Chapter 44:
Osmoregulation & Excretion

1. Osmoregulation
2. Nitrogenous Wastes
3. Excretory Processes
4. Hormonal Control of Osmoregulation & Excretion

1. Osmoregulation

Balancing Uptake & Loss of Water, Solutes

Osmoregulation is the process of balancing the uptake and loss of water as well maintaining solute concentrations within acceptable levels:

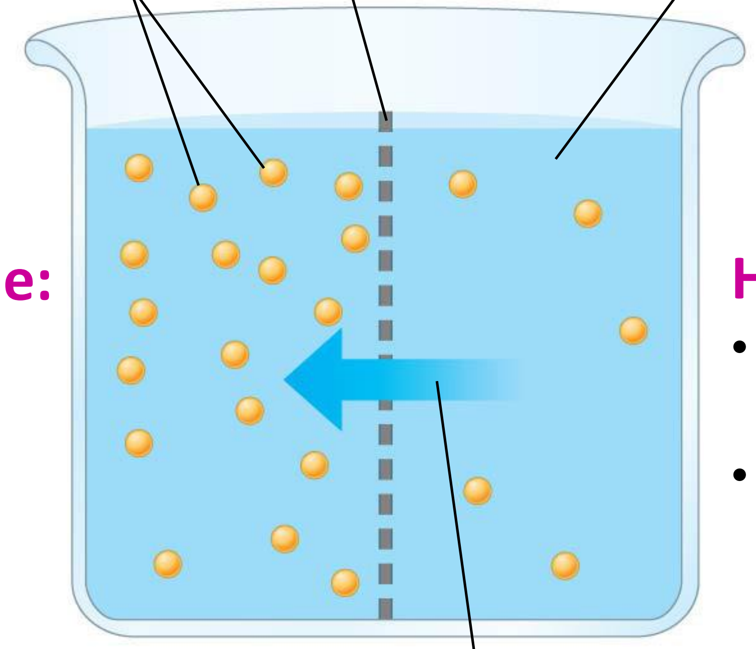
- **the key factor in this balance is <u>osmosis</u>, the diffusion of water from high to low concentration across a semi-permeable membrane**

Osmosis & Osmolarity

Differences in <u>osmolarity</u> (the total solute concentration) across a membrane permeable only to the water will result in <u>osmosis</u> – the diffusion of water from higher to lower concentration:

The side with higher [solute] will gain water and the side with lower [solute] will lose water.

Hyperosmotic side:
- Higher solute concentration
- Lower free H_2O concentration



Hypoosmotic side:
- Lower solute concentration
- Higher free H_2O concentration

Osmolarity & Aquatic Animals

Some aquatic animals such as marine invertebrates are <u>osmoconformers</u> that are isoosmotic with their surroundings and thus don't regulate their osmolarity. However most are <u>osmoregulators</u> that expend energy to regulate their osmolarity.

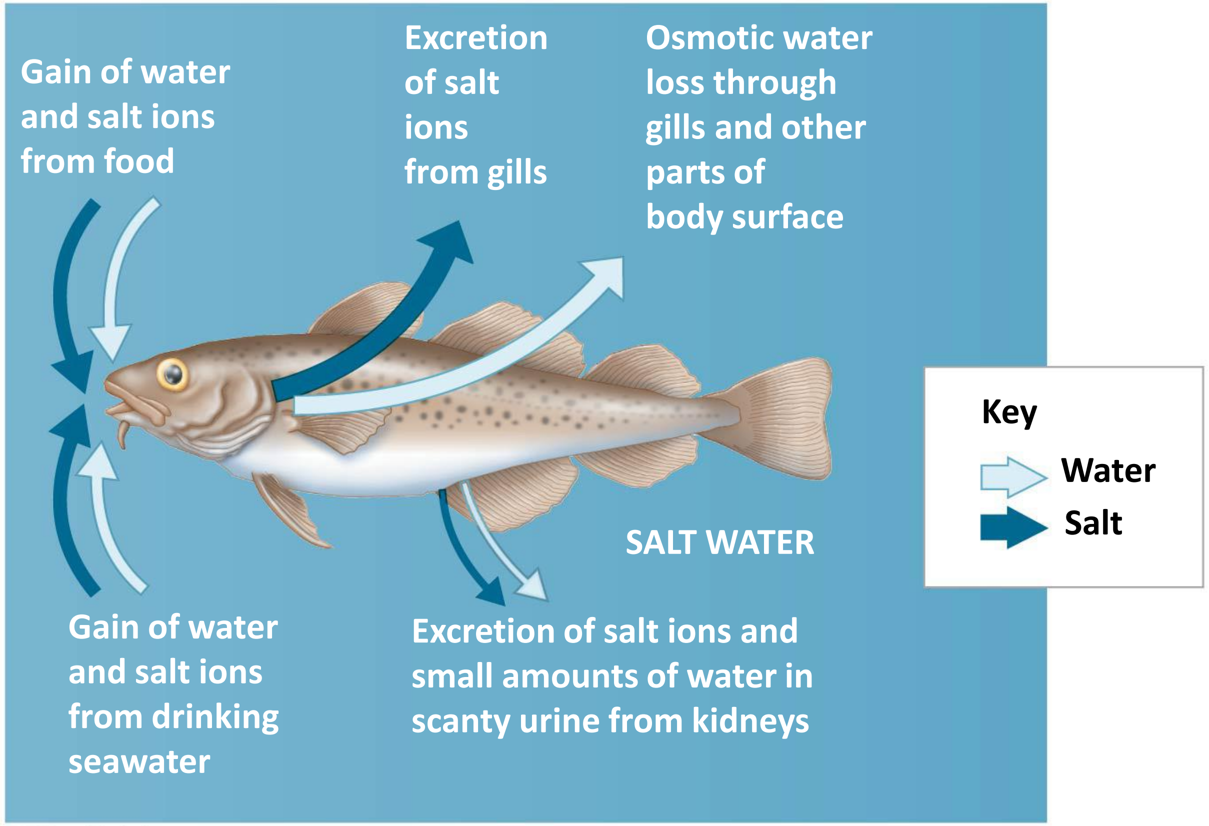
- **most aquatic animals are <u>stenohaline</u> and cannot tolerate large fluctuations in the osmolarity of their environment**
- **some animals such as salmon and bull sharks are <u>euryhaline</u> and can survive large fluctuations in the osmolarity of their environment**

Osmoregulation in Marine Fish

Marine bony fish are *hypoosmotic* to sea water and thus will lose water and take in excess salt. To counter this bony fish:

- ingest sea water
- reduce the amount of water excreted in the urine
- excrete excess salt from gills and kidneys

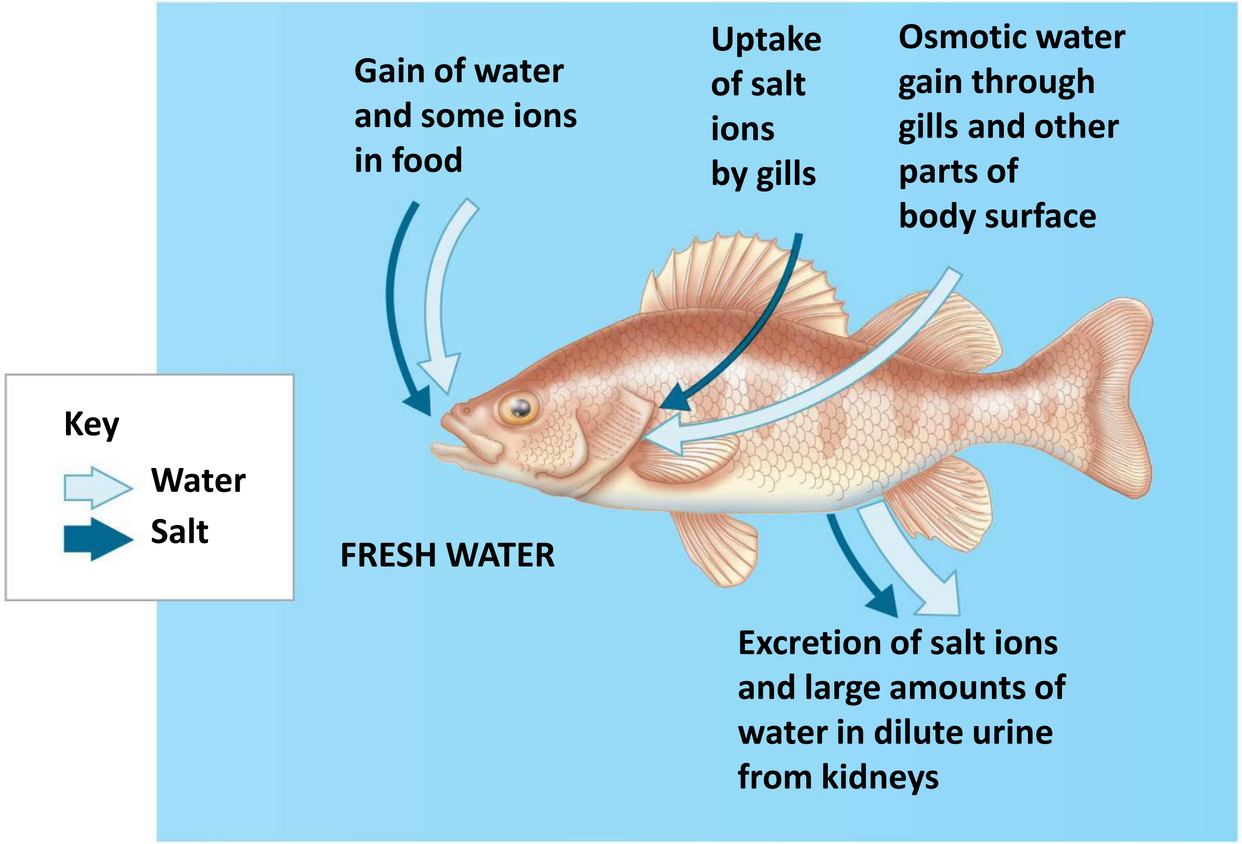
(a) Osmoregulation in a marine fish



Osmoregulation in Freshwater Fish

Freshwater fish are *hyperosmotic* to sea water and thus will gain water and lose salt. To counter this freshwater fish:

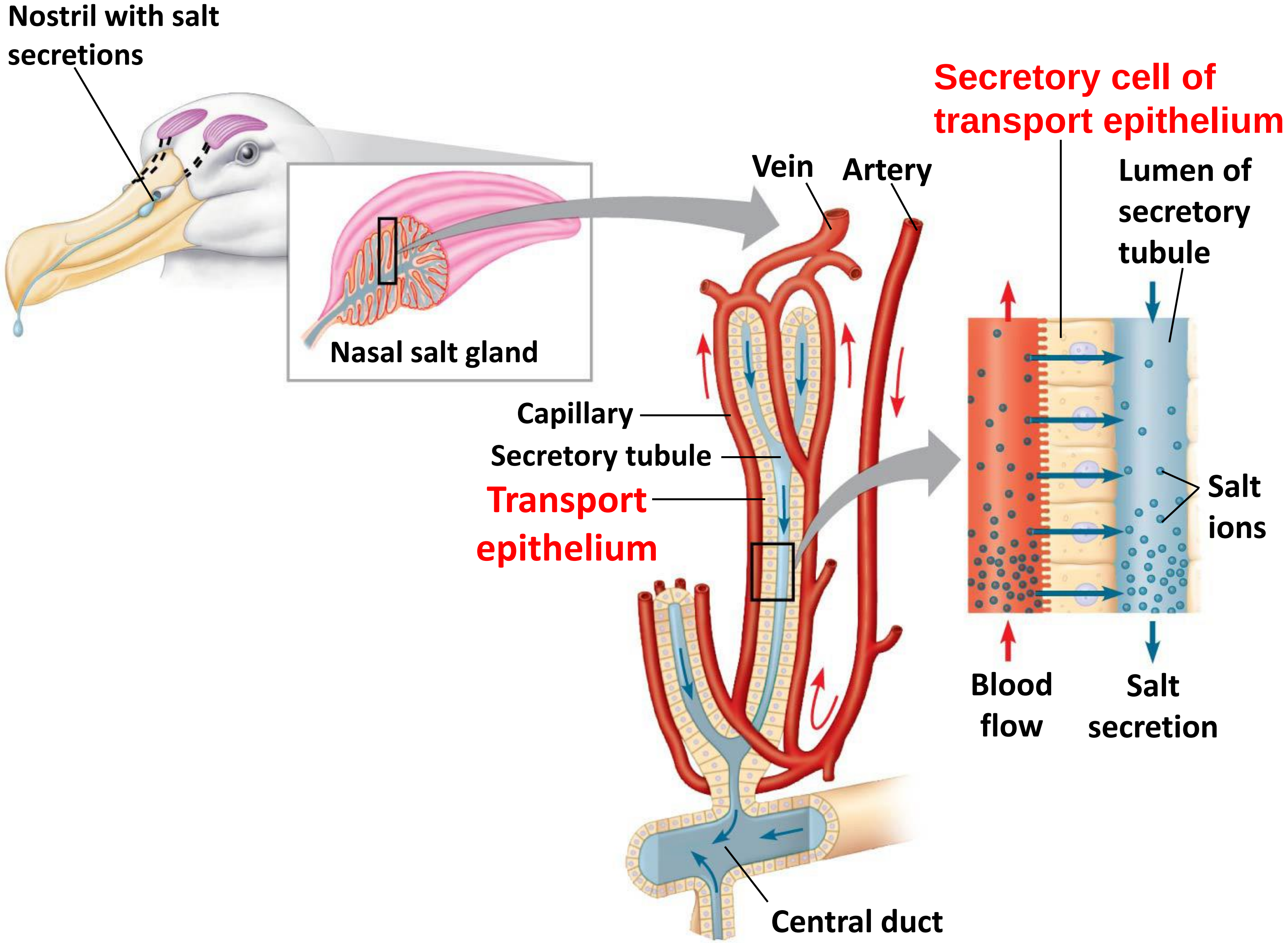
(b) Osmoregulation in a freshwater fish



- excrete large amounts of water from the kidneys
- uptake salt in the gills

Transport Epithelia in Osmoregulation

- transport epithelia are cell layers specialized for moving solutes in specific directions typically arranged in tubular networks such as the nasal glands of marine birds to excrete excess salt

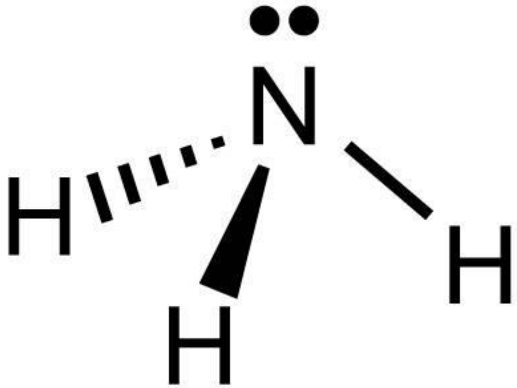


2. Nitrogenous Wastes

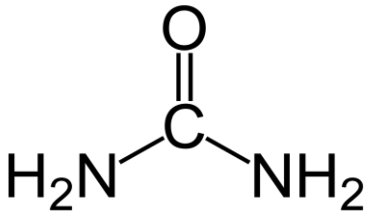
Forms of Nitrogenous Waste

All animals produce nitrogenous waste in the form of ammonia (NH_3) due to the break down of proteins and nucleic acids. Ammonia is quite toxic and thus must be handled in 1 of 2 ways:

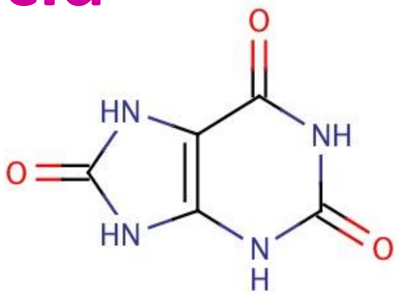
1. rapid elimination from the body
2. conversion to the less toxic nitrogen compounds urea or uric acid



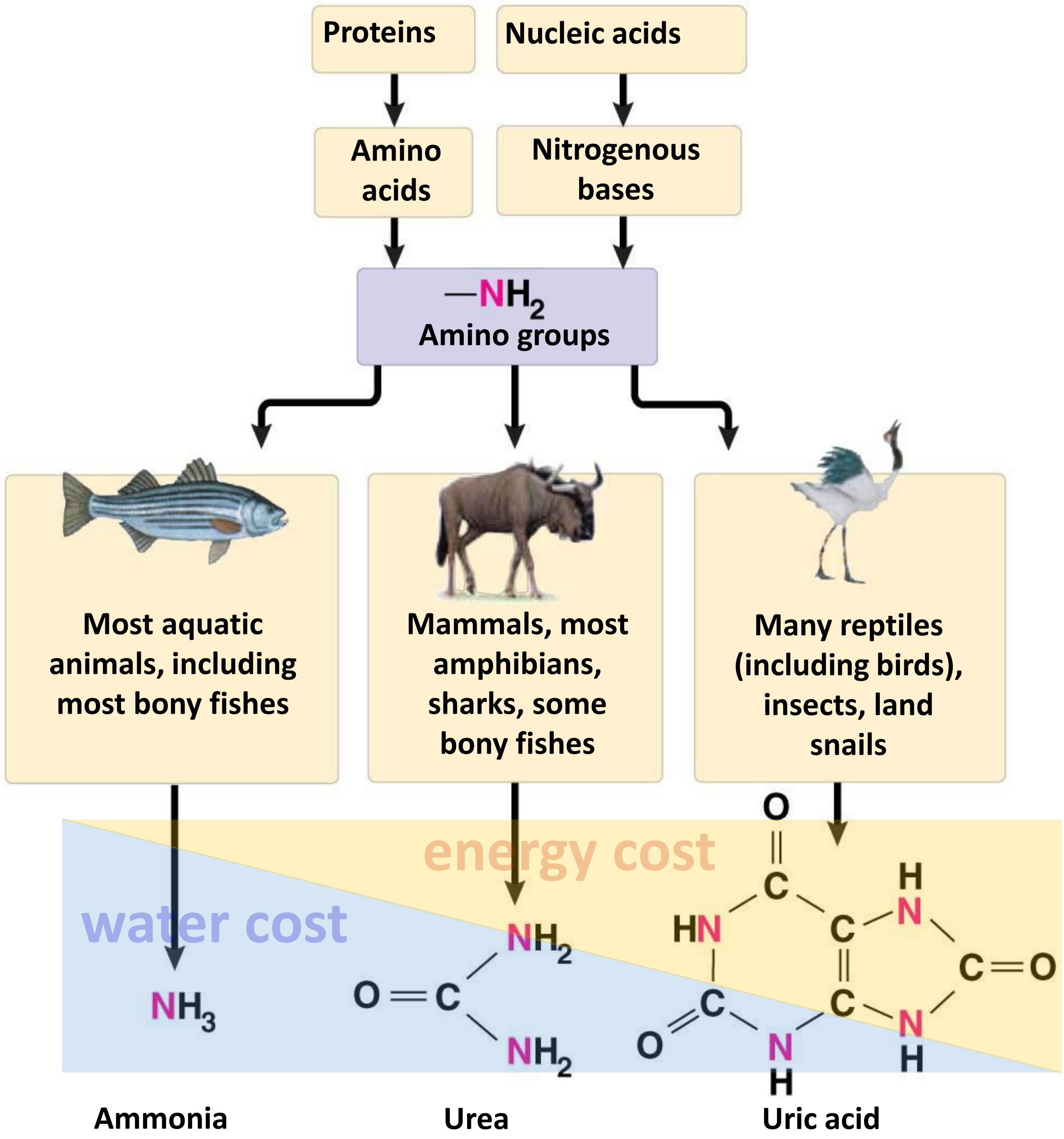
ammonia



urea



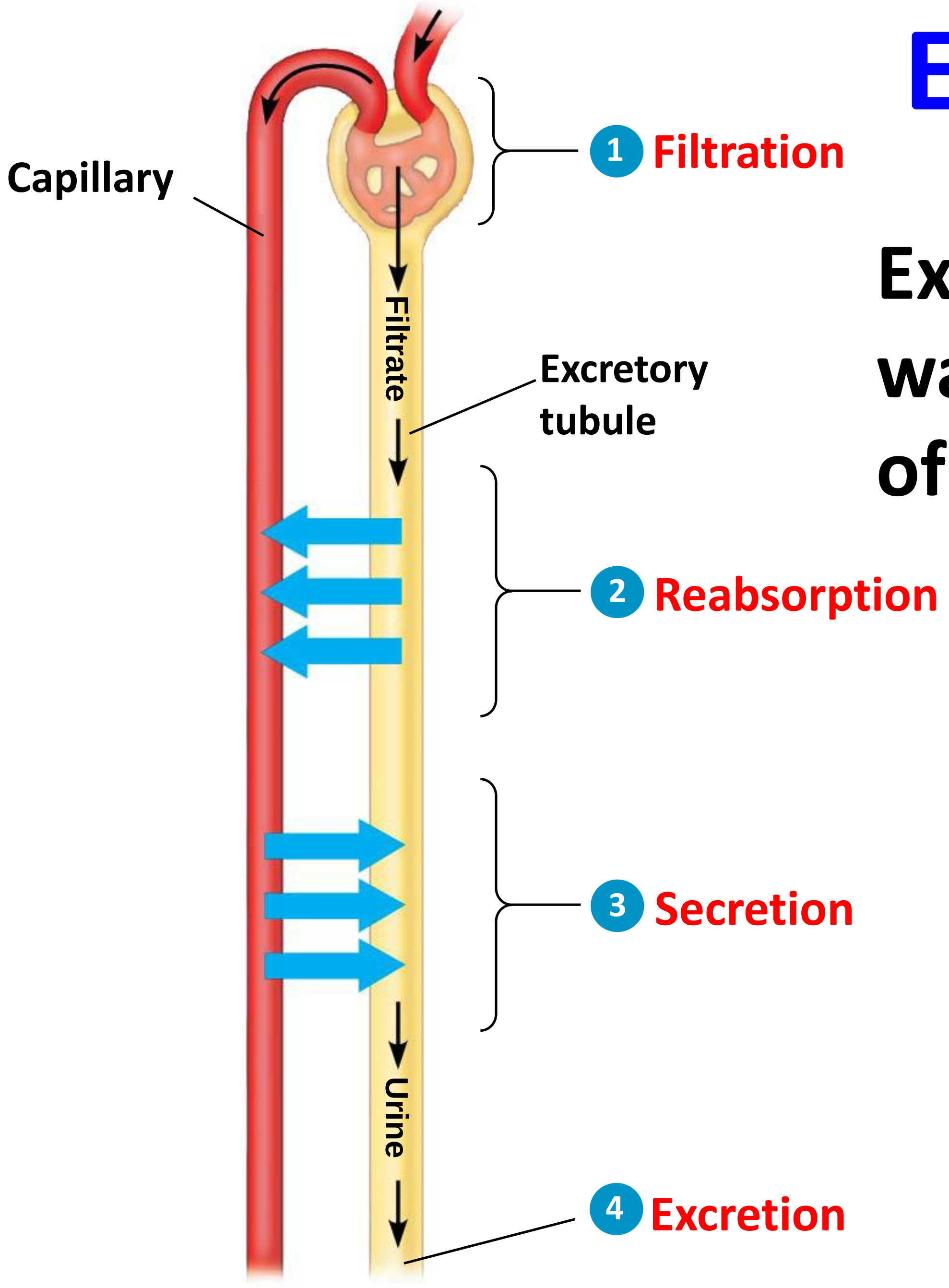
uric acid



- most aquatic animals can rapidly eliminate ammonia into the surrounding water
- mammals, amphibians and some aquatic animals expend energy to convert ammonia to urea which requires more water for excretion than uric acid
- reptiles, birds & insects convert ammonia to uric acid which is more energetically expensive than urea but requires little water to be excreted

3. Excretory Processes

Excretory Systems in General



Excretory systems get rid of nitrogenous waste and osmoregulate through a series of general steps:

FILTRATION – removal of soluble portion of body fluid to form crude filtrate

REABSORPTION – reclaiming water and valuable solutes

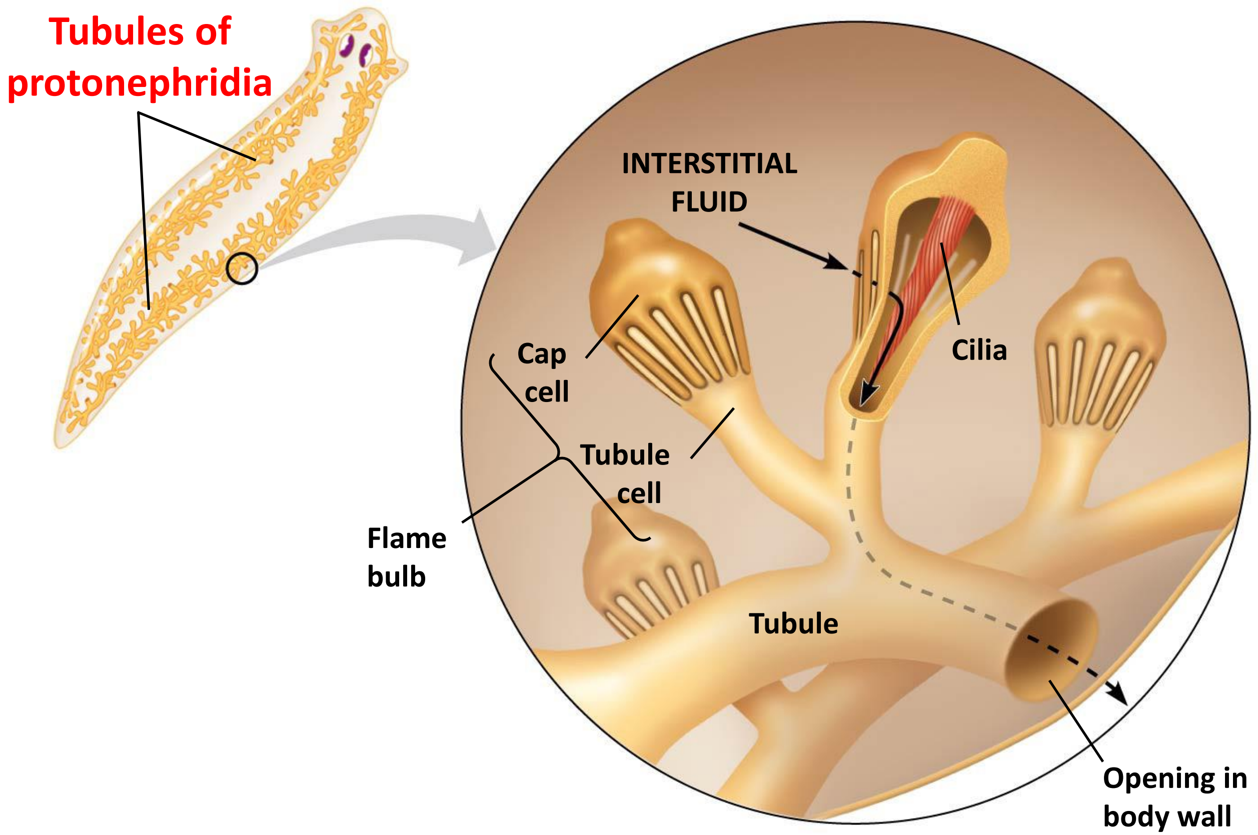
SECRETION – transferring additional wastes to the filtrate

EXCRETION – elimination of urine from body

Protonephridia

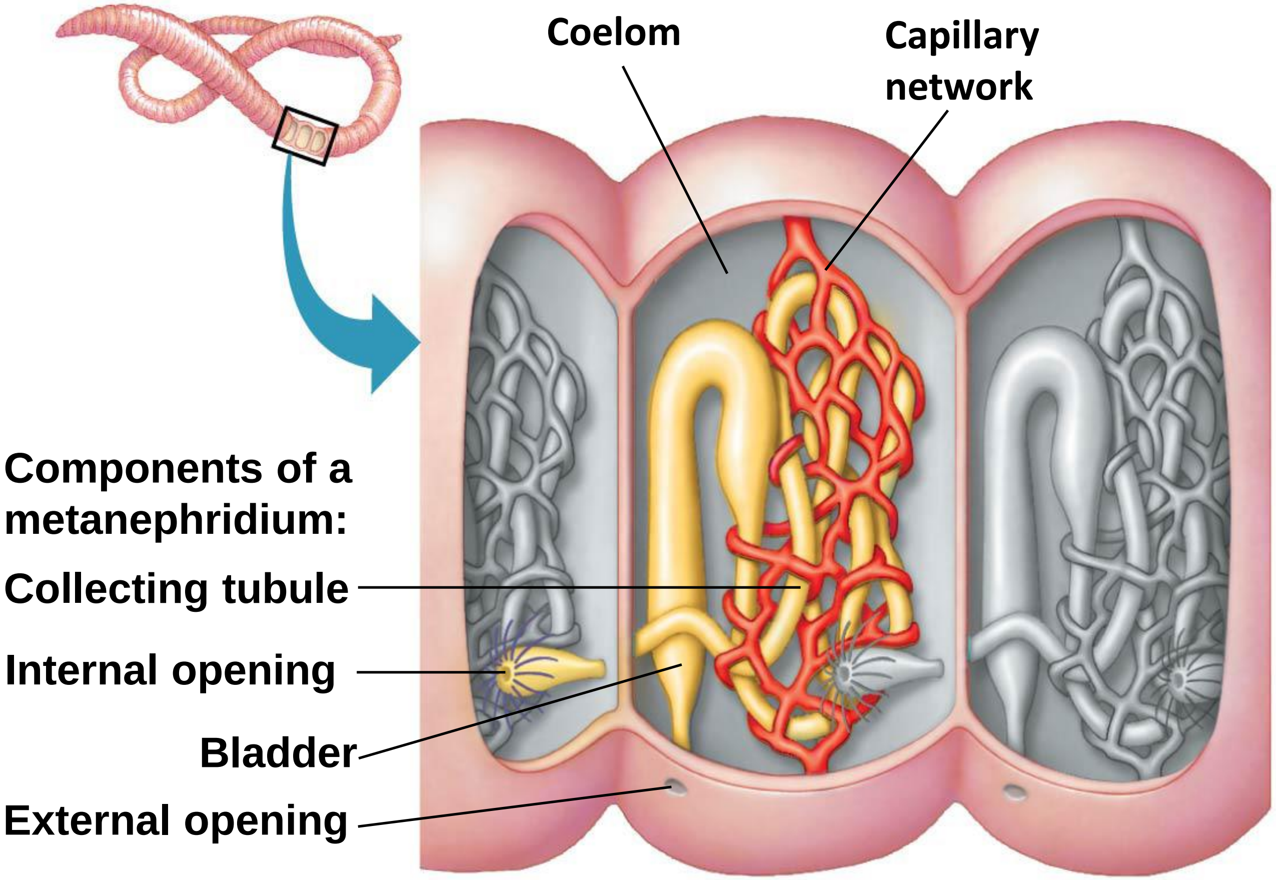
<u>Protonephridia</u> are a simple type of excretory system consisting of networks of dead-end tubules that excrete a dilute waste fluid into excretory tubules:

- flame bulbs with cilia move fluid through perforated cap cells that filter out waste into excretory tubules
- found in flatworms



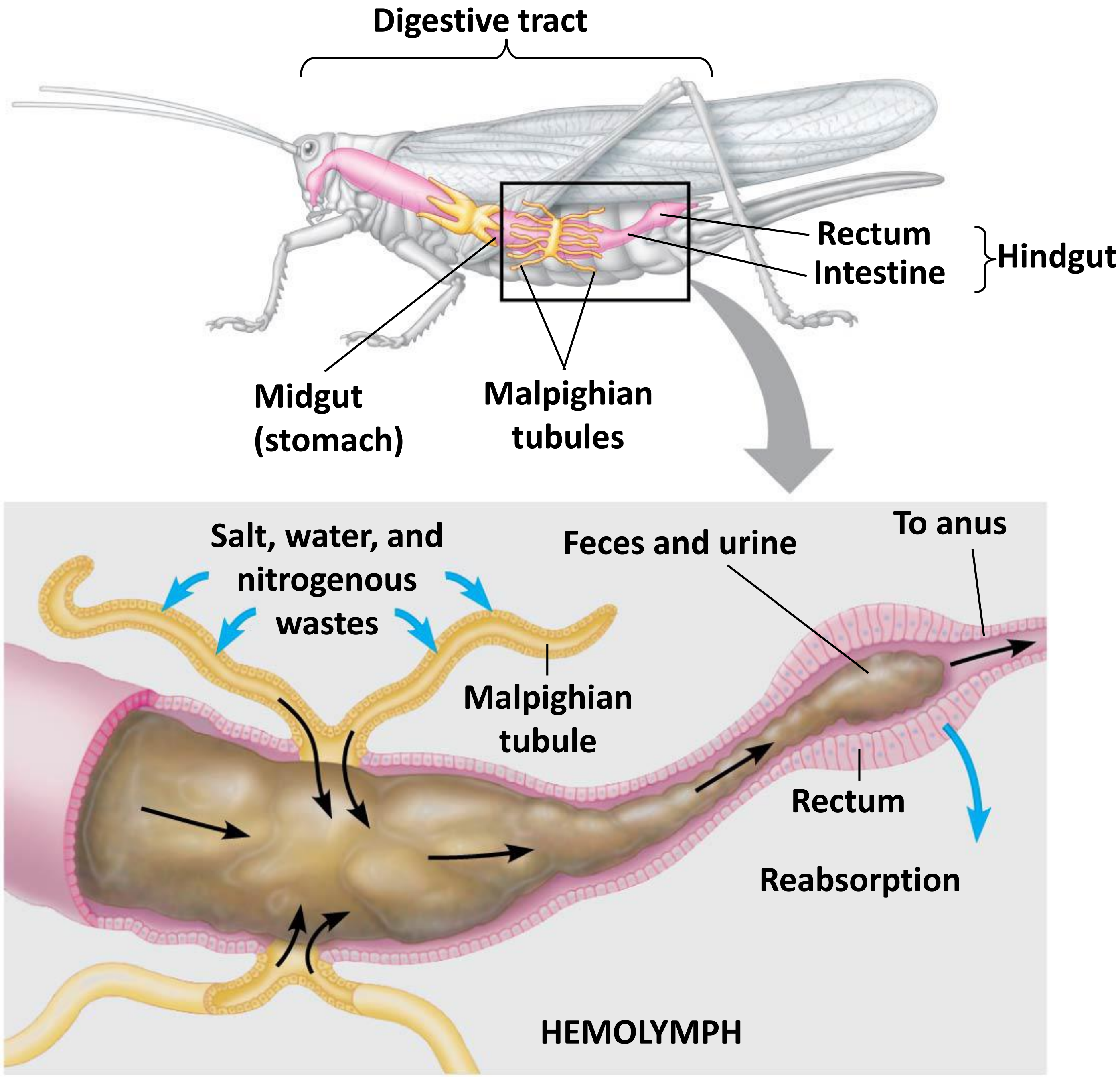
Metanephridia

Metanephridia are excretory organs in segmented worms (annelids), and some arthrophods and molluscs:



- blood filtrate collects in the coelom and is transferred via cilia into a collecting tubule
- reabsorption & secretion across the tubule results in a dilute urine that is released out of the body

Malpighian Tubules

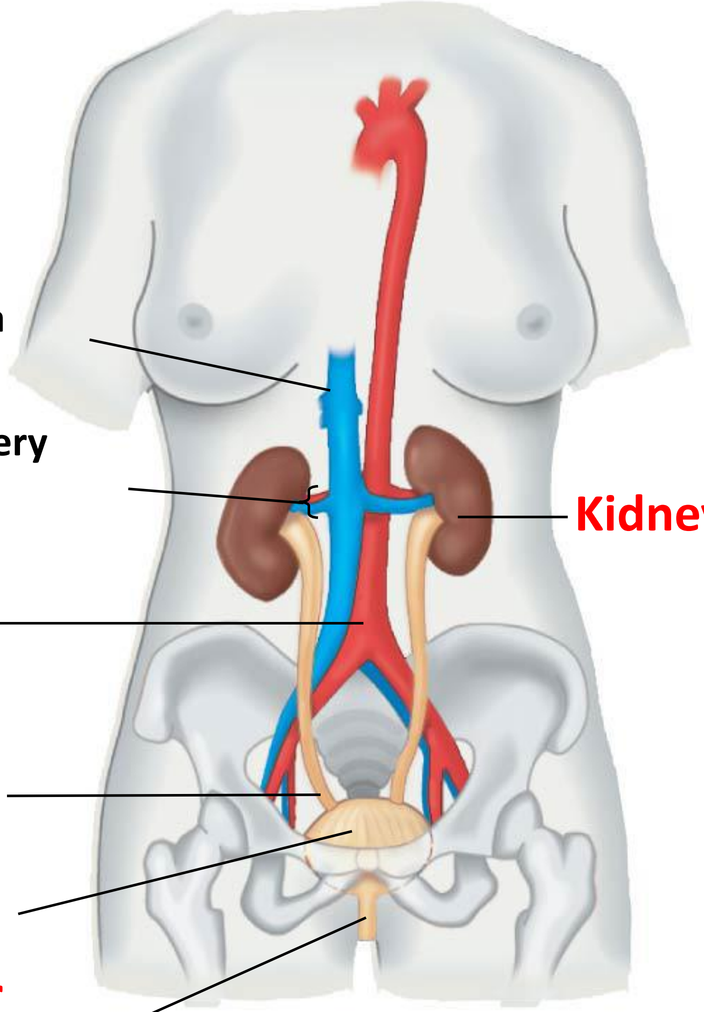


In most insects & other terrestrial arthropods, excretion occurs via <u>Malpighian tubules</u>:

- nitrogenous & other wastes are transferred to Malpighian tubules connected to the gut
- waste then passes out of body through the anus

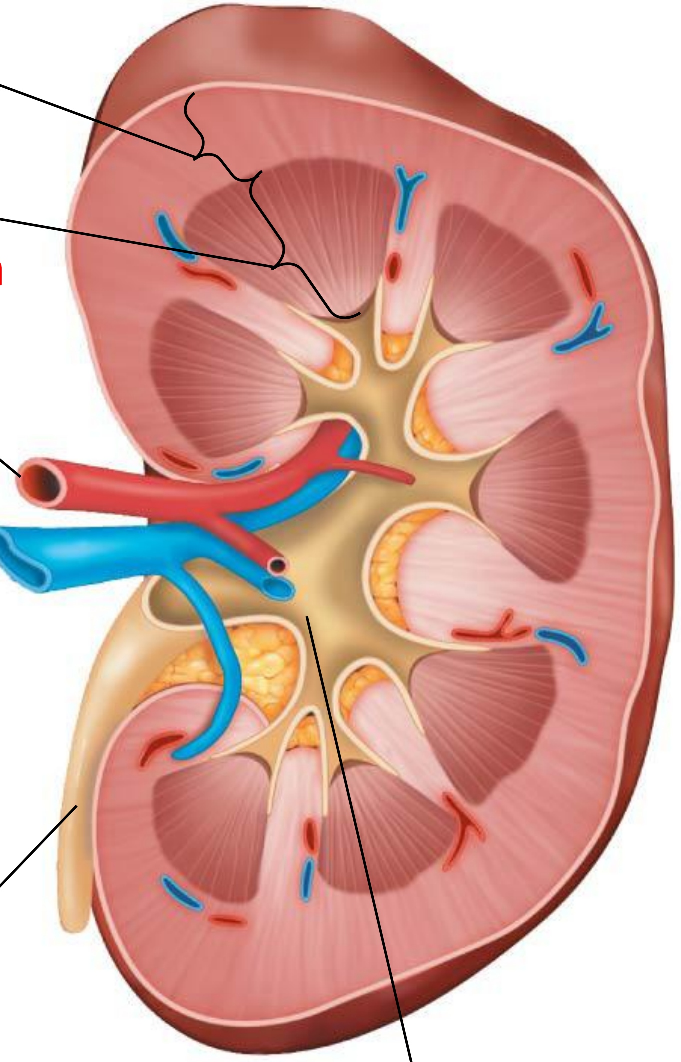
Kidneys

Excretory Organs

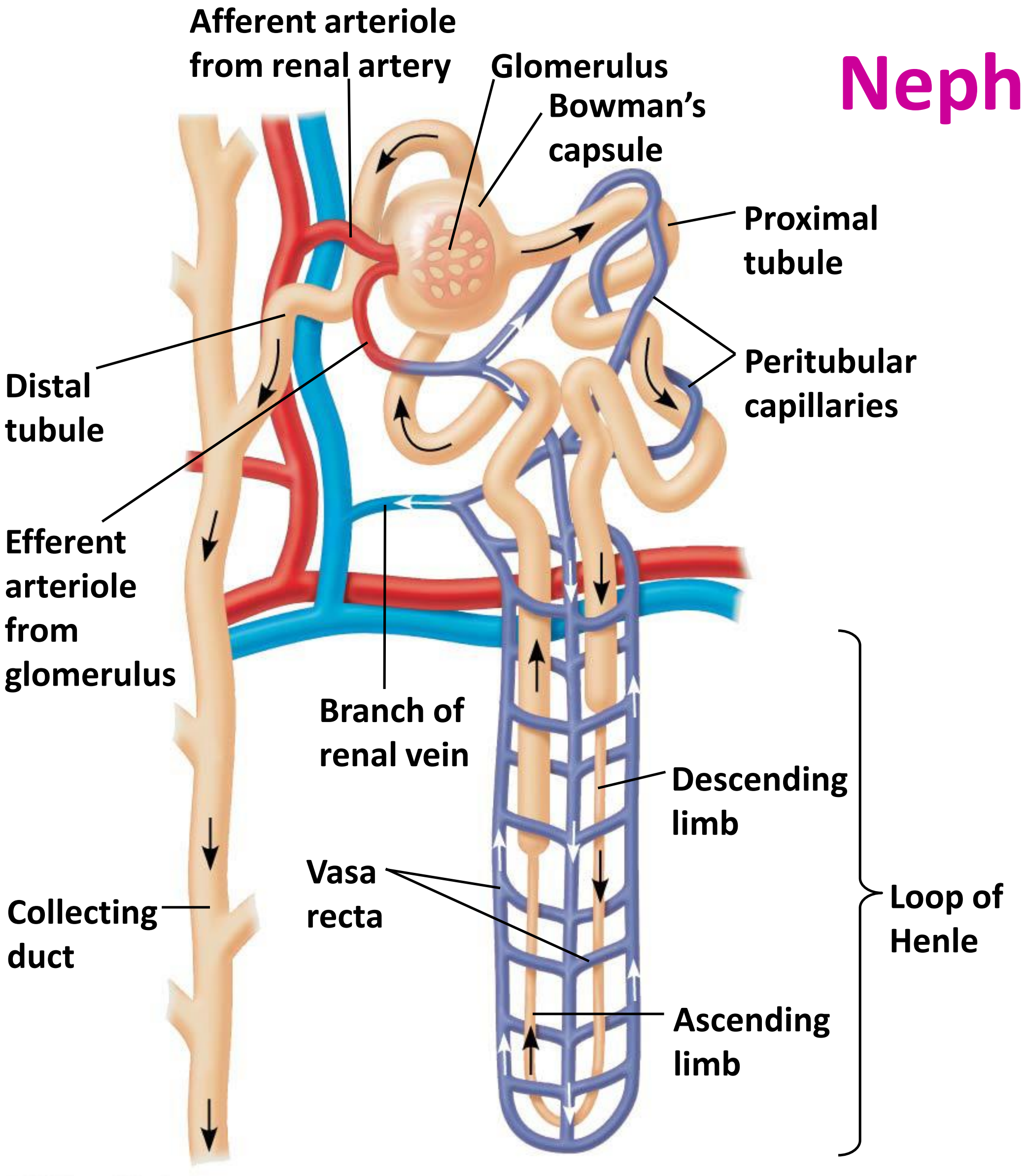


- kidneys are the main excretory organs in vertebrates

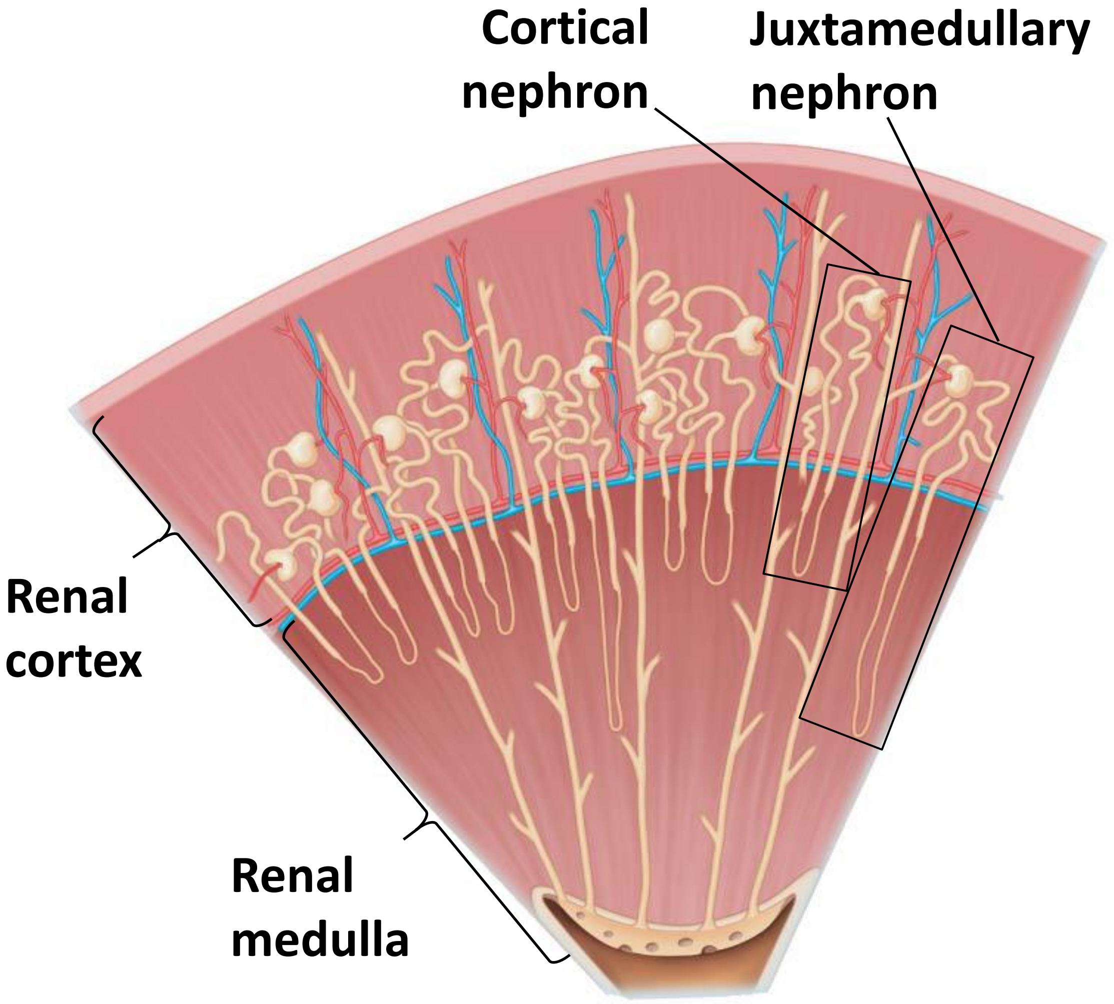
Kidney Structure



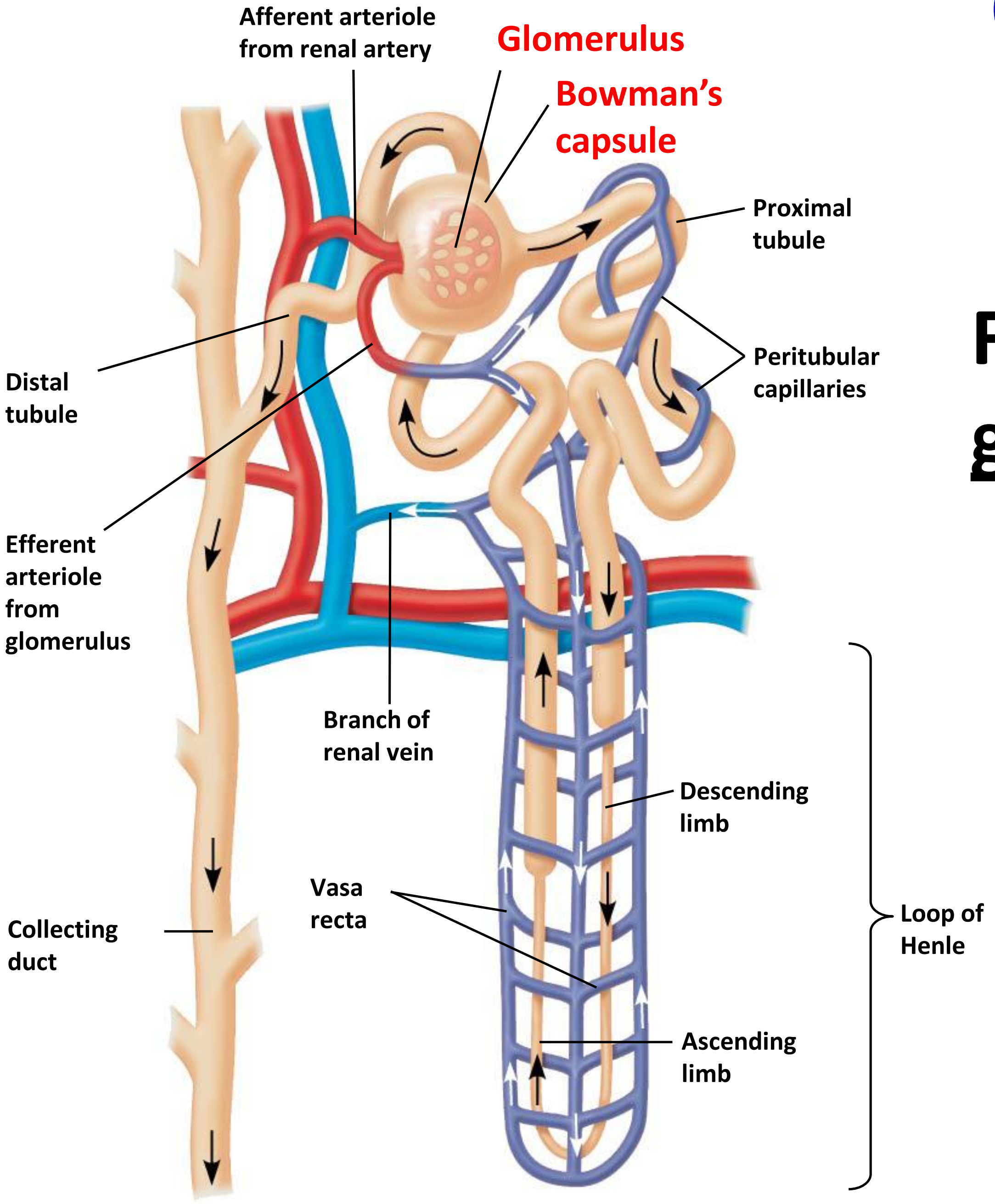
Nephrons – the Function Unit of the Kidney



Nephron Structure



Glomerulus & Bowman's Capsule

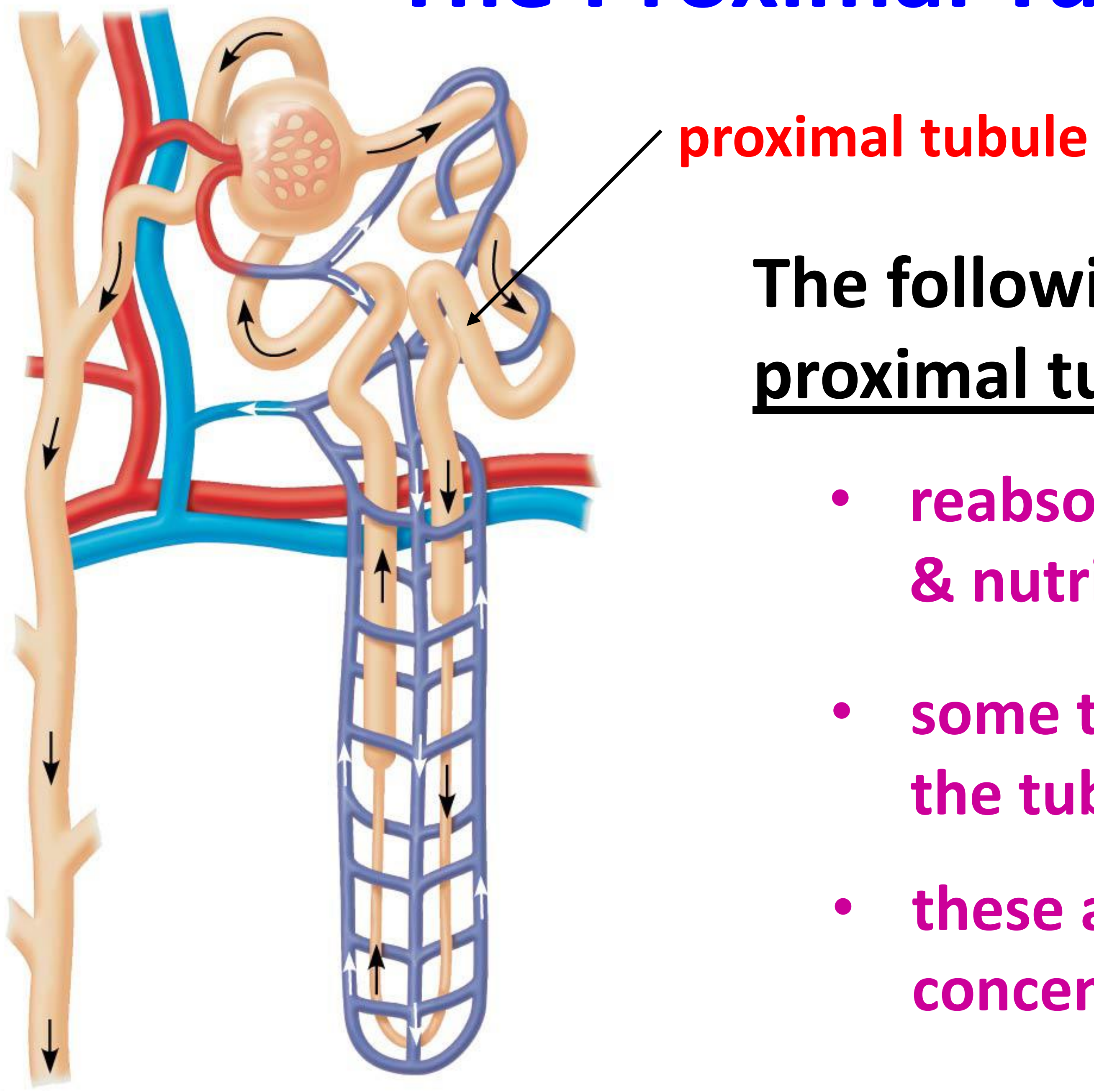


Fluid from the blood leaks from the <u>glomerulus</u> into <u>Bowman's capsule</u>:

Blood vessels from a human kidney. Arterioles and peritubular capillaries appear pink; glomeruli appear yellow.

- the crude filtrate produced contains salts, glucose, amino acids, vitamins, nitrogenous wastes, & other small molecules

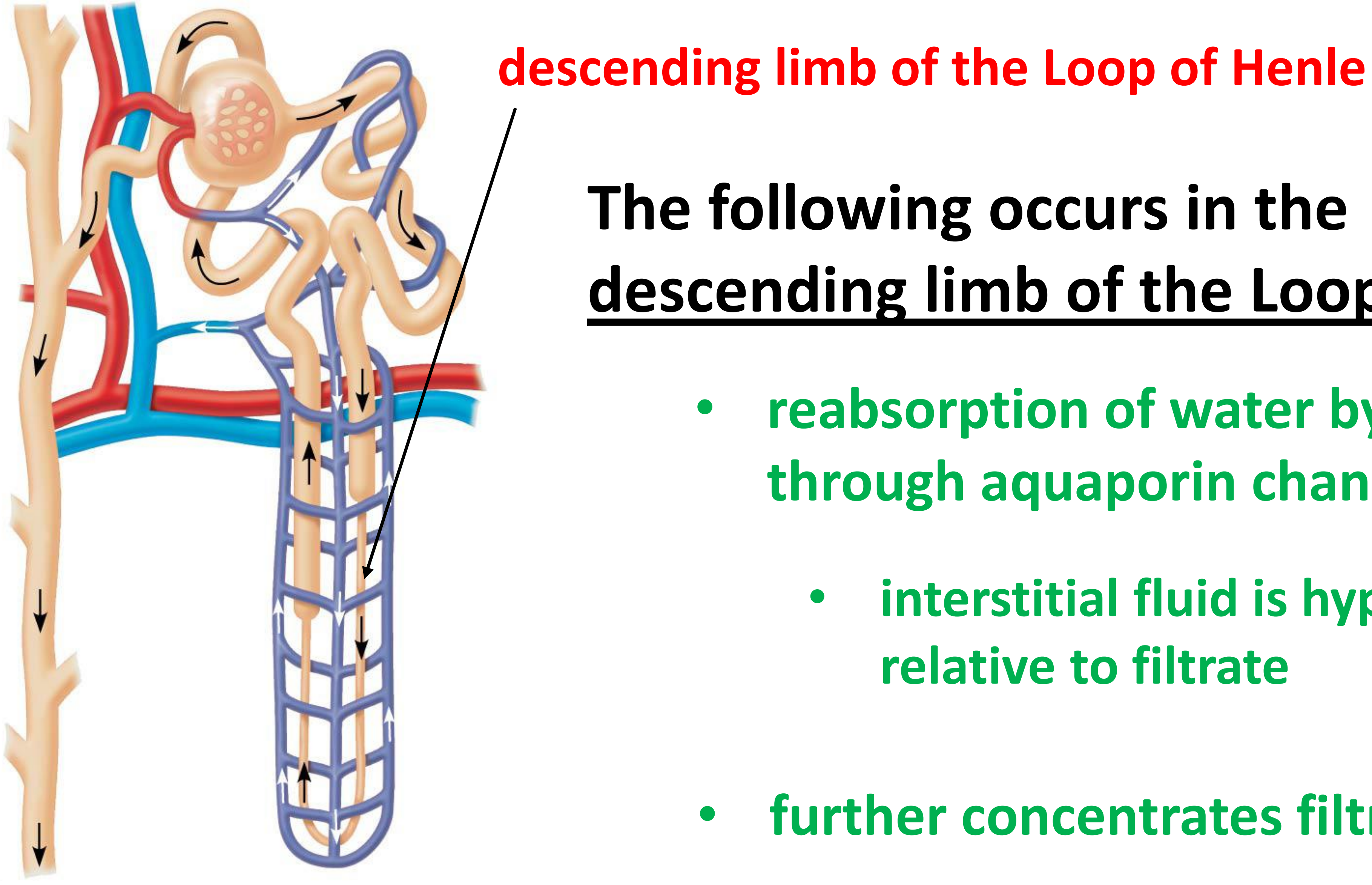
The Proximal Tubule



The following occurs in the <u>proximal tubule</u>:

- reabsorption of water, minerals & nutrients (e.g., glucose)
- some toxins are secreted into the tubule
- these activities result in a more concentrated filtrate

The Descending Loop of Henle

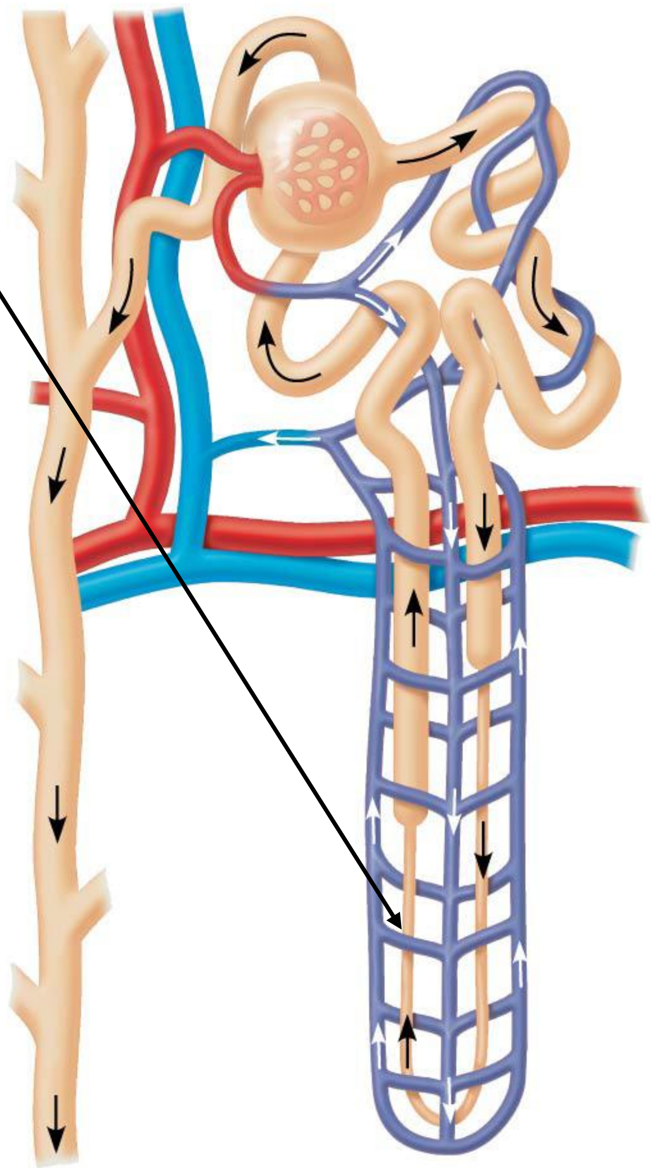


The following occurs in the <u>descending limb of the Loop of Henle</u>:

- reabsorption of water by diffusion through aquaporin channels
  - interstitial fluid is hyperosmotic relative to filtrate
- further concentrates filtrate

The Ascending Loop of Henle

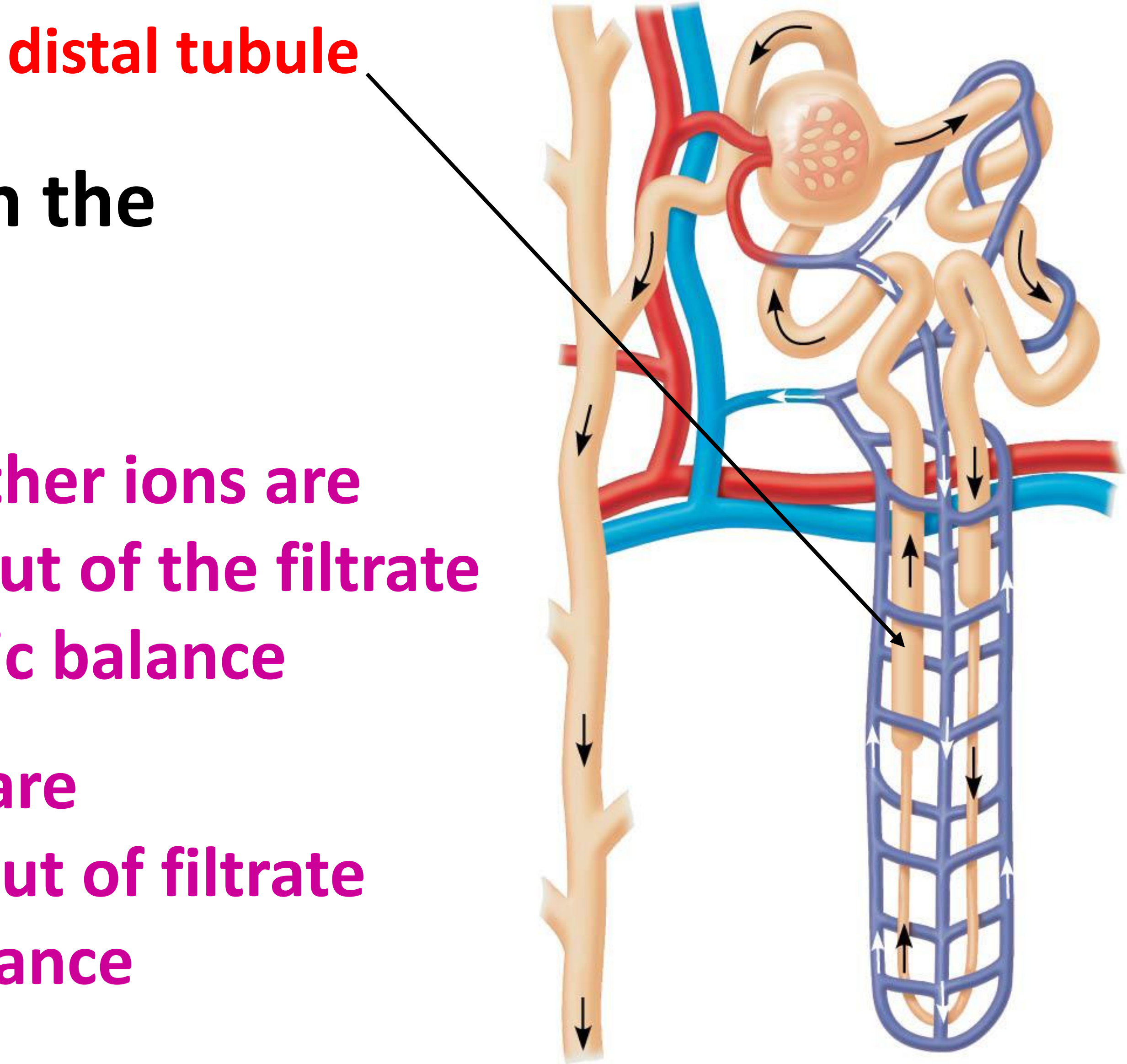
ascending limb of the Loop of Henle



The following occurs in the <u>ascending limb of the Loop of Henle</u>:

- reabsorption of salt ions
    - interstitial fluid is hypoosmotic relative to filtrate
- filtrate becomes more dilute

The Distal Tubule



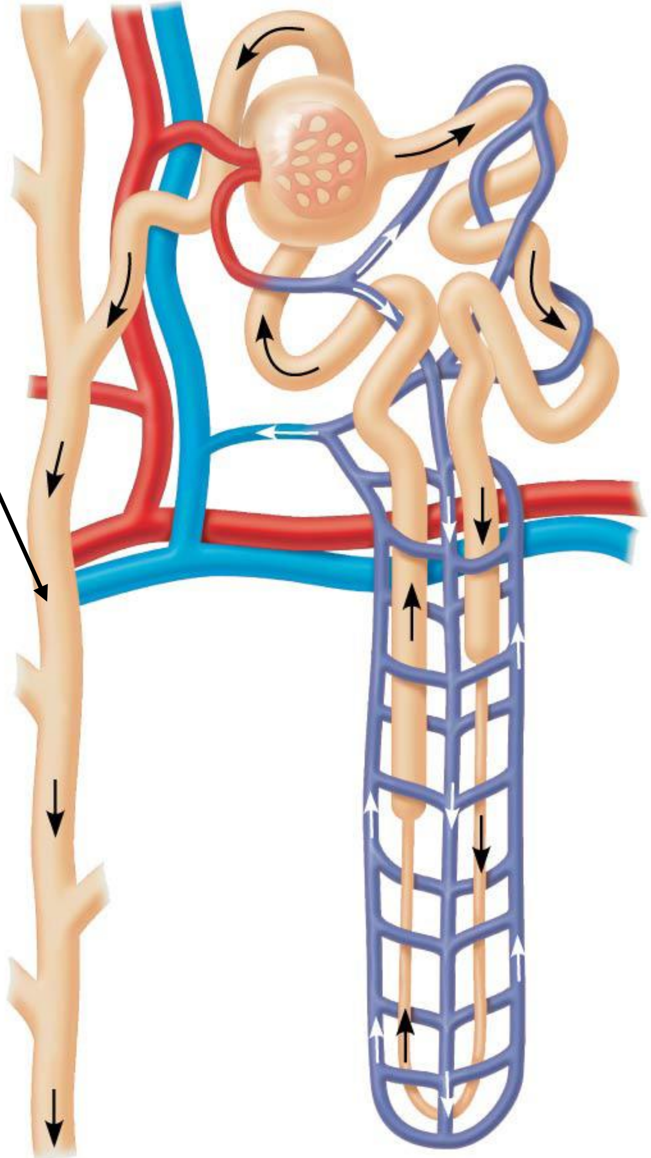
The following occurs in the <u>distal tubule</u>:

- Na^+, K^+ & Cl^- and other ions are transported in or out of the filtrate to maintain osmotic balance
- H^+ and HCO_3^- ions are transported in or out of filtrate to maintain pH balance

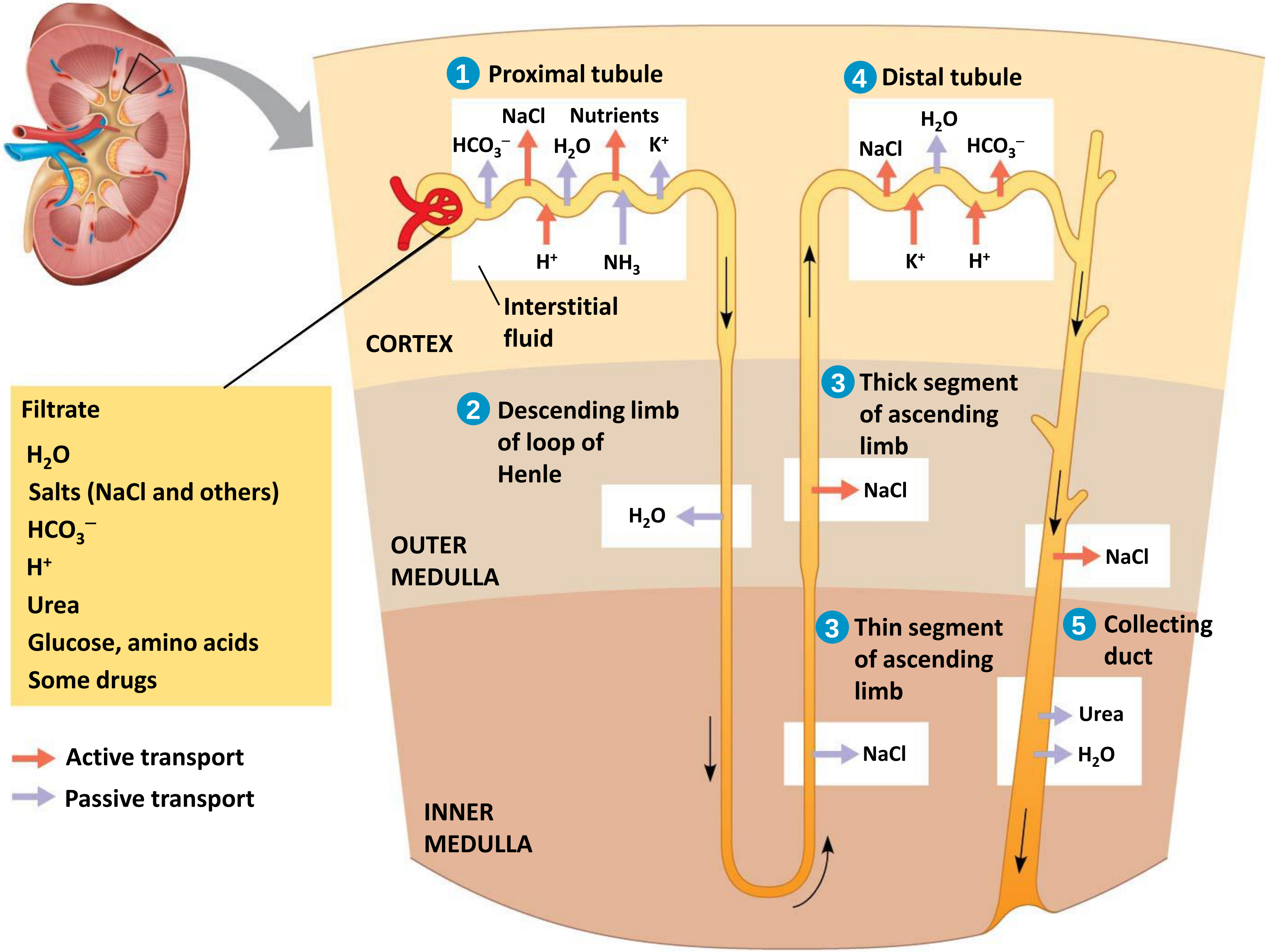
The Collecting Duct

The following occurs in the <u>collecting duct</u>:

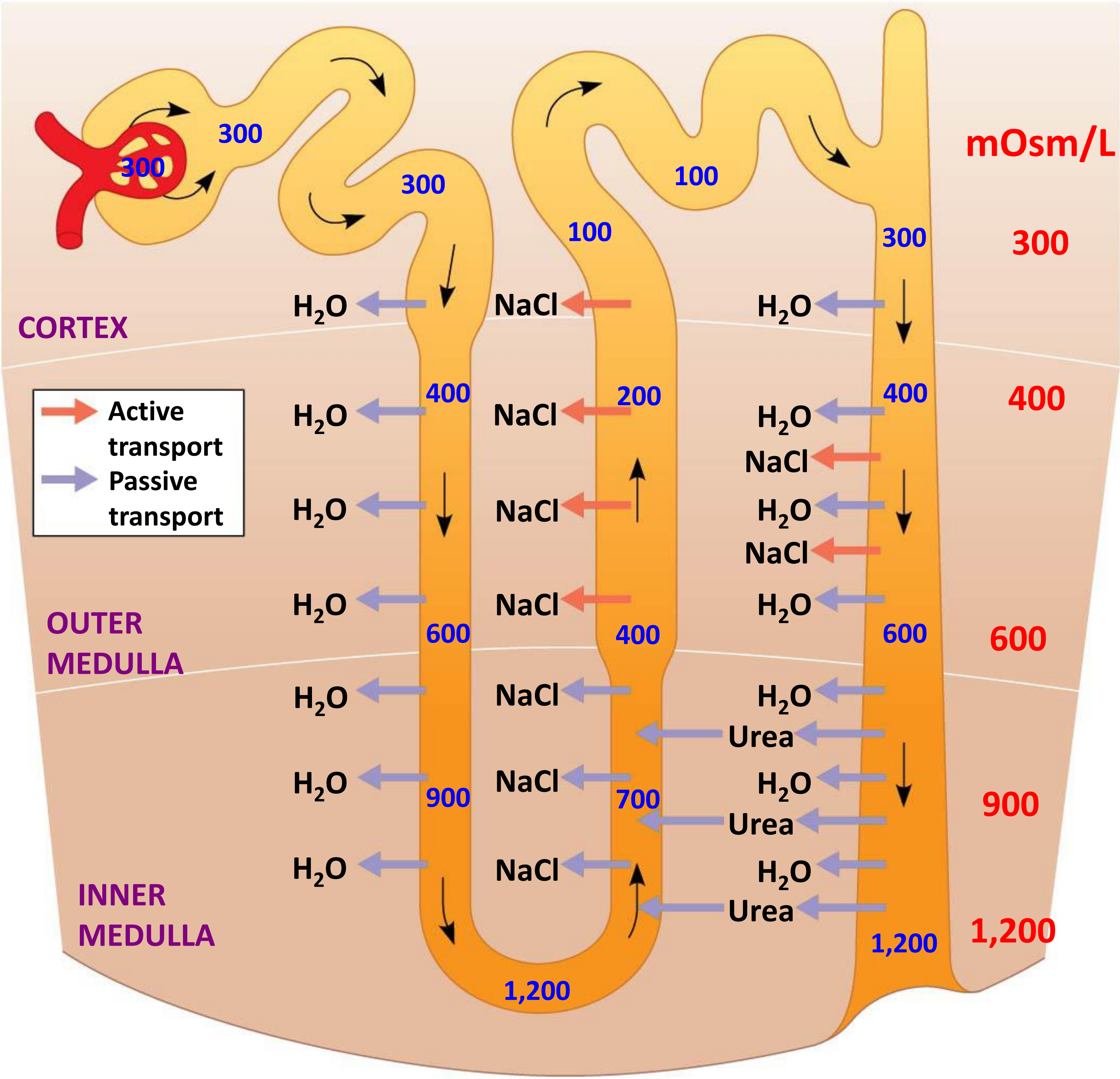
- reabsorption of water and valuable solutes
- resulting urine is conducted to the renal medulla on its way to the renal pelvis and ureter



Summary of Nephron Function



Osmolarity in the Cortex vs Medulla

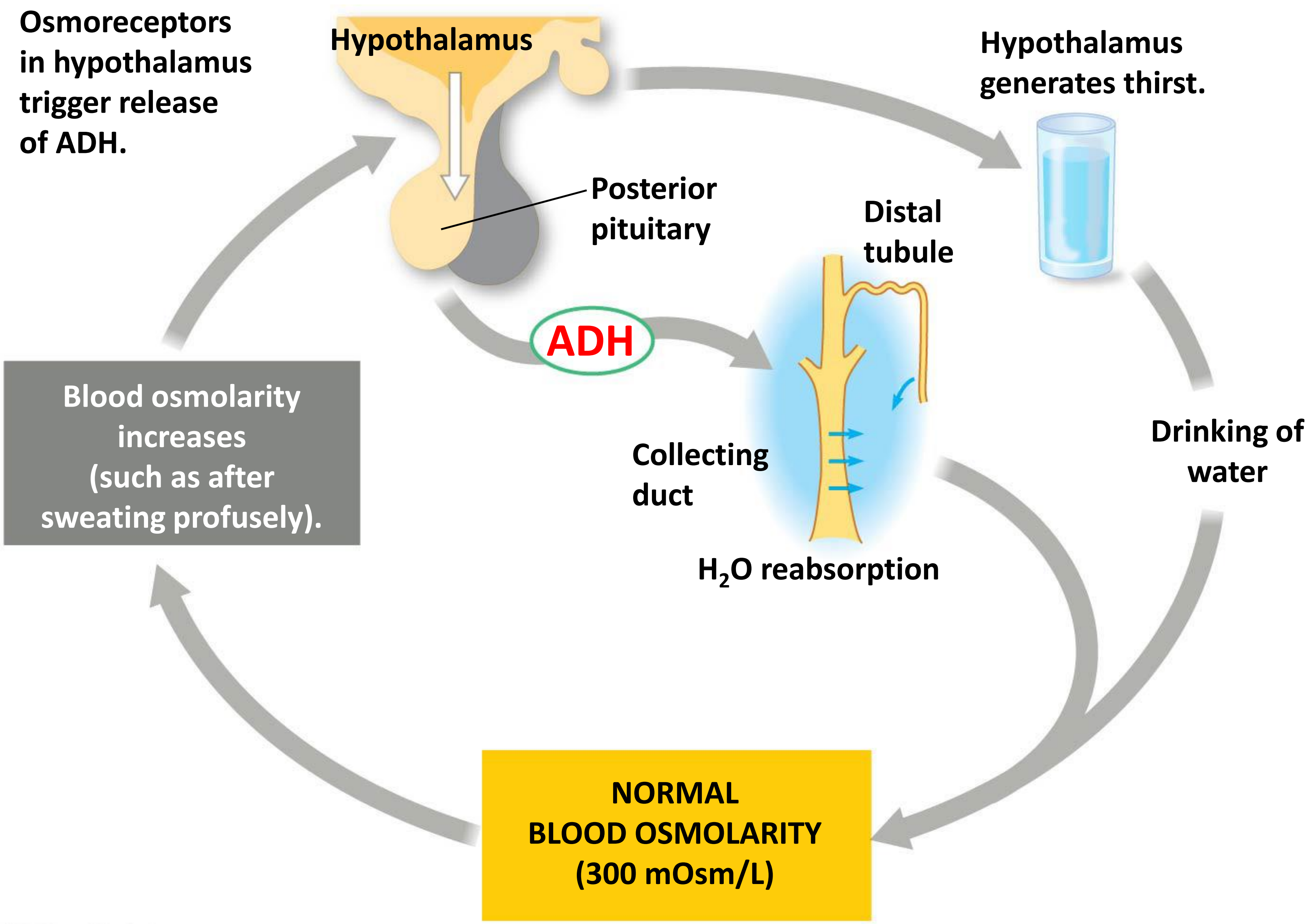


The osmolarity of the interstitial fluids surrounding the nephron increases from cortex to medulla.

This gradient is responsible for the passive transport of water and solutes in various sections of the nephron.

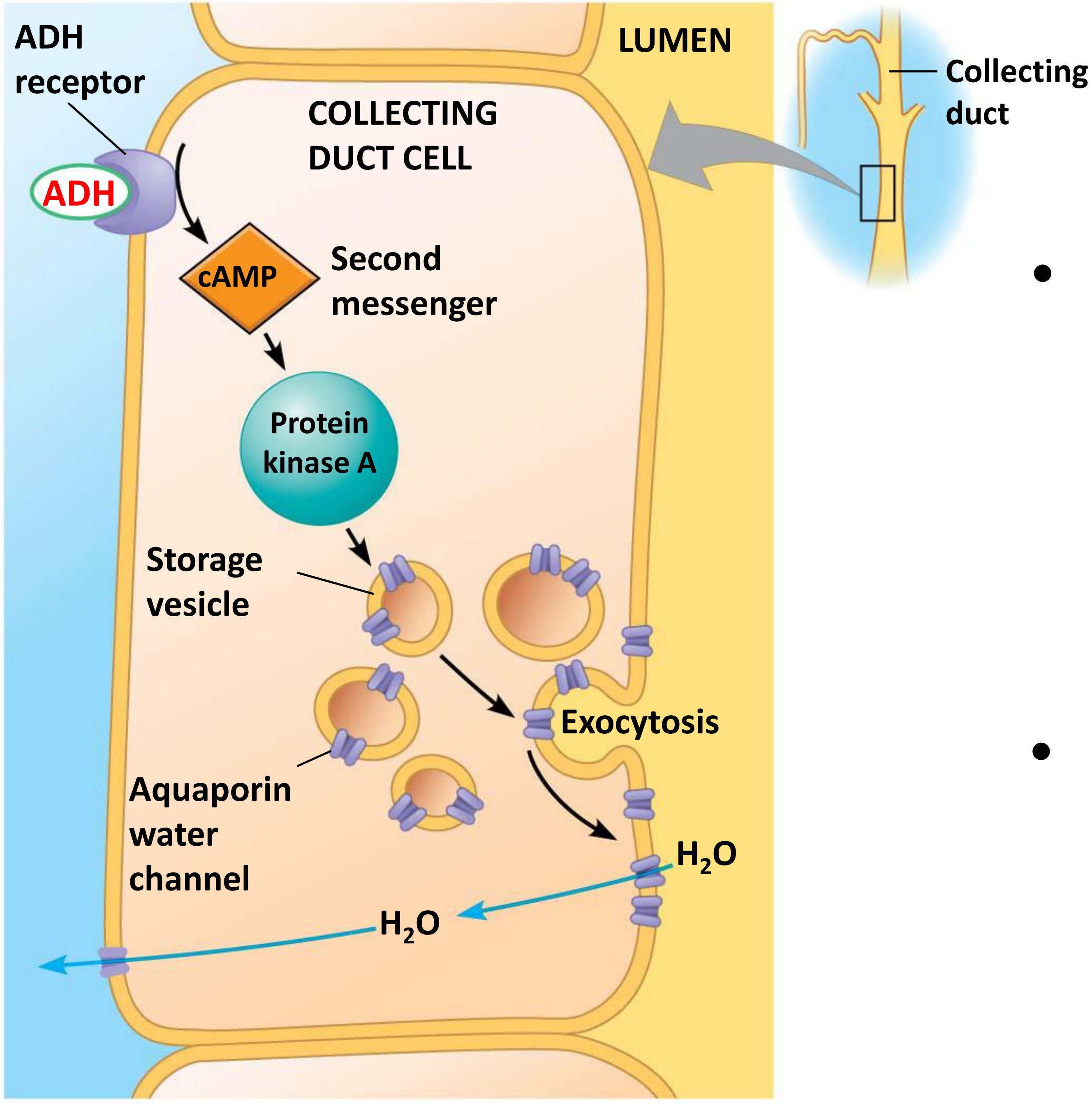
4. Hormonal Control of Osmoregulation & Excretion

Antidiuretic Hormone



- antidirutic hormone or ADH (aka vasopressin) released by the posterior pituitary gland stimulates greater water reabsorption in the kidney blood when osmolarity increases due to dehydration

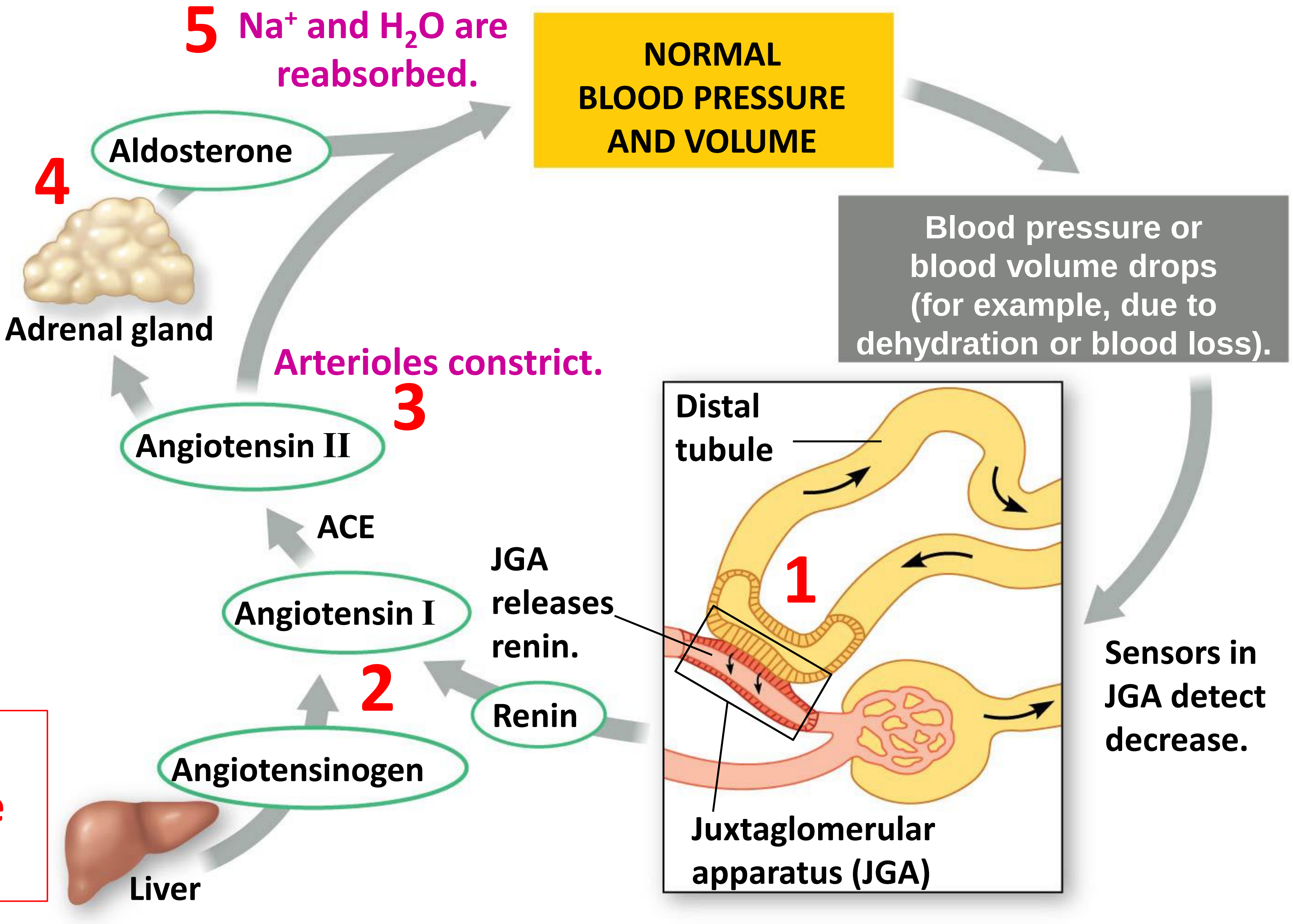
...more on ADH



- the effect of ADH is to increase the number of <u>aquaporin</u> water channels on the apical surface of collecting duct epithelial cells
- this results in more water reabsorption from the collecting duct to the interstitial fluid

Renin-Angiotensin-Aldosterone System (RAAS)

- the RAAS is a complex hormonal feedback system that increases water reabsorption in the kidney in response decreased blood pressure



<u>Atrial natriuretic peptide</u> (ANP) inhibits renin release when blood pressure rises.