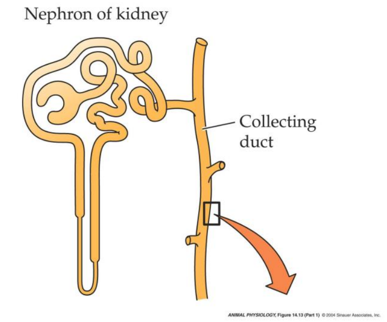
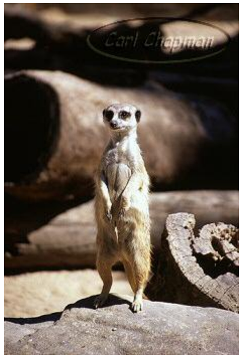
Excretion



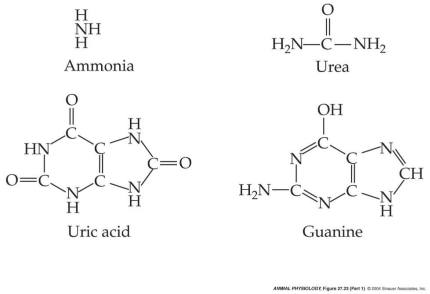
Basic mechanisms of Kidney function

Urine formation in Amphibians



Urine formation in Mammals

Urine formation in Insects



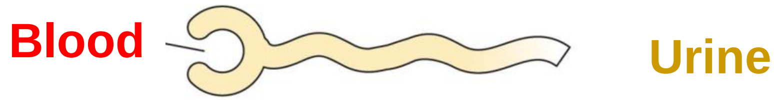
Nitrogen balance

Kidneys

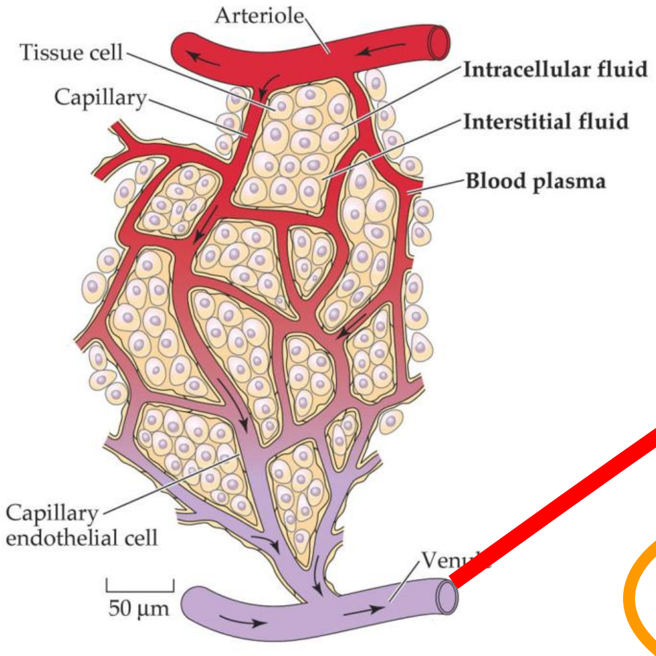
- The most fundamental function of **kidneys**) is to **regulate the composition of blood plasma** by **removing** water and solutes from the plasma in a **controlled way.**

- **Kidneys are fluid-processing organs.** They start with blood plasma and produce urine

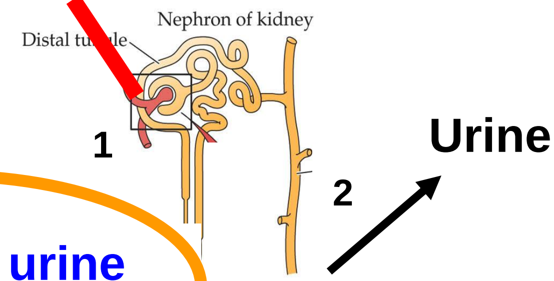
- The regulatory role of the kidney can be evaluated by comparing the **output** (**urine**) and the **input** (**blood plasma**). **U/P ratio**



Basic mechanisms of Kidney function



Animals need to maintain the composition and volumes of their 3 body-fluids compartments within viable limits.



1. **Primary urine**
2. **Definitive urine**

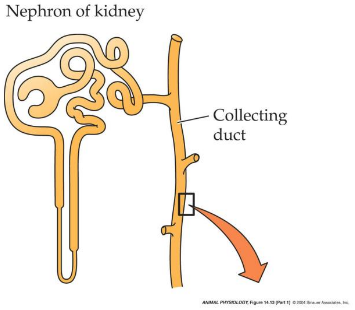
Urine: fluid produced by the kidneys.
Complex solution of inorganic and organic solutes.

Functions: waste elimination, osmoregulation, regulation of pH, blood pressure, etc

Basic mechanisms of Kidney function

Kidney has 3 features in common:

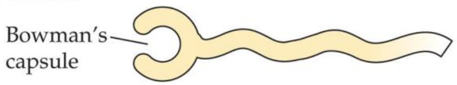
- **Tubular** structure (exterior)
- Produce and **eliminate** aqueous solutions derived from extra cellular fluids (Blood)
- Function is regulation of **composition** and **volume** of extracellular fluids by means of controlled excretion of water and solutes.



Basic mechanisms of kidney function

The **nephron** is the basic unit of the kidney

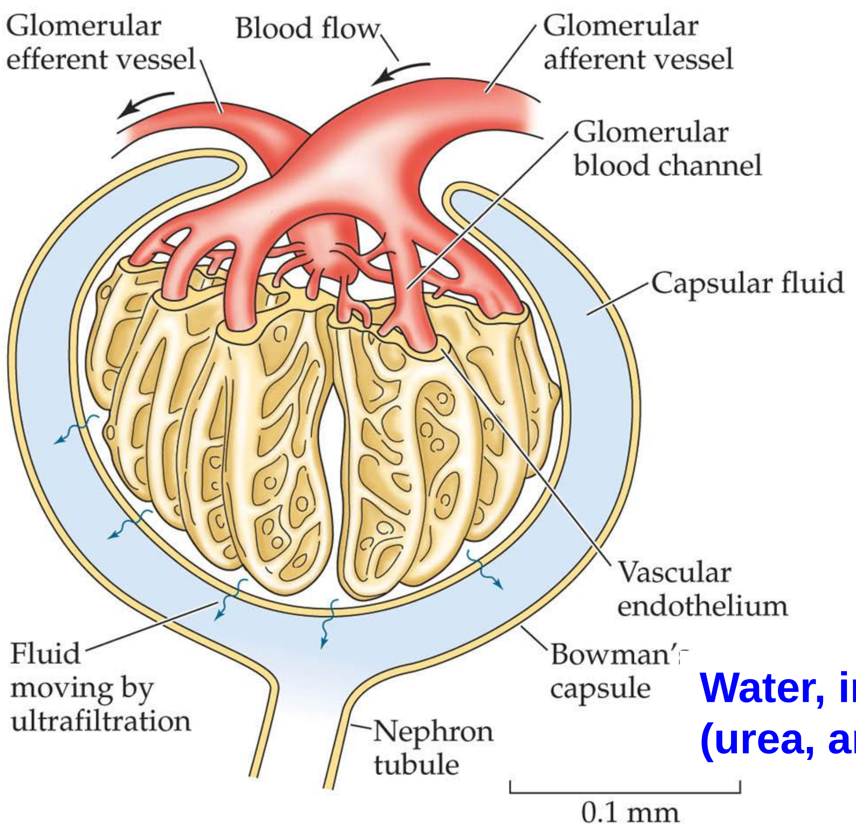
(a) The general form of a vertebrate nephron at the end where primary urine is formed



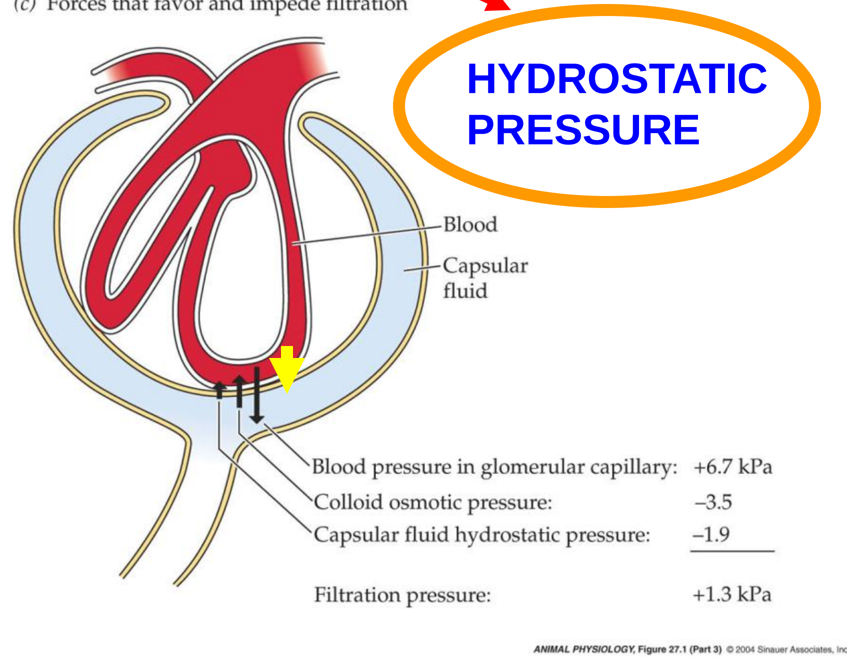
The **nephron** is the first **interphase** between the **circulatory** and **excretory** system.

Primary urine is introduced into kidneys tubules by **ultra filtration**

(b) A human glomerulus positioned in a Bowman's capsule



(c) Forces that favor and impede filtration



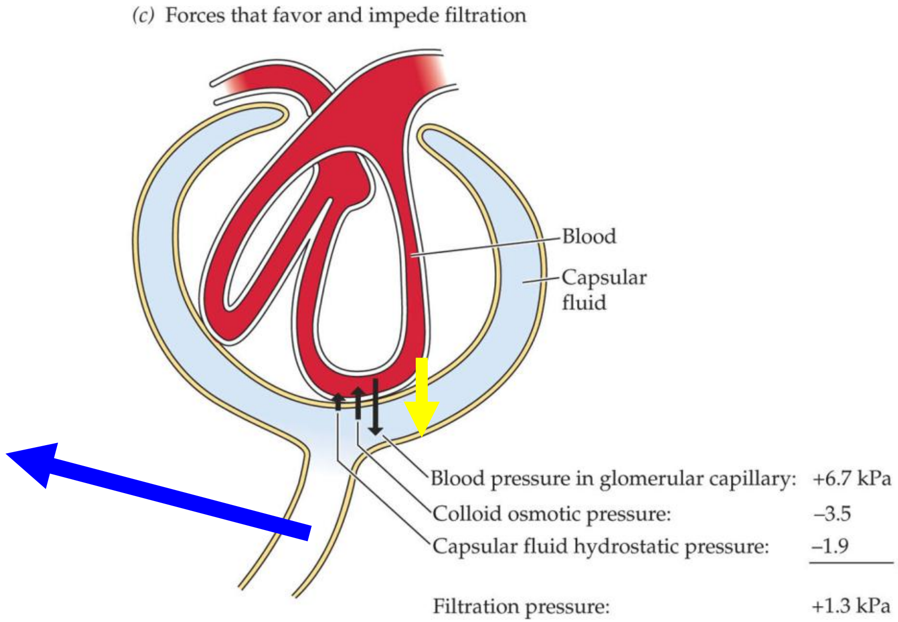
Water, inorganic ions and small organic molecules (urea, amino acids, glucose).

Basic mechanisms of kidney function

The **filtration rate** is the rate of primary urine formation
(**GRF: glomerular filtration rate**)

120 ml/min in an Adult human = all blood filtered in 30 minutes

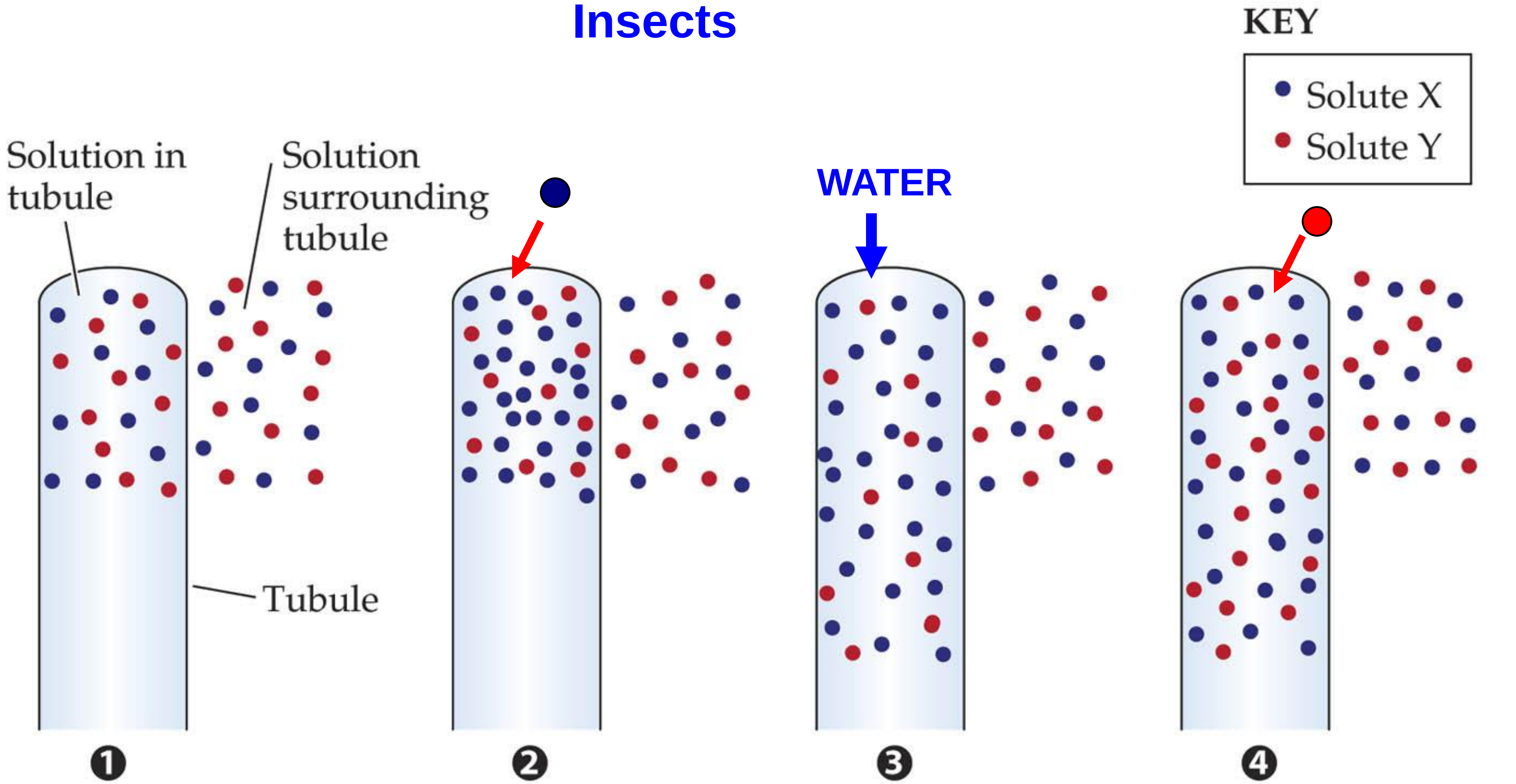
Most water and molecules are reabsorbed back



Regulation: Filtration and reabsorption

Formation of primary urine by **active solute secretion**

Insects



Energy from ATP is used
to secrete **X** into the tube
Osmotic pressure increases

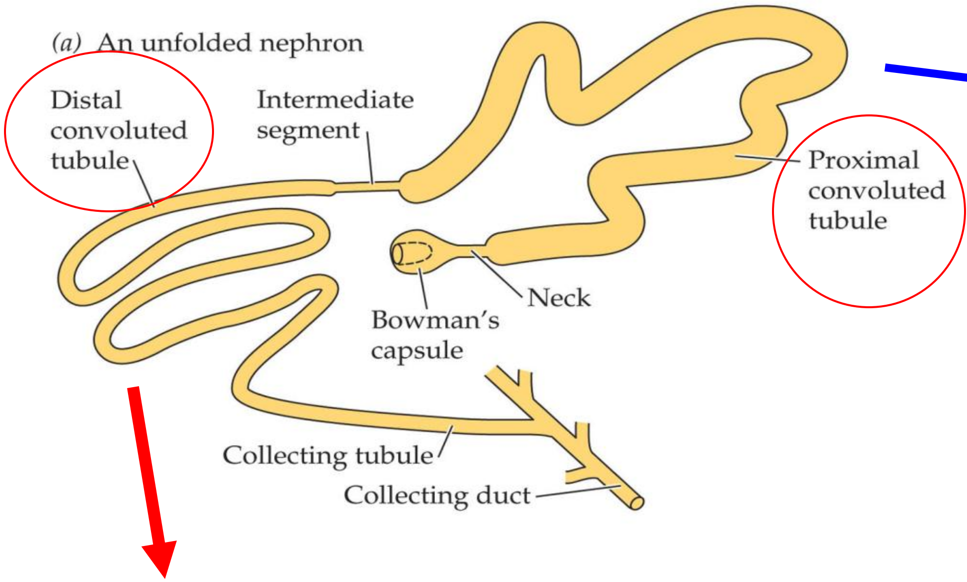
Water enters by osmosis
Solute **Y** is diluted

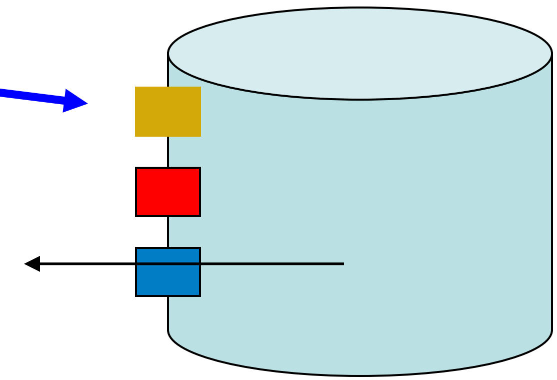
Solute **Y** diffuses
Following a concentration
gradient

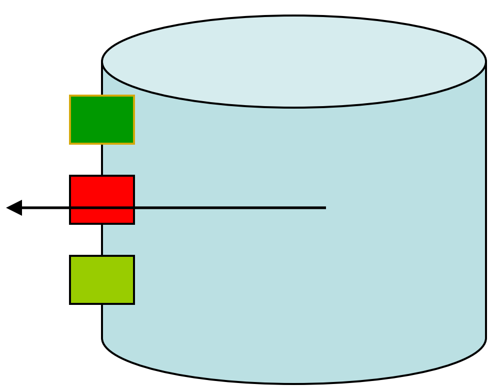
The active secretion of X drives the diffusion of many solutes

The permeability of the epithelium determines which ones will diffuse.

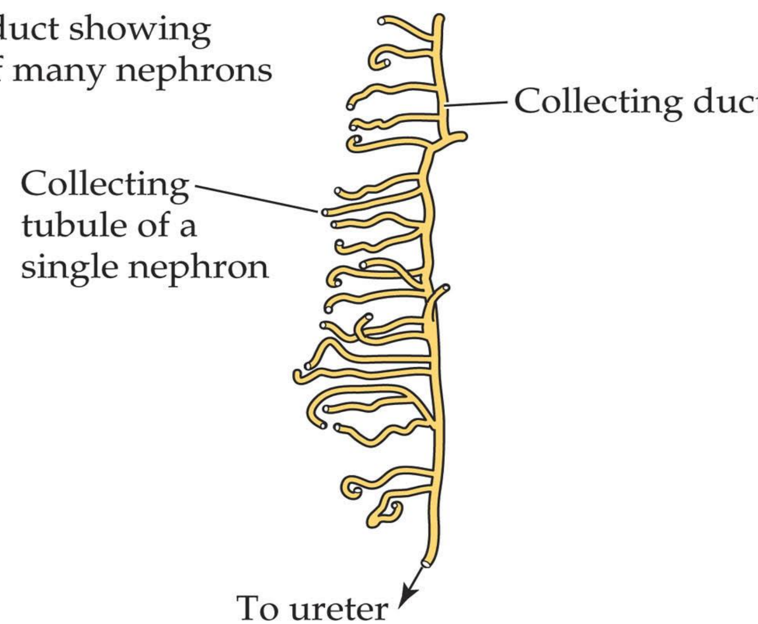
Amphibian nephrons and their connections to collecting ducts







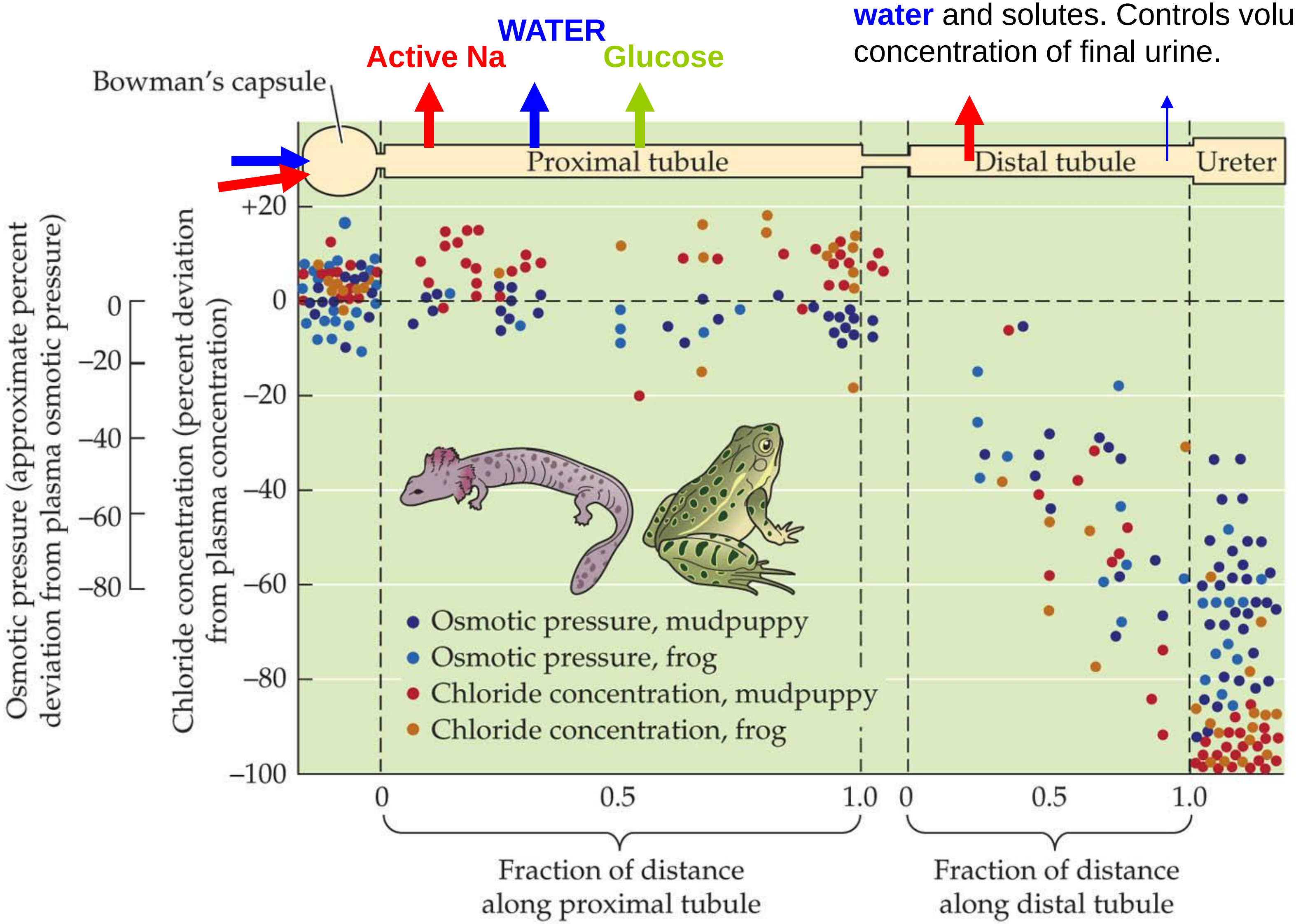
(c) A collecting duct showing attachment of many nephrons



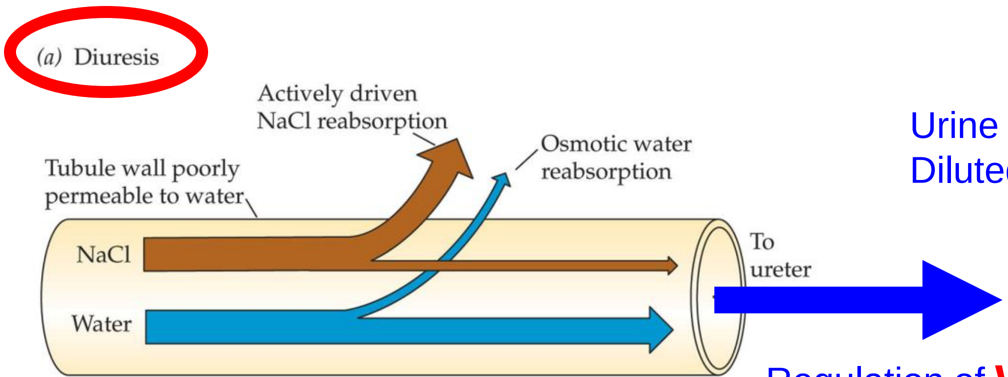
Urine formation in amphibians during diuresis

Prox Conv Tube: Isosmotic, reabsorbs water and solutes.

Dist Conv Tube: **differentially** reabsorbs **water** and solutes. Controls volume and concentration of final urine.



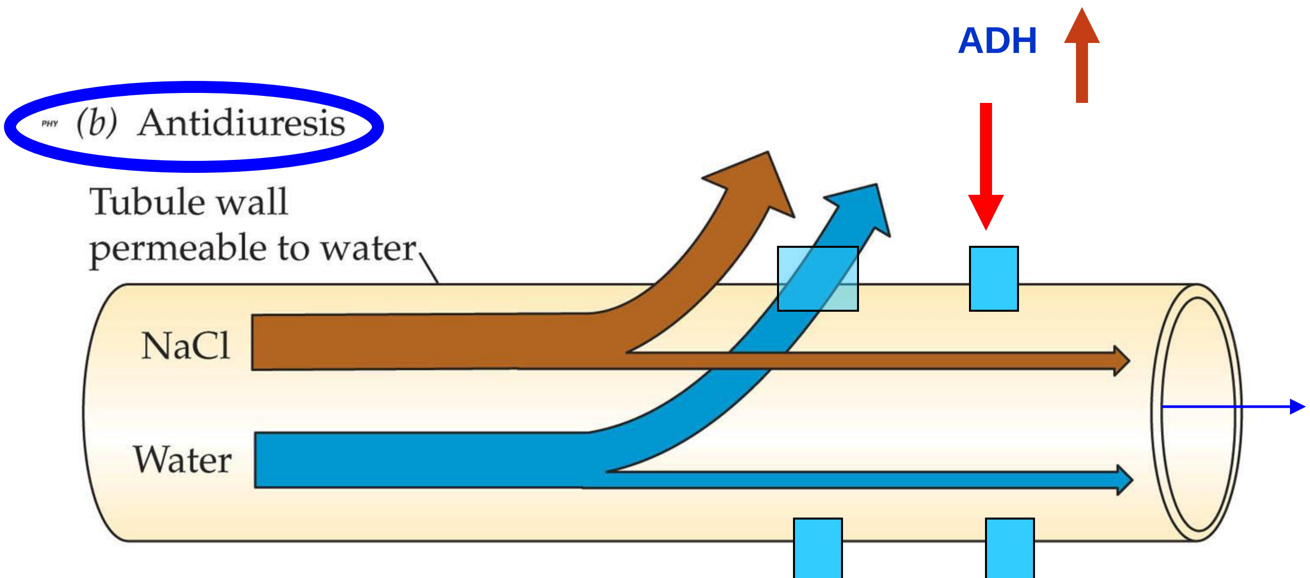
The distal convoluted tubule can differentially reabsorb water and solutes, controlling water excretion



Urine **hyposmotic** to plasma
Diluted and abundant

UP < 1

Regulation of **water permeability** by antidiuretic hormone



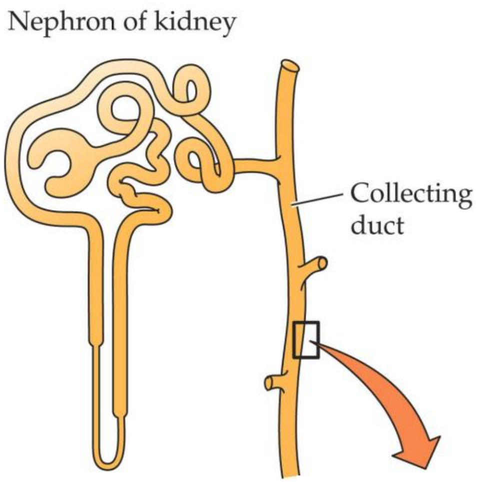
UP = 1

Urine **isosmotic** to plasma
concentrated and small amount

Aquaporin

Two types of water: 1) required for solutes, 2) pure, **osmotically free water.**

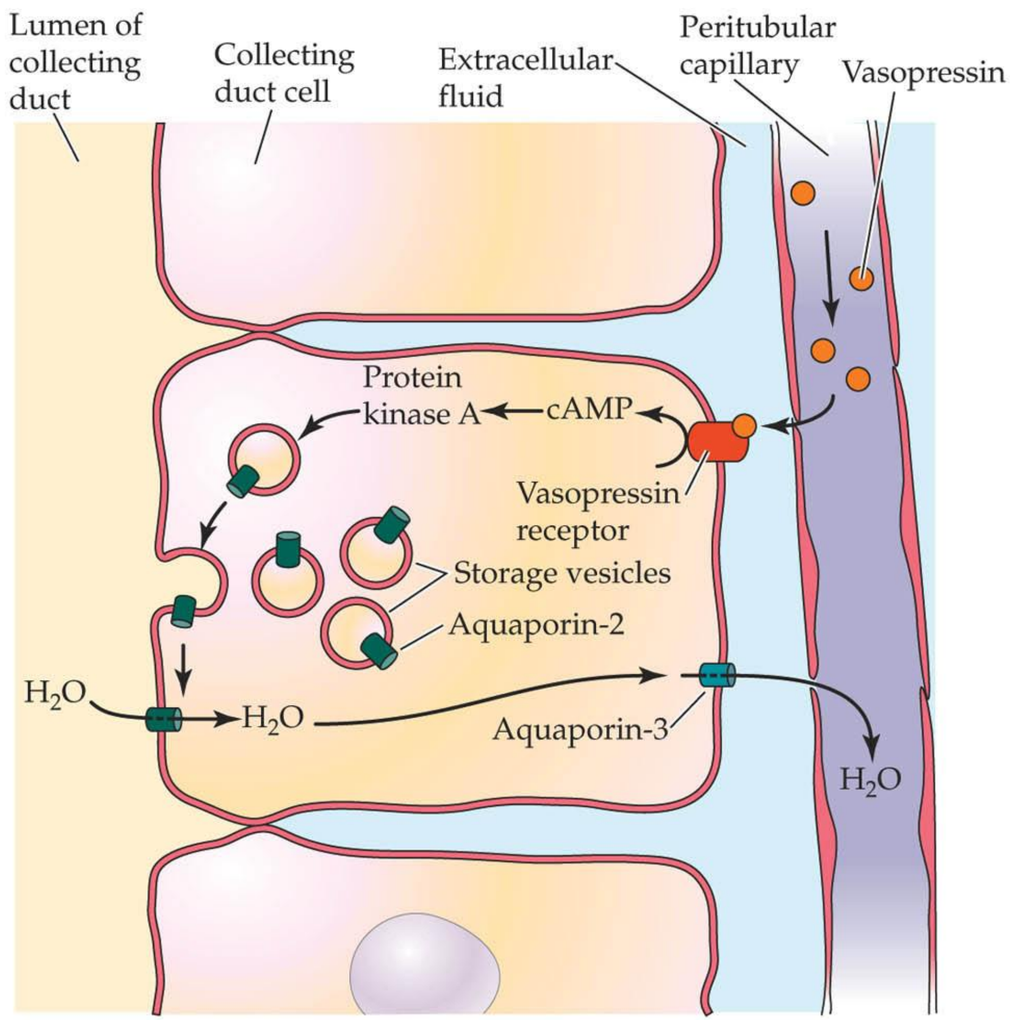
The action of an antidiuretic hormone (ADH)



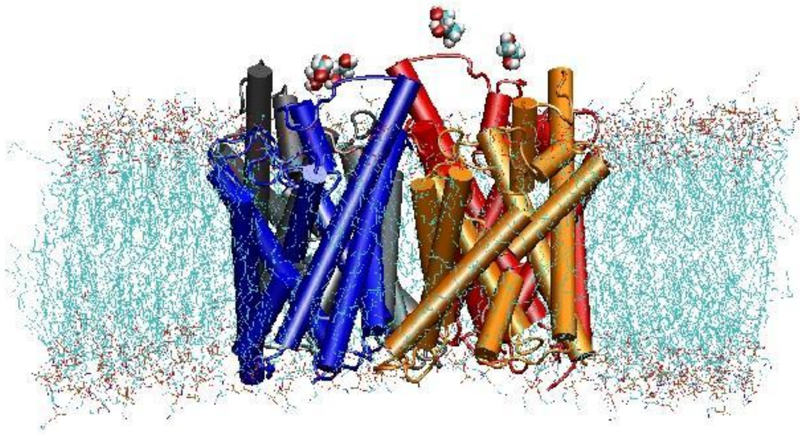
Vasopressin (ADH) regulates the balance of water by controlling the insertion and retrieval of aquaporin proteins

Aquaporin-2 is regulated

Aquaporin-3 is constitutive



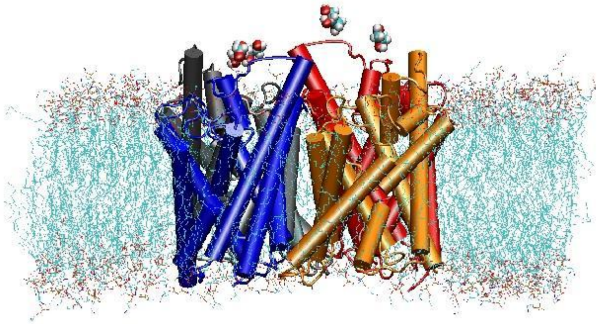
Aquaporin

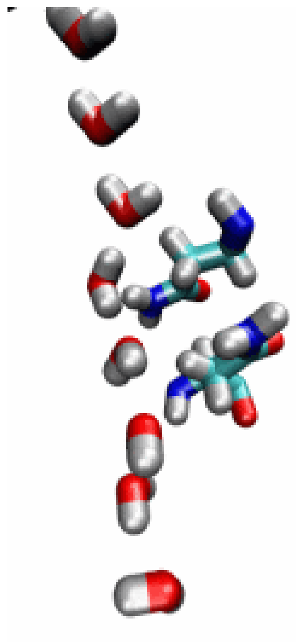


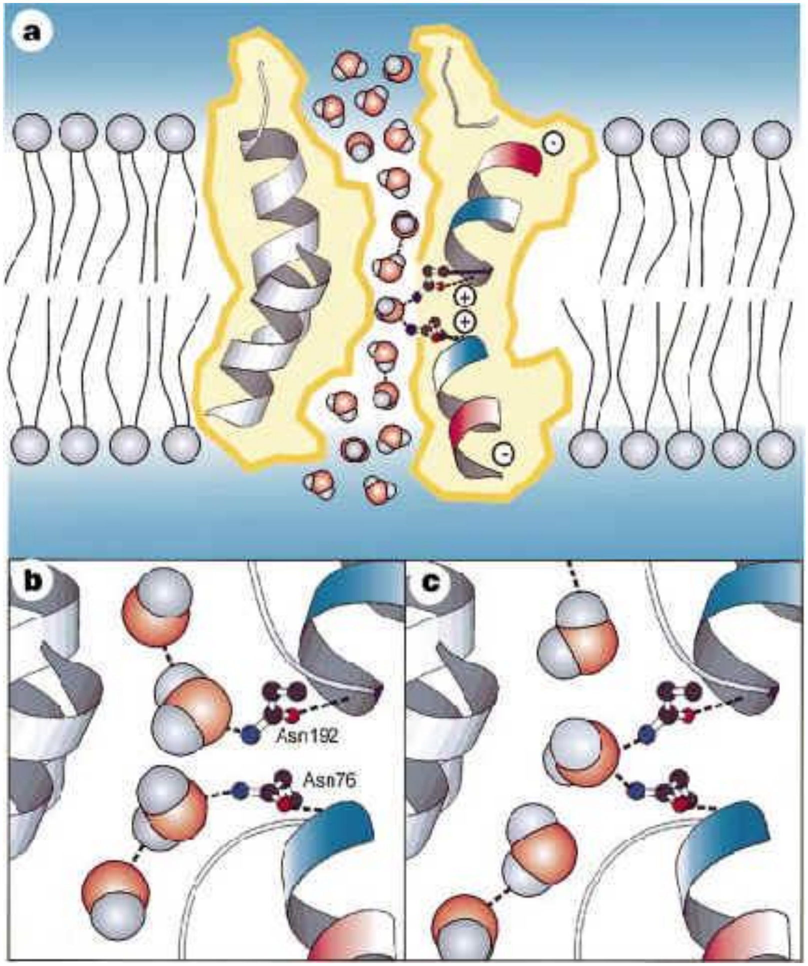
Tetramers in the cell membrane,

Facilitate the transport of water

Aquaporin

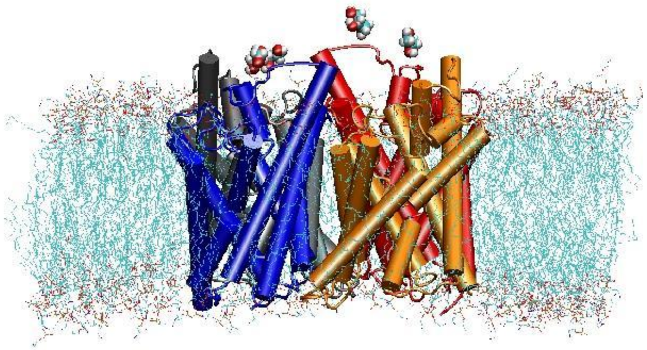






a: partial charges from the helix dipoles restrict the orientation of the water molecules passing through the constriction of the pore
b and **c**: hydrogen bonding of a water molecule with Aspargines 76 and/or 192, which extend their amido groups into the constriction of the pore.

Aquaporin



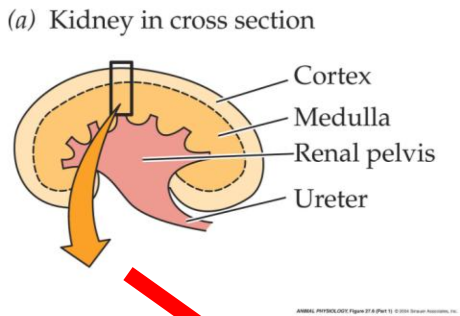
The Nobel Prize in Chemistry 2003

Peter Agre

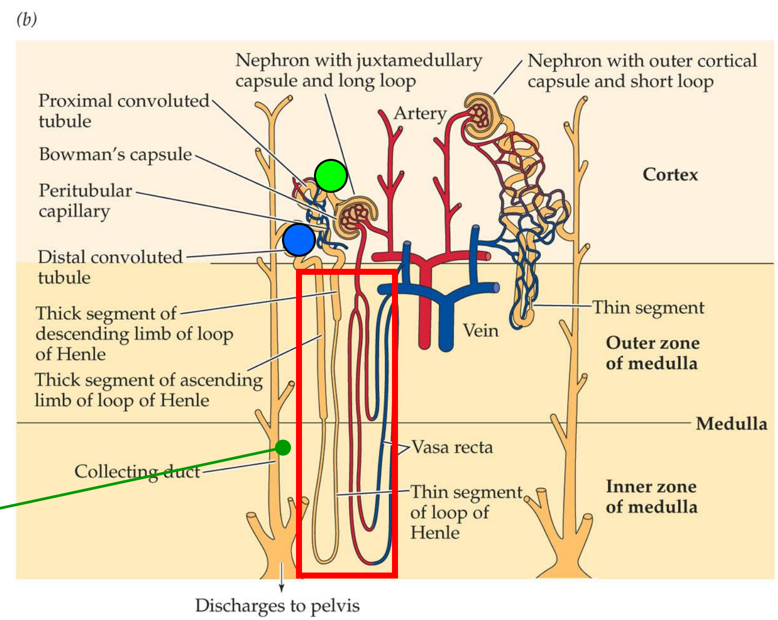
Johns Hopkins University School of Medicine
Baltimore

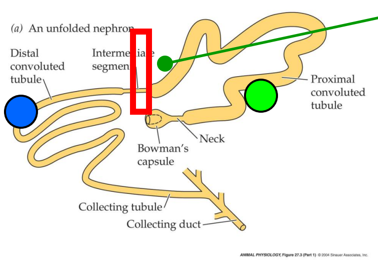
Urine formation in mammals

Hyperosmotic urine: mammals, birds and insects



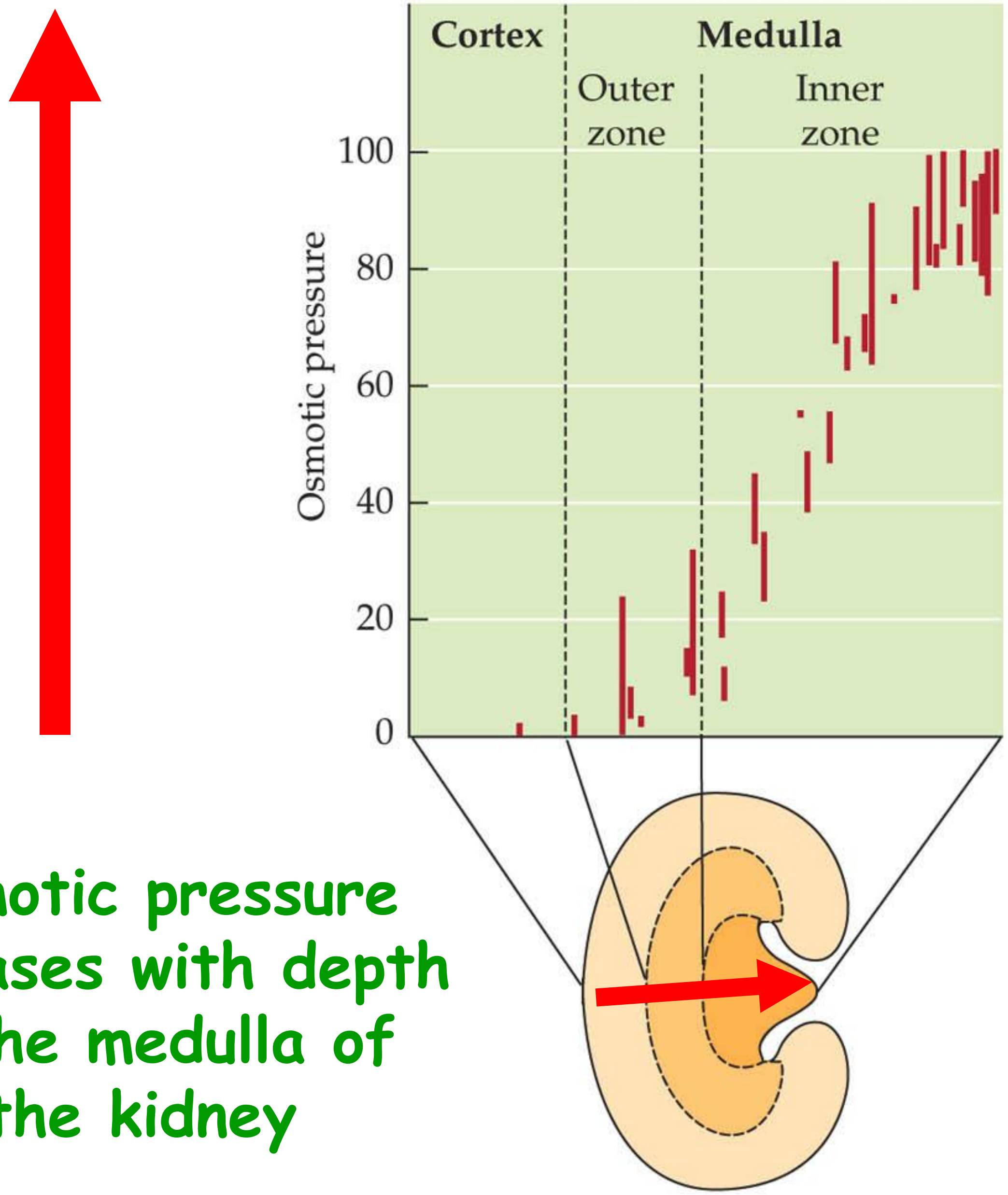
ANATOMY explains PHYSIOLOGY





1. Loop of Henle,
2. Parallel array conformation

Urine formation in **mammals**



ANATOMY explains PHYSIOLOGY

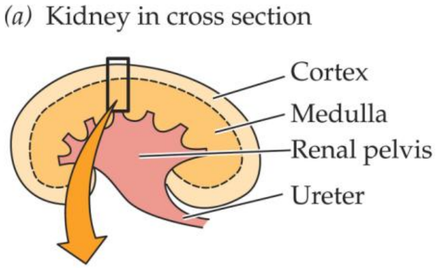
Hyperosmotic urine

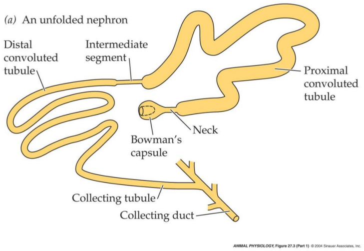
Osmotic pressure increases with depth in the medulla of the kidney

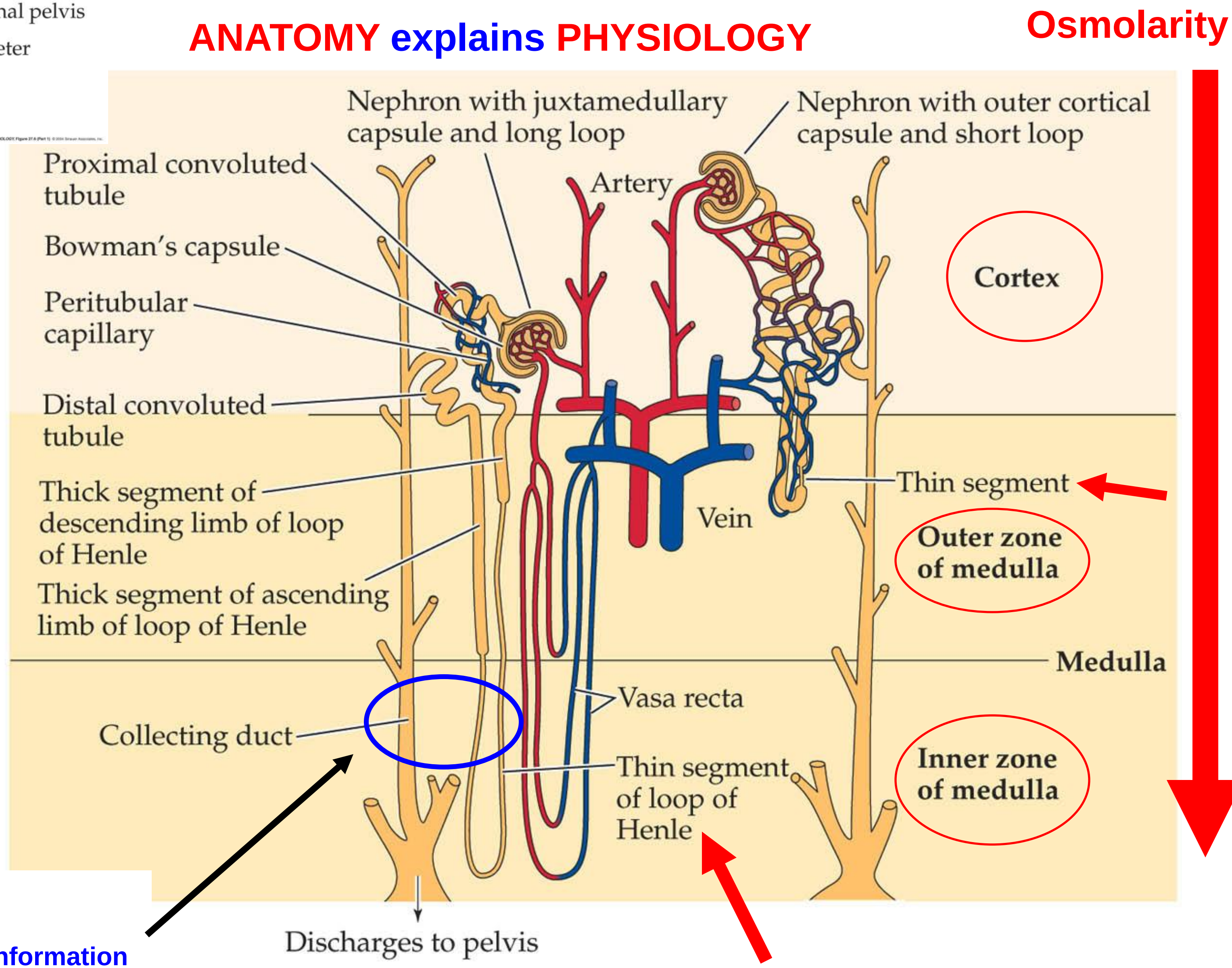
Urine formation in mammals

Hyperosmotic urine: mammals, birds and insects

ANATOMY explains PHYSIOLOGY

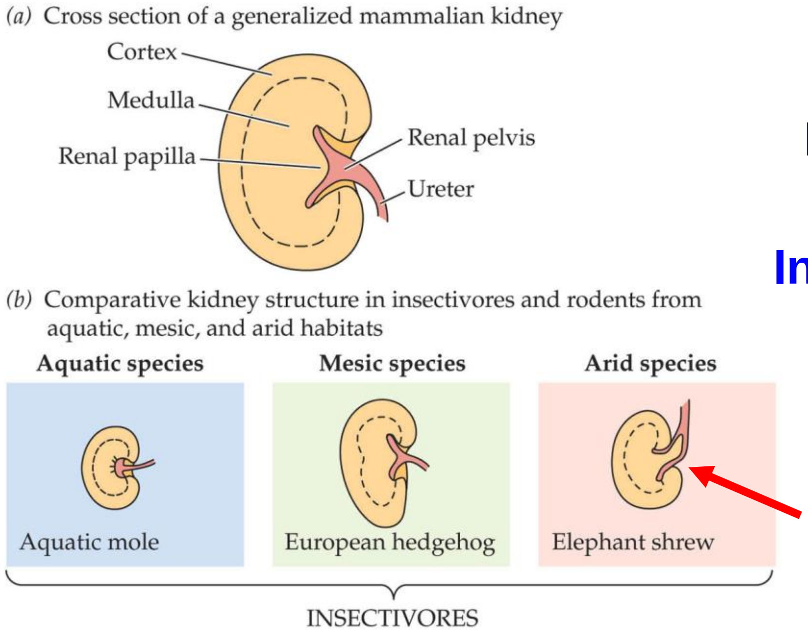






1. **Loop of Henle,**
2. **Parallel array conformation**

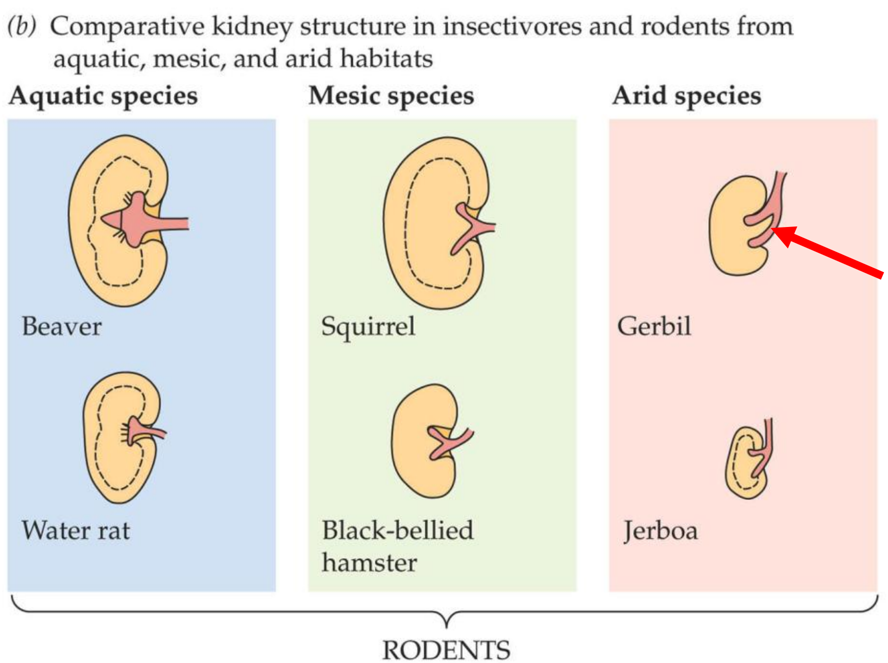
Evolutionary development of renal papilla in mammals native to different habitats

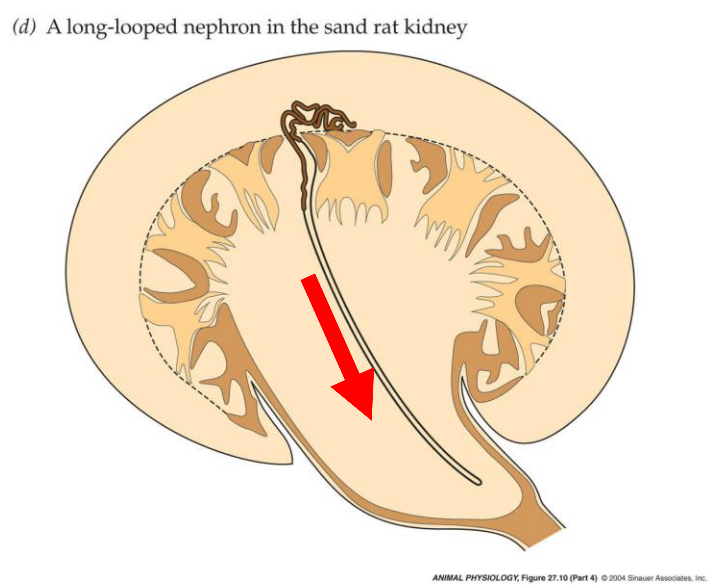


Hyperosmotic urine: long loops of Henle

Inner medula (renal papilla): long loops of Henle

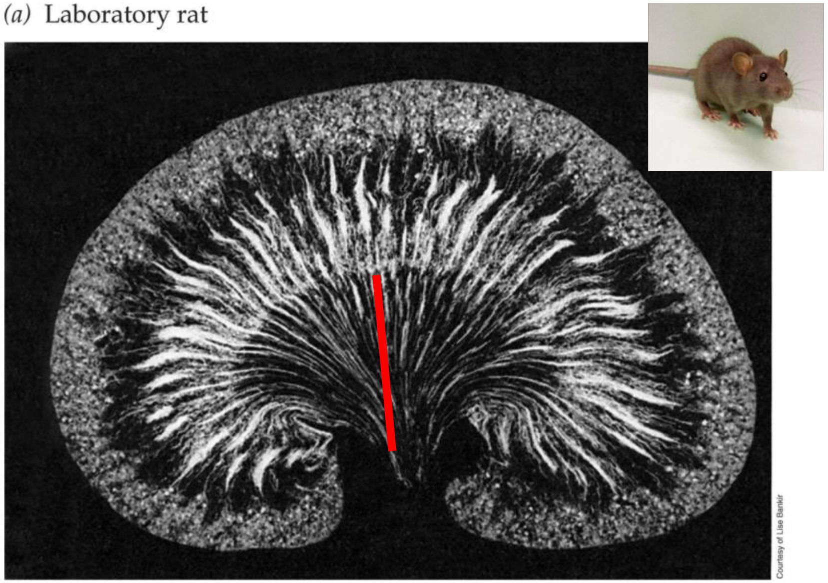
Mesic: intermediate moisture conditions



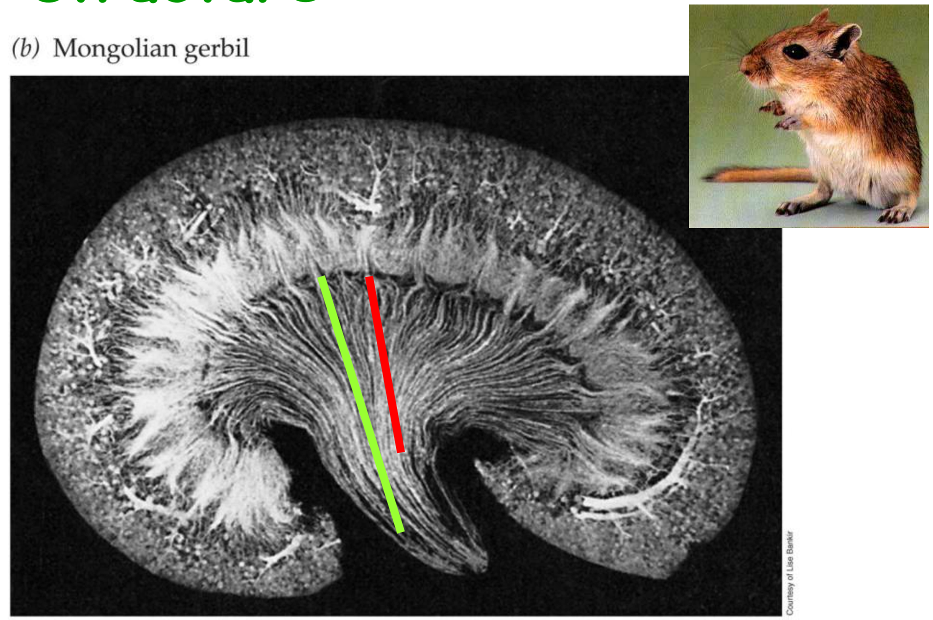


Kidney structure

(a) Laboratory rat

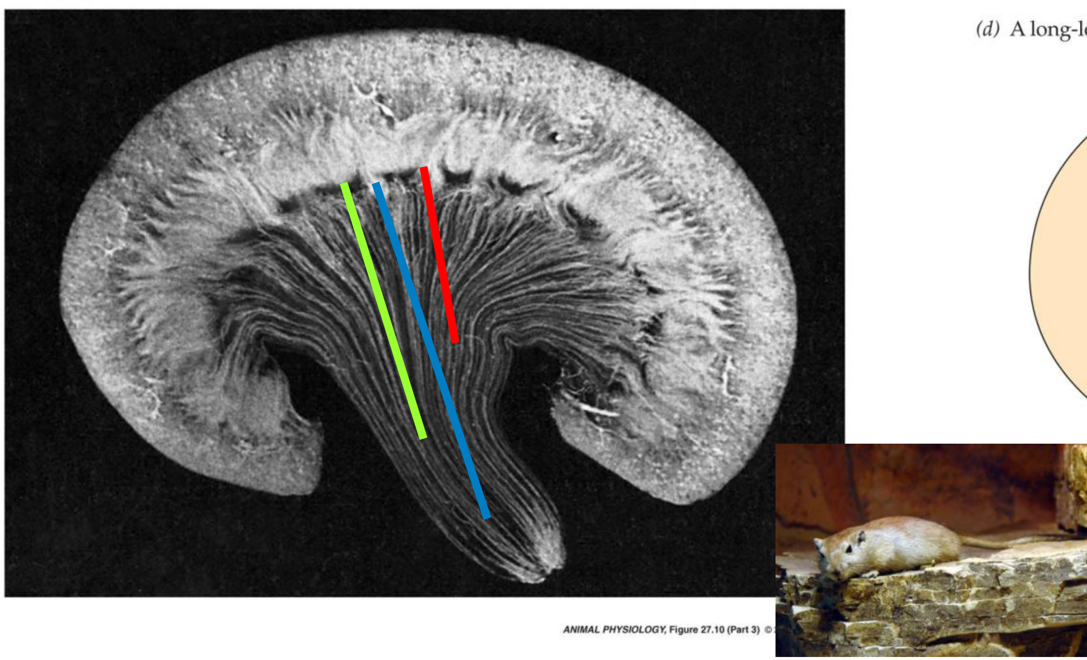


(b) Mongolian gerbil



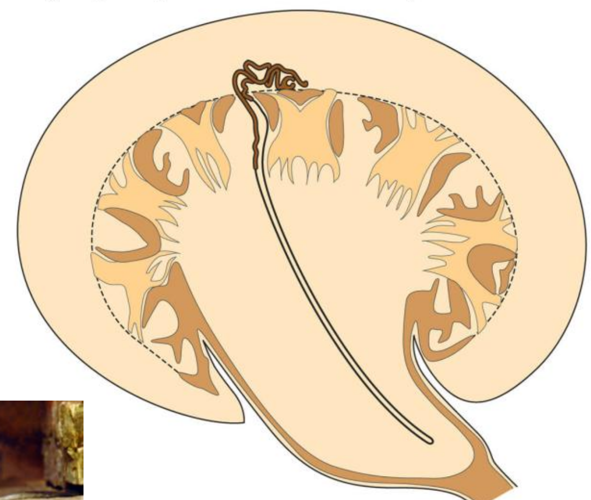
ANIMAL PHYSIOLOGY, Figure 27.10 (Part 2) © 2004 Sinauer Associates, Inc.

(c) Sand rat



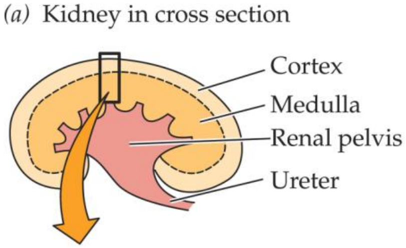
ANIMAL PHYSIOLOGY, Figure 27.10 (Part 3) ©

(d) A long-looped nephron in the sand rat kidney

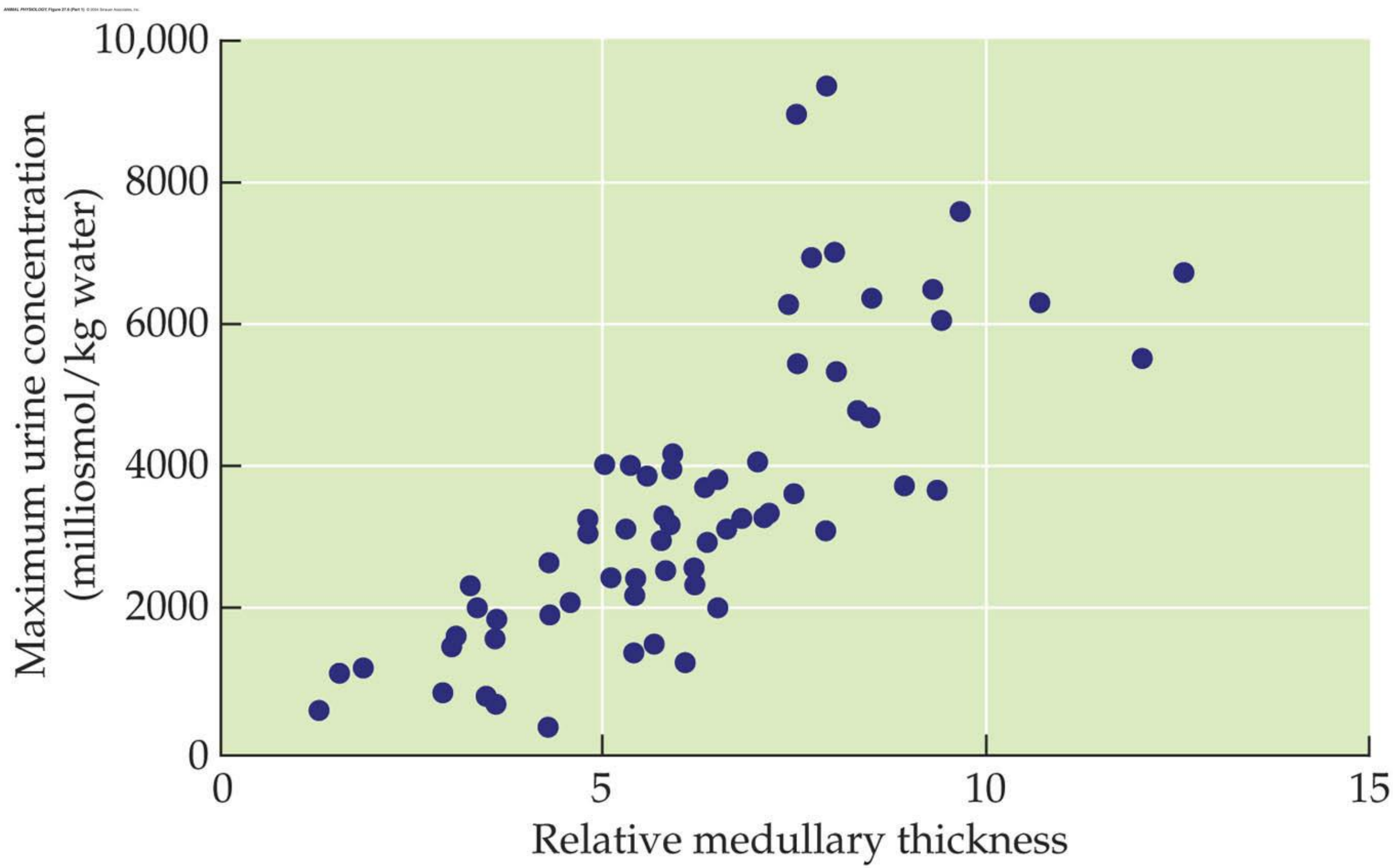


ANIMAL PHYSIOLOGY, Figure 27.10 (Part 4) © 2004 Sinauer Associates, Inc.

Maximum urine concentration correlates with the relative thickness of the medulla

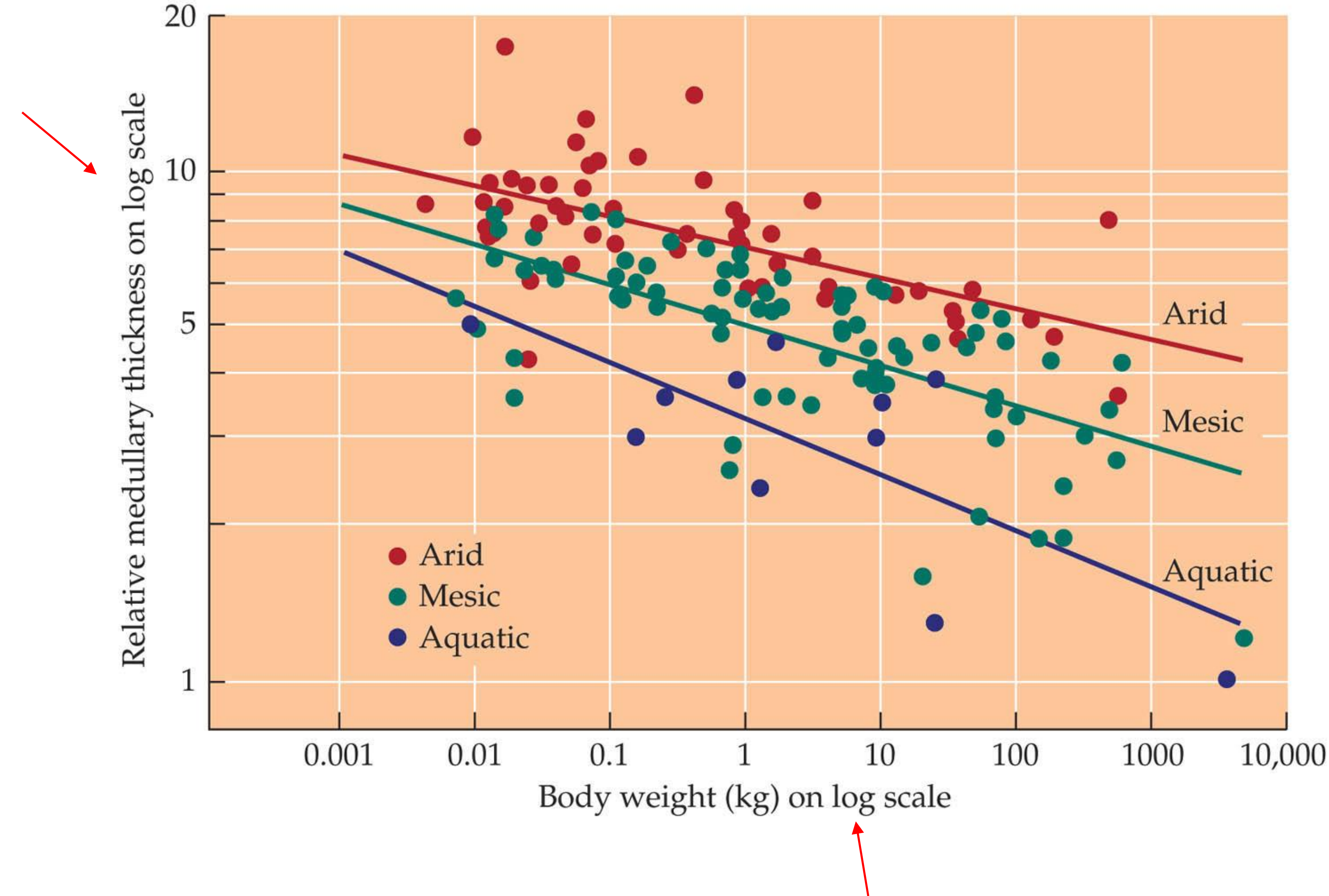


68 species of mammals
(medulla size relative to kidney size)

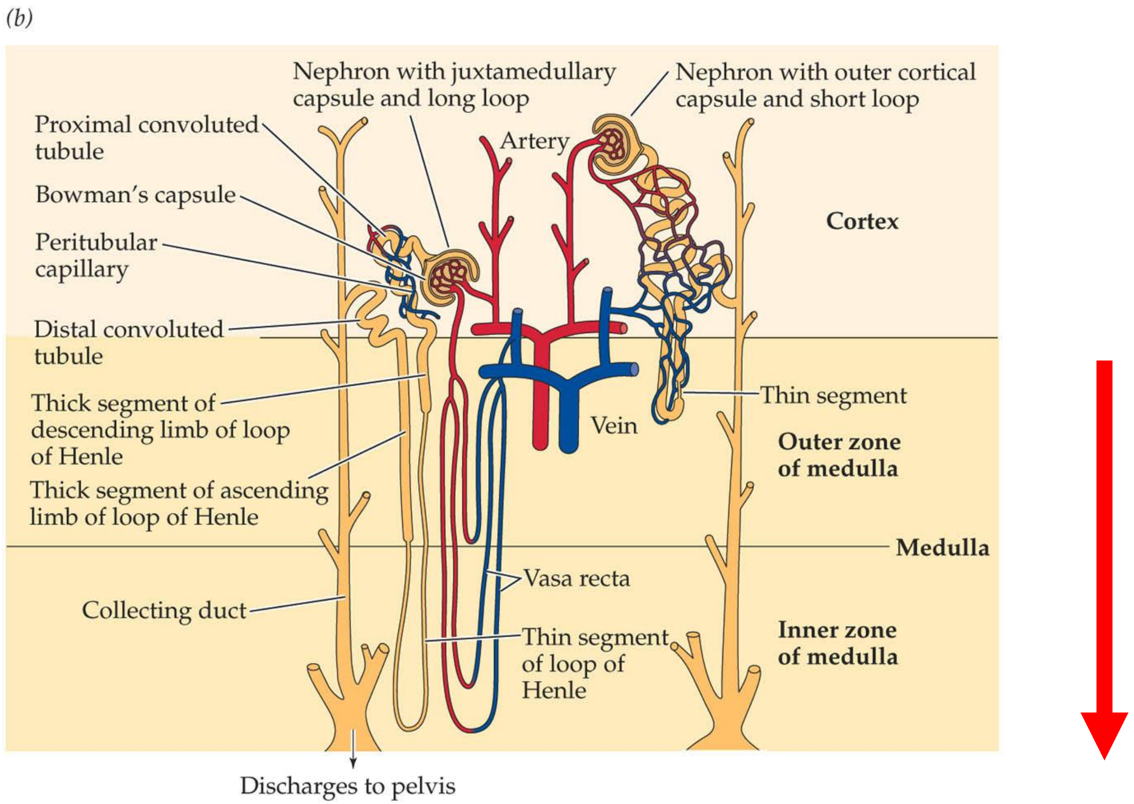


The relation between relative medullary thickness and body size

Each point is a species of mammal
(medulla size relative to kidney size)

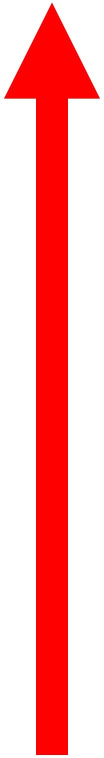


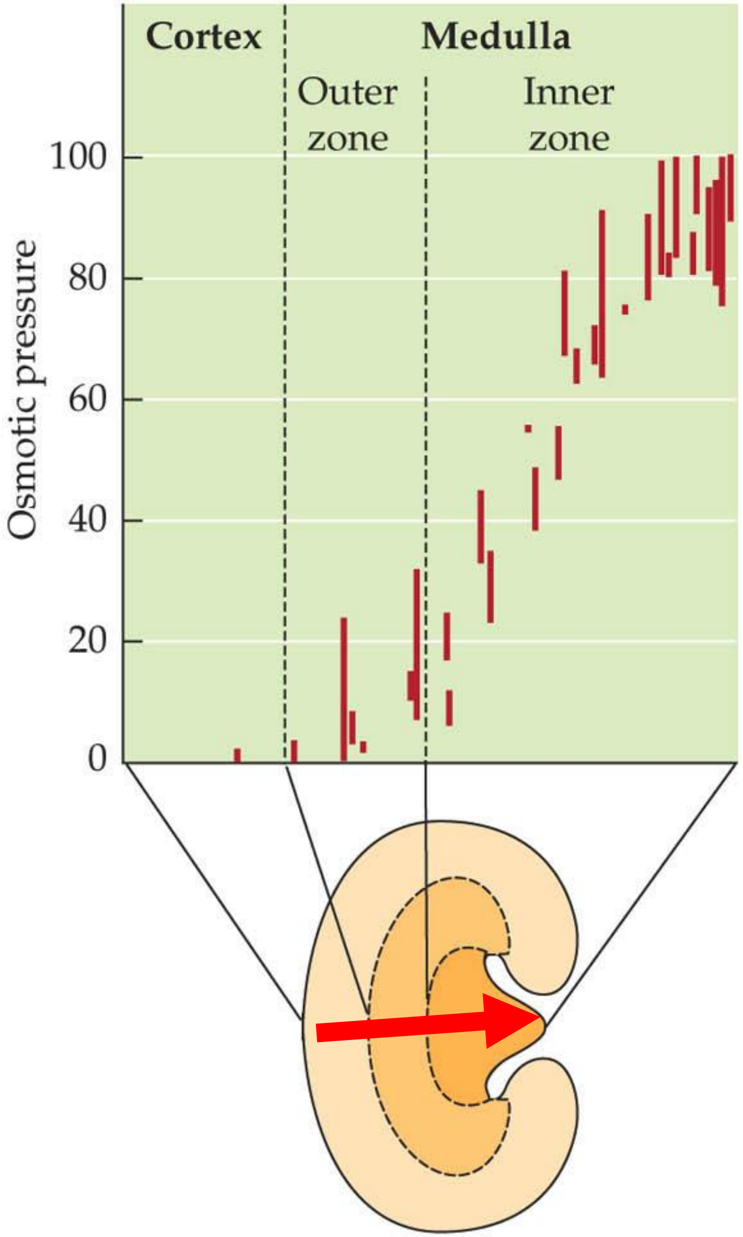
Countercurrent multiplication is the key to produce concentrated urine



There is a **NaCl gradient** in the medullary interstitial fluid that surrounds the collecting ducts

Osmotic pressure increases with depth in the medulla

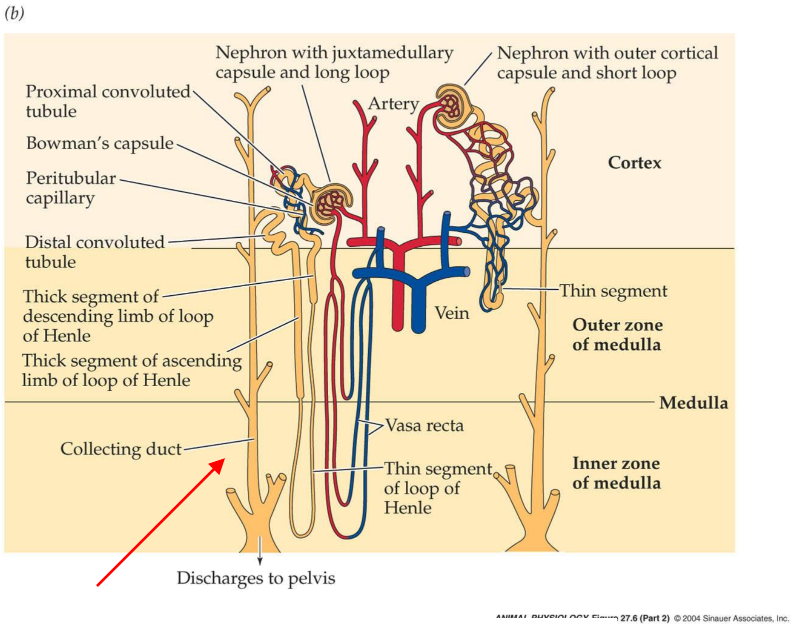




About 1000 mOsm greater

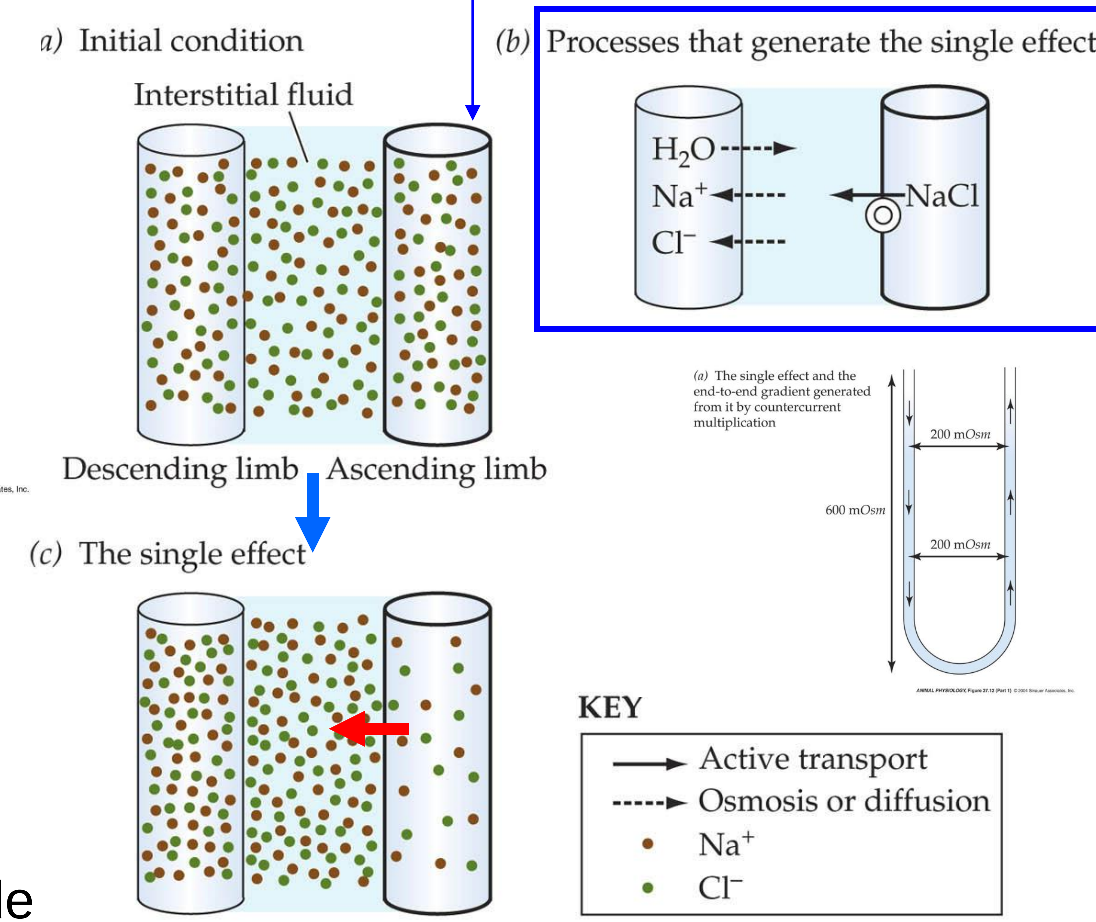
NaCl gradient

Countercurrent multiplication is the key to produce concentrated urine



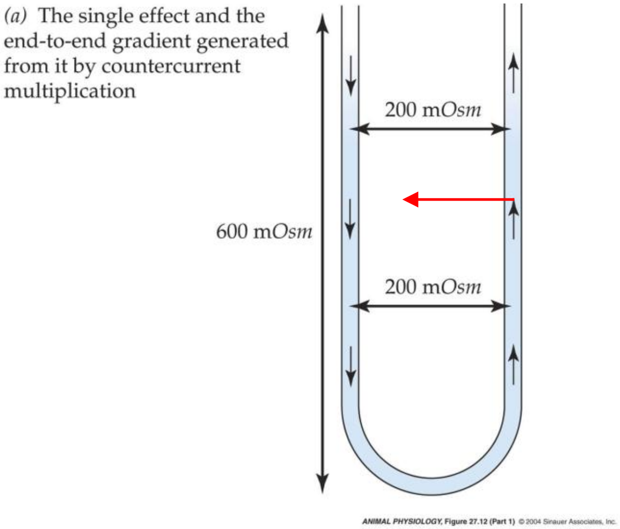
There is a **NaCl gradient** in the medullary interstitial fluid that surrounds the collecting ducts

Impermeable to water



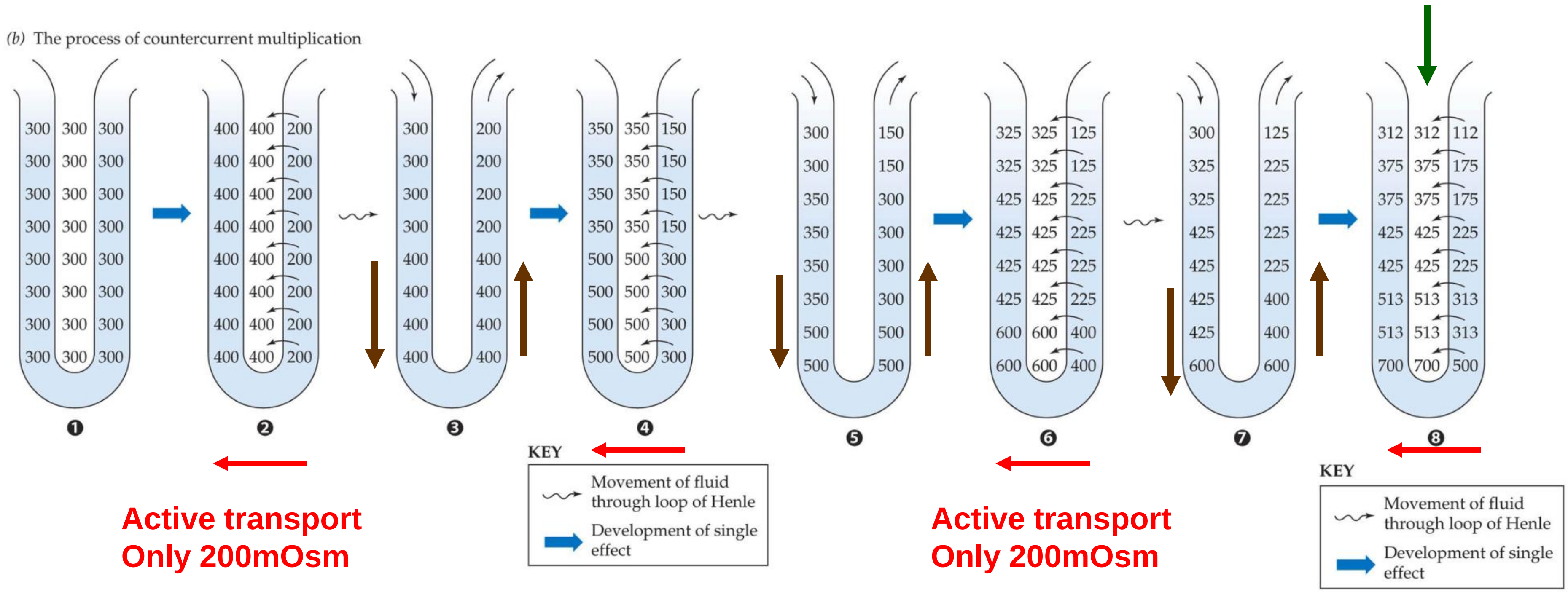
The **single effect** is the process that generates the side to side gradient

Countercurrent multiplication in the loop of Henle



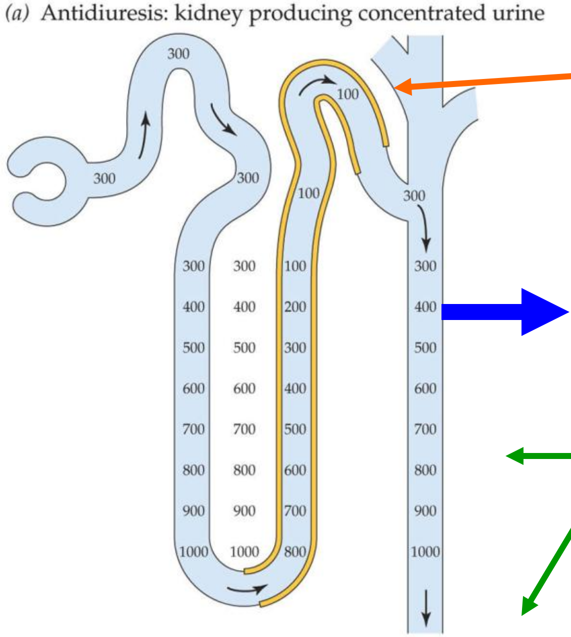
The **single effect** is the process that generates the side to side gradient **(active transport)**

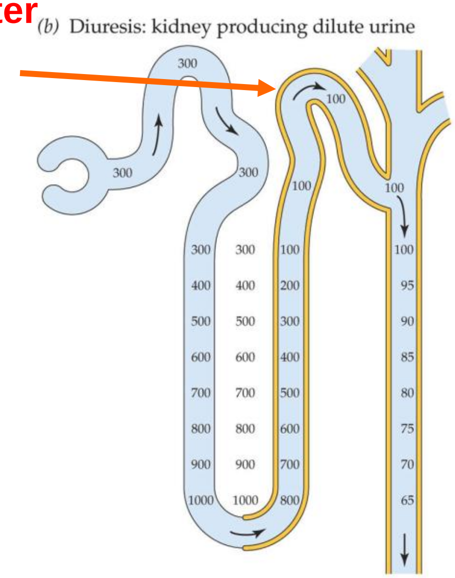
The **countercurrent multiplication** is the process that generates the **end to end** gradient



Osmotic pressures attributable to nonurea solutes in nephrons and collecting ducts

Impermeable to water

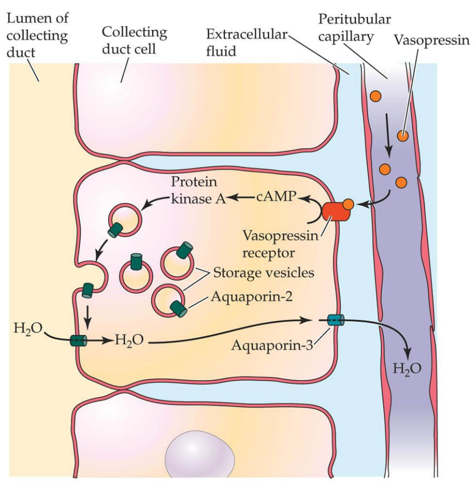


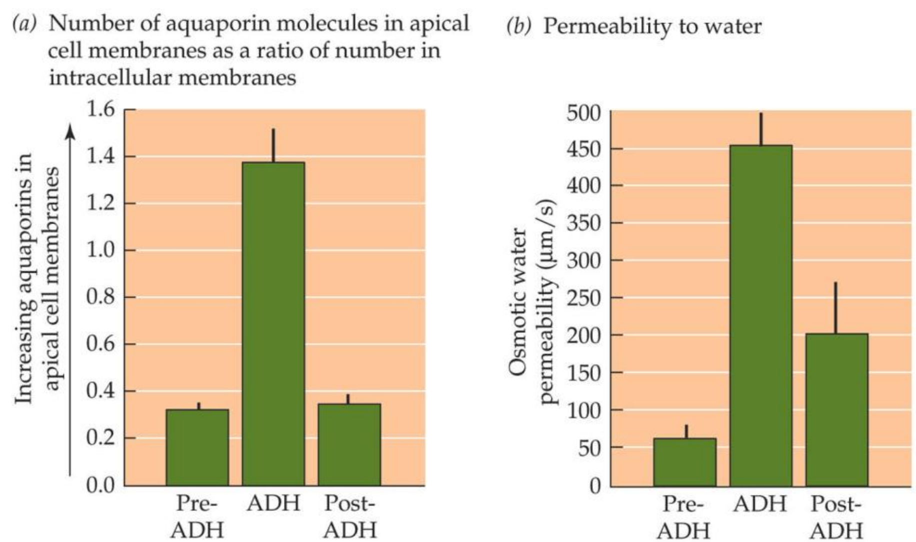


ADH

Collecting tubes **permeable** to water

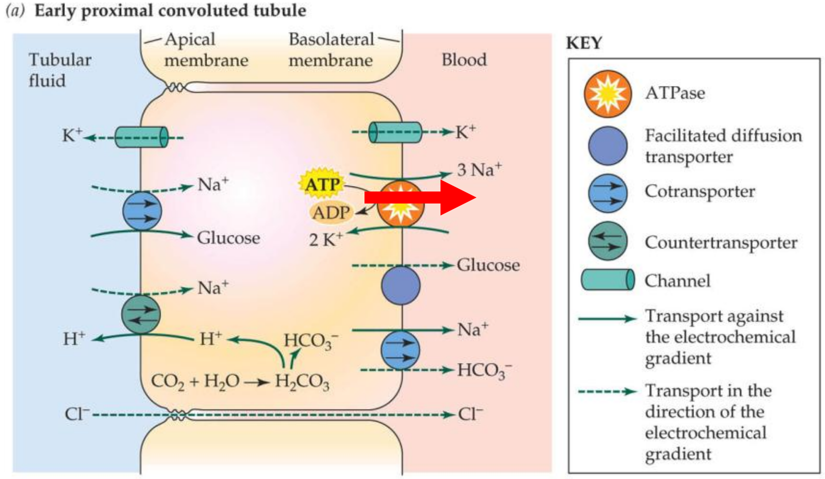
Collecting tubes **poorly permeable** to water





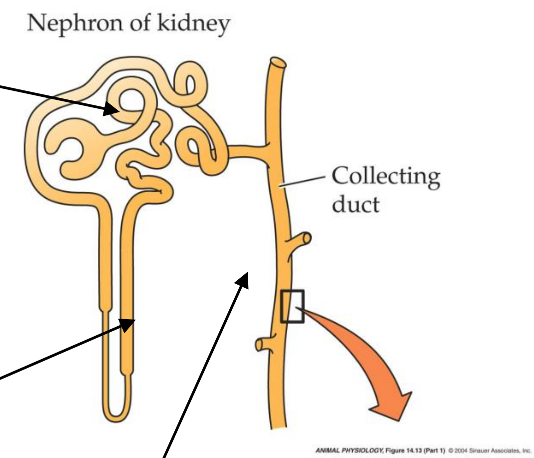
Major molecular mechanisms of NaCl reabsorption and associated processes

Energy for Na reabsorption comes from the gradient originated by the pump



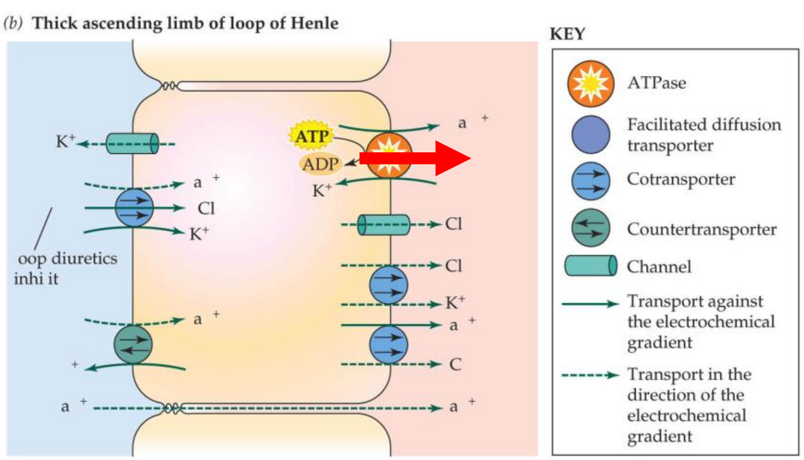
Cotransport of glucose, AA

1

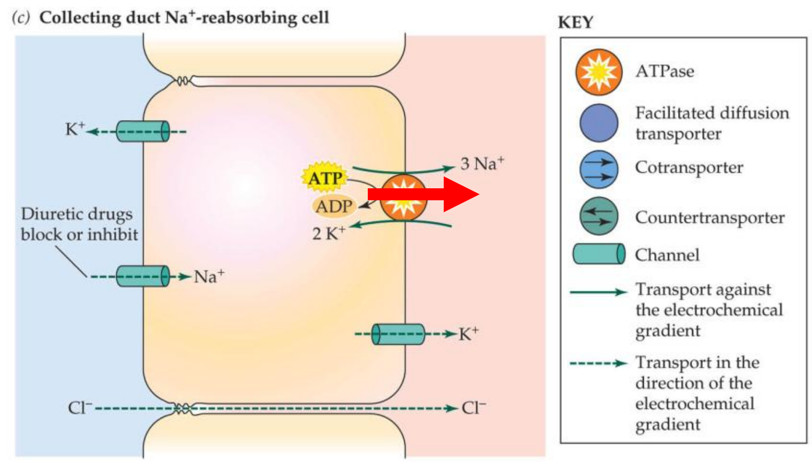


2

3



Cotransport of Na, K and 2Cl

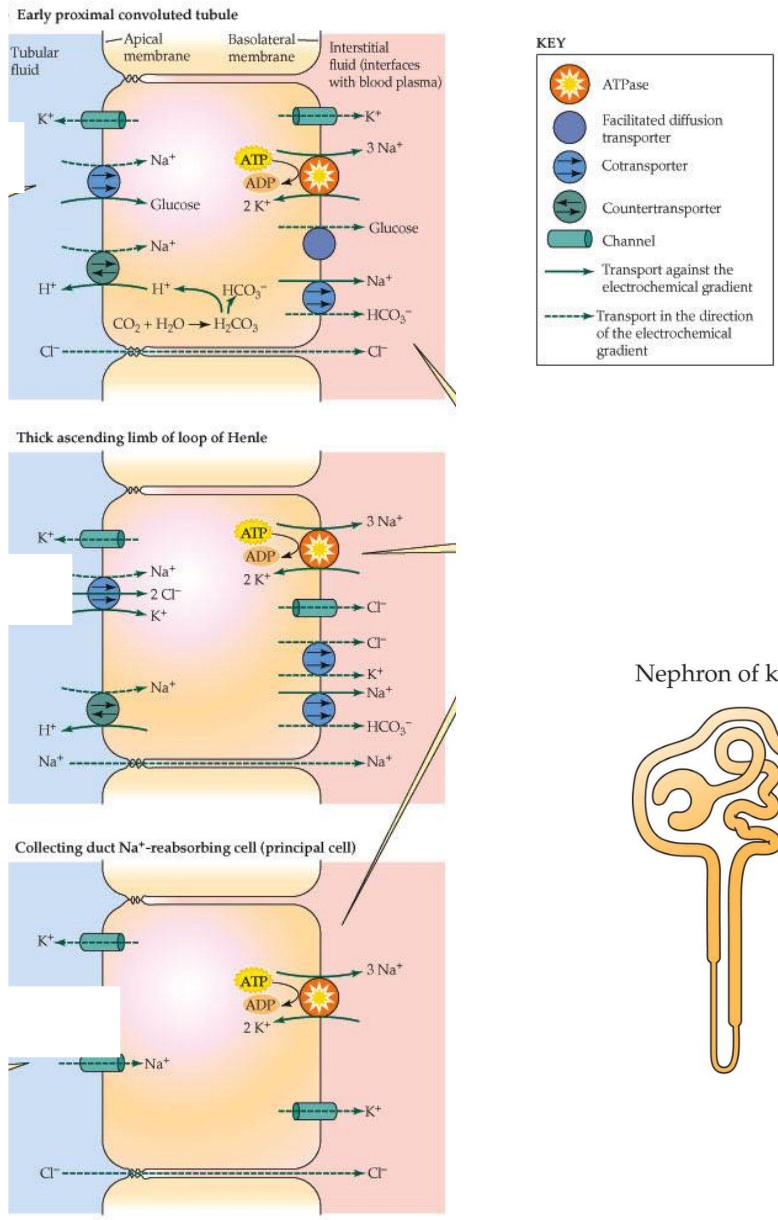


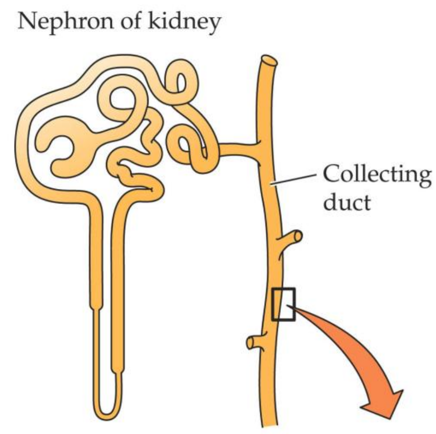
Na enter by a channel

Cotransport of glucose, AA

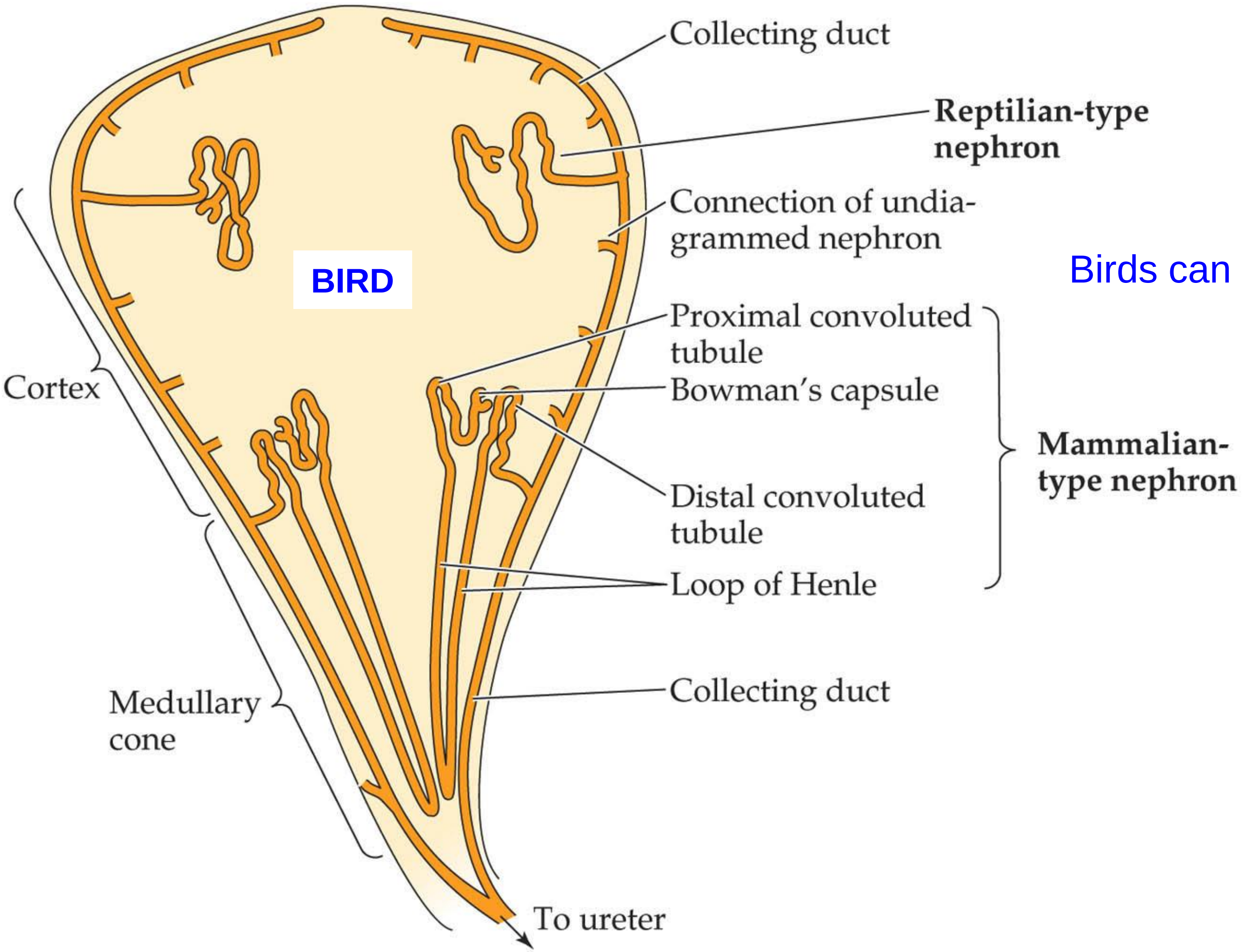
Cotransport of Na, K and 2Cl

Na enter by a channel





Kidneys of other vertebrates



ANIMAL PHYSIOLOGY, Figure 27.18 © 2004 Sinauer Associates, Inc.

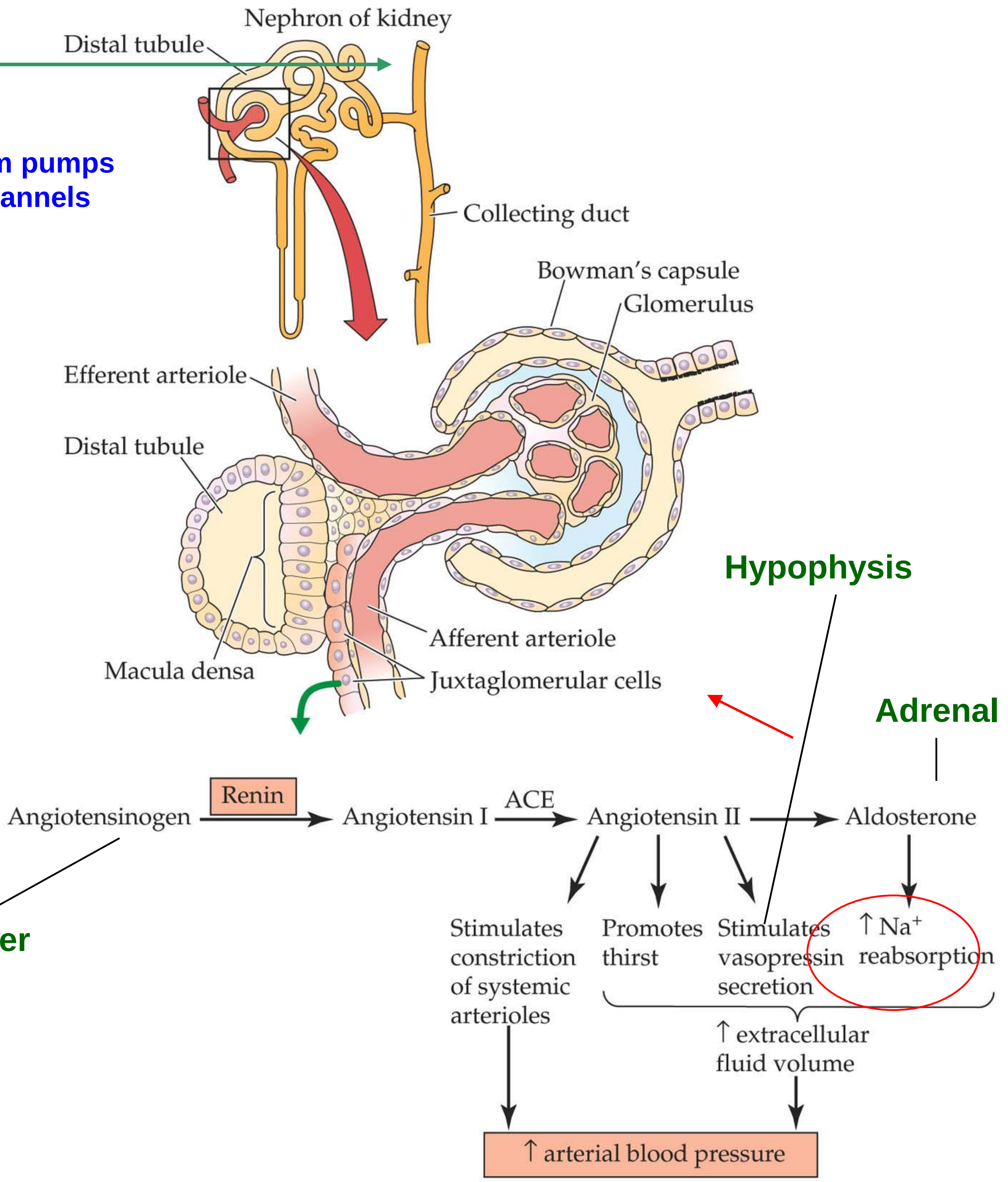
Birds can produce hyperosmotic urine

Freshwater teleosts and reptiles nephron similar to amphibians.

The renin-angiotensin-aldosterone system

Aldosterone stimulates the conservation of sodium

Sodium pumps and channels



Liver

Angiotensinogen : large protein

↓

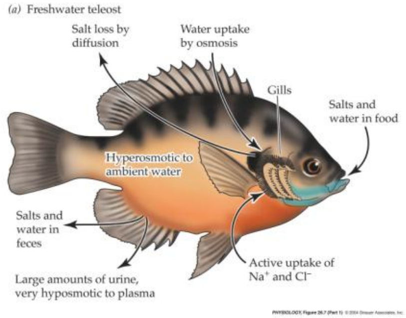
Angiotensin I : 10 AA

↓

Angiotensin II : 8 AA

Some nitrogenous compounds excreted by animals

Ammonotelic: produce ammonia



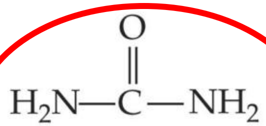
Ureotelic: produce urea

Ammonia: toxic and low solubility
Cheap to make (aquatic)

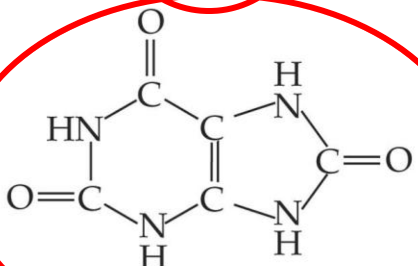
Urea: less toxic and high solubility
Expensive to make (4-5 ATP)

Uricotelic: produce uric acid

Ammonia



Urea



Uric acid

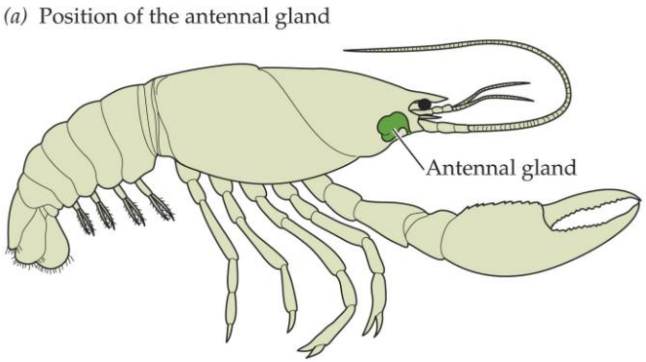
Kidneys

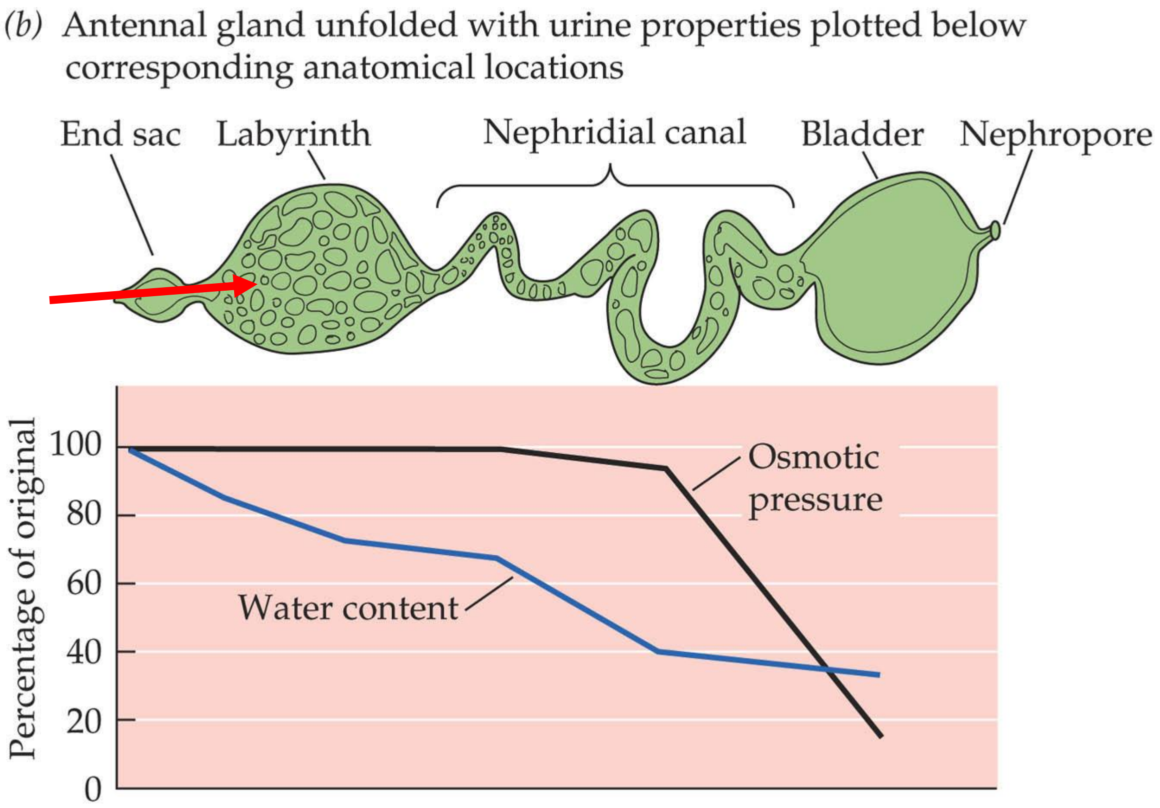
Gills

Uric acid: low toxicity and low solubility
Precipitates (easy to store). Expensive to make.

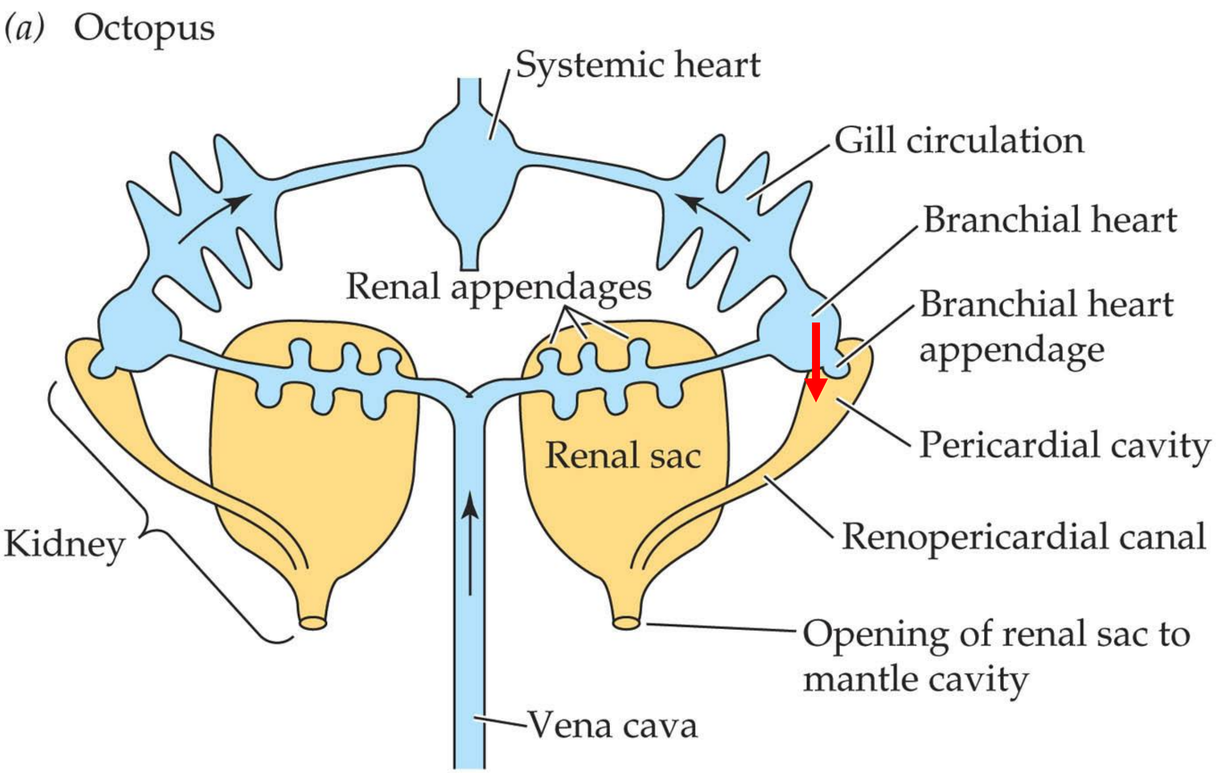
The antennal gland and urine formation in a freshwater crayfish

Produce dilute urine by filtration and active reabsorption of ions



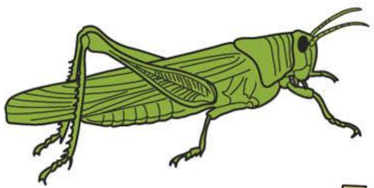


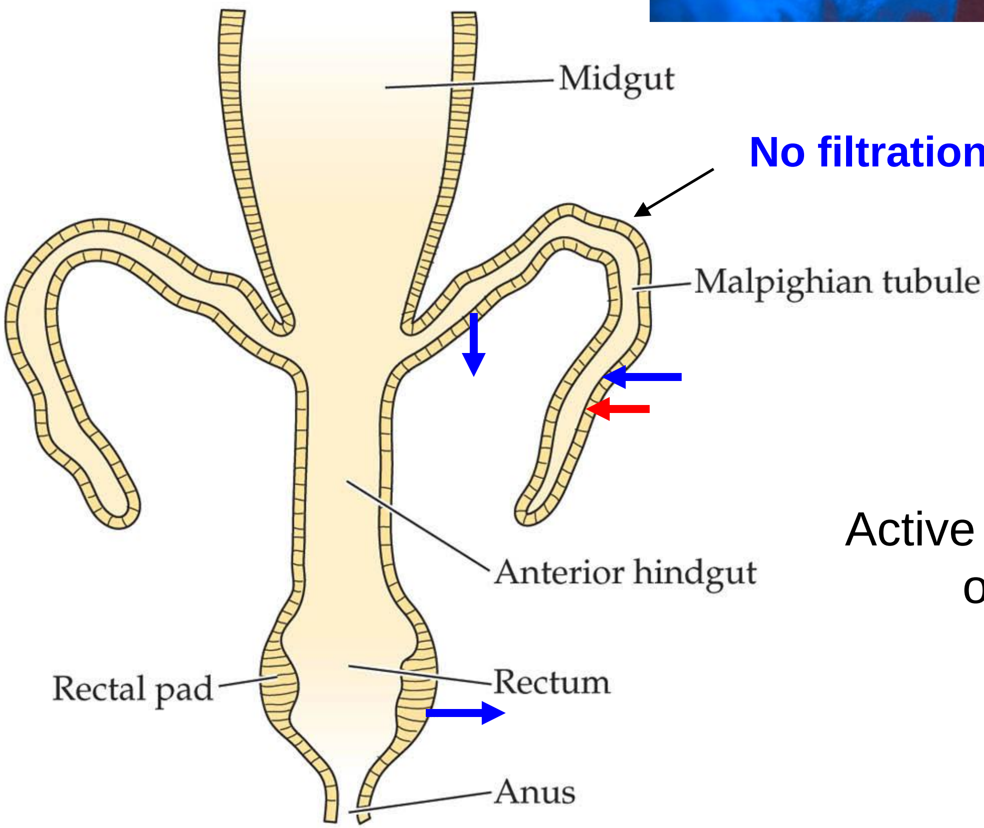
The kidneys of molluscs and their relations to the circulatory system

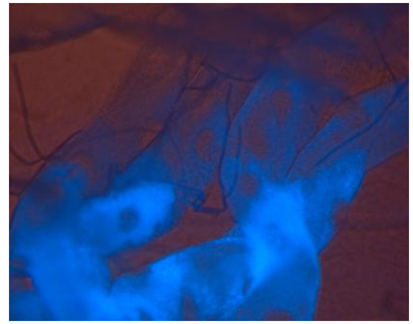


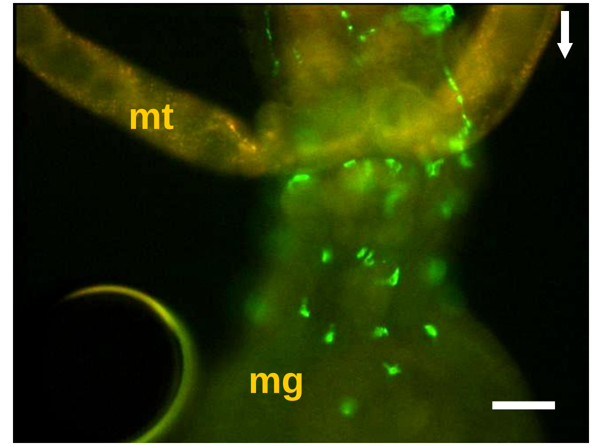
Filtration in the pericardial cavity and modification in the canals and sacs

The Malpighian tubules of an insect form the primary urine

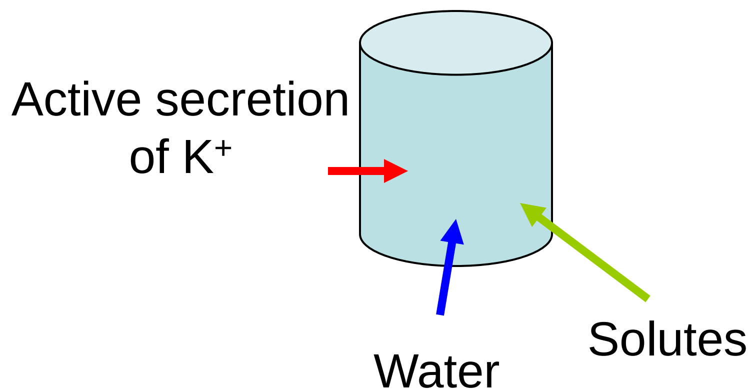








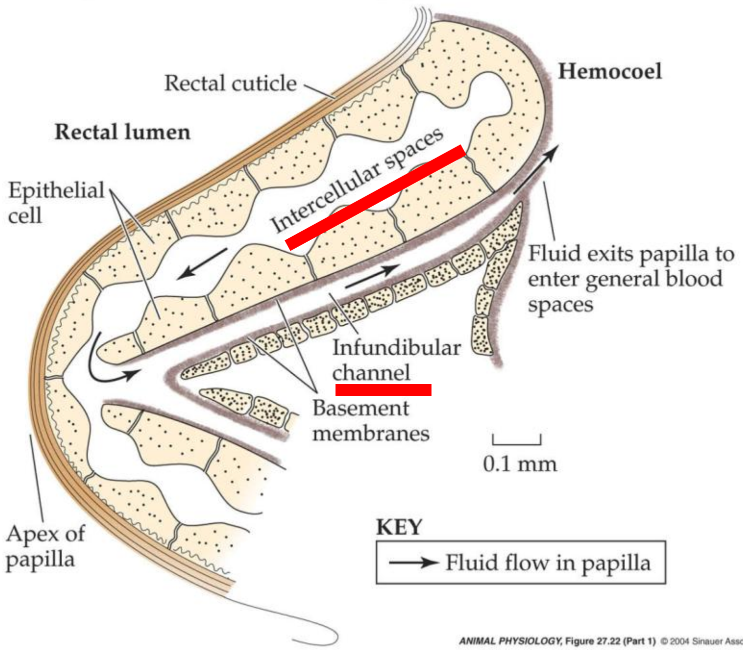
Secretory mechanism



The hindgut modulates urine composition concentration and volume

Modification of the urine in the hindgut

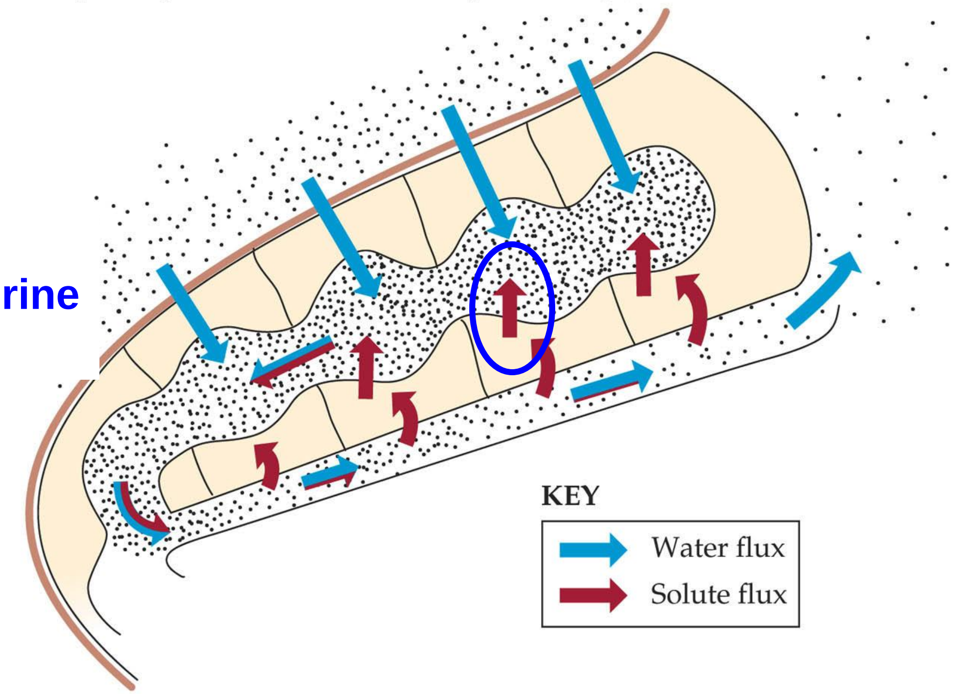
(a) Diagrammatic structure of rectal papilla



ANIMAL PHYSIOLOGY, Figure 27.22 (Part 1) © 2004 Sinauer Associates, Inc.

Water reabsorption in excess of solutes
by local osmosis produce hyperosmotic urine

(b) Proposed processes of water absorption from rectal lumen



ANIMAL PHYSIOLOGY, Figure 27.22 (Part 2) © 2004 Sinauer Associates, Inc.