Body Systems and Cell Transport

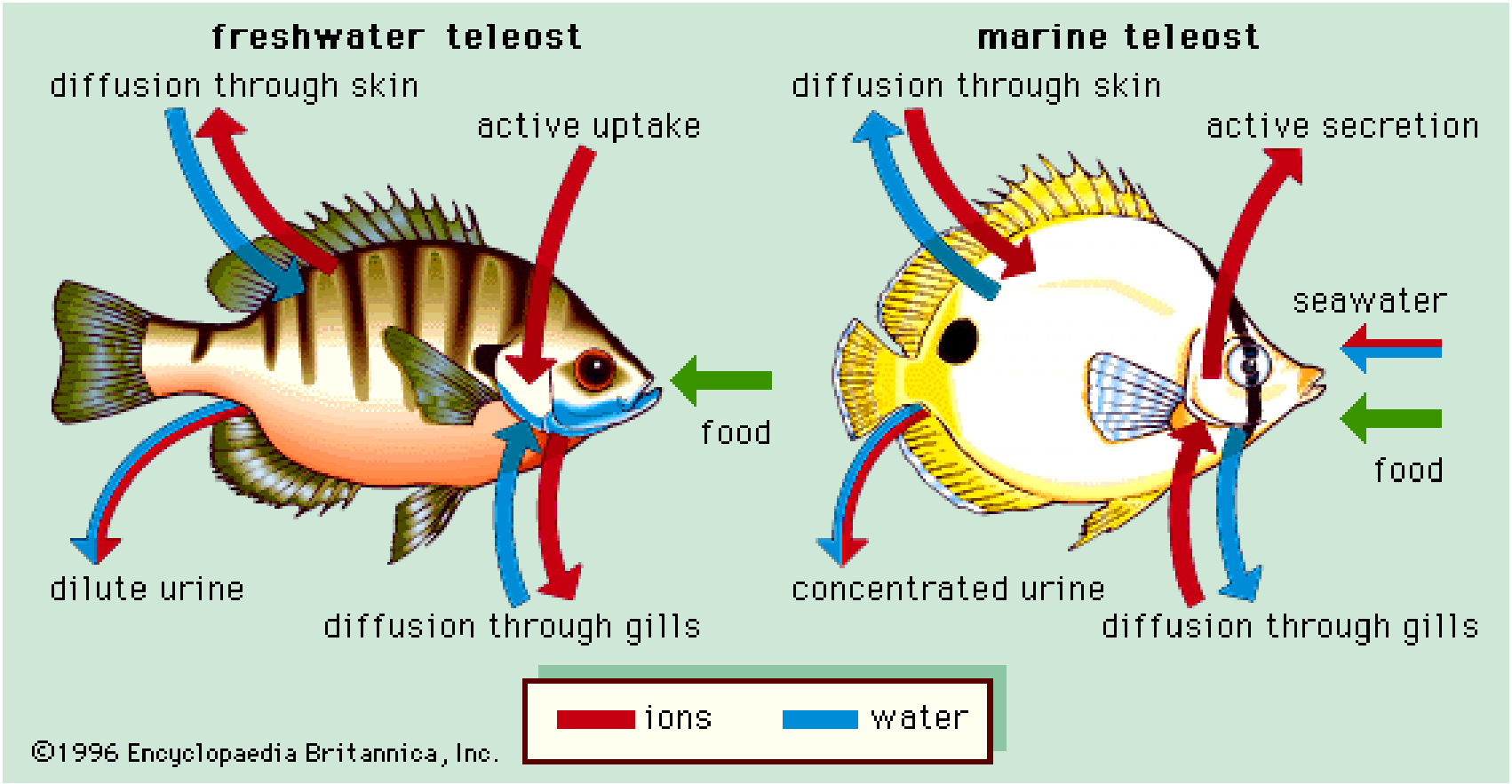
Ch44: Osmoregulation and Excretion

Osmoregulation

- Osmoregulation = process by which animals control solute concentrations and balance water gains and loss
  - Process of homeostasis
  - Osmolarity or osmotic pressure = total solute concentration expressed as molarity
- Excretion = process that rids the body of nitrogenous metabolites and other waste products

Adaptations

- Osmoconformers and Osmoregulators
- Anhydrobiosis
- Cuticle
- Exoskeleton
- Scales
- Salt glands


freshwater teleost
diffusion through skin
active uptake
food
dilute urine
diffusion through gills
marine teleost
diffusion through skin
active secretion
seawater
food
concentrated urine
diffusion through gills
ions
water
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Nitrogenous Waste

- Produced from breakdown of protein and nucleic acids
- An animal's nitrogenous wastes reflect its phylogeny and habitat

- Ammonia
  - Most common is aquatic species
  - Very toxic, so animals need access to lots of water
  - Excreted through gills

Nitrogenous Waste

- Urea
  - Conversion of ammonia to urea in the liver
  - Done by mammals, sharks, amphibians, and some bony fish
  - Low toxicity and less water is lost, but uses energy to do the transfer
- Uric acid
  - Nontoxic and does not dissolve easily in water
  - Insects, land snails, reptiles (birds)
  - High energy cost

Animal Diversity

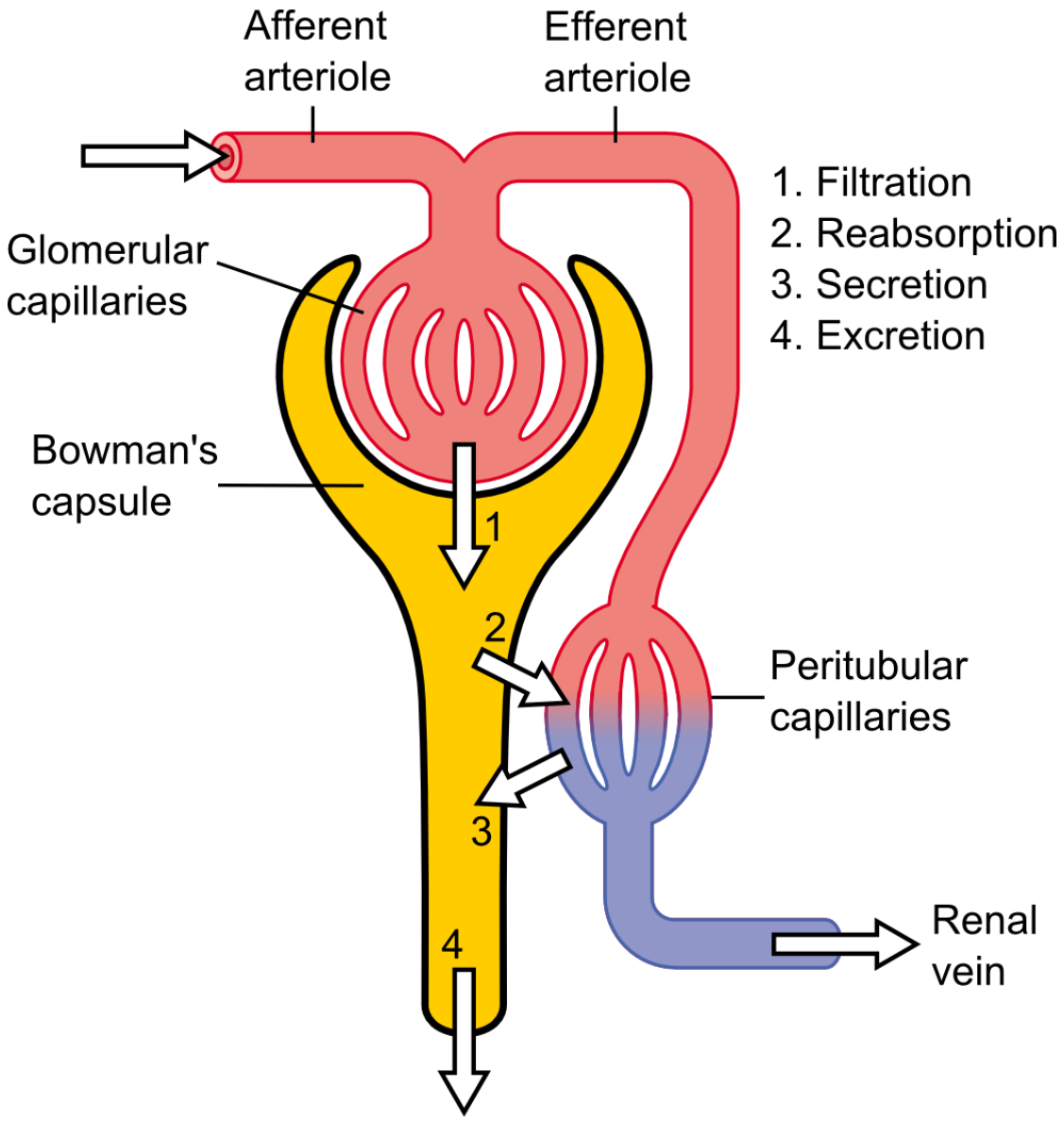
- Protonephridia – flame bulb system
  - Flatworm
- Metanephridia – located in each segment of the earthworm
  - Annelids
- Malpighian tubules – releases waste into digestive tract
  - Arthropods
- Kidneys – nephron
  - Mammals

Urinary System

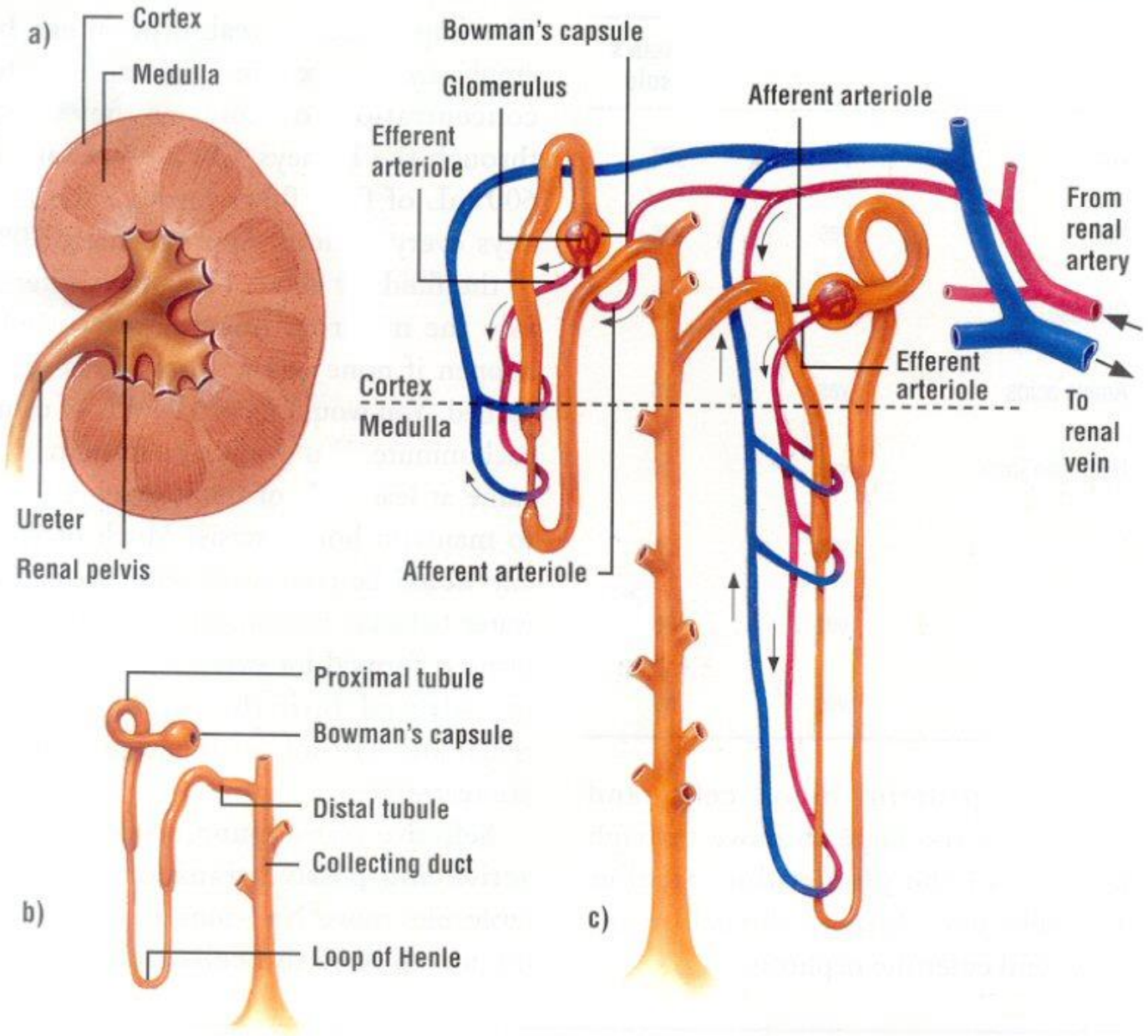
- Organs: kidney, ureter, bladder, urethra
- Nephron = main filtering structure of the kidneys
- Nephron parts: glomerulus, Bowman's capsule, proximal and distal tubules, loop of Henle, collecting duct

Excretory Process

- Filtration
  - Particles are moving from high to low pressure from glomerulus to Bowman's capsule
- Reabsorption
  - Substances from filtrate move back into the blood
- Secretion
  - Toxins and excess ions move from blood to filtrate
- Excretion
  - Urine leaves the body

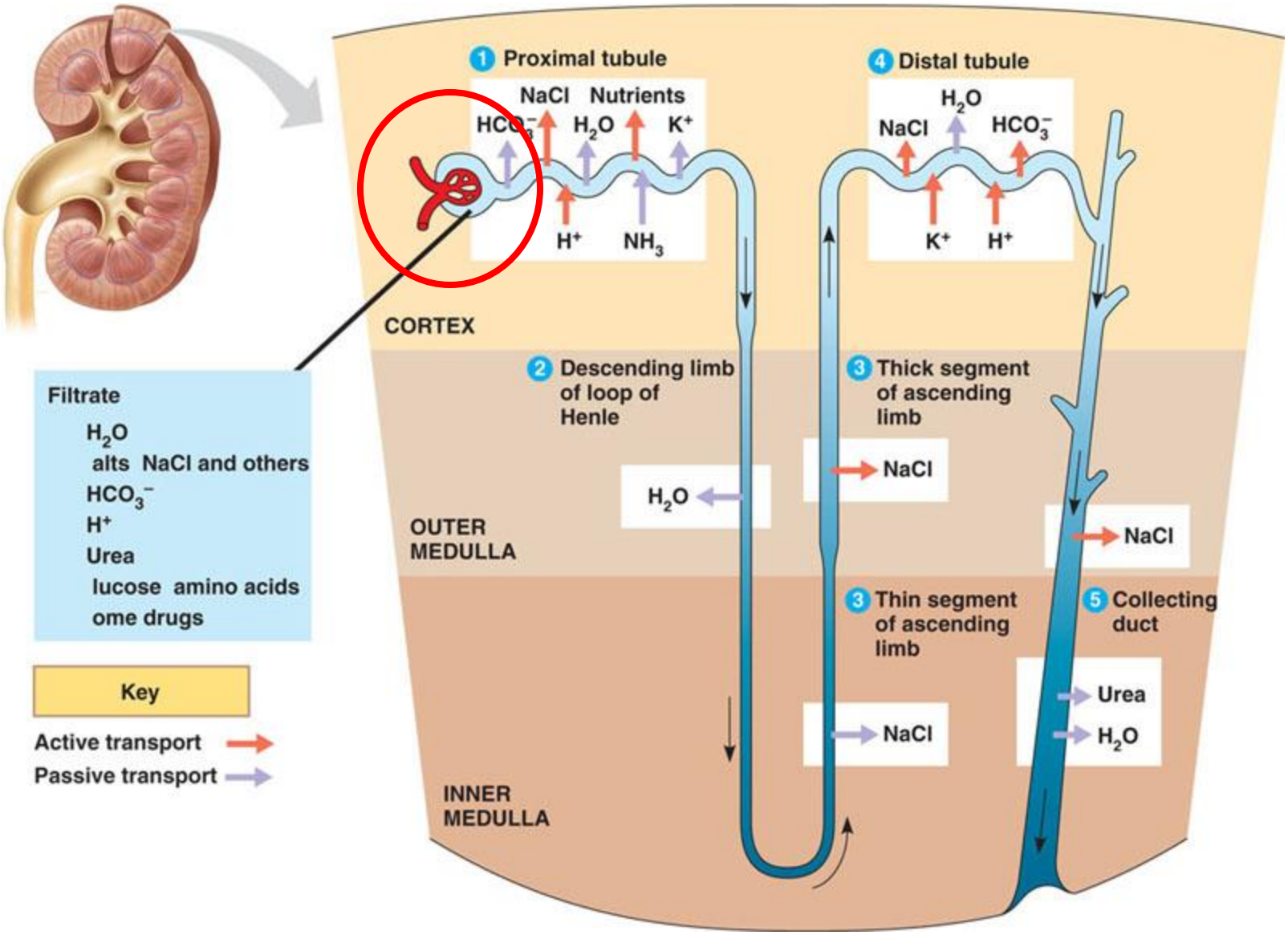


Excretion = Filtration – Reabsorption + Secretion


a)
Cortex
Medulla
Ureter
Renal pelvis
b)
Proximal tubule
Bowman's capsule
Distal tubule
Collecting duct
Loop of Henle
c)
Bowman's capsule
Glomerulus
Afferent arteriole
Efferent arteriole
From renal artery
Efferent arteriole
Cortex
Medulla
To renal vein
Afferent arteriole

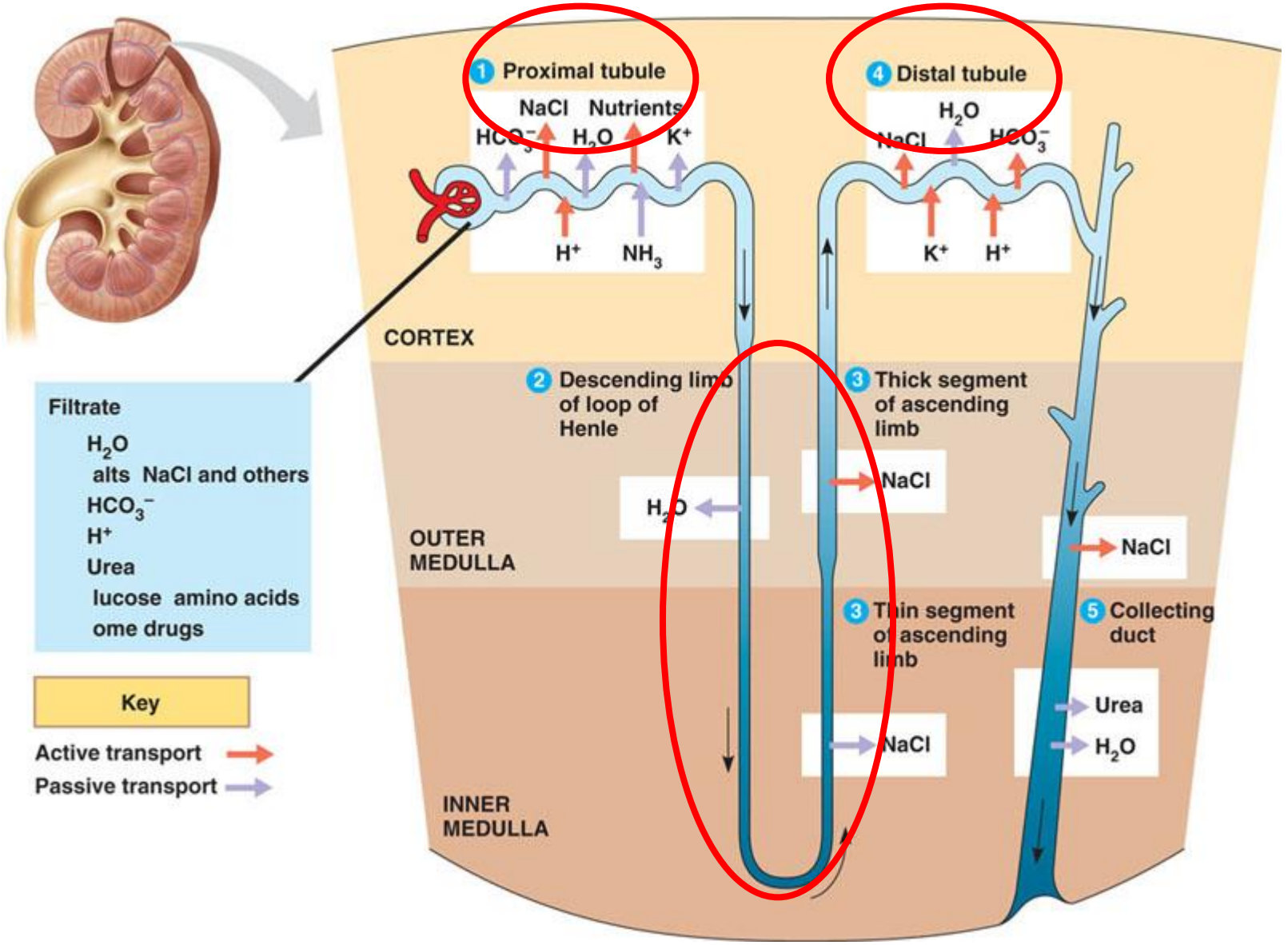
Filtration

- Occurs at the glomerulus to the Bowman's capsule
- Least selective transport in the kidneys
- Moves all particles in blood from high to low pressure into the renal tubules, except blood cells and proteins (too large to fit through the membrane)


1 Proximal tubule
NaCl
Nutrients
HCO_3^-
H_2O
K^+
H^+
NH_3
4 Distal tubule
H_2O
NaCl
HCO_3^-
K^+
H^+
CORTEX
2 Descending limb of loop of Henle
3 Thick segment of ascending limb
H_2O
NaCl
NaCl
OUTER MEDULLA
3 Thin segment of ascending limb
5 Collecting duct
NaCl
Urea
H_2O
INNER MEDULLA
Filtrate
H_2O
alts NaCl and others
HCO_3^-
H^+
Urea
lucose amino acids
ome drugs
Key
Active transport
Passive transport

Reabsorption

- Occurs in proximal tubule, loop of Henle, and distal tubule
- Moves H_2O, bicarbonate ions (for pH balance), NaCl, Nutrients (glucose and amino acids), and K+ back into blood
- Both passive and active transport are used in this process
- Loop of Henle only transports H_2O (through aquaporin channels) and NaCl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lucose amino acids
ome drugs
Key
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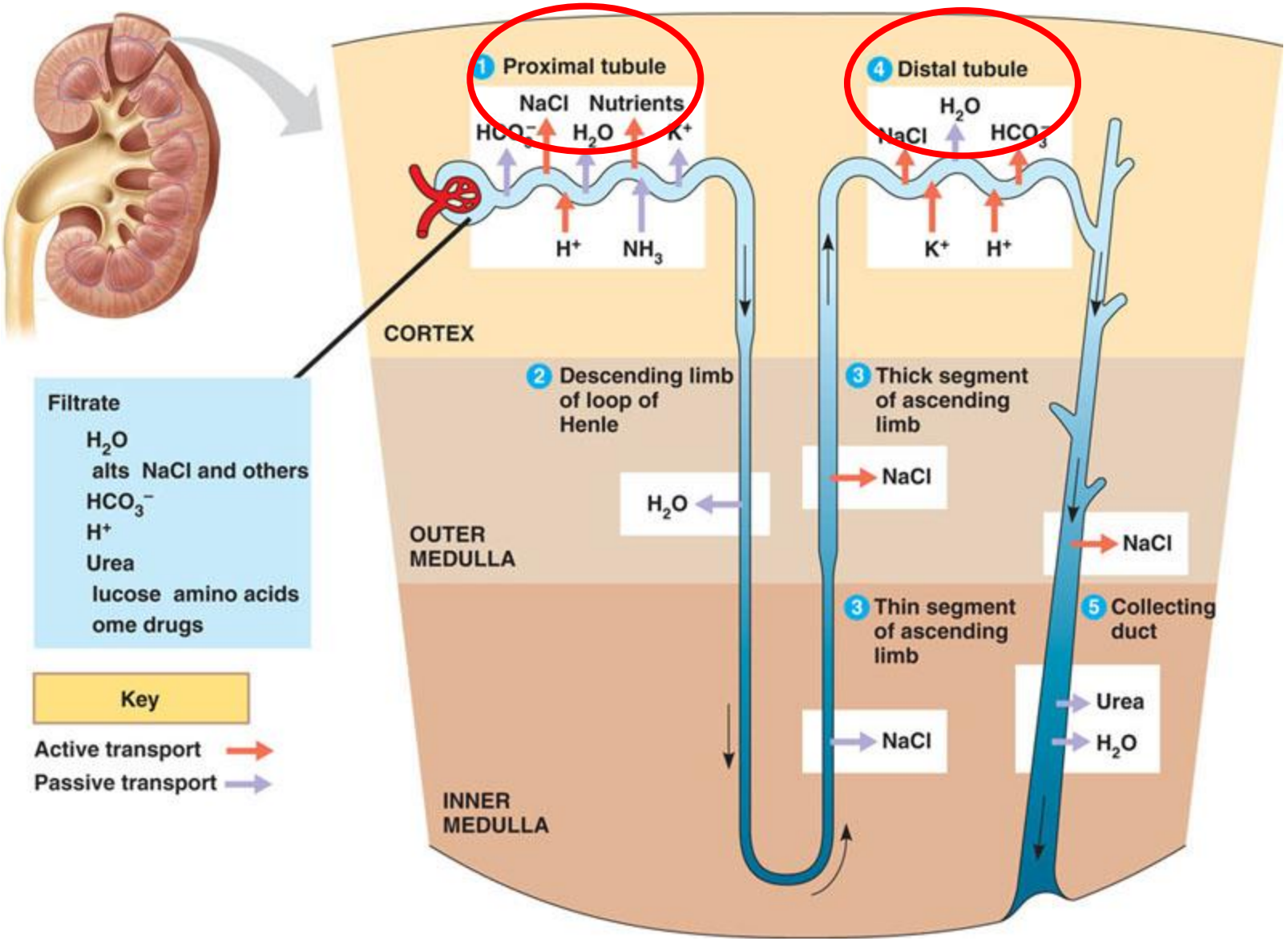
Secretion

- Occurs in proximal and distal tubules
- Moves H^+ (for pH balance), K^+, toxins, drugs, from blood into the filtrate in the renal tubules
- Mainly active, but some passive transport is used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ome drugs
Key
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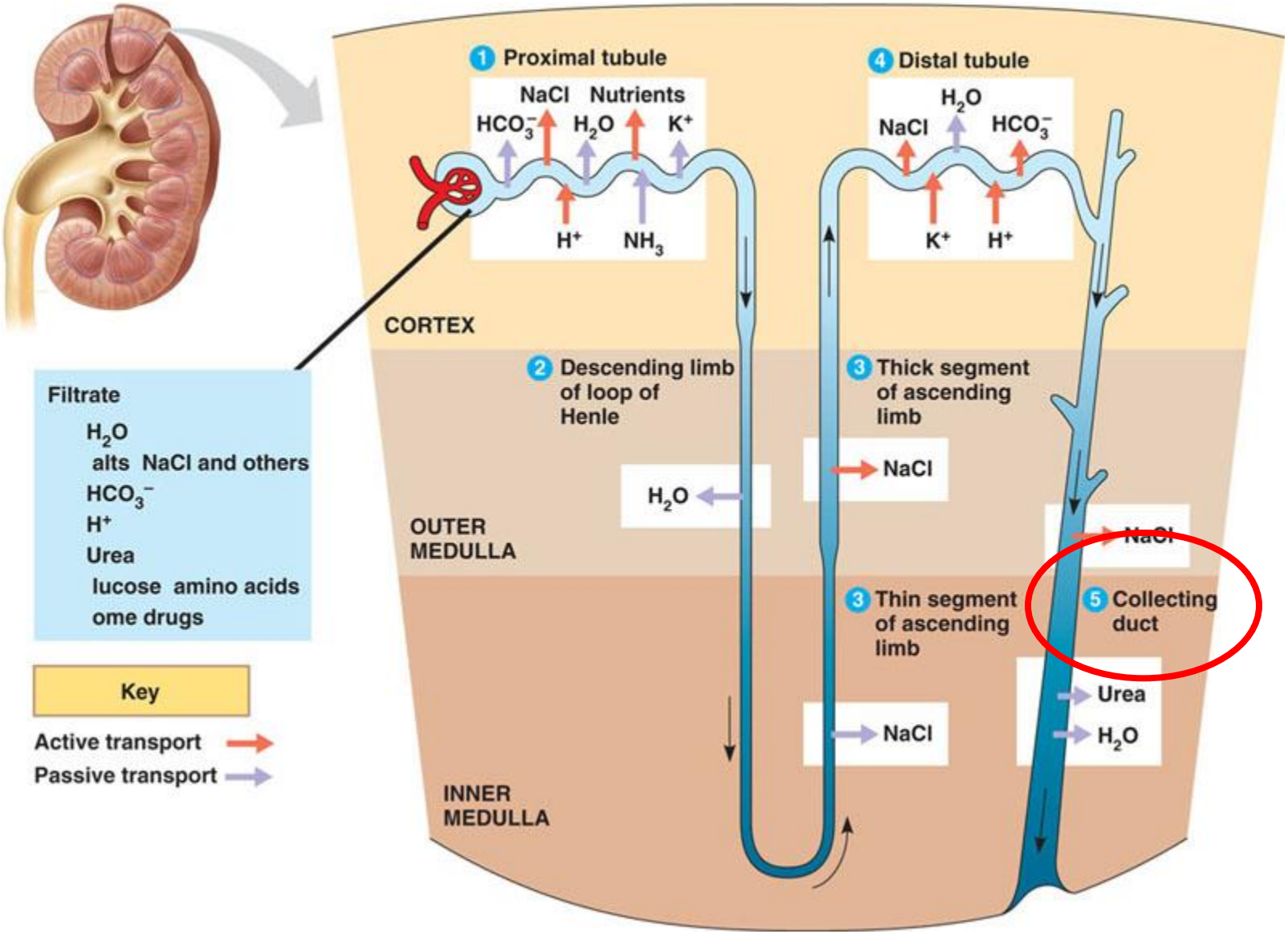
Passive transport

Excretion

- End result is a highly concentrated (high osmolarity) urine
  - Urine is acidic, has an odor, light yellow in color
  - Should not contain red blood cells, white blood cells, or high amounts of glucose
    - Presence of these indicates a health problem
- Urea is the main nitrogen waste in mammals, but has small amounts of uric acid and ammonia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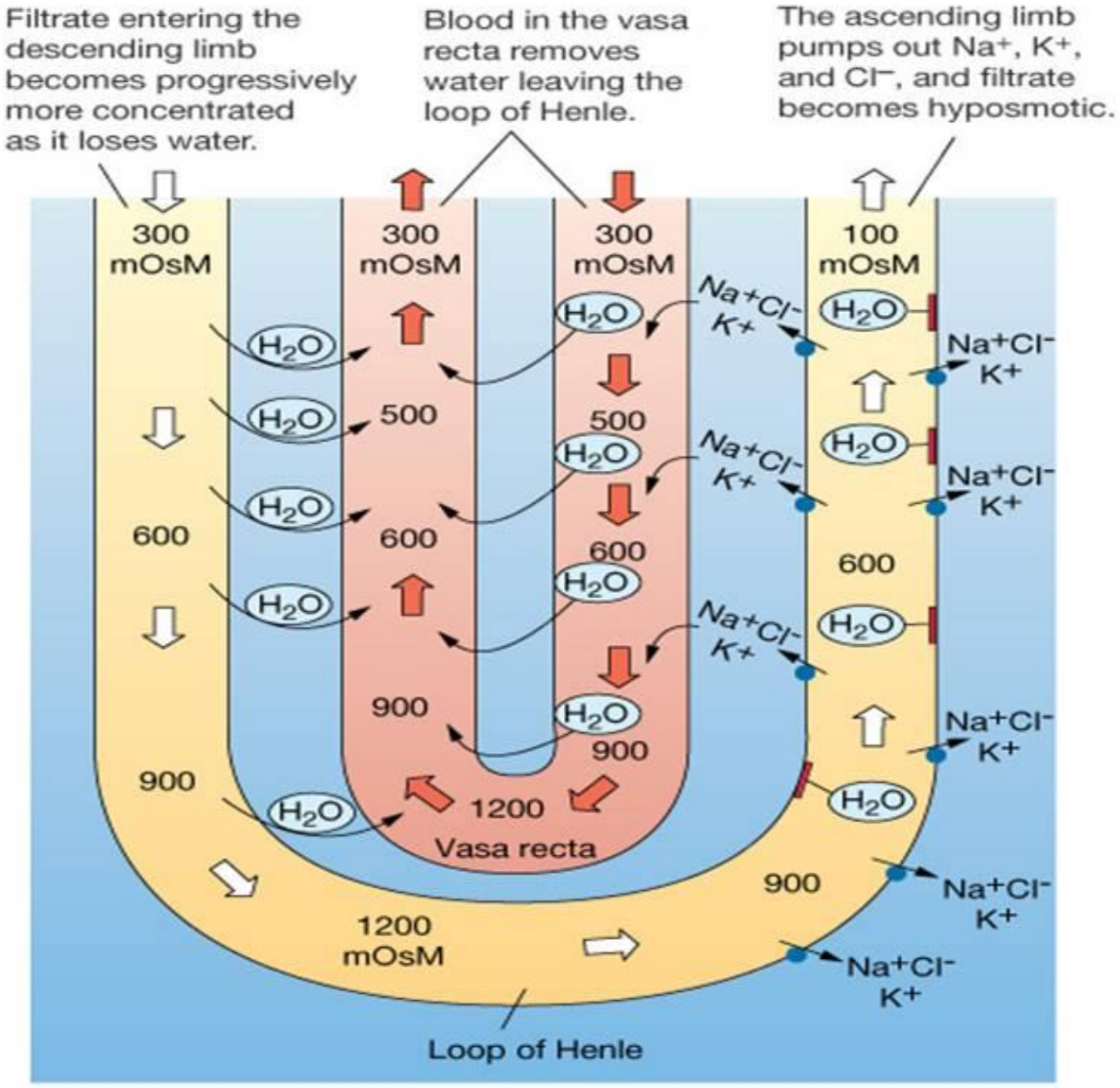
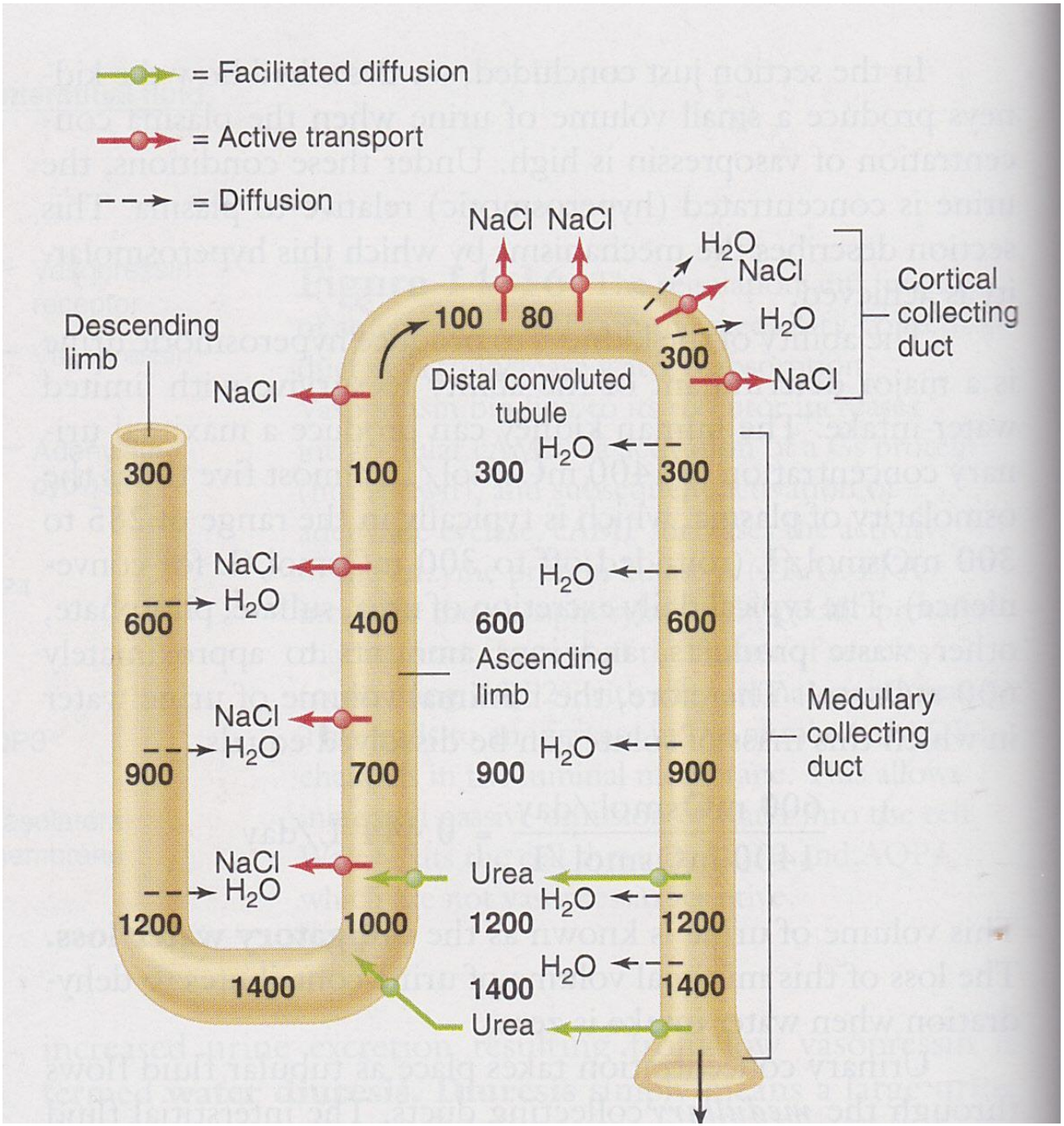
Countercurrent Exchange

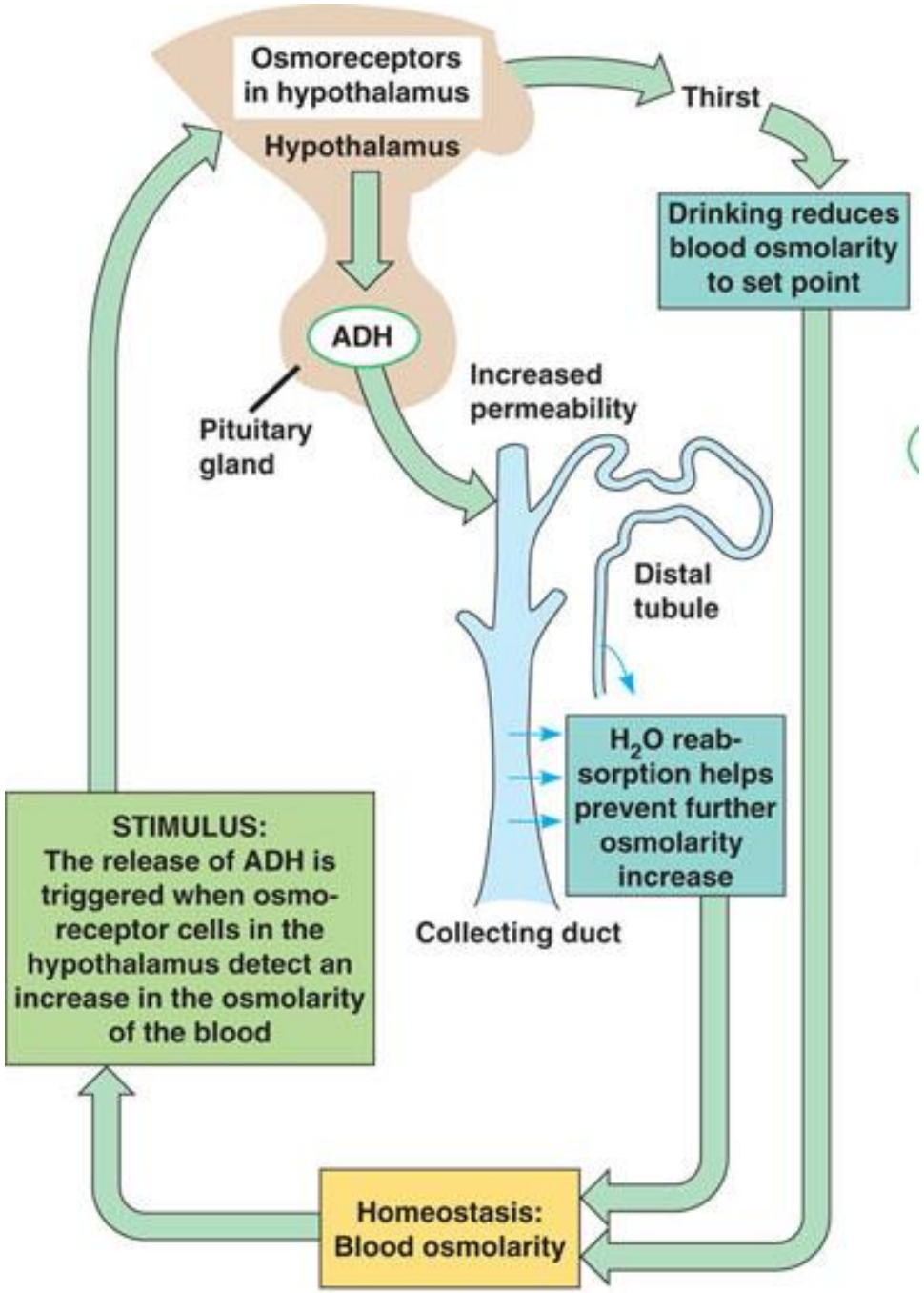
- NaCl and Urea moving out of the renal tubules creates a higher osmolarity in interstitial fluid
- As water moves from the cortex to the medulla 3 different times, it passes through differing interstitial fluid concentrations
- The medulla is more concentrated so more water moves out of the filtrate
- Kidneys will use energy to do countercurrent exchange – blood moves in the opposite direction of the filtrate flow


Filtrate entering the descending limb becomes progressively more concentrated as it loses water.
Blood in the vasa recta removes water leaving the loop of Henle.
The ascending limb pumps out Na+, K+, and Cl−, and filtrate becomes hyposmotic.
300 mOsM
300 mOsM
300 mOsM
100 mOsM
H2O
Na+Cl- K+
500
600
900
1200
Vasa recta
1200 mOsM
Loop of Henle

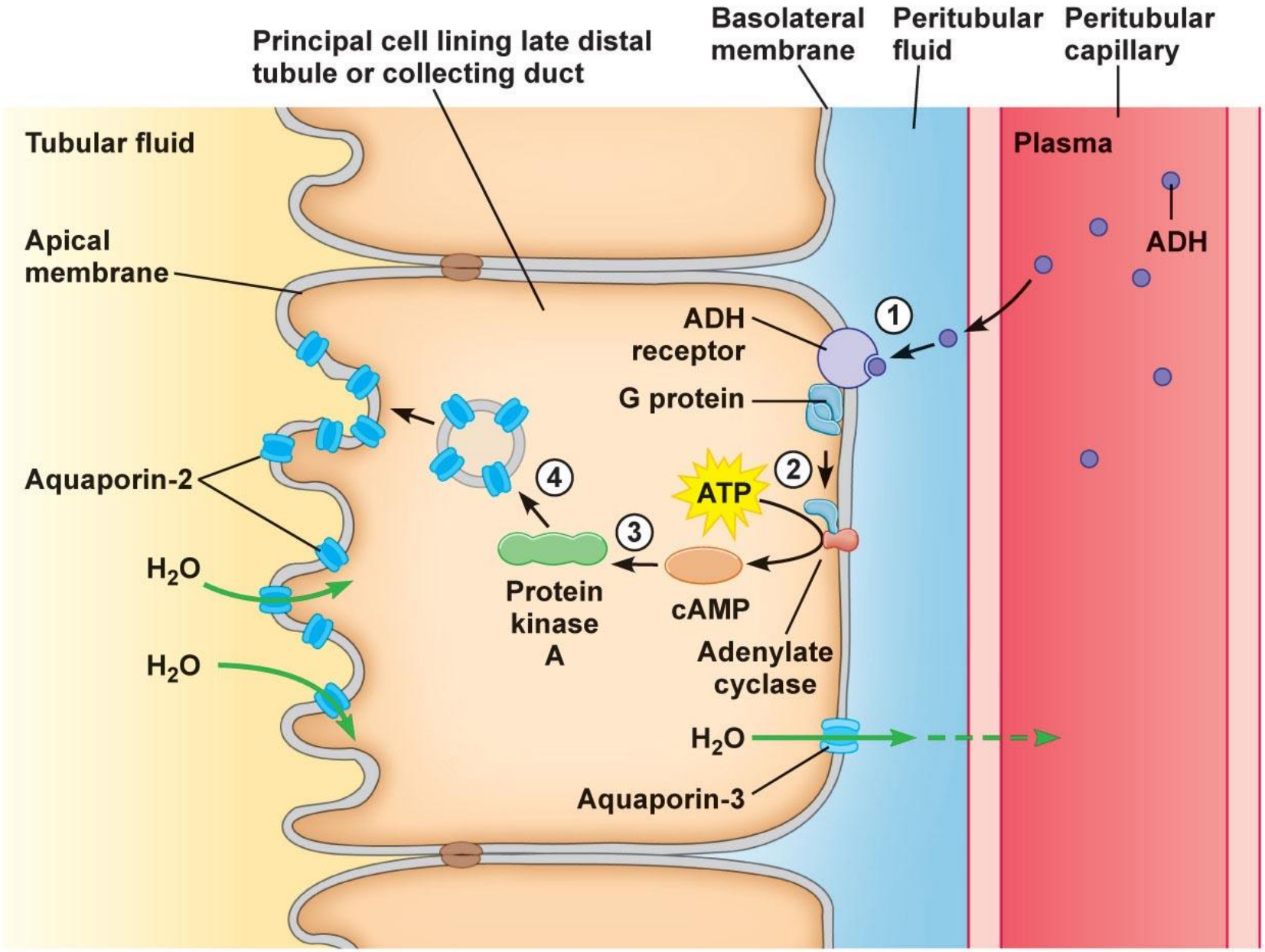

= Facilitated diffusion
= Active transport
= Diffusion
NaCl NaCl
H_2O
NaCl
H_2O
NaCl
Cortical collecting duct
Descending limb
100 80
300
Distal convoluted tubule
NaCl
300 100 300 300
H_2O
NaCl
H_2O
600 400 600 600
Ascending limb
NaCl
H_2O
900 700 900 900
Medullary collecting duct
NaCl
H_2O
Urea
H_2O
1200 1000 1200 1200
H_2O
1400 1400 1400
Urea

Antidiuretic Hormone

- Increase in blood osmolarity occurs – more solute
- Hypothalamus releases hormones which triggers the release of ADH from pituitary gland
- Thirst response is triggered as well as ADH acting on the kidneys
- ADH binds to a receptor in the collecting duct, activates cAMP, second messenger causes aquaporin protein channels to attach to membrane
- Aquaporin moves water from filtrate back into blood


Osmoreceptors in hypothalamus
Hypothalamus
Thirst
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: The release of ADH is triggered when osmo-receptor cells in the hypothalamus detect an increase in the osmolarity of the blood
Homeostasis: Blood osmolarity

(a)



Renin-Angiotensin-Aldosterone System

- Low blood volume and blood pressure is detected by juxtaglomerular apparatus near glomerulus and renin is released

- Renin coverts the protein angiotensinogen from the liver into angiotensin I

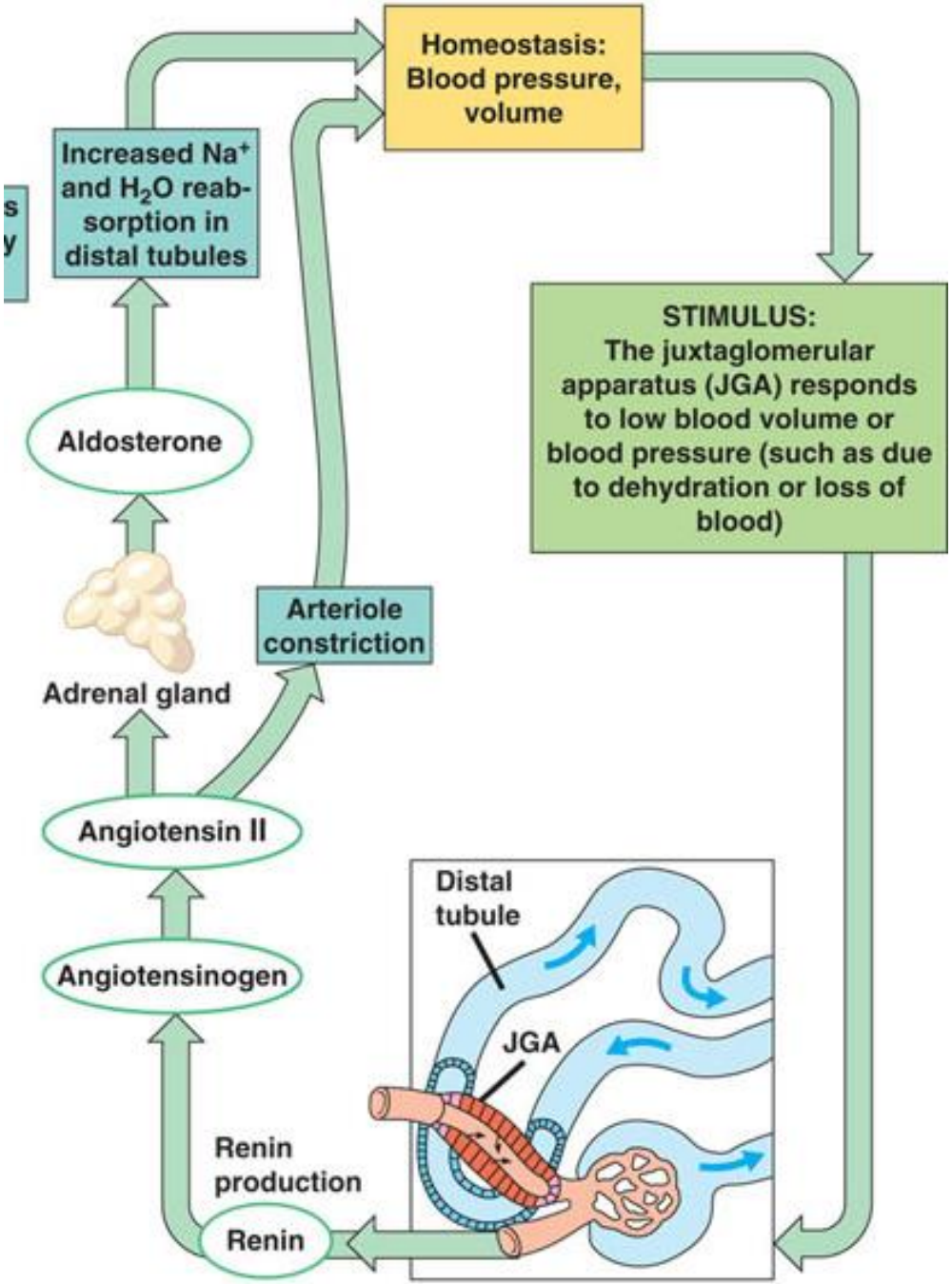
- Angiotensin I is converted into angiotensin II by an enzyme

Renin-Angiotensin-Aldosterone System

- Angiotensin II causes arterioles to constrict and acts on adrenal gland to release aldosterone (mineralcorticoids)

- Aldosterone causes Na+ and water to be reabsorbed into the blood

- Volume and pressure will go back to the normal limits


Homeostasis: Blood pressure, volume
Increased Na+ and H2O reab-sorption in distal tubules
STIMULUS: The juxtaglomerular apparatus (JGA) responds to low blood volume or blood pressure (such as due to dehydration or loss of blood)
Aldosterone
Arteriole constriction
Adrenal gland
Angiotensin II
Angiotensinogen
Distal tubule
JGA
Renin production
Renin
(b)