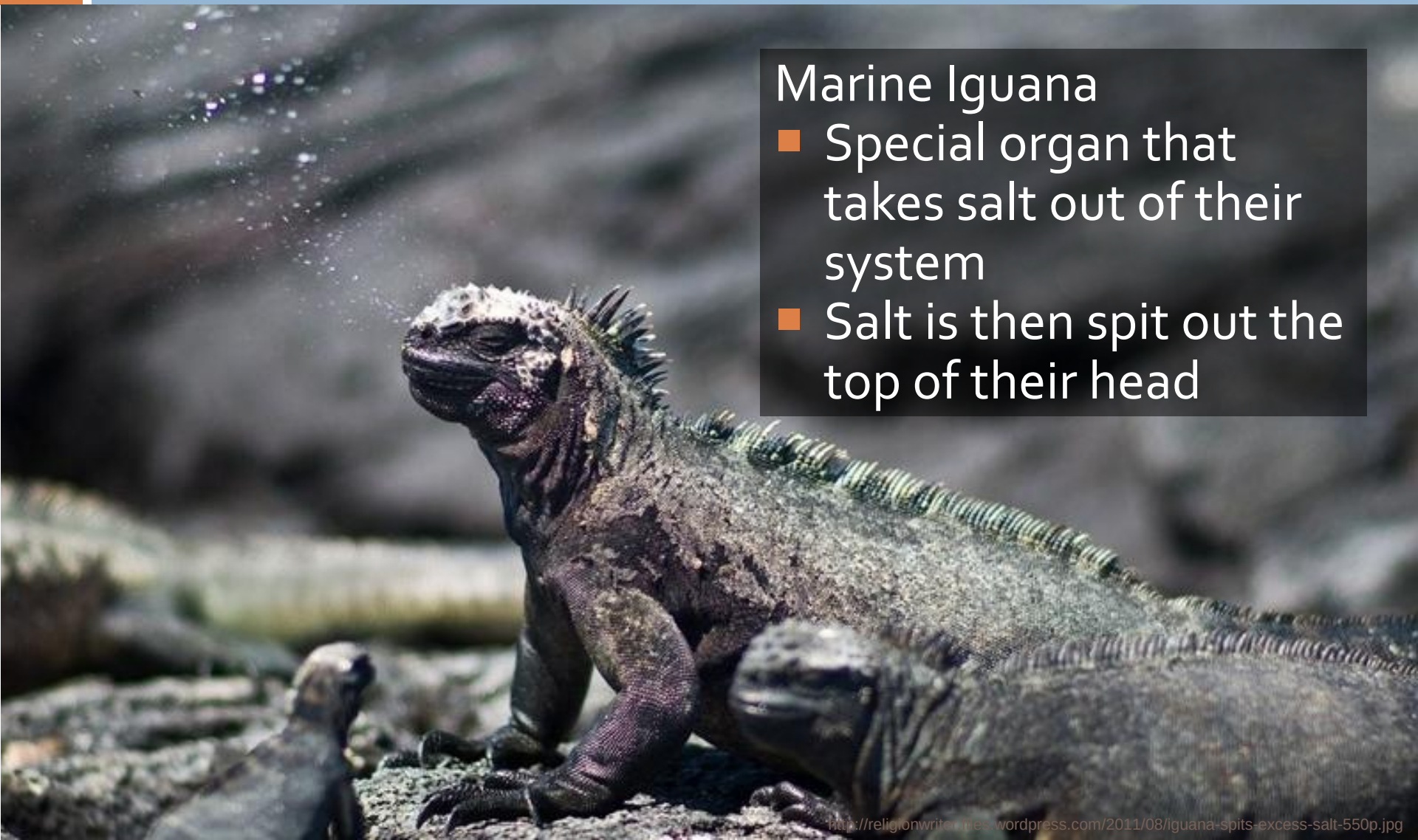
Osmoregulation

Osmoregulators
Human osmoregulation

Osmoregulation

- Management of the body's water content (blood volume and thus blood pressure)
- Management of solute composition (body fluid composition, metabolite concentration, blood pH levels)
- Control movements of solutes between internal fluids and external environment (excretion of metabolic waste)

Example of Osmoregulator



Marine Iguana

- Special organ that takes salt out of their system
- Salt is then spit out the top of their head

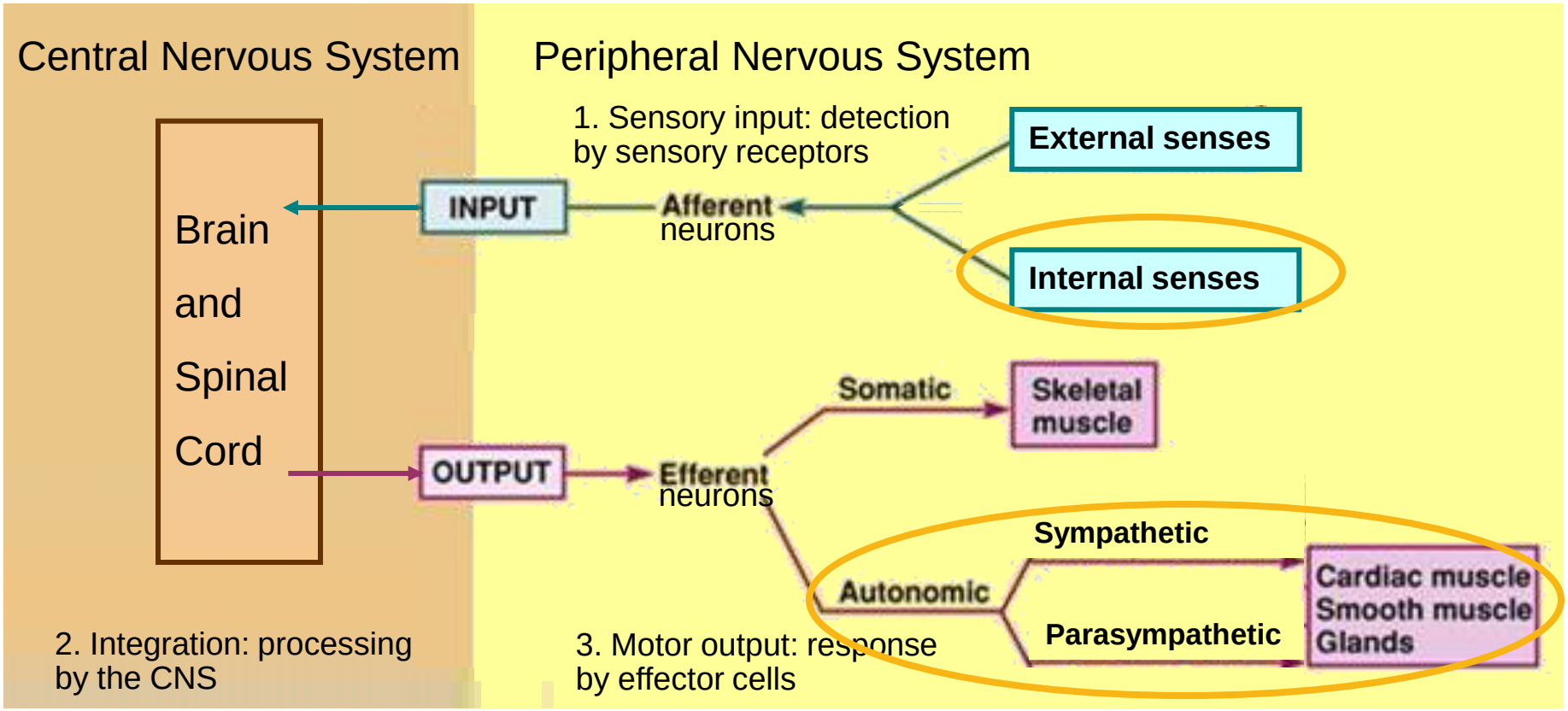
http://religionwriter.files.wordpress.com/2011/08/iguana-spits-excess-salt-550p.jpg

Example of Osmoregulator

Osmoregulation in Humans

- Excretory system is regulated by the endocrine system (hormones used for homeostasis)
- 3 sets of hormones in osmoregulation
  - ADH: antidiuretic hormone
  - RAAS: renin-angiotensin-aldosterone system
  - ANF: atrial natriuretic factor

Osmoregulation: Nervous and Endocrine System



Hormones in Human Osmoregulation

Stimulus	High levels	Low levels
Blood osmolarity	ADH	
Blood pressure & blood volume	ANF	RAAS

Kidney's Effect on Blood

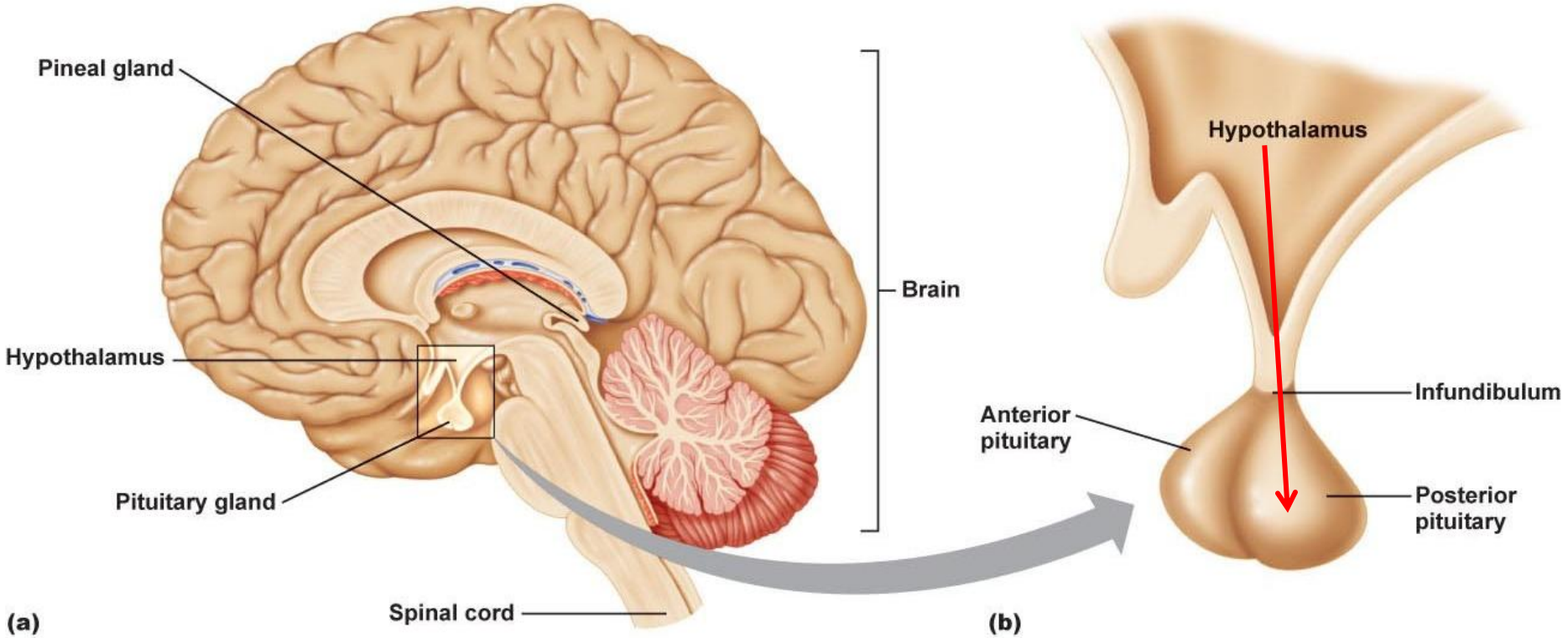
- Osmolarity: solute concentration (that contributes to osmotic pressure)
  - Osmotic pressure: the force applied to prevent osmosis into the solution
- Blood Pressure: pressure on the blood vessels due to pumping of blood
  - Also relates directly to blood volume
- pH Balance

Stimulus: high blood osmolarity

- Stimulus: increase blood osmolarity
  - Detection by osmoreceptors in hypothalamus
  - Sends signal to pituitary to release ADH

Antidiuretic hormone (ADH)

- A short peptide hormone
- Produced by the hypothalamus
- Stored in posterior pituitary gland



Response to high blood osmolarity

- Q: What would be some expected responses of the body to high solute concentration in the blood?
- A: Dilute the blood… but how?

Retain and Intake Water

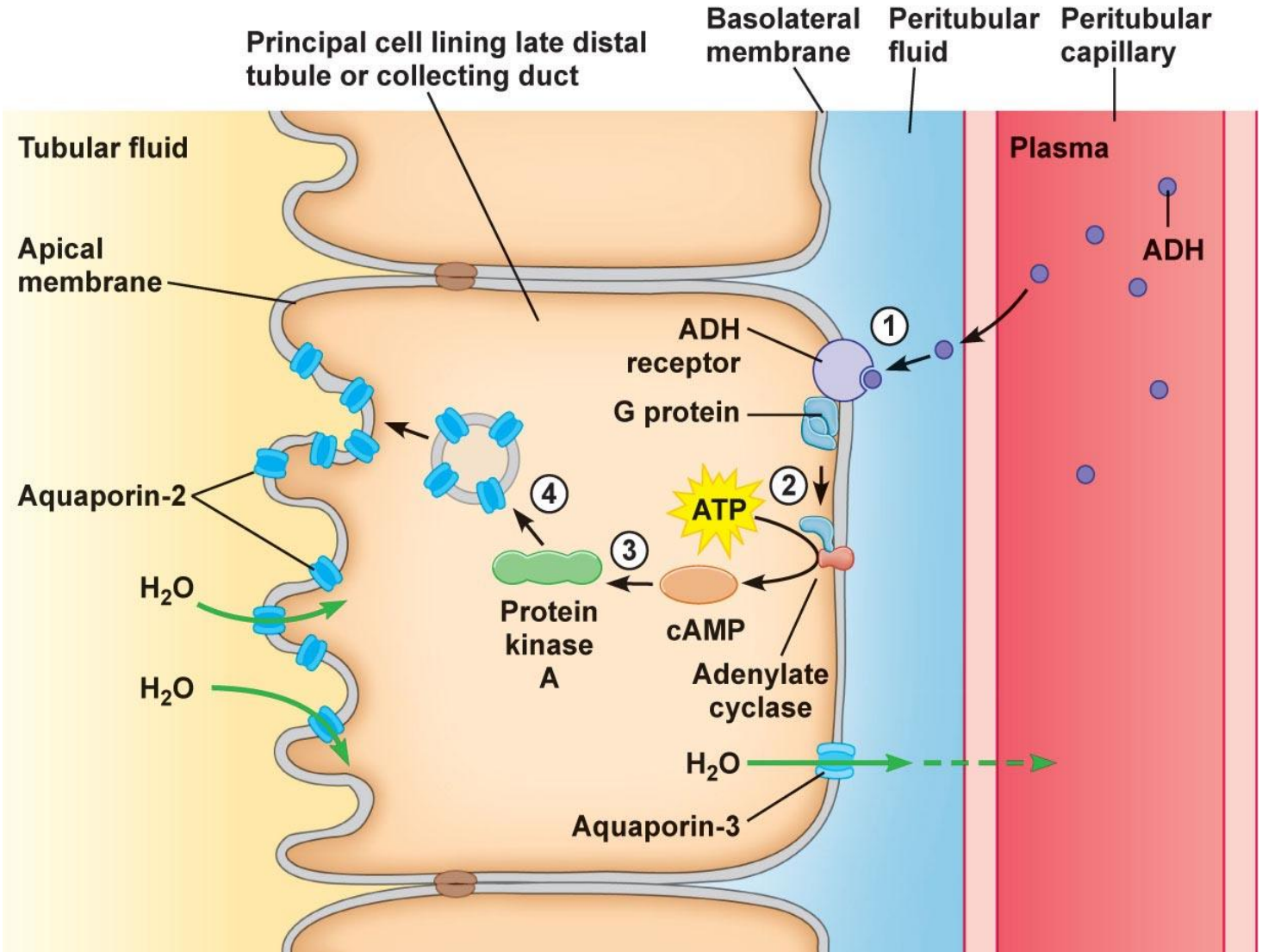
http://apparentlyweareadults.files.wordpress.com/2012/09/gotta-go.png?w=300&h=300

http://images.wisegeek.com/water-glasses.jpg

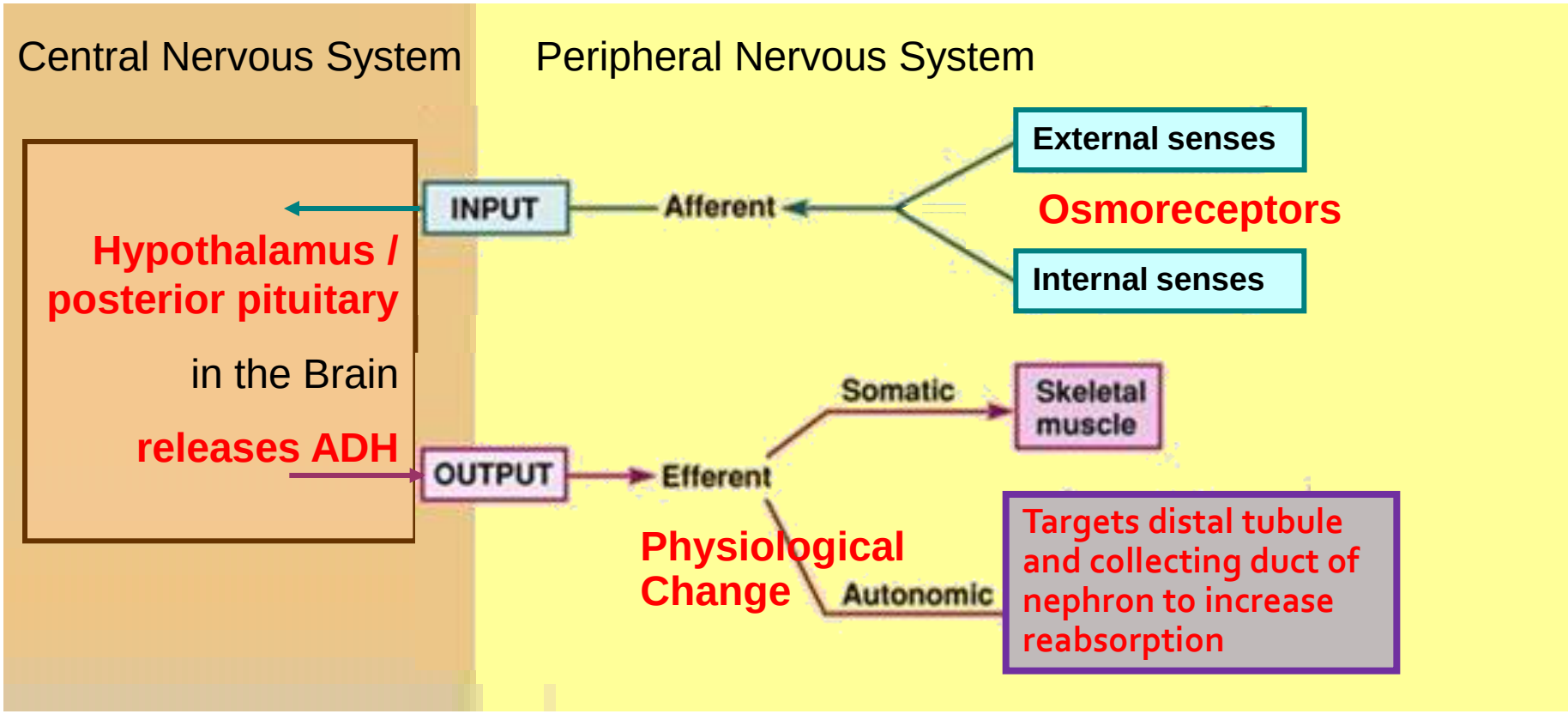
Antidiuretic hormone (ADH)

- It's in the name
- Diuresis: increased urination
- Anitdiuretic:
  - opposes diuresis
  - Less urination
  - Retain water

ADH Target


Principal cell lining late distal tubule or collecting duct
Basolateral membrane
Peritubular fluid
Peritubular capillary
Tubular fluid
Plasma
Apical membrane
ADH
ADH receptor
G protein
Aquaporin-2
ATP
Protein kinase A
cAMP
Adenylate cyclase
H_2O
H_2O
H_2O
Aquaporin-3
1
2
3
4

Nervous System Controls Osmoregulation



Effects of ADH: Retain Water

- Stimulus: increase blood osmolarity
  - Detection by osmoreceptors in hypothalamus
  - Sends signal to pituitary to release ADH
- Target: distal tubule, collecting ducts
  - Increase number of aquaporins for more water reabsorption
  - Increase permeability of epithelium to water
  - increase water **reabsorption** into body / blood

Effects of ADH: Intake Water

- Increase sensation of **thirst**
  - increase volume of water in body / blood

Effects of ADH

- Direct effect:
  - dilution of blood → lowers blood osmolarity
- Side effect:
  - reduces volume of urine
  - more concentrated urine
  - less frequent urination

Source of Osmolarity Disturbances

- What type of situation would cause increased osmolarity?

Source of Osmolarity Disturbances

- Water loss:
  - Sweating
  - Dehydration
  - Diarrhea

Response to high blood osmolarity

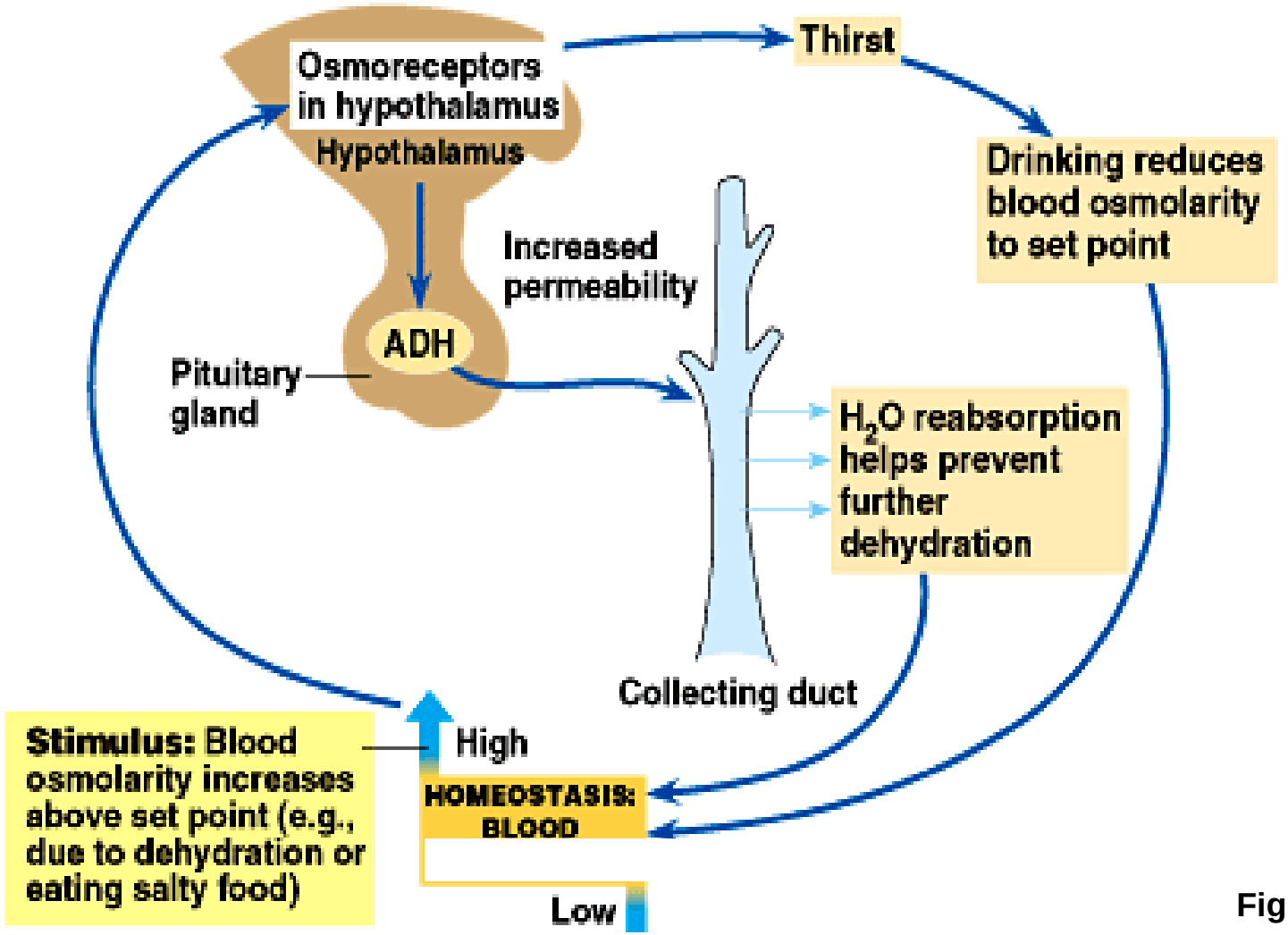
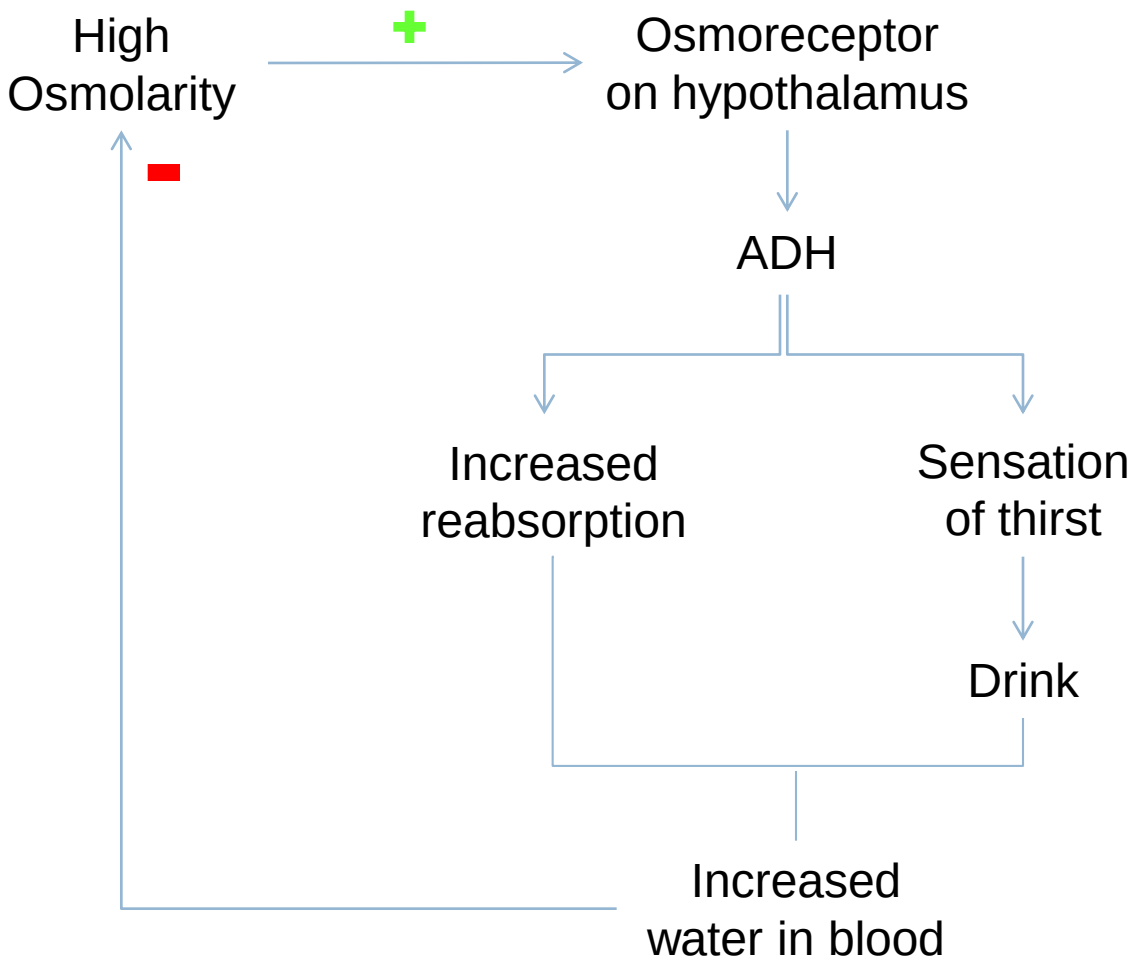


Fig. 44.24a

Negative Feedback on High Osmolarity



Diuretics

- Inhibit the release of ADH
- Effect:
  - less reabsorption of water
  - Increased urine output
- Examples: Alcohol and coffee

Diabetes

- Common symptoms: frequent urination
- Types of diabetes:
  - Mellitus (related to insulin and glucose)
    - Type 1
    - Type 2
  - Insipidus (related to reabsorption)

Diabetes Insipidus

- Cause: deficiency in ADH
- Effect: Inability of kidneys to conserve water
- Symptoms:
  - Dilute urine, frequent urination
  - Excessive thirst
- Treatment:
  - Drinking sufficient water
  - Take ADH medication
- Not the same as diabetes mellitus: urine does not contain glucose and is not sweet

Response to low blood pressure and low blood volume

- Q: What would be some expected responses of the body to
  - low blood pressure?
  - low blood volume?
- A: Increase it… but how?

Constrict area and Retain water

http://victorianparis.files.wordpress.com/2011/02/belle-epoque-corset1.jpg

RAAS: Responds to low blood pressure and blood volume

- Named after the hormones involved
  - Renin
  - Angiotensin
  - Aldosterone
  - System

Blood Pressure

- Q: What part of the kidney would be most directly affected by low blood pressure?
- A: Glomerulus: high blood pressure needed for filtration

Blood Pressure

- Stimulus: low blood volume and pressure
- Detected by **juxtaglomerular apparatus (JGA)**
  - Juxta(position) = next to
  - receptors next to the glomerulus
  - near the afferent arteriole
  - Secretes enzyme **renin**

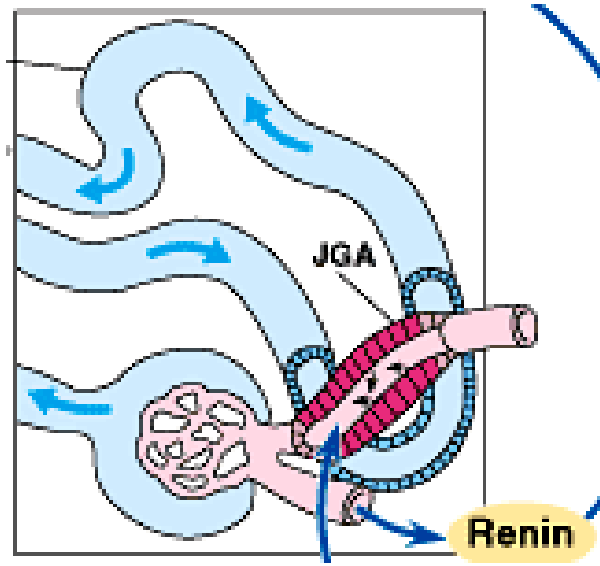


Fig. 44.24b

Effect of Renin

- Renin catalyzes: angiotensinogen → **angiotensin II**
- Angiotensinogen only active when needed
  - Constitutively produced
  - But activated by enzyme cleavage

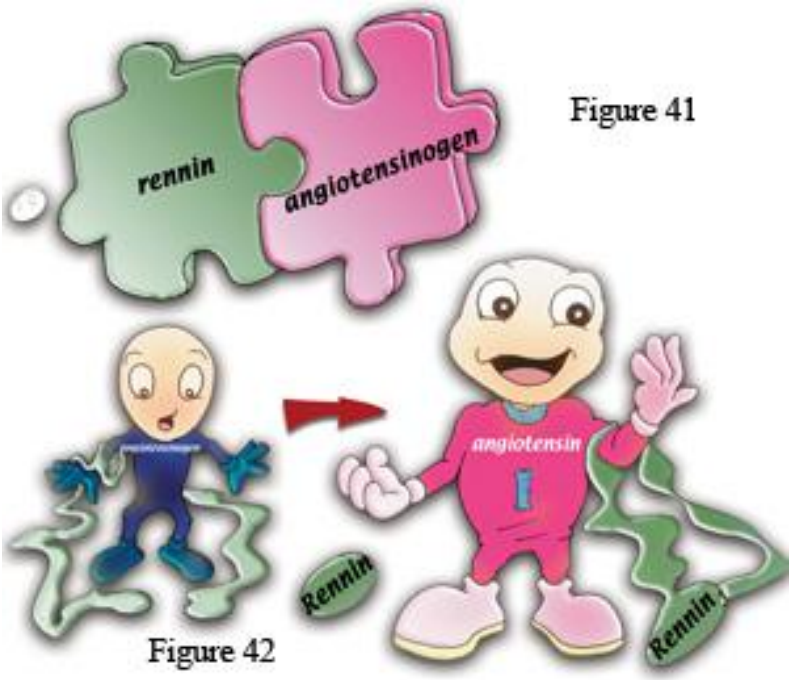
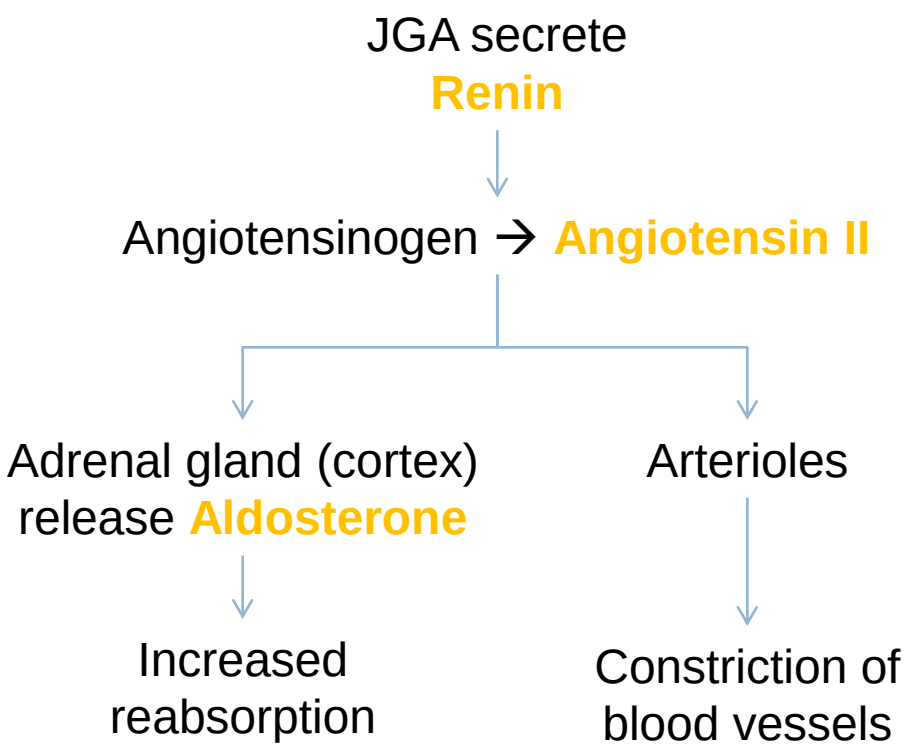


Figure 41

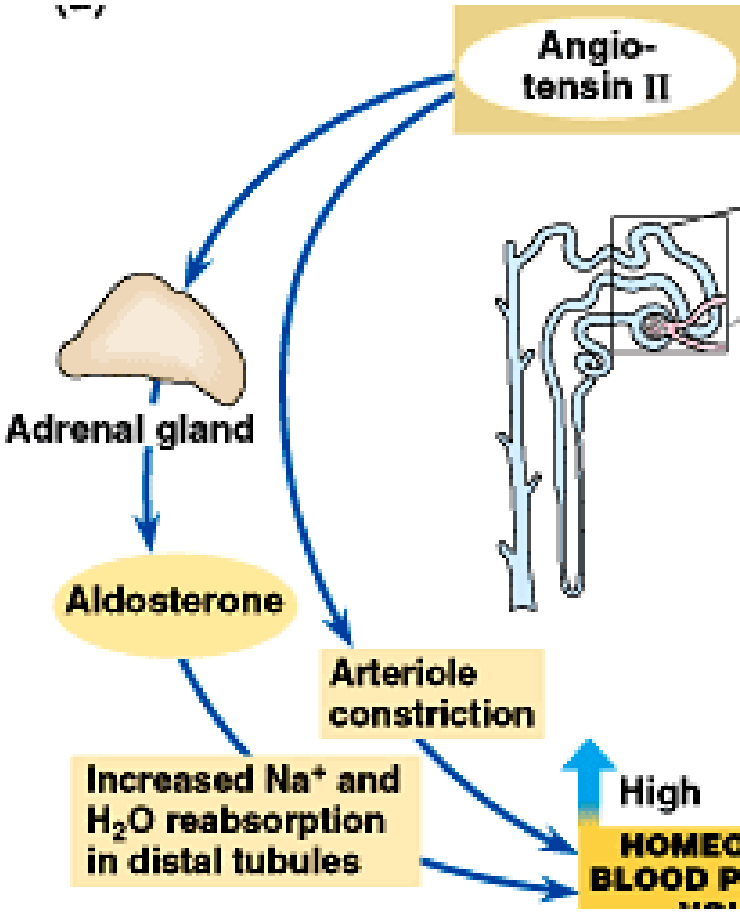
Figure 42

Two Effects of Angiotensin II



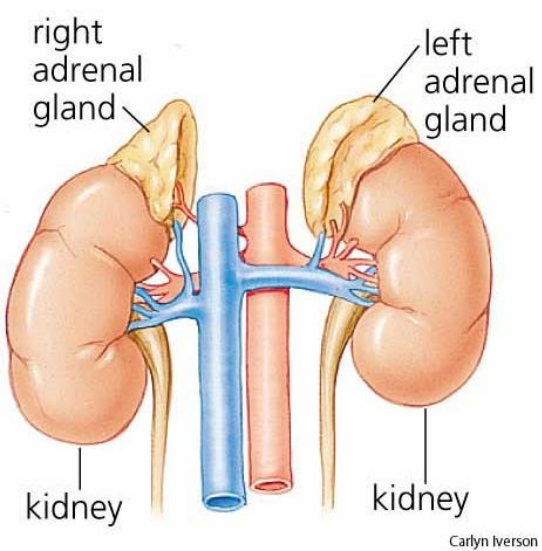
Effects of Angiotensin II: Constrict area

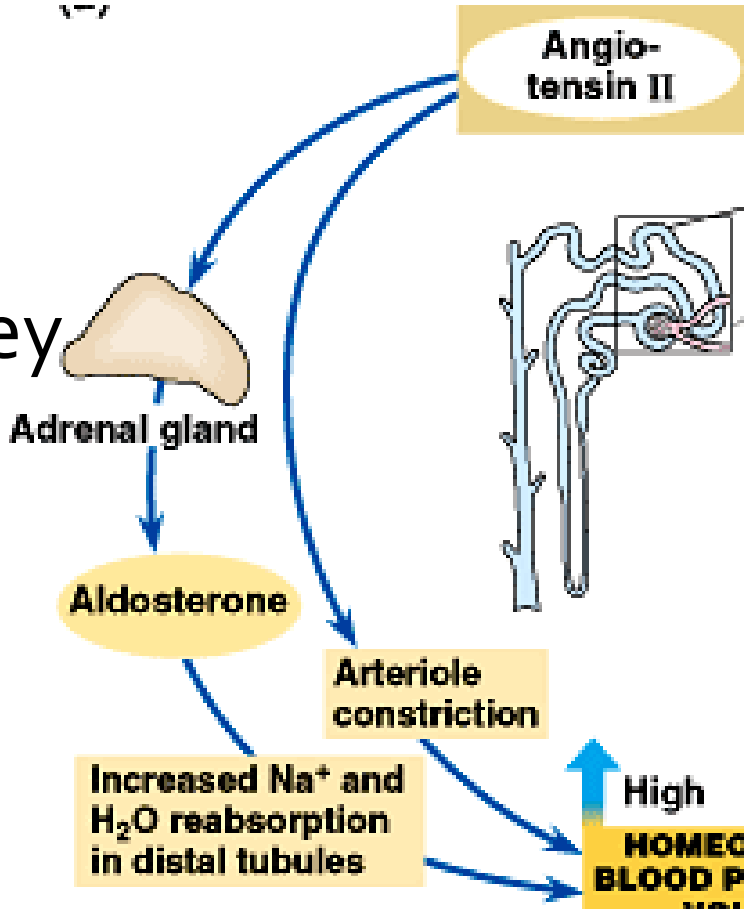
- Blood vessel **constriction**
- Increases **blood pressure**



Effects of Angiotensin II: Retain water

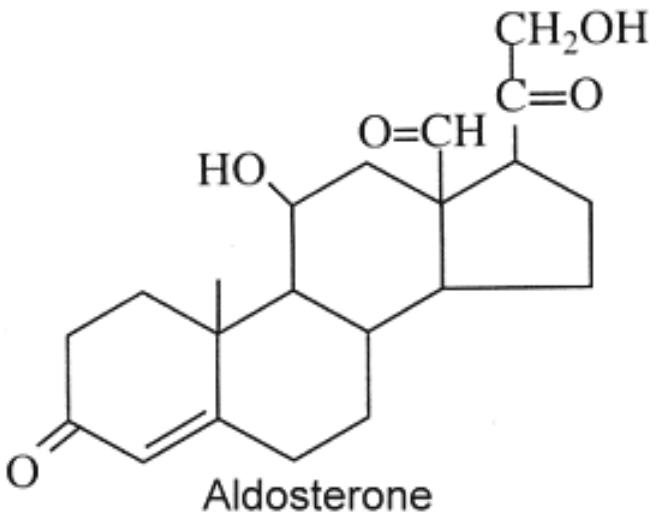
- Stimulate **adrenal gland (cortex layer)** to release **aldosterone**
- Adrenal gland is above kidney
- Cortex is the outer layer





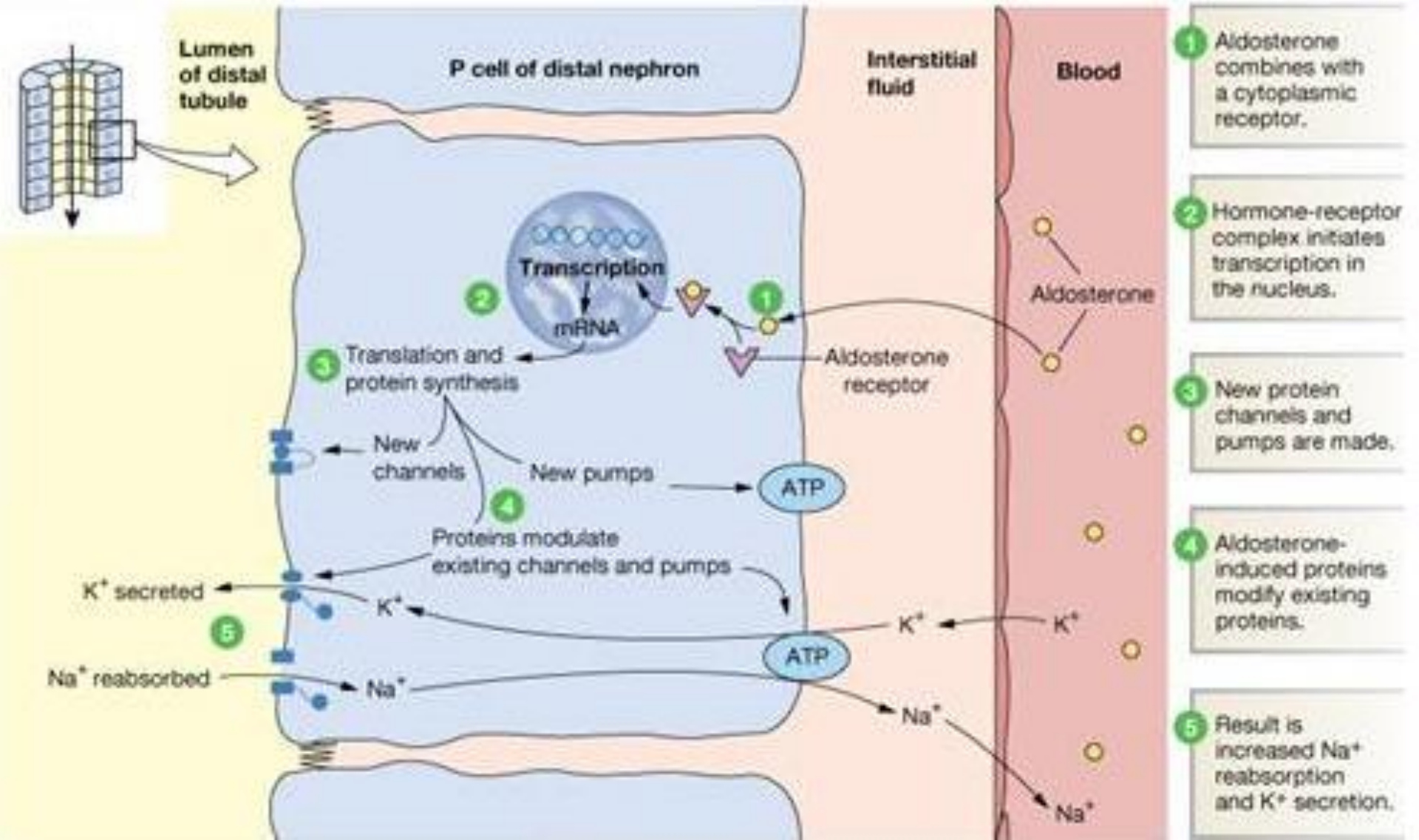
Effects of Aldosterone

- Steroid hormone
- Target: distal tubules
  - Increase number of sodium channels/pumps
  - Increase reabsorption of sodium
  - Increase **osmolarity**

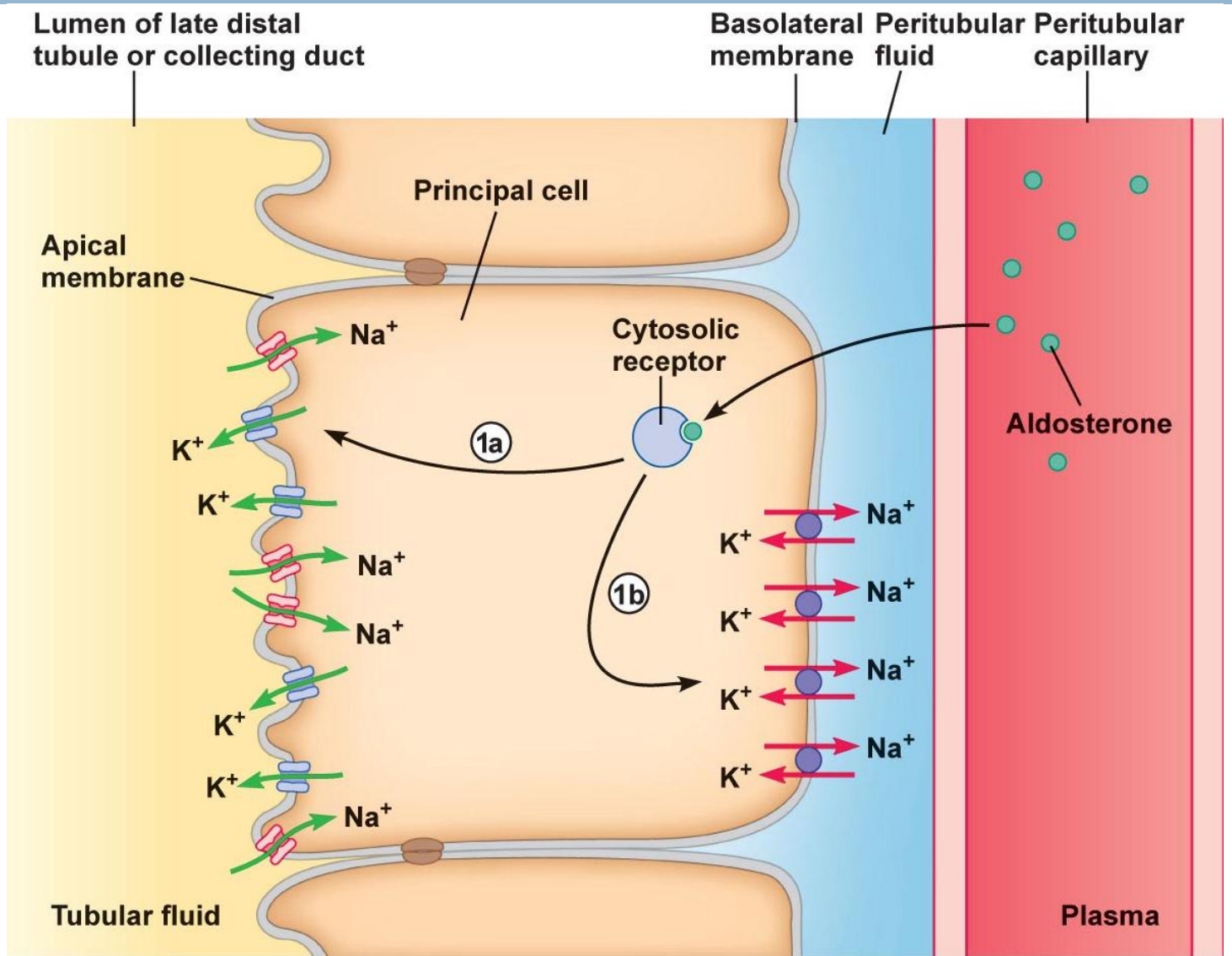


Aldosterone

Aldosterone Target



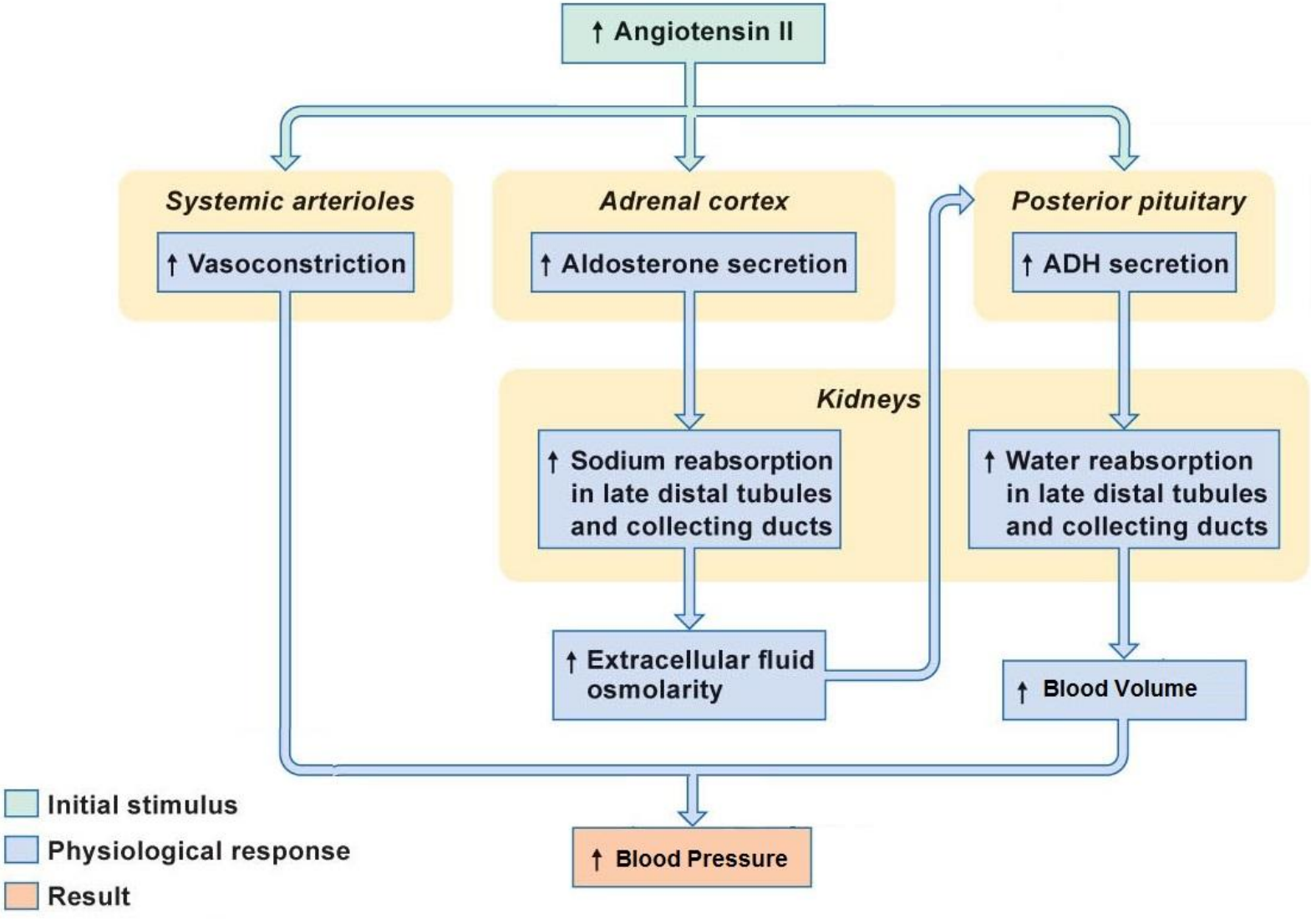
Aldosterone Target



Secondary Effect of Aldosterone

- Increased osmolarity stimulates **ADH**
  - Increase **reabsorption** of water
- Effect:
  - Increases blood **volume**
  - Increase blood **pressure**

Effects of Angiotensin II



Response to low blood pressure and low blood volume

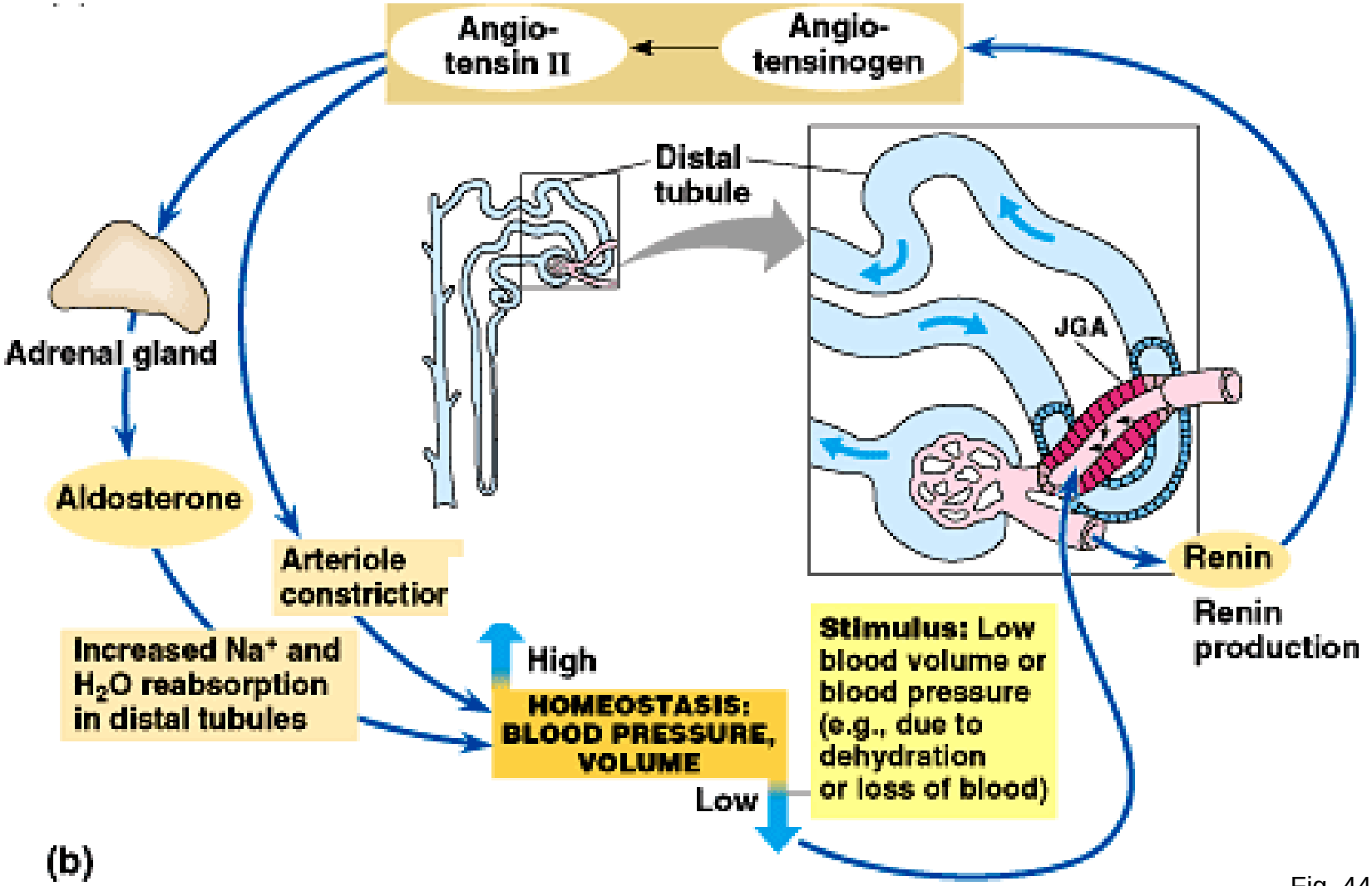
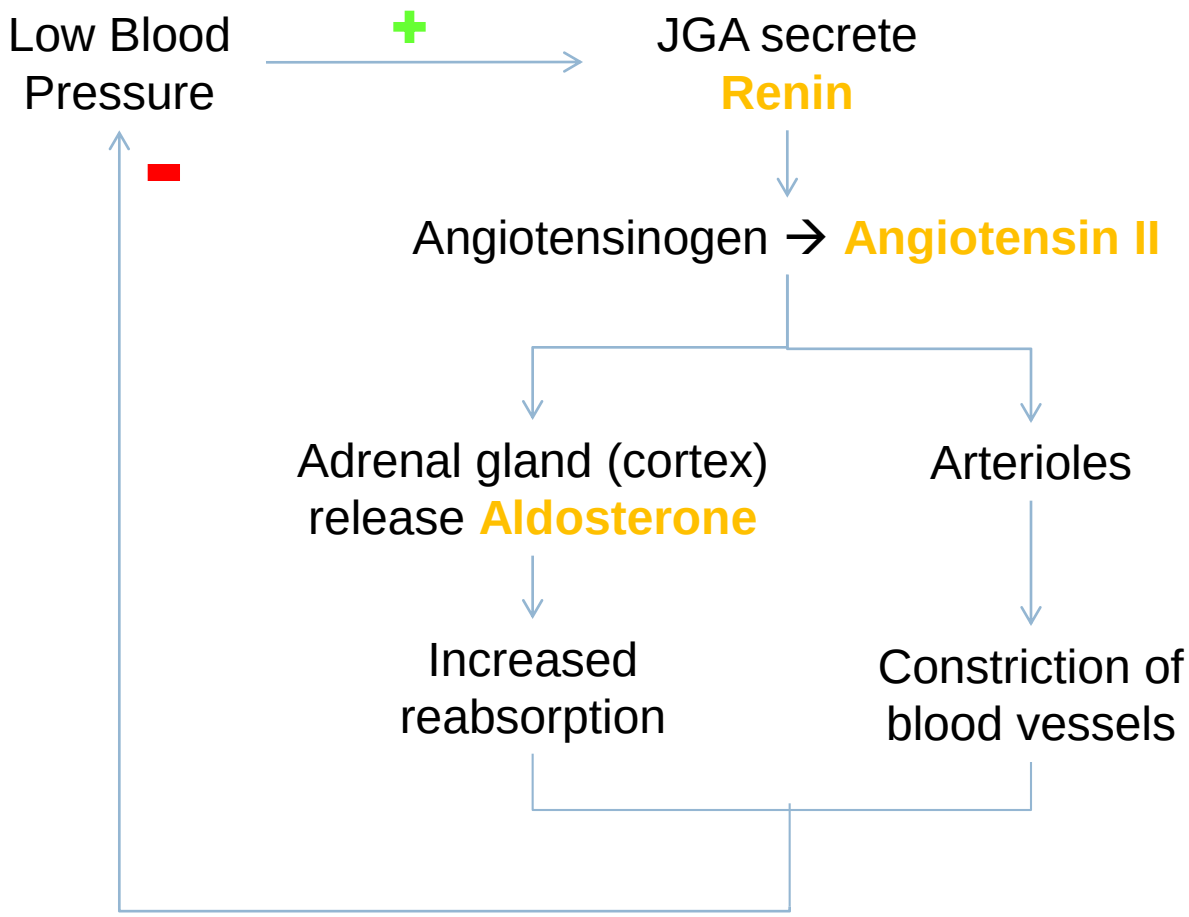


Fig. 44.24b

Negative Feedback on Low Blood Pressure



Thought Question: Water Reabsorption

- Why would you need 2 different sets of enzymes (ADH & RAAS) for the same final effect (increased reabsorption)?
- In other words why is RAAS even necessary?
- Hint: What is stimulates RAAS? What is the cause of that stimulus and how is it different than the cause of the ADH stimulus.

Source of Blood Pressure Disturbances

- What type of situation would cause a decrease in blood pressure?

Source of Blood Pressure Disturbances

- Water loss:
  - Sweating
  - Dehydration
  - diarrhea
- Blood loss:
  - Cut/bleeding out
  - internal bleeding
- Low salt diet

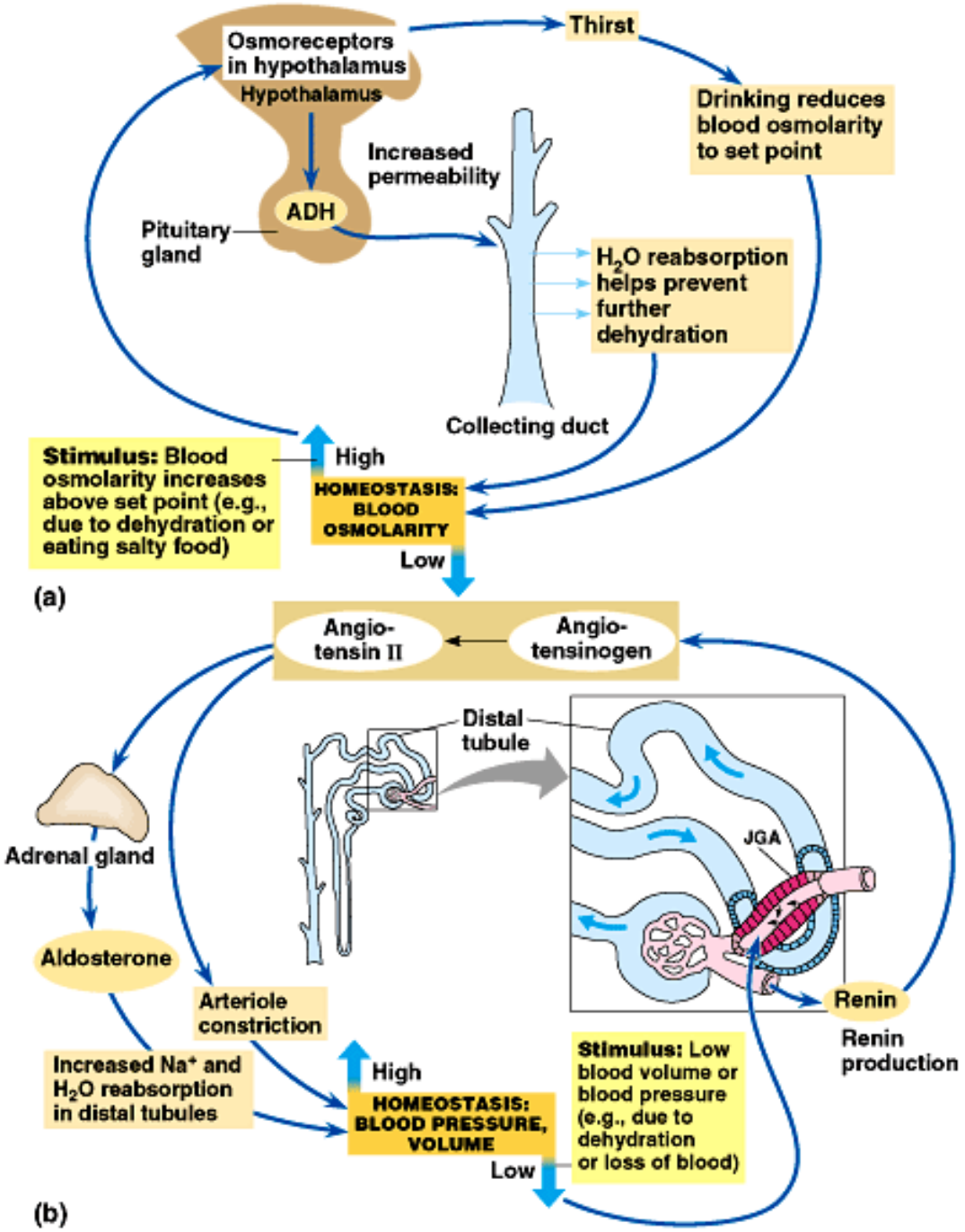
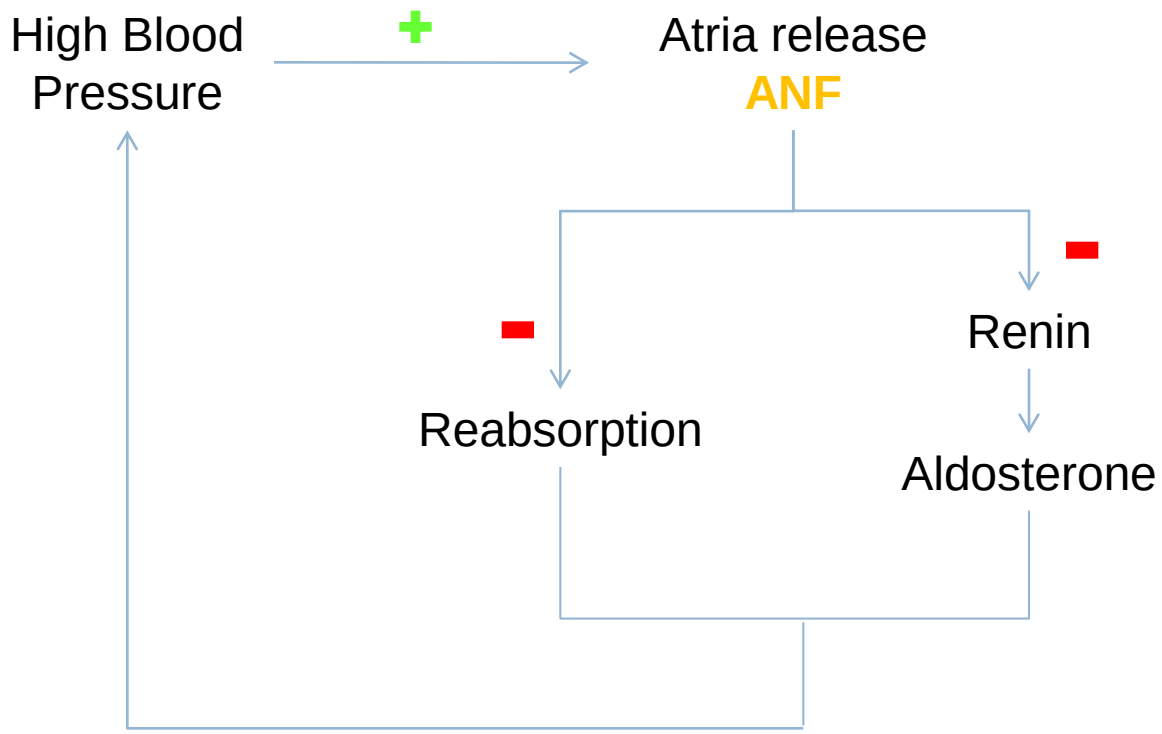


Fig. 44.24

Atrial natriuretic factor (ANF)

- Also known as atrial natriuretic peptide (ANP)
- Peptide hormone
- Location: from walls of atria in heart
- Stimulus: increased blood volume and pressure
- Effect:
  - Inhibits NaCl reabsorption (antagonistic to aldosterone) → decrease water reabsorption → decrease blood volume / pressure
  - Inhibit renin, reduce aldosterone release

Negative Feedback on High Blood Pressure



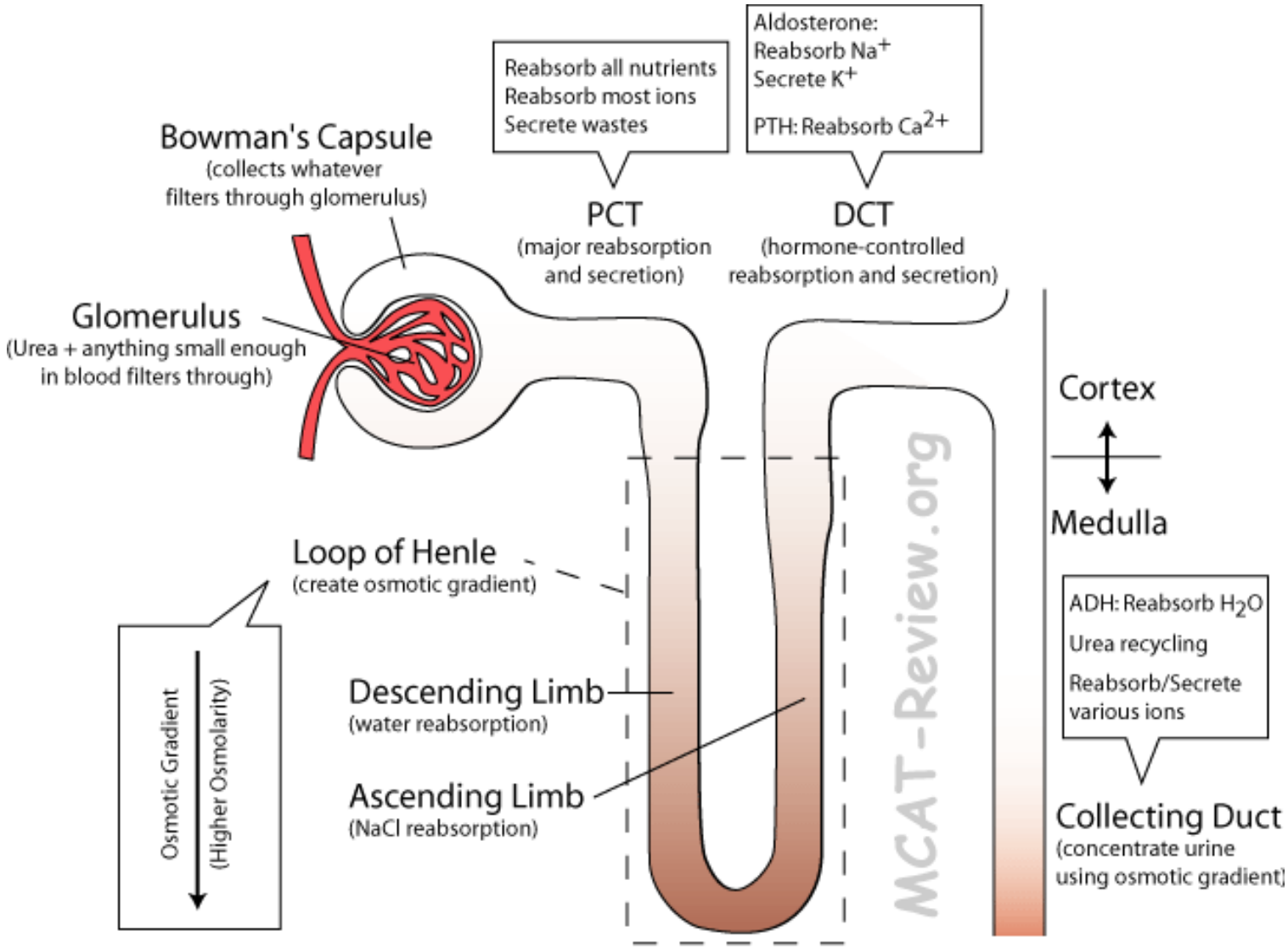
Comparing Excretory Hormones

	ADH	RAAS	ANF
Stimulus			
Cause			
Effect on reabsorption			
Effect on blood vessels			

Comparing Excretory Hormones

	ADH	RAAS	ANF
Stimulus	High osmolarity	Low blood pressure / volume	High blood pressure / volume
Cause	Water loss	Water loss Low salt diet Blood loss	Water retention High salt diet
Effect on reabsorption	Increased	Increased	Decreased
Effect on blood vessels		Constriction	

Osmoregulation Overview



pH Balance

- How do living systems regulate the amount of acid / base in their systems?
- Buffers: conjugate acid-base pairs

$$HCl \rightleftharpoons Cl^- + H^+$$

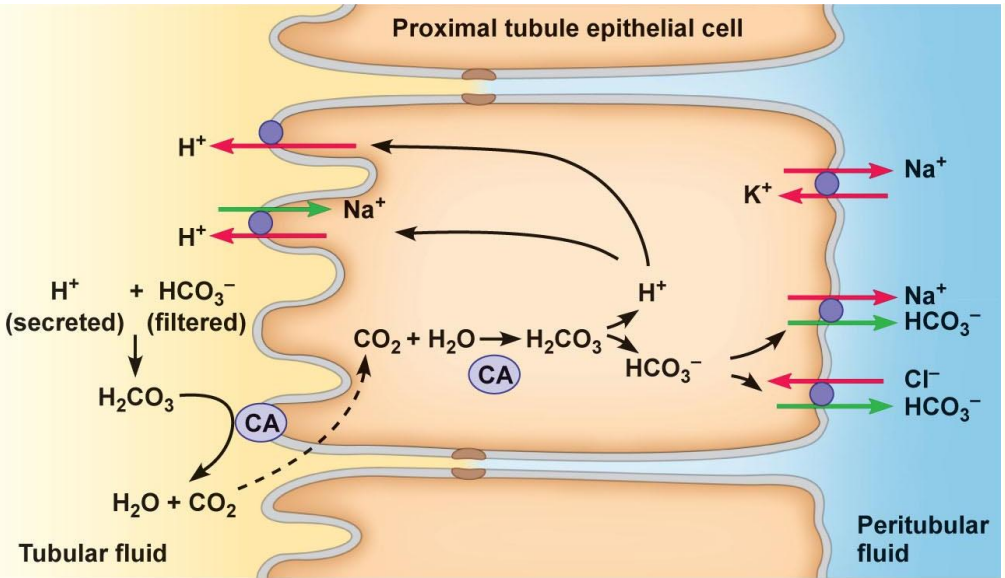
pH Balance

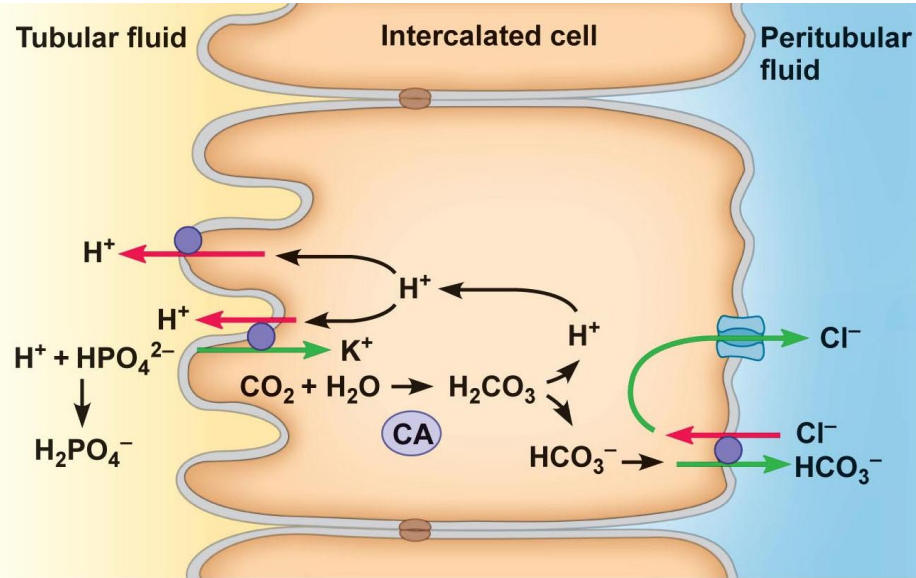
- Regulation of pH involves conversion of CO_2 to other compounds

$$H_2O + CO_2 \rightleftharpoons \underset{\text{carbonic acid}}{H_2CO_3} \rightleftharpoons \underset{\text{carbonate ion}}{HCO_3^- + H^+}$$

pH regulation in convoluted tubules

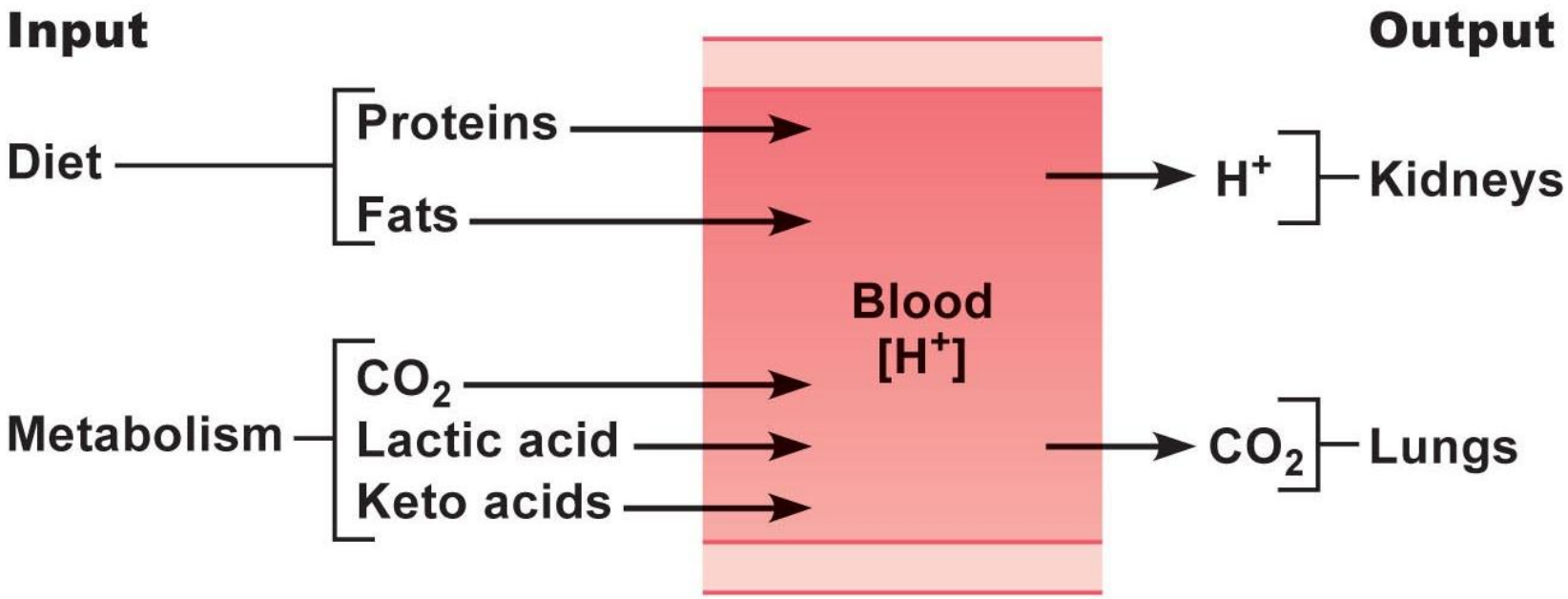
- Proximal and distal tubules use different transporters to regulate pH levels
- Net effect:
  - reabsorption of HCO3-
  - secretion of H+





Source of pH Disturbances

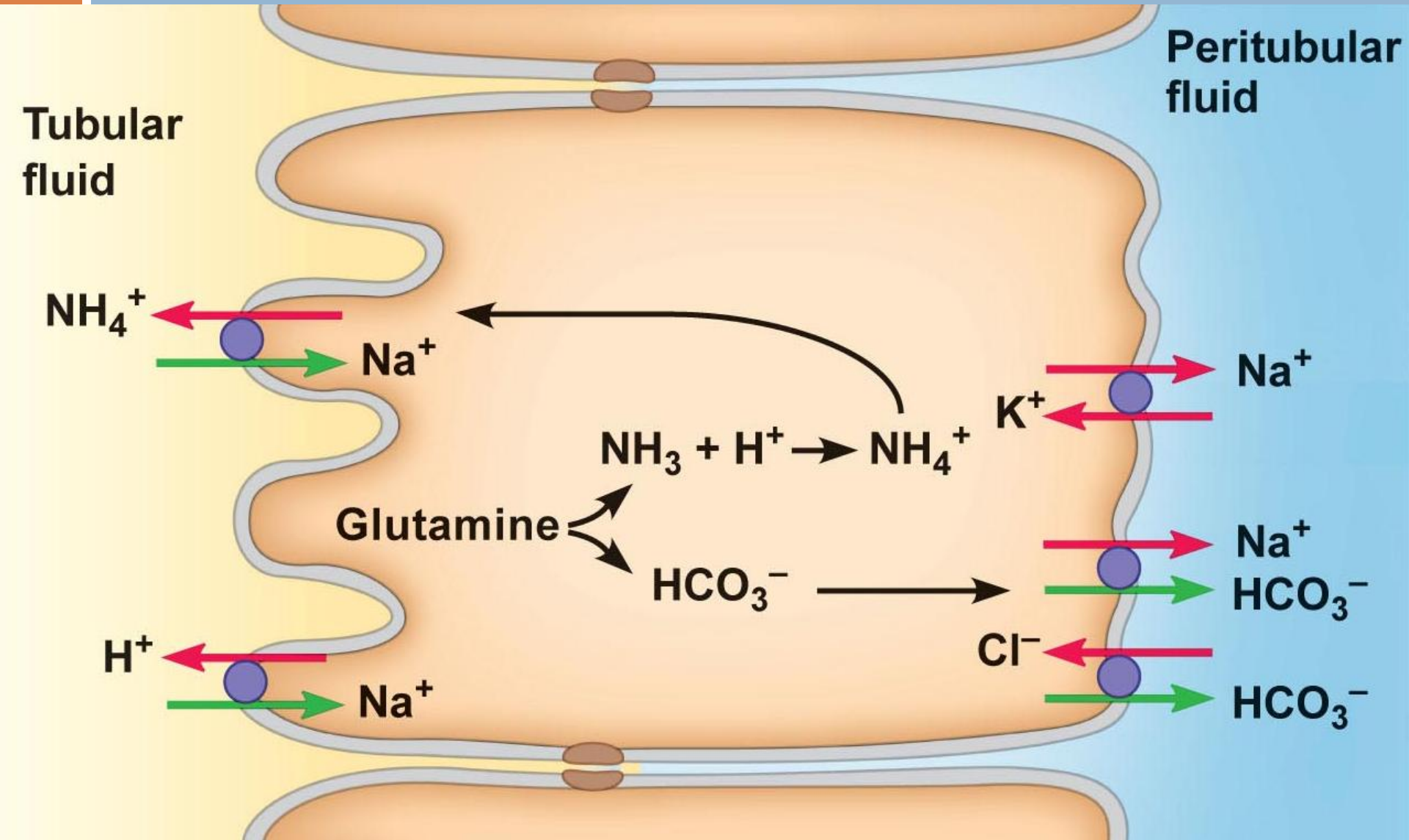
- Input:
  - Dietary sources - proteins and fats
  - Metabolism - carbon dioxide, lactic acid
- Output:
  - Lungs - carbon dioxide
  - Kidneys - hydrogen ions



pH Disturbance: Acidosis

- Stimulus: decrease pH
- Respiratory cause:
  - hypoventilation in lung disease (increase CO_2)
- Metabolic cause:
  - High fat/protein diet (increase H+)
  - Exercise (lactic acid)
  - Diarrhea (loss of HCO_3-)
- Regulation:
  - Buffering: shift equilibrium to not ionize (decrease H+)
  - Respiration: increase breathing to remove CO_2 which decreases H+
  - Kidneys: increase reabsorption of HCO_3- and secretion of H+
- Effect: raise pH

pH Regulation: Acidosis



pH Disturbance: Alkalosis

- Stimulus: increase in pH
- Respiratory cause:
  - hyperventilation (decrease CO_2)
- Metabolic cause:
  - Vomiting (loss of H^+)
- Regulation:
  - Buffering: shift equilibrium to ionize
  - Respiration: fainting results in decreased breathing rate increasing CO_2 and thus H^+
  - Kidneys: decrease reabsorption of HCO_3^- and secretion of H^+
- Effect: lowers pH

Questions

- How does blood osmolarity affect blood volume?
- How does blood osmolarity affect blood pressure?
- How does blood volume relate to blood pressure?
- If the blood vessels are exhibiting low blood pressure, what can you do to the blood volume to fix the problem?
- When could a decrease in blood volume NOT correlate to an increase in blood osmolarity?