THE UNIVERSITY OF MELBOURNE

Melbourne Veterinary School

Structure and Function of the Kidney – Dilution and Concentration of Urine; Anti-diuretic Hormone

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VETS30017 / VETS90125

Intended learning outcomes

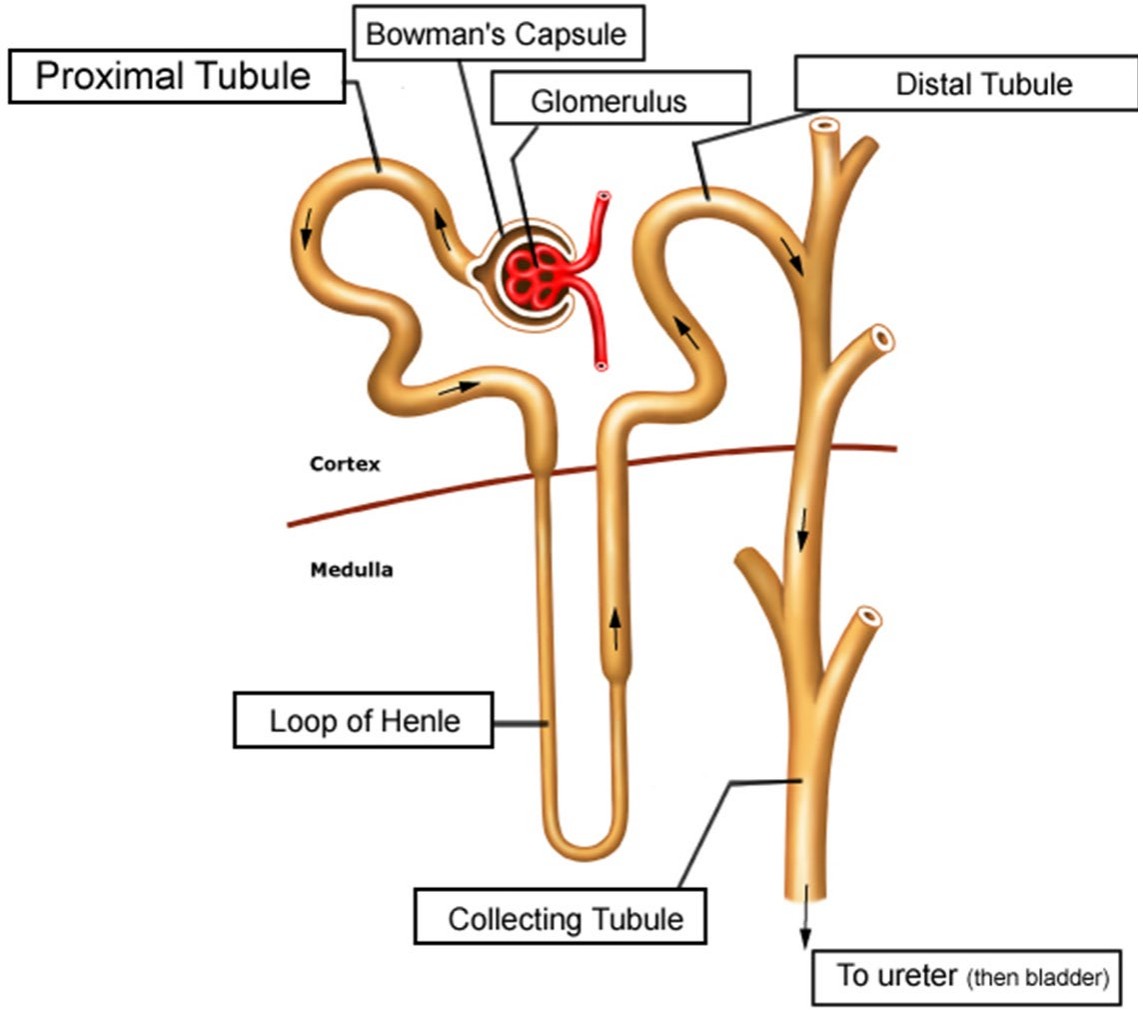
- Describe the sequence of events and mechanisms involved for the kidney to produce either dilute or concentrated urine
- Explain the role of the loop of Henle, countercurrent exchange multiplication and vasa recta in the production of dilute or concentrated urine
- Describe the role of ADH and urea in making concentrated urine

Dilute or concentrated urine?

- Kidneys excrete water in a controlled way that balances total body water
- Kidneys regulate water and solutes excreted in urine in response to water in the body
- Produce dilute or concentrated urine to excrete excess water or reabsorb water needed by the body
- Can excrete concentrated or dilute urine without major changes in excretion of solutes

How does the kidney dilute or concentrate urine?

- Filtrate at glomerulus isosmotic to plasma
- Fluid remains isosmotic in proximal tubule
- Descending loop of Henle – water reabsorbed by osmosis, filtrate becomes more concentrated
- Ascending loop of Henle – impermeable to water, filtrate diluted
- Distal and collecting tubules – how much water remains in filtrate is controlled by ADH

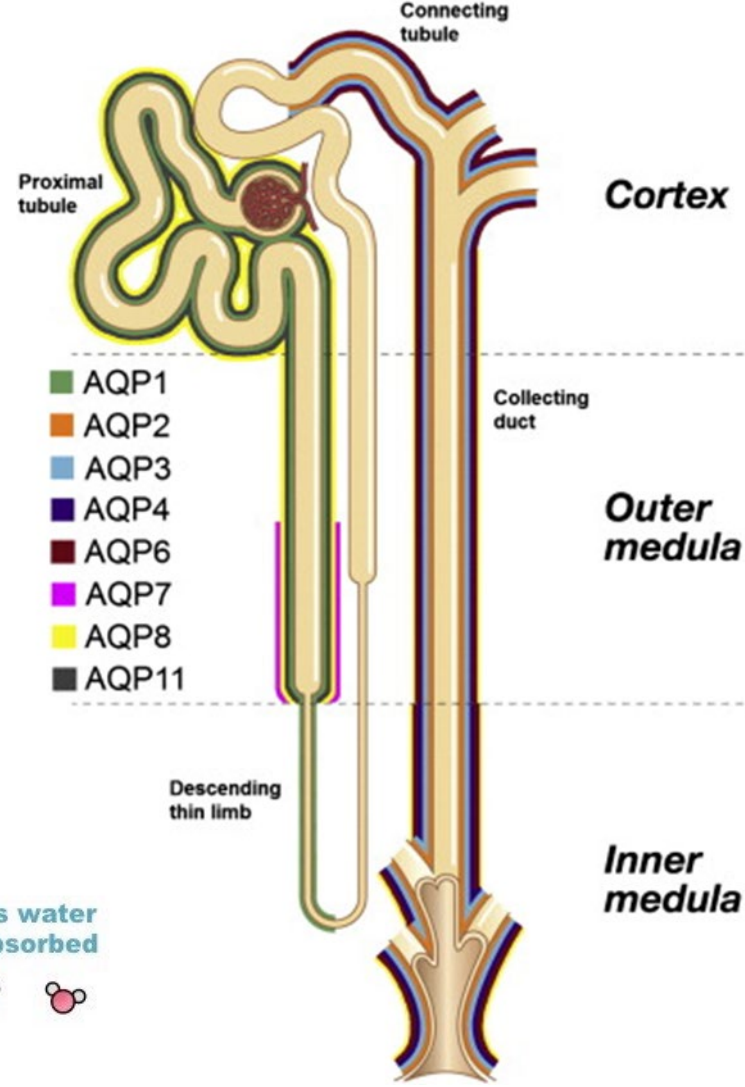


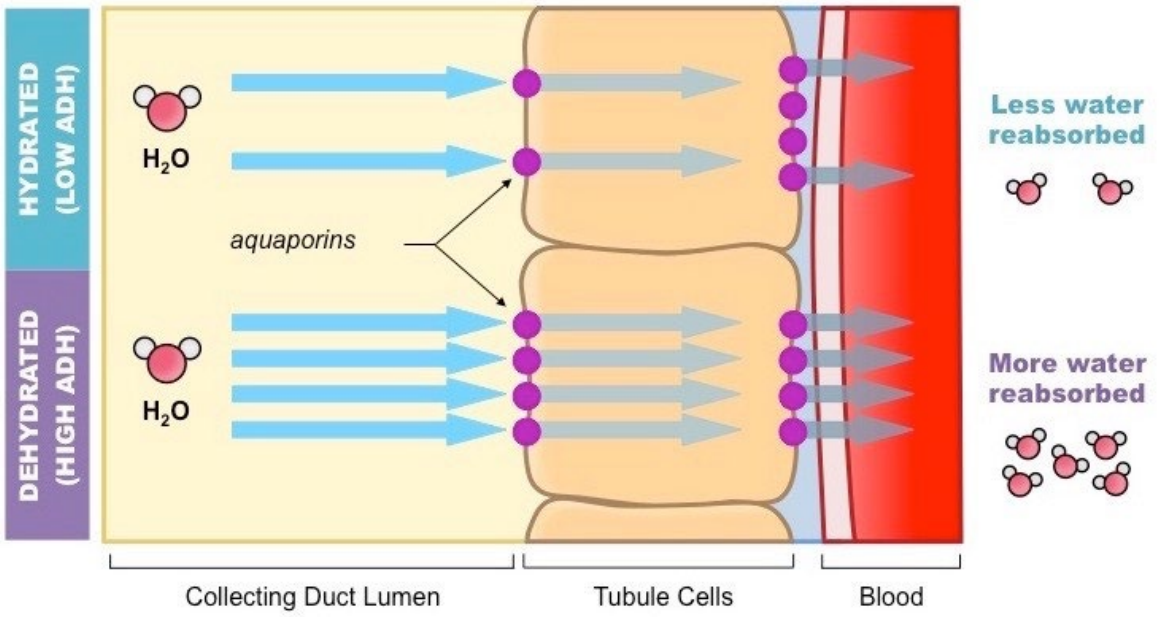
How does the kidney dilute or concentrate urine?

- Two main mechanisms:
  - Anti-diuretic hormone (ADH)
  - Osmolarity of the medullary interstitial fluid (countercurrent multiplier mechanism)
- Dilution of urine
  - Mainly relies on absence of ADH
- Concentration of urine
  - Relies on both mechanisms
- Unless there is excessive fluid intake, urine usually needs to be concentrated to some extent

Anti-diuretic hormone (ADH; vasopressin)

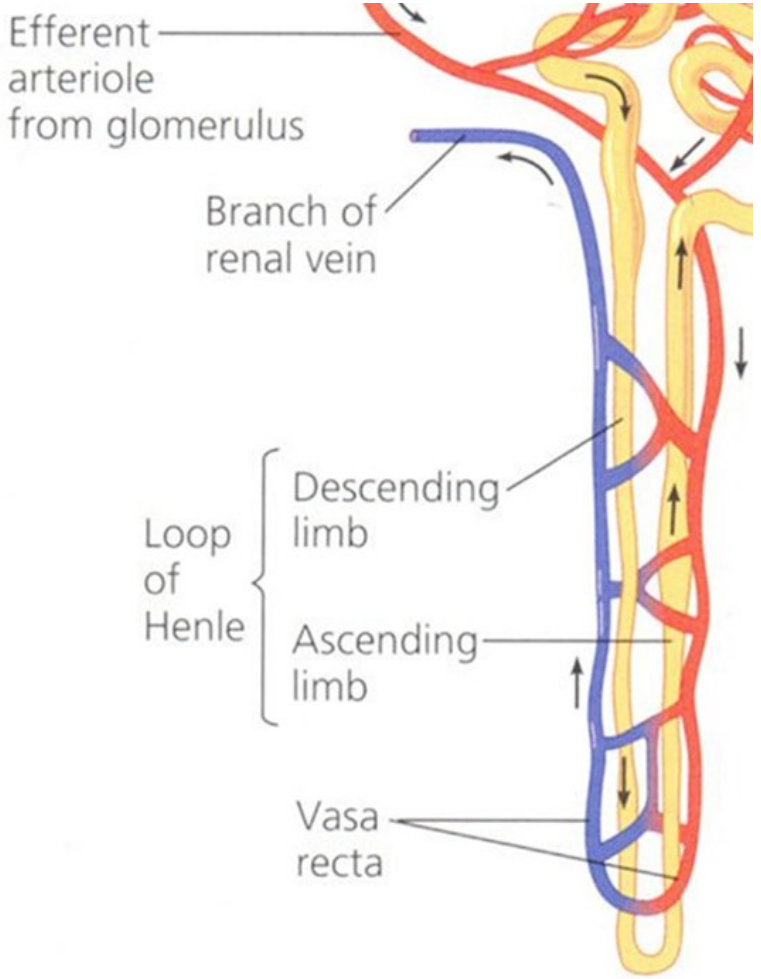
- Secreted by posterior pituitary gland in response to increased osmolarity of body fluids, ↓ BP, ↓ blood volume
- Allows water reabsorption through aquaporins in collecting tubule, collecting duct



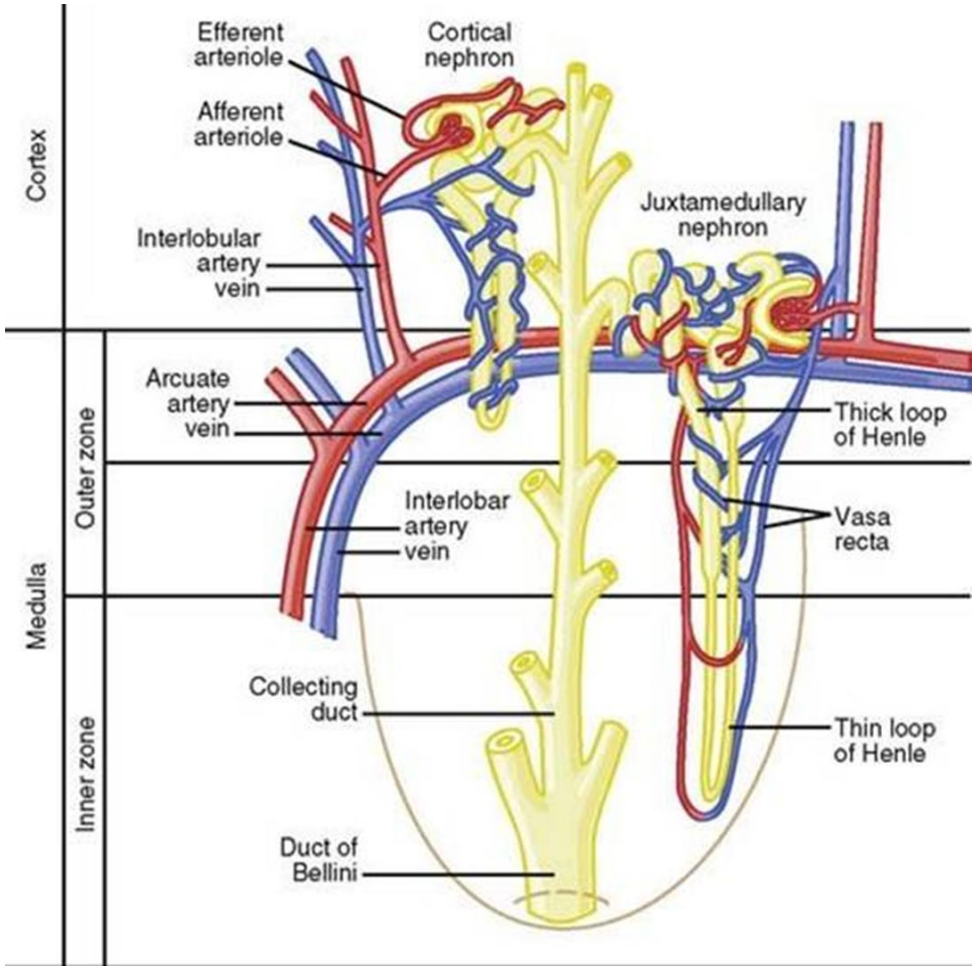


Countercurrent multiplier mechanism

- Medullary interstitium hyperosmolar
  - Active transport of solutes but not water in thick ascending loop of Henle
  - Descending loop of Henle very permeable to water – urine concentrates as water moves into medullary interstitium



Countercurrent multiplier mechanism



- Both types of nephrons contribute to urine concentration
- Only birds and mammals can concentrate urine to > plasma osmolarity

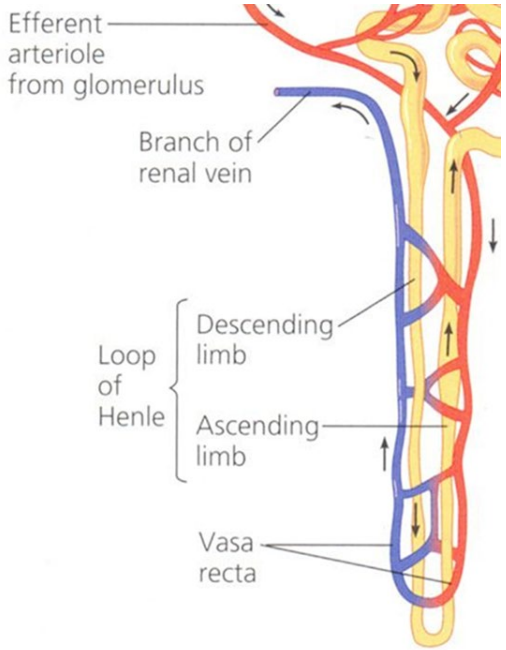
Countercurrent multiplier mechanism

Water exiting the descending limb by osmosis equilibrates concentration between tubule and interstitial fluid

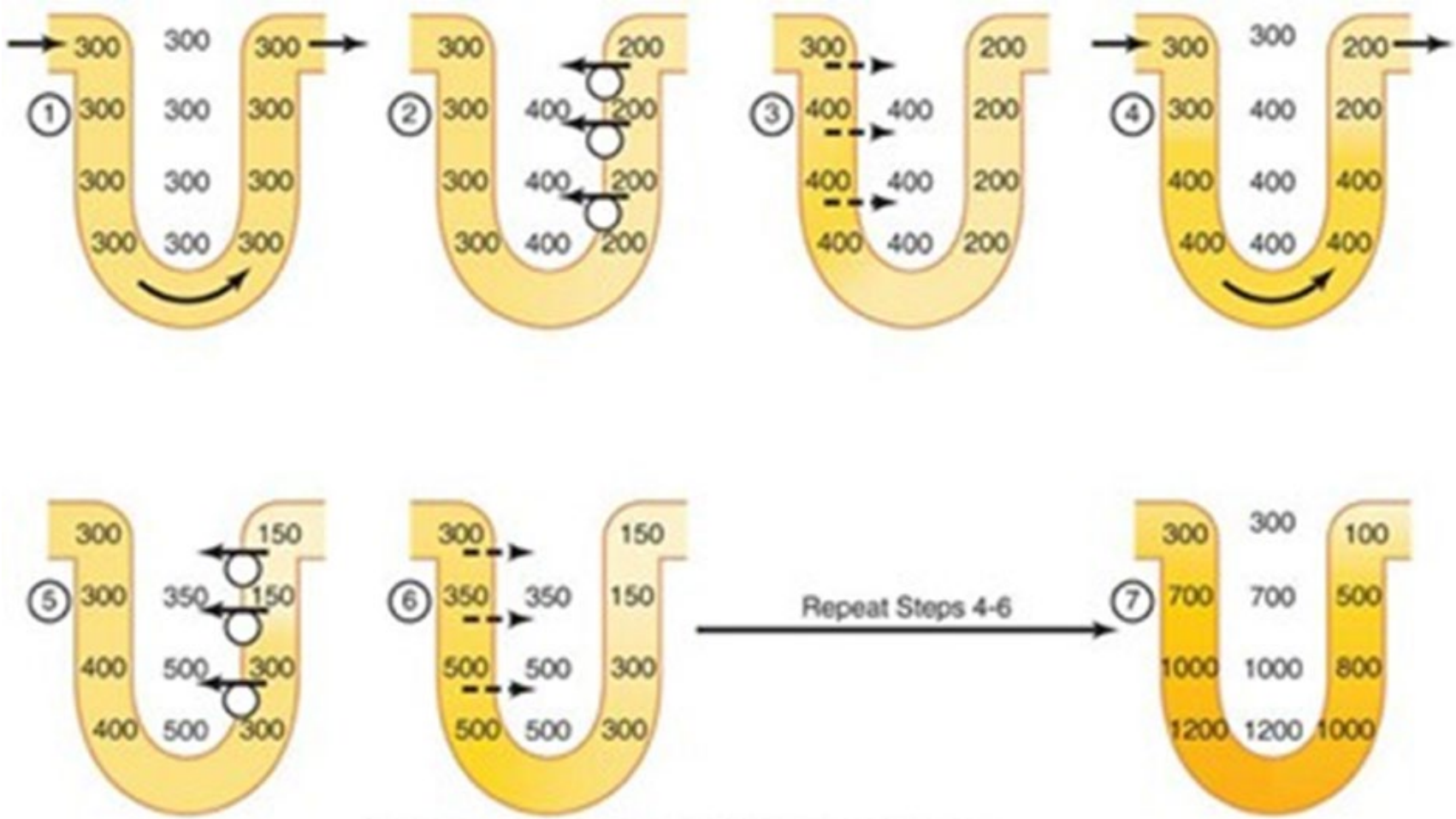
This fluid moves to ascending limb and more solutes added to interstitium

Interstitial fluid becomes progressively more concentrated

Solutes actively transported to interstitial fluid from the tubule while water remains behind (thick ascending limb)

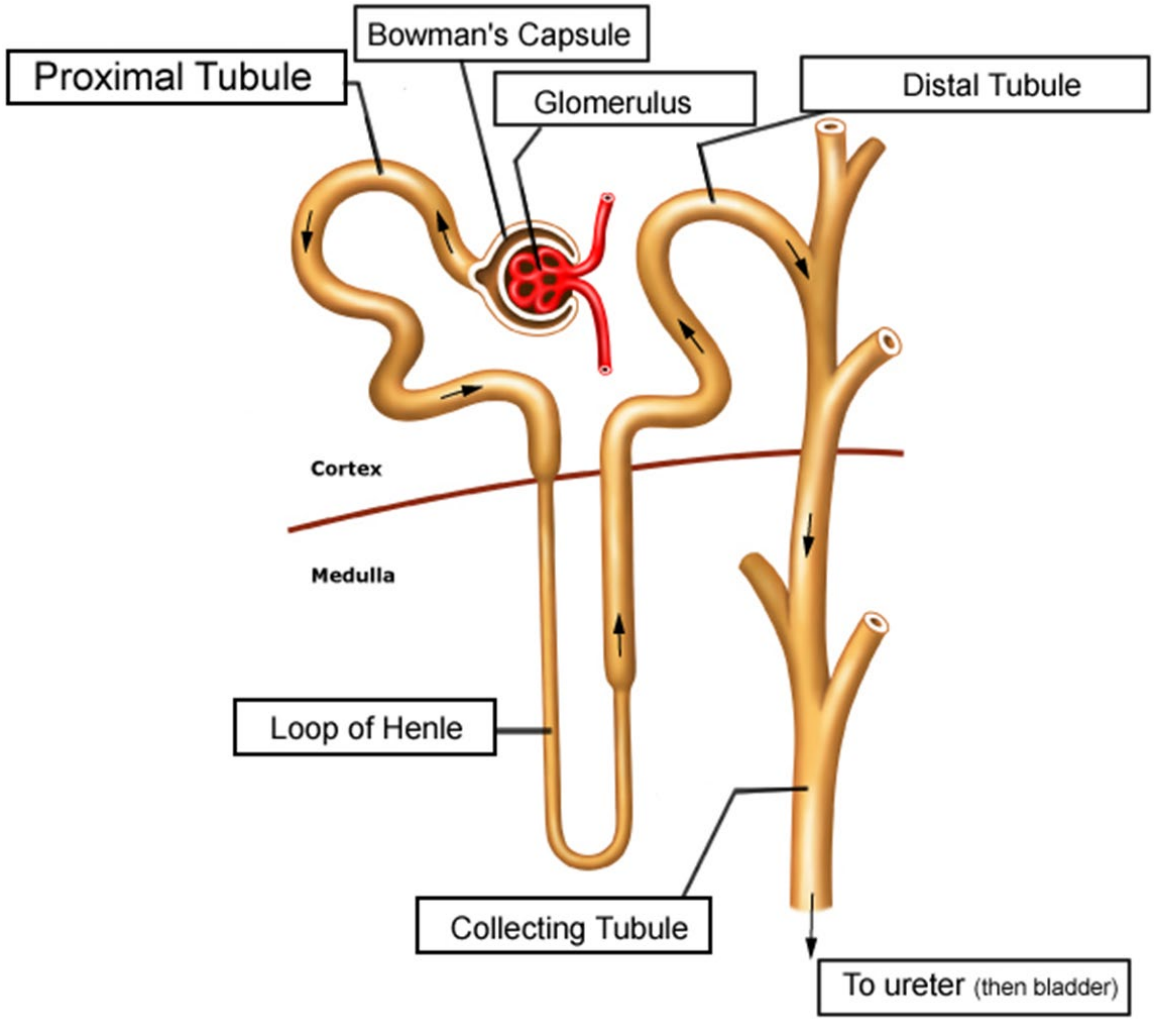


Countercurrent multiplier mechanism



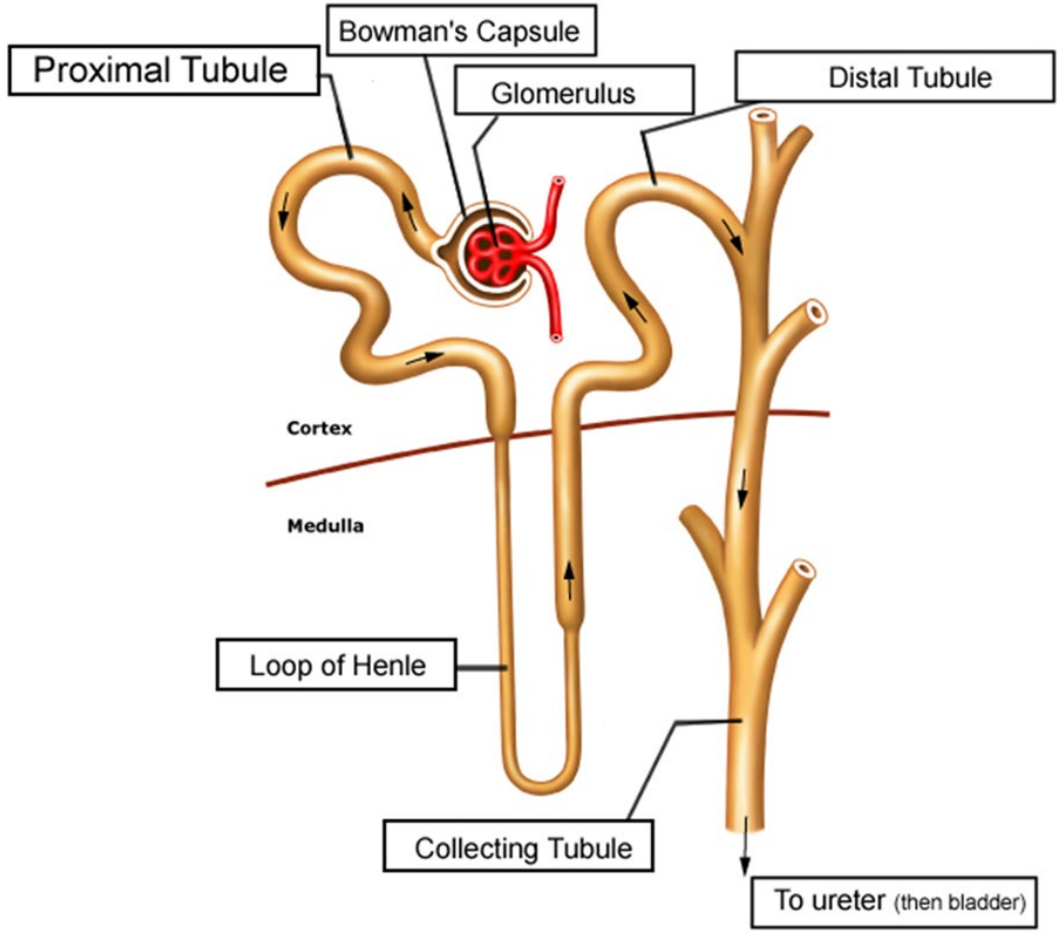
Countercurrent multiplier system

- Water reabsorption in medulla relatively small compared to cortex
  - 65% in proximal tubule
  - 20% in loop of Henle
  - Remainder in distal tubule/collecting duct (ADH)
- Helps keep medullary interstitium hyperosmolar

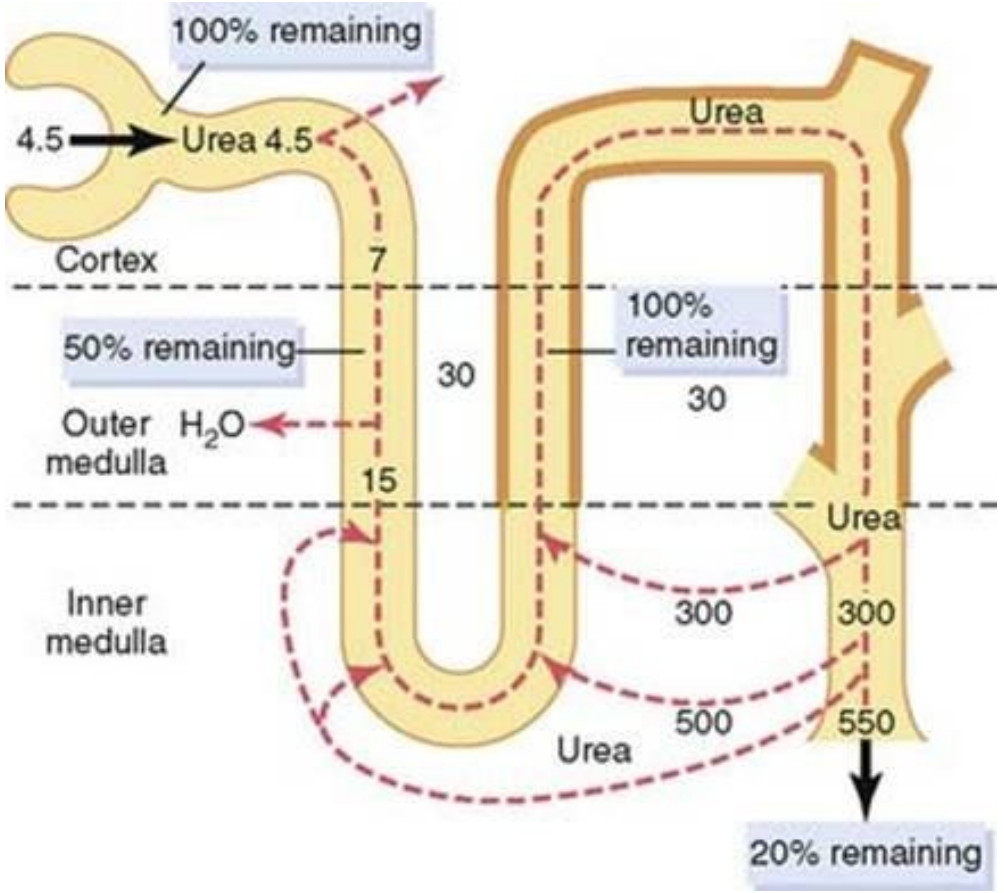


Countercurrent multiplier system

- What's the point?
  - Hyperosmolar medullary interstitium is not so important for concentrating filtrate in loop of Henle, but becomes VERY important when the filtrate needs to be concentrated in the collecting duct in the presence of ADH



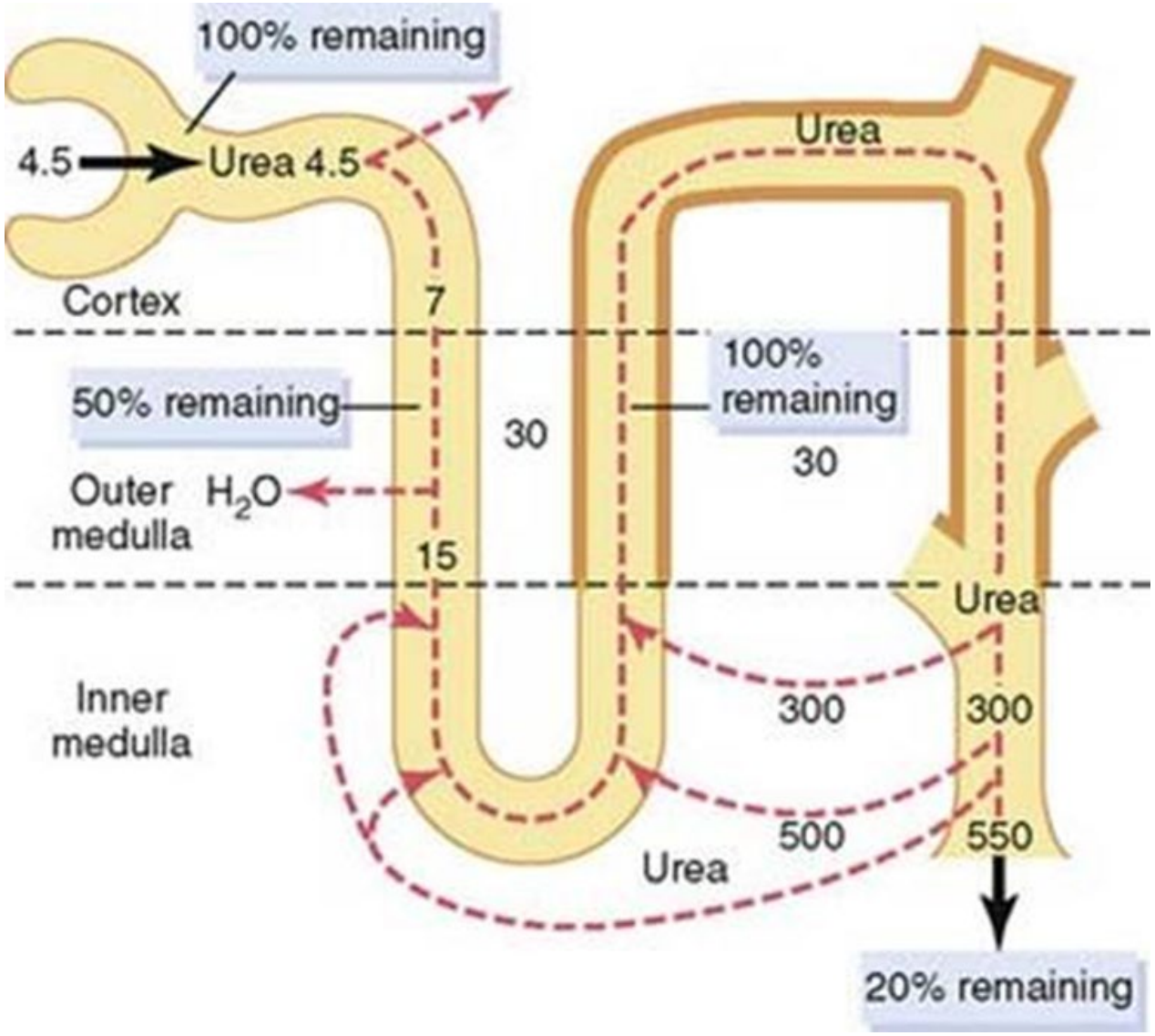
Role of urea recycling



- Why reabsorb some urea if it's a waste product?
  - It's a solute that helps maintain high osmolarity in medullary interstitium
  - 40-50% osmolarity due to urea
- Recycled from medullary collecting duct back into loop of Henle
- Urea transport proteins assist this, activated by ADH

Guyton & Hall, 12th Ed. 2011

Role of urea recycling



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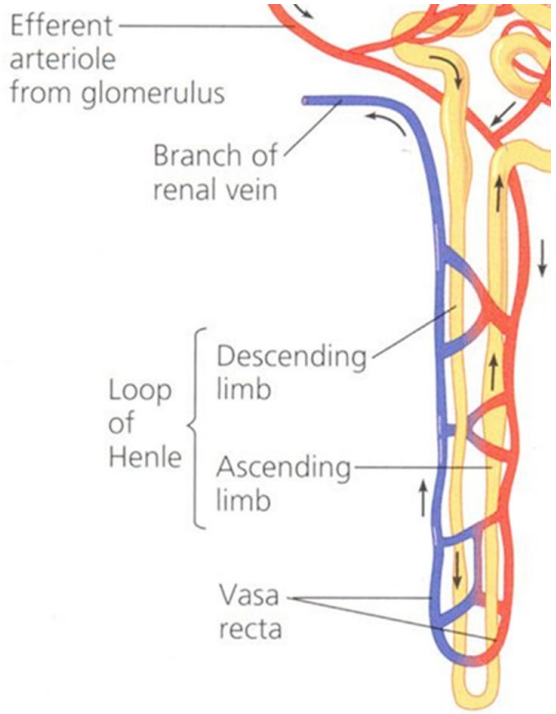
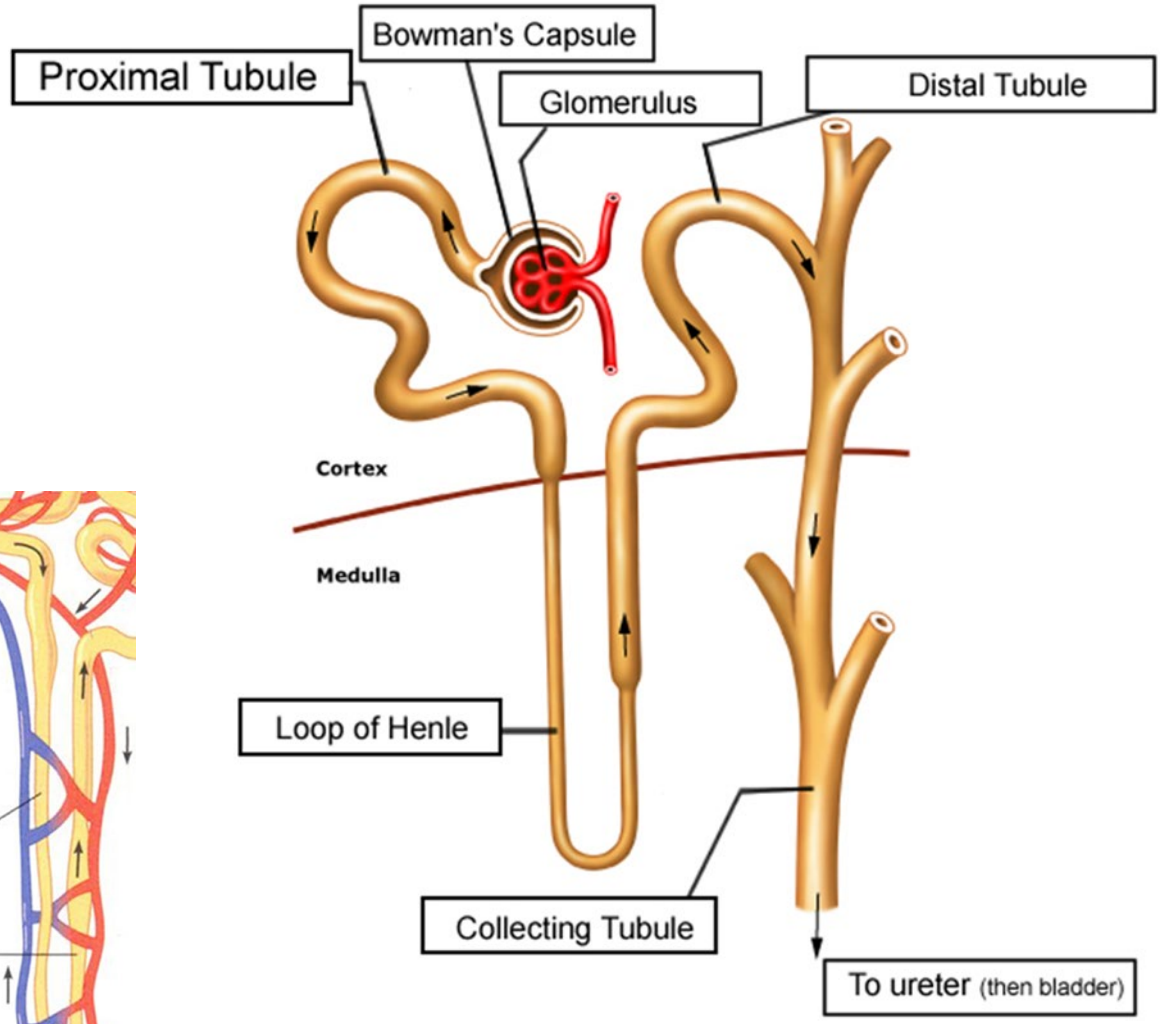
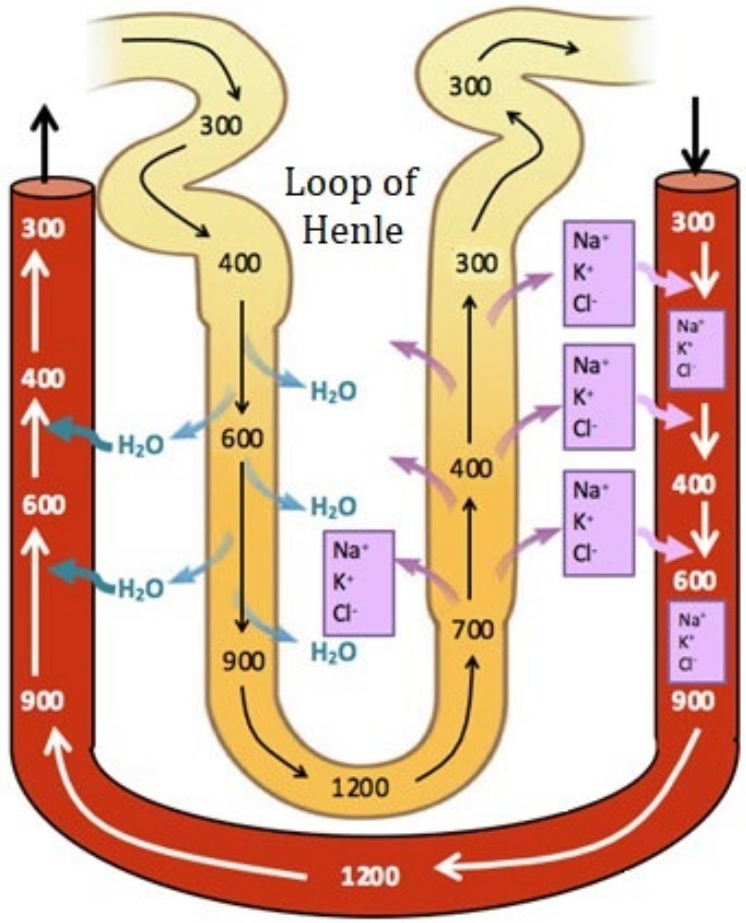
Countercurrent exchange mechanism

- So if water is reabsorbed into the medulla, how does it remain hyperosmolar?
  - Countercurrent multiplier
  - Vasa recta





Maintaining the hyperosmolar medullary interstitium



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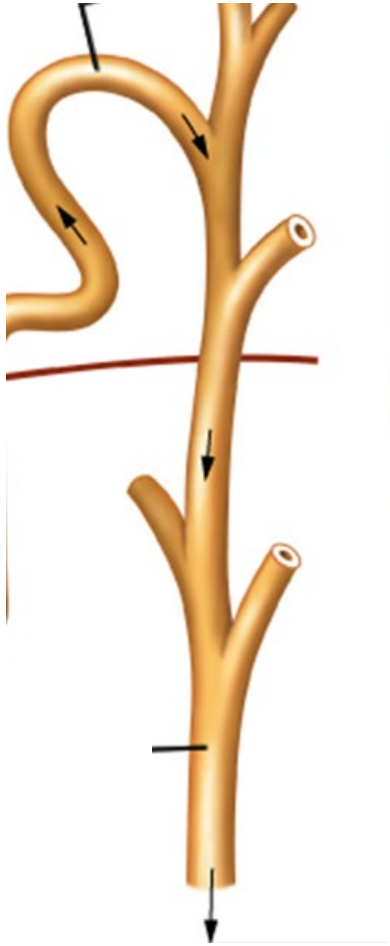
- Medullary blood flow MUCH lower than cortical blood flow
  - Small % of total renal blood flow
- Vasa recta work as countercurrent exchangers
  - Don’t create hyperosmolar medullary interstitium but help maintain it

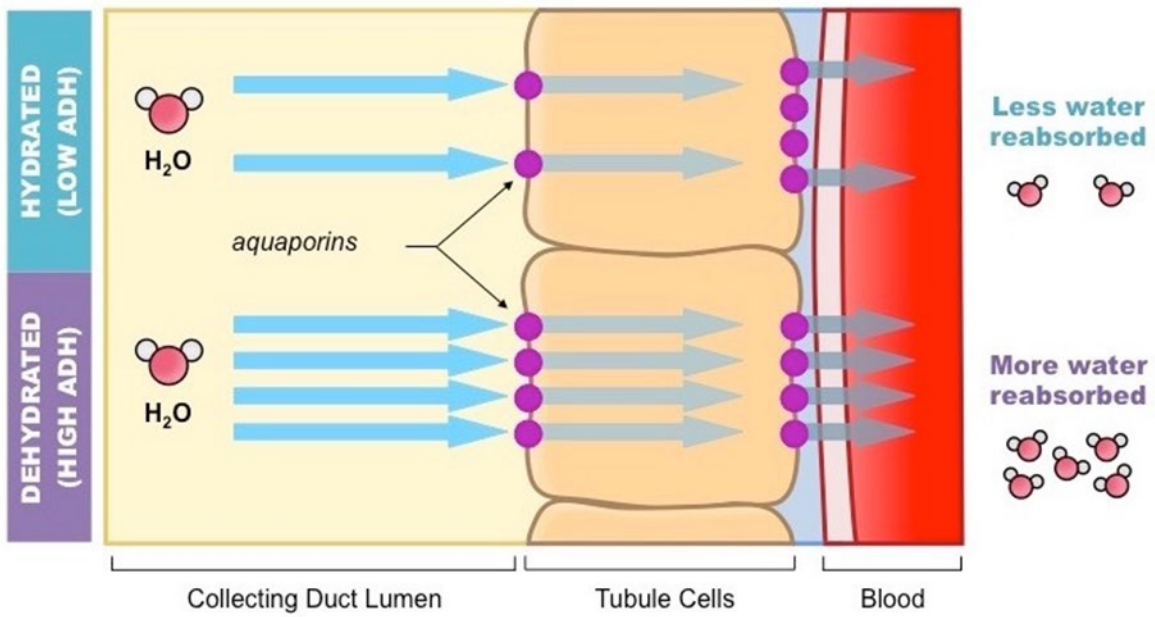
Obligatory water loss

- Even if urine maximally concentrated, some water must be lost in order to excrete wastes/solutes
- Urine concentrating ability limited by medullary interstitial fluid osmolarity
- E.g. if excess sodium intake, more water required to remove excess sodium

Concentrating urine – collecting tubule/duct

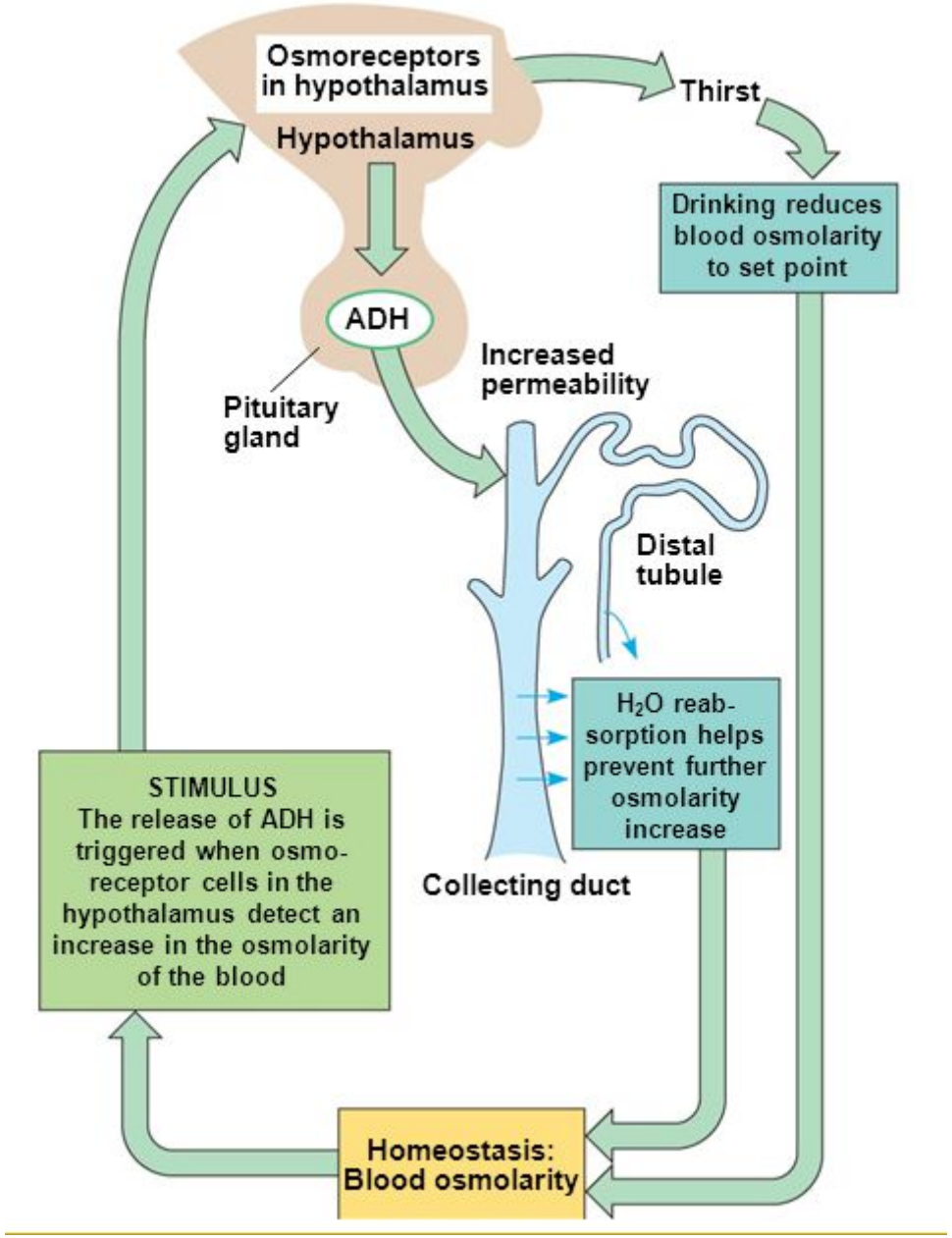
- ADH
  - Only aquaporins in distal part of nephron (principal cells) need ADH to function
  - In presence of ADH, much water can be reabsorbed
  - If no ADH, collecting duct/tubule impermeable to water





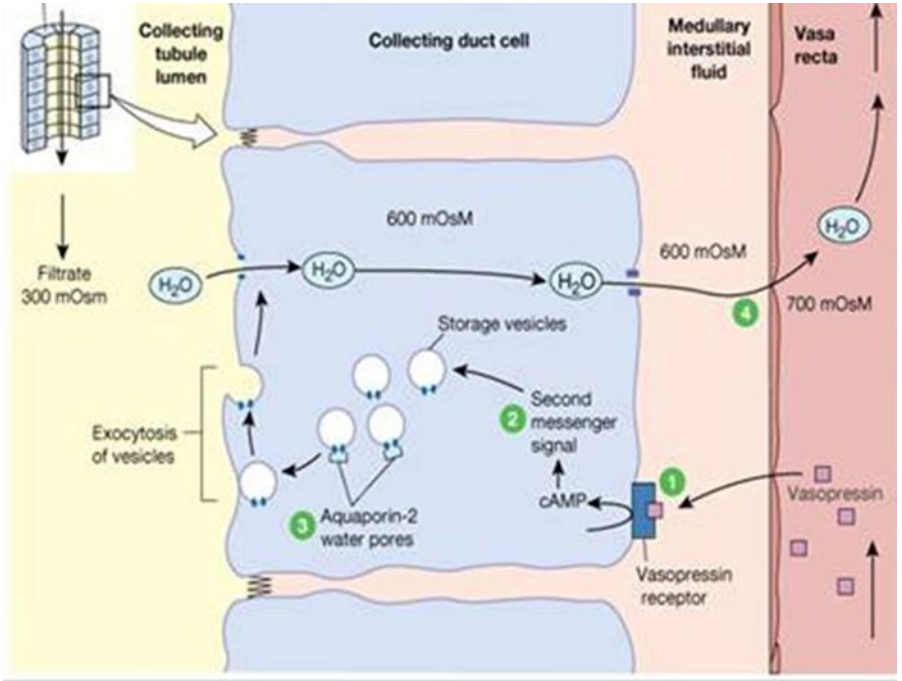
Anti-diuretic hormone

- Negative feedback mechanism



What could possibly go wrong?

- Diabetes insipidus
  - Can’t produce ADH (central DI)
  - Produce ADH but aquaporins don’t respond (nephrogenic DI)



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