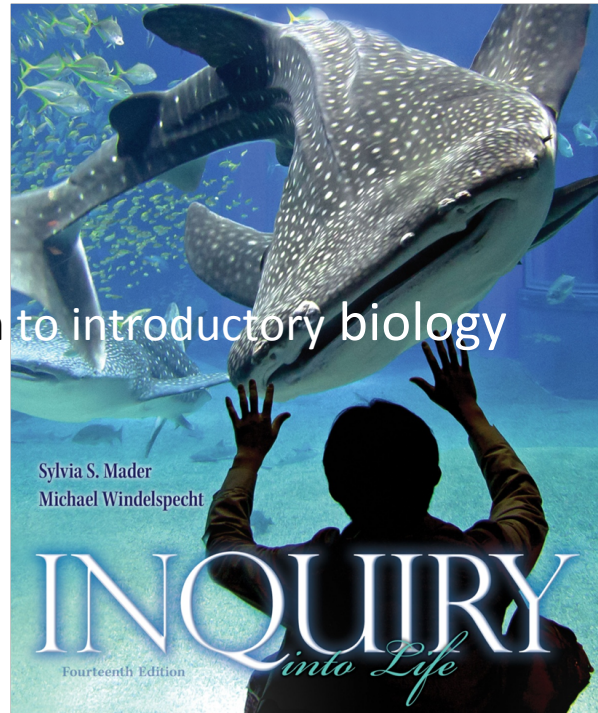


# Fundamental Biology

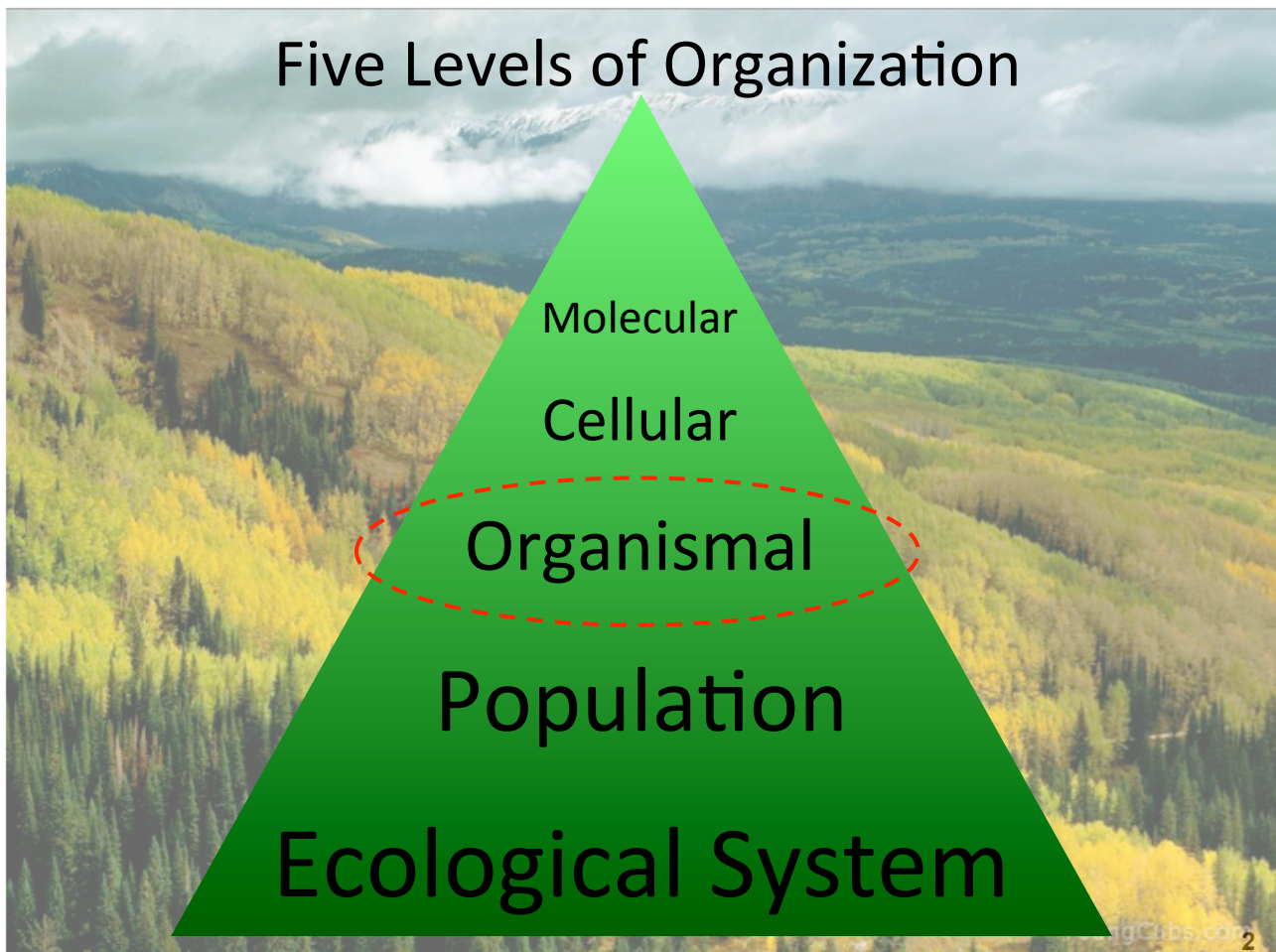
## BI 1101

an interdisciplinary approach to introductory biology

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Iriawati  
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SITH-ITB



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# Learning outcomes

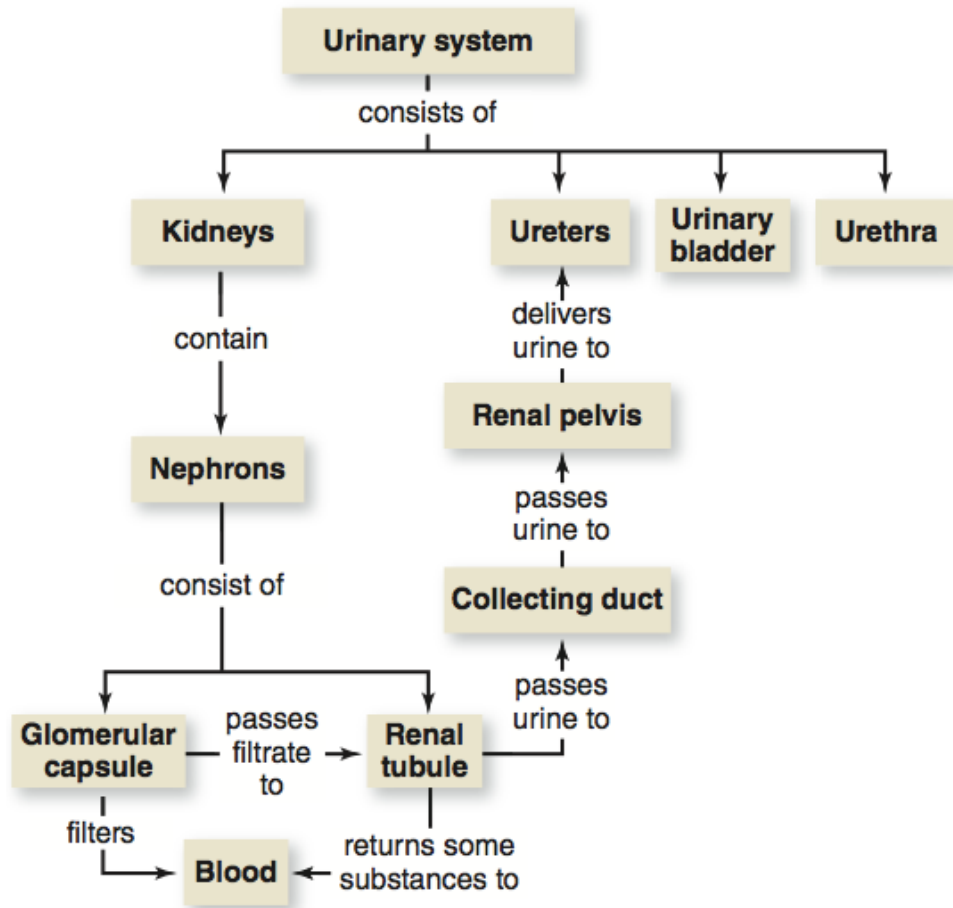
After this lecture, you should be able to:

1. Describe four ways that heat is gained or lost by an animal.
2. Describe five categories of adaptations that help animals thermoregulate.
3. Compare the osmoregulatory problems of freshwater fish, saltwater fish, and terrestrial animals.
4. Compare the three ways that animals eliminate nitrogenous wastes.
5. Describe the structure and functions of the human kidney.
6. Explain how the kidney promotes homeostasis.
7. Describe four major processes that produce urine and the key events in the conversion of filtrate into urine.
8. Explain why a dialysis machine is necessary and how it works.

3

## CONTROL OF BODY TEMPERATURE AND WATER BALANCE

4



5

## Introduction

- During cold winters, bears are often dormant.
- Physiological processes aid homeostasis, keeping the body temperature about 5°C below normal.
  - Body fat and dense fur provide insulation.
  - Blood flow to extremities is reduced.
  - Nitrogen-containing wastes are metabolized differently.

- Animals live nearly everywhere on Earth → The extremely dry, frigid Arctic habitat or perpetual humidity of a tropical rain forest.
- These habitats select for very different ways of regulating body temperature, conserving water, and disposing of wastes.
  - In hot, dry areas, an animal must conserve enough water for cells to function and, produce enough sweat to tolerate the heat.
  - At another extreme, frigid water surrounds an animal living in an Arctic freshwater lake. An animal in this habitat must continually pump excess water out of its body and conserve salts, all while surviving the cold.



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## Introduction

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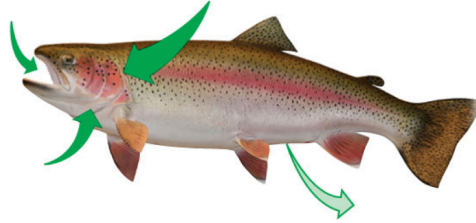
- Homeostasis is the maintenance of steady internal conditions despite fluctuations in the external environment.
- Examples of homeostasis include
  - *thermoregulation*—the maintenance of internal temperature within narrow limits,
  - *osmoregulation*—the control of the gain and loss of water and solutes, and
  - *excretion*—the disposal of nitrogen-containing wastes.



## Big Ideas



**Thermoregulation**



**Osmoregulation and  
Excretion**

9

# THERMOREGULATION

# An animal's regulation of body temperature helps maintain homeostasis

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## Thermoregulation is

- the process by which animals maintain an internal temperature within a tolerable range → requires the ability to balance heat gained from and lost to the environment
- a form of homeostasis.
  - An animal maintain homeostasis by controlling how much heat it produces. When cells generate ATP in aerobic respiration they also produce metabolic heat. The more active the animal, the higher its metabolic rate and the more heat it produces.

# An animal's regulation of body temperature helps maintain homeostasis

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- **Ectothermic** animals
  - gain most of their heat from external sources and
  - include many fish, most amphibians, lizards, and most invertebrates.
- **Endothermic** animals
  - derive body heat mainly from their metabolism and
  - include birds, mammals, a few reptiles and fish, and many insects.



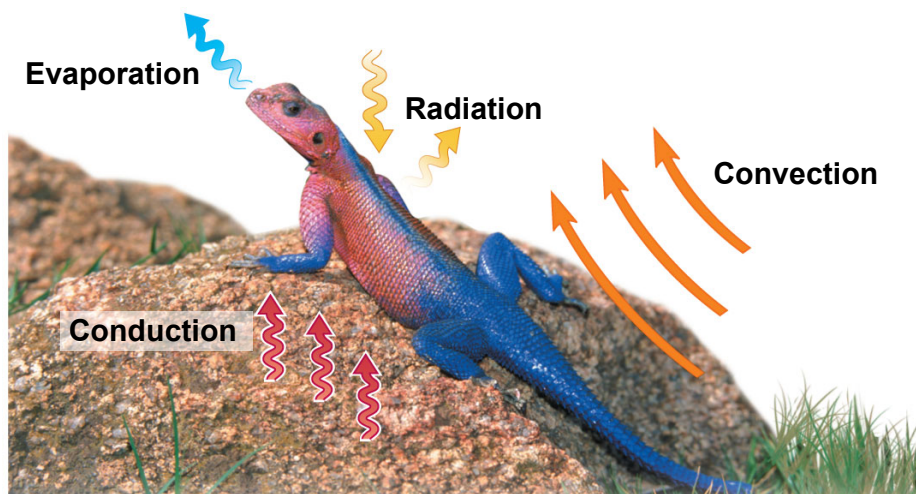
## Heat is gained or lost in four ways

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- Heat exchange with the environment may occur by
    - *conduction*—the transfer of heat by direct contact,
    - *convection*—the transfer of heat by movement of air or liquid past a surface,
    - *radiation*—the emission of electromagnetic waves, or
    - *evaporation*—the loss of heat from the surface of a liquid that is losing some of its molecules as a gas.
- 

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Figure 25.2



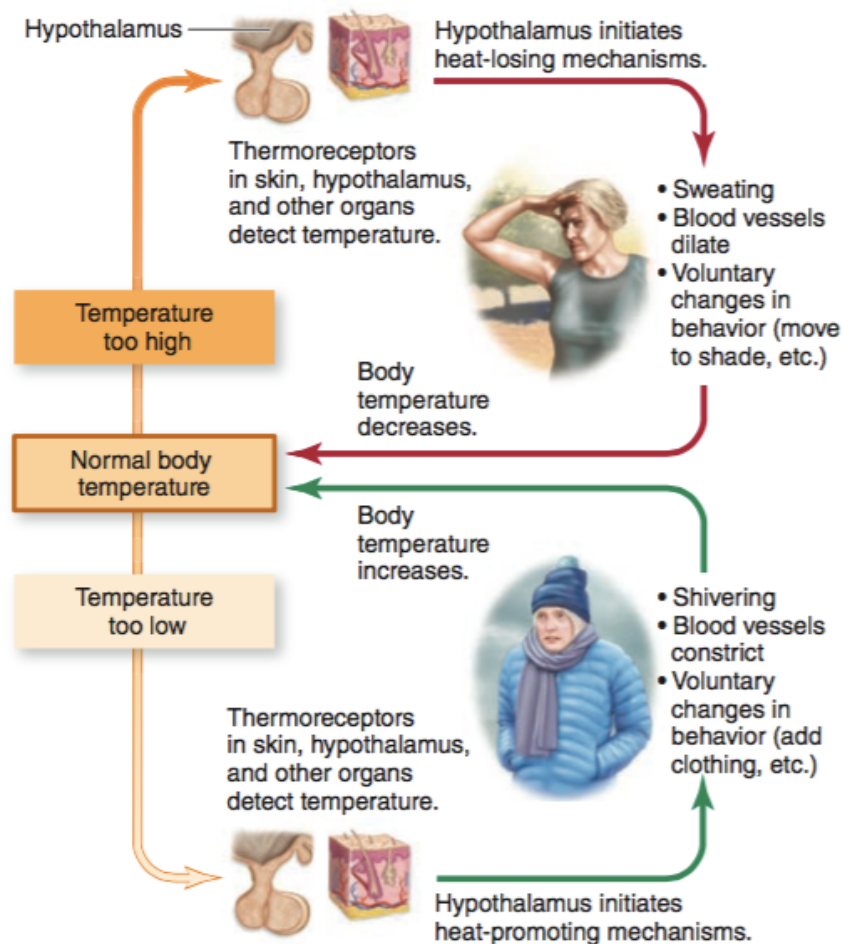
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## Thermoregulation involves adaptations that balance heat gain and loss

Five general categories of adaptations help animals thermoregulate.

- Increased metabolic heat production occurs when
  - hormonal changes boost the metabolic rate in birds and mammals,
  - birds and mammals shiver,
  - organisms increase their physical activity, and
  - honeybees cluster and shiver.







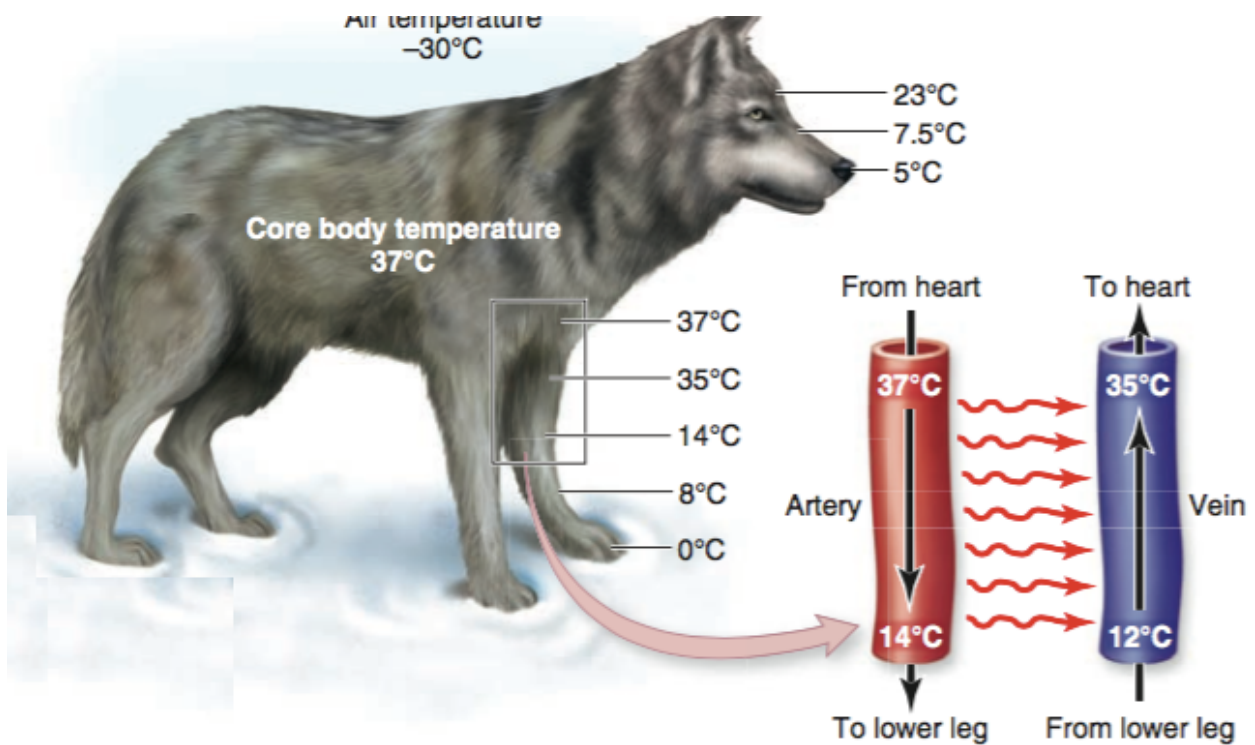
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## Thermoregulation involves adaptations that balance heat gain and loss

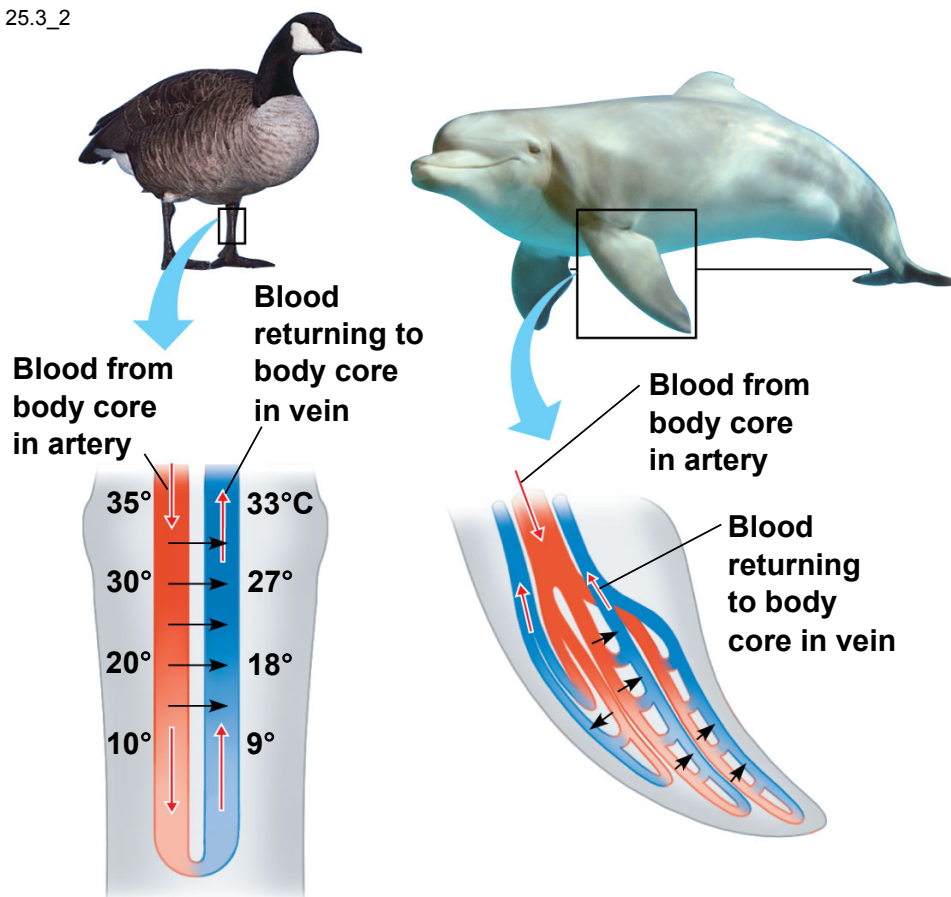
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- Insulation is provided by
  - hair,
  - feathers, and
  - fat layers.
- Circulatory adaptations include
  - increased or decreased blood flow to skin and
  - **countercurrent heat exchange**, with warm and cold blood flowing in opposite directions.



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Figure 25.3\_2



20



# Thermoregulation involves adaptations that balance heat gain and loss

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- Evaporative cooling may involve
  - sweating,
  - panting, or
  - spreading saliva on body surfaces.
- Behavioral responses
  - are used by endotherms and ectotherms and
  - include
    - moving to the sun or shade,
    - migrating, and
    - Bathing.



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# OSMOREGULATION AND EXCRETION

Animals balance the level of water and solutes  
through osmoregulation

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- **Osmoregulation** is the homeostatic control of the uptake and loss of water and solutes such as salt and other ions.
- Osmosis is one process whereby animals regulate their uptake and loss of fluids.



## Animals balance the level of water and solutes through osmoregulation

---

- **Osmoconformers**

- have body fluids with a solute concentration equal to that of seawater,
- face no substantial challenges in water balance, and
- include many marine invertebrates.

## Animals balance the level of water and solutes through osmoregulation

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- **Osmoregulators**

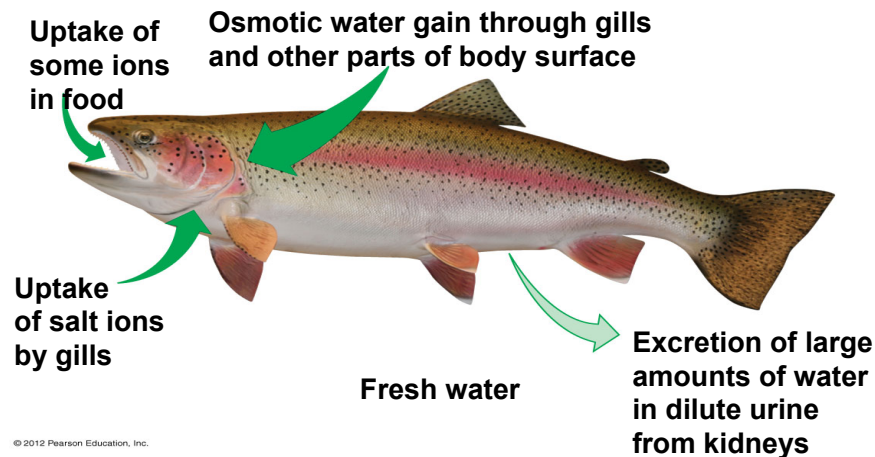
- have body fluids whose solute concentrations differ from that of their environment,
- must actively regulate water movement, and
- include
  - many land animals,
  - freshwater animals such as trout, and
  - marine vertebrates such as sharks.

## Animals balance the level of water and solutes through osmoregulation

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### ■ Freshwater fish

- gain water by osmosis (mainly through gills),
- lose salt by diffusion to the more dilute environment,
- take in salt through their gills and in food, and
- excrete excess water in dilute **urine**.



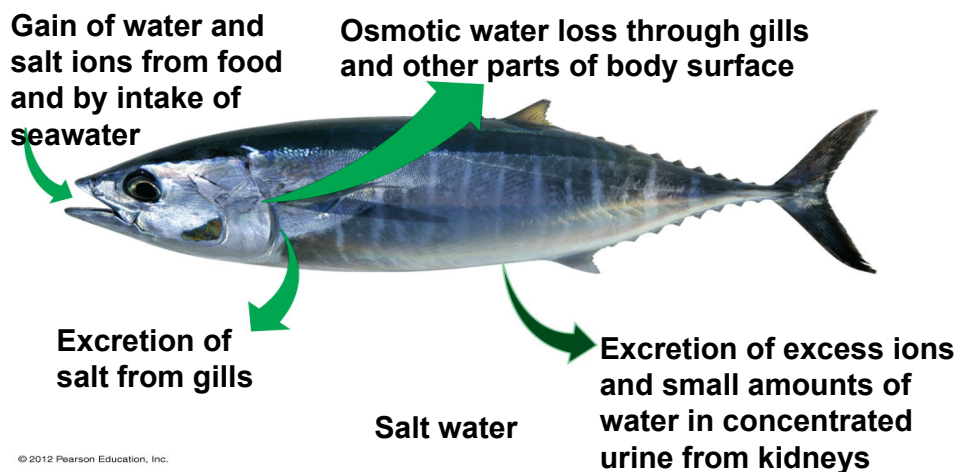
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## 25.4 Animals balance the level of water and solutes through osmoregulation

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### • Saltwater fish

- lose water by osmosis from the gills and body surface,
- drink seawater, and
- use their gills and kidneys to excrete excess salt.



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## Animals balance the level of water and solutes through osmoregulation

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- Land animals
  - face the risk of dehydration,
  - lose water by evaporation and waste disposal,
  - gain water by drinking and eating, and
  - conserve water by
    - reproductive adaptations,
    - behavior adaptations,
    - waterproof skin, and
    - efficient kidneys.

## EVOLUTION CONNECTION: A variety of ways to dispose of nitrogenous wastes has evolved in animals

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- Metabolism produces toxic by-products.
- Nitrogenous wastes are toxic breakdown products of proteins and nucleic acids.
- Animals dispose of nitrogenous wastes in different ways.

## EVOLUTION CONNECTION: A variety of ways to dispose of nitrogenous wastes has evolved in animals

---

- **Ammonia** ( $\text{NH}_3$ ) is
  - poisonous,
  - too toxic to be stored in the body,
  - soluble in water, and
  - easily disposed of by aquatic animals.

## EVOLUTION CONNECTION: A variety of ways to dispose of nitrogenous wastes has evolved in animals

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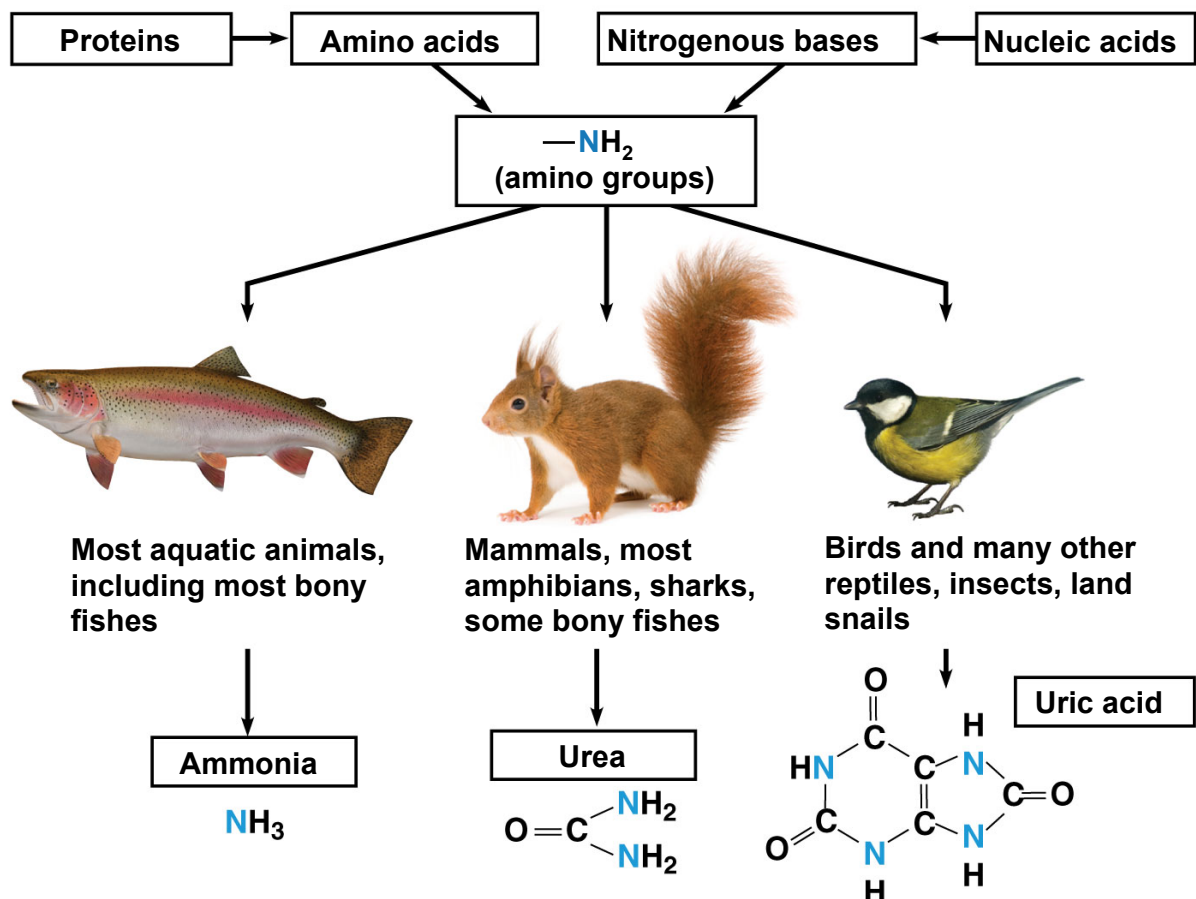
- **Urea** is
  - produced in the vertebrate liver by combining ammonia and carbon dioxide,
  - less toxic,
  - easier to store, and
  - highly soluble in water.



# EVOLUTION CONNECTION: A variety of ways to dispose of nitrogenous wastes has evolved in animals

- **Uric acid is**

- excreted by some land animals (insects, land snails, and many reptiles),
- relatively nontoxic,
- largely insoluble in water,
- excreted as a semisolid paste, conserving water, but
- more energy expensive to produce.



## The urinary system plays several major roles in homeostasis

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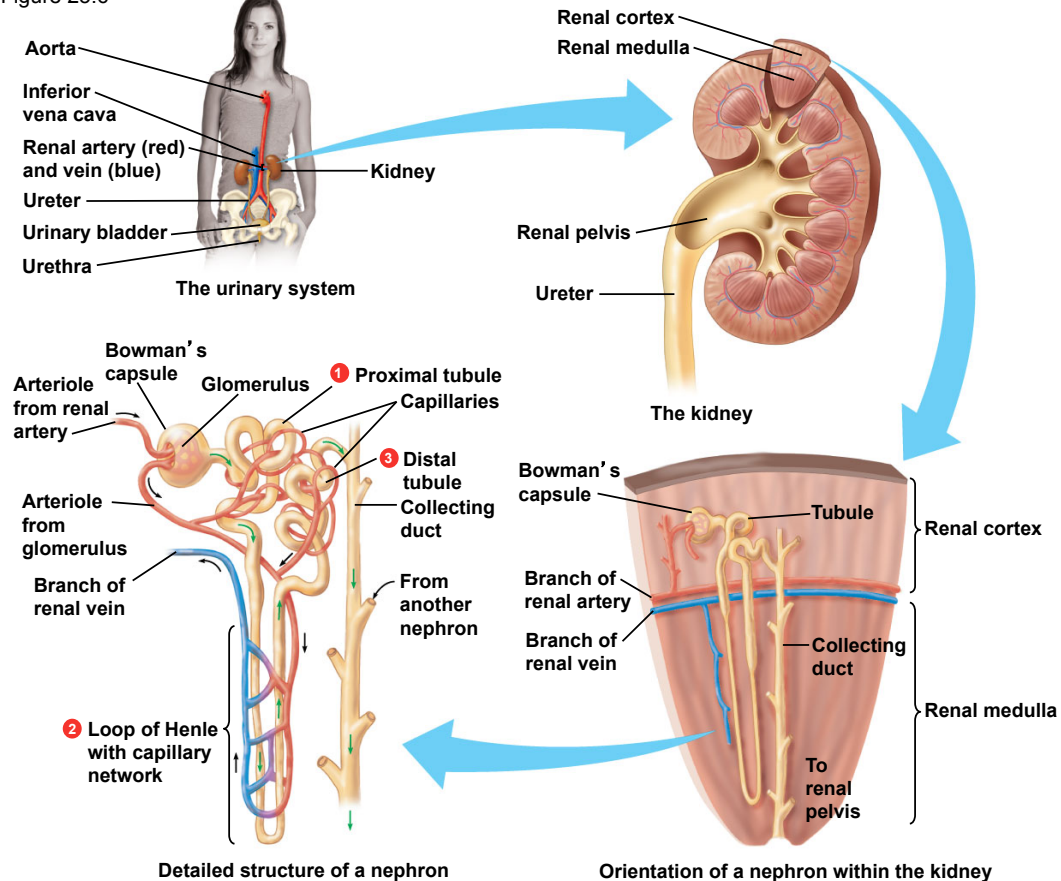
- The **urinary system**
  - forms and excretes urine and
  - regulates water and solutes in body fluids.
- In humans, the kidneys are the main processing centers of the urinary system.

## The urinary system plays several major roles in homeostasis

---

- **Nephrons**
  - are the functional units of the kidneys,
  - extract a fluid **filtrate** from the blood, and
  - refine the filtrate to produce **urine**.
- Urine is
  - drained from the kidneys by **ureters**,
  - stored in the **urinary bladder**, and
  - expelled through the **urethra**.

Figure 25.6



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Overview: The key processes of the urinary system are filtration, reabsorption, secretion, and excretion

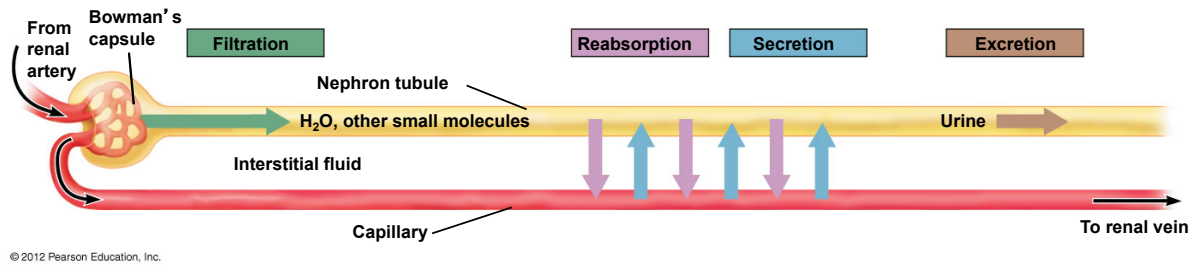
- **Filtration**

- Blood pressure forces water and many small molecules through a capillary wall into the start of the kidney tubule.

- **Reabsorption**

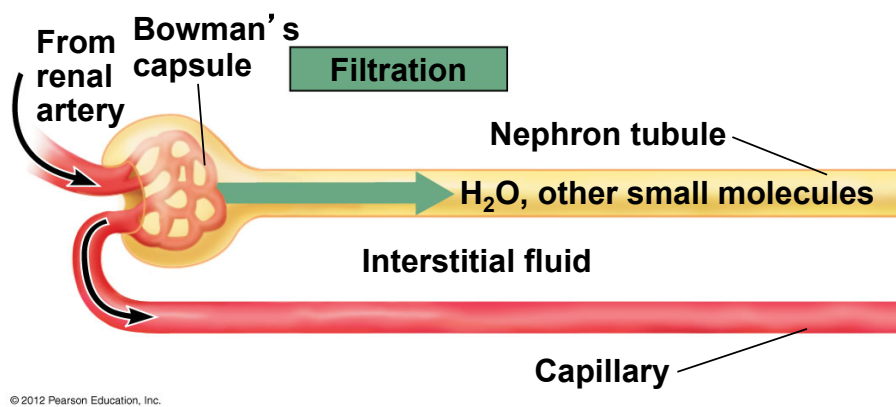
- refines the filtrate,
- reclaims valuable solutes (such as glucose, salt, and amino acids) from the filtrate, and
- returns these to the blood.

Figure 25.7



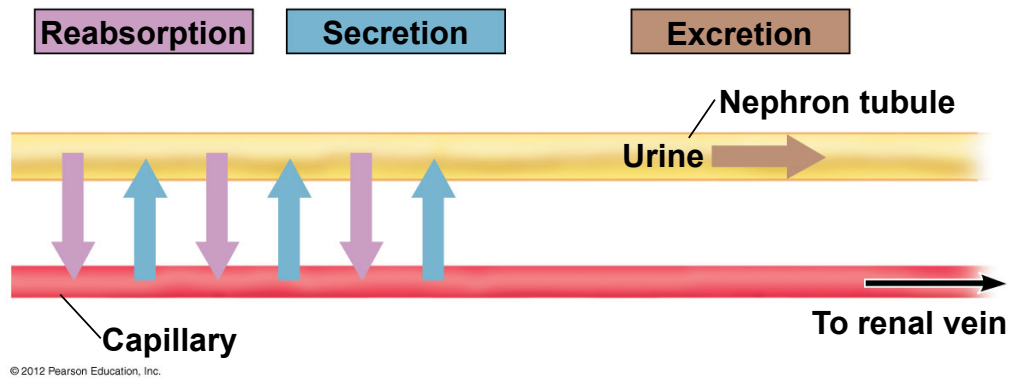
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Figure 25.7\_1



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## 25.7 Overview: The key processes of the urinary system are filtration, reabsorption, secretion, and excretion

- Substances in the blood are transported into the filtrate by the process of **secretion**.
- By **excretion** the final product, urine, is excreted via the ureters, urinary bladder, and urethra.

## Blood filtrate is refined to urine through reabsorption and secretion

- Reabsorption in the proximal and distal tubules removes
  - nutrients,
  - salt, and
  - water.
- pH is regulated by
  - reabsorption of  $\text{HCO}_3^-$  and
  - secretion of  $\text{H}^+$ .
- High NaCl concentration in the medulla promotes reabsorption of water.

Figure 25.8\_1

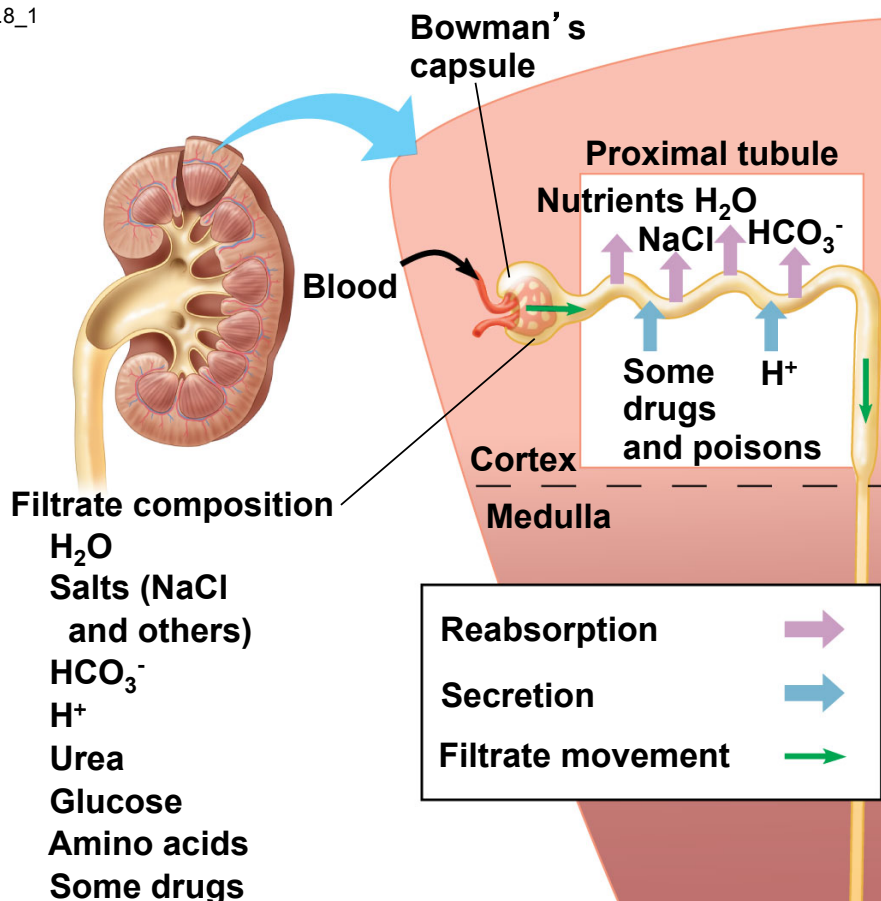
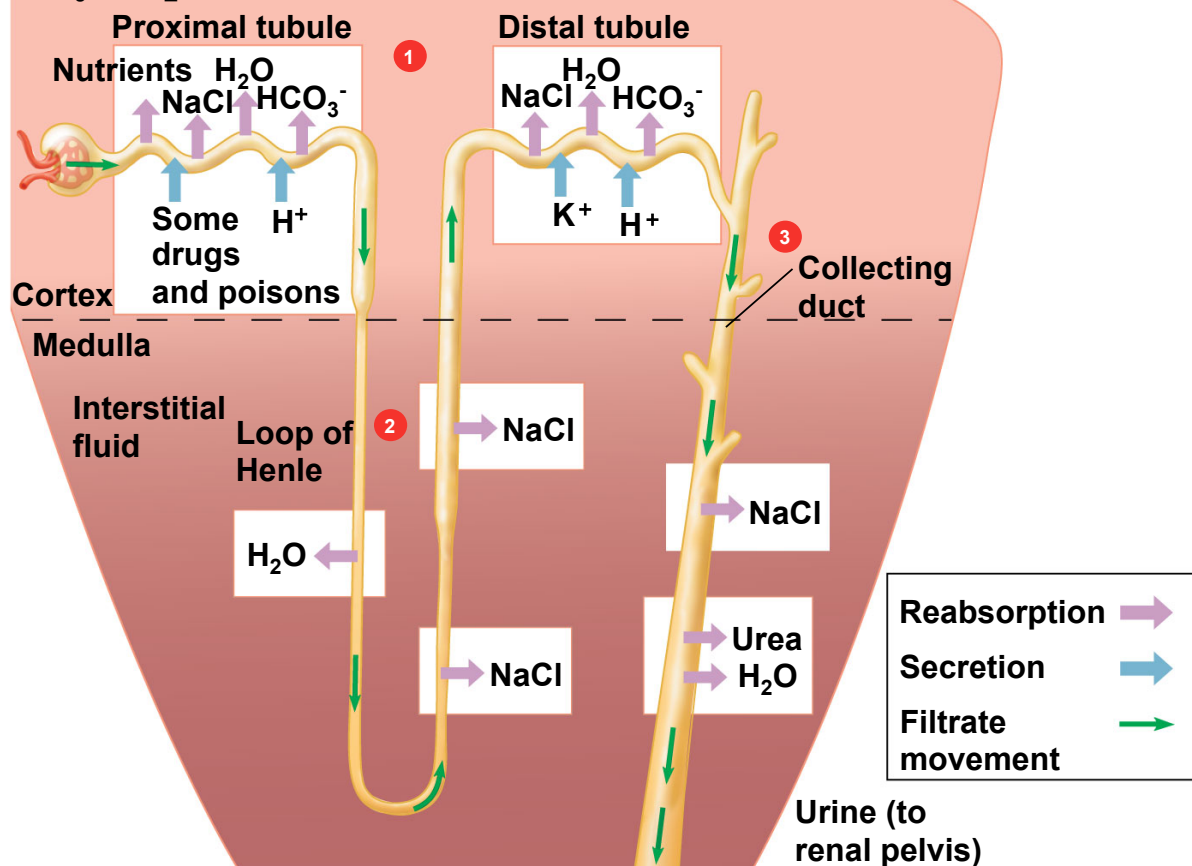


Figure 25.8\_2

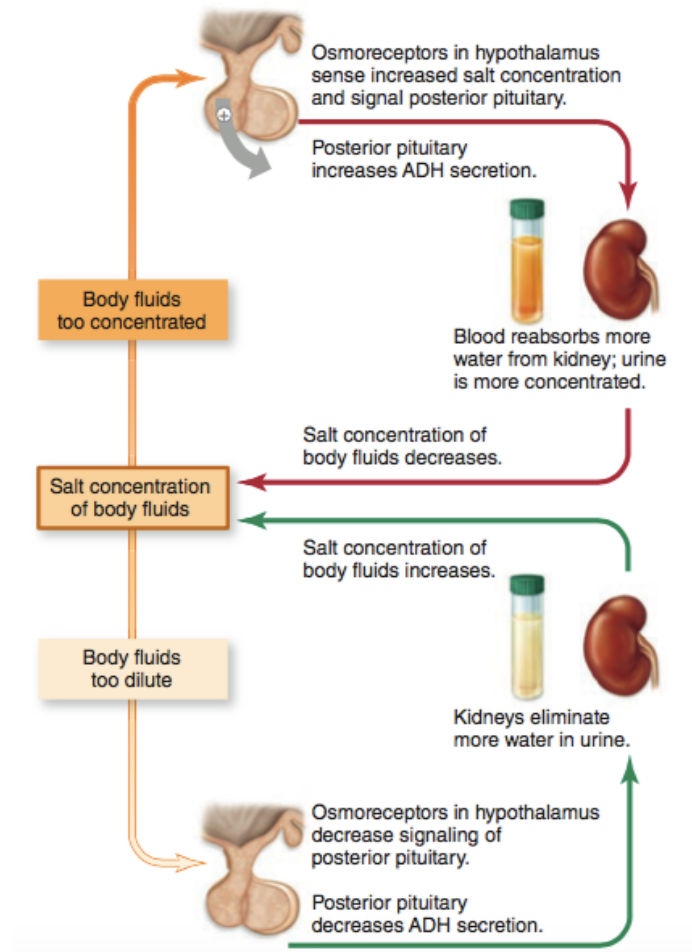


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## Hormones regulate the urinary system

- **Antidiuretic hormone (ADH)** regulates the amount of water excreted by the kidneys by
  - signaling nephrons to reabsorb water from the filtrate, returning it to the blood, and
  - decreasing the amount of water excreted.
- **Diuretics**
  - inhibit the release of ADH and
  - include alcohol and caffeine.

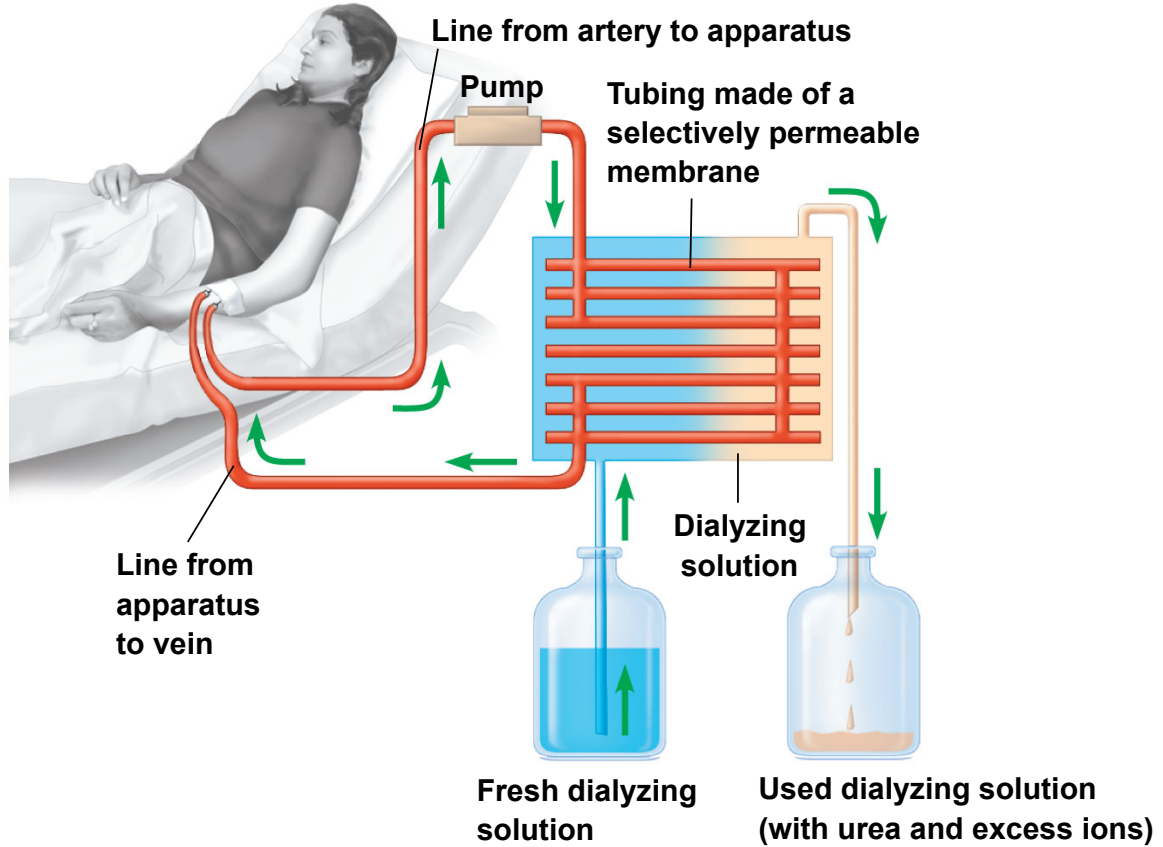


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## CONNECTION: Kidney dialysis can be lifesaving

- Kidney failure can result from
  - hypertension,
  - diabetes, and
  - prolonged use of common drugs, including alcohol.
- A dialysis machine
  - removes wastes from the blood and
  - maintains its solute concentration.

Figure 25.9\_1



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Figure 25.9\_2



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