Chapter 44

Osmoregulation and Excretion

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

Key concepts

Balance solutes and remove wastes.

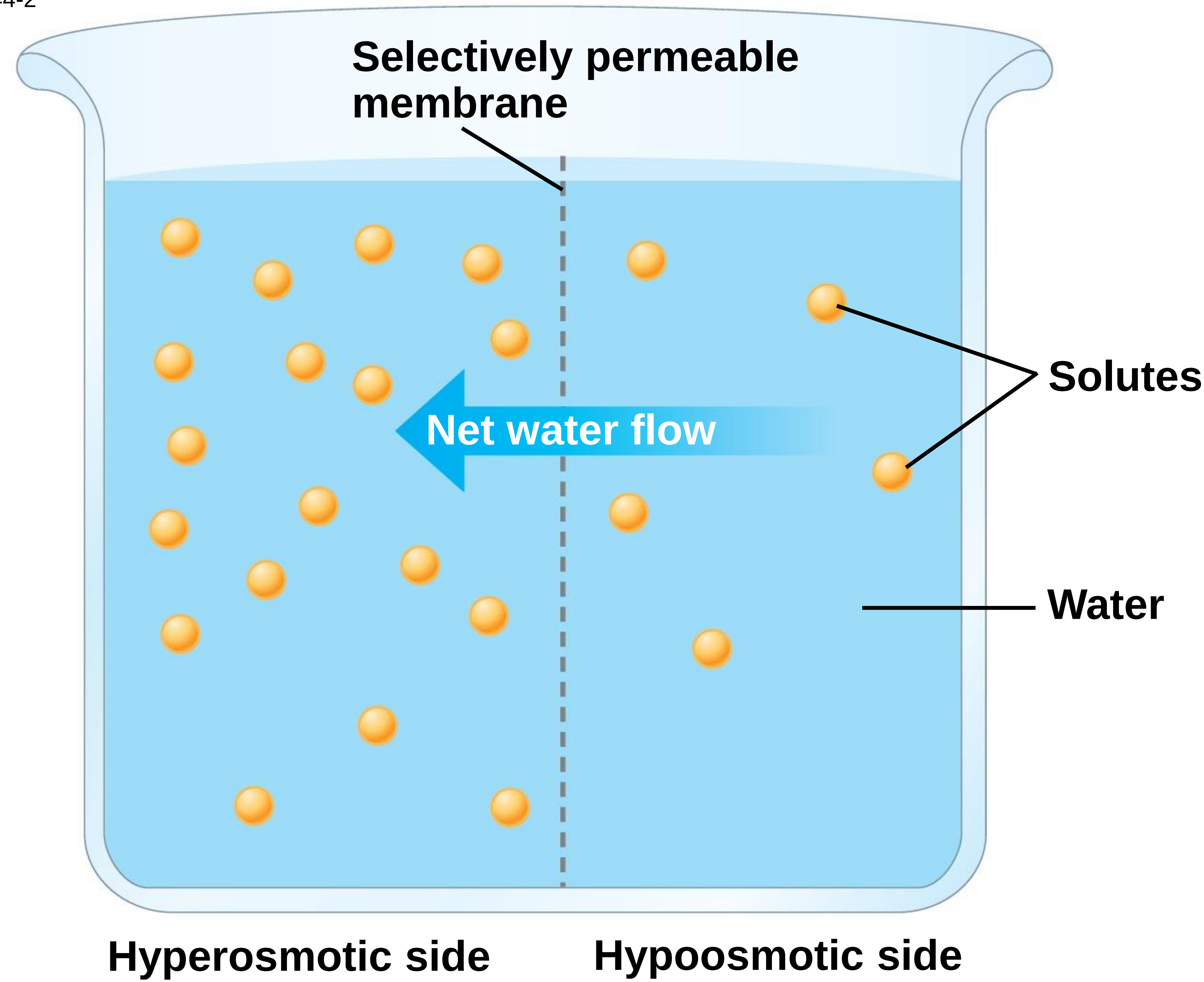
Overview: A Balancing Act

- **Osmoregulation** regulates solute concentrations and balances the gain and loss of water
- **Excretion** gets rid of nitrogenous metabolites and other waste products

Fig. 44-1

albatross

Fig. 44-2



Selectively permeable membrane
Solutes
Net water flow
Water
Hyperosmotic side
Hypoosmotic side

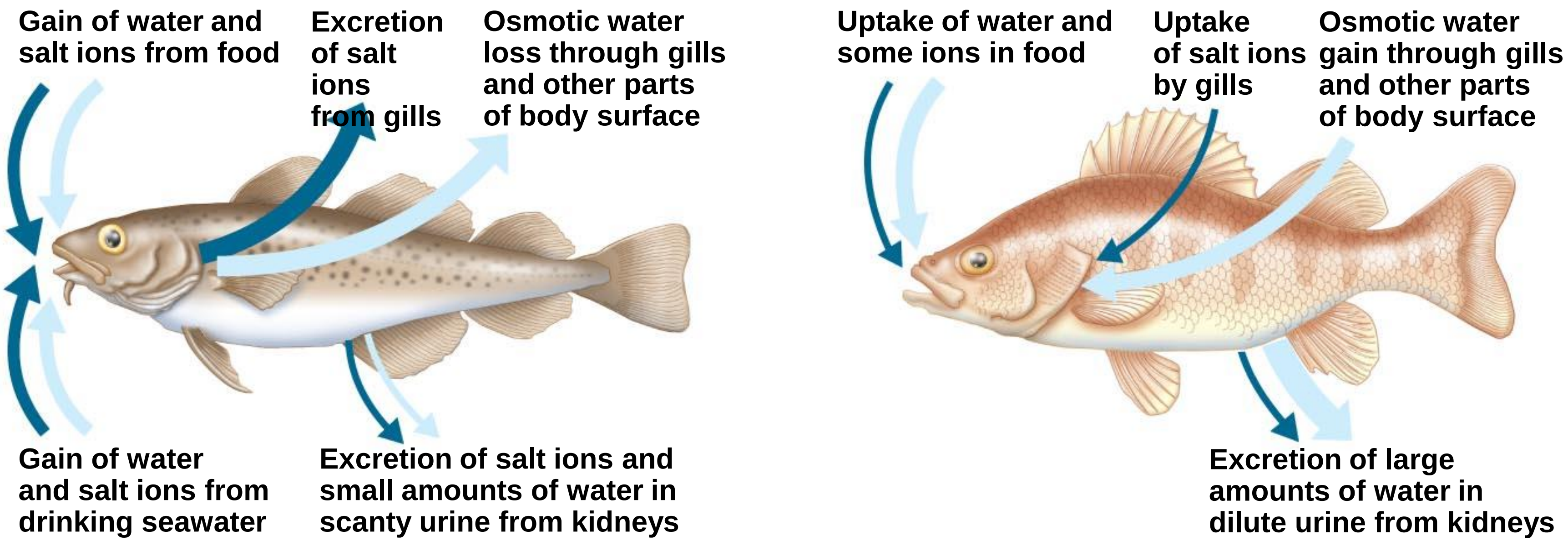
Osmotic Challenges

- **Osmoconformers**, consisting only of some marine animals, are isoosmotic with their surroundings and do not regulate their osmolarity
- **Osmoregulators** expend energy to control water uptake and loss in a hyperosmotic or hypoosmotic environment

- Most animals are **stenohaline**; they cannot tolerate substantial changes in external osmolarity

- **Euryhaline** animals can survive large fluctuations in external osmolarity

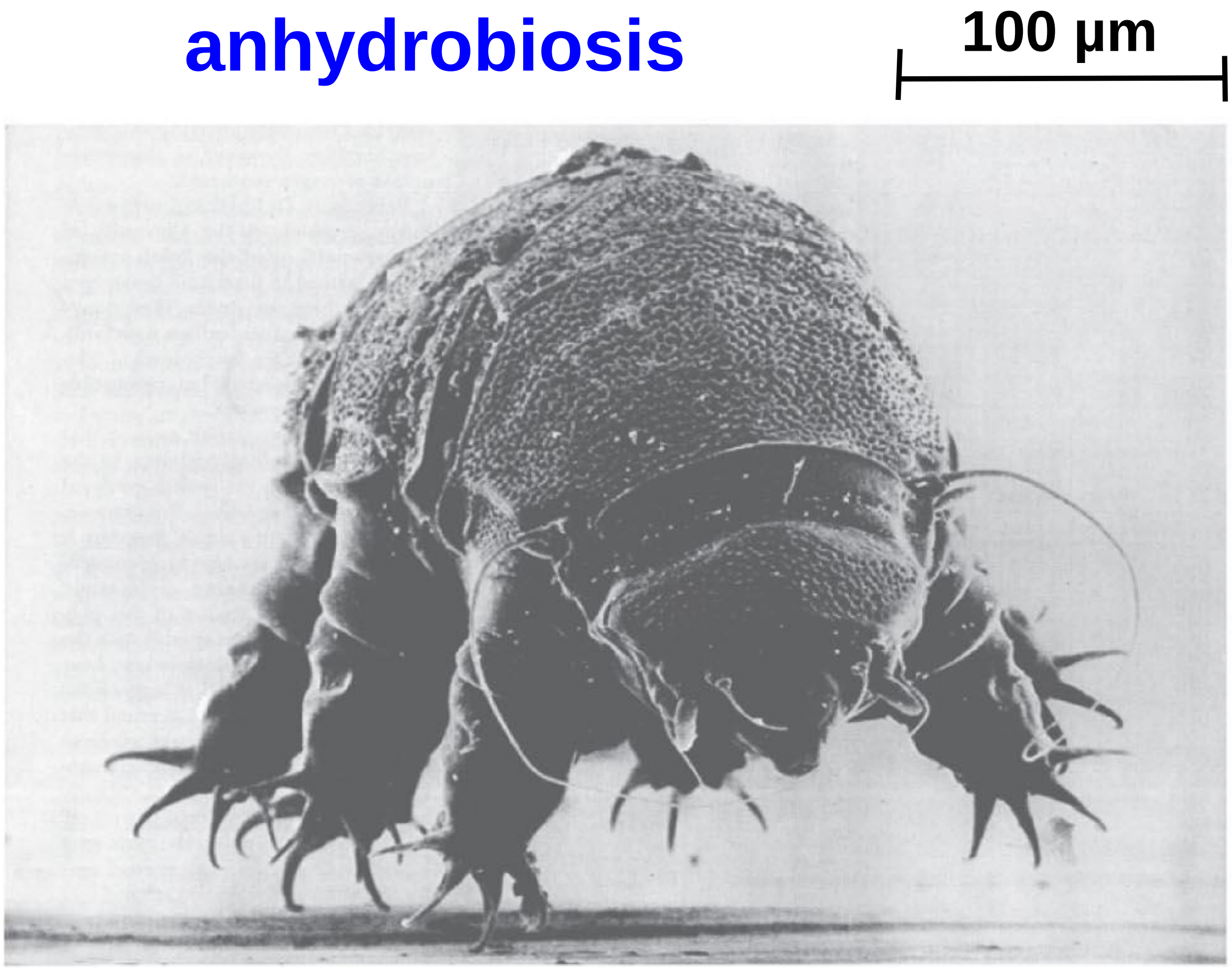
Fig. 44-4



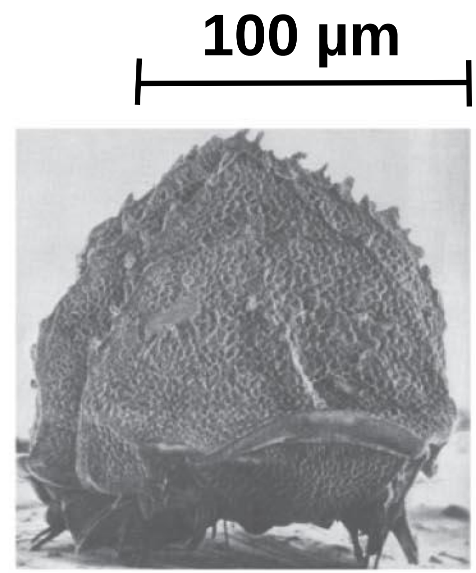
(a) Osmoregulation in a saltwater fish **(b) Osmoregulation in a freshwater fish**

Fig. 44-5

anhydrobiosis



(a) Hydrated tardigrade



(b) Dehydrated tardigrade

Fig. 44-6

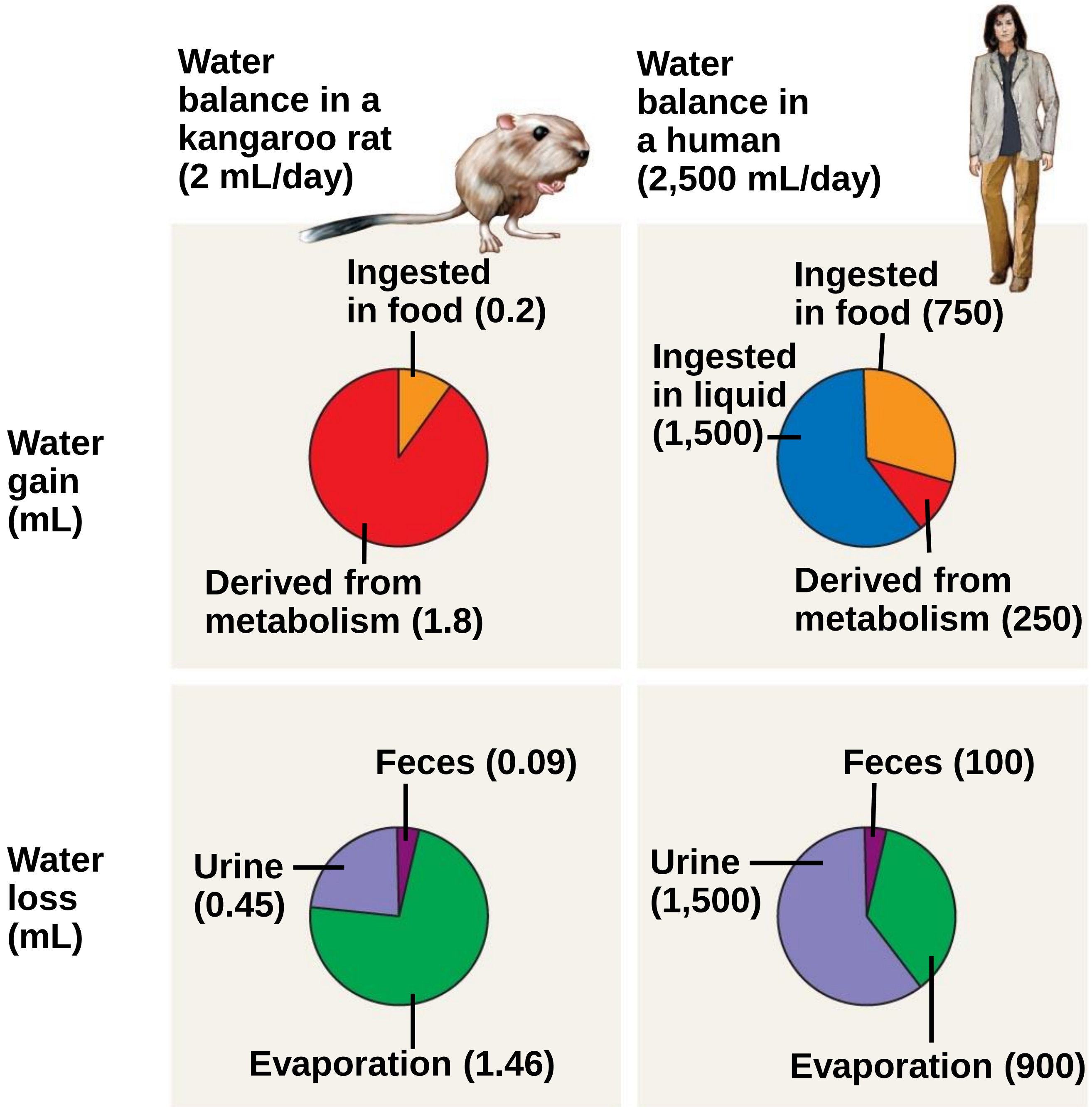

Water balance in a kangaroo rat (2 mL/day)
Water balance in a human (2,500 mL/day)
Water gain (mL)
Ingested in food (0.2)
Derived from metabolism (1.8)
Ingested in food (750)
Ingested in liquid (1,500)
Derived from metabolism (250)
Water loss (mL)
Feces (0.09)
Urine (0.45)
Evaporation (1.46)
Feces (100)
Urine (1,500)
Evaporation (900)

Fig. 44-7

Transport epithelia

EXPERIMENT

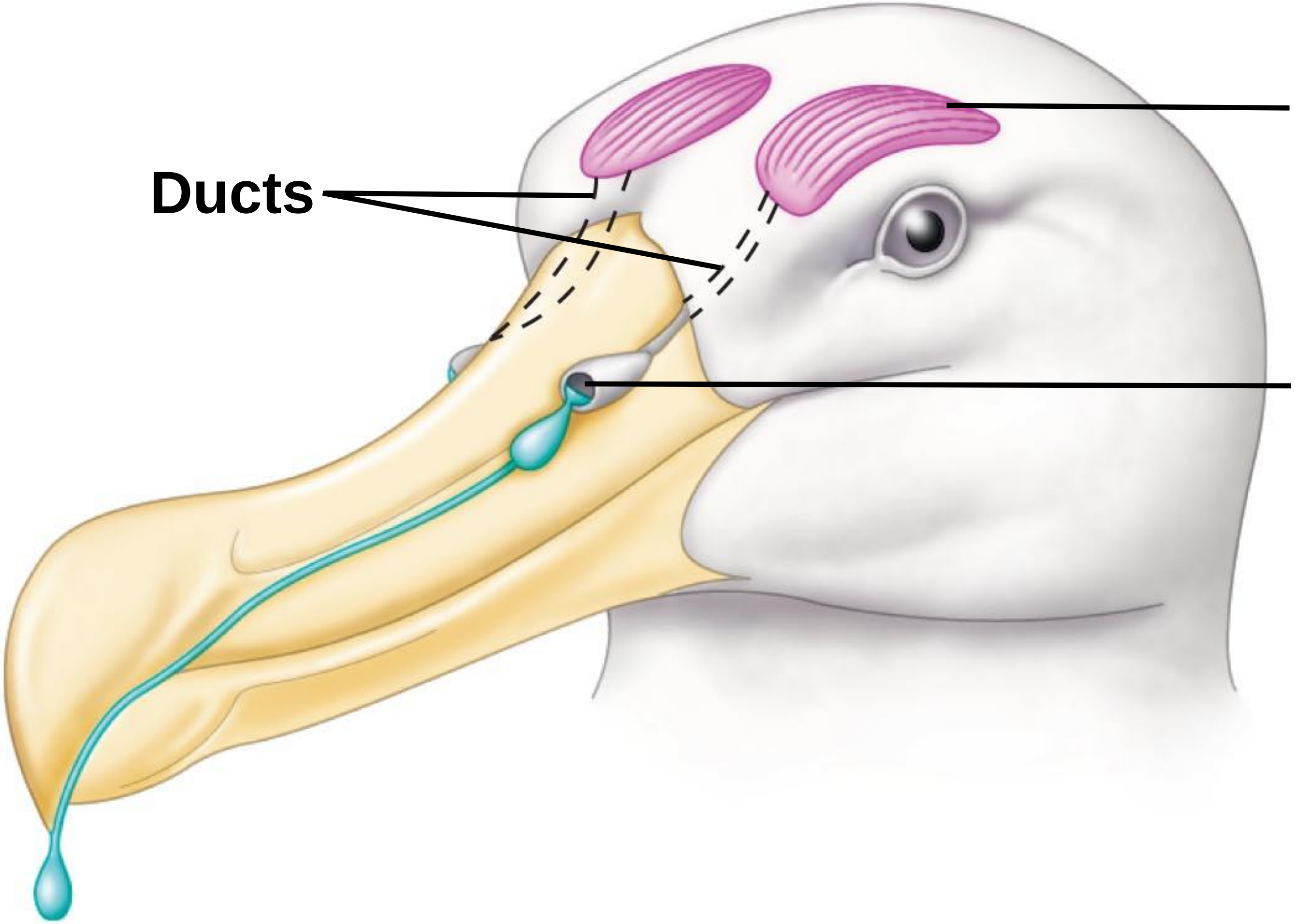
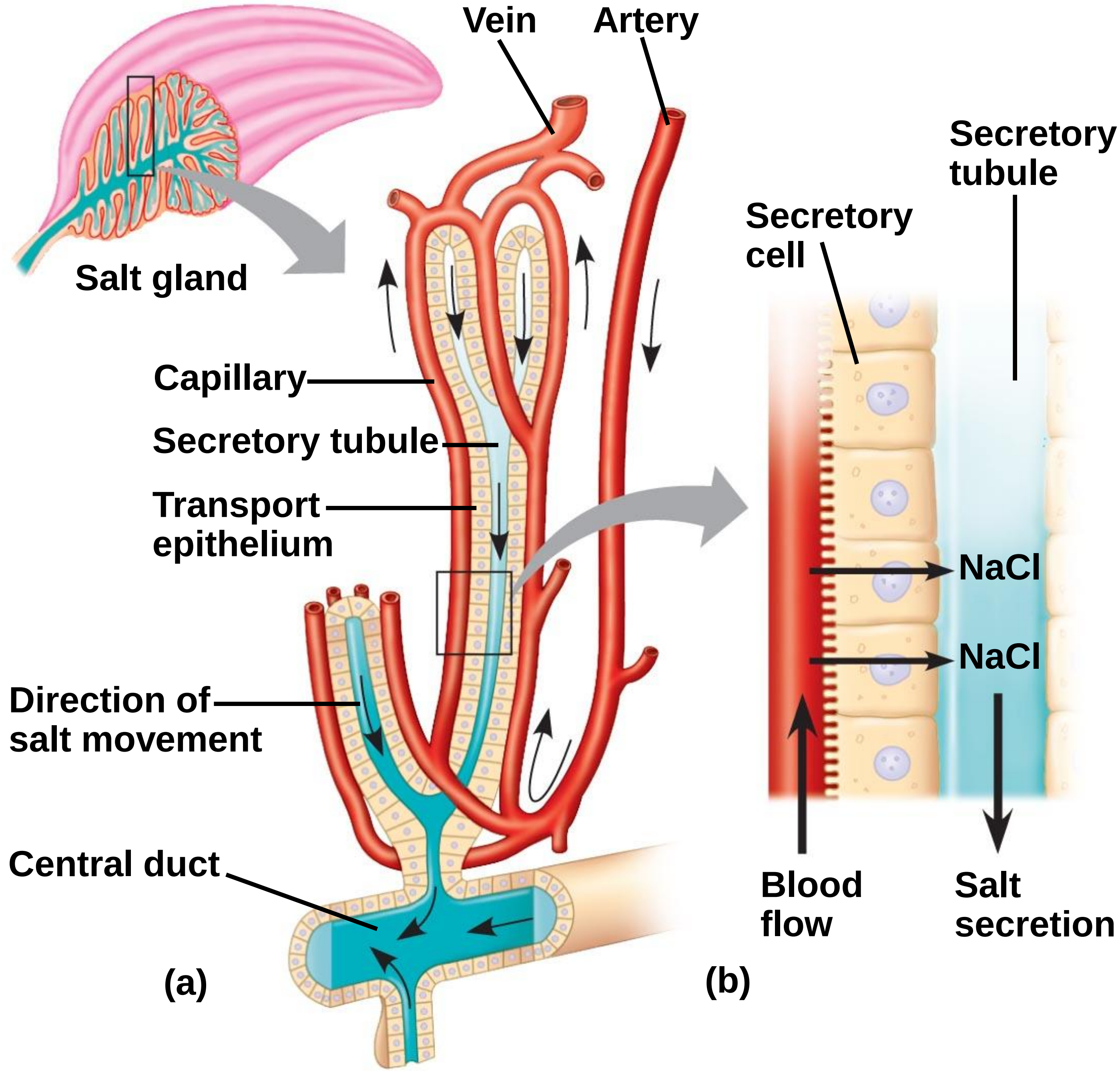


Fig. 44-8



Vein
Artery
Salt gland
Capillary
Secretory tubule
Transport epithelium
Direction of salt movement
Central duct
(a)
Secretory tubule
Secretory cell
NaCl
NaCl
Blood flow
Salt secretion
(b)

Fig. 44-9

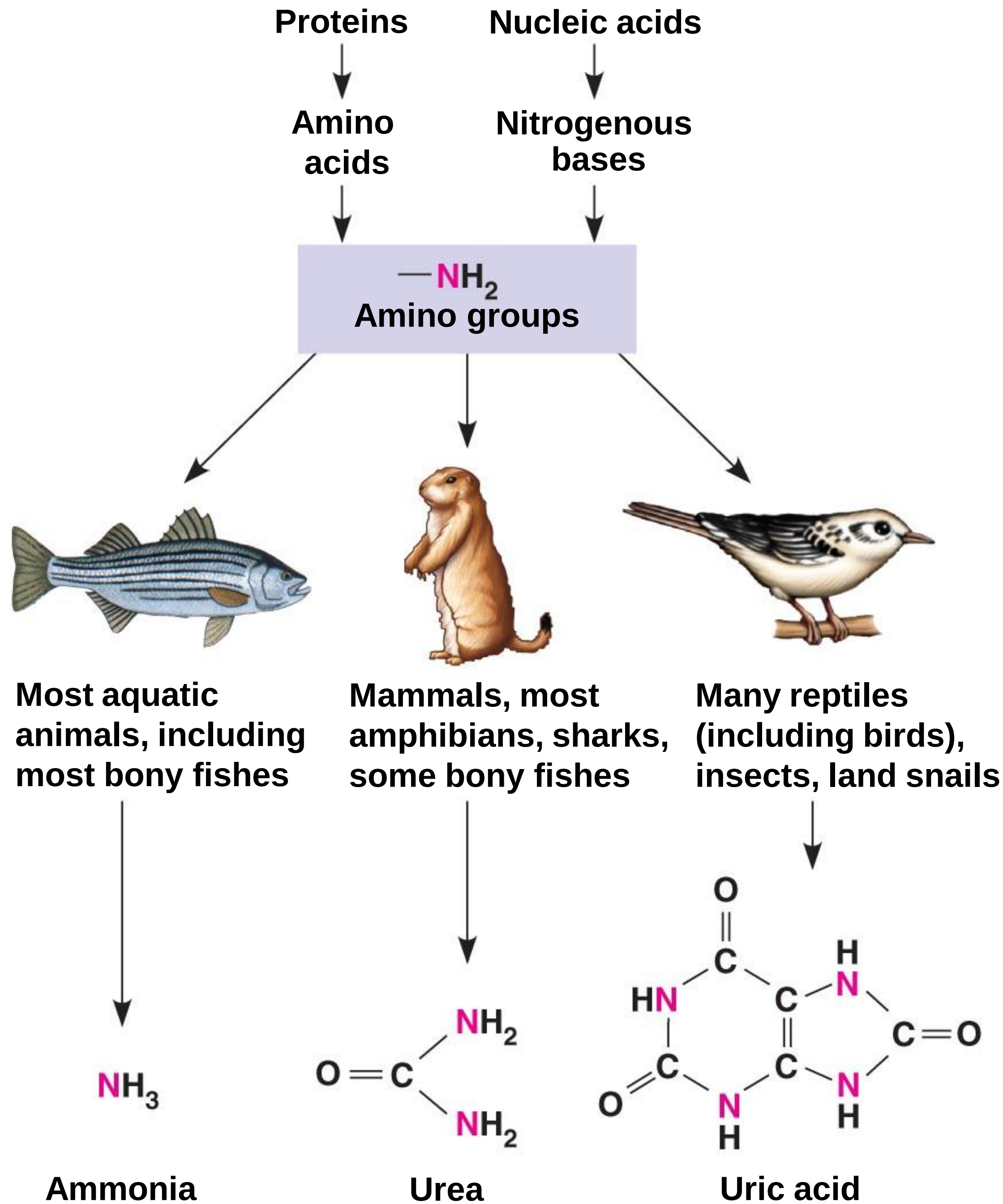

Proteins
Nucleic acids
Amino acids
Nitrogenous bases
—NH2
Amino groups
Most aquatic animals, including most bony fishes
Mammals, most amphibians, sharks, some bony fishes
Many reptiles (including birds), insects, land snails
NH3
Ammonia
Urea
Uric acid

Fig. 44-10

Excretory Processes

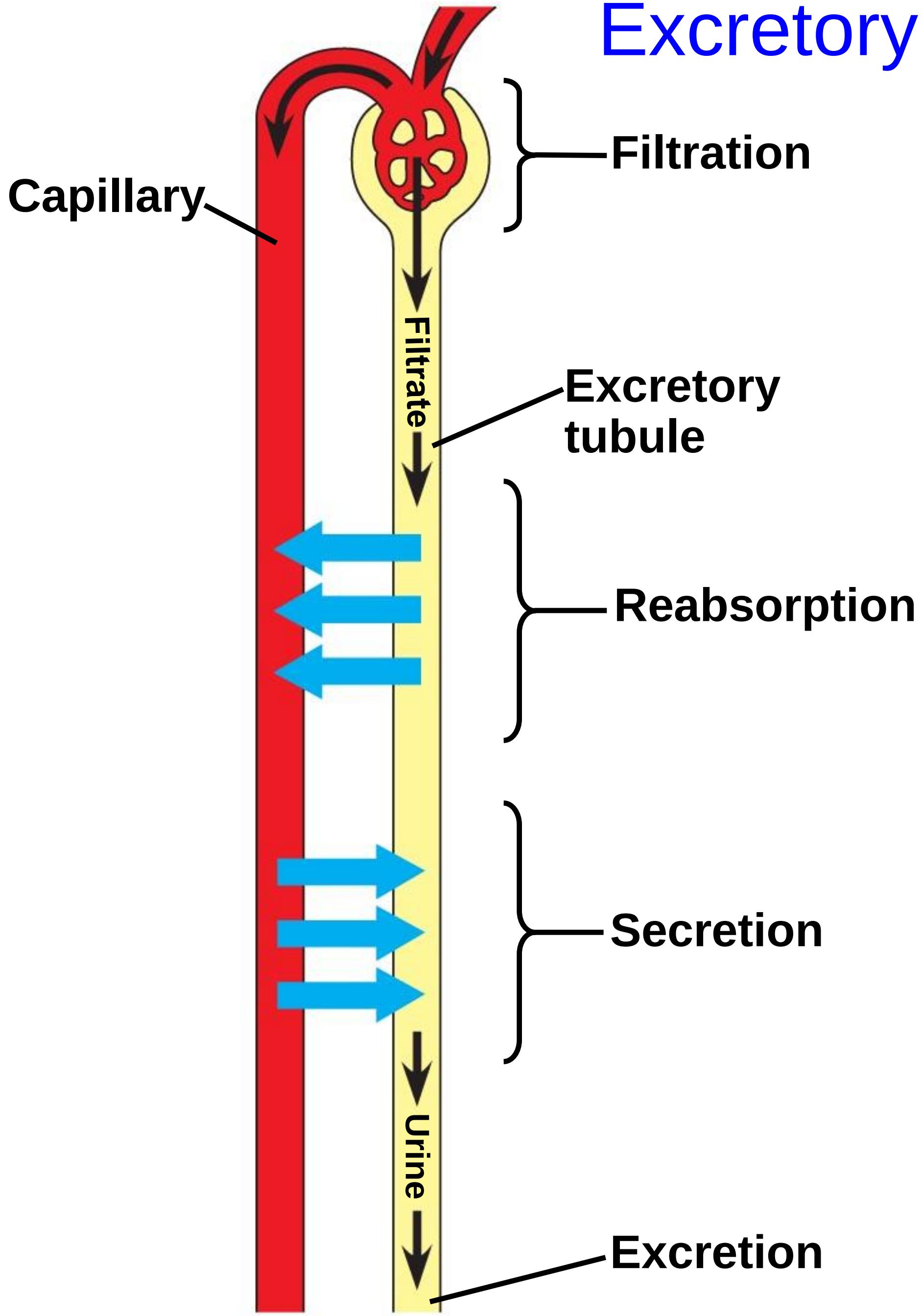


Fig. 44-11

Protonephridia

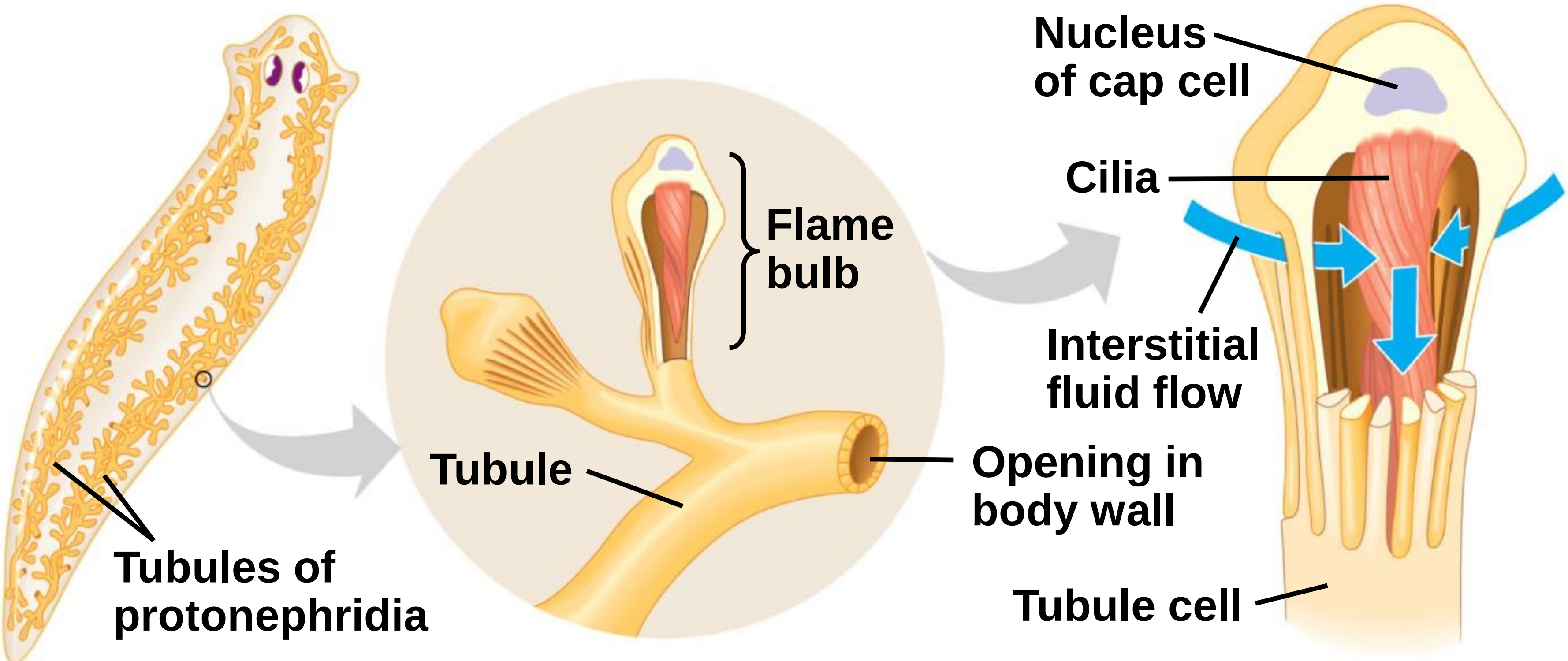


Fig. 44-12

Metanephridia

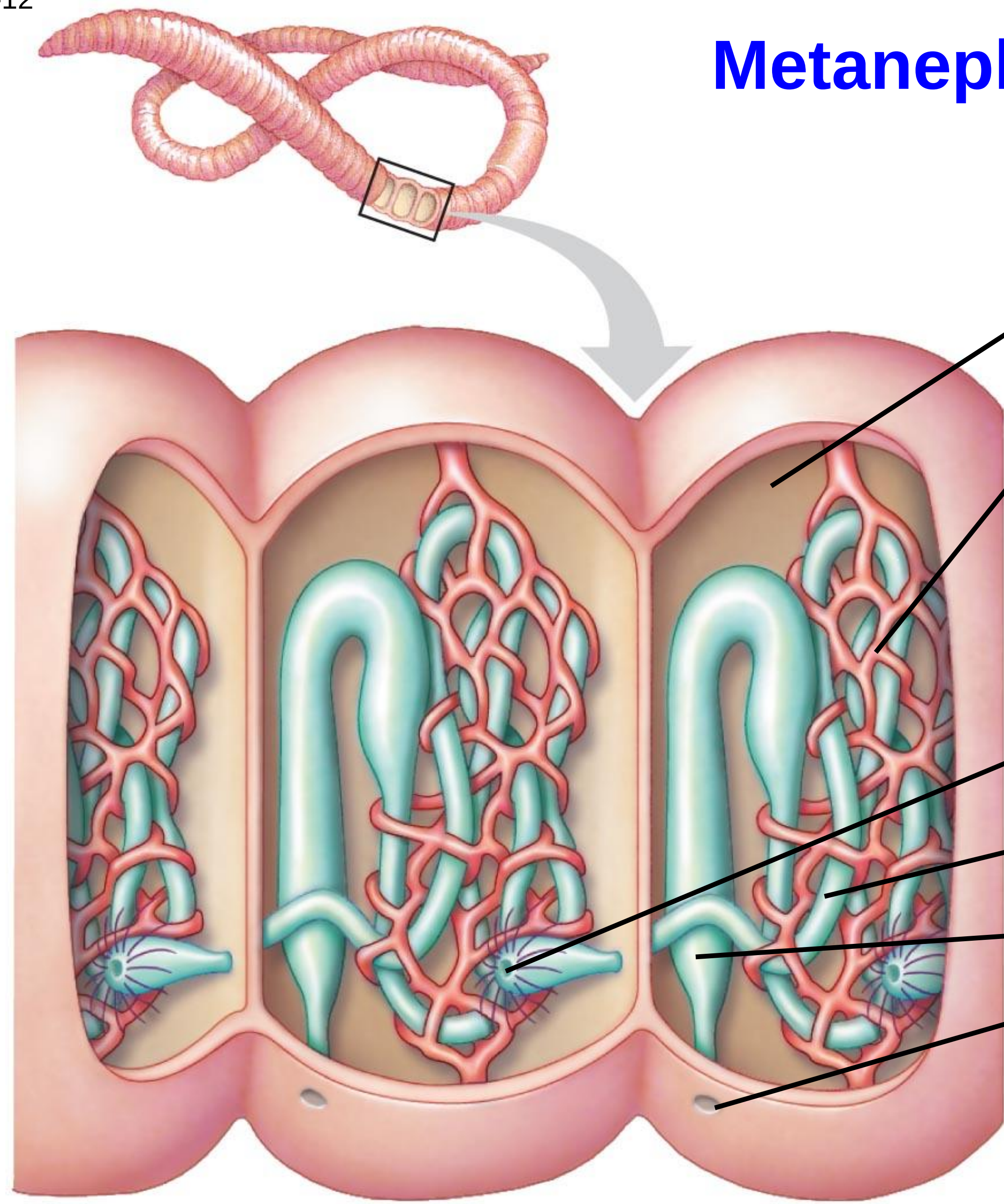
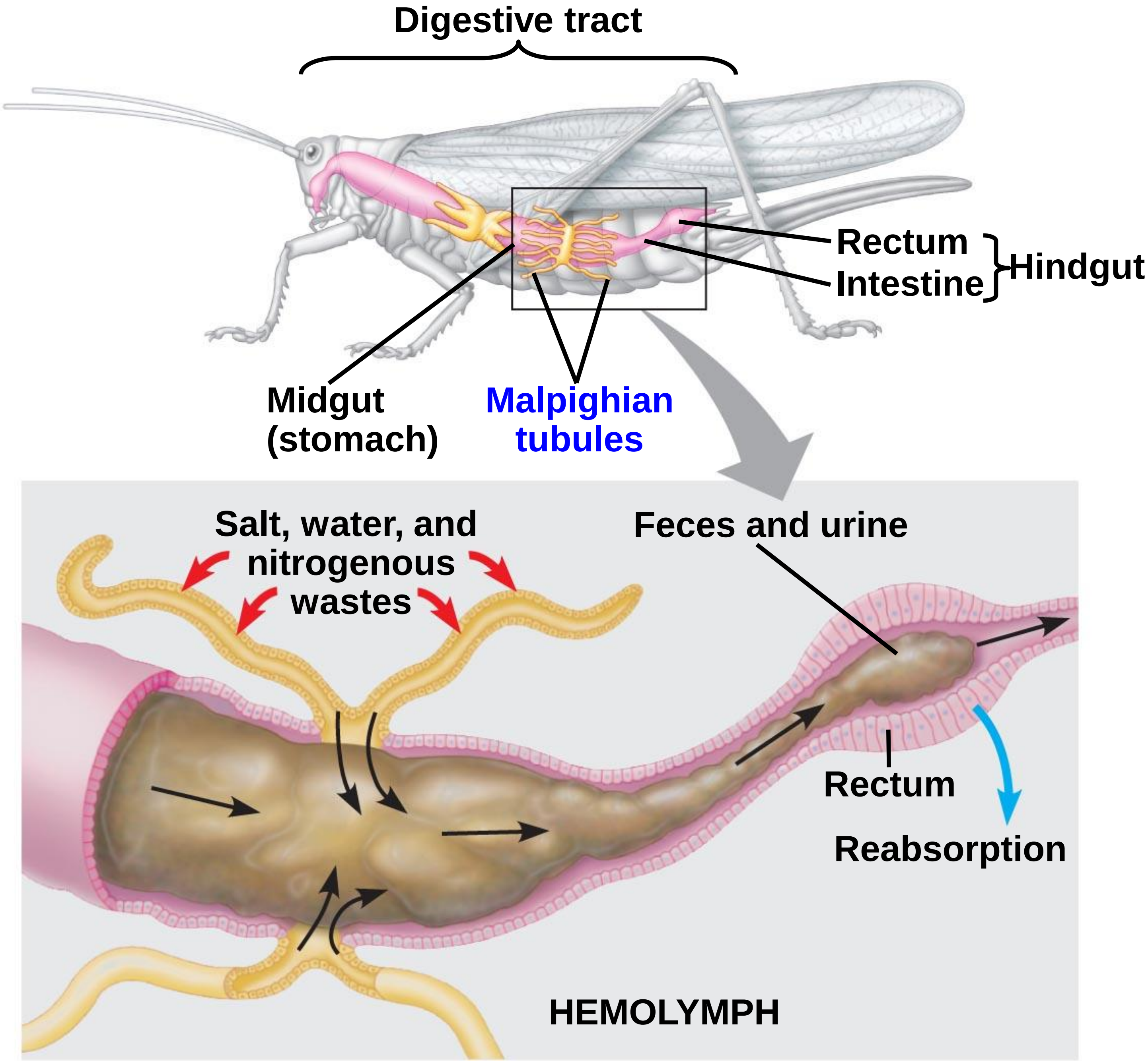
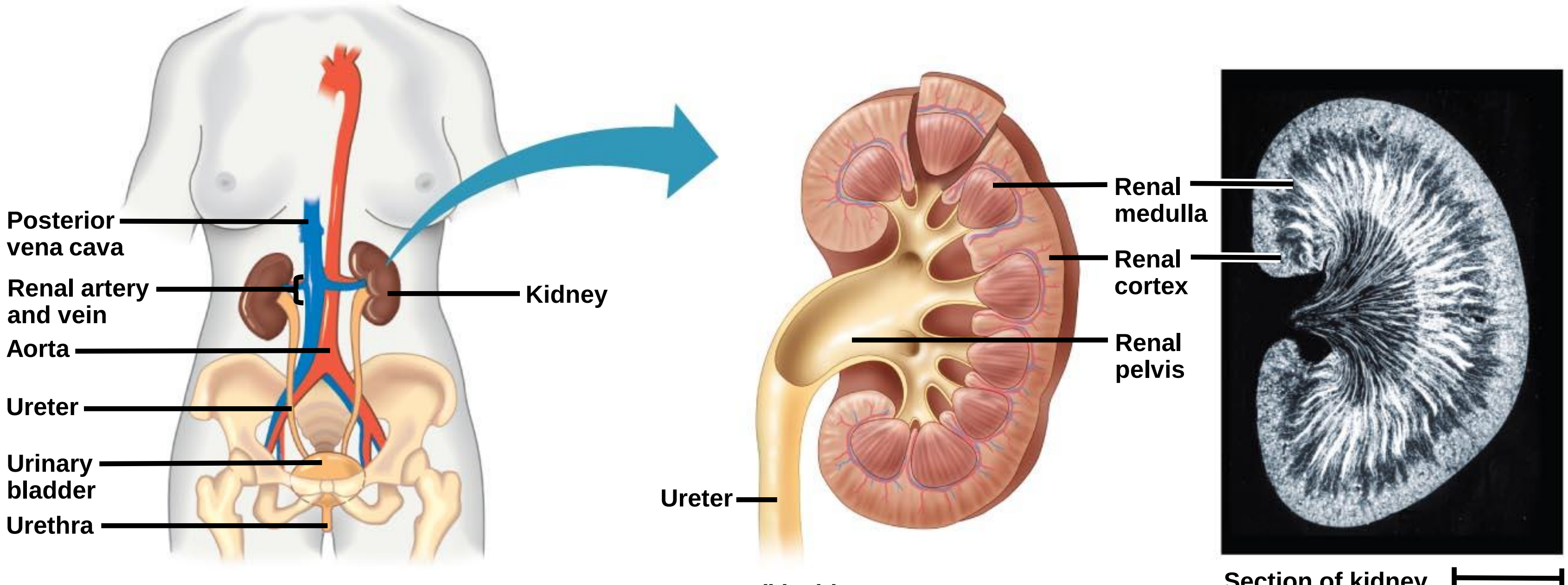


Fig. 44-13



Digestive tract
Rectum
Intestine
Hindgut
Midgut
(stomach)
Malpighian
tubules
Salt, water, and
nitrogenous
wastes
Feces and urine
Rectum
Reabsorption
HEMOLYMPH

Fig. 44-14ab

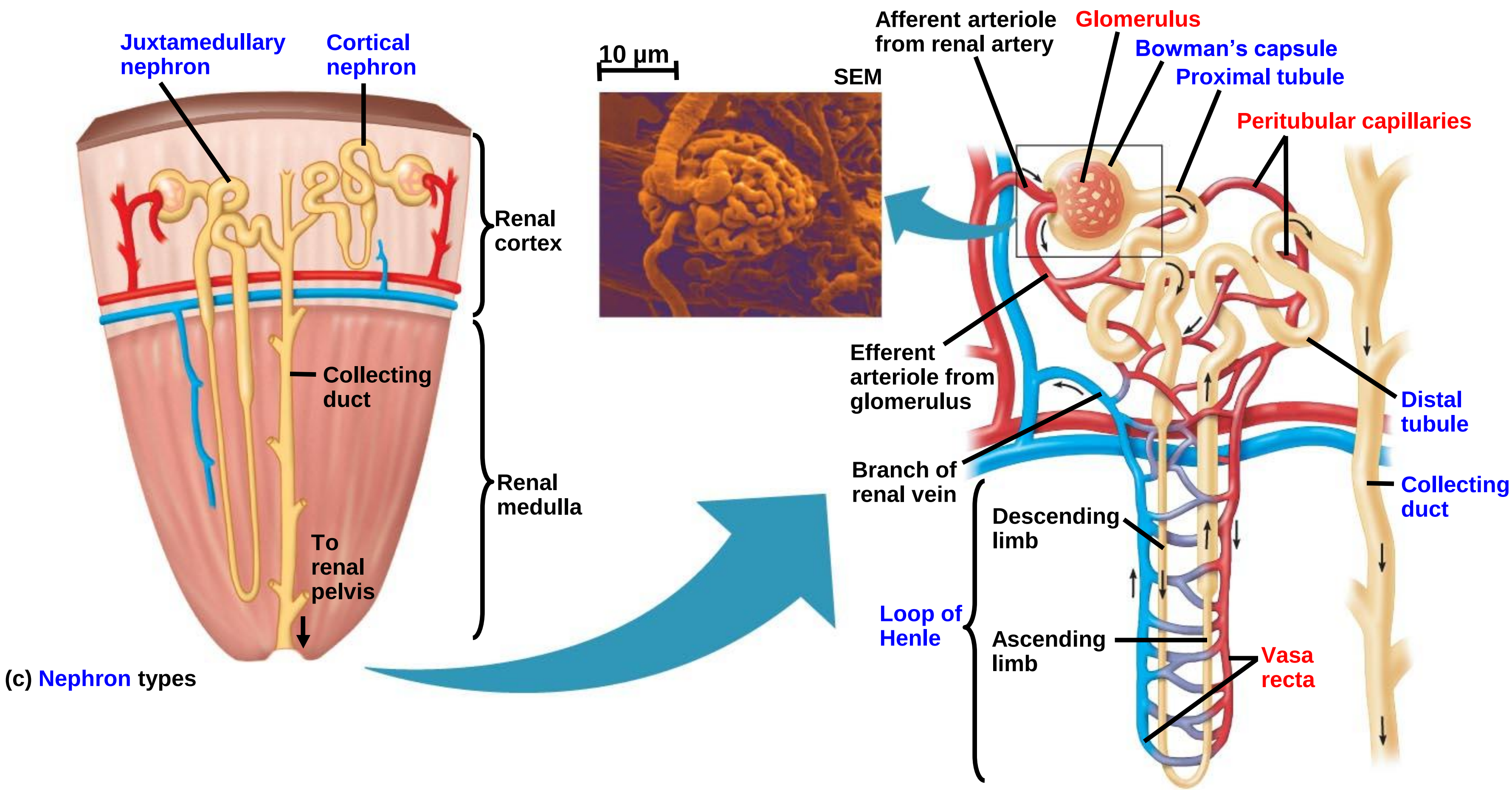


(a) Excretory organs and major associated blood vessels

(b) Kidney structure

Section of kidney from a rat

Fig. 44-14cd

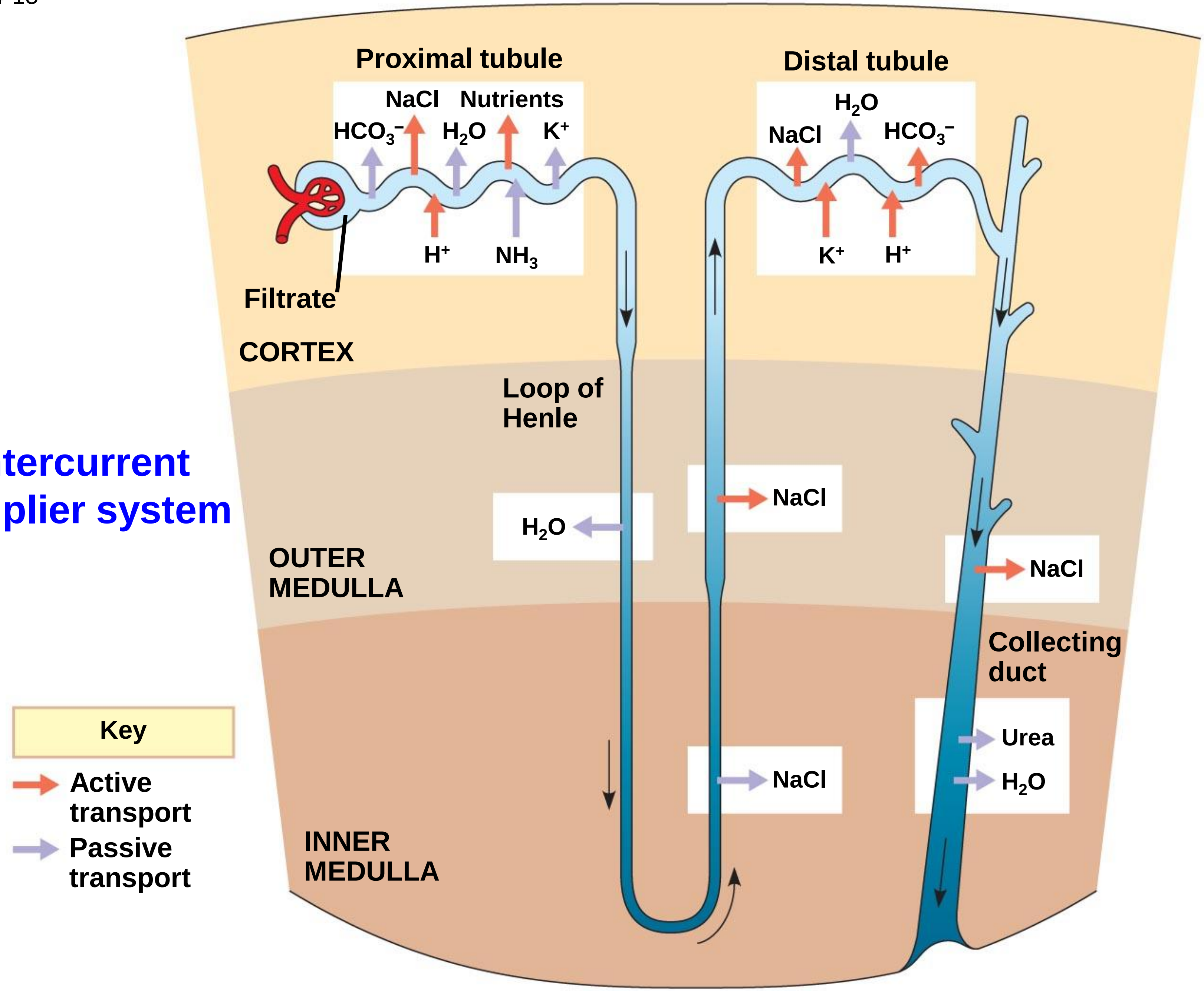


(c) Nephron types

(d) Filtrate and blood flow

Fig. 44-15

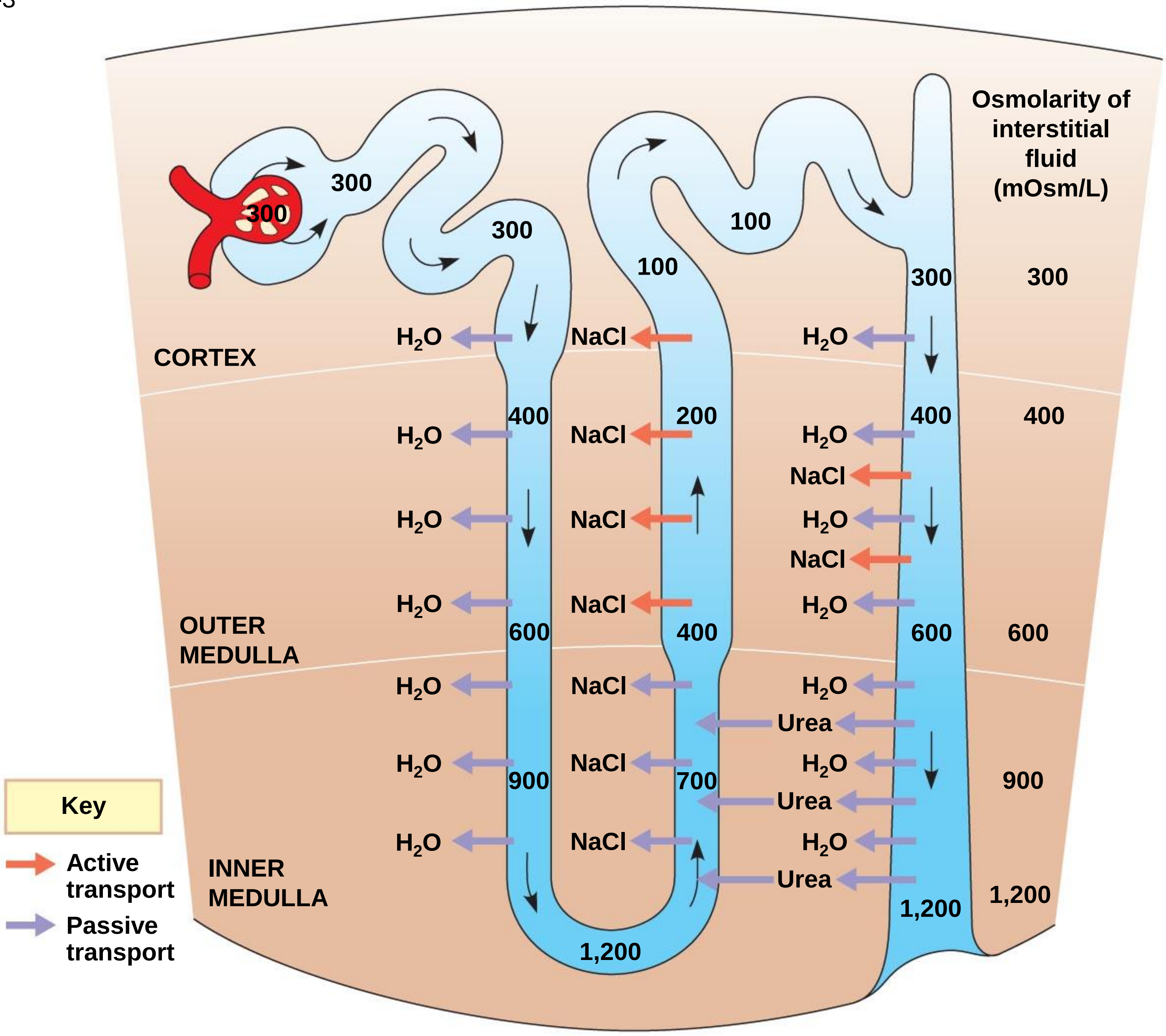
countercurrent multiplier system



Solute Gradients and Water Conservation

- Urine is much more concentrated than blood
- The cooperative action and precise arrangement of the loops of Henle and collecting ducts are largely responsible for the osmotic gradient that concentrates the urine
- NaCl and urea contribute to the osmolarity of the interstitial fluid, which causes reabsorption of water in the kidney and concentrates the urine

Fig. 44-16-3



Osmolarity of interstitial fluid (mOsm/L)
300
300
300
100
100
300
300
CORTEX
H2O
NaCl
H2O
400
200
400
400
H2O
NaCl
H2O
NaCl
H2O
NaCl
H2O
NaCl
H2O
NaCl
H2O
OUTER MEDULLA
600
400
600
600
H2O
NaCl
H2O
Urea
H2O
NaCl
H2O
900
700
900
Urea
H2O
NaCl
H2O
Urea
INNER MEDULLA
1,200
1,200
1,200
Key
Active transport
Passive transport

Mammals

- The juxtamedullary nephron contributes to water conservation in terrestrial animals
- Mammals that inhabit dry environments have long loops of Henle, while those in fresh water have relatively short loops

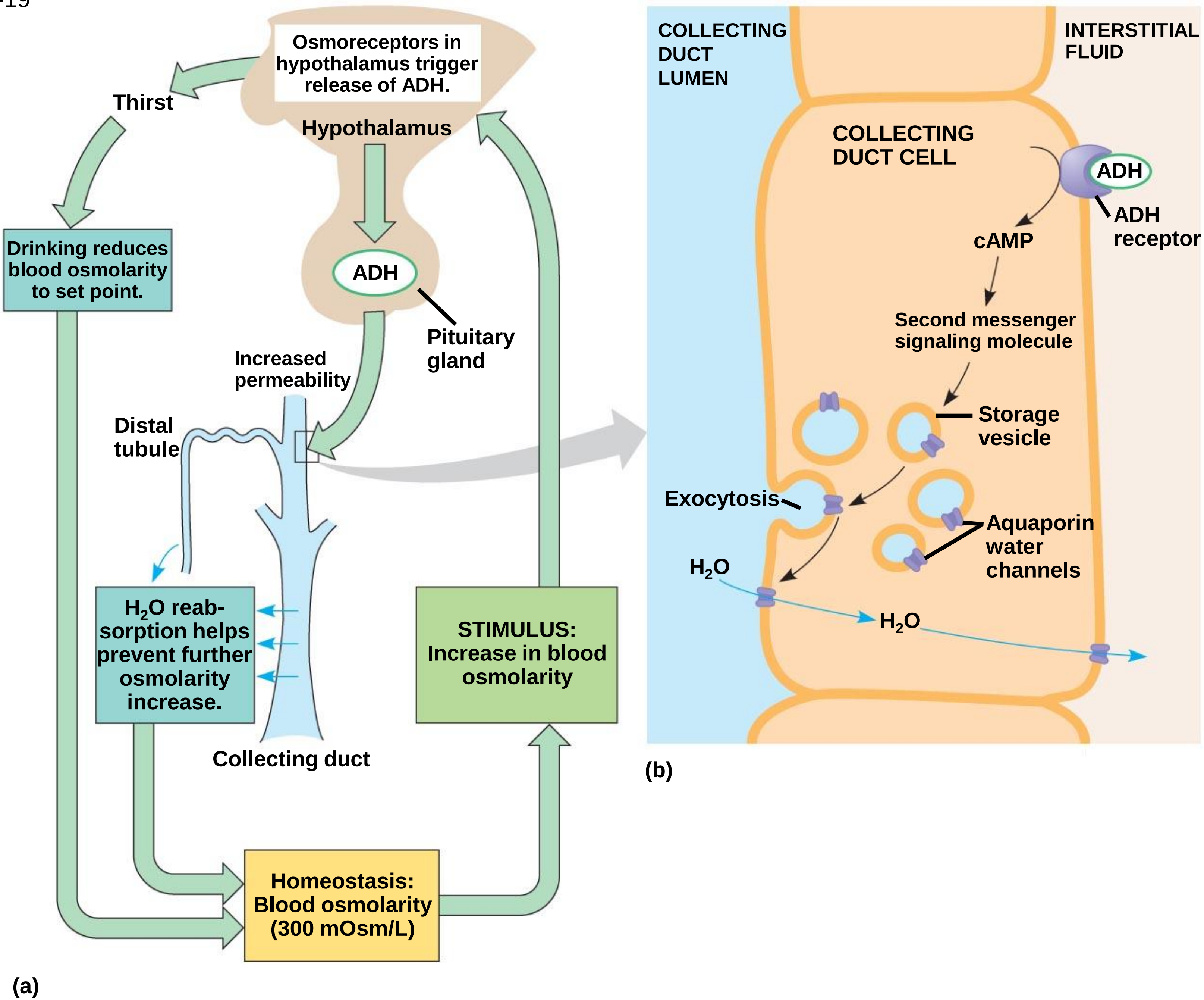
Birds and Other Reptiles

- Birds have shorter loops of Henle but conserve water by excreting uric acid instead of urea
- Other reptiles have only cortical nephrons but also excrete nitrogenous waste as uric acid

Concept 44.5: Hormonal circuits link kidney function, water balance, and blood pressure

- The kidneys of the South American vampire bat can produce either very dilute or very concentrated urine
- This allows the bats to reduce their body weight rapidly or digest large amounts of protein while conserving water

Fig. 44-19

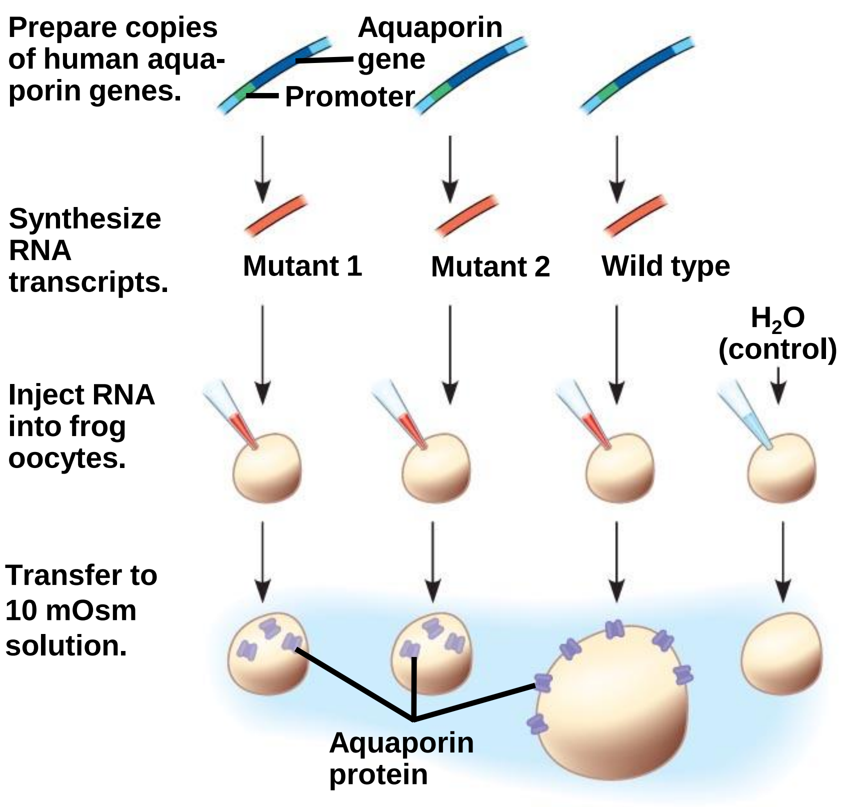


Osmoreceptors in hypothalamus trigger release of ADH.
Thirst
Hypothalamus
Drinking reduces blood osmolarity to set point.
ADH
Pituitary gland
Increased permeability
Distal tubule
H_2O reab-sorption helps prevent further osmolarity increase.
Collecting duct
STIMULUS: Increase in blood osmolarity
Homeostasis: Blood osmolarity (300 mOsm/L)
(a)
COLLECTING DUCT LUMEN
INTERSTITIAL FLUID
COLLECTING DUCT CELL
ADH
ADH receptor
cAMP
Second messenger signaling molecule
Storage vesicle
Exocytosis
Aquaporin water channels
H_2O
H_2O
(b)

- Mutation in ADH production causes severe dehydration and results in diabetes insipidus
- Alcohol is a diuretic as it inhibits the release of ADH

Fig. 44-20

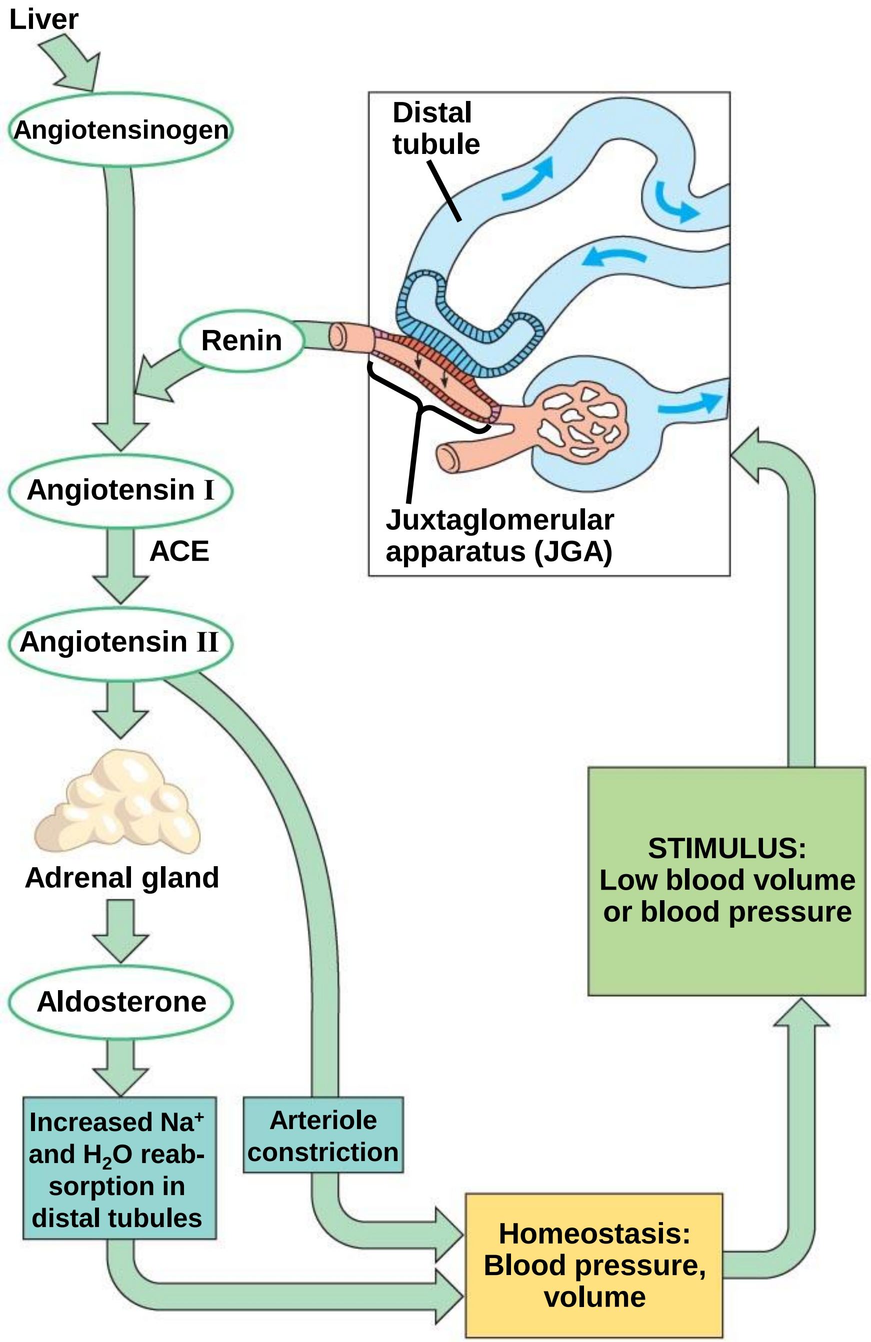
EXPERIMENT



RESULTS

Injected RNA	Permeability (µm/s)
Wild-type aquaporin	196
None	20
Aquaporin mutant 1	17
Aquaporin mutant 2	18

Fig. 44-21-3


Liver
Angiotensinogen
Renin
Angiotensin I
ACE
Angiotensin II
Adrenal gland
Aldosterone
Increased Na^+ and H_2O reab-sorption in distal tubules
Arteriole constriction
Homeostasis: Blood pressure, volume
STIMULUS: Low blood volume or blood pressure
Distal tubule
Juxtaglomerular apparatus (JGA)

Homeostatic Regulation of the Kidney

- ADH and RAAS both increase water reabsorption, but only RAAS will respond to a decrease in blood volume
- Another hormone, **atrial natriuretic peptide (ANP)**, opposes the RAAS
- ANP is released in response to an increase in blood volume and pressure and inhibits the release of renin

You should now be able to:

1. Distinguish between the following terms: isoosmotic, hyperosmotic, and hypoosmotic; osmoregulators and osmoconformers; stenohaline and euryhaline animals
2. Define osmoregulation, excretion, anhydrobiosis
3. Compare the osmoregulatory challenges of freshwater and marine animals
4. Describe some of the factors that affect the energetic cost of osmoregulation

5. Describe and compare the protonephridial, metanephridial, and Malpighian tubule excretory systems

6. Using a diagram, identify and describe the function of each region of the nephron

7. Explain how the loop of Henle enhances water conservation

8. Describe the nervous and hormonal controls involved in the regulation of kidney function