Physiology of excretory system

Excretory organs

Kidneys

-Water
-Salts
-Urea
-Uric acid

Skin

-Water

-Salts

-Urea

-Uric acid

Liver

-Hormones

Lungs

-CO_2

GI tract

Function of kidneys

1. Adjust salt and water excretion to maintain a constant *extracellular fluid volume* and *osmolality*;
2. They help to maintain *acid-base homeostasis*;
3. They *eliminate end-products* of metabolism and foreign substances while
4. Preserving useful compounds (e.g., glucose) by reabsorption;
5. The produce *hormones* (e.g., erythropoietin) and hormone activators (renin),
6. Have *metabolic functions* (protein and peptide catabolism, gluconeogenesis, etc.).

Function of kidneys

7. Regulate blood volume
8. Help regulate electrolyte content of the blood
9. Regulate acid-base balance (pH)
10. Regulate blood pressure
11. Regulates red blood cell production

The Formation of Urine

- The Nephron Unit
- Each kidney contains about 1 million nephron units
- The number does not increase after birth
- They cannot be replaced if damaged
- 2 parts:
  - Tubular component (renal tubule)
  - Vascular component

Nephron functions include:

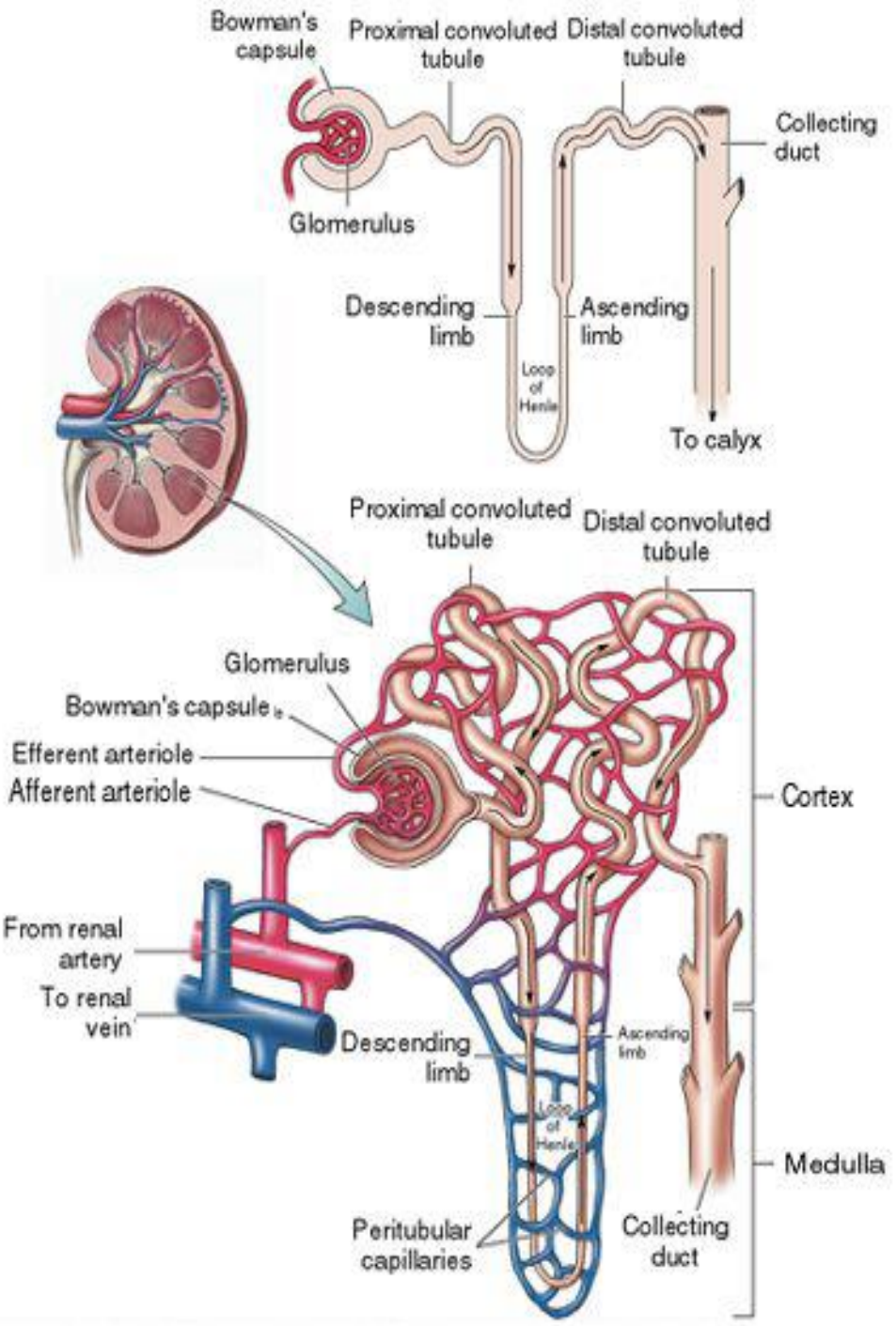
- Production of filtrate
- Reabsorption of organic nutrients
- Reabsorption of water and ions
- Secretion of waste products into tubular fluid

Two types of nephron

- Cortical nephrons
  - ~85% of all nephrons
  - Located in the cortex
- Juxtamedullary nephrons
  - Closer to renal medulla
  - Loops of Henle extend deep into renal pyramids

Renal Tubules

- Glomerular capsule (Bowman's Capsule) – "C" shaped capsule surrounding the glomerulus
- Glomerulus – cluster of capillaries
  - Proximal convoluted tubule (PCT)
  - Loop of Henle – ascending and descending limb
  - Distal Convoluted tubule (DCT)
  - Collecting duct



Functions of Nephron Structures

- Afferent Arteriole
  - Transports arterial blood to the glomerulus for filtration

- Efferent Arteriole
  - Transports filtered blood from the glomerulus, through the peritubular capillaries and the vasa recta, and to the kidney venous system

- Glomerulus
  - The **site for blood filtration**
  - operates as a nonspecific filter; in that, it **will remove both useful and non-useful** material
  - the product of the glomerulus is called **filtrate**

- Bowman's Capsule
  - A sac that encloses Bowman's Capsule and **transfers filtrate** from the **glomerulus** to the **Proximal Convoluted Tubule (PCT)**

- Proximal Convoluted Tubule (PCT)
  - A thick, constantly actively segment of the nephron that **reabsorbs most of the useful substances of the filtrate**: sodium (65%), water (65%), bicarbonate (90%), chloride (50%), glucose (nearly 100%!), etc.
  - **The primary site for secretion** (elimination) of drugs, waste and hydrogen ions

- Decending Limb of the Loop of Henle
  - A part of the counter current multiplier
  - freely **permeable to water** and relatively **impermeable to solutes** (salt particles)
  - receives filtrate from the PCT, allows water to be absorbed and sends "salty" filtrate on the next segment. **"Saves water and passes the salt"**

- Ascending Limb of the Loop of Henle
  - a part of the counter current multiplier
  - **impermeable to water** and **actively transports (reabsorbs) salt** (NaCl) to the interstitial fluid of the pyramids in the medulla. "**Saves salt and passes the water.**"
  - the passing **filtrate becomes dilute** and the **interstitium becomes hyperosmotic**

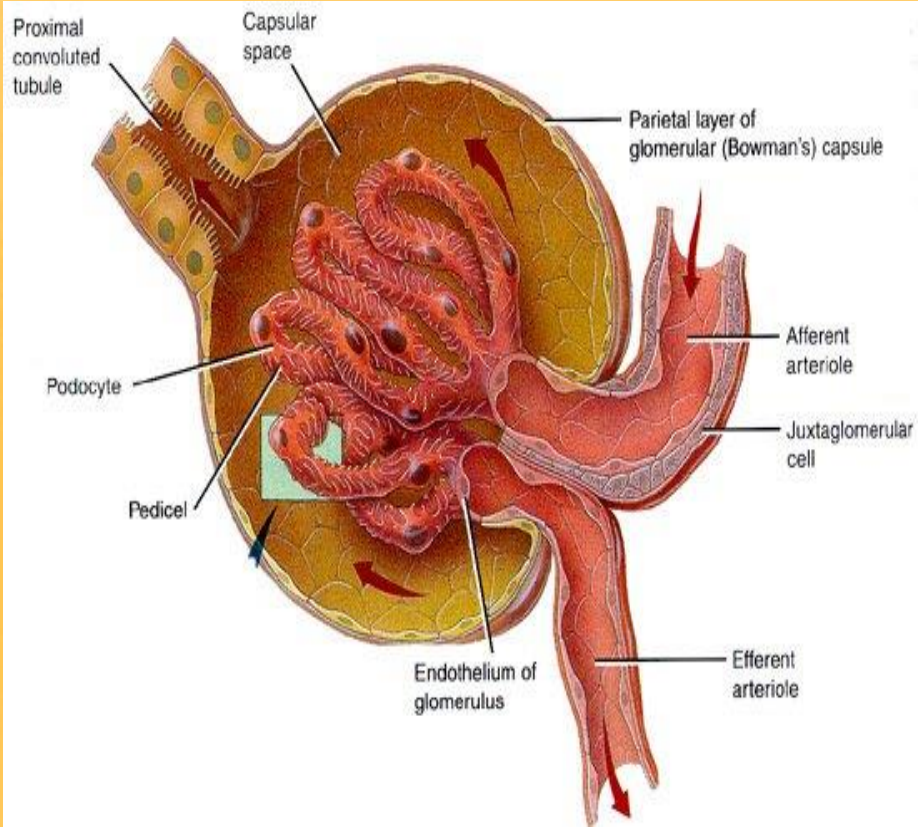
- Distal Convoluted Tubule (DCT)
  - receives dilute fluid from the ascending limb of the Loop of Henle
  - **Variably active** portion of the nephron
  - When **aldosterone** hormone is present, **sodium is reabsorbed** and **potassium is secreted.** Water and chloride follow the sodium.

- Collecting Duct
  - receives fluid from the DCT
  - **variably active** portion of the Nephron
  - when antidiuretic hormone (**ADH**) is present, this duct will become **porous to water**. Water from the collecting duct fluid then moves by osmosis into the "salty" (hyperosmotic) interstitium of the medulla.
  - The last segment to save water for the body

- Peritubular Capillaries
  - transport reabsorbed materials from the PCT and DCT into kidney veins and eventually back into the general circulation
  - help complete the conservation process (reabsorption) that takes place in the kidney

The Juxtaglomerular Apparatus

The juxtaglomerular apparatus consists of specialized **macula densa cells** that develop in the distal convoluted tubule (DCT) and specialized **granular juxtaglomerular (JG) cells** that develop mainly in the afferent arteriole.



The Juxtaglomerular Apparatus

Used in maintaining blood pressure

- **if the blood pressure drops, the granular JG cells release renin**
- **renin converts the blood protein angiotensinogen into angiotensin I which converts to angiotensin II**
- **angiotensin II acts as a vasoconstrictor to raise blood pressure.**
- **Angiotensin II also stimulates the release of aldosterone hormone from the adrenal cortex**
- **aldosterone stimulates the DCT to reabsorb salt (NaCl).**
- **Salt reabsorption attracts water to the blood by osmosis and raises blood volume, as well as, contributing to the increase in blood pressure.**

- the macula densa cells monitor the salt content of the blood
- if the blood salt content gets too high, the macula densa cells begin to inhibit the granular cells and suppress renin release
- suppression of renin acts as a negative feedback mechanism to prevent further increases in angiotensin II, Aldosterone and blood pressure
- eventually the blood pressure will come back down
- the “push/pull” action of the granular cells and macula densa cells provide an effective mechanism for regulating blood pressure in the kidney

Renal Vasculature

- Receives blood from the renal artery
- Renal artery branches into the afferent arterioles (Branches to form glomerulus)
- Afferent arterioles feed into Bowman's capsule
- The efferent arterioles exit Bowman's capsule
- The efferent arterioles form the peritubular capillaries
- The peritubular capillaries empty into the venules, large veins, and then into the renal veins

It is imperative you know the relationship between the tubular and vascular structures.

Urine Formation

- Formed in the nephron unit
- Water and dissolved substances move through the renal tubules and vessels
- Three processes are involved in urine formation
  - Glomerular filtration
  - Tubular reabsorption
  - Tubular secretion

Normal Urine

- Clear and pale to deep yellow or amber
- Slightly aromatic in odor
- Slightly acidic 5.0 – 8.0
- With a sp. Gravity of 1.010 – 1.030
- **Composition**:
  - Urea: 500mmol/day
  - Na^+ and Cl^-: 100-300mmol/day (roughly matched to intake)
  - K^+: 50-300 mmol/day (roughly matched to intake)
  - Creatinine: 7mmol/day
  - $H_2PO_4^-$ and HPO_4^{2-}: 20-60 mmol/day
  - Ca^{2+}: 3-8 mmol/day
  - Mg^{2+}: 2-9 mmol/day

Composition of Urine

- Sterile
- 95 % water
- Nitrogen containing waste – urea, uric acid, ammonia, creatinine
- Electrolytes
- Light yellow color of urine is due to a pigment called urochrome
- Urochrome is formed from the breakdown of hemoglobin in the liver

Urine Specific Gravity

- Ratio of the amount of solute to the total volume
- Solute = substance dissolved in the urine
- The greater the solute = greater the specific gravity
- Concentrated Urine = high specific gravity
  - Ex. dehydration
- Dilute Urine = low specific gravity
  - Ex. Overhydration, diabetes insipidus

Urine Characteristics

- Amount – 1500 ml in 24 hours
- pH – average 6.0
- Specific Gravity – heavier than water (1.010-1.030)
- Color – yellow (amber, straw colored, concentrated, orange, brown, red, sediment, clear or cloudy)
- Dehydrated = deep yellow, dark
- Overhydrated = pale yellow, colorless

Abnormal Constituents of Urine

- Albumin (protein)
- Glucose
- Red blood cells
- Hemoglobin
- White blood cells
- Ketone bodies
- Bilirubin

Urine Testing

- Urinalysis
- Microscopic exam
- Culture and sensitivity
- Urine dipstick
- Urine Drug and alcohol screening
- 24 hour urine testing