Urinary system (excretory system)

The organ system that cleans the blood (removes urea and other nitrogen-containing wastes) and balances the blood (adjusts the blood's solutes (ions, pH, nutrients, water content) to their proper concentrations)

- The kidney filters (takes the liquid part) of the blood into tubules called nephrons. The nephrons reabsorb (transport) only the proper amounts of solutes and water back into the blood

  √ Wastes and excess solutes and excess water are not reabsorbed back into the blood (The kidney forms the urine out of them)

- The other excretory system organs (ureters, bladder, urethra) store urine and channel it out of the body

Fig 25.1

Major blood components:

- Water
- Blood cells (RBC, WBC, platelets)
- Proteins (albumin, antibodies, clotting factors, etc.)
- Ions (Na^+, Cl^-, K^+, H^+, HCO_3^-, Ca^{2+}, etc.)
- Nutrients (glucose, amino acids, fatty acids, vitamins, etc.)
- Nitrogen-containing wastes (Urea, uric acid, etc.)

  √ The nitrogen-containing wastes are made by the liver from NH_3 (ammonia), a cellular waste product

Figs 18.3 and 25.22

Kidneys

A pair of organs (located near the lowest ribs) that clean and balance the blood and form the urine.

• Cortex = The outermost region of the kidney; where most of the nephrons are located

√ In the cortex, the nephrons filter, clean, and adjust the blood

• Medulla = The middle region of kidney; it contains renal pyramids and renal columns

√ Renal pyramids = Medulla regions where urine (formed in the cortex) passes through the medulla on its way to the renal pelvis

√ Renal columns = Medulla regions where arteries and veins pass through medulla (carrying blood to and from cortex)

• Renal pelvis = A cavity in the innermost part of kidney that collects urine from the renal pyramids and drains it into the ureters

Figs 25.1, 25.7 and 25.8

Structures connected to kidney:

- Renal artery = Blood vessel that brings blood to be cleaned/balanced to kidney
- Renal vein = Blood vessel that carries cleaned/balanced blood away from kidney
- Ureter = Tube that carries urine from kidney to bladder
- Adrenal gland = An endocrine gland that sits superiorly on each kidney
    - √ An entirely separate organ from kidney

Figs 25.1, 25.7 and 25.8

Nephrons

Tubular structures in the renal cortex that filter the blood, reabsorb solutes and water, and form the urine. Only the balanced amounts of water and solutes are reabsorbed back into the blood. Wastes (like urea) and excess water/solutes are not reabsorbed (they form the urine)

• The glomerular capsule (Bowman's capsule) = The enlarged end of the nephron that encloses a glomerulus and together they filter the smaller blood molecules into the nephron

• The proximal convoluted tubule = The nephron region where the most reabsorption of solutes and water from filtrate occurs
  - √ This region of the nephron can reabsorb water and all solute types (except urea)

• The nephron loop (Loop of Henle) = The nephron region that loops down toward the medulla then up again into the cortex
  - √ The nephron loop specializes in NaCl and water reabsorption

• The distal convoluted tubule = The final nephron region
  - √ This region of the nephron can reabsorb water and all solute types (except urea)

Figs 25.9, 25.10, and 25.17

Filtration

The selective passage of molecules through a porous membrane based on the size of the molecules. Filtration is powered by blood pressure.

• The glomerular capsule and the glomerulus together form the renal corpuscle (the filter of the nephron)

•Blood cells and blood proteins are too large to enter the nephron. All other blood solutes are small enough to filter into the nephron. These include water, ions, nutrients (such as glucose, amino acids, and vitamins), and nitrogen containing wastes (such as urea)

• Filtrate = The liquid that passes from the blood into the nephron

Figs 25.10 and 25.16

Collecting ducts

Tubes that collect filtrate from the ends of nephrons and transport the filtrate through the medulla to the renal pelvis

- The final reabsorption of water and NaCl from the filtrate takes place in the collecting duct
- Each collecting duct receives filtrate from many nephrons
- The renal pyramids of the medulla are clusters of collecting ducts
- Urine = The filtrate that exits the collecting duct into the renal pelvis

Figs 25.10 and 25.17

Capillaries associated with the nephron:

- Glomerulus = A ball of capillaries at the end of each afferent arteriole in the cortex.
  - √ Smaller molecules of the blood are filtered from the glomerulus into the nephron
  - √ The blood that does not filter into the nephron exits the glomerulus via an efferent arteriole
- Peritubular capillary bed = A capillary bed that surrounds all regions of the nephron
  - √ The blood that enters the peritubular capillary bed has low amounts of water and solutes (because these entered the nephron at the glomerulus)
  - √ The peritubular capillary bed receives balanced amounts of the solutes and water back from the nephron by reabsorption
  - √ The blood at the end of the peritubular capillary bed is cleaned and balanced. It drains into venules, which cross the medulla and exit the kidney by the renal vein

Figs 25.10 and 25.16

Ureters

Tubes that carry urine from the renal pelvis to the urinary bladder

• Urine is moved by peristalsis of the ureter's smooth muscles

Figs 25.7

Urinary bladder

A hollow expandable organ that holds urine until urination

• The bladder walls are smooth muscle with an internal epithelial lining

Figs 25.3 and 25.4

Urethra

The tube that carries urine from the bladder to outside the body

• Two sphincters control exit of urine from the body

√ Internal urethral sphincter = An involuntary smooth muscle sphincter at the exit of the bladder

√ External urethral sphincter = A voluntary skeletal muscle sphincter (located inferiorly to the internal urethral sphincter)

• The urethra exits the body near the vagina in women, and from the end of the penis in men

Figs 25.3 and 25.4

Urination (micturition)

The emptying of urine in the bladder

- When the volume of urine in bladder reaches about 200 ml, an involuntary reflex is triggered that contracts the bladder smooth muscles
  - √ This forces urine passed the internal urethral sphincter
  - √ Voluntary contraction of the external urethral sphincter is now required to prevent urination
  - √ This causes the first urge to urinate
- We voluntarily open the external urethral sphincter when convenient to urinate

Urinary disorders:

- Urinary retention = The inability to start urination
  - √ A common side effect of anesthetics
  - √ Also common in elderly males due to enlarged prostate gland (located near junction of bladder and urethra)
- Incontinence = The inability to prevent urination due to inability to control external urethral sphincter
  - √ Normal in children under two and in some seniors

Urinalysis

Analysis of urine as a medical diagnostic tool

Tables 25.1 and 25.2

Balance of substances in the blood

Maintaining the proper concentration of each substance in the blood

• Balance of blood substances is needed for the proper functioning of the body

- Example: The nervous system does not function properly if Na^+ and K^+ are not at their proper concentrations

• Balance is maintained by matching the amount of the substance that enters the blood (by eating and drinking, for example) with the amount that is taken out of the blood (in urine, feces, perspiration, and vomit, for example)

√ Of all the organs, the kidney has the most precise control of removal of substances from the blood, so the kidney is the major organ for maintaining balance of blood substances

• Major aspects of the blood that are balanced by the kidney:

√ Water balance
√ Sodium and potassium balance
√ Blood pressure
√ H^+ balance (pH)

Water balance

Maintaining the proper concentration of water in the blood

• Water is gained from beverages and foods; Water is lost in urine, feces, perspiration, and evaporation from the skin and the lungs

• Kidney water balancing is regulated by the pituitary hormone ADH (antidiuretic hormone)

• Below normal water concentration in the blood (dehydration) = High osmolarity of the blood's solutes = More ADH secreted

• Above normal water concentration in the blood (overhydration) = Low osmolarity of the blood's solutes = Less ADH secreted

• If there were no ADH, the nephron would reabsorb no water from the filtrate, so large amounts of water would leave the body in the urine

• ADH causes the nephrons to reabsorb water from the filtrate into the blood.

√ High ADH = More water reabsorbed from the filtrate and less water exits body in urine; this adds water to the blood

√ Low ADH = Less water reabsorbed from the filtrate and more water exits body in urine; this removes water from the blood

√ If a person is dehydrated (too little water in the blood, so high blood osmolarity), the pituitary secretes more ADH. Higher ADH leads to an increase in blood water concentration

√ If a person is overhydrated (too much water in the blood, high blood osmolarity), the pituitary secretes less ADH. Lower ADH leads to a decrease in blood water concentration

Figs 26.10 and 26.11

Sodium (Na^+) and potassium (K^+) balance

Maintaining the proper concentration of sodium and potassium ions in the blood

- Sodium and potassium are gained from beverages and foods; They are lost in urine, feces, and perspiration

- Sodium and potassium balance are regulated by the adrenal hormone aldosterone

- If there were no aldosterone, the nephron would retain potassium in the blood but remove large amounts sodium from the blood into the urine

- Aldosterone causes the nephrons to reabsorb sodium from the filtrate to the blood and simultaneously to secrete potassium from the blood into the filtrate

  √ More aldosterone = More sodium retained by the body and more potassium exits body in urine

  √ Less aldosterone = More potassium retained by the body and more sodium exits body in urine

  √ When blood Na^+ is low or K^+ is high, more aldosterone is released

  √ When blood Na^+ is high or K^+ is low, less aldosterone is released

Fig 26.13

Secretion

Transport of solutes from the blood in the peritubular capillary bed to the filtrate in the nephron

- Only certain solutes in the blood can be secreted (K^+, H^+, and certain poisons)

Regulation of blood pressure

The body will attempt to reverse a sudden drop in blood pressure (as might occur during hemorrhage or shock) by increasing blood volume and increasing vasoconstriction (constriction of the blood vessels)

The kidney is part of the pathways that increase blood pressure if it is low

• When blood pressure is low, the pituitary gland secretes more ADH, which increases the blood volume by increasing the nephron's water reabsorption

• When blood pressure is low the following pathway is activated:

– The nephron secretes the protein renin into the blood.

– Renin leads to the activation of angiotensin II in the blood

– Angiotensin II raises blood pressure by causing vasoconstriction

– Angiotensin II also raises blood pressure by causing the adrenal gland to secrete more aldosterone, which increases the nephrons' Na^+ reabsorption into the blood, which brings water into the blood from the tissues by osmosis, which increases blood pressure by increasing blood volume

Fig 25.14

pH (acid-base) balance

[Review acids, bases, buffers, and the pH scale in the Water lecture outline. Also, review the effects of CO_2 on the blood's H^+ concentration in the Respiratory system lecture outline]

Blood is normally pH 7.35 – 7.45

- Acidosis (acidic blood) = Blood pH below 7.35
  - √ Common causes: Ingestion of acids and certain poisons, excessive diarrhea, diabetes, respiratory diseases
  - √ Depresses the nervous system; at extremes the signals to inspiratory muscles can slow or cease entirely, leading to death
- Alkalosis (basic blood) = Blood pH above 7.45
  - √ Common causes: Ingestion of bases and certain poisons, excessive vomiting
  - √ Over-stimulates the nervous and muscular systems; at extremes the respiratory muscles can seize, leading to death

Figs 2.17, 26.16, and 26.18; Table 26.2

Blood pH is regulated by three systems:
- The carbonic acid/bicarbonate ion buffer in the blood
- The breathing rate
- The kidneys

Regulation of blood pH by the blood's carbonic acid/bicarbonate ion buffer

- This buffer is the primary regulator of blood pH
- Bicarbonate ion decreases blood H^+ (counteracts acidosis)
- Carbonic acid increases blood H^+ (counteracts alkalosis)

Regulation of blood pH by the lungs (respiratory compensation)

The respiratory system can change blood pH by changing breathing rate

- Increased breathing rate decreases blood H^+ (counteracts acidosis)
- Decreased breathing rate increases blood H^+ (counteracts alkalosis)

Fig 26.16

Regulation of blood pH by the kidneys (renal compensation)

The kidneys can change blood pH by changing the amount of bicarbonate ion and hydrogen ion that are reabsorbed or secreted

- If the blood H^+ is high (acidosis), the nephrons secrete H^+ out of the blood and reabsorb HCO_3^- into the blood
- If the blood H^+ is low (alkalosis), the nephrons reabsorb H^+ into the blood and but HCO_3^- is not reabsorbed into the blood

Figs 25.19 and 26.17