THE UNIVERSITY OF MELBOURNE

Melbourne Veterinary School

Structure and Function of the Kidney - Overview

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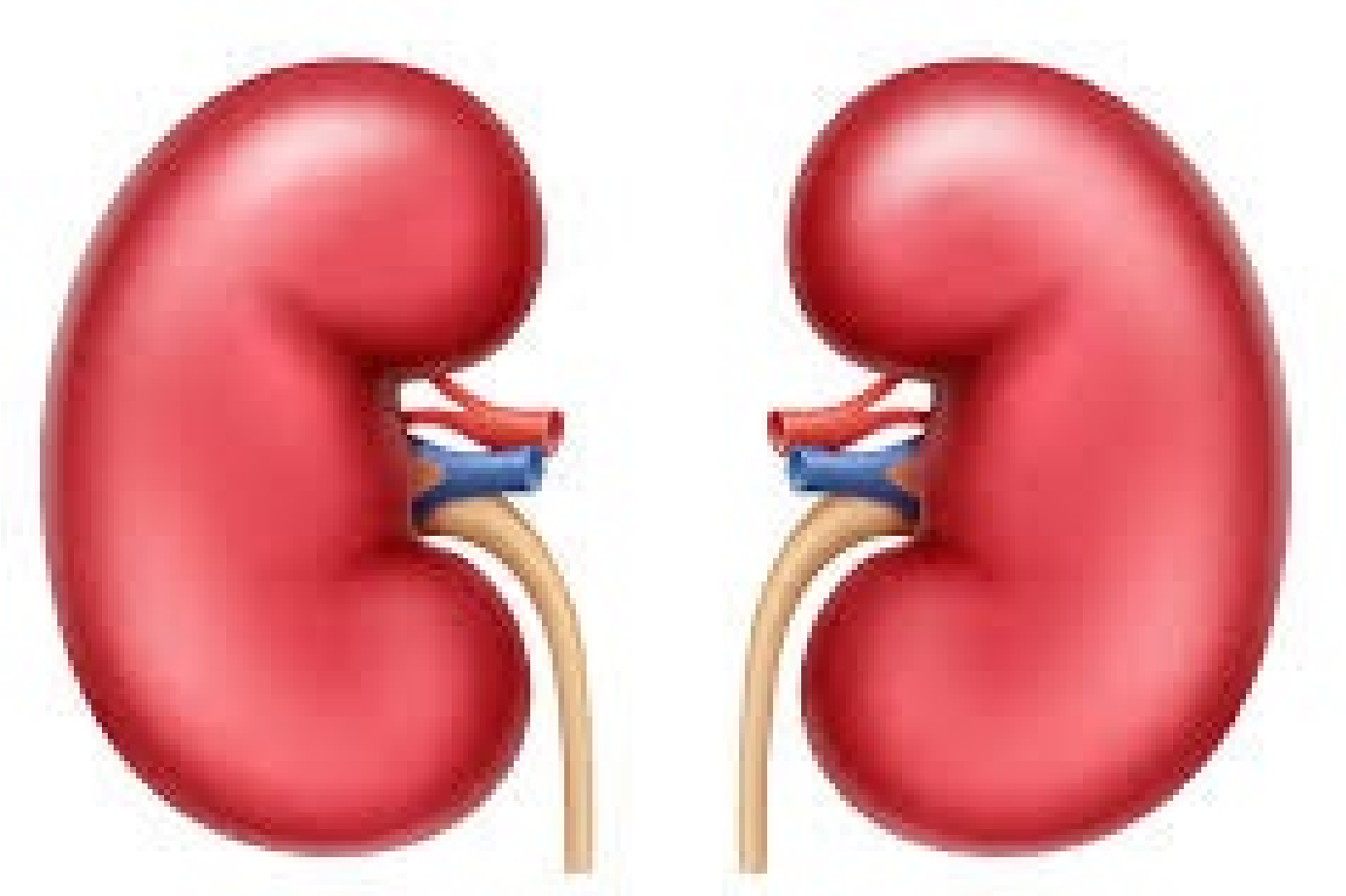
VETS30017 / VETS90125

Intended Learning Outcomes

- Define the main functions of the kidney
- Describe the functional anatomy of the nephron
- Broadly explain how glomerular filtration occurs, why it is important and the factors that regulate it
- Broadly explain tubular processes involved in producing and modifying urine

Main kidney functions



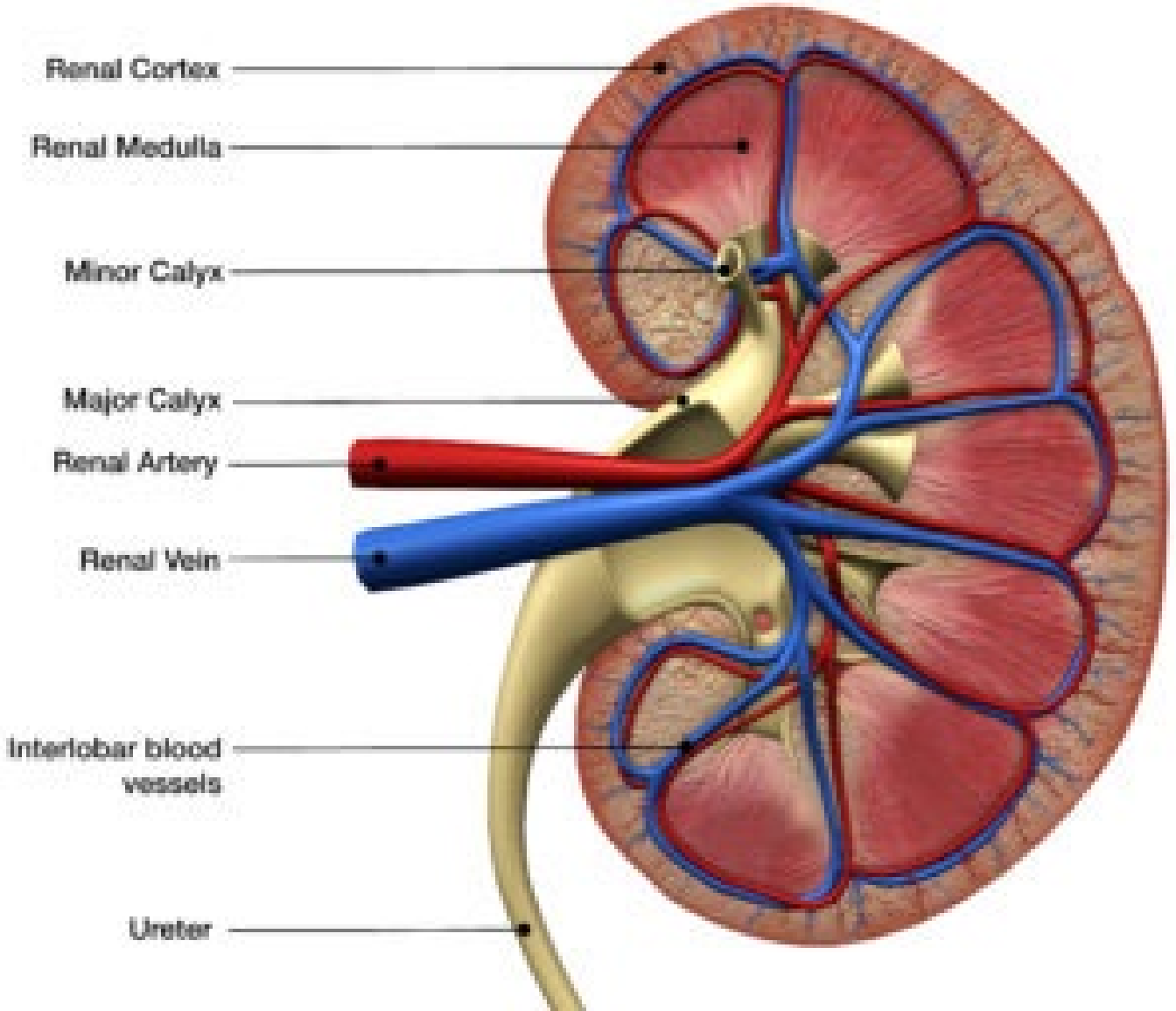
Main kidney functions

- “Make urine”
- Removal of metabolic waste and chemicals from the body
- Regulation of water and electrolyte balance, and body fluid osmolality
- Regulation of arterial pressure
- Regulation of acid-base balance
- Secretion, metabolism and excretion of hormones
- Gluconeogenesis

What waste?

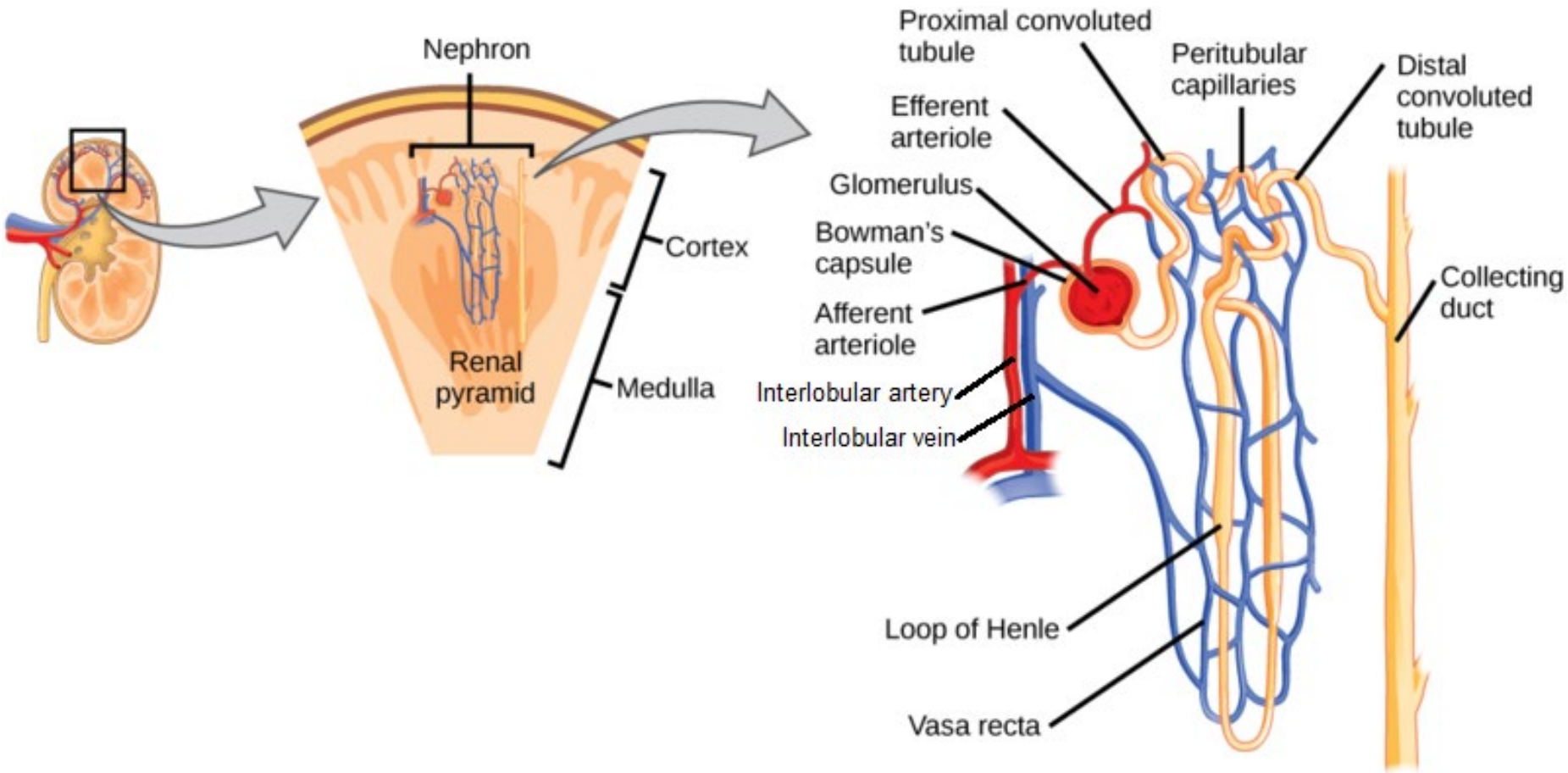
- Urea
  - From amino acid metabolism
- Creatinine
  - From muscle creatine
- Uric acid
  - From breakdown of nucleic acids
- Bilirubin
  - From haemoglobin breakdown
- Hormone metabolites

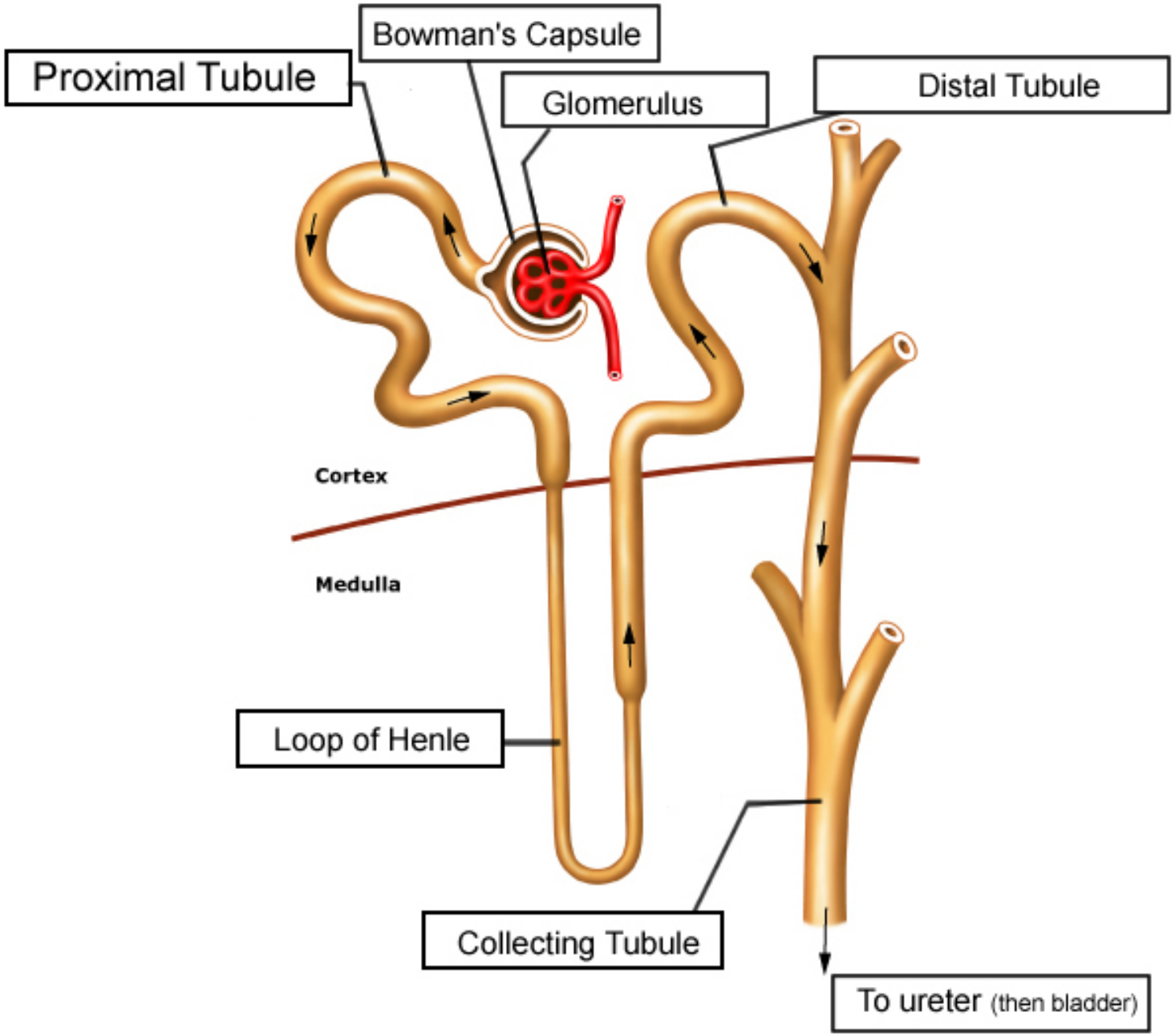
How do kidneys do all that?



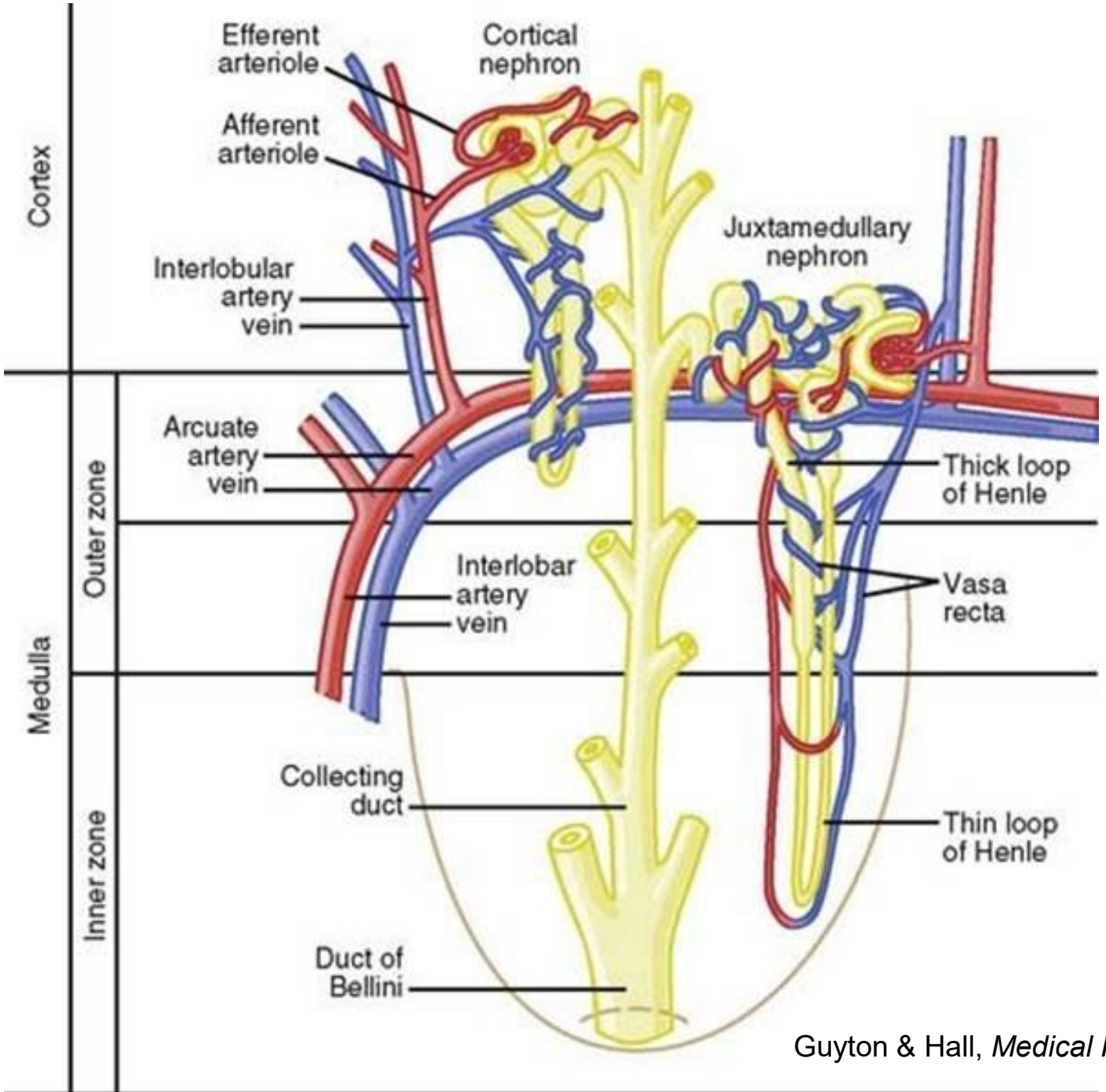
How do kidneys do all that?

- The nephron:





https://www.biologycorner.com/anatomy/urinary/urinary_labeling_key.html



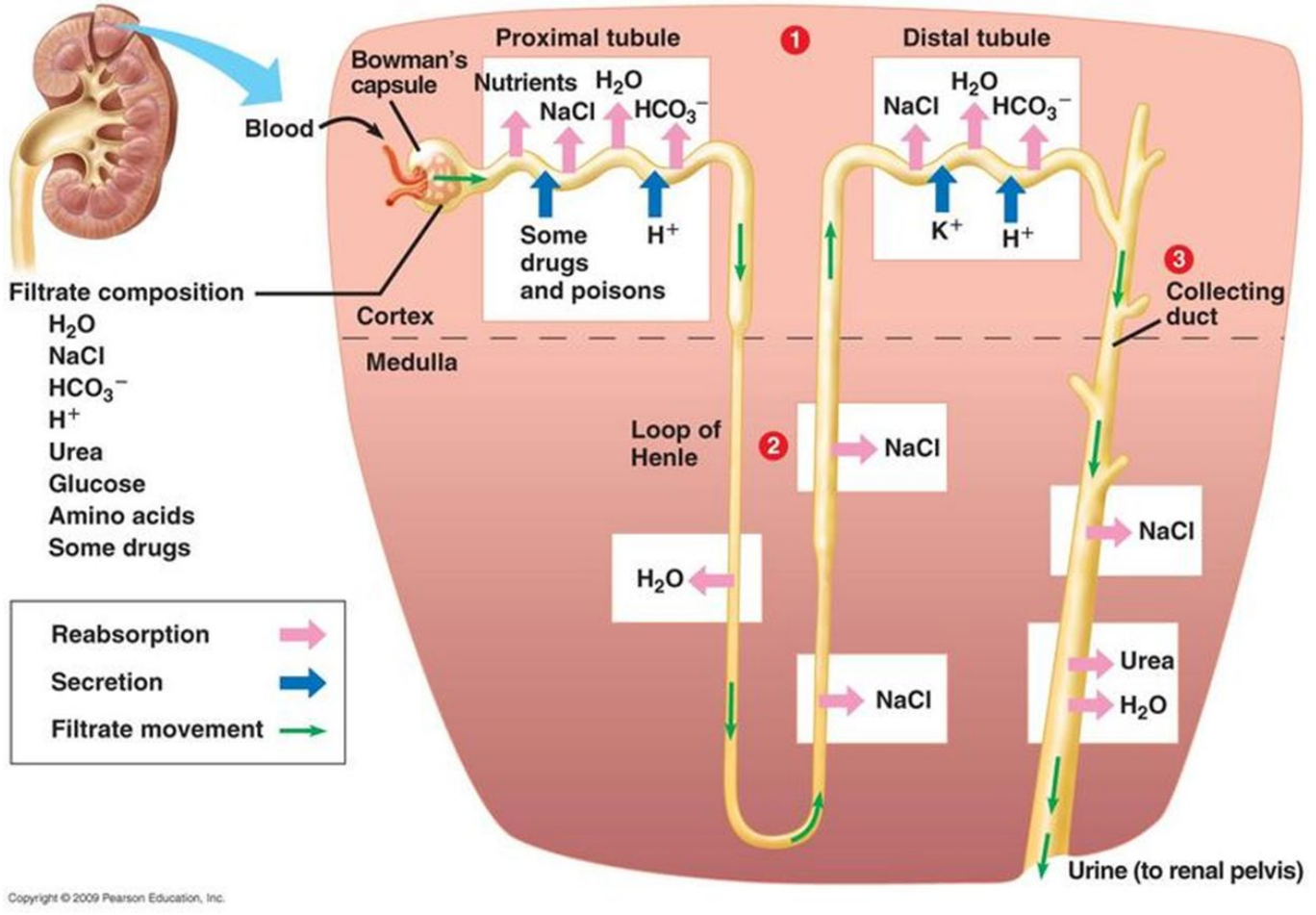
Guyton & Hall, *Medical Physiology*

Why have 2 different types?

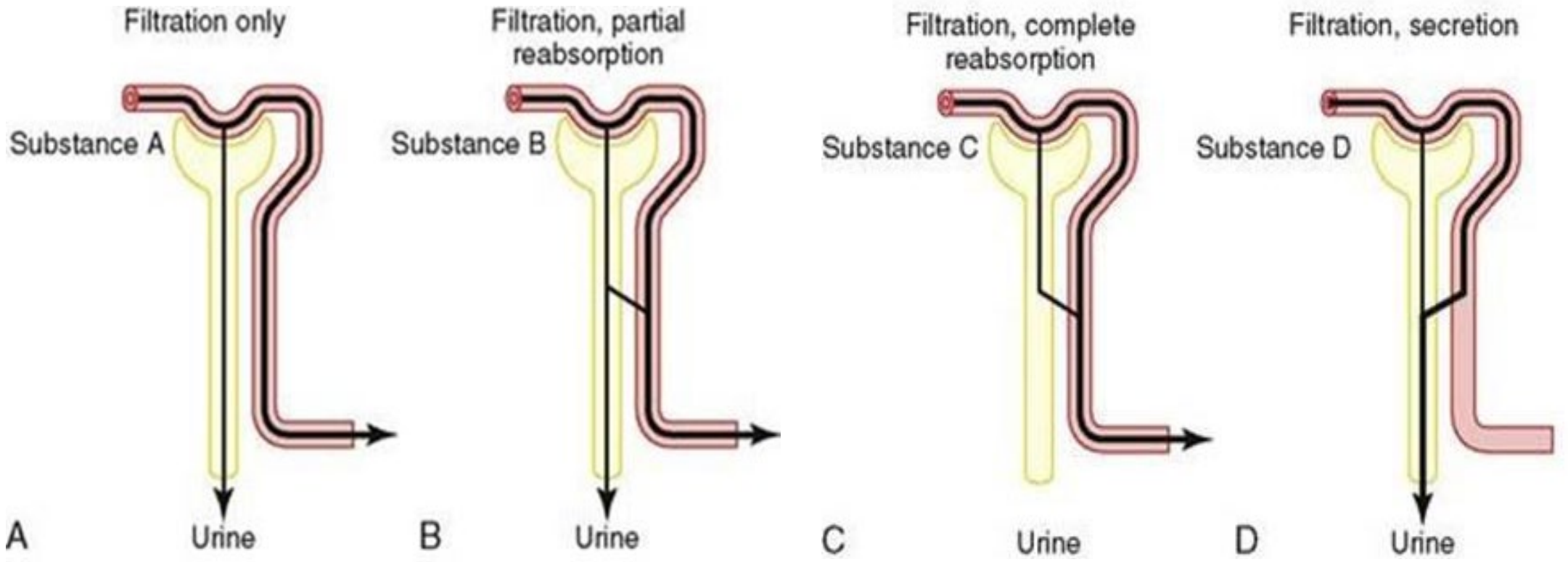
- Not all animals have juxtamedullary nephrons
  - Mammals ✓
  - Birds ✓
  - Reptiles ✗
- Not all nephrons are required for urine concentration
  - Only juxtamedullary nephrons have specialised vasa recta
- Tubular epithelium differs between 2 types

Urine formation

- Three main processes:
  - Glomerular filtration
  - Reabsorption of substances from renal tubules into blood
  - Secretion of substances into blood from renal tubules



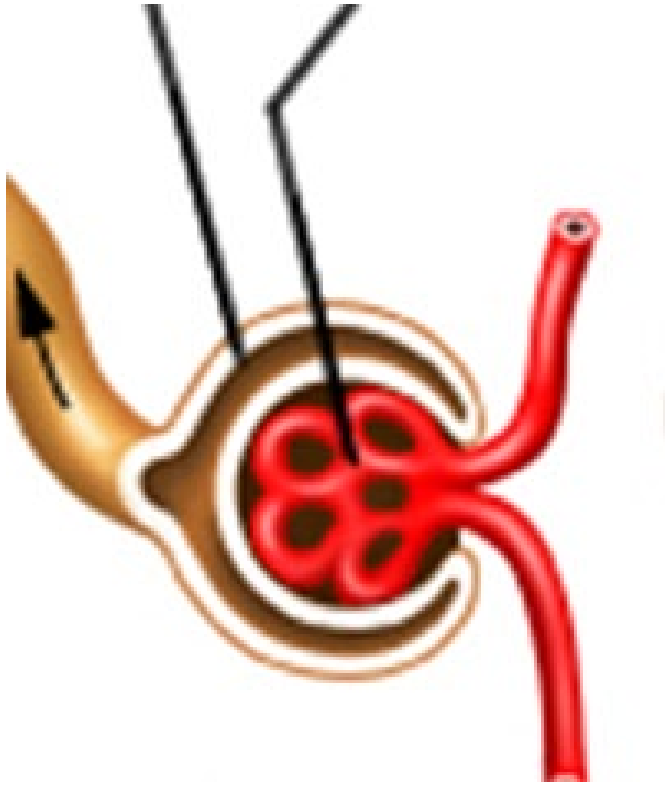
Ways substances are handled by the kidneys



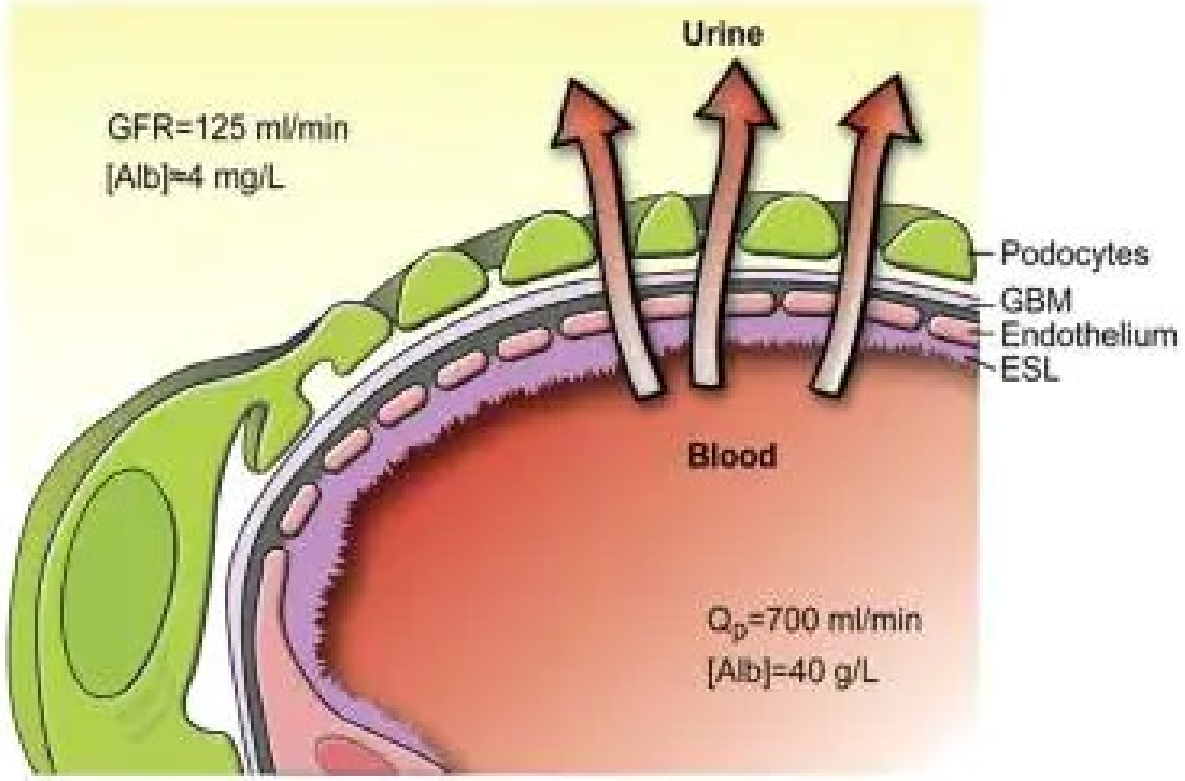
Guyton & Hall, 14th Ed. 2021

Glomerular filtration

- Large amount of fluid leaves capillaries in glomerular tuft and enters Bowman's capsule
- Afferent and efferent arterioles
- Glomerular capillaries
  - 3 layers – endothelium, BM, epithelium (podocytes)
  - Epithelium fenestrated



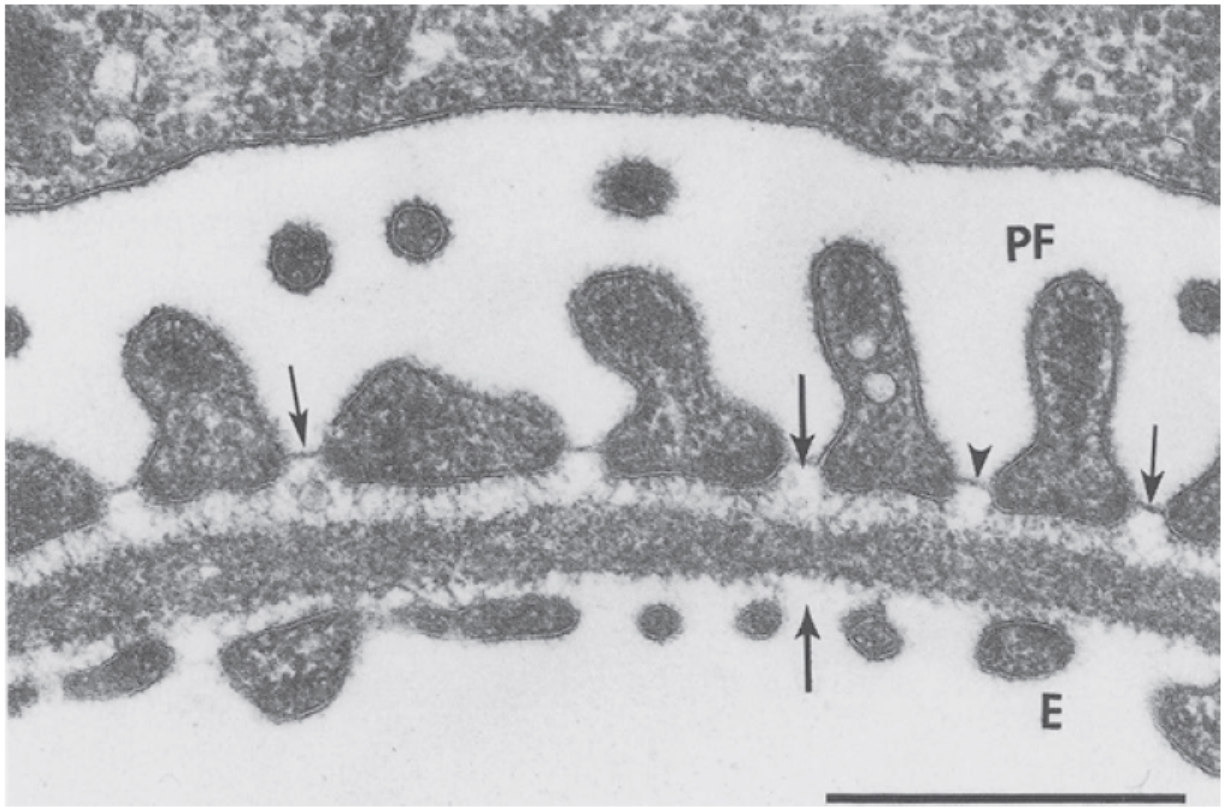
Glomerular filtration

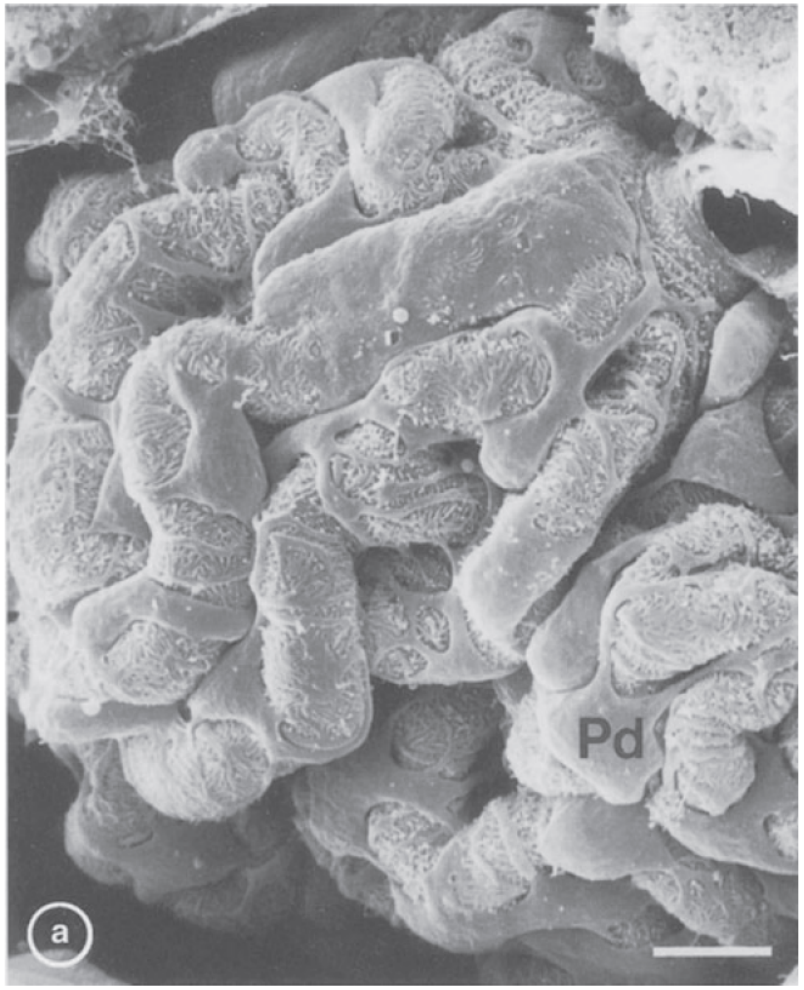


medscape.com

- Endothelial cells negatively charged
- Albumin negatively charged
- Prevents most albumin leaking out of capillaries

Glomerular filtration





Bachmann & Kriz, 1998

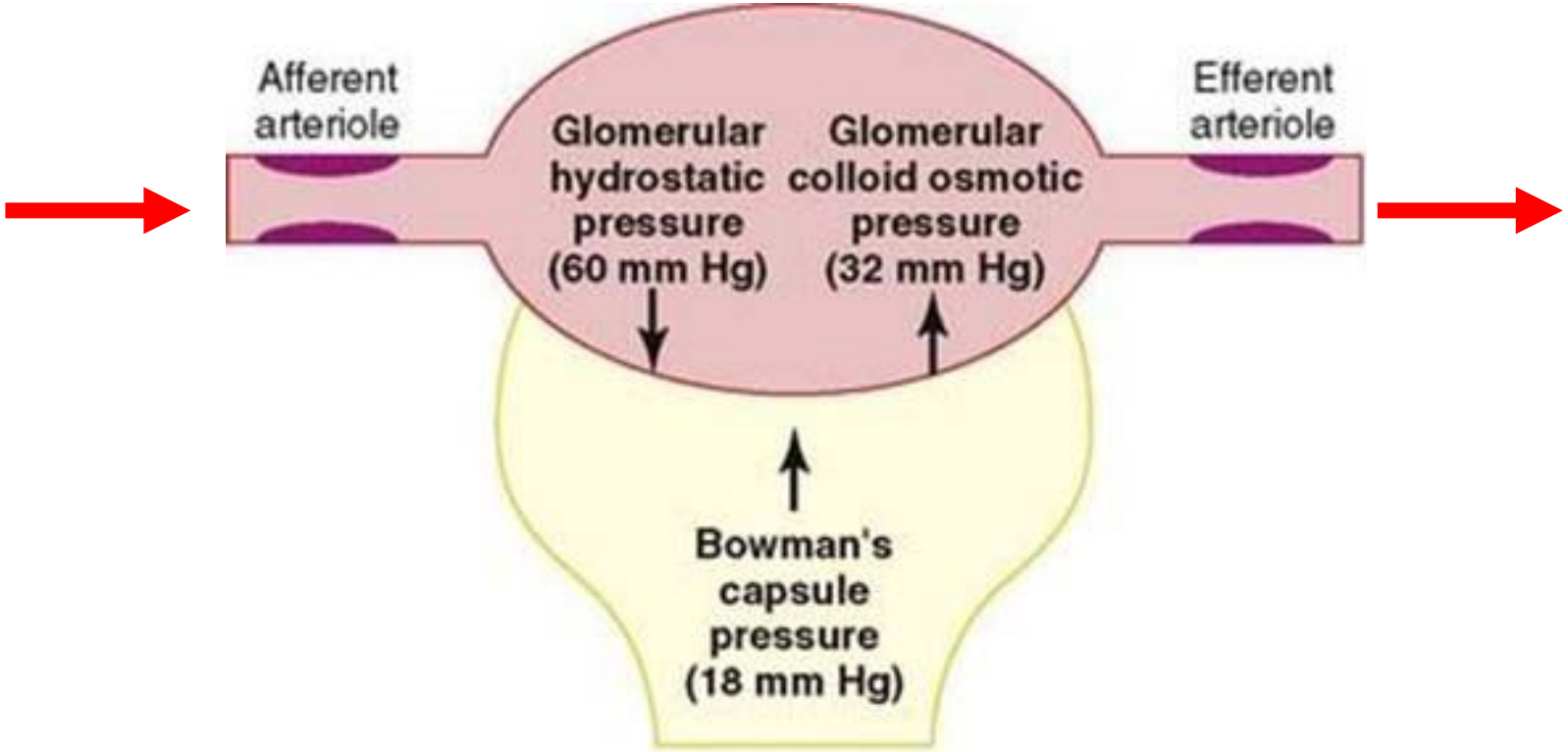
Glomerular filtration rate

- = the flow of plasma from the glomerulus into Bowman's space over a specified period of time (mL/min)
- Chief measure of kidney function
- Determined by several factors
  - Pressure (hydrostatic and osmotic)
    - Capillary
    - Bowman's space
  - Permeability of filtrate barrier
  - Area available for filtration

Glomerular filtration rate

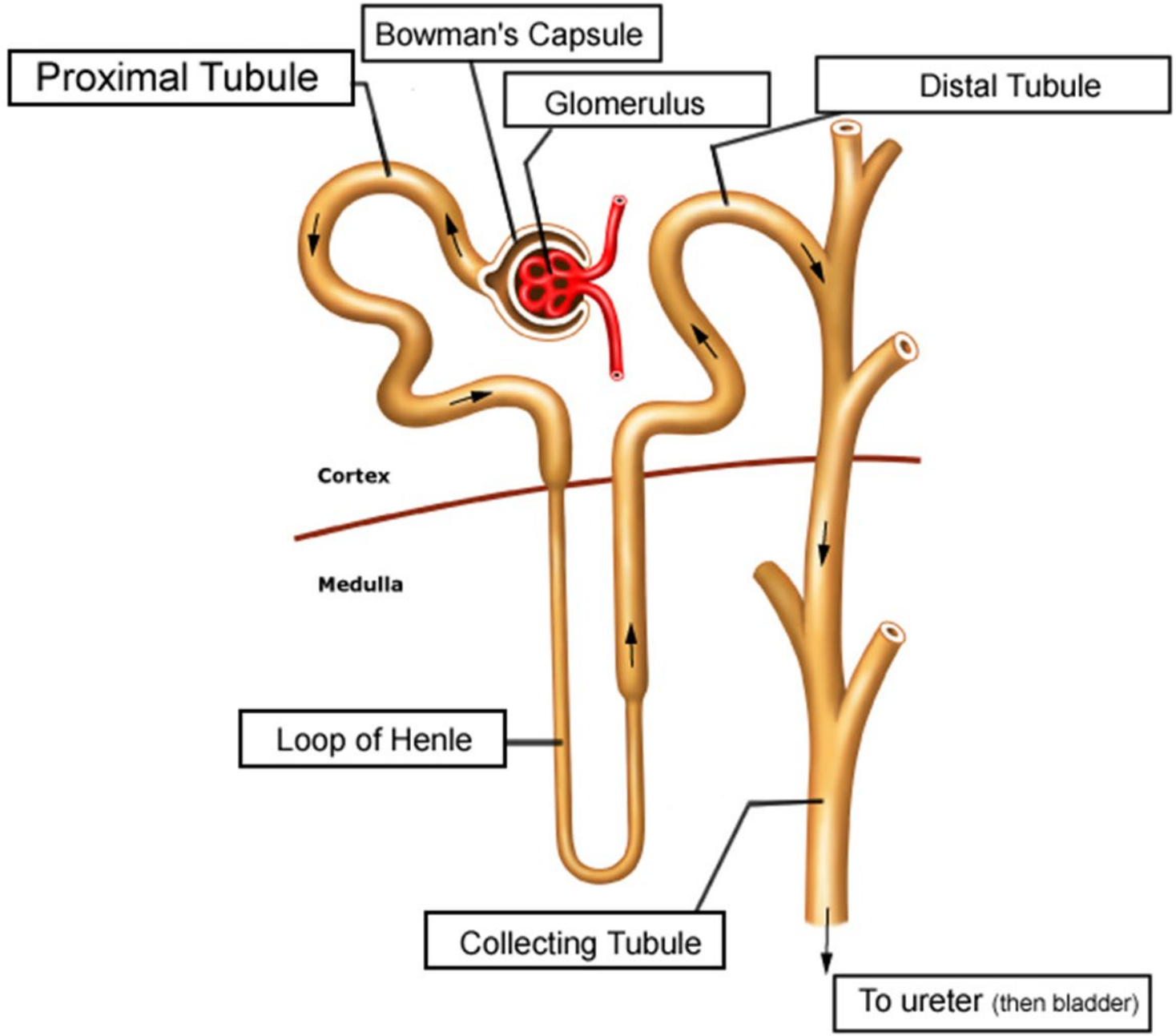
- Regulated by several mechanisms to keep GFR relatively constant despite changes in BP, intravascular volume, etc.

Glomerular filtration rate



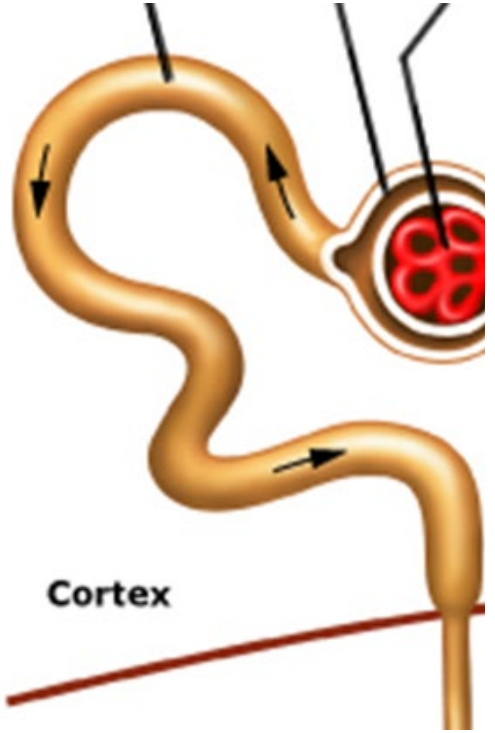
Net filtration pressure (10mmHg)	=	Glomerular hydrostatic pressure (60 mmHg)	-	Bowman's capsule pressure (18 mmHg)	-	Glomerular colloid osmotic pressure (32 mmHg)

Guyton & Hall, 14th Ed. 2021


Proximal Tubule
Bowman's Capsule
Glomerulus
Distal Tubule
Cortex
Medulla
Loop of Henle
Collecting Tubule
To ureter (then bladder)

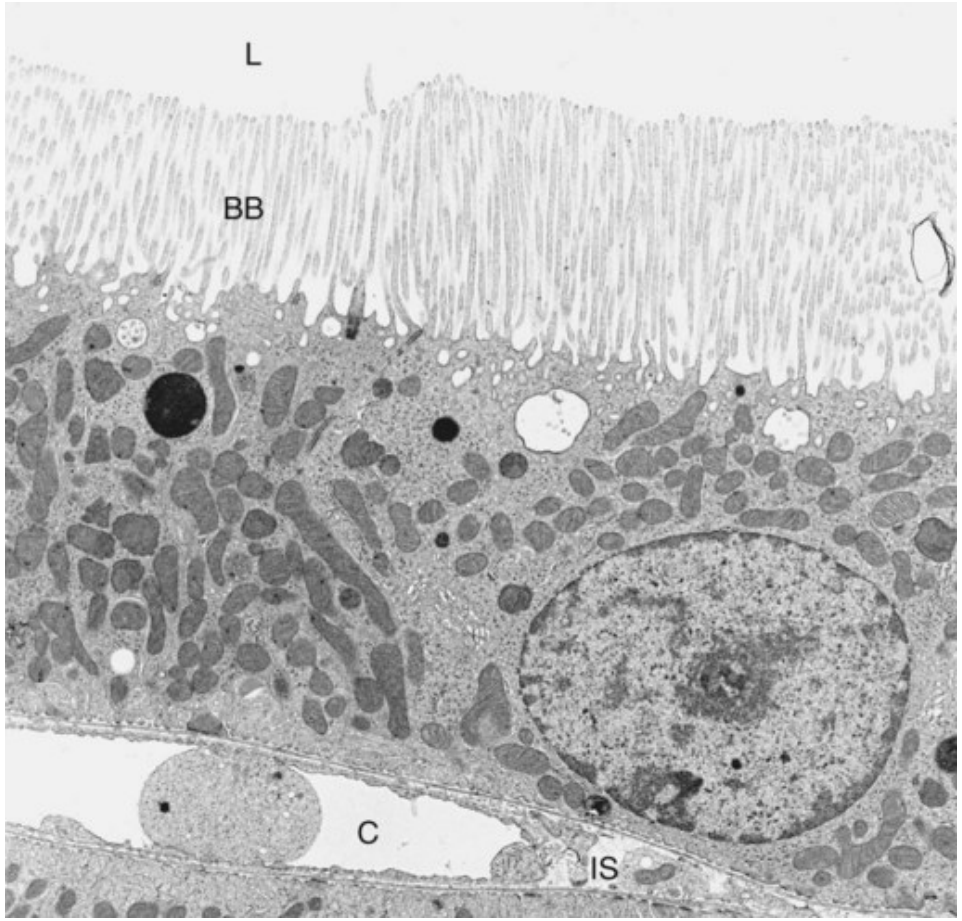
Proximal tubule

- Primarily **reabsorption** of water, sodium, chloride, bicarbonate
- All glucose and amino acids reabsorbed
- Passive and active reabsorption
- Some secretion
- Fluid composition remains very similar along the PT, just volume changes



Proximal tubule

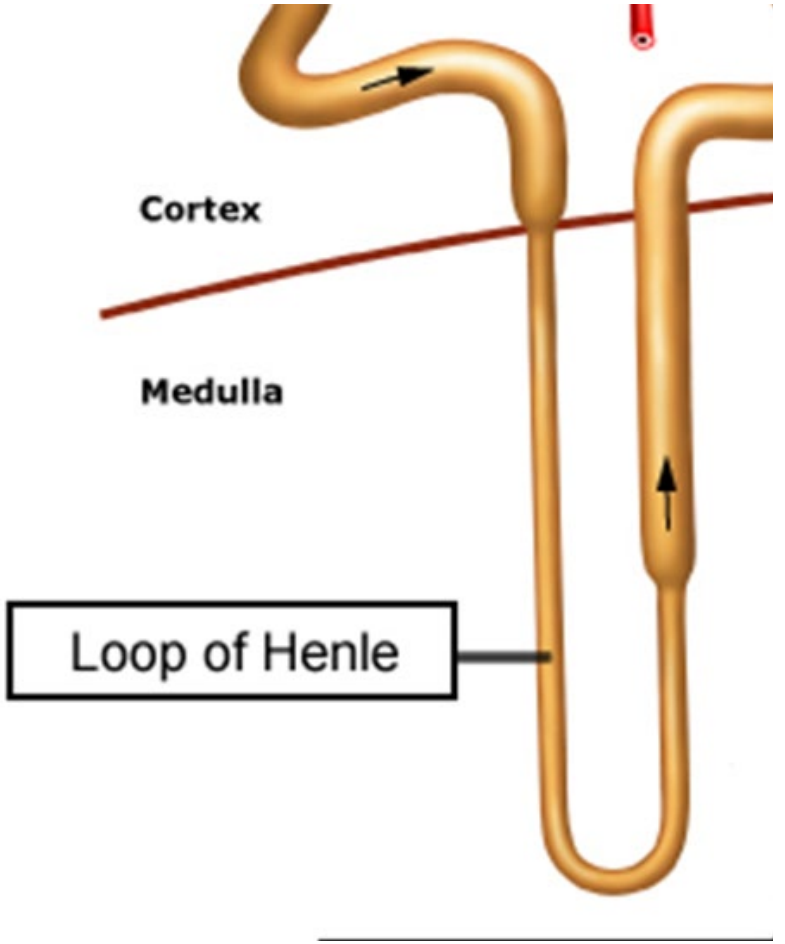
- Tubular epithelial cells
  - Brush border allows greater surface area for reabsorption

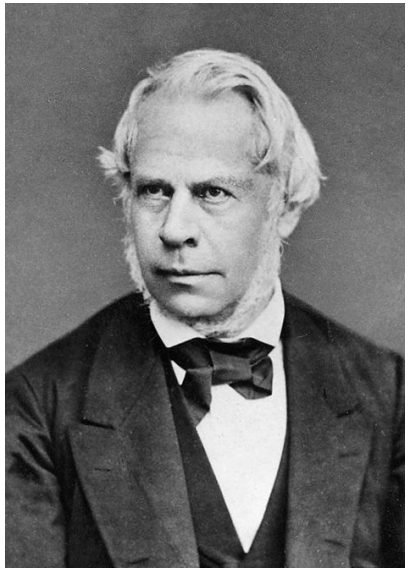


Klein; Cunningham 6th Edition, 2020

Loop of Henle

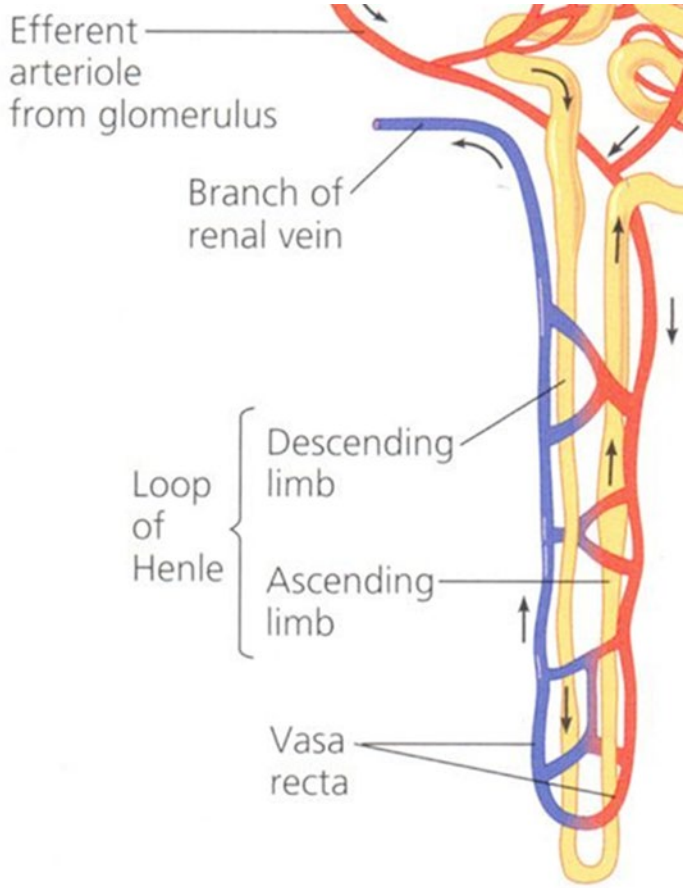
- 3 functionally distinct parts:
  - Thin descending
  - Thin ascending
  - Thick ascending
- Thin parts – not much active transport, mainly diffusion
- Thick part – active reabsorption
- Thin parts – important for urine concentration



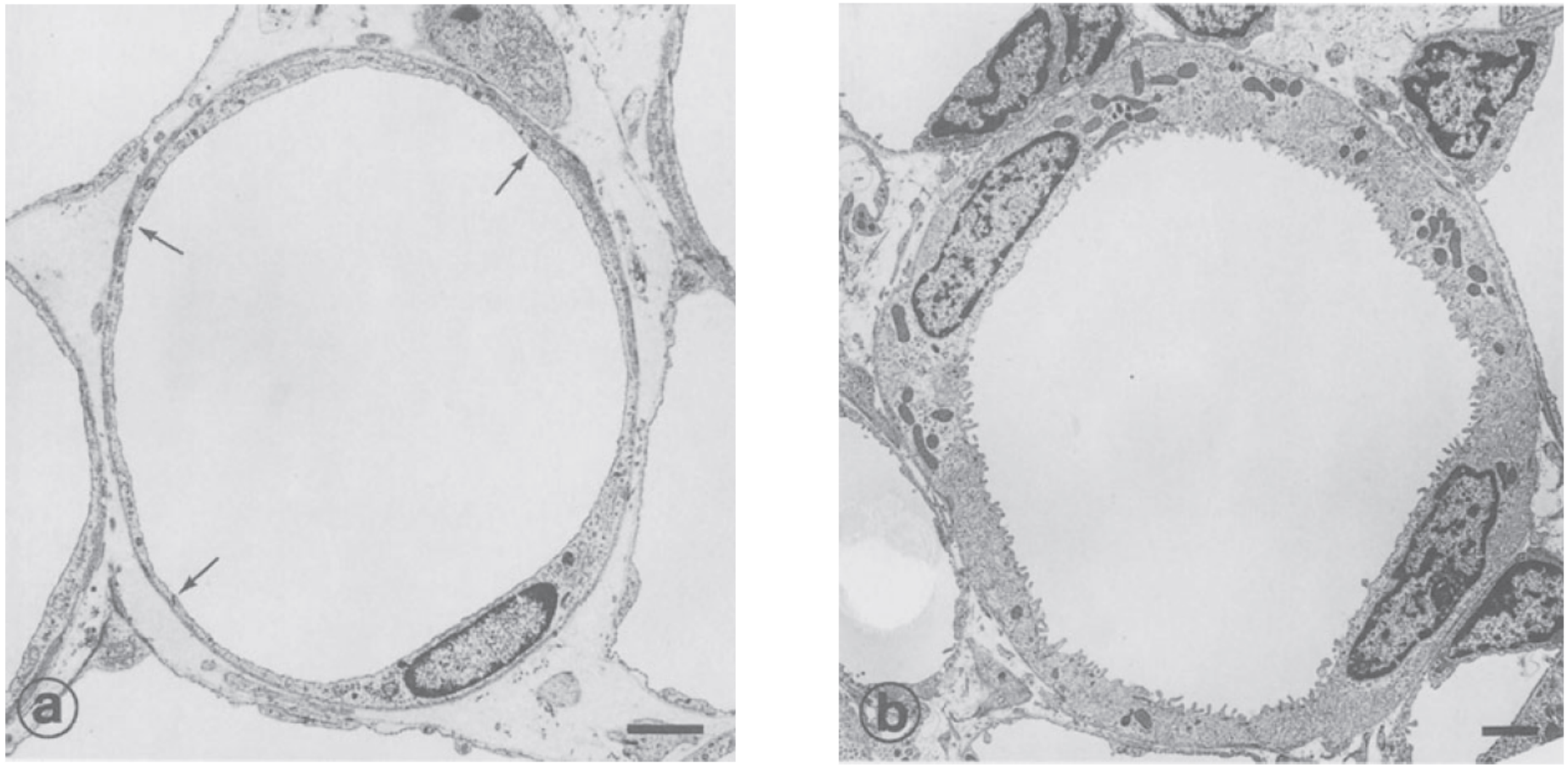


Loop of Henle – the thin bits

- Thin descending loop of Henle
  - Highly permeable to water and moderately permeable to most solutes
  - 20% of filtered water reabsorbed here
- Thin ascending loop of Henle
  - Impermeable to water
  - Important in concentrating urine



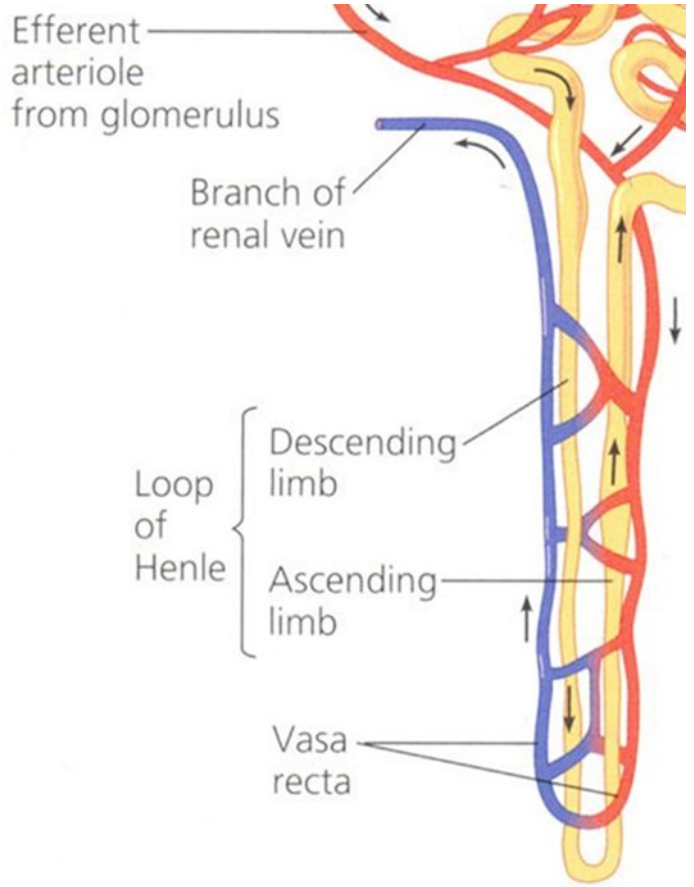
Loop of Henle – the thin bits



Bachmann & Kriz, 1999

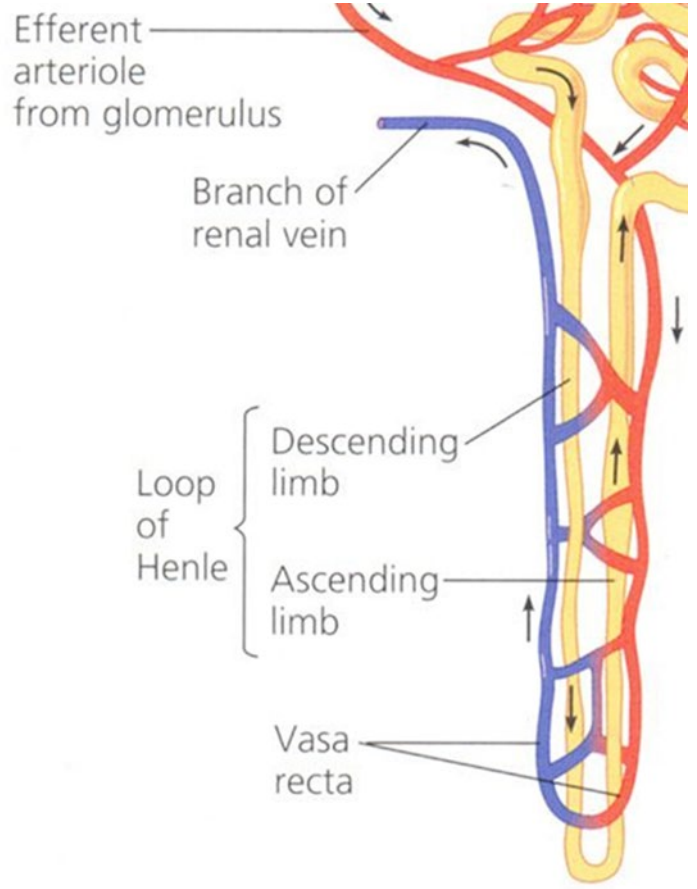
Loop of Henle – the thick bit

- Thick ascending loop of Henle
  - Active reabsorption of Na^+, K^+, Cl^-
  - 25% of filtered load of these electrolytes and other ions reabsorbed here
  - Impermeable to water

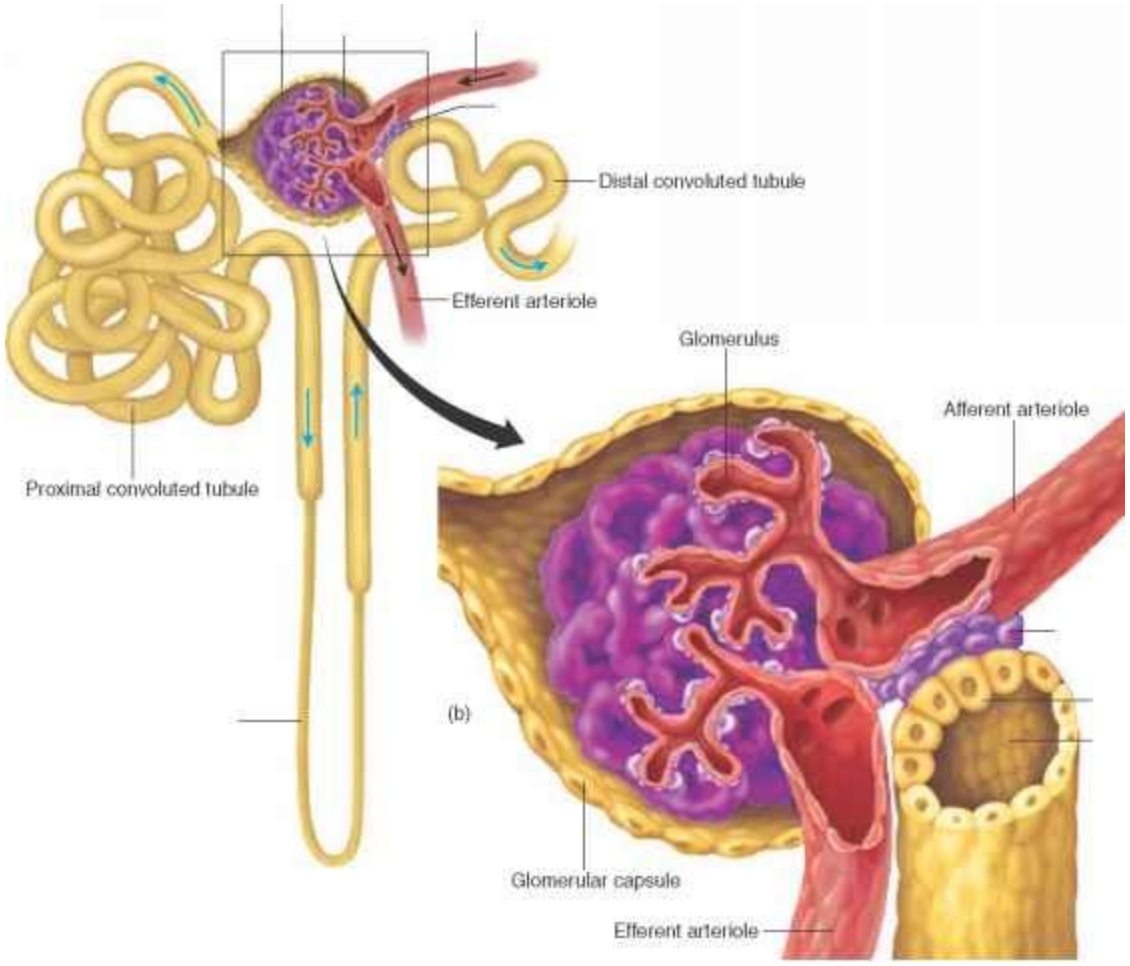


Loop of Henle – vasa recta

- Blood flow through medulla is much less than the cortex – 1-2% of renal blood flow
- Vasa recta are specialised peritubular capillaries
- Important in mechanism for kidneys to concentrate urine



Distal tubule – first half



- First part forms macula densa
  - Sits adjacent to afferent and efferent arterioles of glomerulus
  - Part of juxtaglomerular apparatus
  - Feedback mechanism within same nephron

Distal tubule – first half

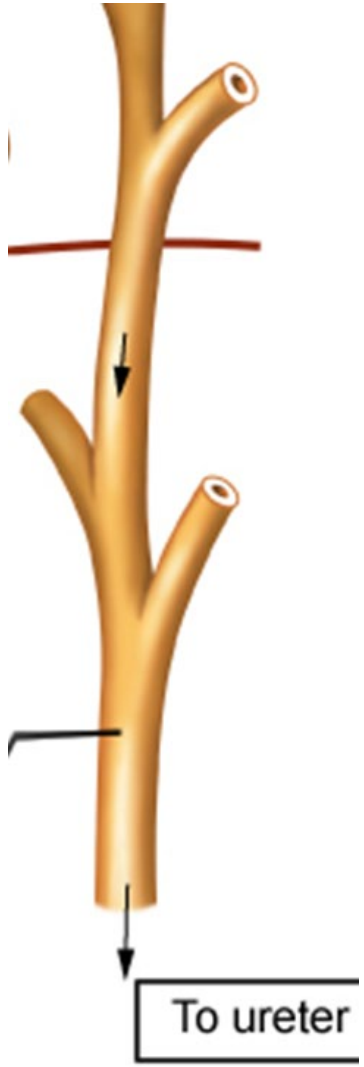
- Remainder of function similar to thick ascending loop of Henle
  - Active reabsorption sodium and chloride
  - Impermeable to water
  - “Diluting segment”

Distal tubule – second half + cortical collecting tubule

- Principal cells
  - More sodium and water reabsorption, potassium secretion
- Intercalated cells
  - Acid-base regulation
  - Potassium reabsorption or secretion
- Reabsorption under hormonal control
  - Aldosterone
- Permeability under control of vasopressin (ADH)

Collecting ducts

- Medulla
- Final site for urine processing
- Vasopressin (ADH) controls permeability
- Also some role in acid-base regulation
  - H^+ excretion
- Some urea reabsorbed



Physiological control in the kidneys

- Through constriction or relaxation of renal vasculature
- Sympathetic nervous system
  - Innervates all renal blood vessels, including glomerular afferent and efferent arterioles
  - Most important mechanism for decreasing GFR in severe, acute, disturbances
- Hormonal/autacoid control
  - Various hormones constrict or relax renal blood vessels, including glomerular afferent and efferent arterioles

Main hormones at play in the kidneys (alter GFR)

- Vasoconstrictors/vasodilators
  - Adrenaline/epinephrine (↓ GFR)
  - Noradrenaline/norepinephrine (↓ GFR)
  - Endothelin (↓ GFR)
  - Angiotensin II (prevents ↓ of GFR)
  - Nitric oxide (↑ GFR)
  - Prostaglandins (prevent ↓ of GFR)

Main hormones at play in the kidneys (alter electrolyte & water handling)

- Hormones that affect sodium/water reabsorption/excretion
  - Vasopressin (anti-diuretic hormone; ADH)
  - Aldosterone
  - Atrial natriuretic peptide (ANP)

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