed adifferentevolutionaryroute indealingwithnitrogen elimination.Theydepend largelyonureotelism,theconversionof ammonia into urea. Mammalian kidneys accumulate urea and excrete it as a concentrated urine, thus also detoxifying ammonia and conserving water .



Mechanismsofeliminating nitrogenous wastes.

Water Balance

Most vertebrates require physiologicalvigilance to maintain internalbalance becausetheexternal world constantly intrudes. Somegroups,suchas**reptiles,** controlwater losswithathickintegumentthatreduces thepermeabilityoftheir skinto water. Inaddition, thekidneys, thecloaca, and eventheurinarybladder are **waterconservers,** meaning that they recover water before nitrogen is eliminated from the body.

Infreshwaterfishes, theosmoticproblem results fromanettendencyforan *inward* flux of water. Relative to fresh water, the bodyof the fish is **hyperosmotic,**meaningthat its bodyfluids areosmoticallymoreconcentrated (hence *hyper*-) than the surrounding water. Because fresh water is relatively dilute and the body is relatively salty

For mostsaltwater 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. Watertends tobedrawnfromthebody, anddehydrationofthebody willresult ifthis condition is notcontrolled physiologically. Inthis respect,To aid inwaterconservation,thekidneys are designed to excretevery littlewater, thus reducing water loss.To address the problemof excess salt, the gills and sometimes specialglands become partners with the kidneys in the business of osmoregulation.

Water Elimination

Water elimination is a problemfor hyperosmotic vertebrates living in fresh water. The vertebrate mechanism of urine formation seems especially well suited to address such aproblem. The kidneys of most insects and some other invertebrateanimals are **secretionkidneys.** vertebratekidneys, likethekidneys ofmostcrustaceans, annelids, and molluscs, are **filtrationkidneys. Inhumans,** each day the kidneys formabout 170 liters (45 gallons) of glomerular filtrate in their 2 million renalcapsules.Thisisfour tofive timesthe totalvolume of water in the body.

In freshwater fishes and aquatic amphibians, the kidneys characteristically havelarge,well-developed glomeruliConsequently,relatively largevolumes of glomerular filtrate are produced. Theprominent distal tubule absorbs solutes (salts, amino acids, etc.) fromthe filtrate to retain these in the body,but it absorbs only a third to a half of the filtered water. In thisinstance, a large proportionof thewater is eliminated intheurine. Thus, the kidney is designed to producelargeamounts ofdiluteurineand address themainosmoticproblem of excess water in freshwater vertebrates.

SaltBalance

Marine reptilesandbirds thateatsaltyfoodsordrinkseawaterto replacelost fluids also ingest high levels of salt Because their kidneys cannot handle this excess salt, it is excreted byspecial **salt glands.** In response to asalt load,salt glands intermittently produce a highly concentrated secretion containing Na_ and Cl_ primarily**. Inreptiles**, thesesaltglandscanbespecialized nasalglands (in some marine.lizards), orbitalglands (in some marine turtles), sublingual glands (inseasnakes), orglands onthetongue’ssurface(inAsiatic saltwater crocodiles and North American crocodiles.

Inmarine birds, paired nasalsaltglands arepresent.Theselarge, specialized glands areusually located withinshallowdepressionsonthedorsalsurfaceof the skulland release their concentrated secretion into the nasalcavity .

Marine mammals lackspecialized saltglands. Theirkidneys produceurine that is much more concentrated than seawater, so mostsalt is eliminated through the kidneys. **Many terrestrial** mammals have sweat glands in the integumentprimarilyservingthermoregulation, buttheyalso eliminatesome salt. **Infreshwater**,theproblem is totallydifferent. Salt tends tobelost to the environment.Freshwaterfishes absorbsalts throughtheirgills. **Inaquatic amphibians**, the skin aids in the regulation of salt balance.

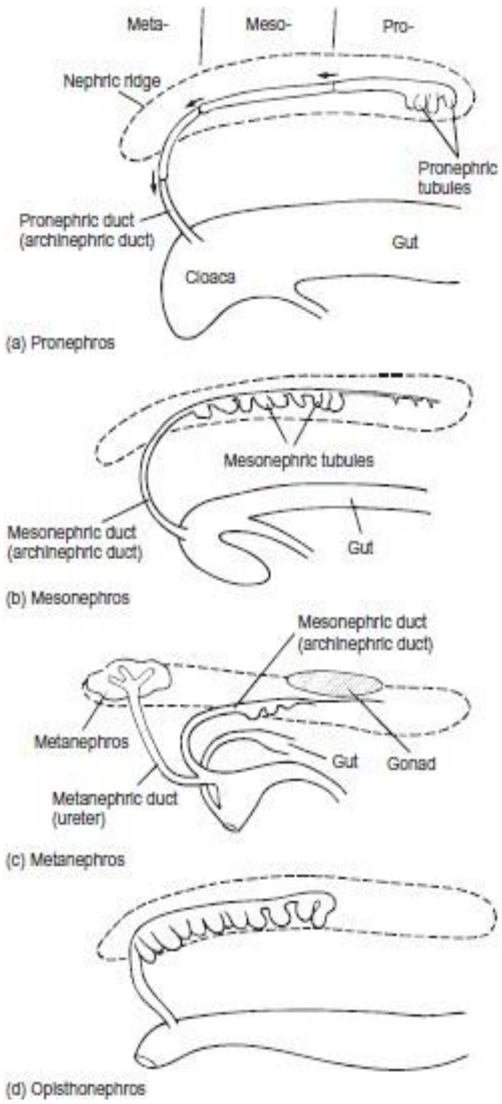
Water Conservation

Terrestrial vertebrates have alternative adaptations to conserve water. In mammals, and to a lesser extent in birds, water conservation is based on modificationoftheloopofHenle. The loopcreates anenvironmentaround the tubules that encourages the absorption of water before it can be excreted from thebody.Consequently,urinebecomesconcentrated,and kidneydesignserves water conservation.

Inthe mammaliankidney, therelationship betweentubuledesignand water conservation is complex. The first step in urine formation is formation of glomerular filtrate Circulating blood cells. Second, mostof the sodium ions, nutrients, and water are reabsorbed in the proximaltubule. Absorption is facilitated by the large surface area of proximaltubule cells and depends on active transport ofsodium. Usable proteins that were part of the glomerular filtratearealso absorbed intheproximaltubule. Third, thefiltrateenters 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 theyarecloseto thoseofseawater. Hagfishtissues toleratetheserelativelyhigh levels of solutes. Because the hagfish is in osmotic equilibriumwith its environment, the nephron does not need to excrete large volumes of urine.
Consequently, the nephron is reduced to little more than a renalcapsule connected to the archinephric ductby ashort, thin-walled duct(figure 14.10a). thewell-developed renalcorpusclearequite large. Becausewaterelimination is not a problem for the hagfish, the well-developed renalcorpuscle probably functions in regulating divalent ions such as Ca___and SO4 .



Embryonic origin of the kidneys