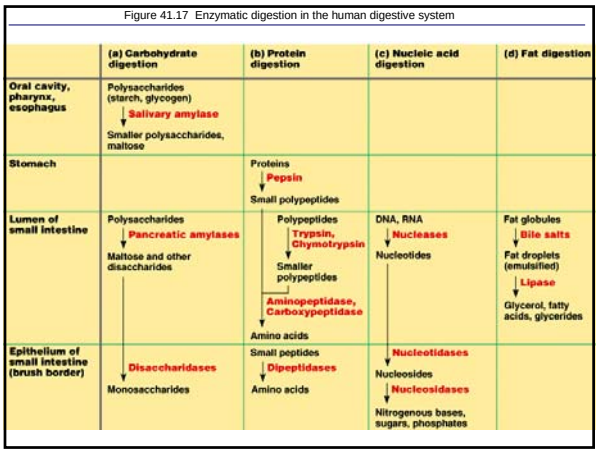
Figure 41.17 Enzymatic digestion in the human digestive system



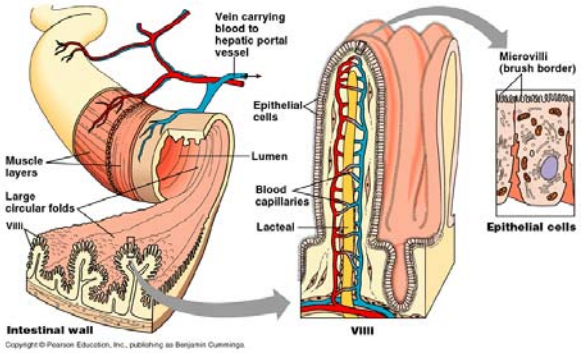
Digestion

- Carbohydrate digestion starts in the mouth
- Protein digestion starts in the stomach
- Nucleic acids & fats start in the small intestine
- Everything completely digested and absorbed by the end of the small intestine

Absorption of Nutrients

- Small Intestine – 300m^2 surface area
- Circular folds, villi, microvilli
- Villus
  - Capillaries – circulatory
    - Amino acids & sugars
    - Hepatic portal vessel to liver
  - Lacteal – lymphatic vessel
    - Chylomicrons (fat, coated w/ cholesterol & proteins)
    - Lymphatic system, drains to large veins returning blood to the heart
  - Passive & active transport across epithelial layers

Figure 41.19 The structure of the small intestine



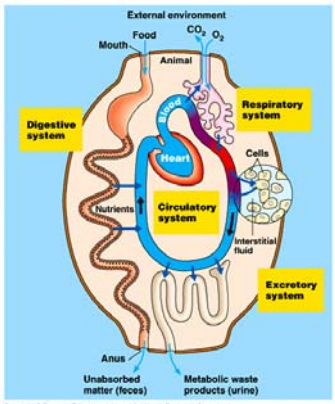
Hormones Regulate Digestion

- Gastrin – induces release of gastric juices
  - Secreted in stomach, released to circ. system
  - Inhibited by high acid in stomach
- Enterogastrones - secreted by duodonum
  - Secretin
    - Stimulates pancreas
  - Cholecystokinin (CCK)
    - Stimulates gall bladder, pancreas, rate of peristalsis

Large Intestine

- Appendages, pouches off the colon
  - Cecum (humans small)
  - Appendix (small immune function)
- Recovery of water is major function
  - 7 liters secreted w/ digestion
  - ~90% recovered
- *Escherichia coli*
  - Live on undigested material
  - Generate gases, vitamins (K & B-complex)

Figure 40.8 Internal exchange surfaces of complex animals



Excretory Systems

- Flame cells & protonepridia (platyhelminthes)
- Metanephridia (annelids, molluscs)
- Malpighian tubules (arthropoda)

Excretion

- Water balance & metabolic wastes
- Diversity of systems, but variation on a tubular theme
  - Protonephridia, flame cells - platyhelminthes
  - Metanephridia – annelids
  - Malpighian tubules – arthropods
  - Kidneys, made up of nephrons - vertebrates

Excretory Systems

- Flame cells & protonepridia (platyhelminthes)
- Metanephridia (annelids, molluscs)
- Malpighian tubules (arthropoda)

Figure 44.18 Protonephridia: the flame-bulb system of a planarian

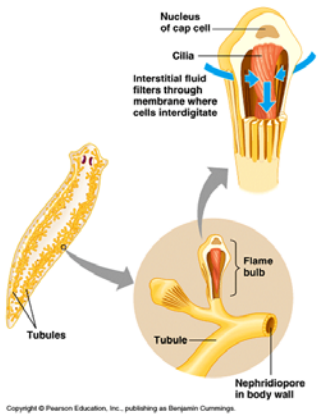


Figure 44.19 Metanephridia of an earthworm

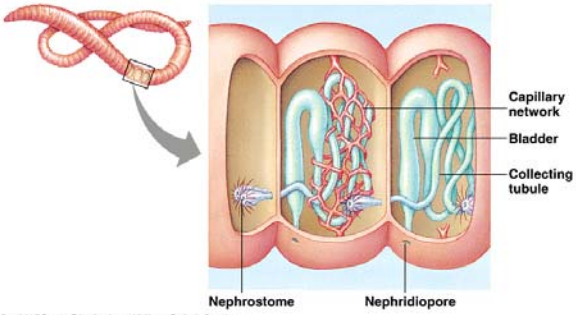
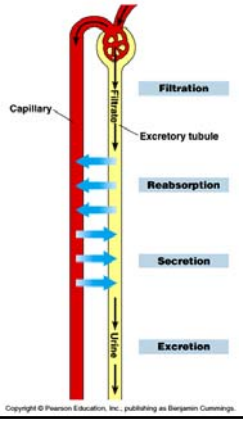


Figure 44.17 Key functions of excretory systems: an overview



Excretory systems

- Ultrafiltration of interstitial fluid (animals with NO blood-circulatory system)
  - Flame cells, protonephridia
- Ultrafiltration of blood circulatory fluid
  - Metanephridia, kidneys

Mammalian Kidney

- Dense network of capillaries and tubules
- Variations on this theme in other vertebrates
  - Adaptations associated with specific environmental challenges
- Nephron is the functional unit

Figure 44.21 The human excretory system at four size scales

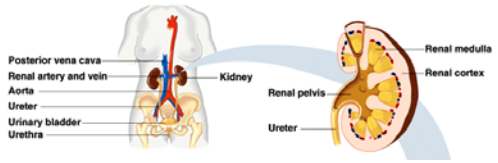


Figure 44.21 The human excretory system at four size scales

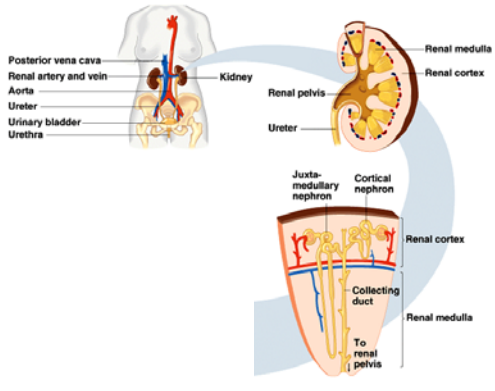
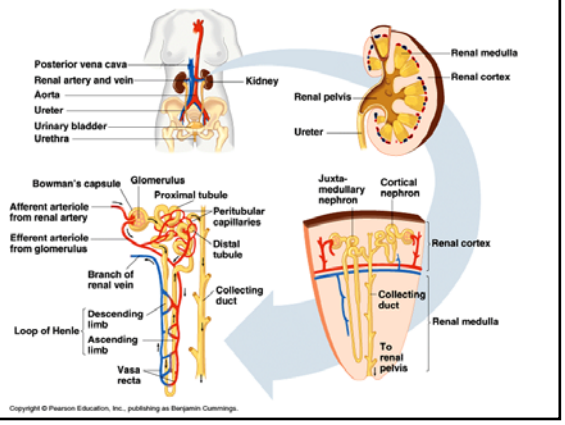


Figure 44.21 The human excretory system at four size scales



Kidney

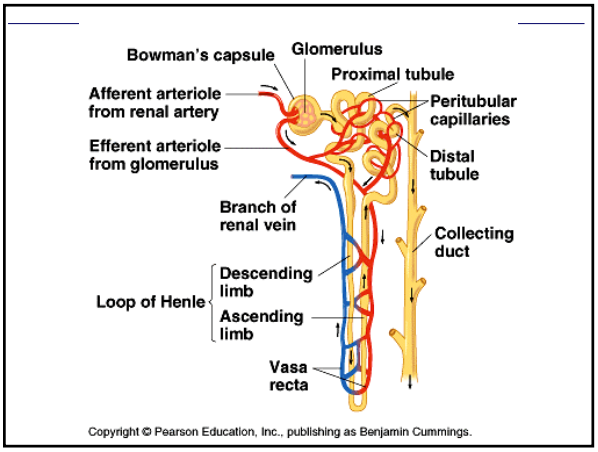
- Renal artery & vein
  - 20% of cardiac output to kidneys
- Ureter
  - Urine to urinary bladder
- Renal cortex and inner medulla

Nephron

- Single long tubule
  - Bowman's capsule – blind end of tubule, surrounds…
- Glomerulus
  - ball of capillaries
- Each human kidney
  - A million nephrons, 80 km of tubule length

Filtration of Blood

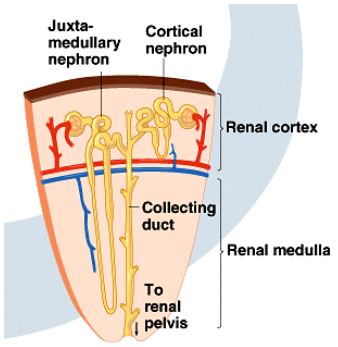
- Blood pressure forces filtration of blood
  - Fluid into lumen of Bowman's capsule
  - Specialized cells – podocytes line capillaries
    - Permeable to water, small molecules, solutes
      - **Non-selective** salts, glucose, vitamins nitrogenous wastes
    - Not permeable to blood cells, macromolecules



Nephrons

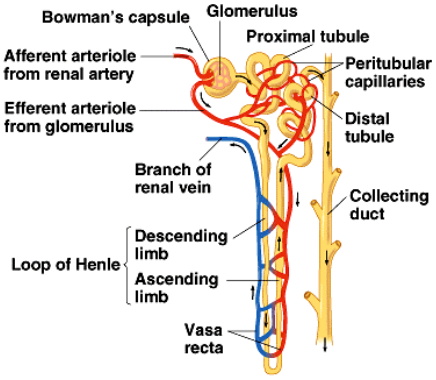
- Cortical nephrons (80%)
- Juxtamedullary nephrons (20%)
  - Only birds and mammals
  - Important for water conservation
- Nephron & collecting duct lined by transport epithelium
- Re-absorption of 99% of water and nearly all sugar, vitamins, nutrients

Figure 44.21 The human excretory system at four size scales



Blood Vessels

- Closely associated with nephron but no direct exchange
  - Exchange of ions & other molecules between fluid inside nephron and the circulatory system is via the interstitial fluid that bathes them both.



Filtrate Turned to Urine

- Differential permeability
- Active and passive transport
- Osmotic gradients

Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium

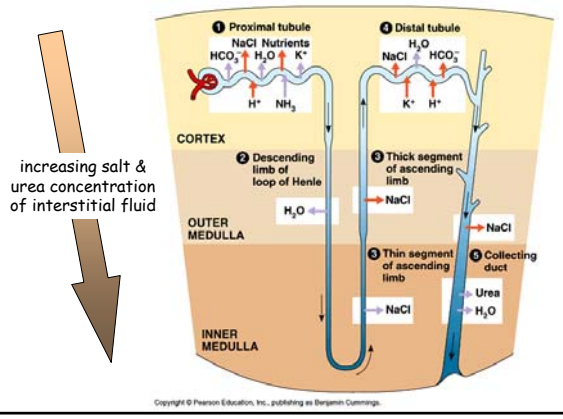
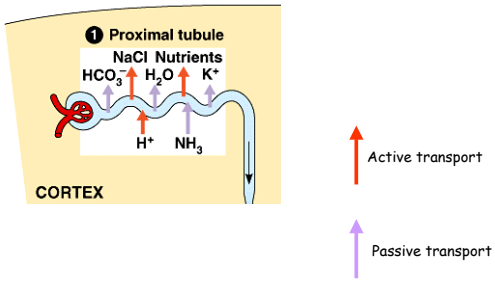


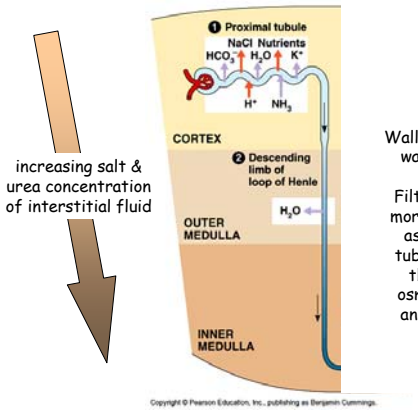
Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium



Proximal Tubule

- Adjusts pH
- Absorbs Bicarbonate
- Transport of glucose, amino acids K^+
- **NaCl & water reabsorption**
  - NaCl diffuses into transport epithelial cells
  - Na^+ active transport to interstial fluid
    - Cl^- passively follows
    - Water follows by osmosis

Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium



Wall is permeable to water, not salts.

Filtrate is getting more concentrated as water leaves tubule because of the increasing osmotic pressure and salts remain behind.

Loop of Henle

- Descending limb
  - Impermeable to salts
  - Water moves by osmosis to interstitial fluid
  - Increasing osmotic gradient toward medulla
  - Filtrate becomes concentrated (lots of NaCl, etc.)

Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium

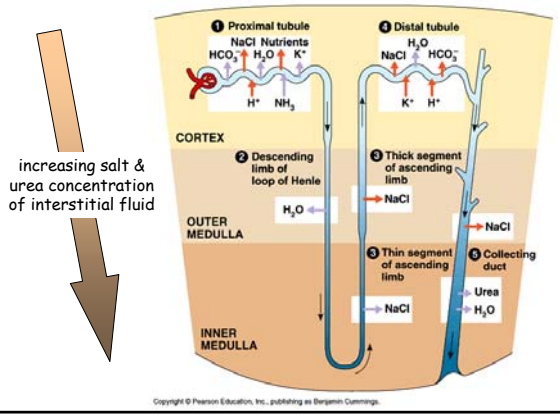
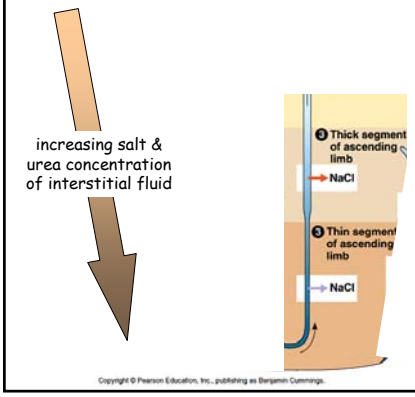


Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium



Wall is permeable to salts, not water now.

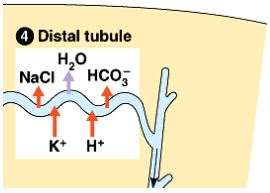
Filtrate is very concentrated, more so than interstitial fluid now, so salt moves out

This helps create/maintain the osmotic gradient between interstitial fluid & filtrate

Loop of Henle

- Ascending limb
  - Permeable to salts
  - Impermeable to water
  - Diffusion of NaCl to interstitial fluid lower portion
  - Active transport of NaCl in upper portion
    - Increases osmolarity of interstitial fluids
  - Filtrate becomes dilute

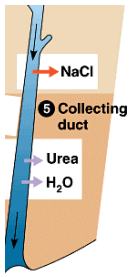
Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium



Distal Tubule

- Selective secretion and reabsorption
- K+
- NaCl
- pH regulation

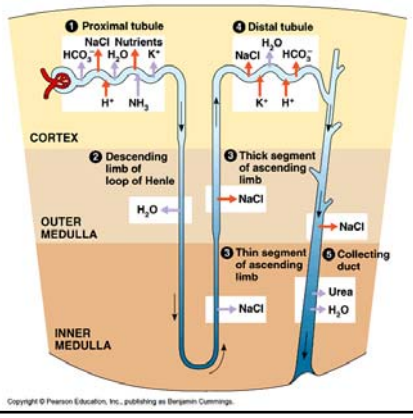
Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium



Collecting Duct

- Active reabsorption of NaCl
- Permeable to water
- Not permeable to salt or urea (in cortex)
- Permeable to urea in medulla
  - Contributes to creation of osmotic gradient of kidney

Figure 44.22 The nephron and collecting duct: regional functions of the transport epithelium



Kidneys

- Hormonal & nervous regulation
- Many adaptations and variations among the vertebrates

Vertebrate Kidneys

- Mammals hyperosmotic, concentrated urine
  - Beavers dilute urine, short loops of Henle
- Birds, shorter loops of Henle
  - Water conserved by producing uric acid
- Reptiles only cortical nephrons, can't concentrate urine
  - Absorption of water in cloaca
- Freshwater fish
  - Must get rid of excess water, conserve salts
    - Urine very dilute
- Amphibians
  - Depends on environment
- Saltwater fish
  - Mostly rids excess salts
  - Ammoniam & NaCl across gills