Chapter 44: Osmoregulation and Excretion

AP Biology 2013

1

Physiological Systems

- Operate in a fluid environment
- Concentrations of water and solutes must be maintained within fairly narrow limits
- Freshwater animals have adaptations to reduce water uptake and conserve solutes
- Desert and marine animals face desiccating environments with the potential to quickly deplete the body water
- Osmoregulation - regulates solute concentrations and balances the gain and loss of water
- Excretion - gets rid of metabolic wastes

Fig. 44.1

2

Osmoregulation

- Based on controlled movement of solutes between internal fluids and external environment
- Osmosis - cells require a balance between osmotic gain and loss of water; water uptake and loss are balanced by various mechanisms of osmoregulation in different environments
- Osmoconformers (marine animals) - isoosmotic with surroundings and do not regulate osmolarity
- Osmoregulators - expend energy to control water uptake and loss
- Stenohaline - cannot tolerate substantial changes in external osmolarity
- Euryhaline - can survive large fluctuations in external osmolarity

3

Marine Animals

- Most invertebrates are osmoconformers; most vertebrates are osmoregulators
- Marine bony fish are hyperosmotic to sea water and lose water by osmosis and gain salt by both diffusion and food
- Balance water loss by drinking seawater and excreting salts

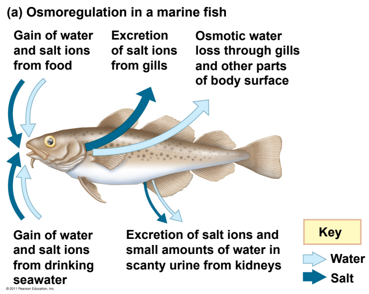


Fig. 44.3

Freshwater Animals

- Constantly take in water from their hypoosmotic environment
- Lose salts by diffusion
- Maintain water balance by excreting large amounts of dilute urine
- Salts lost by diffusion are replaced by foods and uptake across gills

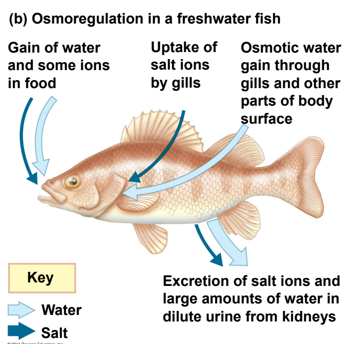


Fig. 44.3

Other Animals

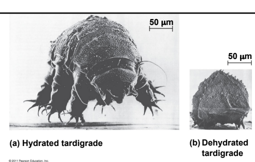


Fig. 44.5

- Some aquatic invertebrates living in temporary ponds can lose almost all their body water and survive in a dormant state (anhydrobiosis)
- Land animals - manage water budgets by drinking and eating moist foods and using metabolic water
  - Desert animals get water savings from simple anatomical features

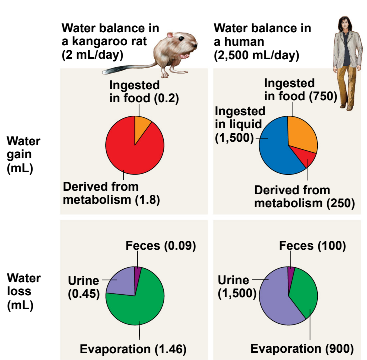


Fig. 44.6

Transport Epithelia

- Specialized cells that regulate solute movement
- Essential components of osmotic regulation and metabolic waste disposal
- Arranged in complex tubular networks
- Ex. salt glands of marine birds (remove excess NaCl from blood)

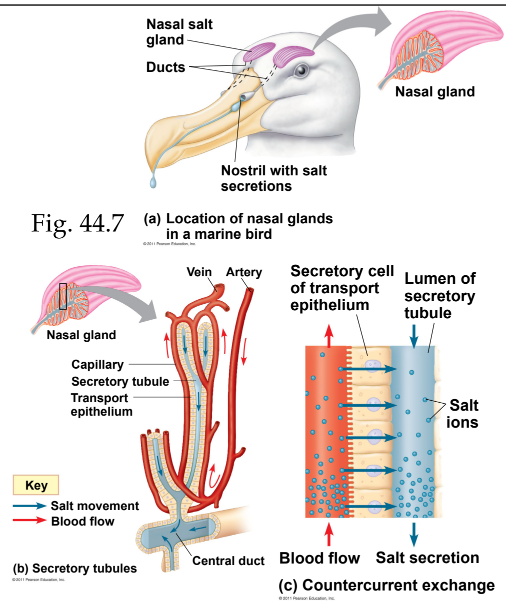


Fig. 44.7

Nitrogenous Wastes

- Different animals excrete nitrogenous waste in different forms
  - Ammonia - need access to lots of water; release across body surface or through gills
  - Urea (mammals and adult amphibians) - liver converts ammonia to less toxic urea which is carried to the kidneys, concentrated and excreted with minimal water loss
  - Uric acid (insects, land snails, reptiles and birds) - uric acid is largely insoluble in water and can be secreted as a paste with little water loss

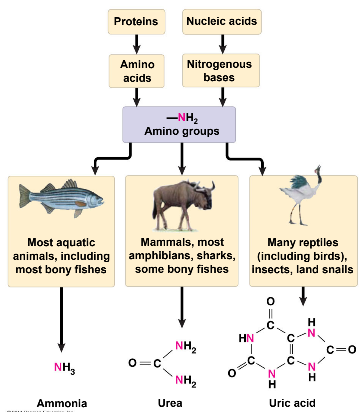


Fig. 44.8

Excretory Systems

- Regulate solute movement between internal fluids and external environment
- Most produce urine by refining a filtrate derived from body fluids
- Key functions: filtration, reabsorption, secretion, and excretion

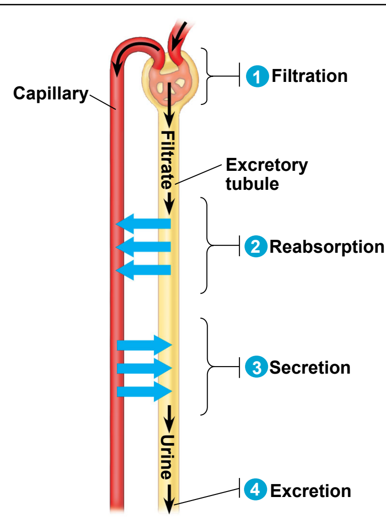
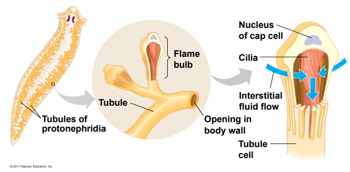


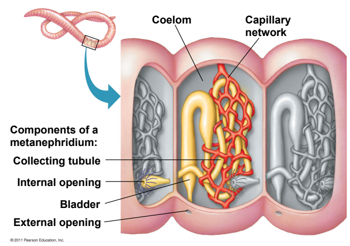
Fig. 44.10

Types of Excretory Systems

- Built around a complex network of tubes
- Protonephridium - network of dead-end tubules lacking internal openings
  - Tubules branch throughout the body and smallest are capped by a cellular unit called a flame bulb that excrete a dilute fluid
- Metanephridia - each earthworm segment has a pair of open-ended metanephridia that consist of tubules that collect coelomic fluid and produce dilute urine



Figs.
44.11 $ 44.12



10

Types of Excretory Systems

- Malpighian Tubules - insects and terrestrial arthropods
  - Remove nitrogenous wastes from hemolymph
  - Produce dry waste matter (adaptation to terrestrial life)
- Kidneys - excretory organs of vertebrates

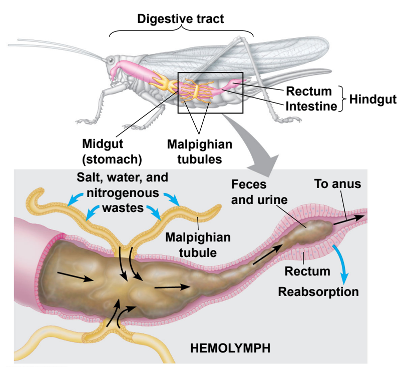


Fig. 44.13

11

Kidneys

- Principal site of water balance and salt regulation in mammals
- Each kidney is supplied with blood by a renal artery and drained by a renal vein
- Urine exists the kidney through a duct called the ureter
  - Both ureters drain into a common urinary bladder
- Kidney has two regions: outer renal cortex and inner renal medulla
- The nephron consists of a single long tubule and a ball of capillaries called the glomerulus

12

Kidney Filtration

- Occurs as blood pressure forces fluid from the blood in the glomerulus into the lumen of the Bowman's capsule
  - Filtration of small molecules is nonselective and the filtrate mixture in the Bowman's capsule mirrors the concentrations of solutes in the blood plasma
- From the Bowman's capsule the filtrate passes through three regions of the nephron: proximal tubule, loop of Henle, and the distal tube
- Fluid from several nephrons flows into a collecting duct

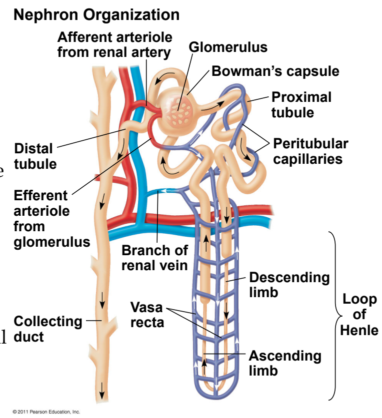
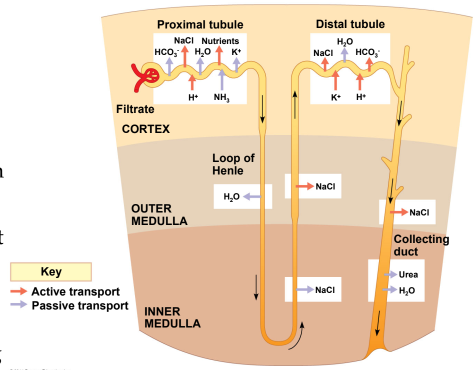


Fig. 44.14

13

Nephron Blood Vessels

- Each nephron is supplied with blood by an afferent arteriole (branch of the renal artery that subdivides into capillaries)
- Capillaries converge as they leave the glomerulus (forming an efferent arteriole)
- Vessels subdivide again forming peritubular capillaries which surround the proximal and distal tubules



- Filtrate becomes urine as it flows through the mammalian nephron and collecting duct

Fig. 44.14

14

Secretion and Reabsorption

- Secretion and reabsorption in the proximal tubule alters the volume and composition of filtrate
- Reabsorption of water continues as filtrate moves into the descending limb of the loop of Henle
- As filtrate travels through the ascending limb of the loop of Henle salt diffuses out of the tubule into the interstitial fluid
- Distal tubule plays a key role in regulating K^+ and NaCl concentration of body fluids
- Collecting duct carries the filtrate through the medulla to the renal pelvis and reabsorbs NaCl

15

Water Conservation

- Kidney can produce urine much more concentrated than body fluids (thus conserving water)
- Arrangement of loops of Henle are responsible for osmotic gradient that concentrates the urine
  - NaCl and urea contribute to the osmolarity of the interstitial fluid (which causes the reabsorption of water)
- The collecting duct is permeable to water but not salt

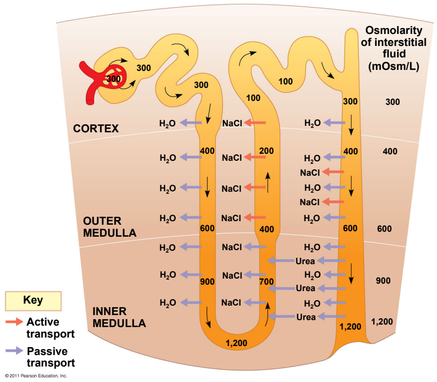


Fig. 44.15

16

Kidney Regulation

- Osmolarity of urine is regulated by the nervous and hormonal control of water and salt reabsorption
- Antidiuretic hormone (ADH) increases water reabsorption in the distal tubules and collecting ducts of the kidney
- Renin-angiotensin-aldosterone system (RAAS) is part of a complex feedback circuit that functions in homeostasis
  - Atrial natriuretic factor (ANF) opposes RAAS

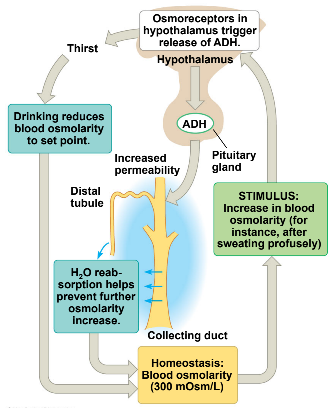


Fig. 44.20

17

Excretory Adaptations

Fig. 44.18

- South American vampire bat - feeds on blood
  - Has a unique excretory system in which its kidneys offload much of the water absorbed from a meal by excreting large amounts of dilute urine
- Form and function of nephrons are related to the requirements for osmoregulation in the animal's habitat
  - Mammals in arid areas have longer loops of Henle
  - Mammals in freshwater areas have shorter loops of Henle

18