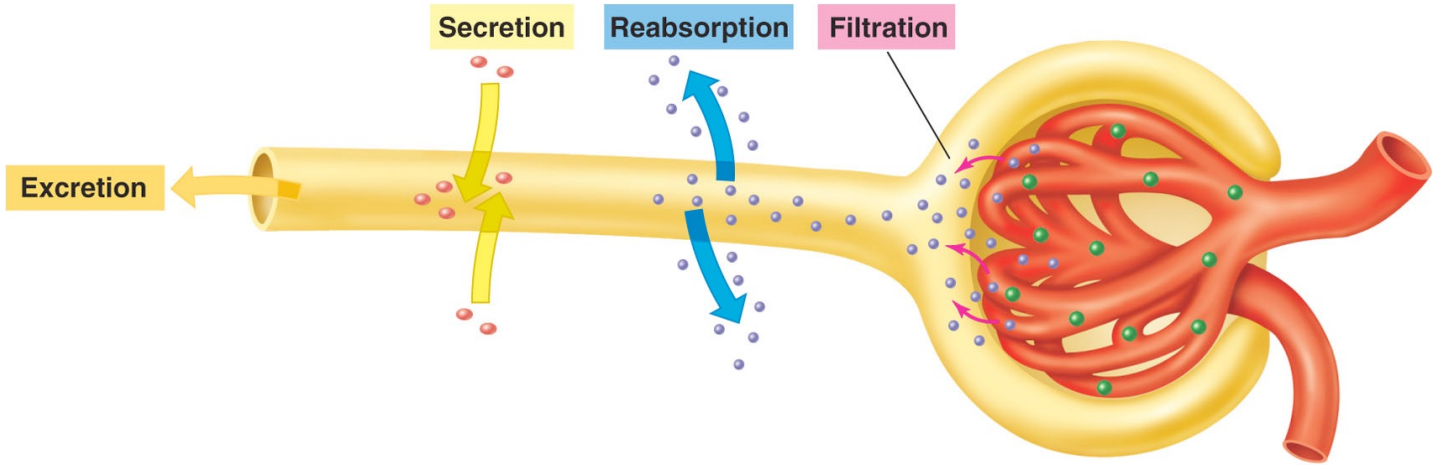
Figure 17.21

1. Filter plasma and water soluble chemicals **from** blood into urine

2. Reabsorb and return needed chemicals from urine and back to blood

3. Secrete additional chemicals into the urine



30% of plasma filtered out with each pass
all blood filtered within 40 min
180L filtered out every day

Figure 17.5

85% of filtered water and NaCl is reabsorbed in **proximal tubule.**

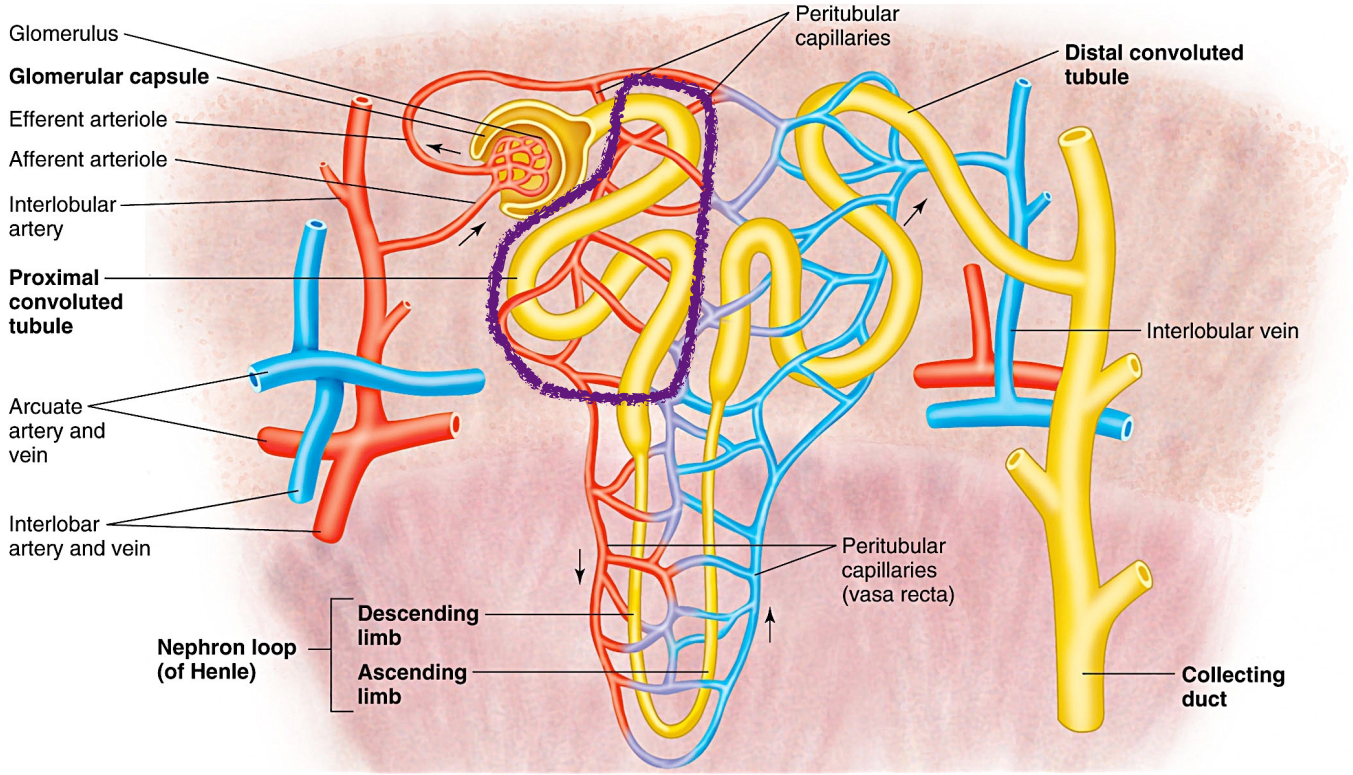
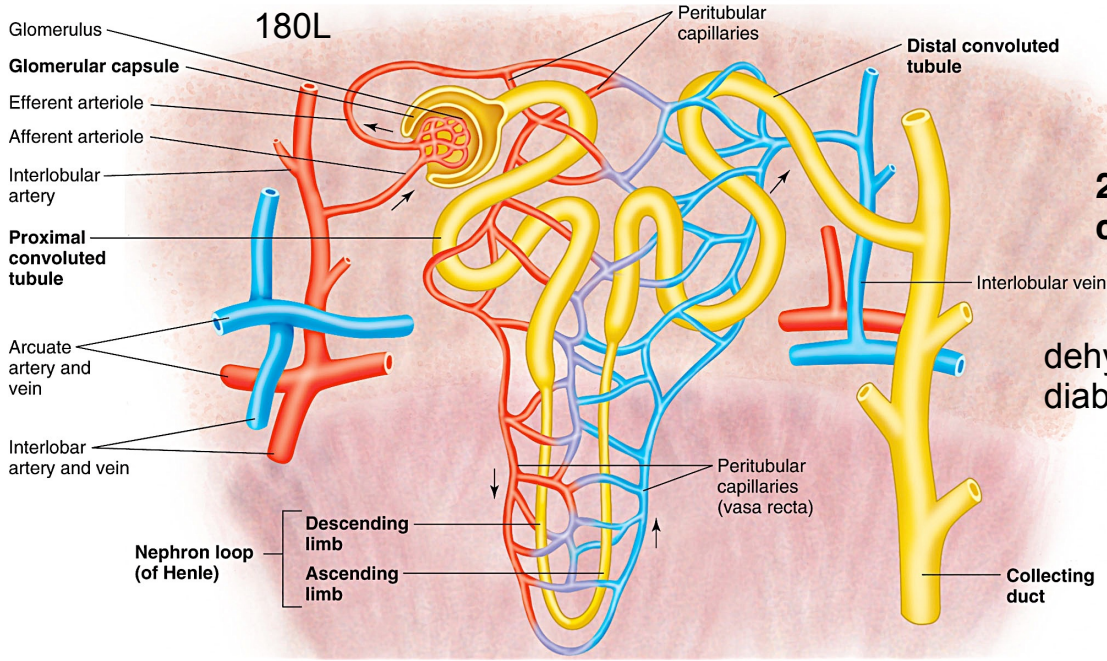


Figure 17.5

plasma filtered by glomerulus = 100% filtrate

85% reabsorbed from **proximal tubule**.



2% reabsorbed from **collecting duct**

dehydration: 3%
diabetes insipidus: 0%

12% reabsorbed from **loop of Henle**

1% excreted as urine

~1.5L

dehydration: 0.4 L
diabetes insipidus: 10L

CounterCurrent Multiplier of Loop of Henle

Interstitial fluid of **Medulla** is very **hypertonic,** so water can be reabsorbed from descending loop of Henle by osmosis .

Hypertonicity is maintained by **ascending loop of Henle**. which **pumps NaCl** into interstitial fluid.

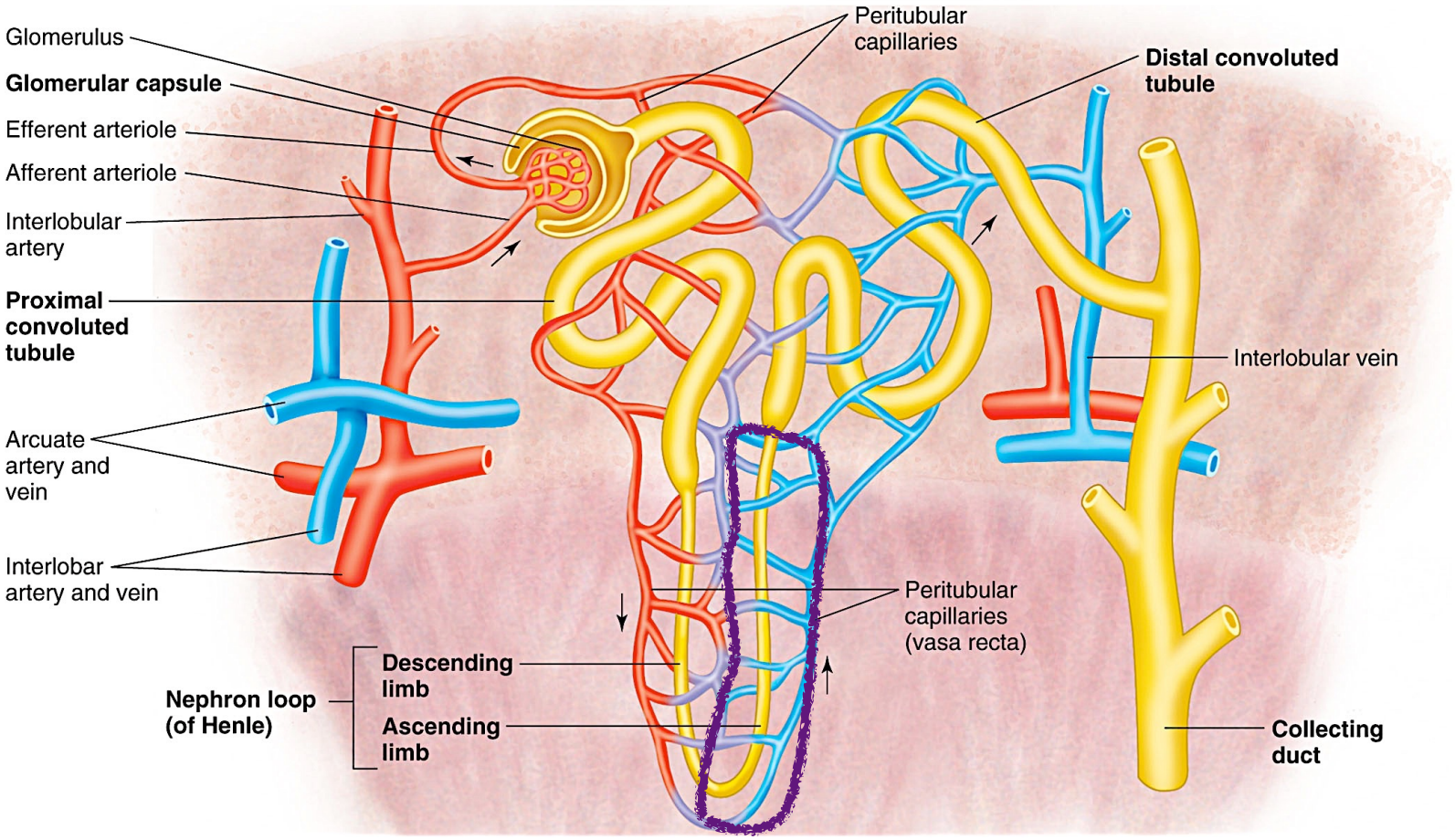
Water (but not NaCl) can be reabsorbed from descending loop by osmosis.

NaCl (but not water) is reabsorbed from ascending loop by active transport.

Countercurrent in Vasa Recta:
Solute concentration is always higher in ascending vessels than descending vessels, so water tends to move into ascending vessels for removal from medulla.

Figure 17.5

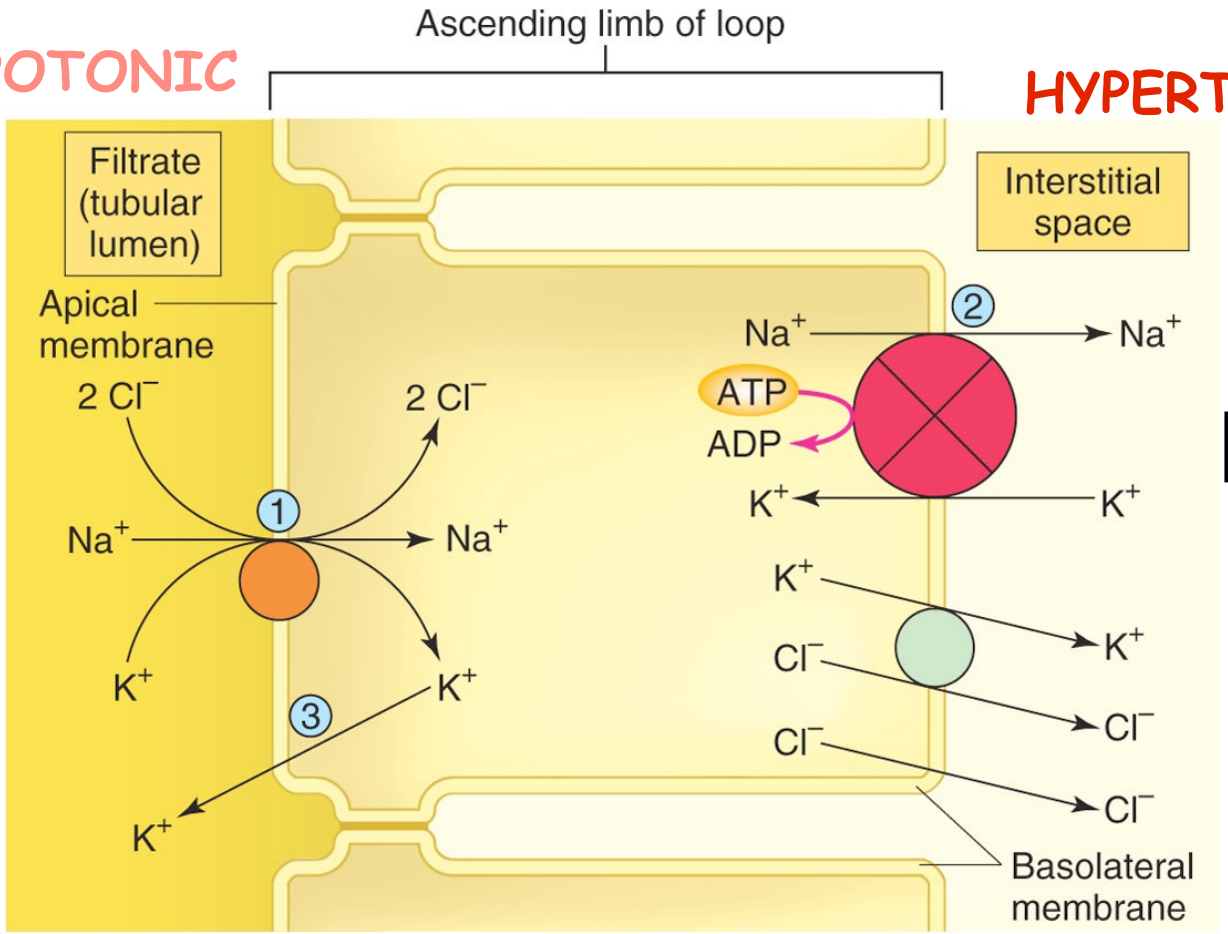
Na is reabsorbed in **Ascending Loop of Henle**



Ascending Limb removes NaCl, making urine **hypotonic** & medulla **hypertonic**

HYPOTONIC

HYPERTONIC



Na+
Cl-

Figure 17.15

Figure 17.5

water is reabsorbed in **Descending Loop of Henle**

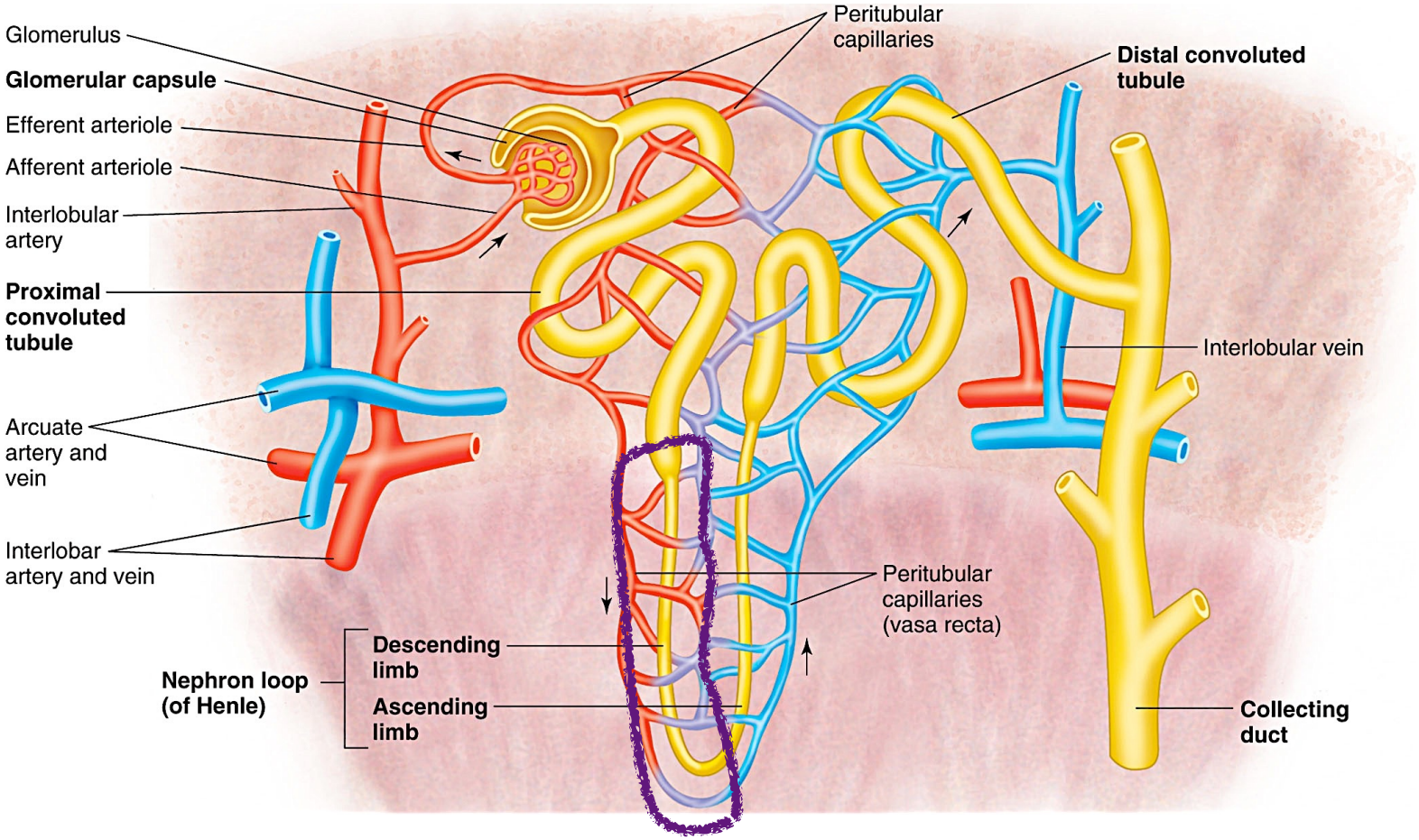
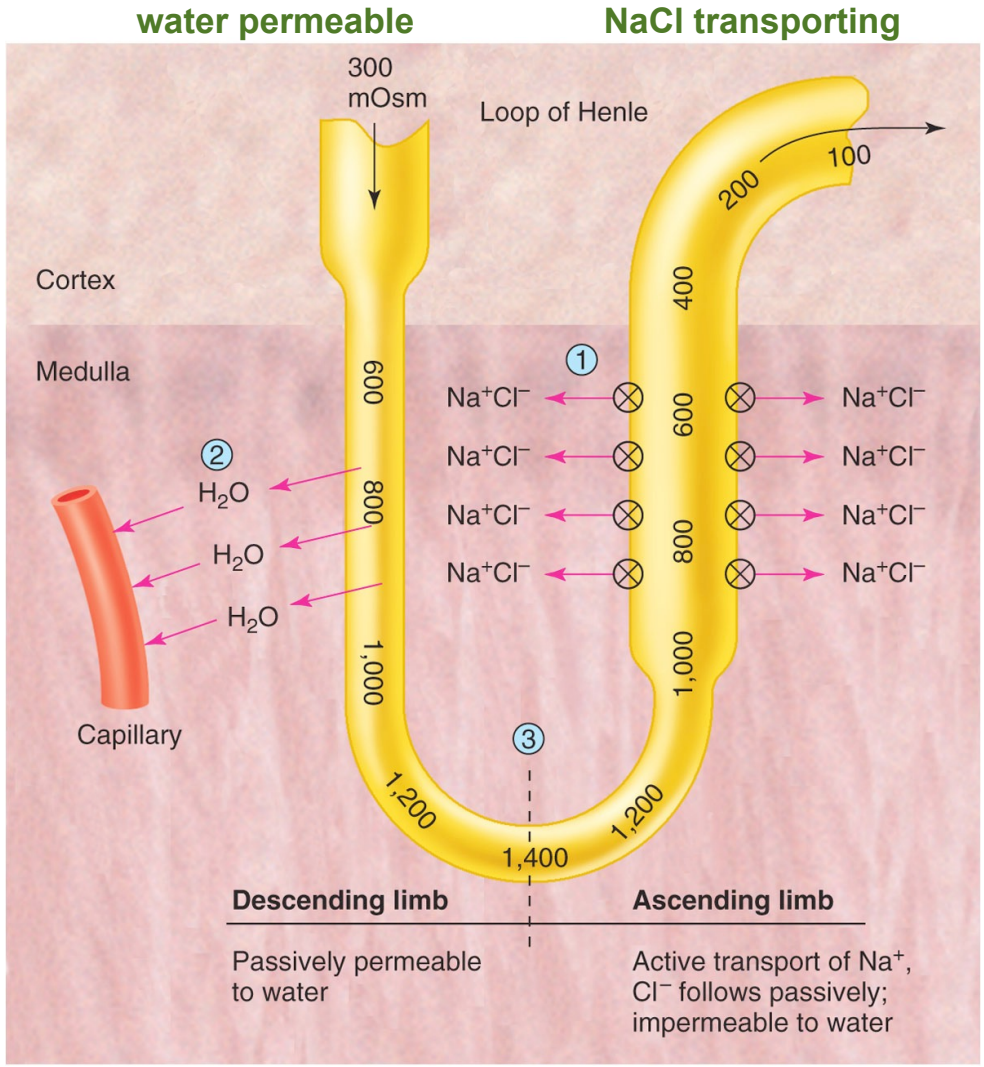
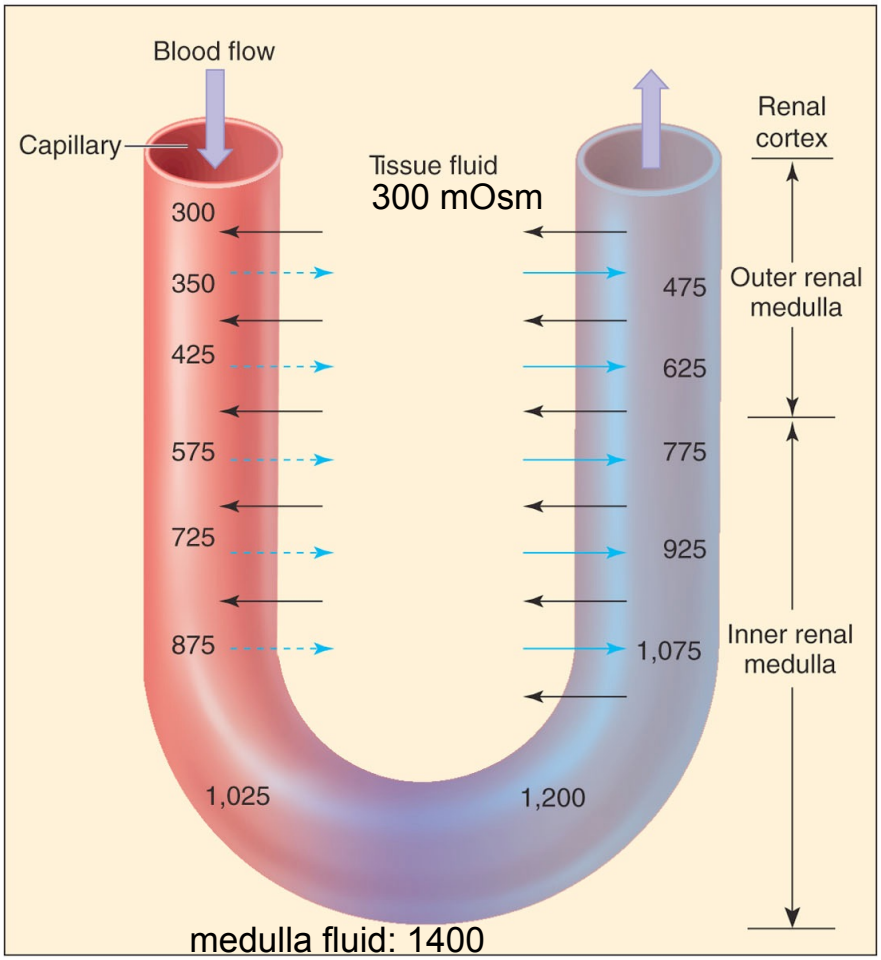
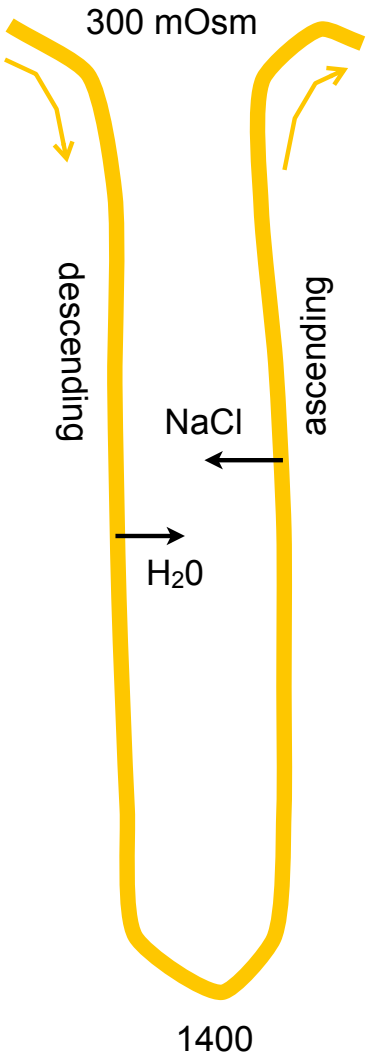


Figure 17.14


water permeable
NaCl transporting
300 mOsm
Loop of Henle
Cortex
Medulla
100
200
400
600
800
1,000
1,200
1,400
1,200
1,000
800
600
1
2
3
Na+Cl−
H2O
H2O
H2O
Capillary
Descending limb
Passively permeable to water
Ascending limb
Active transport of Na+, Cl− follows passively; impermeable to water

Countercurrent in Vasa Recta (Peritubular capillaries):





Countercurrent in Vasa Recta (Peritubular capillaries):

Concentration in venous side always higher than concentration in arterial side, so NaCl always diffuses out of venous side into medulla/ arterial side

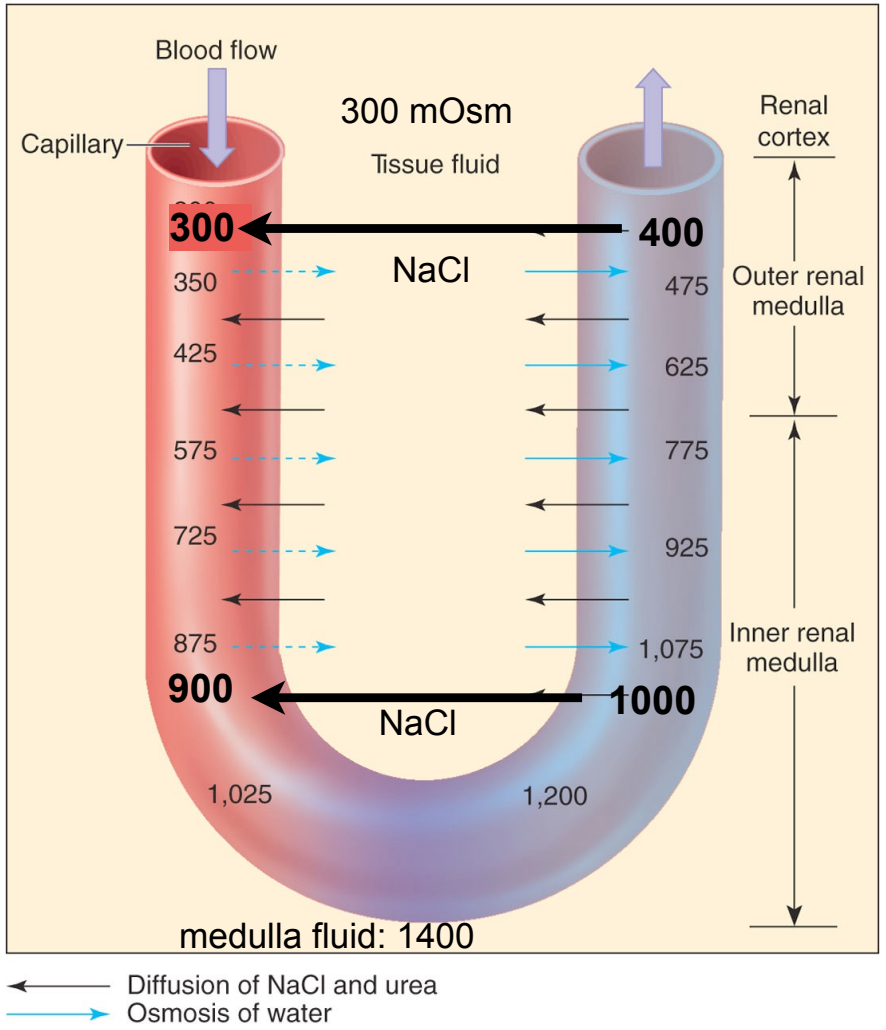
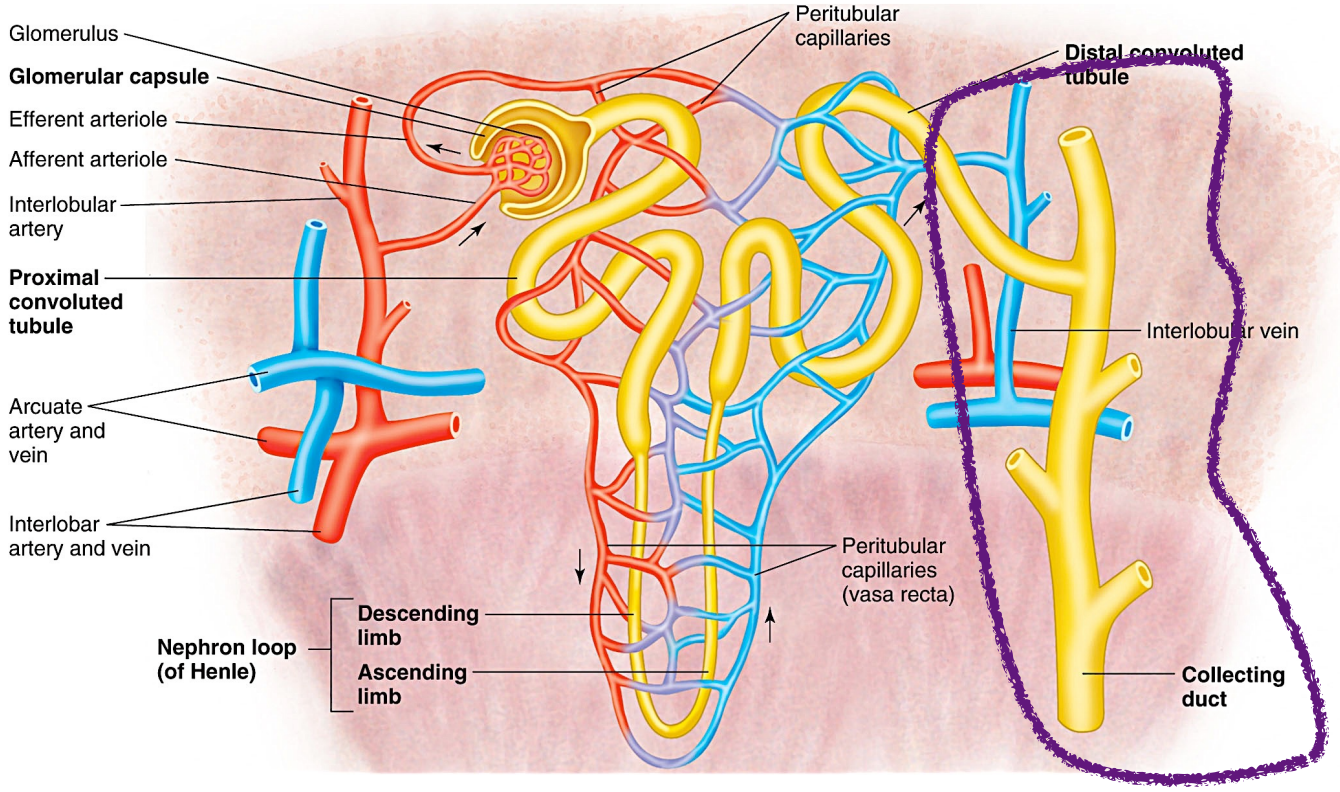


Figure 17.5

water reabsorption from **Collecting Ducts**



Water Reabsorption from Collecting Ducts

Collecting Ducts receive hypotonic urine from ascending loop of Henle & distal tubule.

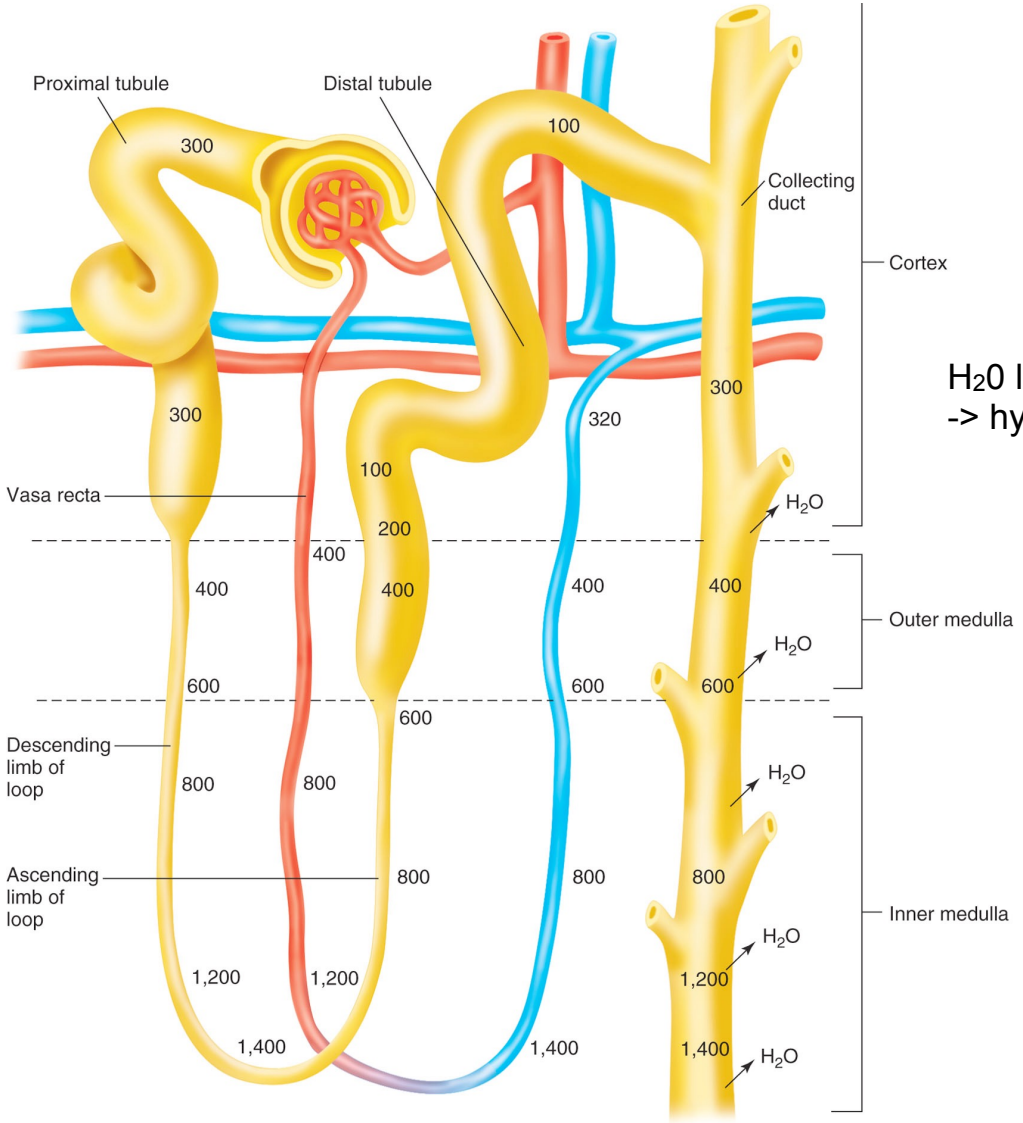
Collecting Ducts travel back through medulla towards calyces & pelveis.

Interstitial fluid of **Medulla** is very **hypertonic,** so water can be reabsorbed from collecting duct by osmosis.

Collecting duct epithelium is water permeable.

Aquaporin channels in collecting duct epithelium enhance osmosis.

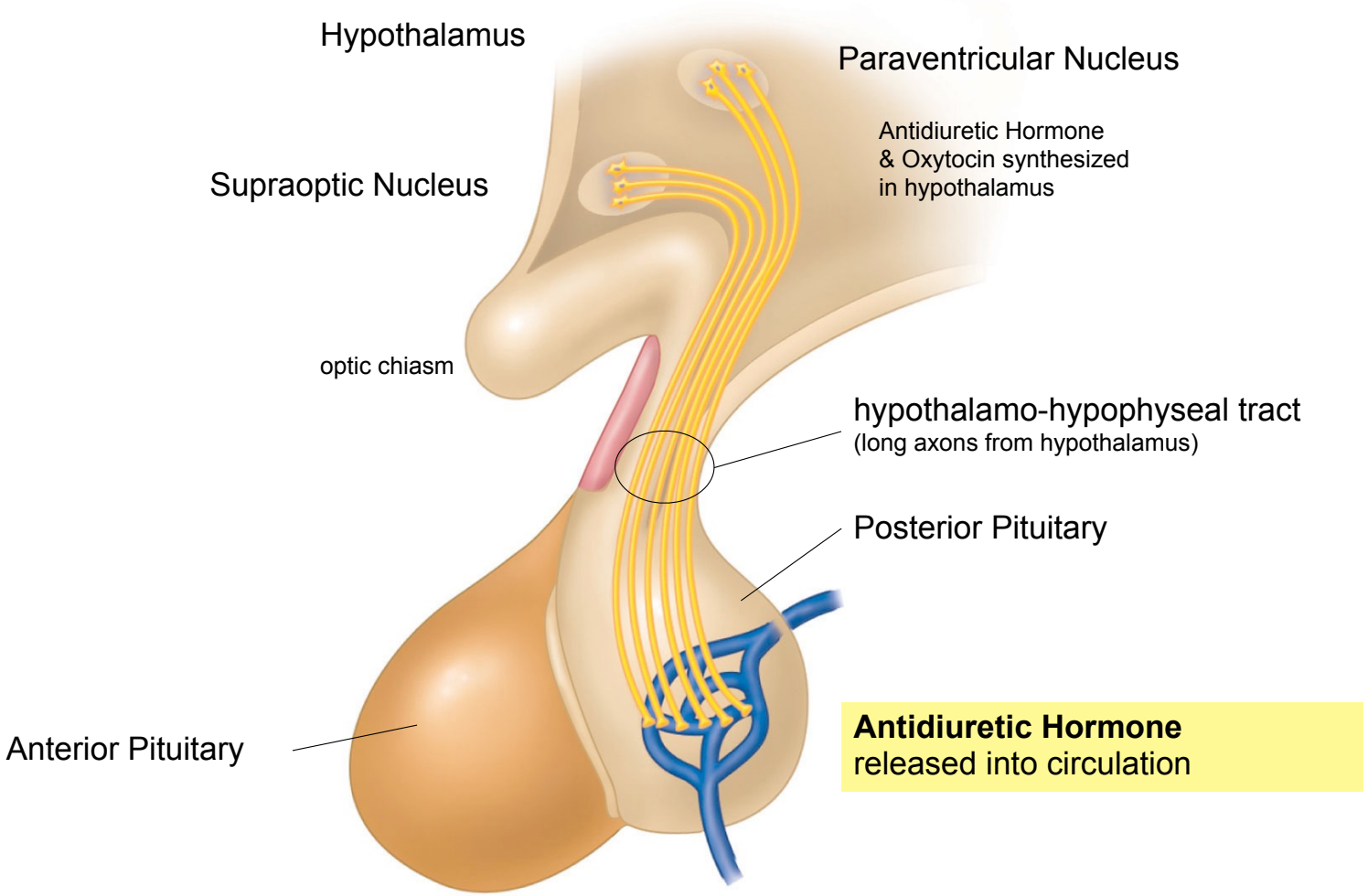
Antidiuretic Hormone (ADH) produced by hypothalamus/pituitary in response to dehydration increase the number of aquaporin channels in collecting ducts.



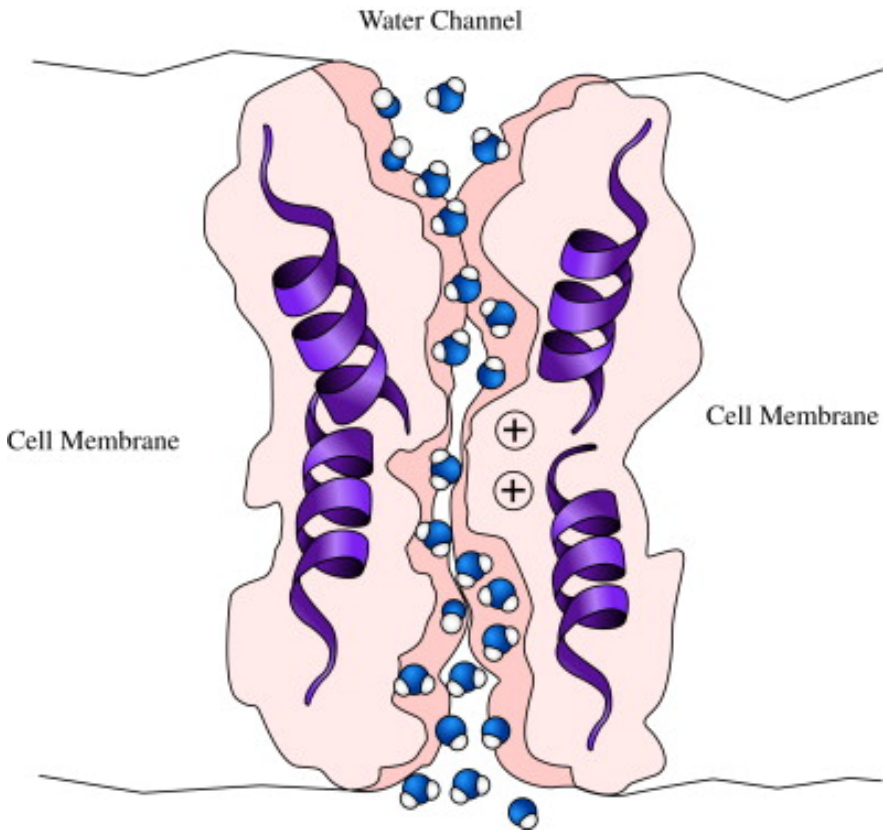
H_20 leaves collecting duct
-> hypertonic medulla

Figure 17.18

Figure 11.13


Hypothalamus
Paraventricular Nucleus
Antidiuretic Hormone
& Oxytocin synthesized
in hypothalamus
Supraoptic Nucleus
optic chiasm
hypothalamo-hypophyseal tract
(long axons from hypothalamus)
Posterior Pituitary
Anterior Pituitary
Antidiuretic Hormone
released into circulation

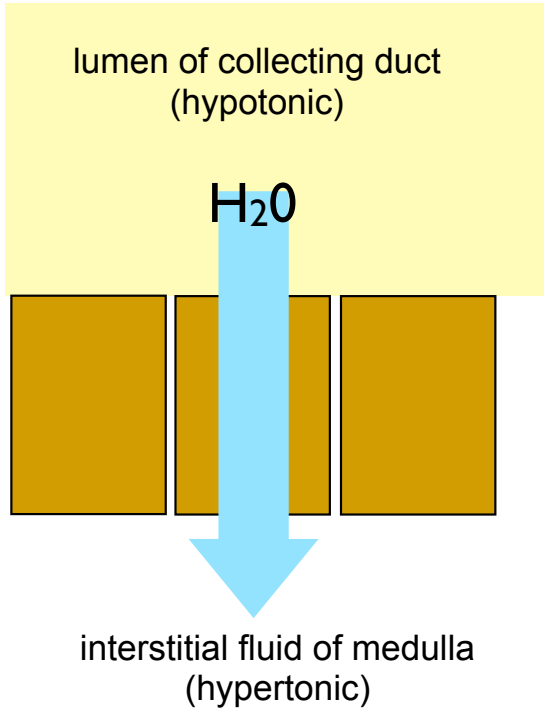
Antidiuretic Hormone causes **aquaporin** channels to be inserted into plasma membrane
-> retention of water in collecting ducts



if aquaporin channels are present, at least 10x greater movement of water across the cell membrane

William Stillwell, in An Introduction to Biological Membranes, 2013

Antidiuretic Hormone causes **aquaporin** channels to be inserted into plasma membrane -> retention of water in collecting ducts



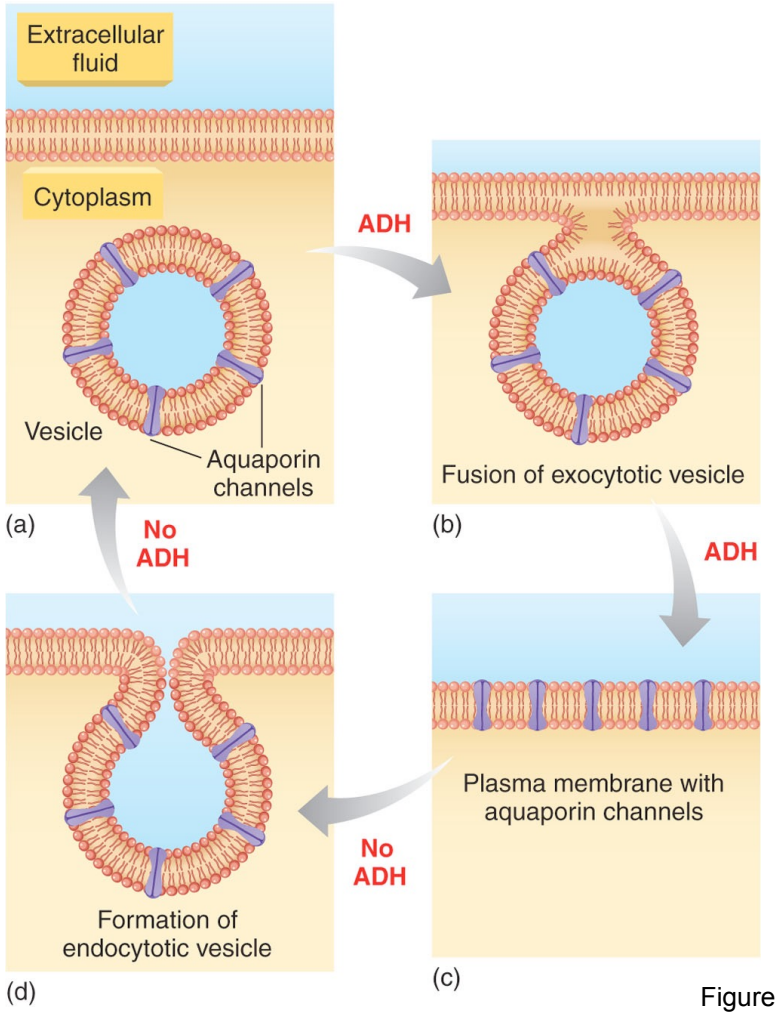
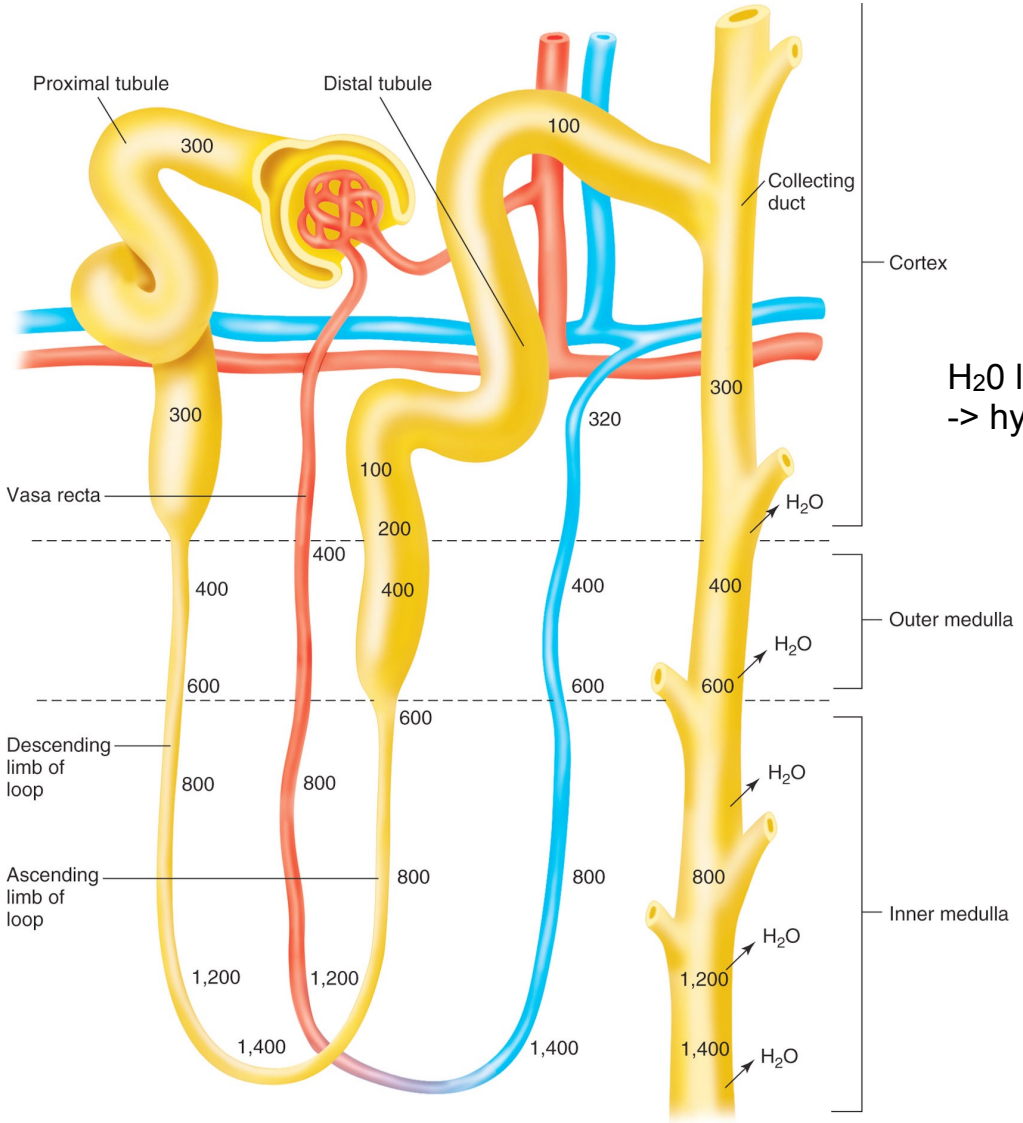


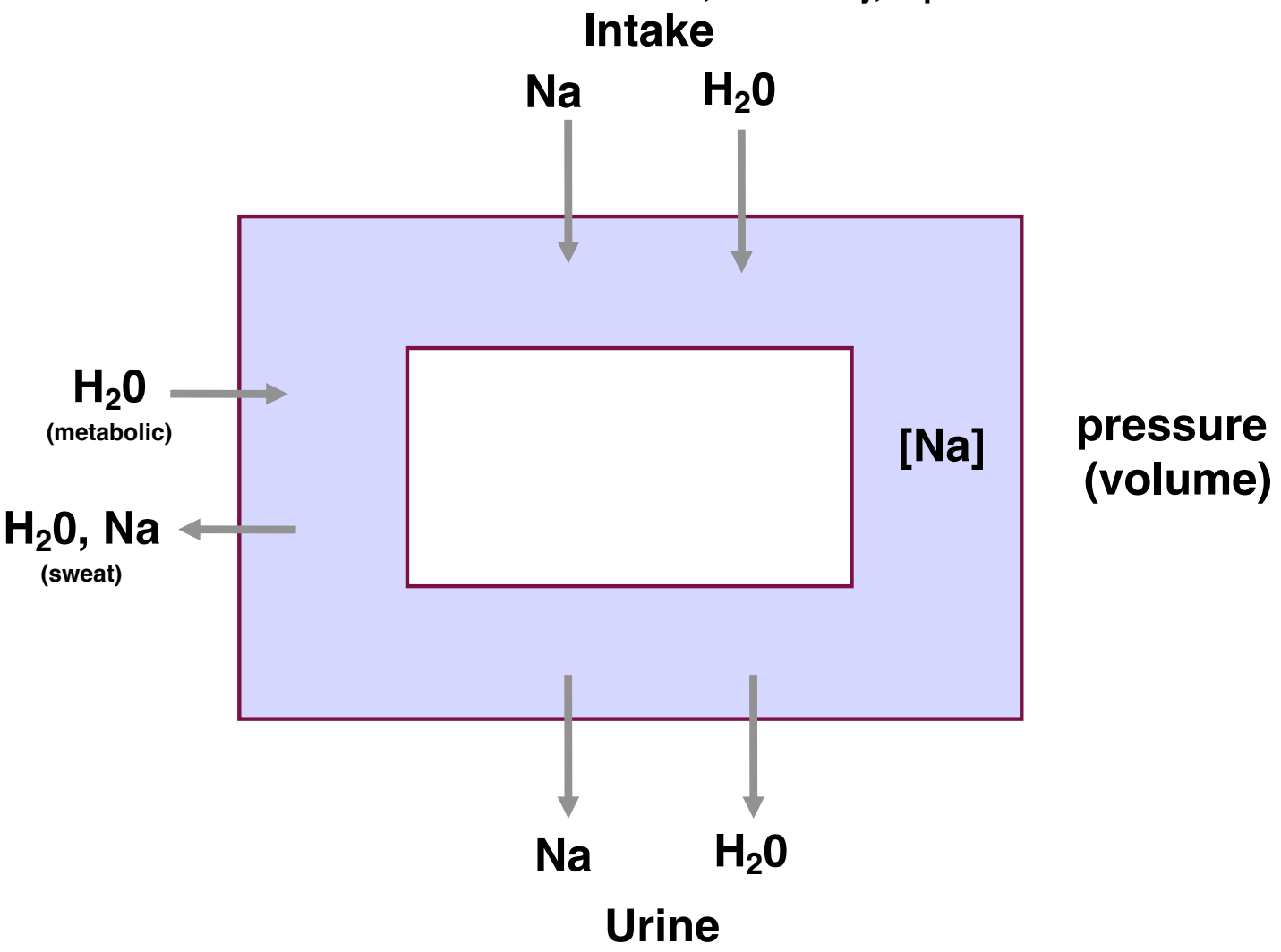
Figure 17.19



H_20 leaves collecting duct
-> hypertonic medulla

Figure 17.18

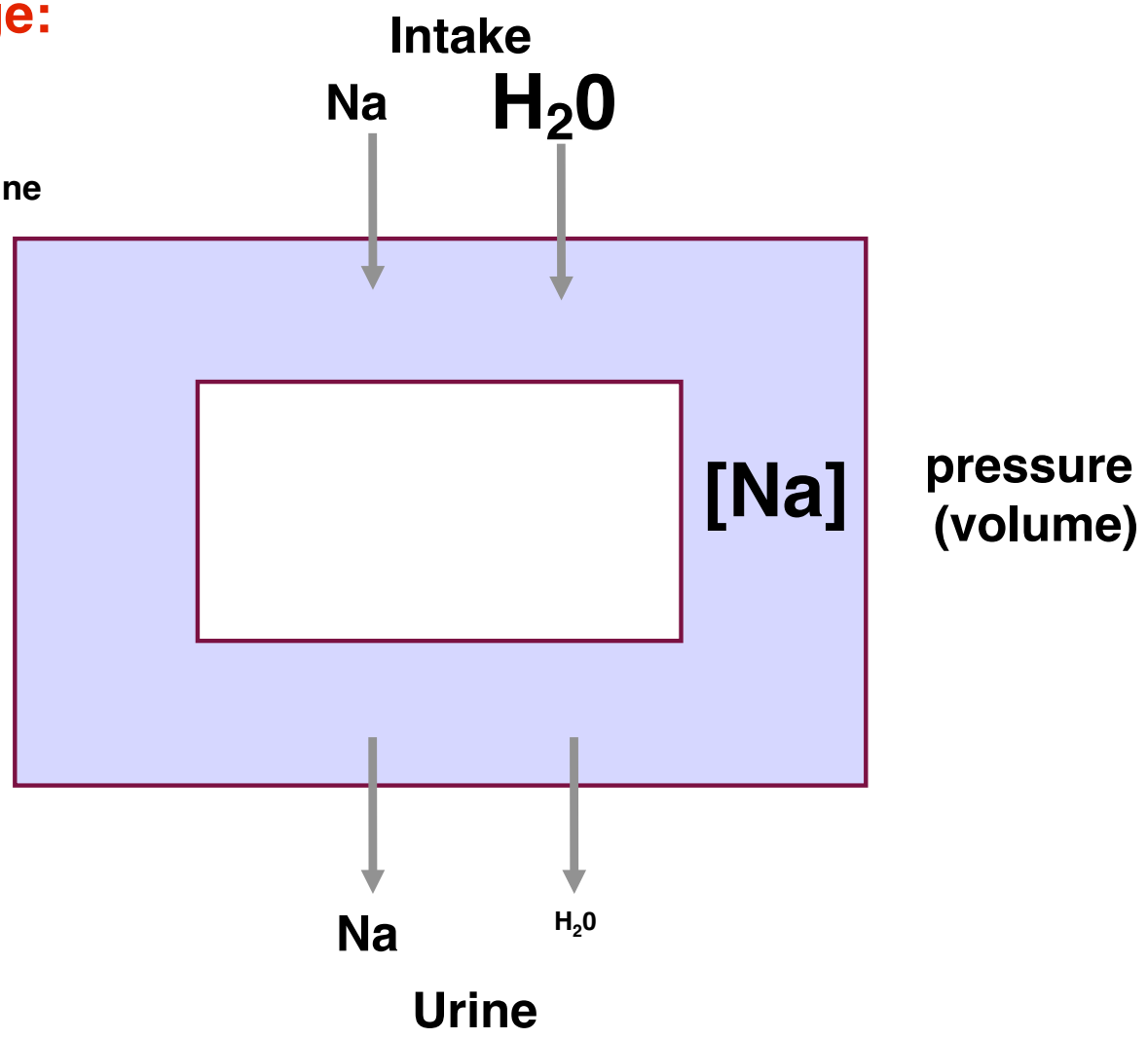
Homeostasis: Maintain constant blood volume, osmolality, & pressure



Osmotic Challenge:

blood too concentrated

increase thirst
reabsorb more H_2O from urine



Osmoreceptors

Cells that respond to changes in plasma osmolality.

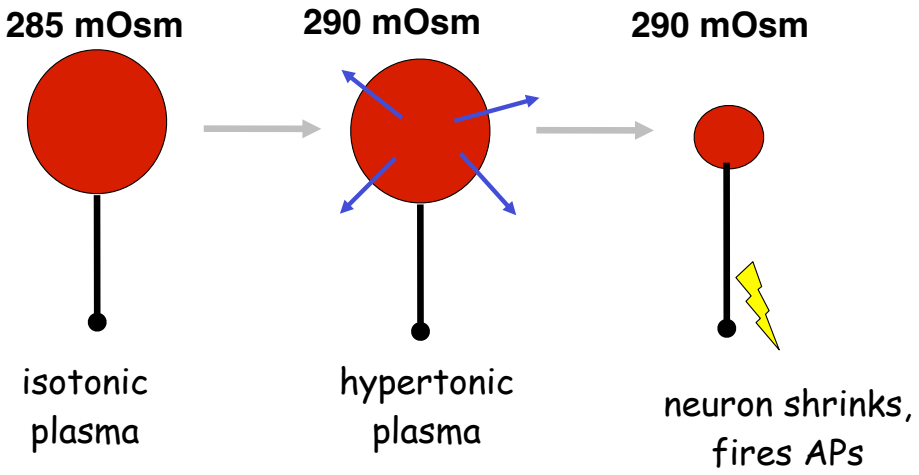
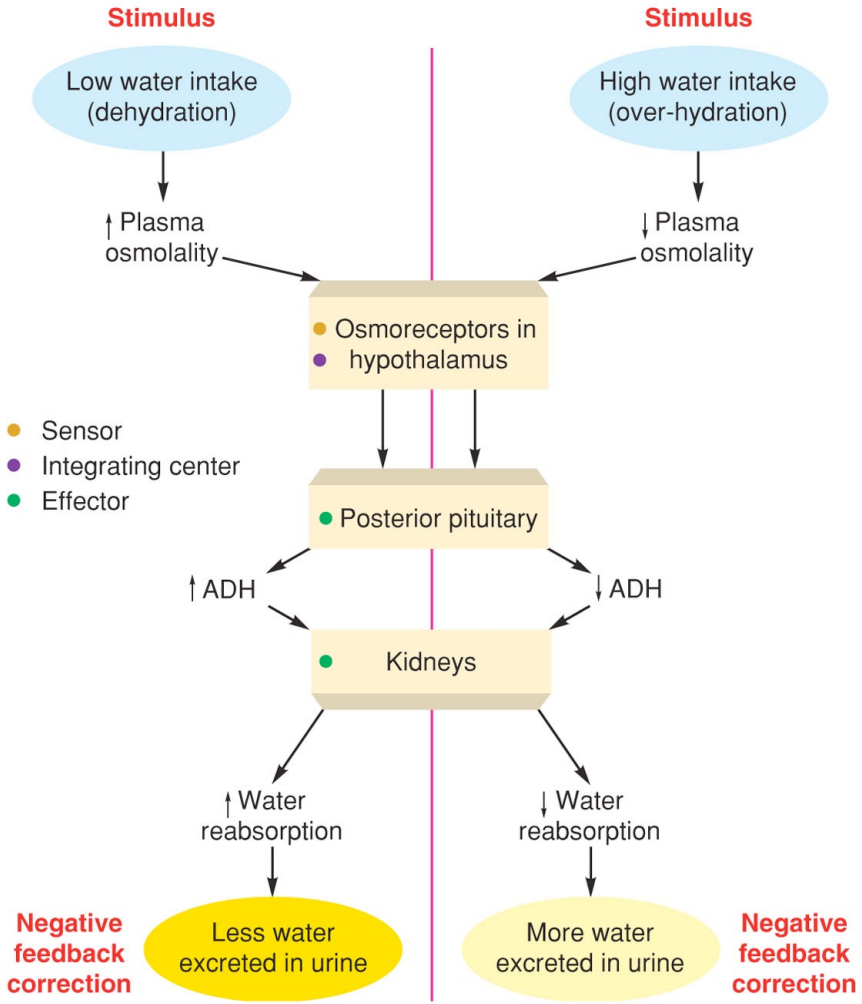
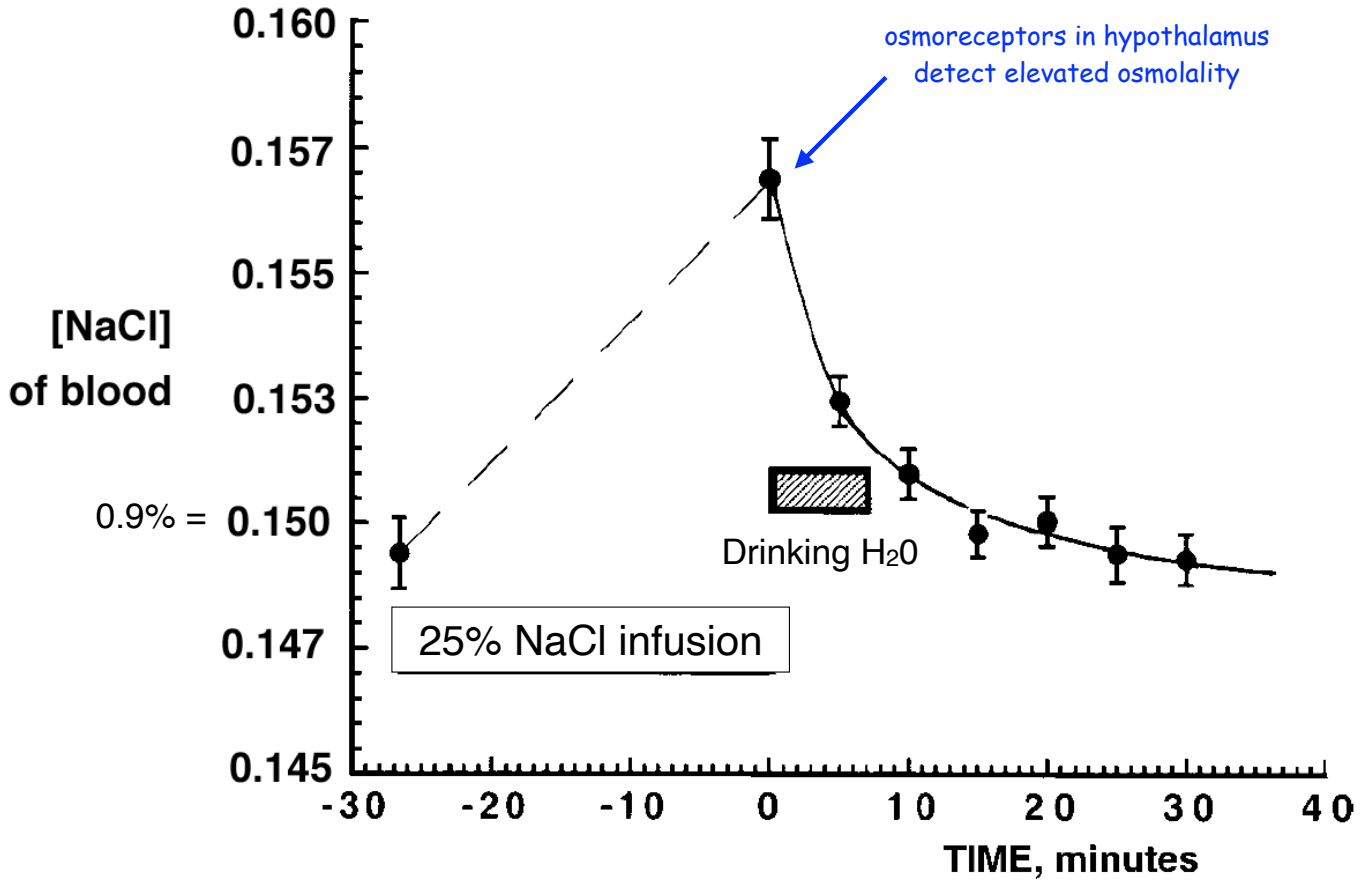


Figure 17.20


Stimulus
Low water intake (dehydration)
↑ Plasma osmolality
Stimulus
High water intake (over-hydration)
↓ Plasma osmolality
Osmoreceptors in hypothalamus
Sensor
Integrating center
Effector
Posterior pituitary
↑ ADH
↓ ADH
Kidneys
↑ Water reabsorption
↓ Water reabsorption
Negative feedback correction
Less water excreted in urine
More water excreted in urine
Negative feedback correction

Elevated [NaCl] in blood above 0.15 M causes drinking in pigs



Diabetes Insipidus

Overproduction of very dilute (*insipid*) urine

Caused by loss of ADH function, so no water reabsorbed in the collecting ducts.

Excrete 25 L of urine /day (**polyuria**, frequent urination)

Osmoreceptors in hypothalamus still generate thirst (**polydipsia**, frequent drinking)

Central Diabetes Insipidus:
caused by damage to cells or fibers in posterior pituitary that produce ADH (e.g. tumors, autoimmune diseases).

Nephrogenic Diabetes Insipidus:
caused by lack of ADH receptors on the collecting ducts of the kidney.

Treatment:
Replacement with synthetic ADH.

Diabetes Insipidus: lack of ADH or its receptors

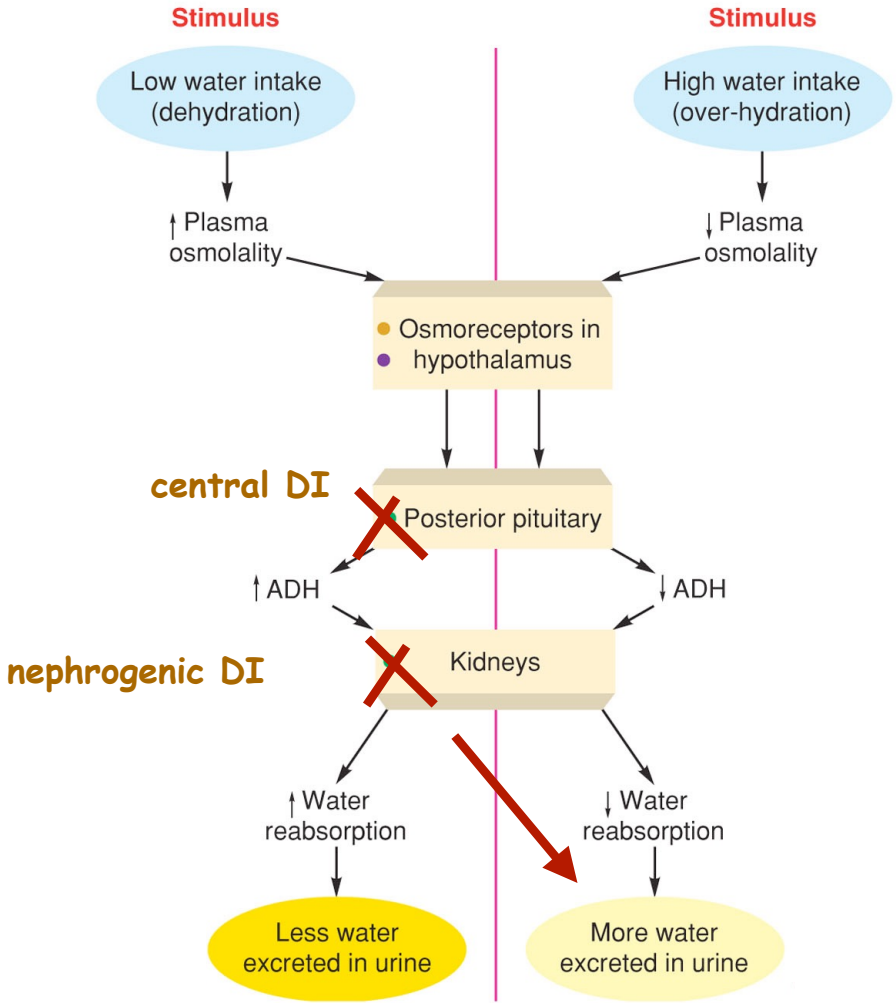
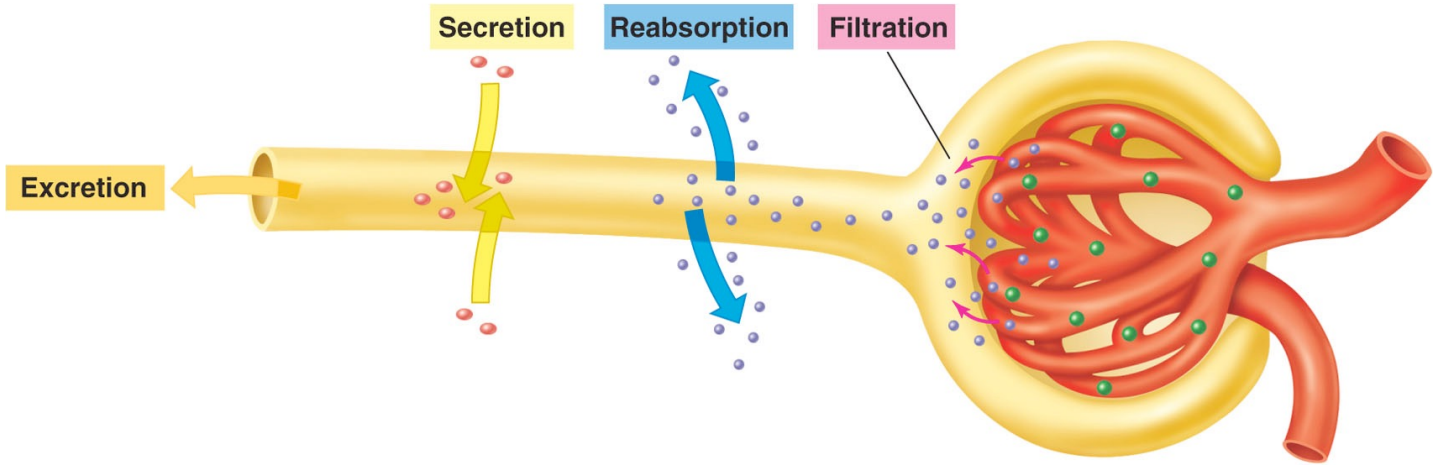


Figure 17.21

1. Filter plasma and water soluble chemicals **from** blood into urine

2. Reabsorb and return needed chemicals from urine and back to blood

3. Secrete additional chemicals into the urine

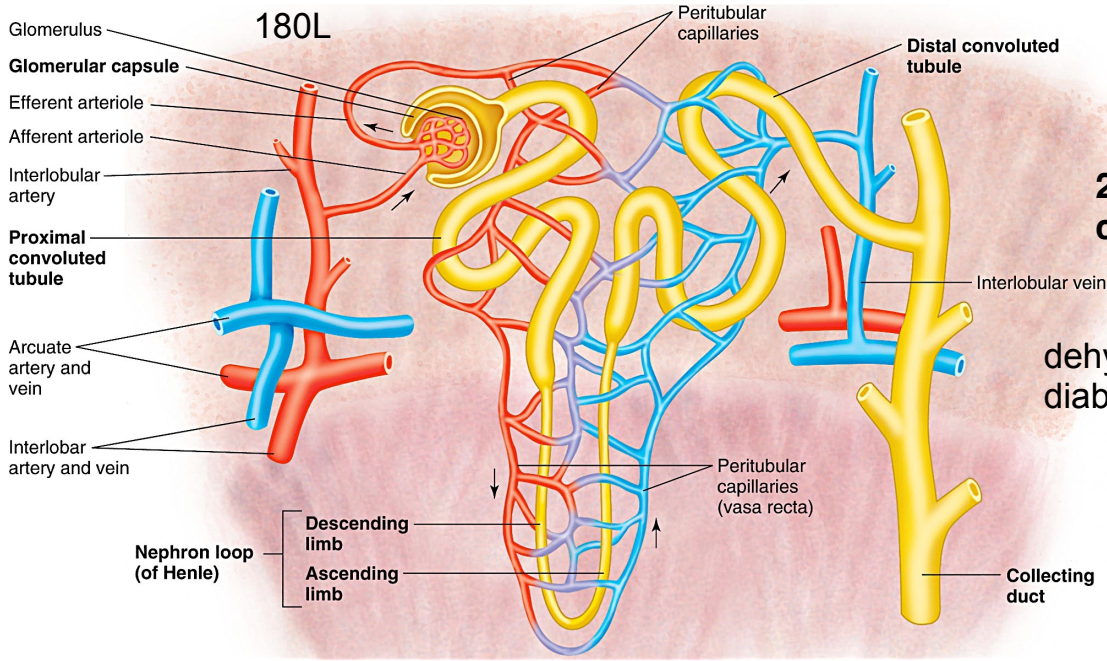


30% of plasma filtered out with each pass
all blood filtered within 40 min
180L filtered out every day

Figure 17.5

plasma filtered by glomerulus = 100% filtrate

85% reabsorbed from **proximal tubule**.



2% reabsorbed from **collecting duct**

dehydration: 3%
diabetes insipidus: 0%

12% reabsorbed from **loop of Henle**

1% excreted as urine

~1.5L

dehydration: 0.4 L
diabetes insipidus: 10L

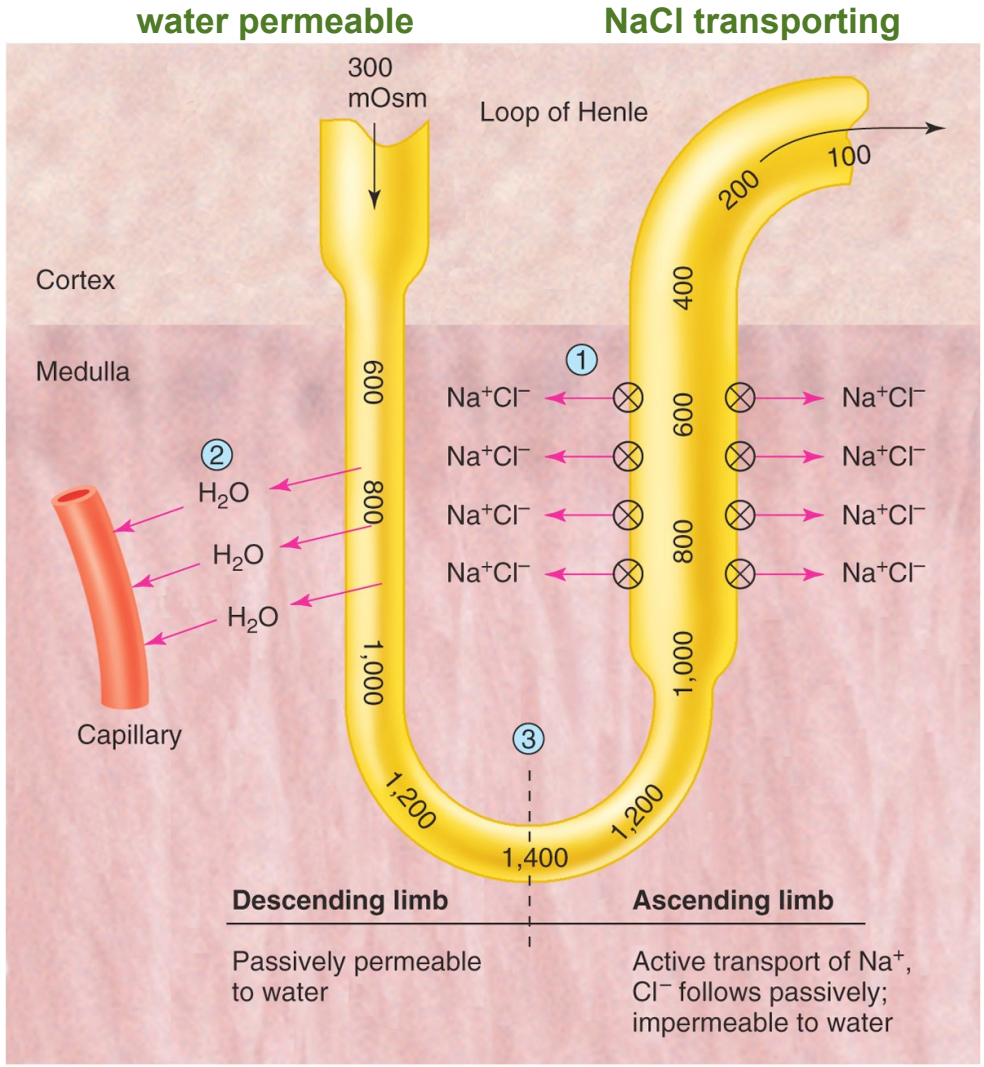
Table 17.2

Table 17.2 | Transport Properties of Different Segments of the Renal Tubules and the Collecting Ducts

Nephron Segment	Active Transport	Passive Transport		
		Salt	Water	Urea
Proximal tubule	Na^+	Cl^-	Yes	Yes
Descending limb of Henle's loop	None	Maybe	Yes	No
Thin segment of ascending limb	None	NaCl	No	Yes
Thick segment of ascending limb	Na^+	Cl^-	No	No
Distal tubule	Na^+	Cl^-	No**	No
Collecting duct*	Slight Na^+	No	Yes (ADH) or slight (no ADH)	Yes

*The permeability of the collecting duct to water depends on the presence of ADH.
**The last part of the distal tubule, however, is permeable to water.

Figure 17.14


water permeable
NaCl transporting
300 mOsm
Loop of Henle
Cortex
Medulla
100
200
400
600
800
1,000
1,200
1,400
1,200
1,000
800
600
1
2
3
Na+Cl−
H2O
H2O
H2O
Capillary
Descending limb
Passively permeable to water
Ascending limb
Active transport of Na+, Cl− follows passively; impermeable to water

Diabetes Insipidus

Overproduction of very dilute (*insipid*) urine

Caused by loss of ADH function, so no water reabsorbed in the collecting ducts.

Excrete 25 L of urine /day (**polyuria**, frequent urination)

Osmoreceptors in hypothalamus still generate thirst (**polydipsia**, frequent drinking)

Central Diabetes Insipidus:
caused by damage to cells or fibers in posterior pituitary that produce ADH (e.g. tumors, autoimmune diseases).

Nephrogenic Diabetes Insipidus:
caused by lack of ADH receptors on the collecting ducts of the kidney.

Treatment:
Replacement with synthetic ADH.

Reabsorption of Sodium: Role of Aldosterone

90% of Na+ is reabsorbed by proximal tubule and ascending loop of Henle (constant rate).

Distal convoluted tubule and collecting duct can reabsorb variable amount of Na+. Regulated by the steroid hormone **aldosterone**, from the adrenal cortex.

Average Na+ intake: 3.4 g/day
Normal range of Na+ excretion: 1 - 5 g/day

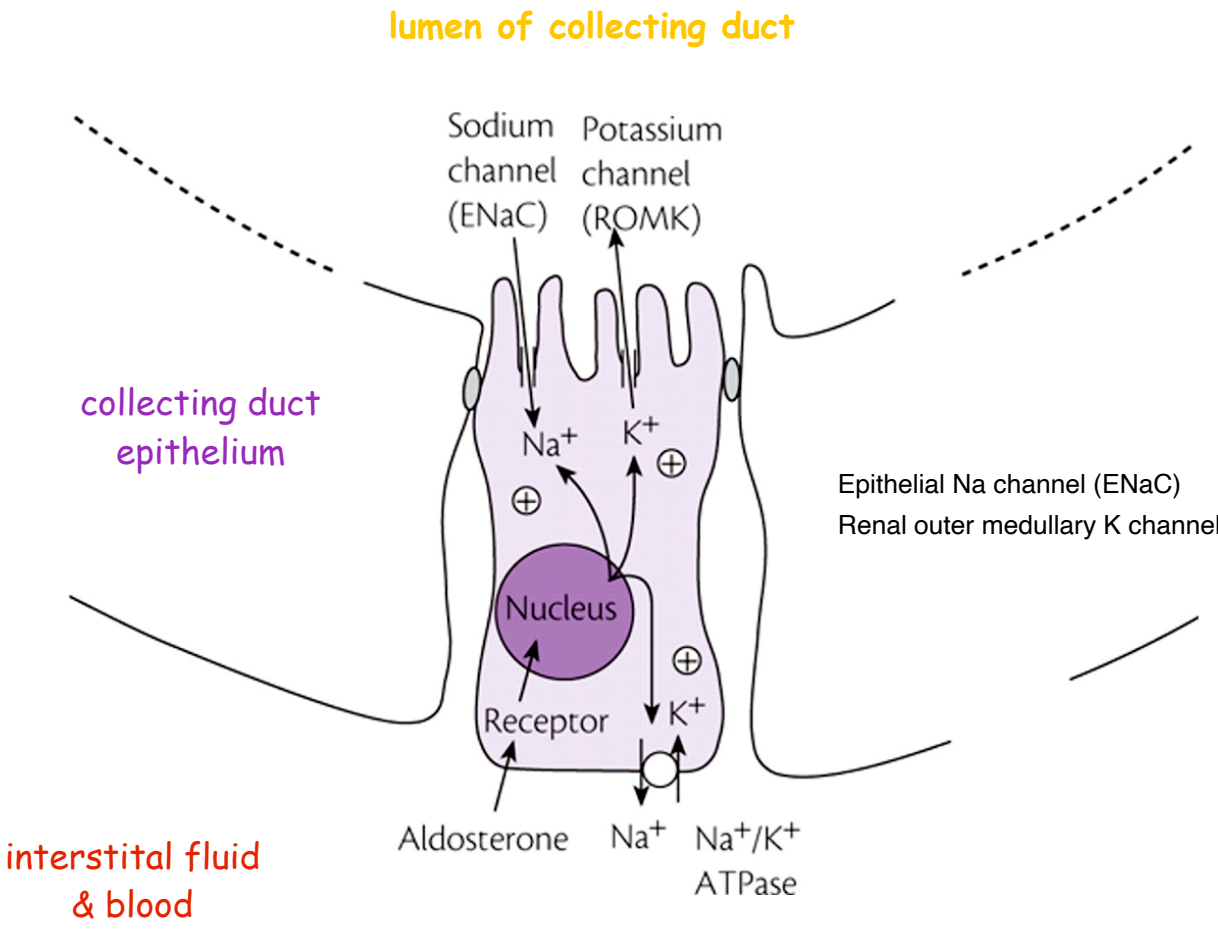
Without Aldosterone:
80% (of remaining 90%) Na+ absorbed by distal convoluted tubule.
So only 2% of filtered Na+ excreted into urine —> **30g** of Na+ excreted per day.

With Maximal Aldosterone:
All remaining Na+ reabsorbed in collecting duct —> **0g** Na+ in the urine.

Aldosterone also stimulates **K+ secretion** into collecting duct, so that plasma K+ remains constant.

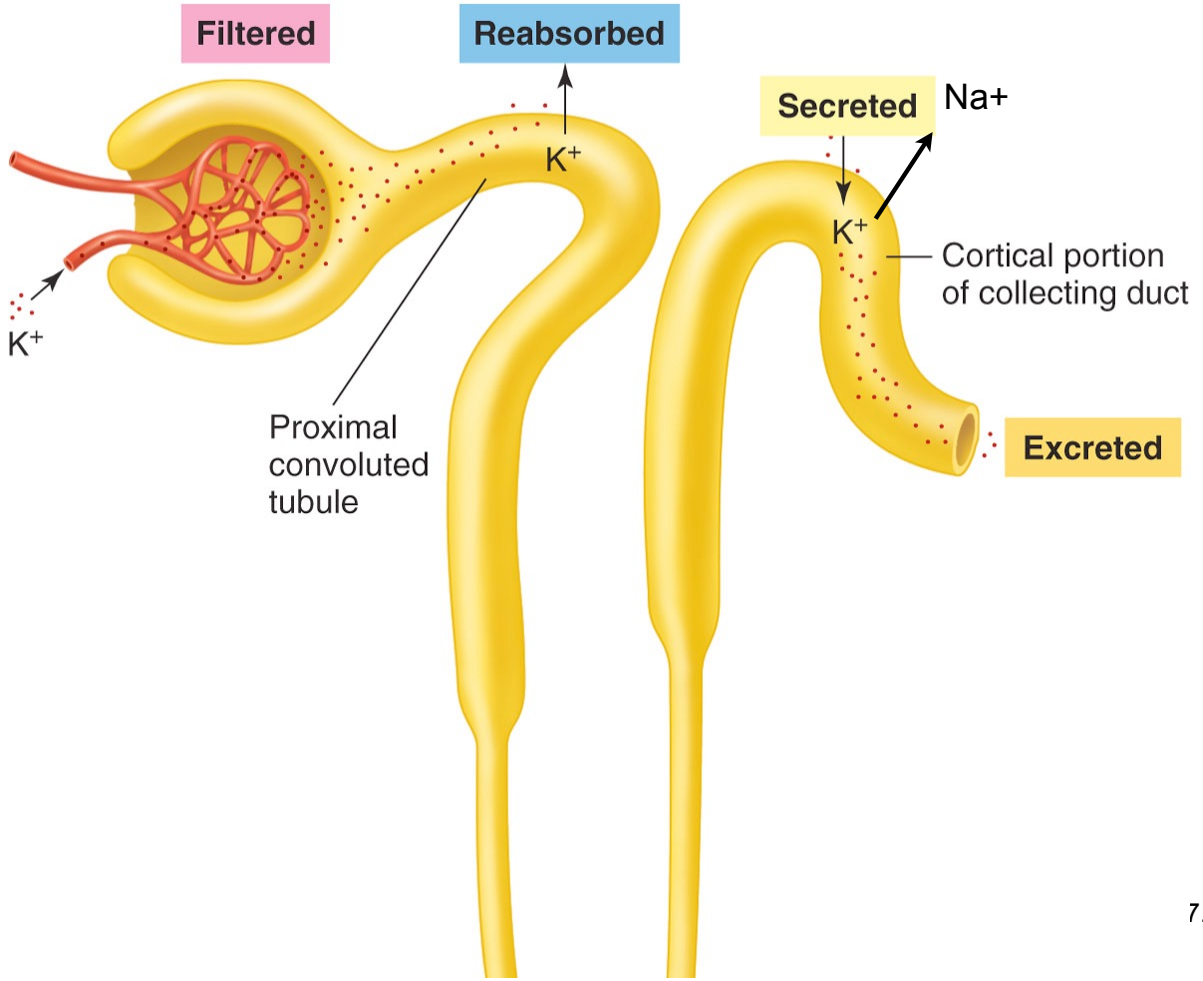
complete loss of aldosterone -> hyponatremia and hyperkalemia

Aldosterone induces synthesis of Na+ and K+ channels in collecting duct epithelium



Epithelial Na channel (ENaC)
Renal outer medullary K channel (ROMK)

Oxford Textbook of Medicine Online


Filtered
Reabsorbed
Secreted
Na+
K+
K+
K+
Cortical portion
of collecting duct
Proximal
convoluted
tubule
Excreted

Reabsorption of Sodium: Role of Aldosterone

Low blood pressure

-> activation of baroreceptors in **juxtaglomerular apparatus**

-> secretion of renin

-> angiotensin I -> angiotesin II (via ACE: angiotensin-converting enzyme)

-> aldostereone secretion by adrenal cortex

-> more sodium channels in collecting duct

-> more sodium retention

-> higher blood pressure

complete loss of aldosterone -> hyponatremia and hyperkalemia

Figure 17.26

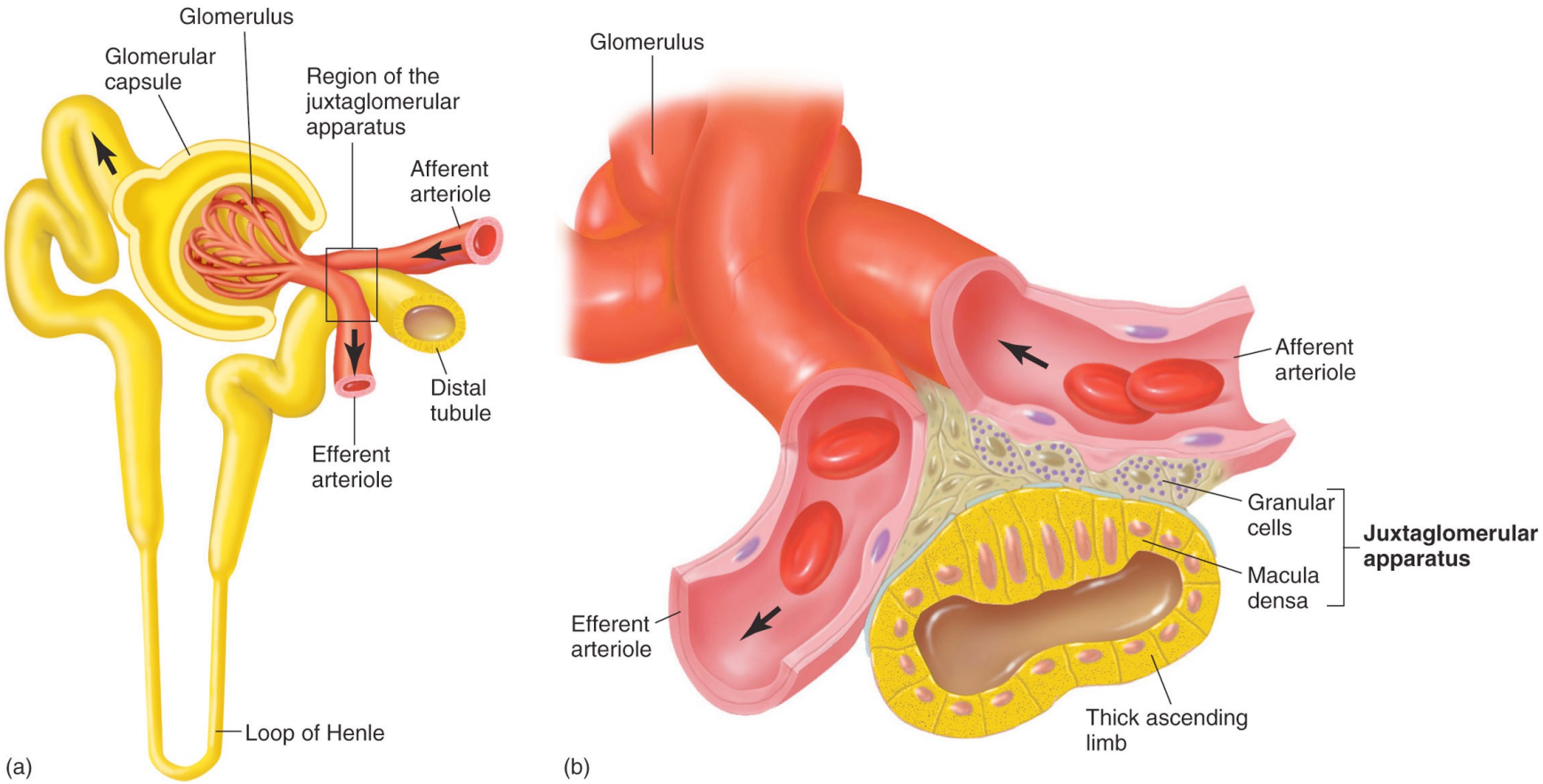
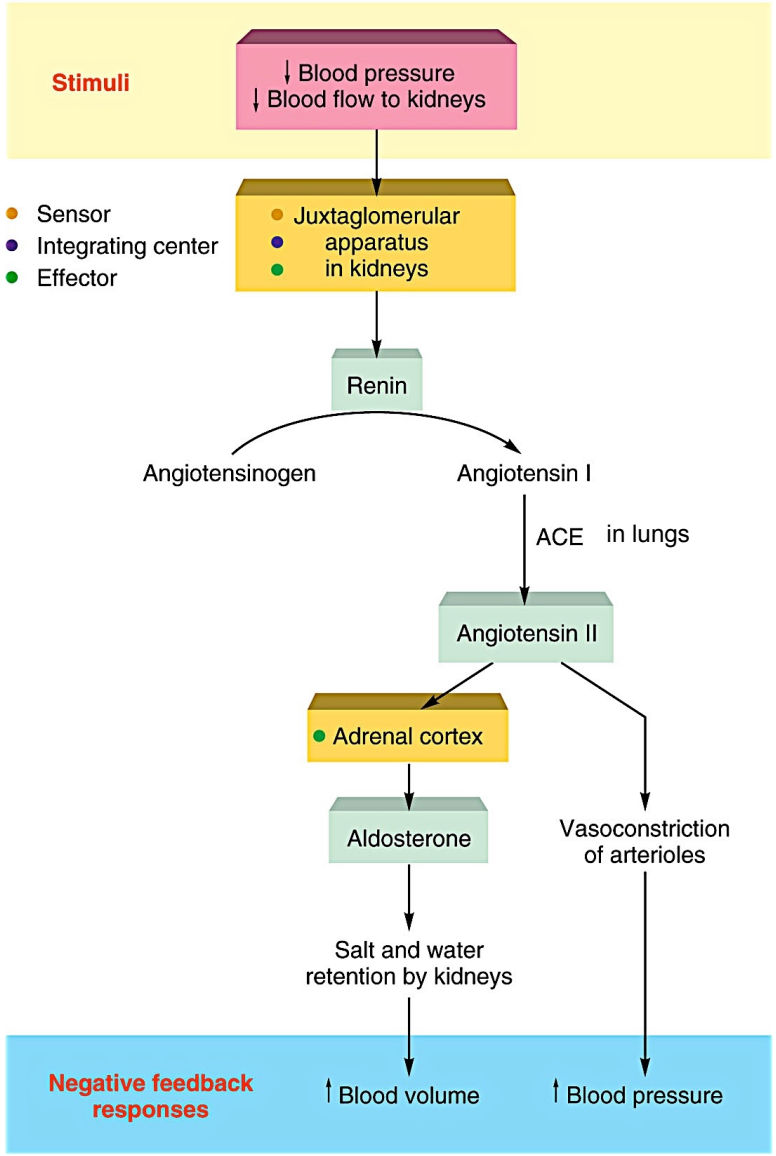
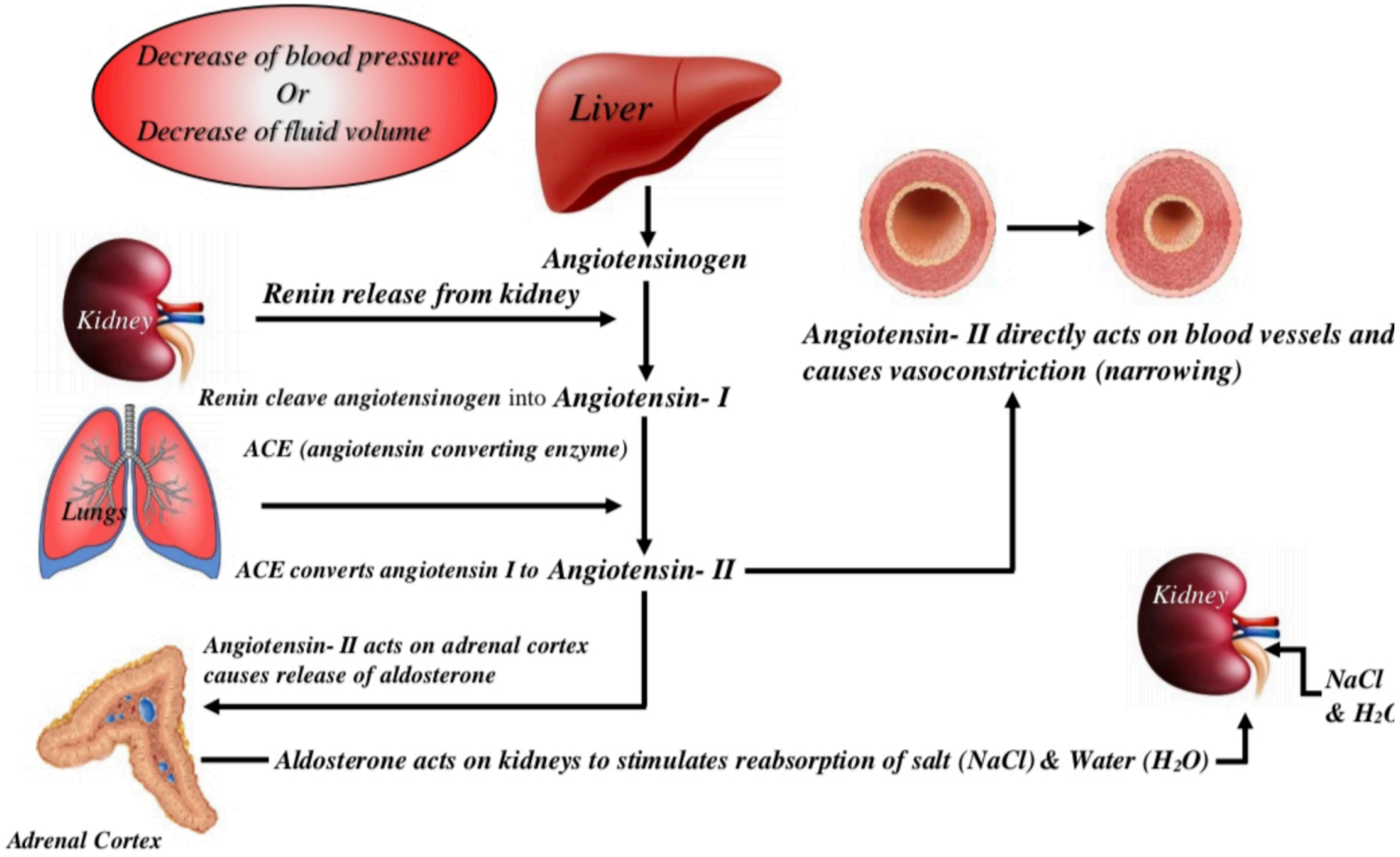
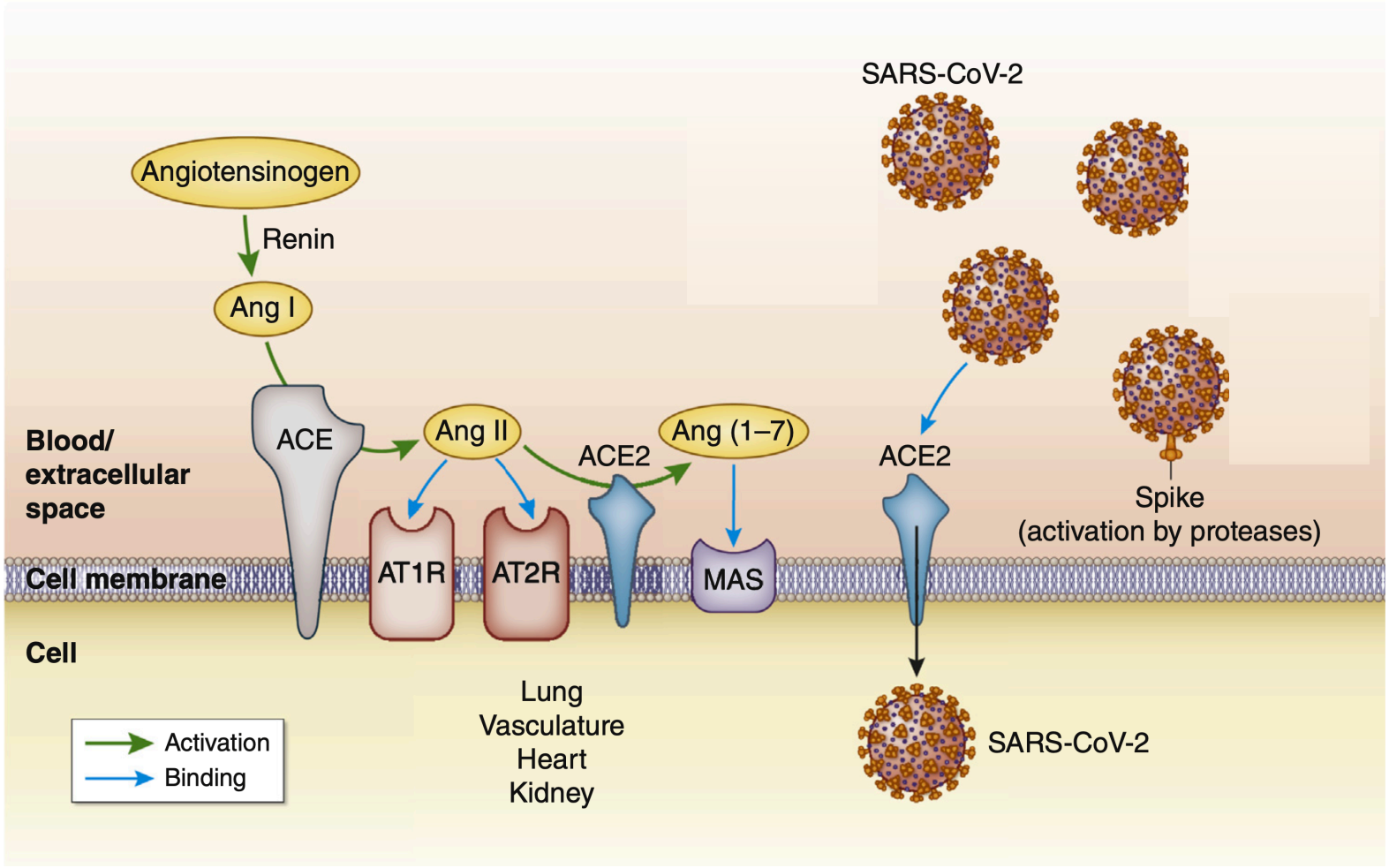

Glomerulus
Glomerular capsule
Region of the juxtaglomerular apparatus
Afferent arteriole
Distal tubule
Efferent arteriole
Loop of Henle
(a)
Glomerulus
Afferent arteriole
Granular cells
Juxtaglomerular apparatus
Macula densa
Efferent arteriole
Thick ascending limb
(b)

Figure 14.12


Stimuli
↓ Blood pressure
↓ Blood flow to kidneys
Sensor
Integrating center
Effector
Juxtaglomerular apparatus in kidneys
Renin
Angiotensinogen
Angiotensin I
ACE in lungs
Angiotensin II
Adrenal cortex
Aldosterone
Vasoconstriction of arterioles
Salt and water retention by kidneys
Negative feedback responses
↑ Blood volume
↑ Blood pressure



Flow chart of Renin-Angiotensin- Aldosterone System (RAAS)



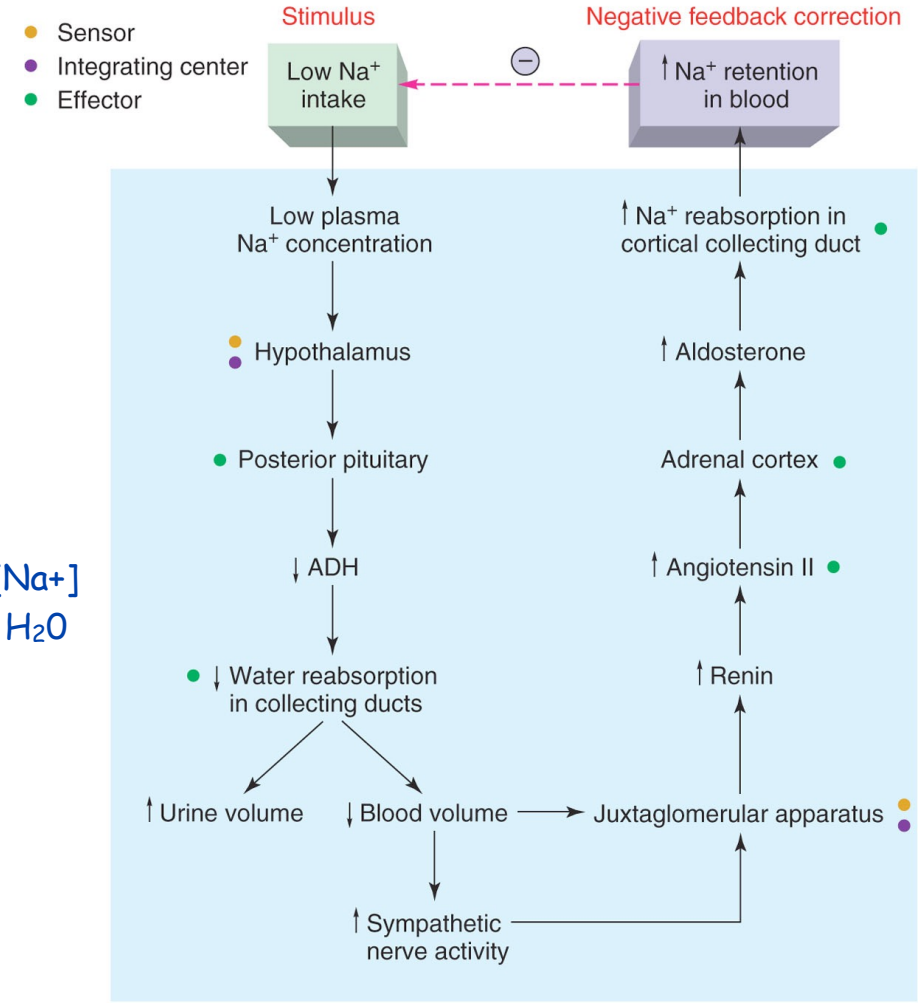
Kidney International (2020) 97, 1091–1096

Table 17.6

Table 17.6 | Regulation of Renin and Aldosterone Secretion

Stimulus	Effect on Renin Secretion	Angiotensin II Production	Aldosterone Secretion	Mechanisms
↓Blood volume	Increased	Increased	Increased	Low blood volume stimulates renal baroreceptors; granular cells release renin.
↑Blood volume	Decreased	Decreased	Decreased	Increased blood volume inhibits baroreceptors; increased Na^+ in distal tubule acts via macula densa to inhibit release of renin from granular cells.
↑ K^+	None	Not changed	Increased	Direct stimulation of adrenal cortex
↑Sympathetic nerve activity	Increased	Increased	Increased	α-adrenergic effect stimulates constriction of afferent arterioles; β-adrenergic effect stimulates renin secretion directly.

Integrated action of ADH & Aldosterone to increase plasma [Na+]

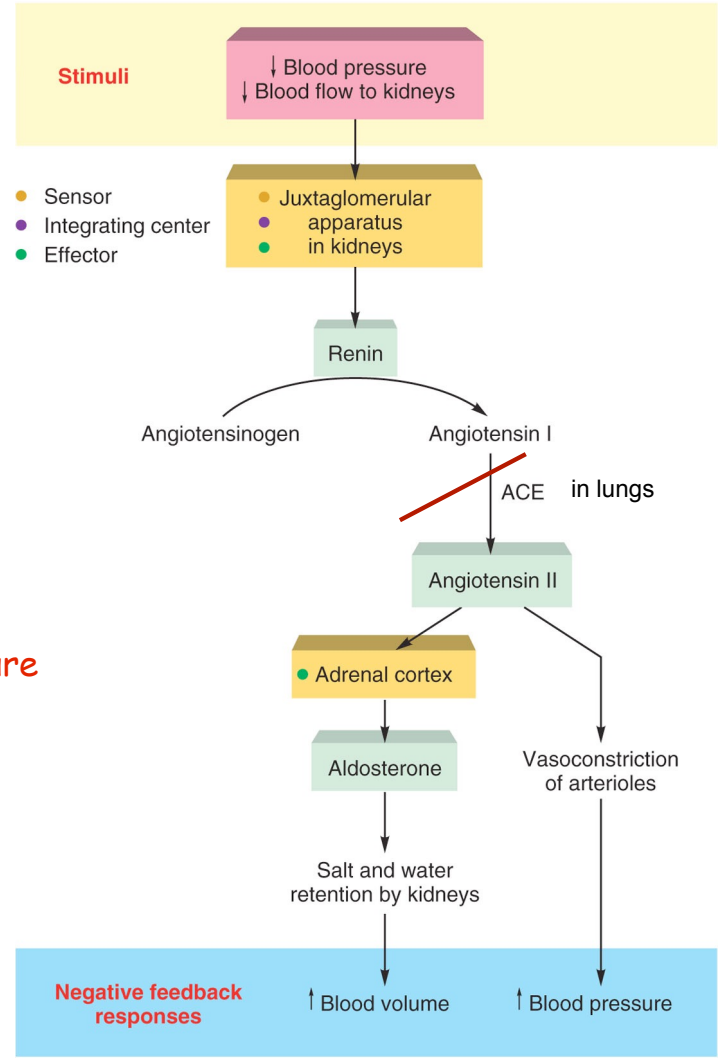


increase [Na+] by losing H_2O

increase [Na+] by reabsorbing more Na+

Figure 17.27

Figure 14.12



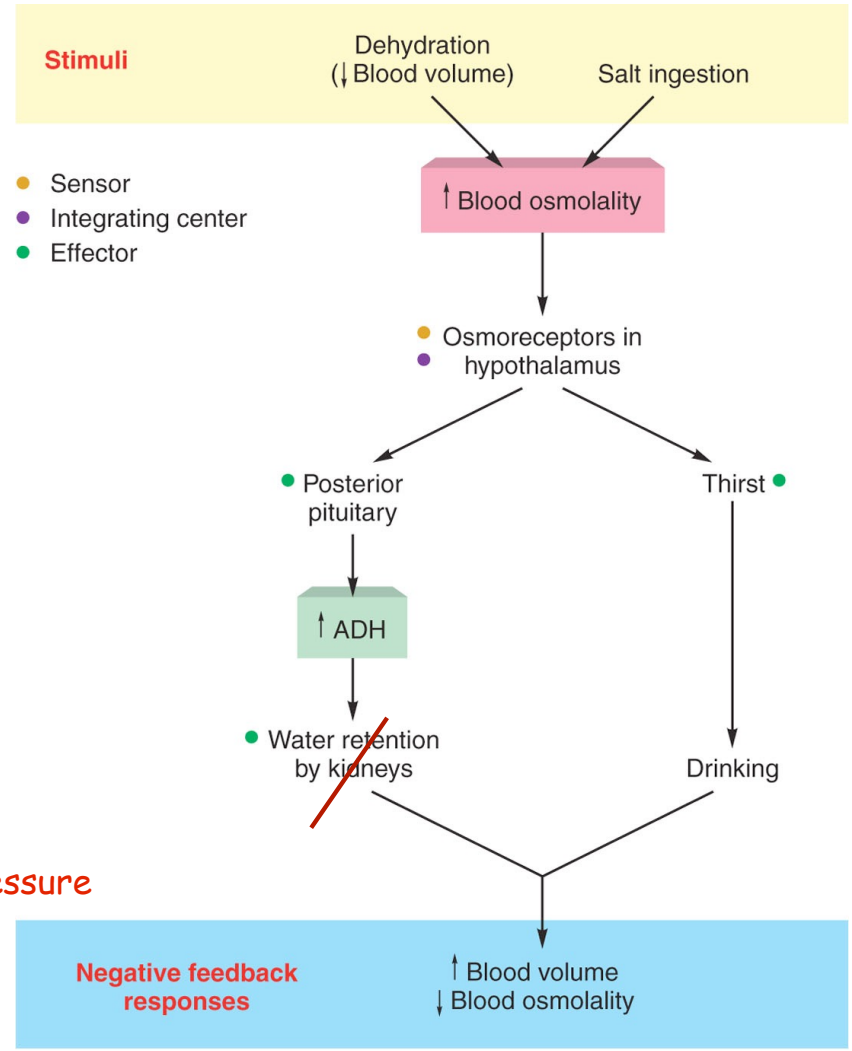
ACE inhibitors

↓

lower blood pressure

angiotensin converting enzyme (ACE)

Figure 14.11



diuretics

↓

lower blood pressure

Diuretics

Drugs that increase urine volume

indirectly lower blood pressure & decrease edema

Increase urine volume by increasing proportion of glomerular filtrate that is excreted (i.e. GFR stays the same, but less water is reabsorbed along the nephron)

Loop Diuretics (e.g. Lasix)
block salt & water reabsorption out of the ascending loop of Henle

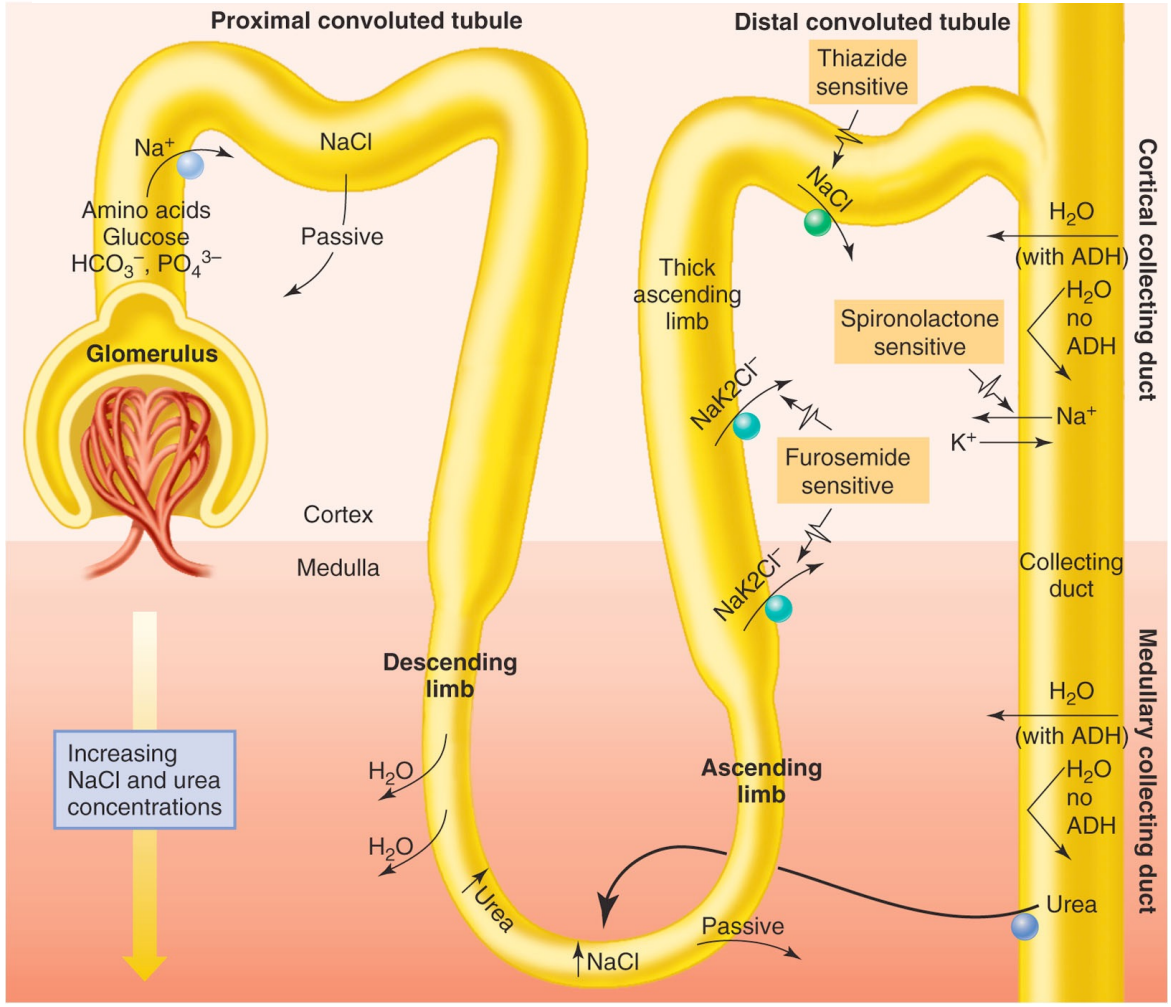
thiazide diuretics
inhibit salt & water reabsorption in distal convoluted tubule

Carbonic Anhydrase Inhibitors:
block bicarbonate & water reabsorption in proximal tubule

Osmotic diuretics (e.g. the sugar mannitol)
filtered by glomerulus but not reabsorbed, so draw more water into tubule

Potassium Sparing Diuretics
Block aldosterone action, so Na+ excreted but K+ retained

Figure 17.30


Proximal convoluted tubule
Distal convoluted tubule
Thiazide sensitive
NaCl
Na^+
Amino acids
Glucose
HCO_3^-, PO_4^{3-}
NaCl
Passive
H_2O
(with ADH)
Thick ascending limb
H_2O no ADH
Spironolactone sensitive
Glomerulus
NaK2Cl
Na^+
K^+
Furosemide sensitive
Cortex
Medulla
NaK2Cl
Collecting duct
Descending limb
H_2O
(with ADH)
Increasing NaCl and urea concentrations
H_2O
Ascending limb
H_2O
no ADH
H_2O
Urea
Urea
Passive
NaCl
Cortical collecting duct
Medullary collecting duct