Osmoregulation

19th March 2012

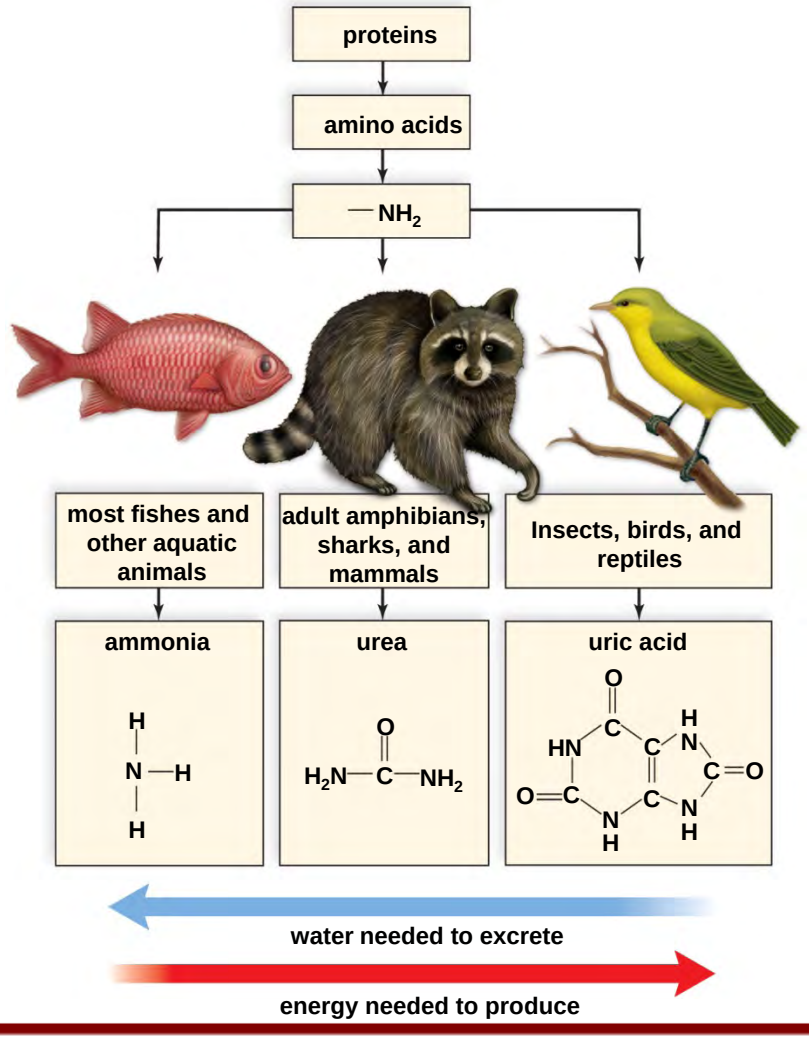
Outline

- Body Fluid Regulation
  - Aquatic Animals
    - Marine Bony Fish
    - Freshwater Bony Fish
  - Terrestrial Animals
- Nitrogenous Waste Products
- Organs of Excretion
- Urinary System in Humans
  - Kidneys
  - Urine

Nitrogenous Waste Products

- Catabolism of amino acids and nucleic acids results in ammonia
  - High solubility permits it to be excreted directly by many aquatic animals
  - Terrestrial animals must convert ammonia to urea or uric acid
    - Urea causes loss of much water per unit of nitrogen
      - Mammals and amphibians
      - Must drink lots of water
    - Uric acid requires much less water per unit of nitrogen excreted
      - Reptiles, birds, and arthropods
      - Require much less water than mammals and amphibians
      - Allows invasion of drier habitats far from standing water

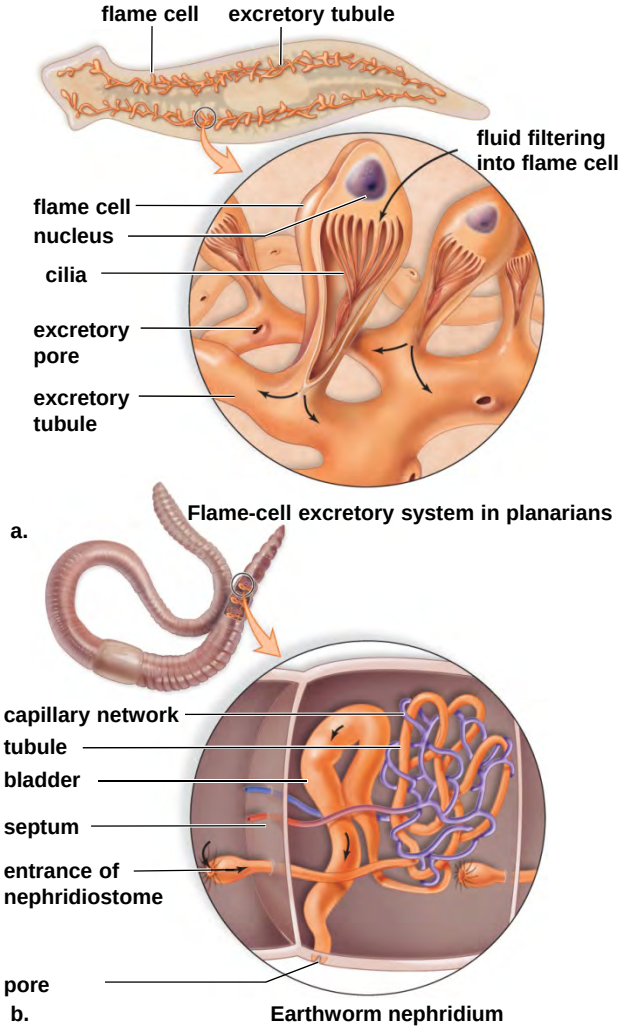
Nitrogenous Wastes



Organs of Excretion in Invertebrates

- Most animals have tubular excretory organs
  - Regulate the water-salt balance of the body
  - Excrete metabolic wastes into the environment
    - Flame Cells in Planarians
    - Nephridia in Earthworms
    - Malpighian Tubules in Insects

Excretory Organs in Animals



Body Fluid Regulation

- An excretory system regulate body fluid concentrations
- Dependent upon concentration of mineral ions such as sodium and potassium
- Water can enter the body through:
  - Drink
  - Food
  - Metabolism

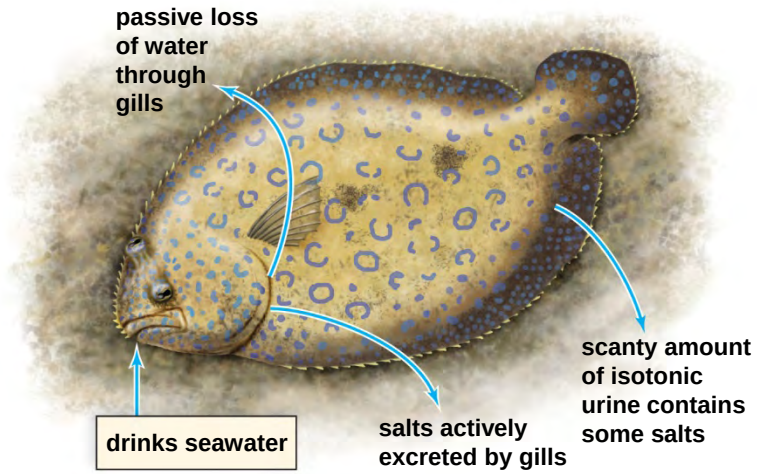
Body Fluid Regulation

- Water tends to move into the region with the lowest water concentration
  - A marine environment
    - High in dissolved salts
    - Tends to promote the osmotic loss of water, and
    - The gain of ions by drinking water
    - Marine invertebrates nearly isotonic to seawater
    - Blood of cartilaginous fishes contains enough urea to match the tonicity of sea water
  - Fresh water environment
    - Tends to promote a gain of water by osmosis, and
    - A loss of ions as excess water is excreted

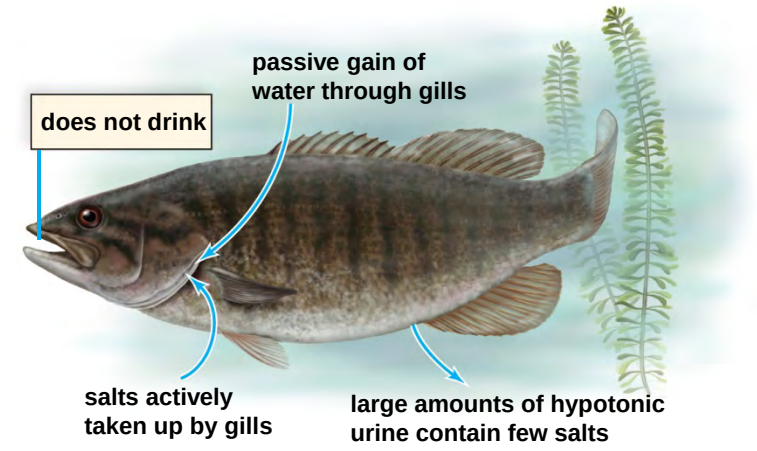
Aquatic Animals

- Bony Fishes
  - Body fluids of bony fishes with only moderate amount of salt
  - Marine bony fishes
    - Body fluids hypotonic to sea water
    - Passively *lose* water through gills
    - Must constantly drink seawater to compensate
    - Excess salt ions actively transported back into seawater through the gills
  - Freshwater bony fishes have opposite problem
    - Body fluids hypertonic to fresh water
    - Passively *gain* water through gills
    - Eliminate excess water through copious hypotonic urine

Body Fluid Regulation in Bony Fishes

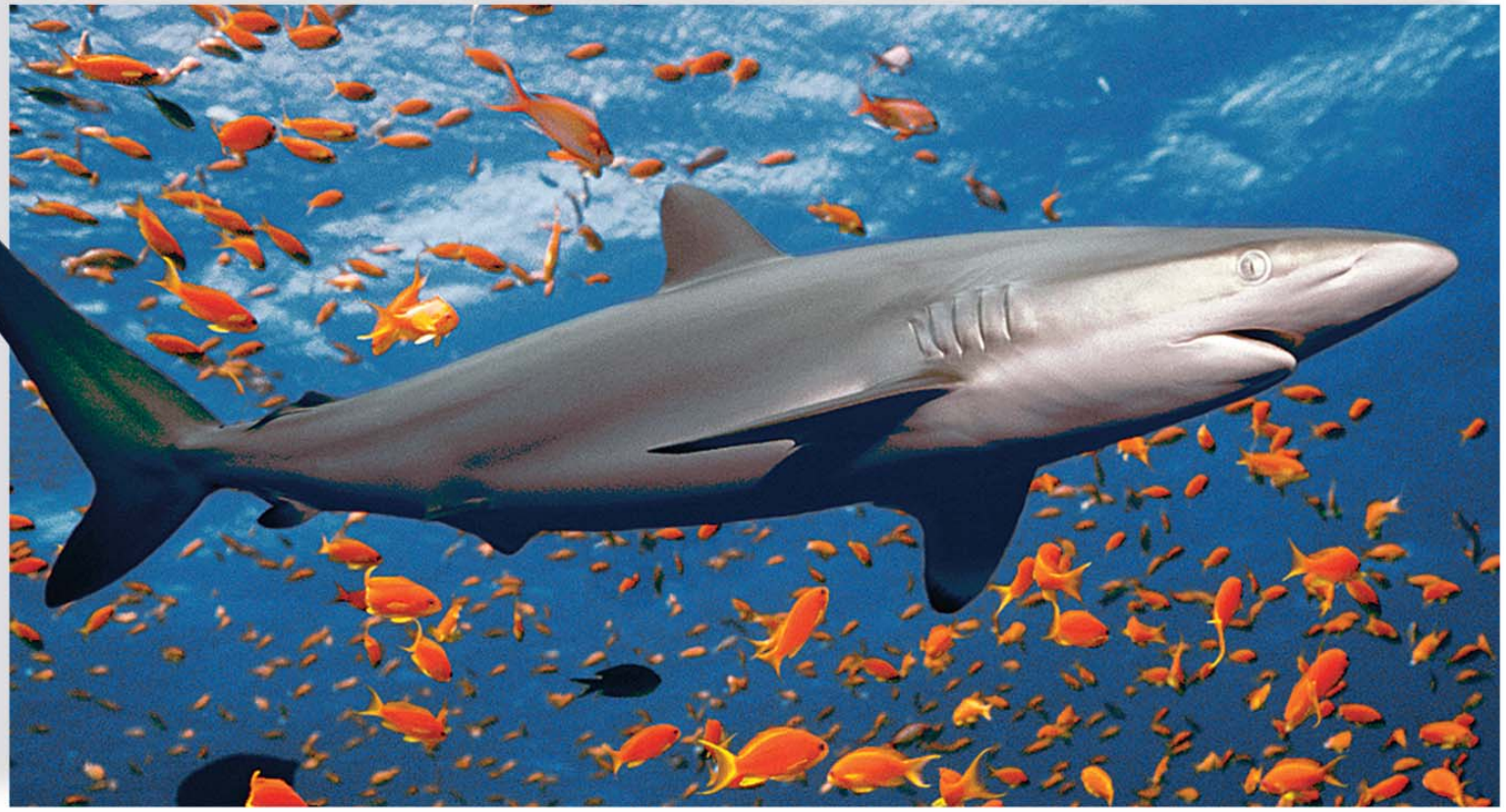


a. Marine bony fish



b. Freshwater bony fish

Osmoregulation in a Shark

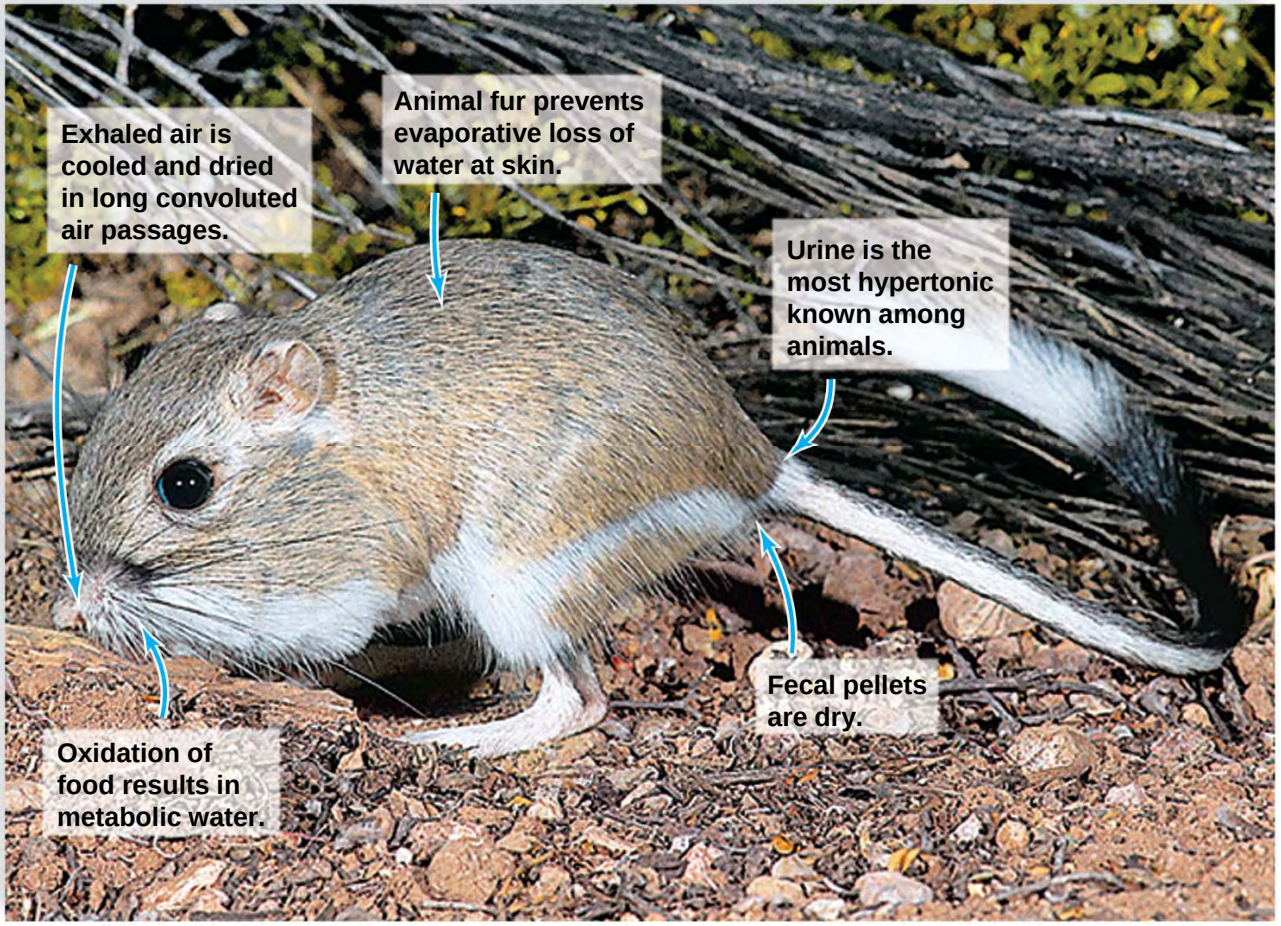


© Digital Vision Ltd

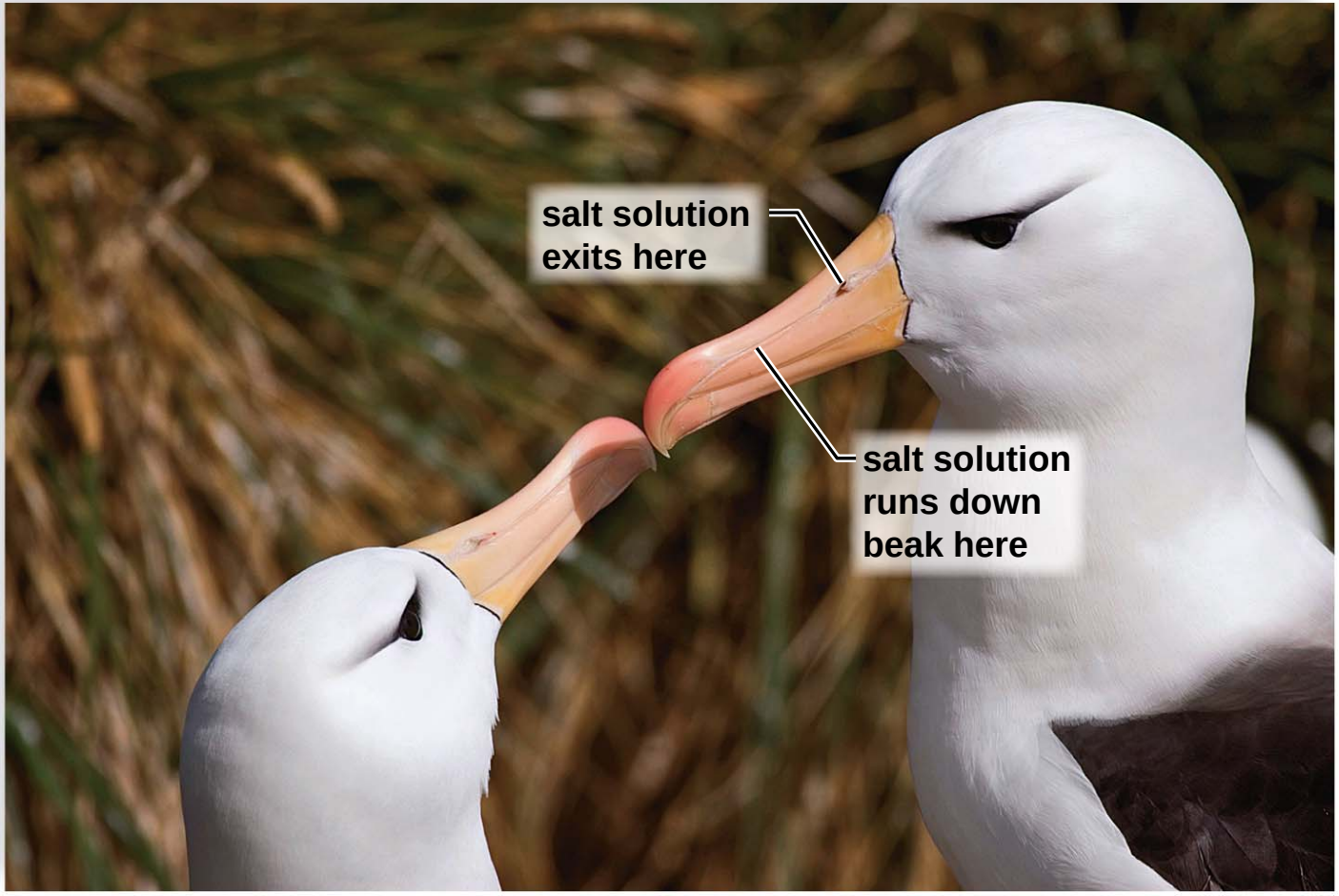
Terrestrial Animals

- Terrestrial animals lose water through excretion and respiration
- Must drink water to make up for loss
  - Some reduce excretory loss by excreting nitrogen as relatively insoluble uric acid
  - Certain animals also have a highly convoluted nasal passage with a mucous membrane surface

Adaptations of a Kangaroo Rat to a Dry Environment



Adaptations of Marine Birds to a High Salt Environment



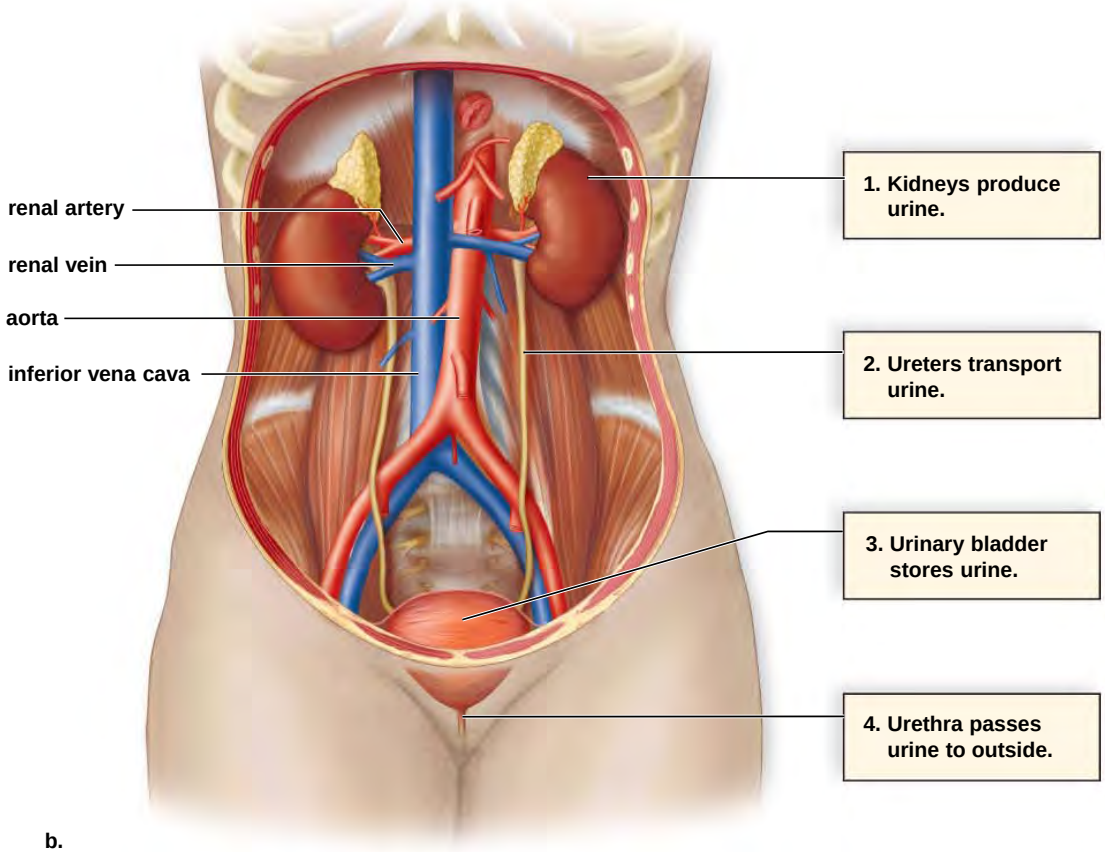
© Eric Hosking/Photo Researchers, Inc.

Urinary System in Humans

- Human kidneys
  - Located on either side of vertebral column, just below the diaphragm
    - Each connected to a ureter
    - Conducts urine from the kidney to the urinary bladder
  - Urine voided through urethra
    - Tube between bladder and exit

The Human Urinary System

a.



b.

Kidneys

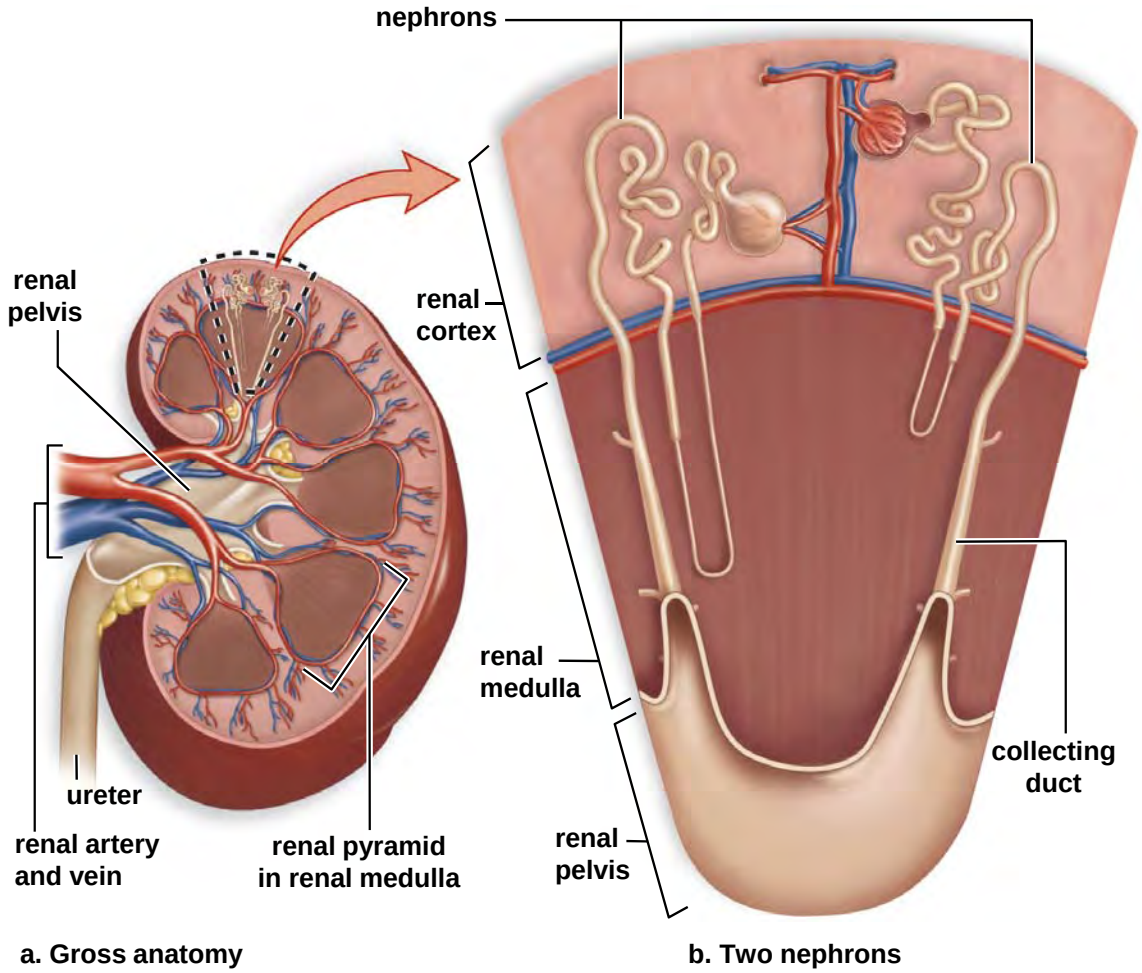
- Renal cortex
  - Outer region
  - Granular appearance
- Renal medulla
  - Cone-shaped renal pyramids
- Renal pelvis
  - Hollow-chambered innermost part of the kidney

Animation

Basic Renal Processes

simplified nephron
basic processes

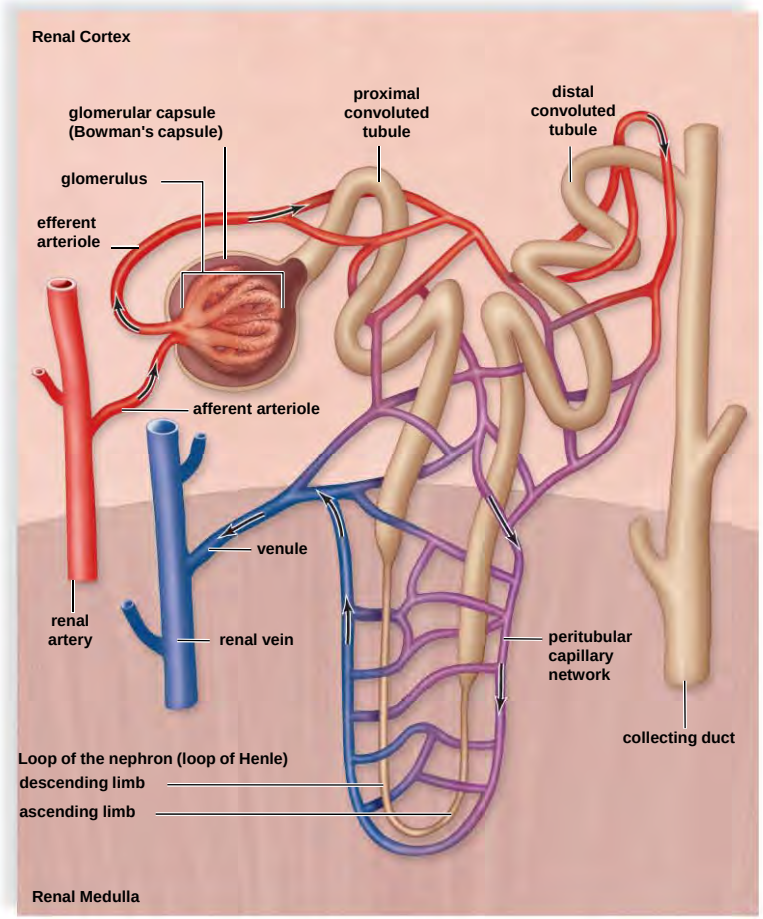
Macroscopic & Microscopic Anatomy of the Kidney



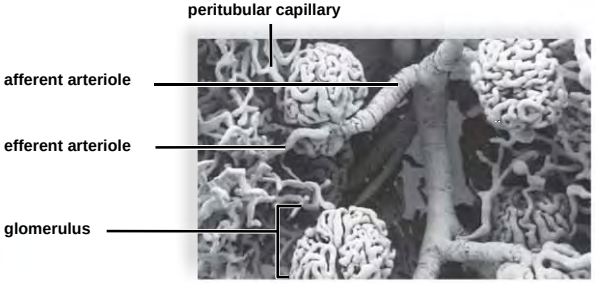
Nephrons

- Each kidney composed of many tubular nephrons
- Each nephron composed of several parts
  - Glomerular capsule
  - Glomerulus
  - Proximal convoluted tubule
  - Loop of the nephron
  - Distal convoluted tube
  - Collecting duct

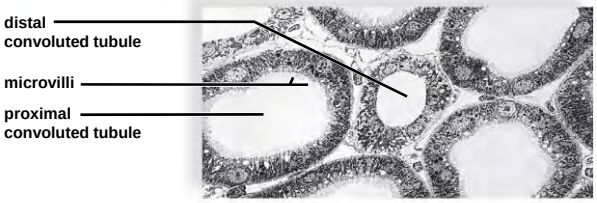
Nephron Anatomy



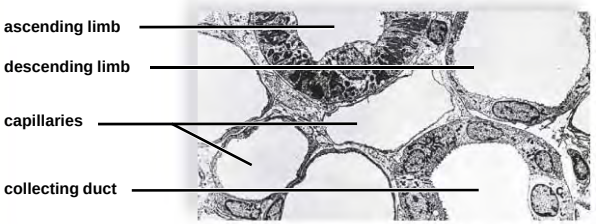
a. Anephron and its blood supply



b. Surface view of glomerulus and its blood supply

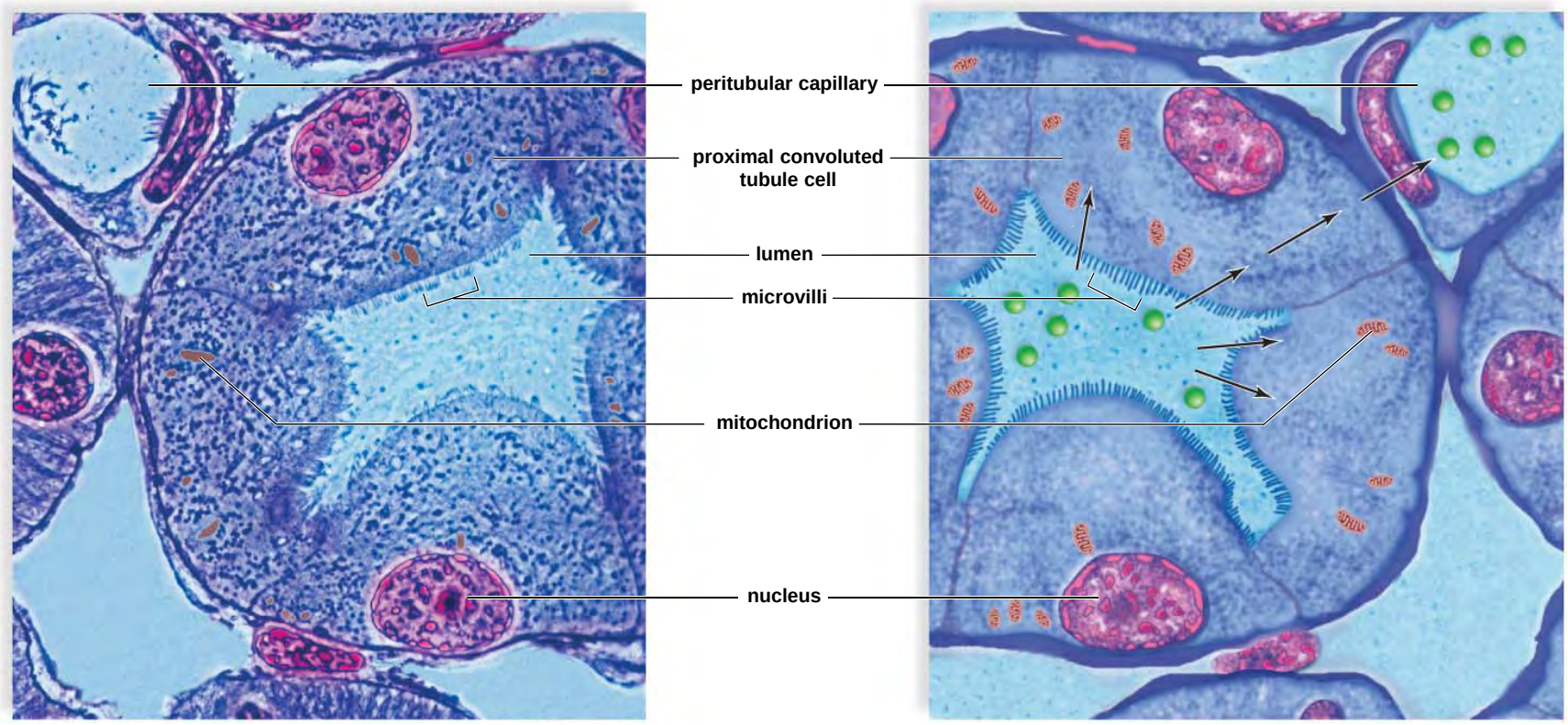


c. Cross sections of proximal and distal convoluted tubules



d. Cross sections of a loop of nephron limbs and collecting duct. (The other cross sections are those of capillaries.)

Proximal Convoluted Tubule

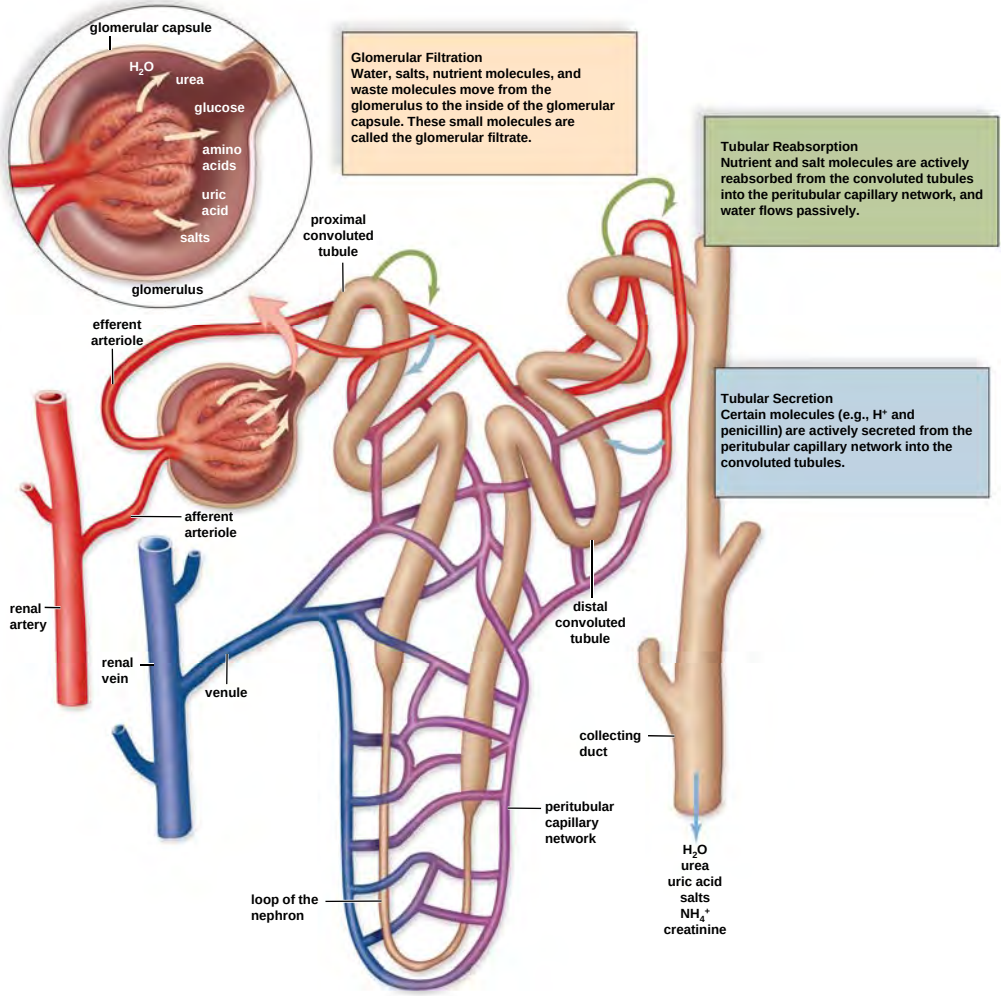


a: © Joseph F. Gennaro, Jr./Photo Researchers, Inc.

Urine Formation

- Urine production requires three distinct processes:
  - Glomerular filtration in glomerular capsule
  - Tubular reabsorption at the proximal convoluted tubule
  - Tubular secretion at the distal convoluted tubule

Processes in Urine Formation

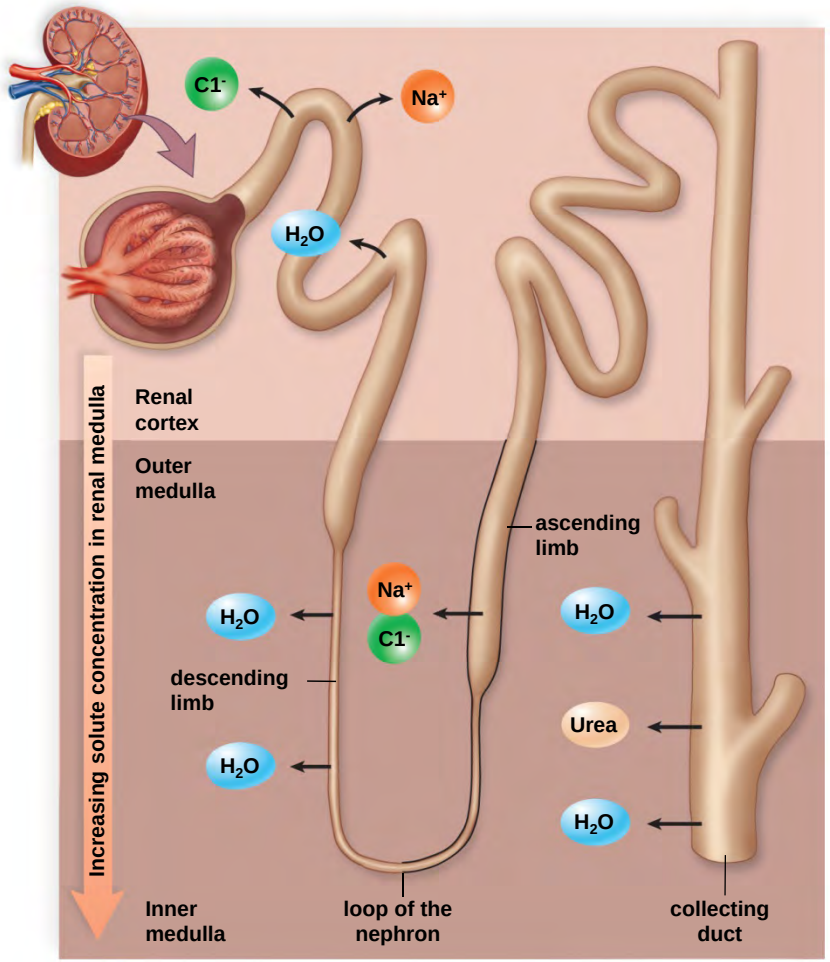


Animation

Renal Clearance

renal clearance
inulin clearance

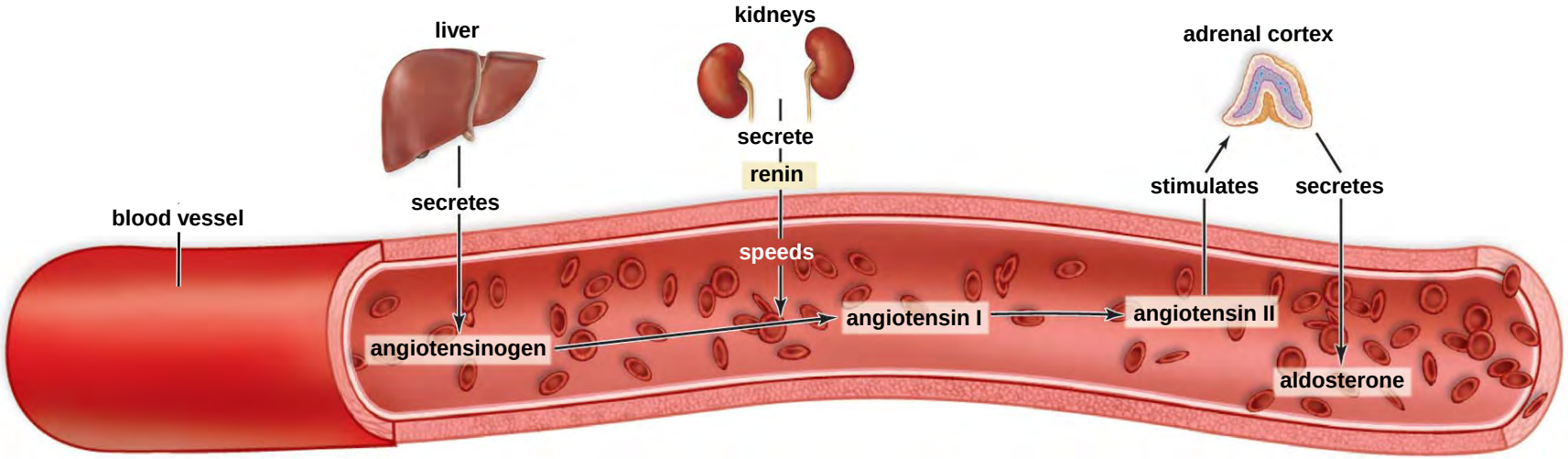
Reabsorption of Salt and Water



Urine Formation and Homeostasis

- Excretion of hypertonic urine
  - Dependent upon the reabsorption of water
  - Absorbed from
    - Loop of the nephron, and
    - The collecting duct
  - Osmotic gradient within the renal medulla causes water to leave the descending limb along its entire length
- Antidiuretic hormone (ADH)
  - Plays a role in water reabsorption
  - Released by the posterior lobe of the pituitary

The Renin-Angiotensin-Aldosterone System



Maintenance of pH and Osmolality

- More than 99% of sodium filtered at glomerulus is returned to blood at the distal convoluted tubule
- Reabsorption of sodium regulated by hormones
  - Aldosterone
  - Renin
  - Atrial Natriuretic Hormone (ANH)
- pH adjusted by either
  - The reabsorption of the bicarbonate ions, or
  - The secretion of hydrogen ions

Review

- Body Fluid Regulation
  - Aquatic Animals
    - Marine Bony Fish
    - Freshwater Bony Fish
  - Terrestrial Animals
- Nitrogenous Waste Products
- Organs of Excretion
- Urinary System in Humans
  - Kidneys
  - Urine