Course: Animal form and function

Chapter: Temperature And Body Fluid Regulation

- Homeostasis and Temperature Regulation
- Heat Gains and Losses
- Temperature Regulation in Invertebrates
- Invertebrate Excretory Systems
- Vertebrate Excretory Systems

INVERTEBRATE EXCRETORY SYSTEMS

- **CONTRACTILE VACUOLES**
- **PROTONEPHRIDIA**
- **METANEPHRIDIA**
- **ANTENNAL (GREEN) AND MAXILLARY GLANDS**
- **MALPIGHIAN TUBULES**
- **COXAL GLANDS**

➢ CONTRACTILE VACUOLES

- Contractile vacuoles are energy-requiring devices that expel excess water from individual cells exposed to hypoosmotic environments.
- Many freshwater species (protozoa, sponges), however, have contractile vacuoles that pump out excess water.

➢ PROTONEPHRIDIA

- The earliest type of nephridium to appear in the evolution of animals was the protonephridium.
- Among the simplest of the protonephridia are flame-cell systems, such as those in rotifers, some annelids, larval molluscs, and some flatworms

Protonephridial (Excretory) System in a Turbellarian.

(a) The system lies in the mesenchyme and consists of a network of fine tubules that run the length of the animal on each side and open to the surface by minute excretory pores called **nephridiopores.**

(b) Numerous fine side branches from the tubules originate in the mesenchyme in enlargements called **flame cells**

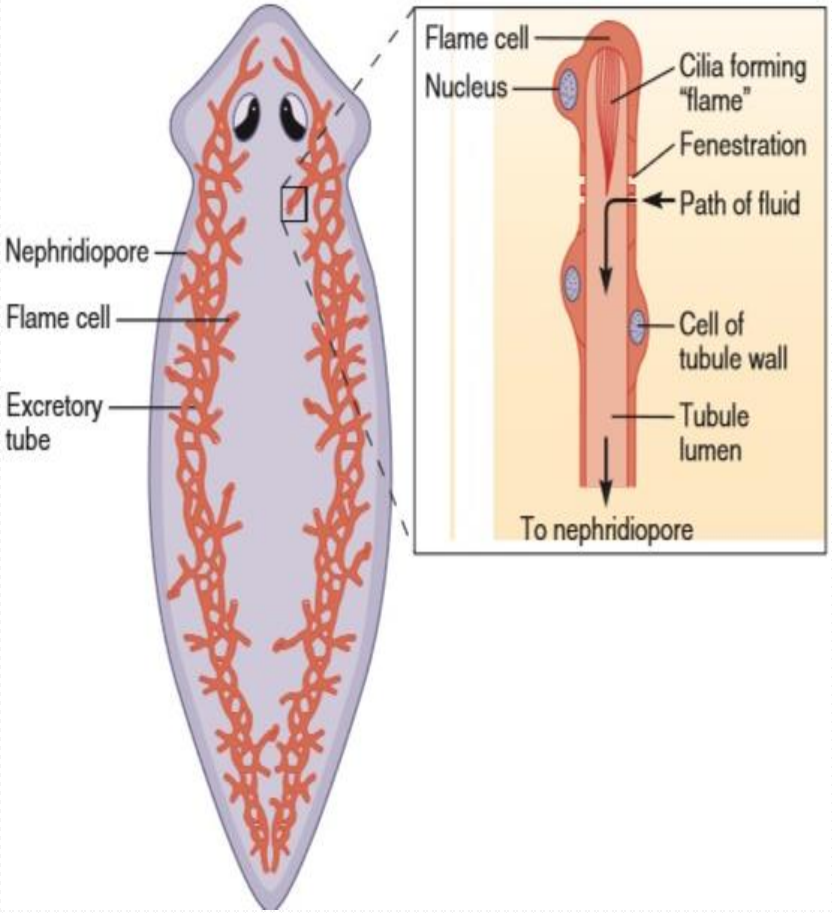

Fig: Protonephridial (Excretory) System in a Turbellarian

➢ METANEPHRIDIA

- Advanced type of excretory structure among invertebrates.
- Also open internally to the body fluids.
- Multicellular
- Each metanephridium begins with a ciliated funnel, the nephrostome, that opens from the body cavity of a segment into a coiled tubule.

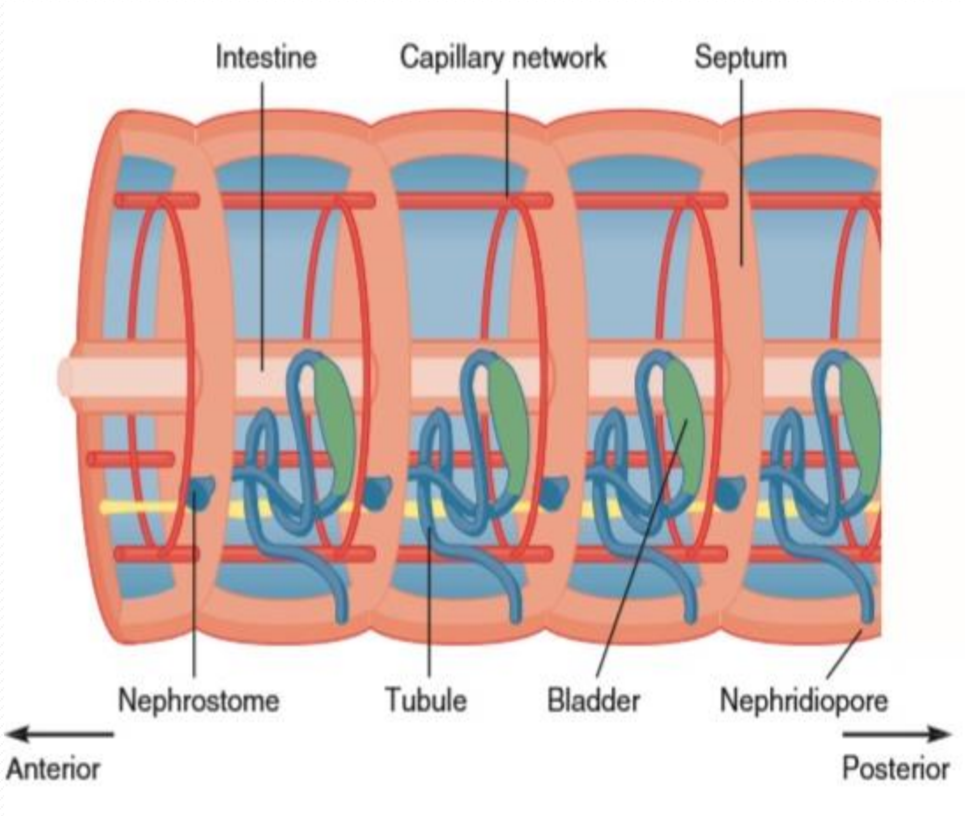

Fig: Earthworm Metanephridium.

➢ ANTENNAL (GREEN) AND MAXILLARY GLANDS

- The excretory organs in some crustaceans (crayfish, crabs) are antennal glands or green glands because of their location near the antenna and their green color.
- Fluid filters into the antennal gland from the hemocoel.
- Hemolymph pressure from the heart is the main driving force for filtration

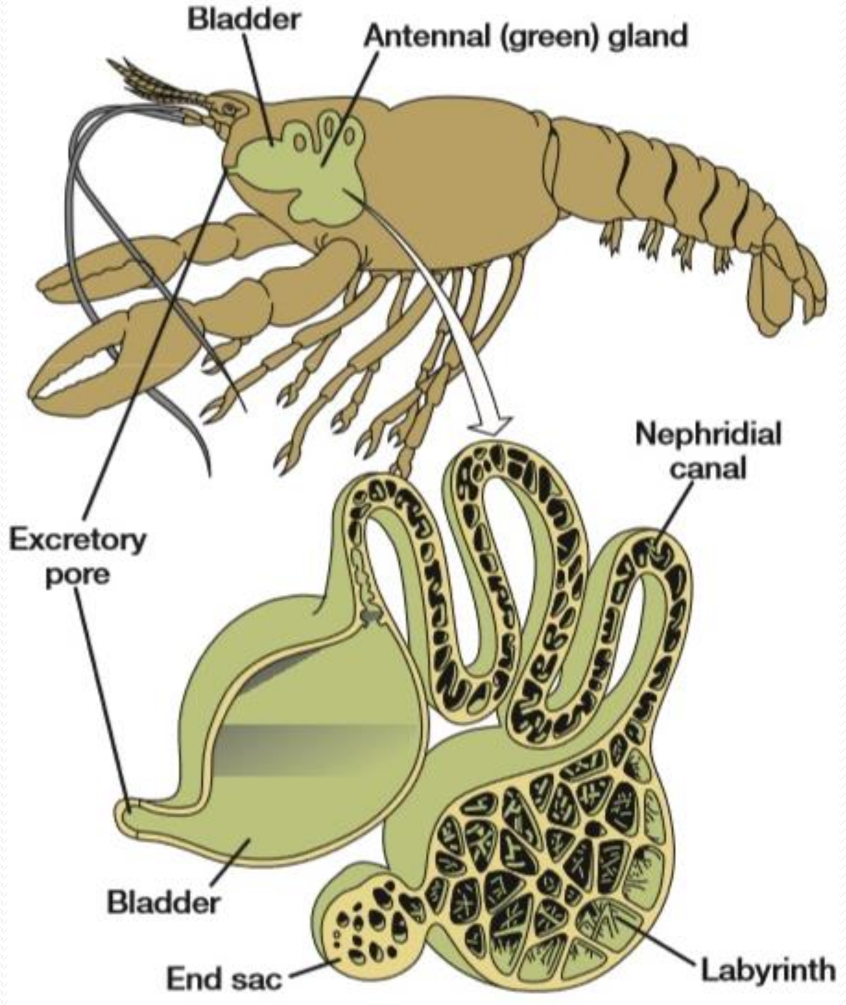

Fig: Antennal (Green) Gland of the Crayfish

➢ MALPIGHIAN TUBULES

- Remove nitrogenous wastes (uric acid) from the hemocoel.
- Various ions are actively transported across the outer membrane of the tubule.
- Some water, ions, and organic compounds are reabsorbed in the basal portion of the Malpighian tubules and the hindgut
- Uric acid moves into the hindgut and is excreted.

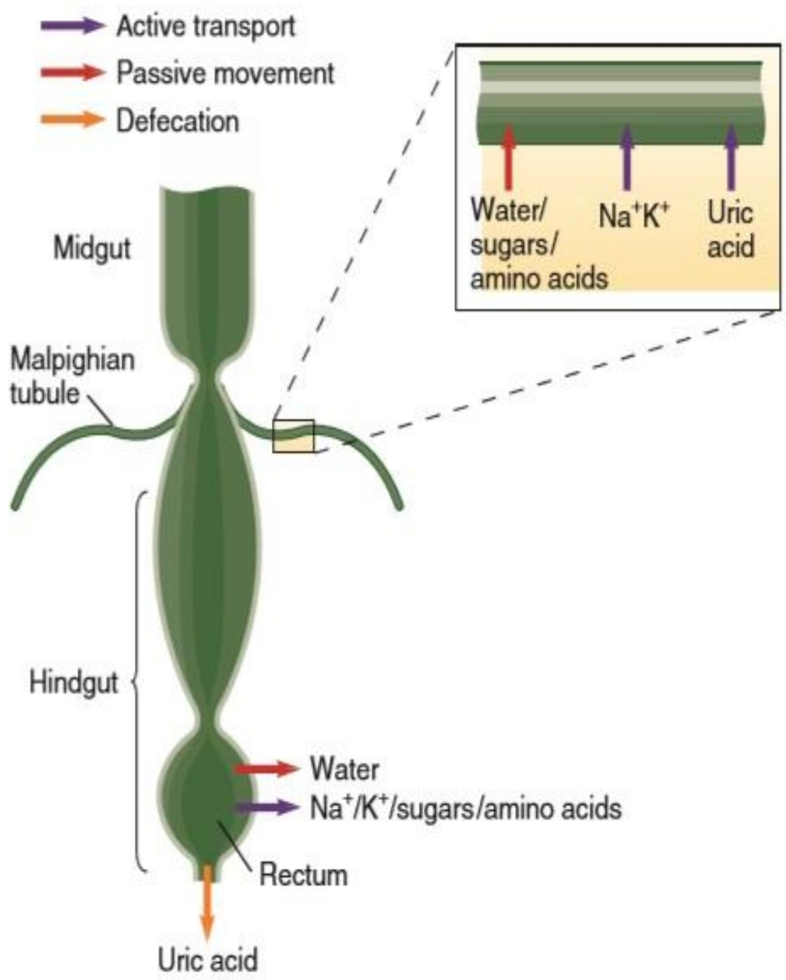

Fig: Malpighian Tubules

➢ COXAL GLANDS

- Common among arachnids (spiders, scorpions, ticks, mites). These spherical sacs resemble annelid nephridia.
- Wastes are collected from the surrounding hemolymph of the hemocoel and discharged through pores on from one to several pairs of appendages near the proximal joint (coxa) of the leg.
- Recent evidence suggests that the coxal glands may also function in the release of pheromones.

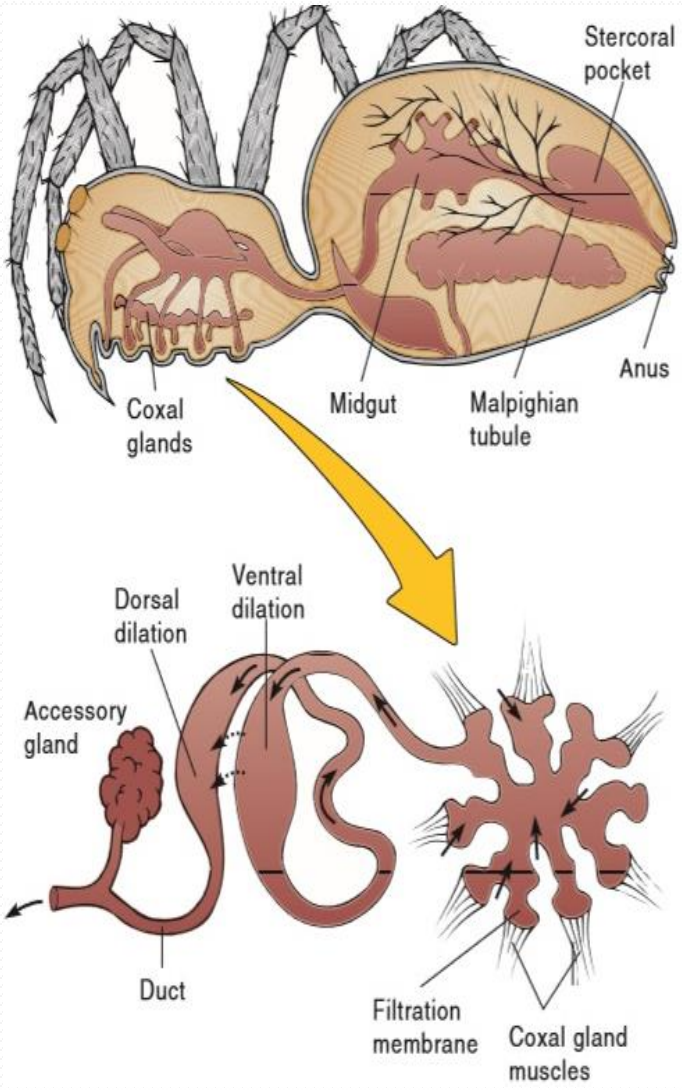

Fig: Coxal Glands in Arachnids.

VERTEBRATE EXCRETORY SYSTEMS

Vertebrates have a closed circulatory system containing blood that is under pressure to force blood through a membrane filter in a kidney, where the following three key functions take place:

1) **Filtration, in which blood passes through a filter that retains blood cells, proteins, and other large solutes but lets small molecules, ions, and urea pass through.**
2) **Reabsorption, in which selective ions and molecules are taken back into the bloodstream from the filtrate.**
3) **Secretion, whereby select ions and end products of metabolism (e.g., K^+, H^+, NH3) that are in the blood are added to the filtrate for removal from the body.**

VERTEBRATE KIDNEY VARIATIONS

Overall, there are three kinds of vertebrate kidneys:

- **Pronephros**
- **Mesonephros**
- **Metanephros**

Pronephros:

- **Appears only briefly in many vertebrate embryos, and not at all in mammalian embryos**
- **Pronephros is the first osmoregulatory and excretory organ of the embryo (tadpoles and other amphibian larvae)**
- **Fewer blood-filtering units than either the mesonephric or metanephric kidneys**

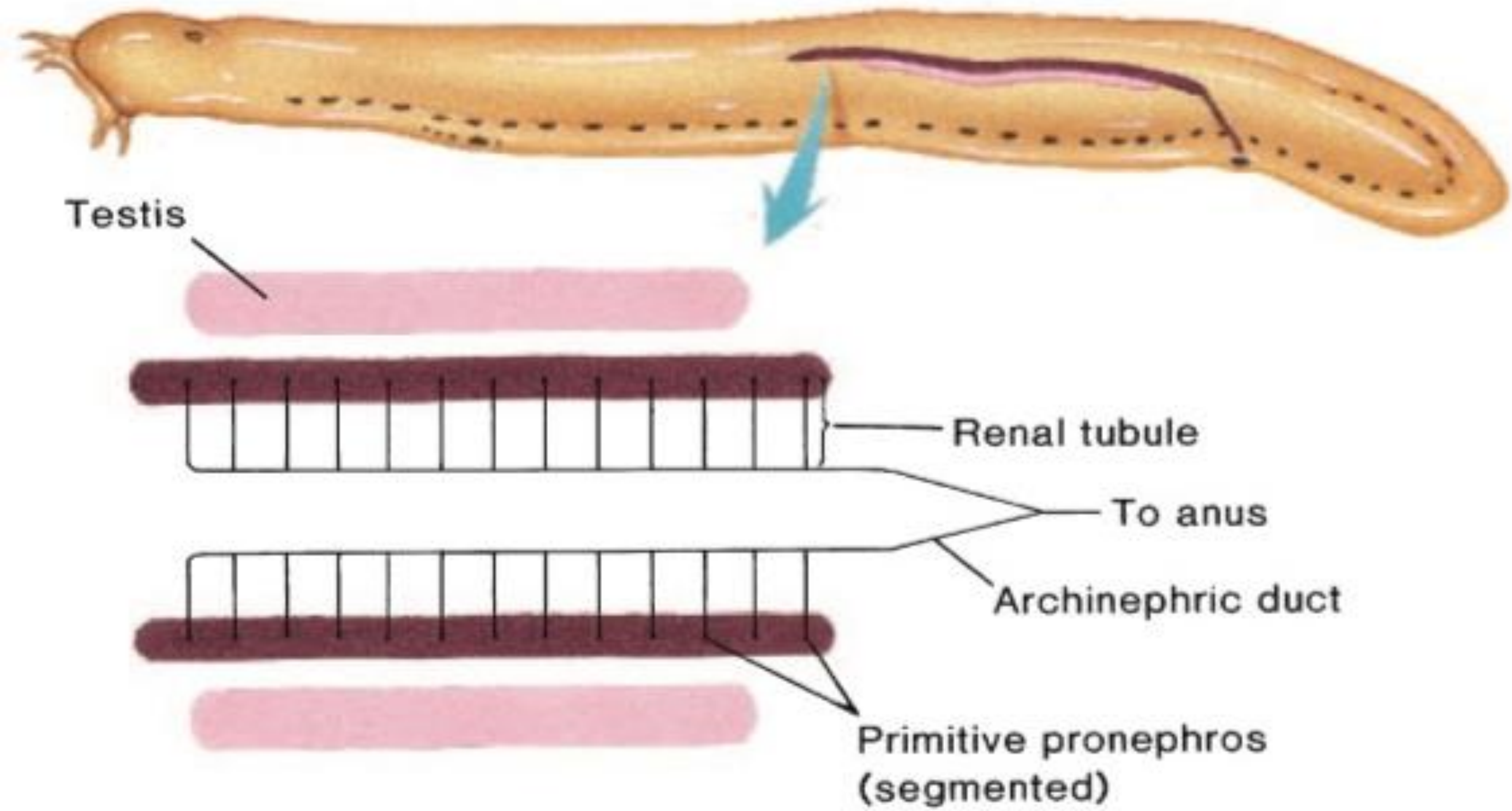

Fig: The primitive pronephric kidney, is found in adult hagfishes and embryonic fishes and amphibians. It is anterior in the body and contains segmental renal tubules that lead from the body of the pronephros to the archinephric duct. Notice that the testes are separated from the kidneys

Mesonephros:

- **During embryonic development of amniotes, or during metamorphosis in amphibians, the mesonephros replaces the pronephros.**
- **The mesonephros is the functioning embryonic kidney of many vertebrates and also adult fishes and amphibians.**

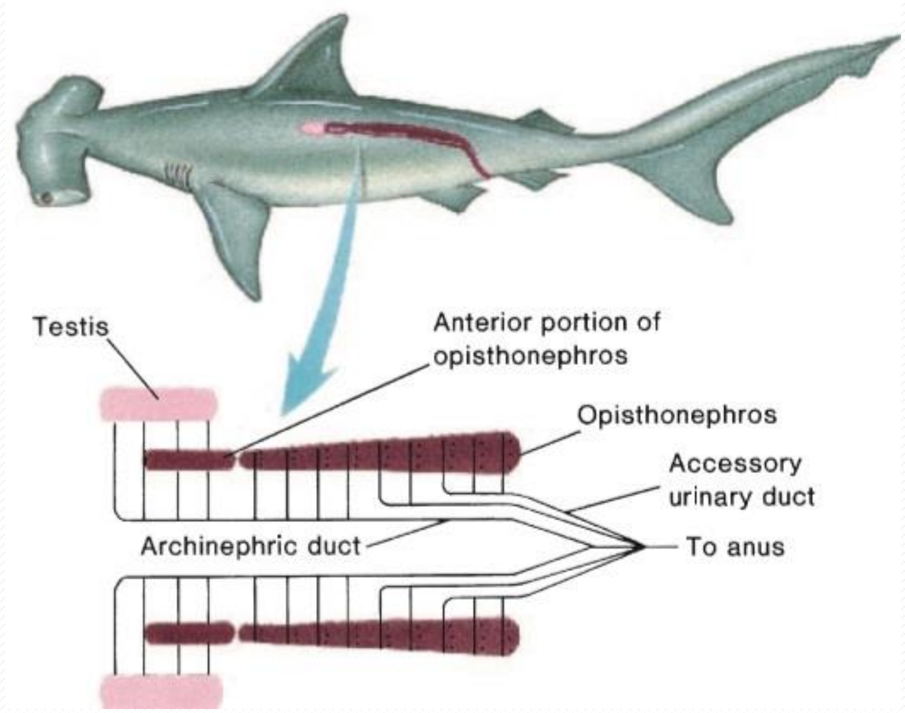

Fig: The mesonephros is the functional kidney in the amniote embryo, adult fishes, and amphibians. It is structurally similar to the nonsegmented opisthonephric (advanced mesonephric) kidney of most nonamniote vertebrates, such as sharks.

Sharks

- **Sharks and their relatives (skates and rays) have mesonephric kidneys.**
- **they have a rectal gland that secretes a highly concentrated salt (NaCl) solution**
- **To reduce water loss, they use two organic molecules—urea and trimethylamine oxide (TMO)**

Counteracting Osmolyte Strategy.

Urea denatures proteins and inhibits enzymes, whereas TMO stabilizes proteins and activates enzymes. Together in the proper ratio, they counteract each other, raise the osmotic pressure, and do not interfere with enzymes or proteins. This reciprocity is termed the counteracting osmolyte strategy.

Metanephros:

- **The mesonephros gives way during embryonic development to the metanephros in adult reptiles, birds, and mammals.**
- **Larger number of filtering units**

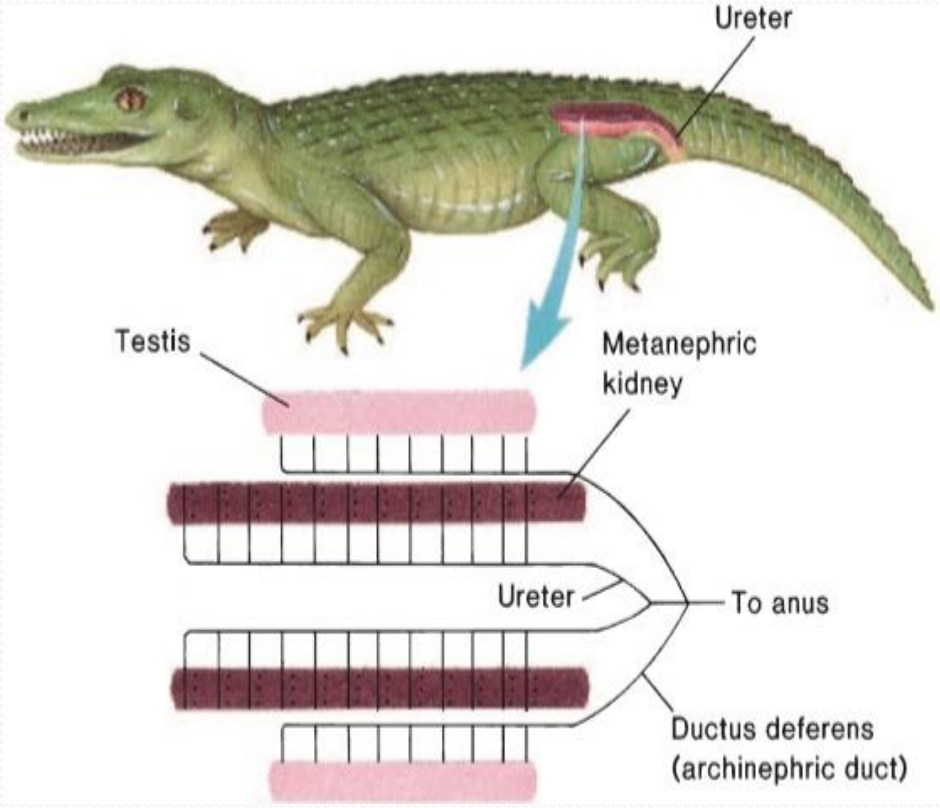

Fig: The metanephric kidney of adult amniotes (reptiles, birds, and mammals) is the most advanced kidney. Notice the separate ureters (new ducts) for carrying urine. The archinephric duct becomes the ductus deferens for carrying sperm. The kidney is more compact and located more caudally in the body.

❖ Maintenance of water and solute concentrations in Teleost Fishes

Fresh water fishes

- **Body fluids of freshwater fishes are hyperosmotic.**
- **do not drink much water**
- **bodies are coated with mucus, which helps stem inward water movement.**
- **Absorb salts and ions by active transport across their gills.**
- **Excrete a large volume of water as dilute urine.**

Marine fishes

- **Body fluids are hypoosmotic with respect to seawater**
- **Drink large quantities of water.**
- **Secrete Na, Cl, and Kions through secretory cells in their gills.**
- **Channels in plasma membranes of their kidneys actively transport the multivalent ions that are abundant in seawater (e.g., Ca^{2+}, Mg^{2+}, SO_4^{2-}, and PO_4^{3-}) out of the extracellular fluid and into the nephron tubes.**

❖ Maintenance of water and solute concentrations in Amphibians

- **Amphibians take up water and ions in their food and drink, through the skin that is in contact with moist substrates, and through the urinary bladder.**
- **This uptake counteracts what is lost through evaporation and prevents osmotic imbalance.**
- **When the environment becomes dry, the bladder enlarges for storing more urine.**
- **If dehydrated, a brain hormone causes water to leave the bladder and enter the body fluid.**

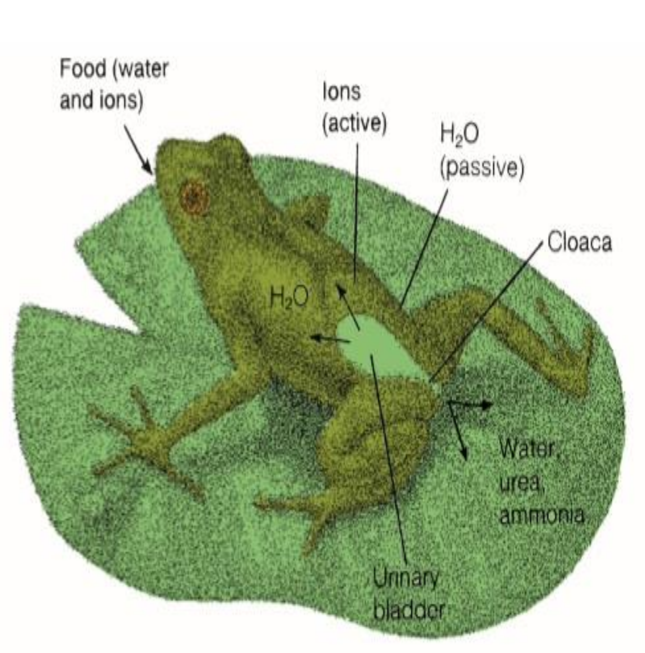

Fig: Water and Ion Uptake in an Amphibian

❖ Maintenance of water and solute concentrations in Reptiles, Birds, and Mammals

- Reptiles, birds, and mammals all possess metanephric kidneys.
- primary regulatory organs for controlling the osmotic balance of the body fluids.
- When animal inhales, the cool, dry air passing through its nose is heated and humidified. At the same time, its nasal tissues are cooled.
- When the animal exhales, it gives up heat to the previously cooled nasal tissue. The air carries less water vapor, and condensation occurs in the animal's nose.

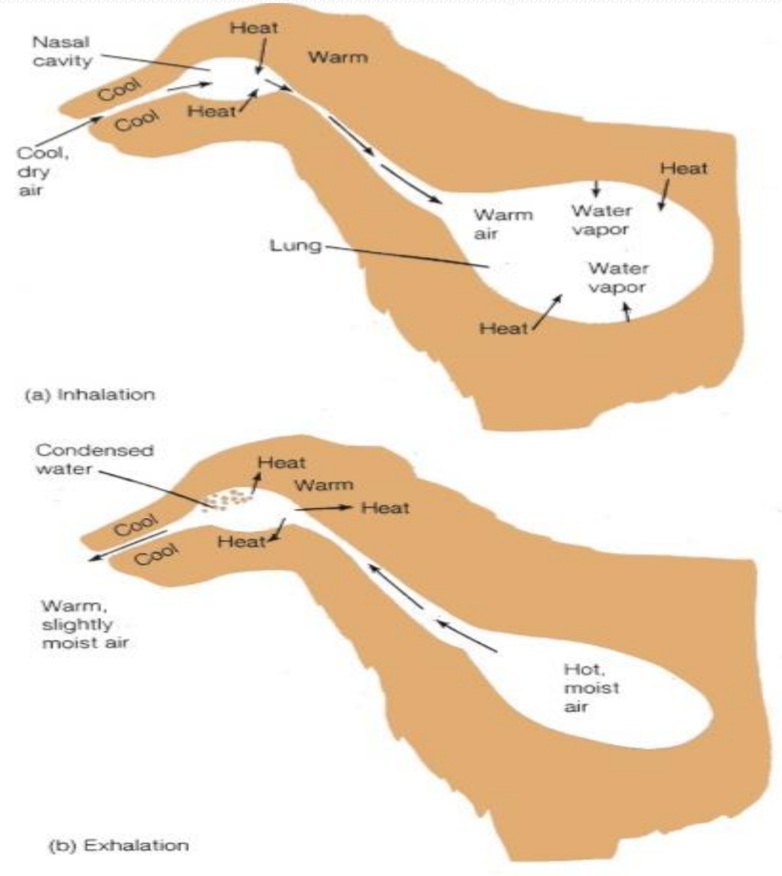

Fig: Water Retention by Countercurrent Heating and Cooling in a Mammal.

❑ HOW THE METANEPHRIC KIDNEY FUNCTIONS

- Metanephric kidney consists of over one million individual filtration, secretion, and absorption structures called nephrons. Fig(a).
- At the beginning of the nephron is the filtration apparatus called the glomerular capsule (formerly Bowman's capsule), Fig(b).
- High blood pressure forces water and ions through small perforations in the walls of the glomerular capillaries to form the glomerular filtrate.

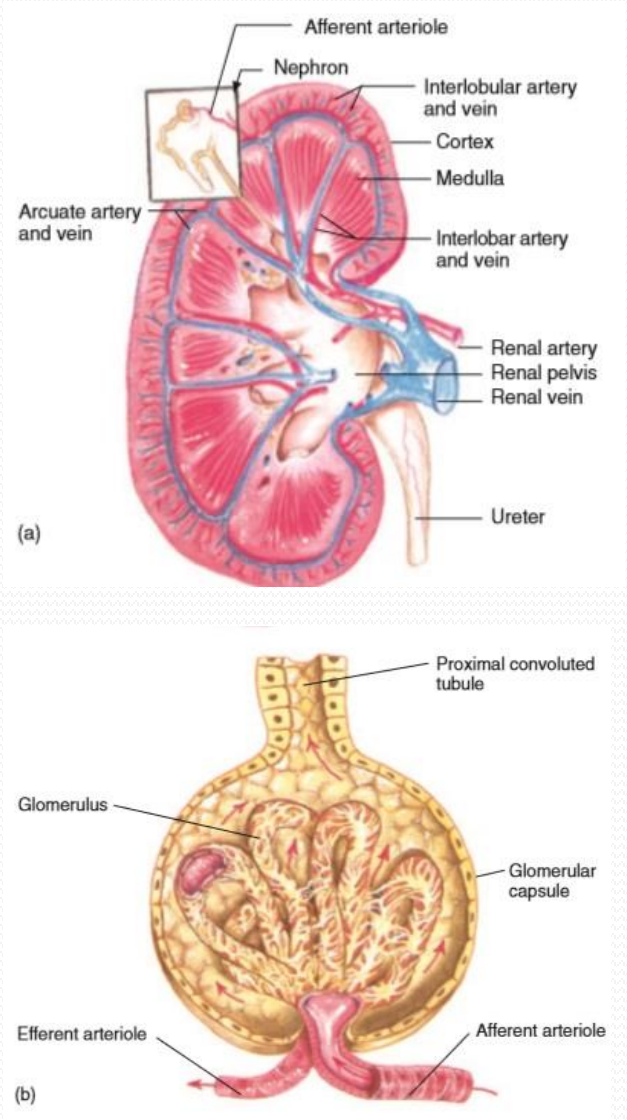

Fig: Filtration Device of the Metanephric Kidney

Metanephric Nephron

- **Afferent arteriol is a branch of the renal vein which carries blood containing nitrogenous wastes. Because Fltration slits are so small, large proteins and blood cells remain in the blood and leave the glomerulus via the efferent (“outgoing”) arteriole.**
- **The efferent arteriole then divides into the peritubular capillaries that wind profusely around the tubular portions of the nephron. Eventually, they merge to form veins that carry blood out of the kidney.**
- **The proximal convoluted tubule reabsorbs glucose and some ions.**
- **The distal convoluted tubule reabsorbs other ions and water.**
- **Both active (ATP-requiring) and passive procedures are involved in the recovery of the substances. Final water reabsorption takes place in the collecting duct.**

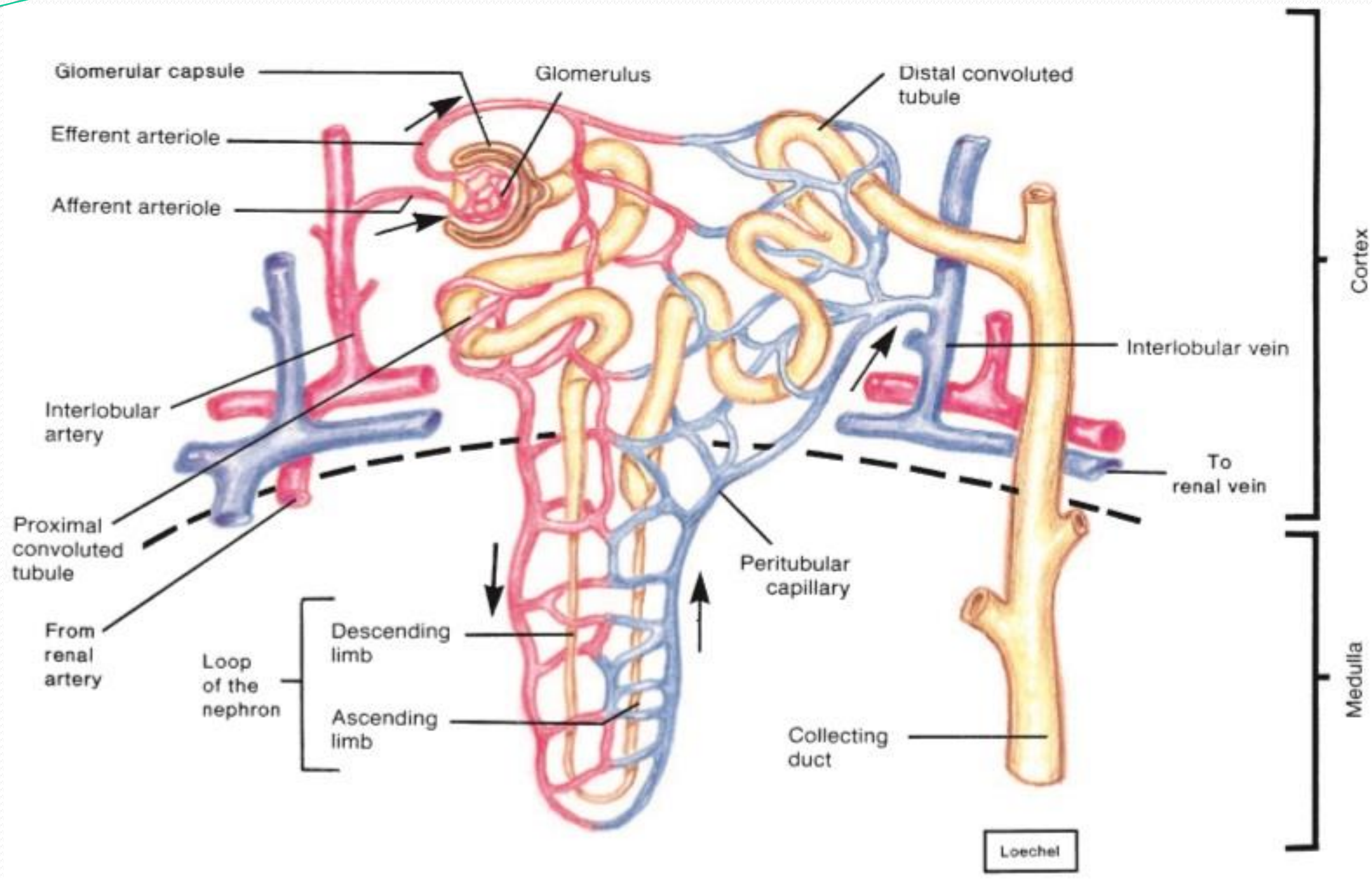

Fig: Metanephric Nephron

Countercurrent Exchange

- **The loop of the nephron increases the efficiency of reabsorption by a countercurrent flow similar to that in the gills of fishes or in the legs of birds, but with water and ions being reabsorbed instead of oxygen or heat.**
- **Generally, the longer the loop of the nephron, the more water and ions that can be reabsorbed**

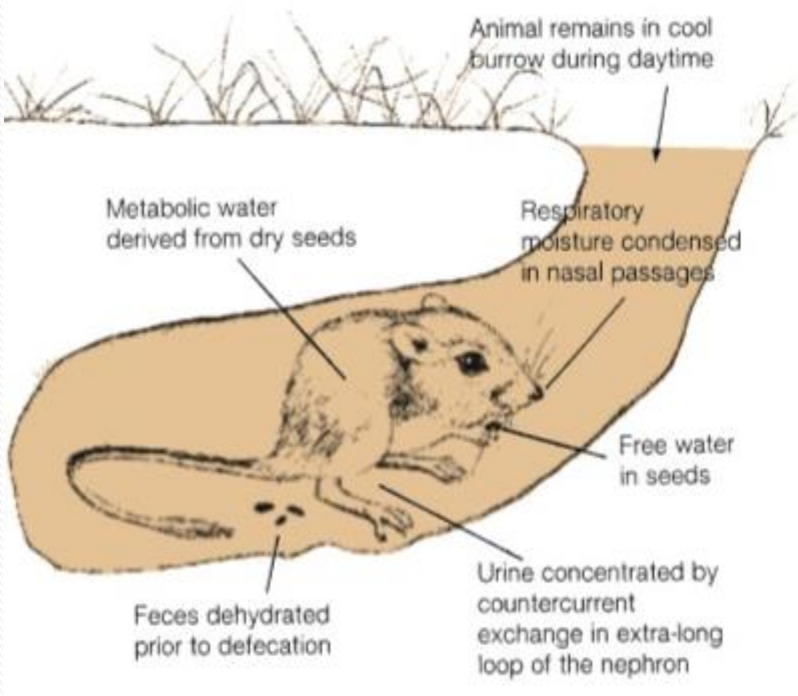

Fig: Kangaroo Rat (*Dipodomys ordii*), a Master of Water Conservation. Its efficient kidneys can concentrate urine 20 times that of its blood plasma. As a result, these kidneys, as well as other adaptations, prevent unnecessary water loss to the environment.

Countercurrent flow mechanism

Proximal convoluted tubule removes some salt (NaCl) and water from the glomerular filtrate and reduces its volume by approximately 25%.

In descending limb of the loop of the nephron, filtrate becomes further reduced in volume and more concentrated. Water moves out of the tubule by osmosis.

The salt flows passively into the descending loop, only to move out again in the ascending loop, creating a recycling of salt through the loop and the extracellular fluid.

- As the filtrate passes into the ascending limb, sodium (Na^+) ions are actively transported out of the filtrate into the extracellular fluid, with chloride (Cl^-) ions following passively

- Because the flows in the descending and ascending limbs are in opposite directions, a countercurrent gradient in salt is set up.

The flows in the descending and ascending limbs are in opposite directions, a countercurrent gradient in salt is set up.

Distal convoluted tubule empties into the collecting duct, which is permeable to urea, and the concentrated urea in the filtrate diffuses out into the surrounding extracellular fluid.

Many peritubular capillaries surrounding each nephron collect the water and return it to the systemic circulation.

Urine from two ureters (one from each kidney) accumulates in the urinary bladder. The urine leaves the body through a single tube, the urethra

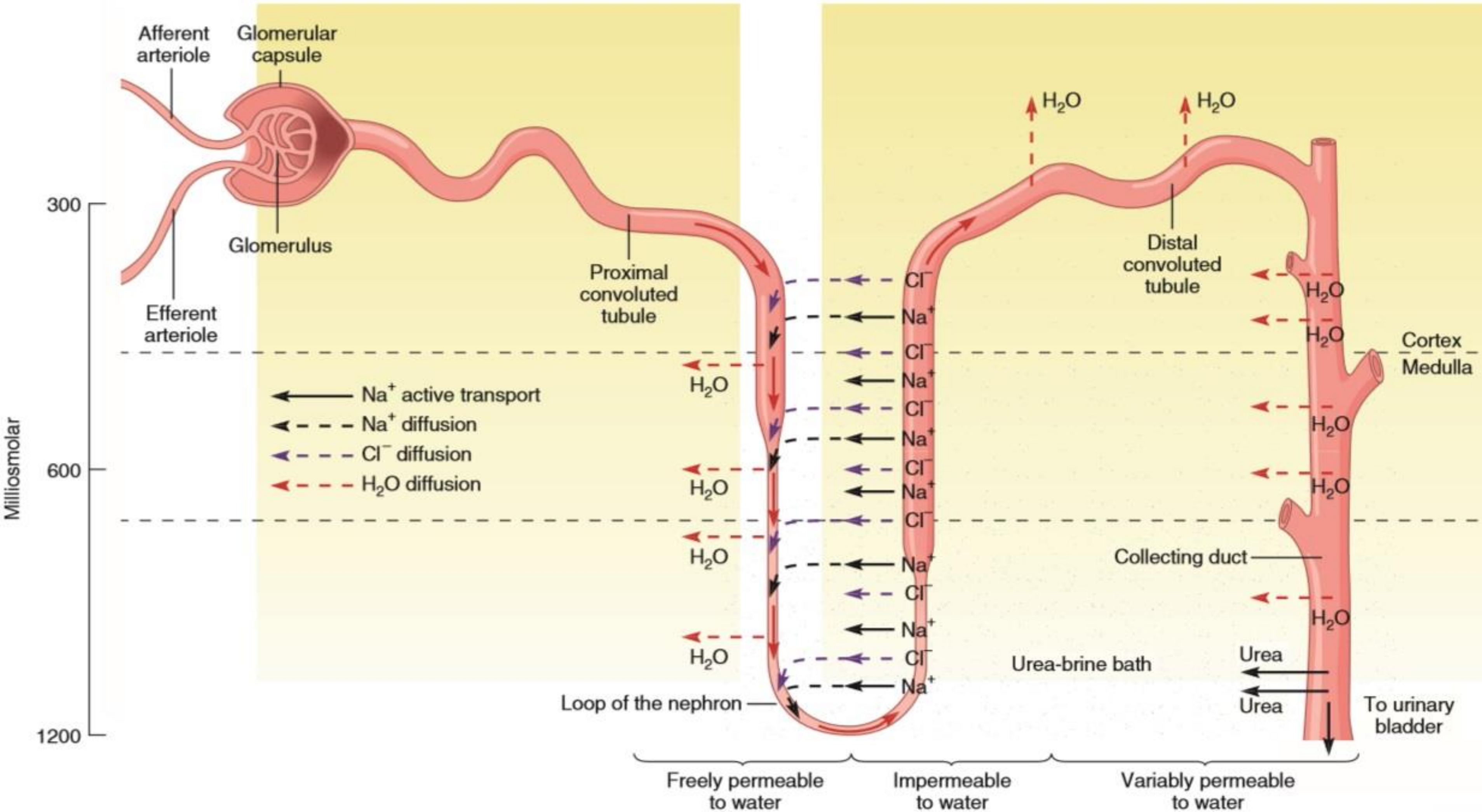

Fig: Countercurrent Exchange. Movement of materials in the nephron and collecting duct. Solid arrows indicate active transport; dashed arrows indicate passive transport. The shading at intervals along the tubules illustrates the relative concentration of the filtrate in milliosmoles**.**