LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 40

Basic Principles of Animal Form and Function

Lectures by
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Overview: Diverse Forms, Common Challenges

- **Anatomy** is the study of the biological form of an organism
- **Physiology** is the study of the biological functions an organism performs
- The comparative study of animals reveals that form and function are closely correlated

Figure 40.1

Concept 40.1: Animal form and function are correlated at all levels of organization

- Size and shape affect the way an animal interacts with its environment
- Many different animal body plans have evolved and are determined by the genome

Evolution of Animal Size and Shape

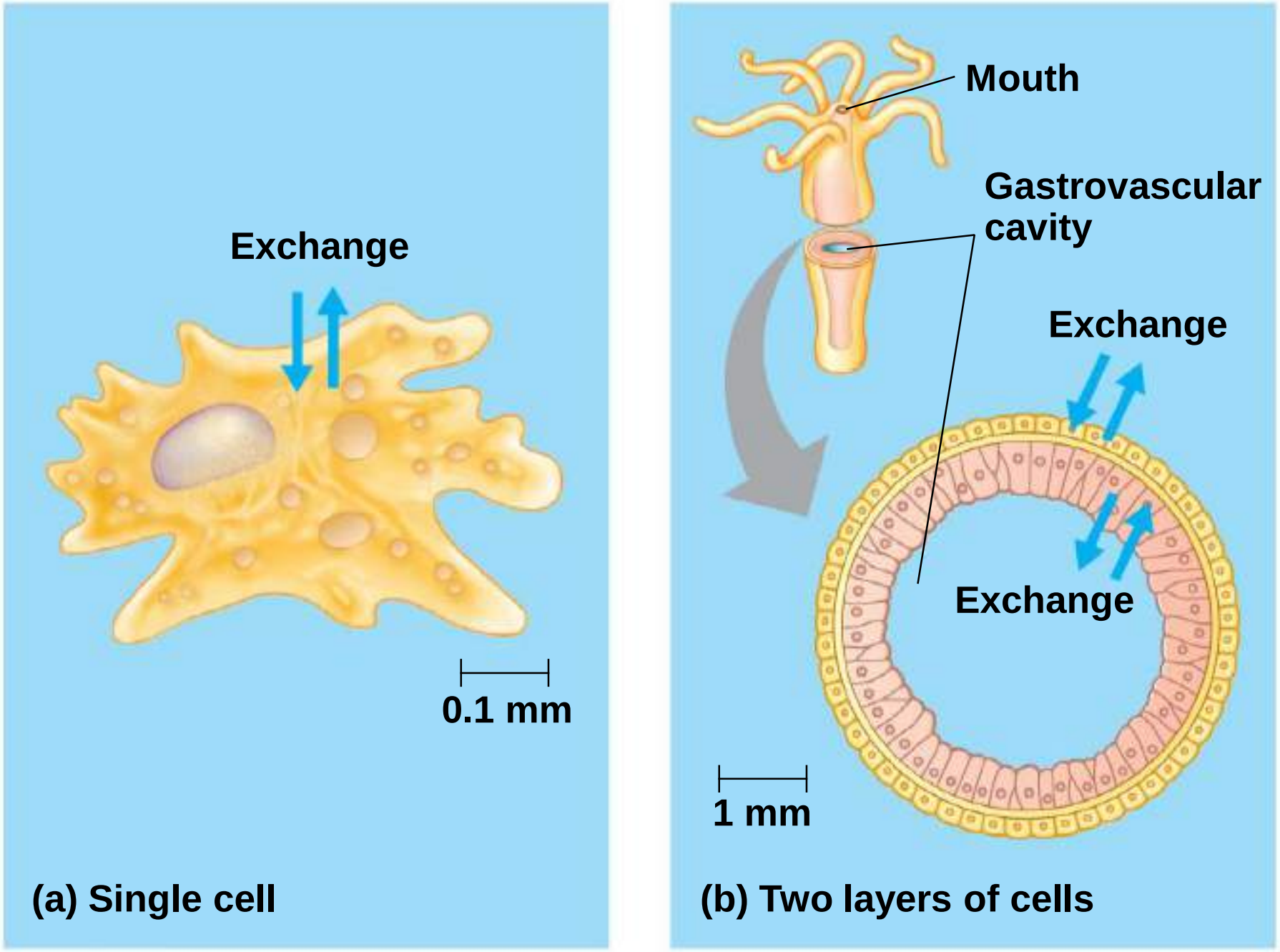
- Physical laws constrain strength, diffusion, movement, and heat exchange
- As animals increase in size, their skeletons must be proportionately larger to support their mass
- Evolutionary convergence reflects different species' adaptations to a similar environmental challenge

Exchange with the Environment

- Materials such as nutrients, waste products, and gases must be exchanged across the cell membranes of animal cells
- Rate of exchange is proportional to a cell's surface area while amount of exchange material is proportional to a cell's volume

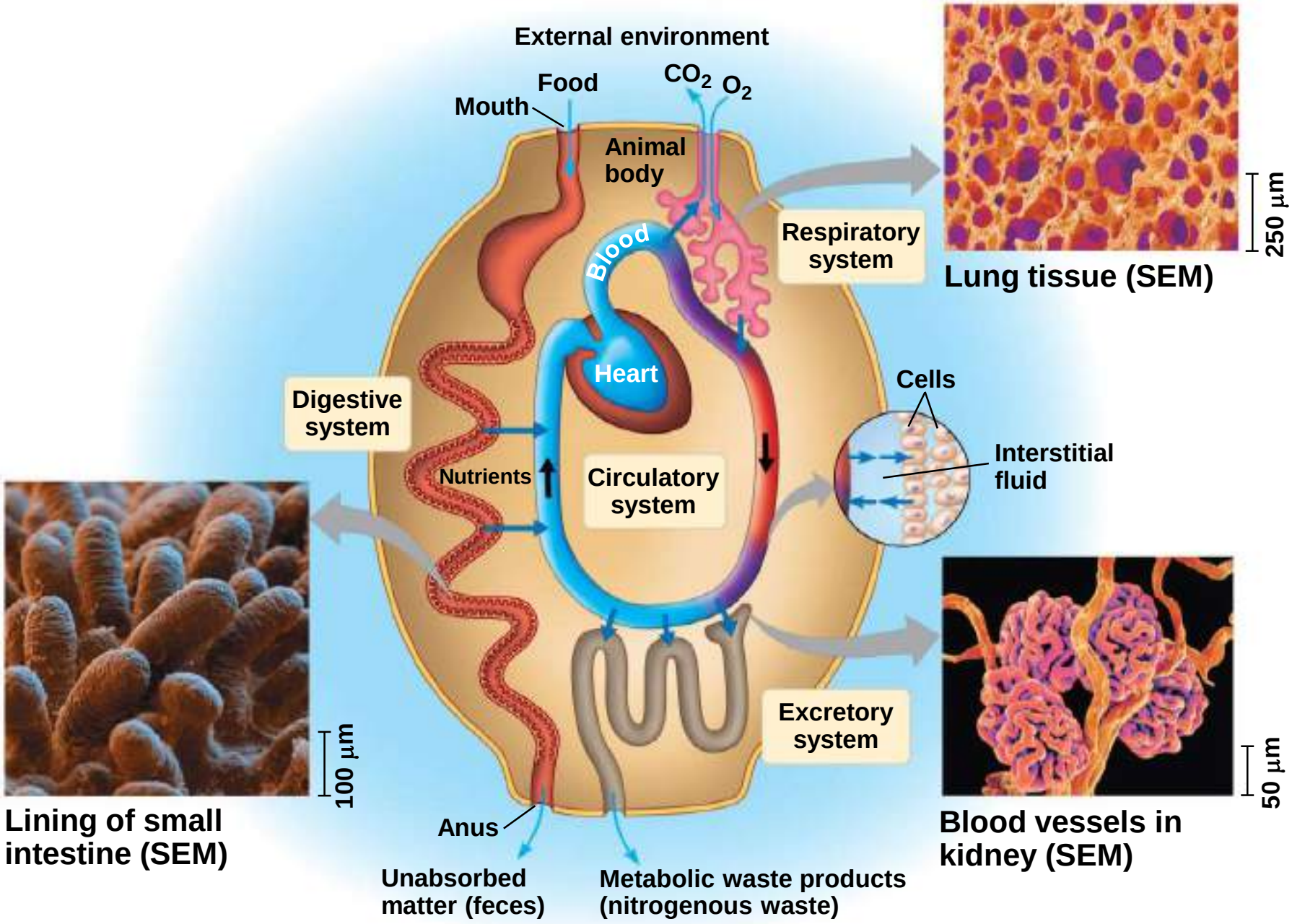
- A single-celled protist living in water has a sufficient surface area of plasma membrane to service its entire volume of cytoplasm
- Multicellular organisms with a saclike body plan have body walls that are only two cells thick, facilitating diffusion of materials

Figure 40.3



- In flat animals such as tapeworms, the distance between cells and the environment is minimized
- More complex organisms have highly folded internal surfaces for exchanging materials

Figure 40.4



- In vertebrates, the space between cells is filled with **interstitial fluid**, which allows for the movement of material into and out of cells
- A complex body plan helps an animal living in a variable environment to maintain a relatively stable internal environment

Hierarchical Organization of Body Plans

- Most animals are composed of specialized cells organized into **tissues** that have different functions
- Tissues make up **organs**, which together make up **organ systems**
- Some organs, such as the pancreas, belong to more than one organ system

Exploring Structure and Function in Animal Tissues

- Different tissues have different structures that are suited to their functions
- Tissues are classified into four main categories: epithelial, connective, muscle, and nervous

Epithelial Tissue

- **Epithelial tissue** covers the outside of the body and lines the organs and cavities within the body
- It contains cells that are closely joined
- The shape of epithelial cells may be cuboidal (like dice), columnar (like bricks on end), or squamous (like floor tiles)

- The arrangement of epithelial cells may be simple (single cell layer), stratified (multiple tiers of cells), or pseudostratified (a single layer of cells of varying length)

Figure 40.5aa

Epithelial Tissue

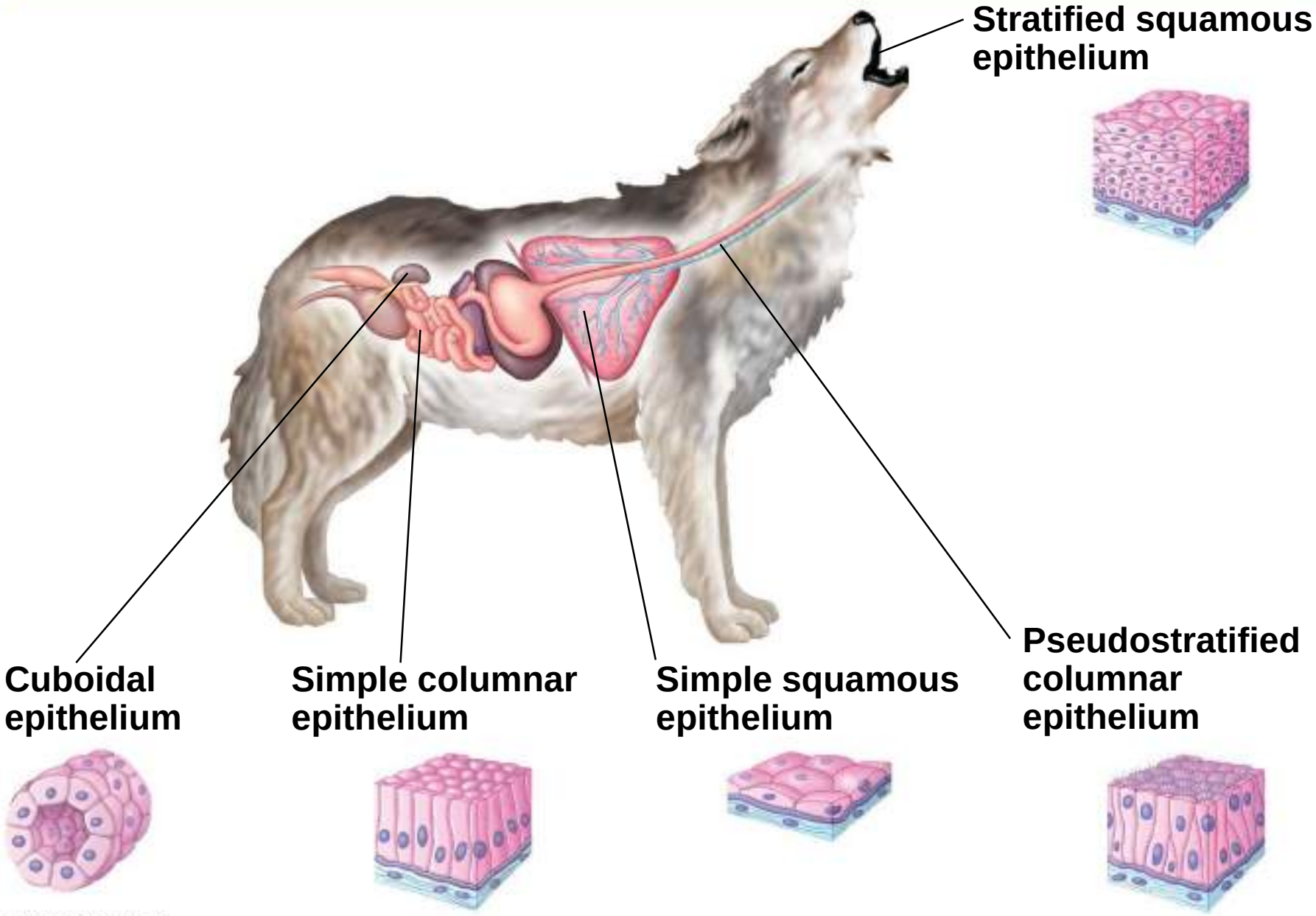
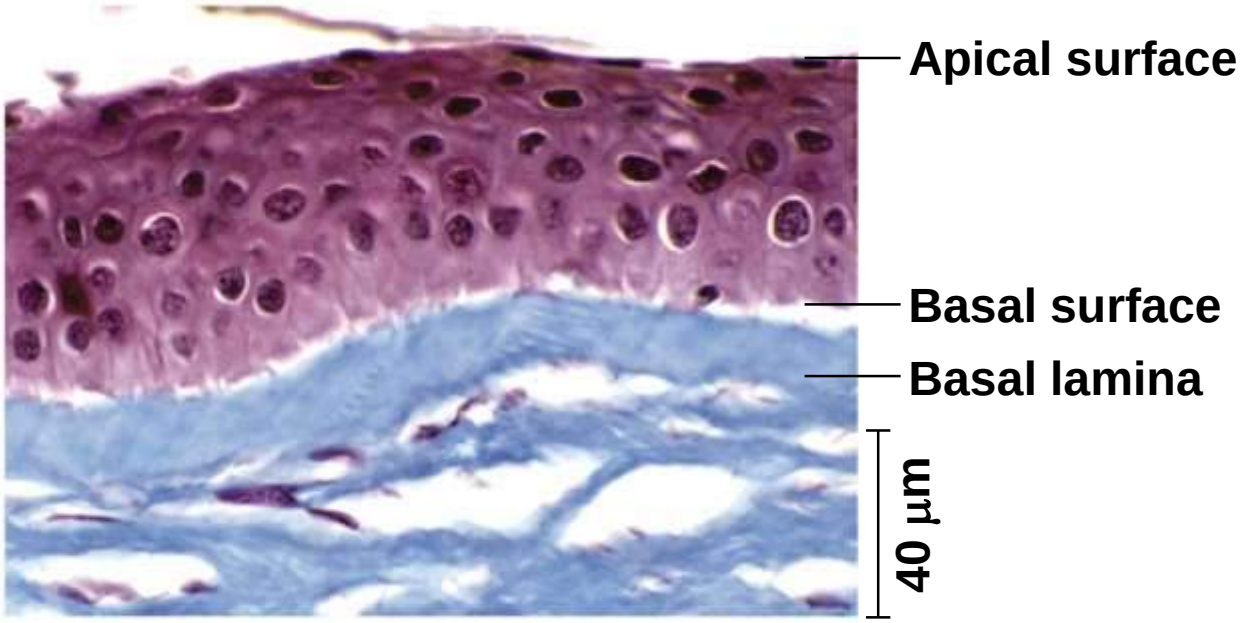


Figure 40.5ab



Polarity of epithelia

Connective Tissue

- **Connective tissue** mainly binds and supports other tissues
- It contains sparsely packed cells scattered throughout an extracellular matrix
- The matrix consists of fibers in a liquid, jellylike, or solid foundation

- There are three types of connective tissue fiber, all made of protein:
  - Collagenous fibers provide strength and flexibility
  - Elastic fibers stretch and snap back to their original length
  - Reticular fibers join connective tissue to adjacent tissues

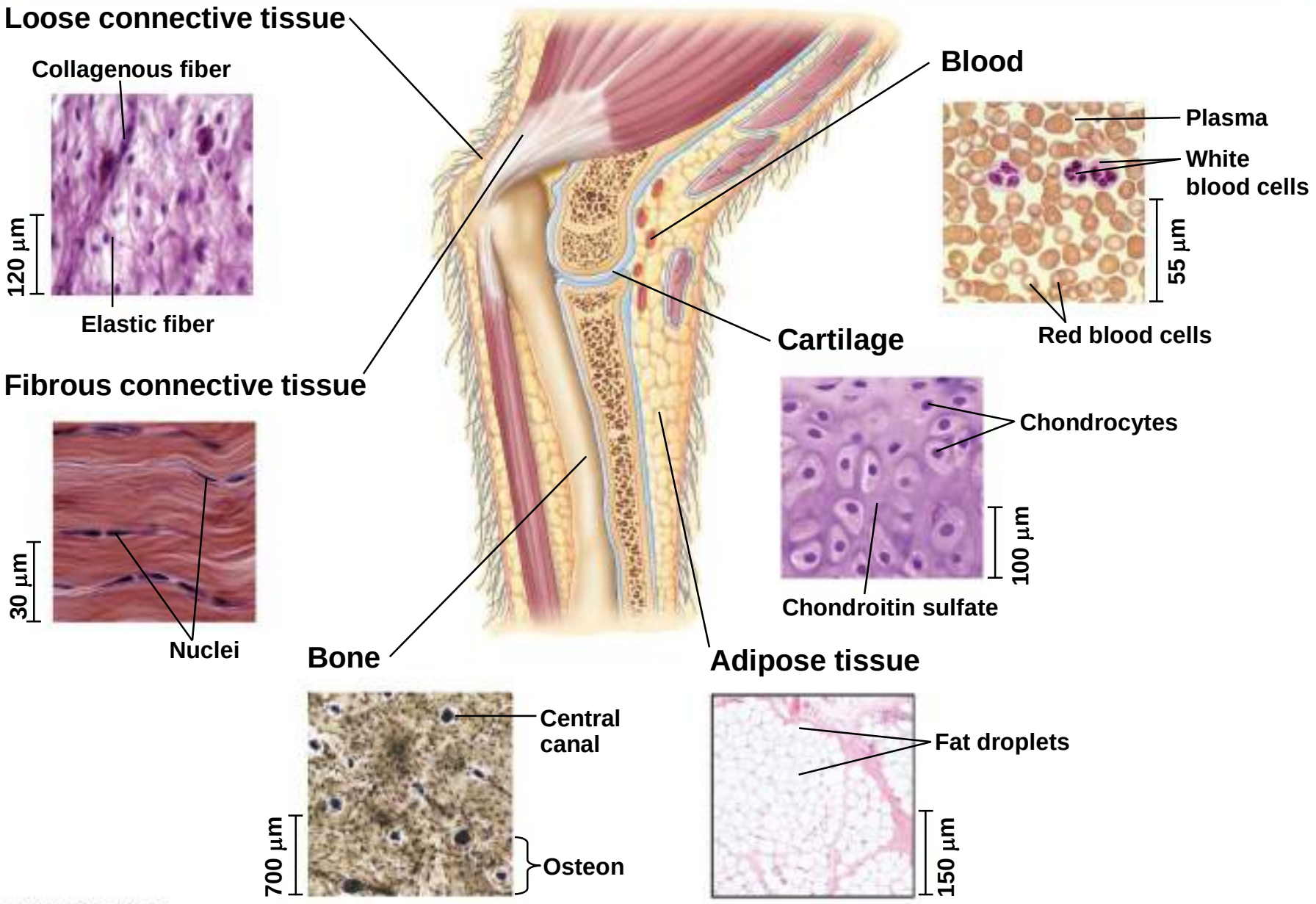
- Connective tissue contains cells, including
  - **Fibroblasts** that secrete the protein of extracellular fibers
  - **Macrophages** that are involved in the immune system

- In vertebrates, the fibers and foundation combine to form six major types of connective tissue:
  - Loose connective tissue binds epithelia to underlying tissues and holds organs in place
  - **Cartilage** is a strong and flexible support material
  - Fibrous connective tissue is found in **tendons**, which attach muscles to bones, and **ligaments**, which connect bones at joints

- **Adipose tissue** stores fat for insulation and fuel
- **Blood** is composed of blood cells and cell fragments in blood plasma
- **Bone** is mineralized and forms the skeleton

Figure 40.5ba

Connective Tissue

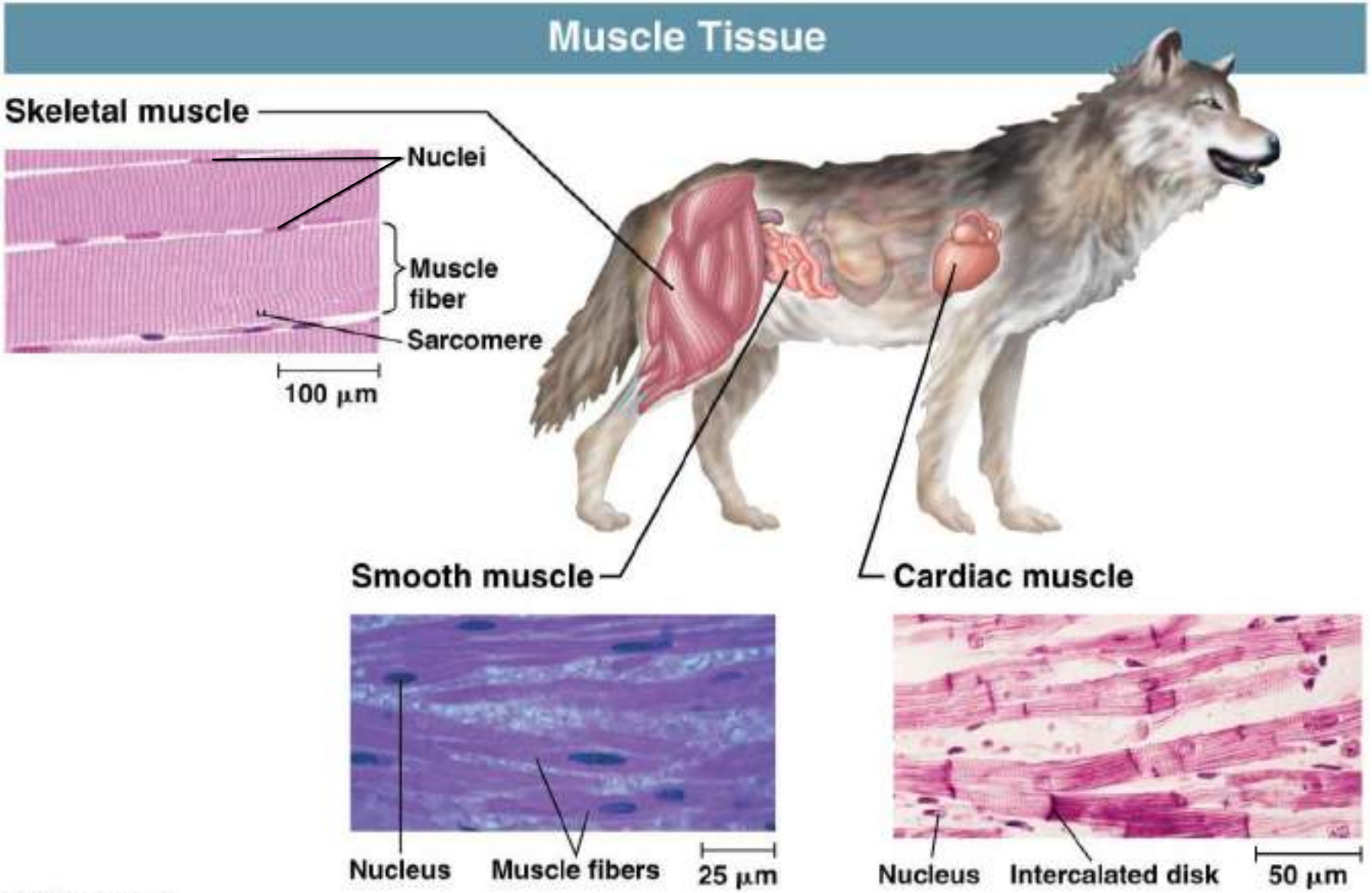


Muscle Tissue

- **Muscle tissue** consists of long cells called muscle fibers, which contract in response to nerve signals

- It is divided in the vertebrate body into three types:
  - **Skeletal muscle**, or striated muscle, is responsible for voluntary movement
  - **Smooth muscle** is responsible for involuntary body activities
  - **Cardiac muscle** is responsible for contraction of the heart

Figure 40.5ca



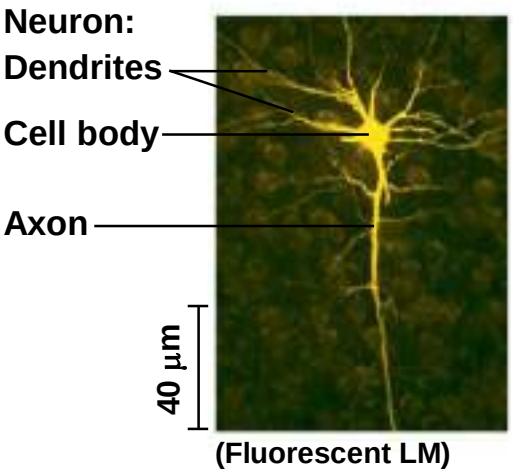
Nervous Tissue

- **Nervous tissue** senses stimuli and transmits signals throughout the animal
- Nervous tissue contains
  - **Neurons**, or nerve cells, that transmit nerve impulses
  - **Glial cells**, or **glia**, that help nourish, insulate, and replenish neurons

Figure 40.5da

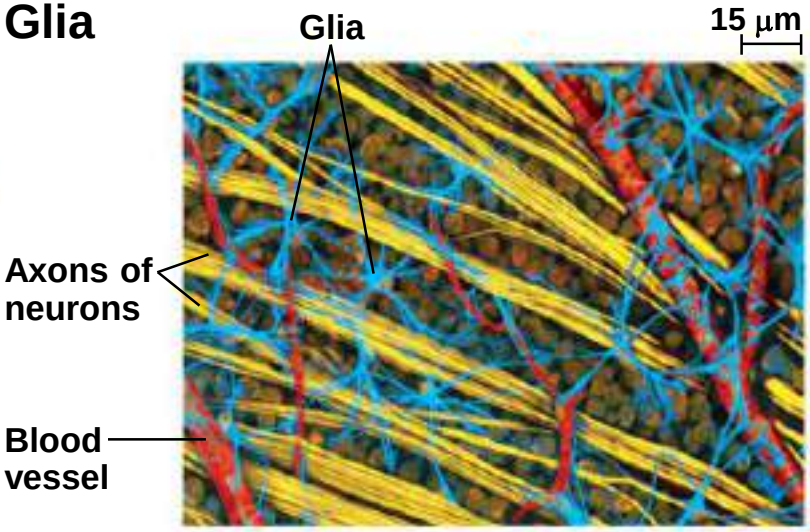
Nervous Tissue

Neurons



(Fluorescent LM)

Glia

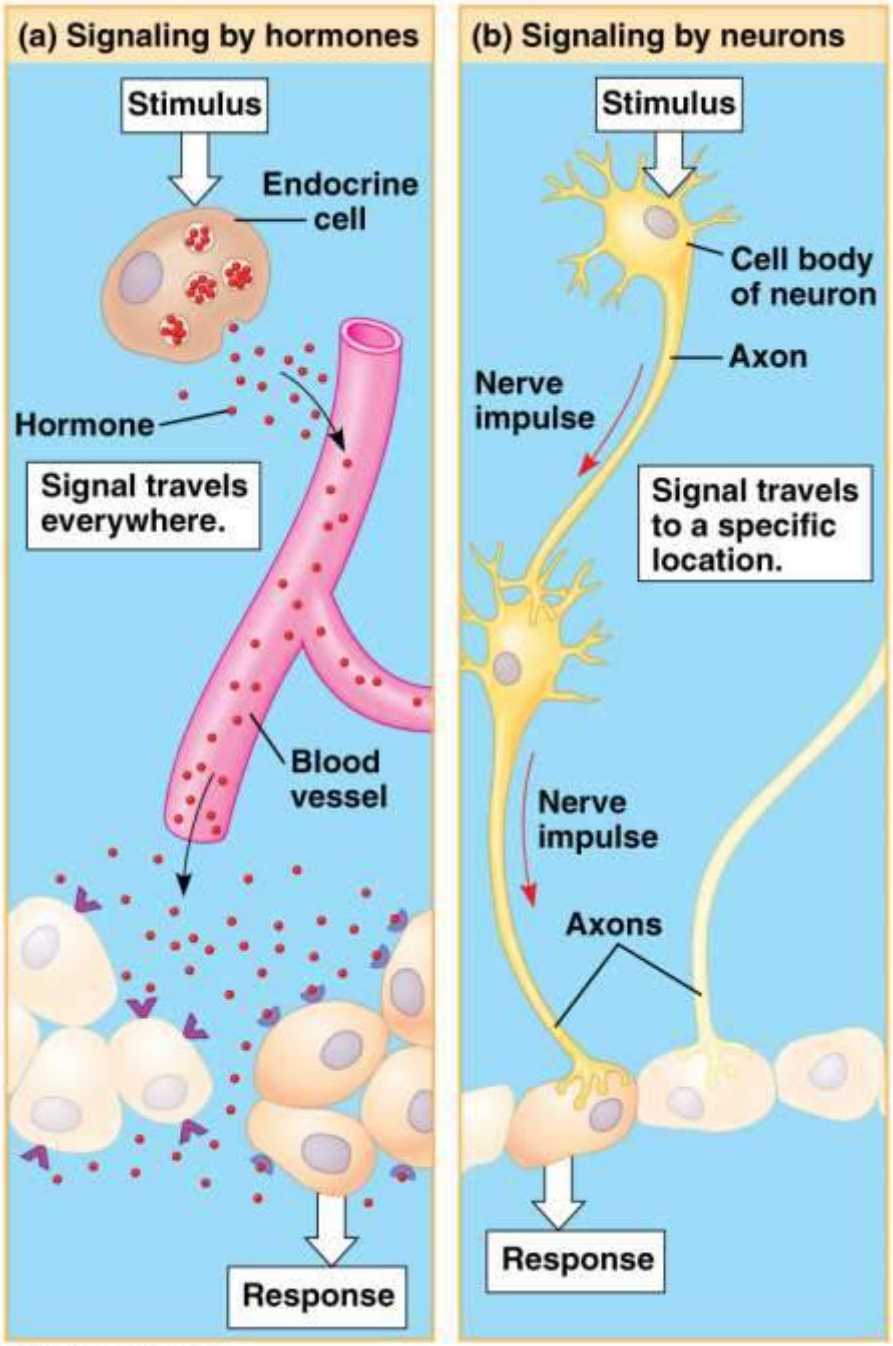


(Confocal LM)

Coordination and Control

- Control and coordination within a body depend on the endocrine system and the nervous system
- The endocrine system transmits chemical signals called **hormones** to receptive cells throughout the body via blood
- A hormone may affect one or more regions throughout the body
- Hormones are relatively slow acting, but can have long-lasting effects

Figure 40.6



- The nervous system transmits information between specific locations
- The information conveyed depends on a signal's pathway, not the type of signal
- Nerve signal transmission is very fast
- Nerve impulses can be received by neurons, muscle cells, endocrine cells, and exocrine cells

Concept 40.2: Feedback control maintains the internal environment in many animals

- Animals manage their internal environment by regulating or conforming to the external environment

Homeostasis

- Organisms use **homeostasis** to maintain a "steady state" or internal balance regardless of external environment
- In humans, body temperature, blood pH, and glucose concentration are each maintained at a constant level

Mechanisms of Homeostasis

- Mechanisms of homeostasis moderate changes in the internal environment
- For a given variable, fluctuations above or below a **set point** serve as a **stimulus**; these are detected by a **sensor** and trigger a **response**
- The response returns the variable to the set point

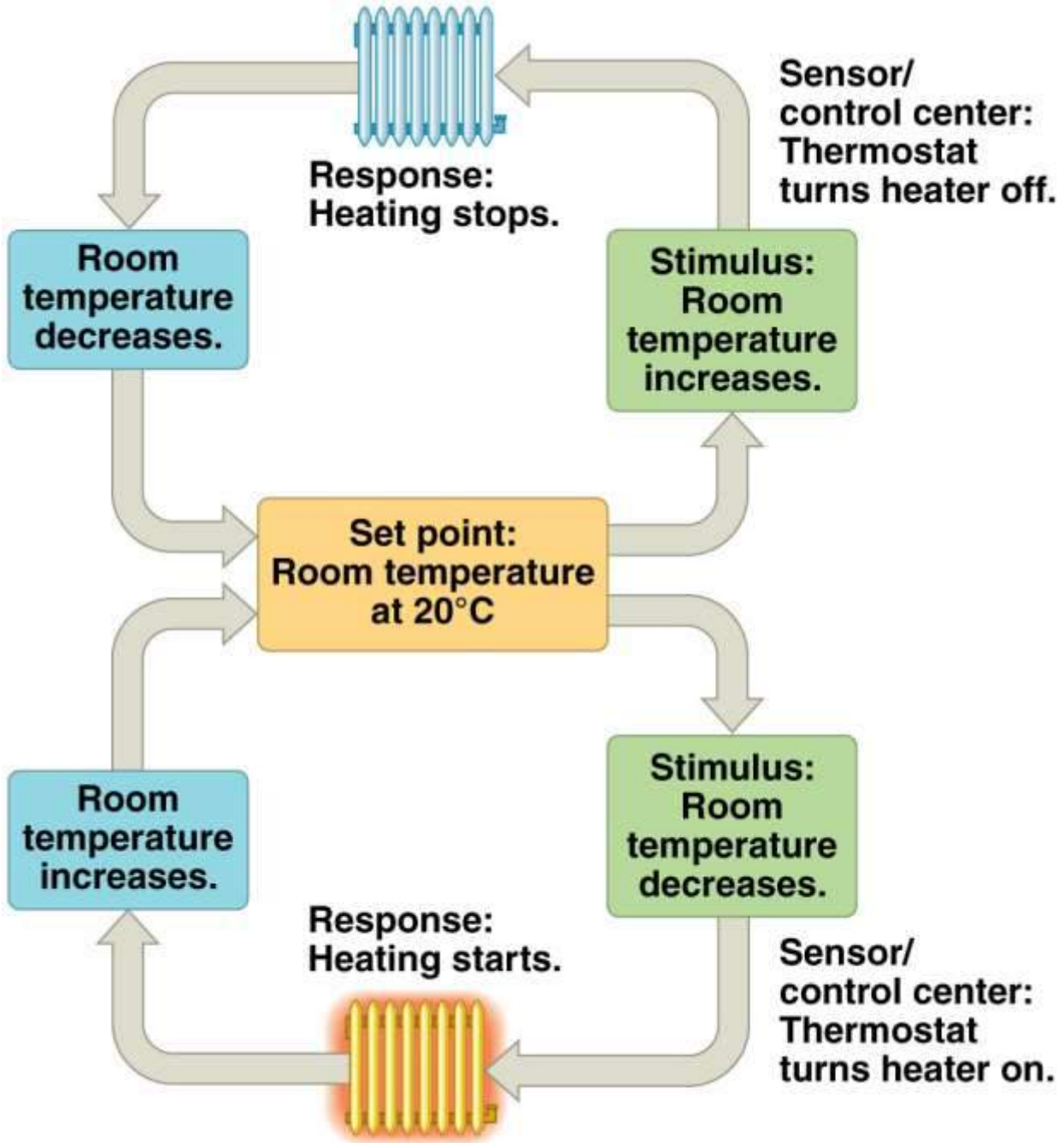
Animation: Negative Feedback

Right-click slide / select “Play”

Animation: Positive Feedback

Right-click slide / select “Play”

Figure 40.8



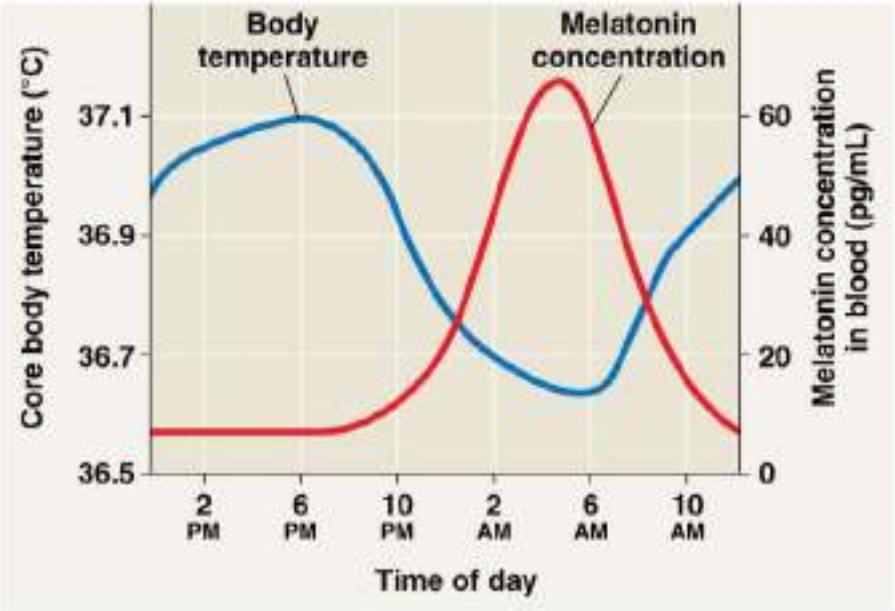
Feedback Control in Homeostasis

- The dynamic equilibrium of homeostasis is maintained by **negative feedback,** which helps to return a variable to a normal range
- Most homeostatic control systems function by negative feedback, where buildup of the end product shuts the system off
- **Positive feedback** amplifies a stimulus and does not usually contribute to homeostasis in animals

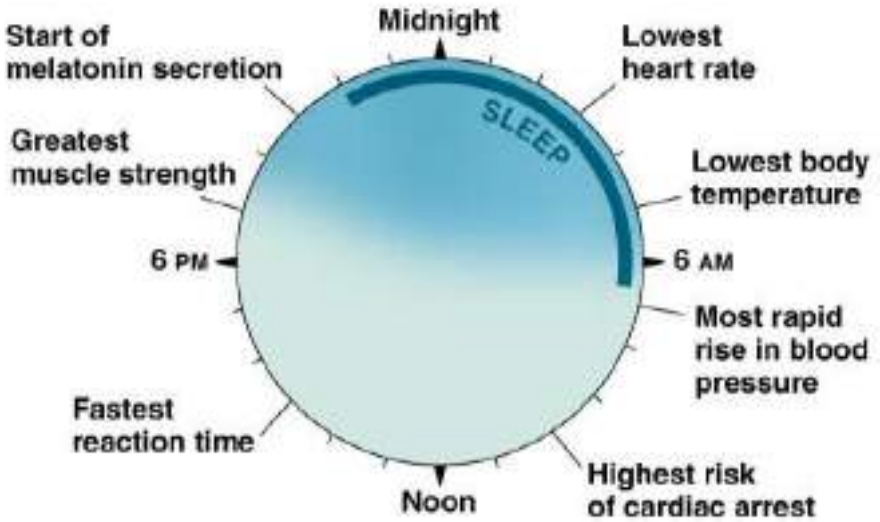
Alterations in Homeostasis

- Set points and normal ranges can change with age or show cyclic variation
- In animals and plants, a **circadian rhythm** governs physiological changes that occur roughly every 24 hours

Figure 40.9



(a) Variation in core body temperature and melatonin concentration in blood



(b) The human circadian clock

Concept 40.3: Homeostatic processes for thermoregulation involve form, function, and behavior

- **Thermoregulation** is the process by which animals maintain an internal temperature within a tolerable range

Endothermy and Ectothermy

- **Endothermic** animals generate heat by metabolism; birds and mammals are endotherms
- **Ectothermic** animals gain heat from external sources; ectotherms include most invertebrates, fishes, amphibians, and nonavian reptiles

- In general, ectotherms tolerate greater variation in internal temperature, while endotherms are active at a greater range of external temperatures
- Endothermy is more energetically expensive than ectothermy

Figure 40.10

(a) A walrus, an endotherm

(b) A lizard, an ectotherm

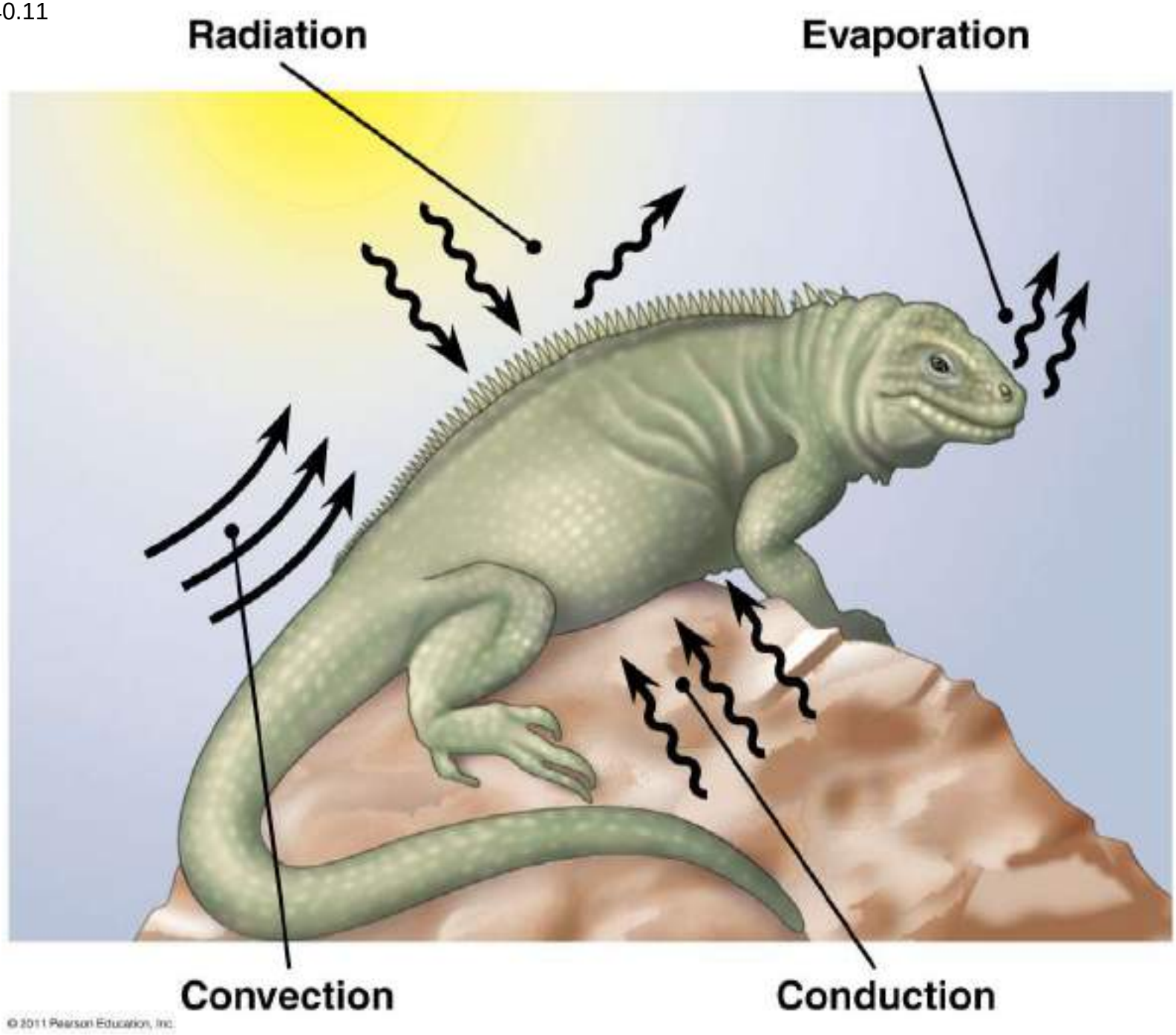
Variation in Body Temperature

- The body temperature of a poikilotherm varies with its environment
- The body temperature of a homeotherm is relatively constant
- The relationship between heat source and body temperature is not fixed (that is, not all poikilotherms are ectotherms)

Balancing Heat Loss and Gain

- Organisms exchange heat by four physical processes: radiation, evaporation, convection, and conduction

Figure 40.11



- Heat regulation in mammals often involves the **integumentary system**: skin, hair, and nails
- Five adaptations help animals thermoregulate:
  - Insulation
  - Circulatory adaptations
  - Cooling by evaporative heat loss
  - Behavioral responses
  - Adjusting metabolic heat production

Insulation

- Insulation is a major thermoregulatory adaptation in mammals and birds
- Skin, feathers, fur, and blubber reduce heat flow between an animal and its environment
- Insulation is especially important in marine mammals such as whales and walruses

Circulatory Adaptations

- Regulation of blood flow near the body surface significantly affects thermoregulation
- Many endotherms and some ectotherms can alter the amount of blood flowing between the body core and the skin
- In vasodilation, blood flow in the skin increases, facilitating heat loss
- In vasoconstriction, blood flow in the skin decreases, lowering heat loss

Cooling by Evaporative Heat Loss

- Many types of animals lose heat through evaporation of water from their skin
- Panting increases the cooling effect in birds and many mammals
- Sweating or bathing moistens the skin, helping to cool an animal down

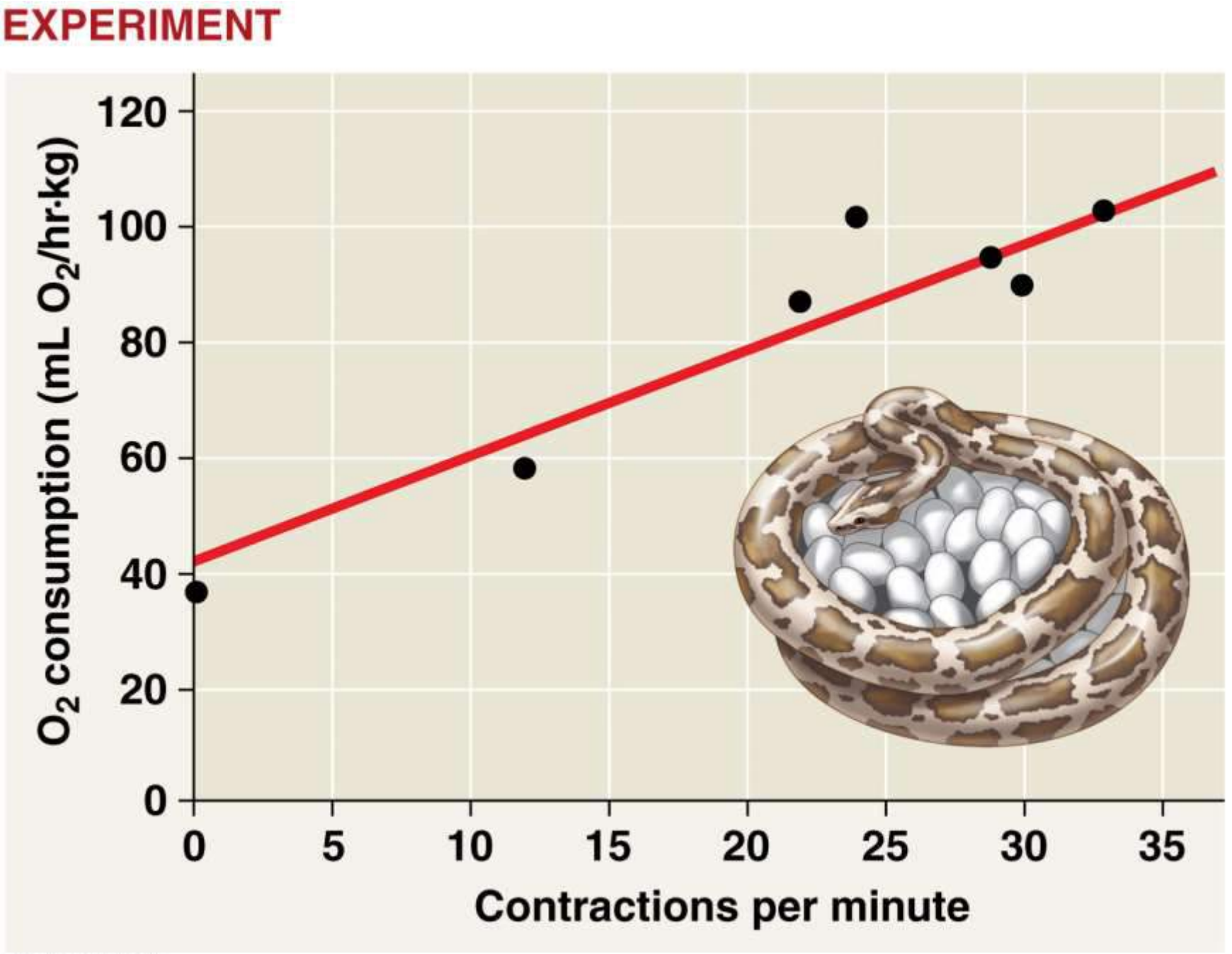
Behavioral Responses

- Both endotherms and ectotherms use behavioral responses to control body temperature
- Some terrestrial invertebrates have postures that minimize or maximize absorption of solar heat

Adjusting Metabolic Heat Production

- Thermogenesis is the adjustment of metabolic heat production to maintain body temperature
- Thermogenesis is increased by muscle activity such as moving or shivering
- Nonshivering thermogenesis takes place when hormones cause mitochondria to increase their metabolic activity
- Some ectotherms can also shiver to increase body temperature

Figure 40.14



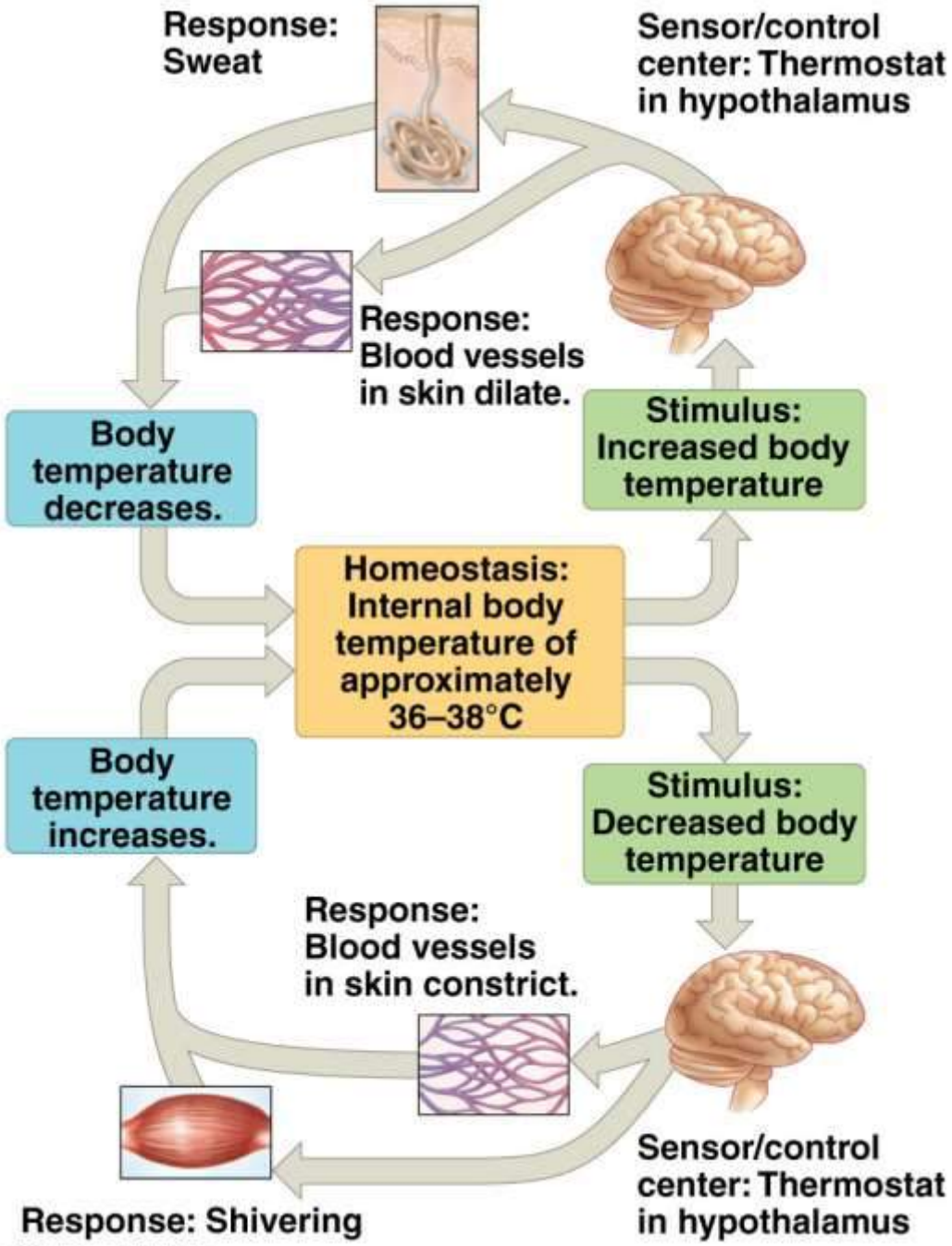
Acclimatization in Thermoregulation

- Birds and mammals can vary their insulation to acclimatize to seasonal temperature changes
- When temperatures are subzero, some ectotherms produce “antifreeze” compounds to prevent ice formation in their cells

Physiological Thermostats and Fever

- Thermoregulation is controlled by a region of the brain called the **hypothalamus**
- The hypothalamus triggers heat loss or heat generating mechanisms
- Fever is the result of a change to the set point for a biological thermostat

Figure 40.16



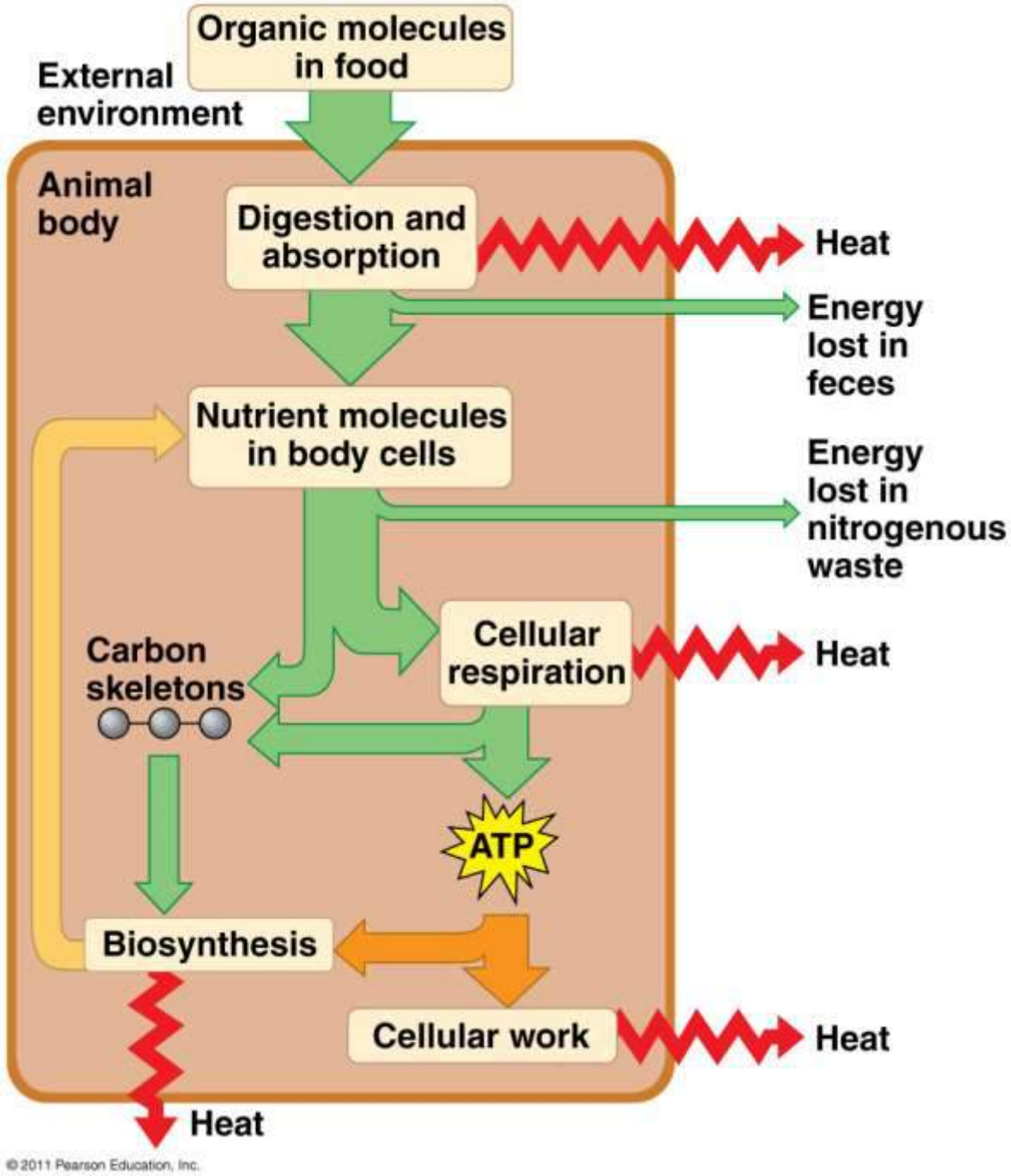
Concept 40.4: Energy requirements are related to animal size, activity, and environment

- **Bioenergetics** is the overall flow and transformation of energy in an animal
- It determines how much food an animal needs and it relates to an animal's size, activity, and environment

Energy Allocation and Use

- Animals harvest chemical energy from food
- Energy-containing molecules from food are usually used to make ATP, which powers cellular work
- After the needs of staying alive are met, remaining food molecules can be used in biosynthesis
- Biosynthesis includes body growth and repair, synthesis of storage material such as fat, and production of gametes

Figure 40.17



Quantifying Energy Use

- **Metabolic rate** is the amount of energy an animal uses in a unit of time
- Metabolic rate can be determined by
  - An animal's heat loss
  - The amount of oxygen consumed or carbon dioxide produced

Minimum Metabolic Rate and Thermoregulation

- **Basal metabolic rate (BMR)** is the metabolic rate of an endotherm at rest at a "comfortable" temperature
- **Standard metabolic rate (SMR)** is the metabolic rate of an ectotherm at rest at a specific temperature
- Both rates assume a nongrowing, fasting, and nonstressed animal
- Ectotherms have much lower metabolic rates than endotherms of a comparable size

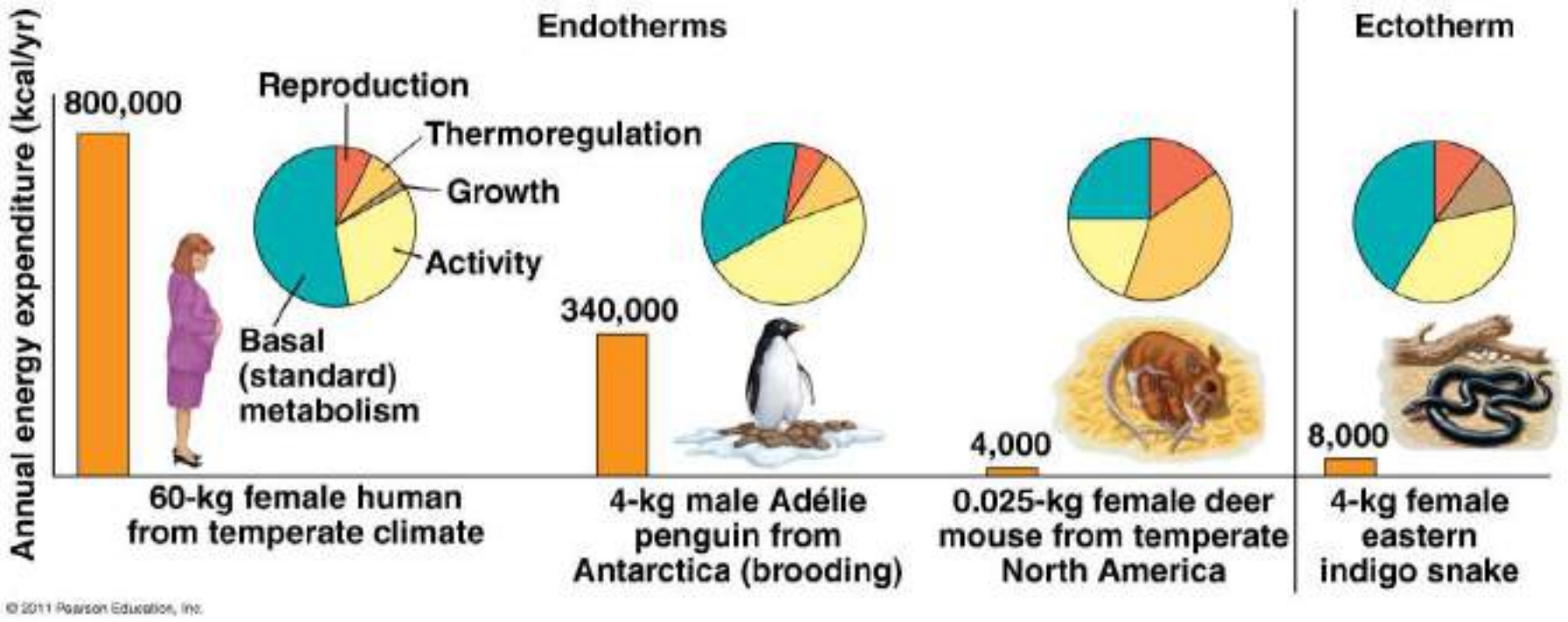
Activity and Metabolic Rate

- Activity greatly affects metabolic rate for endotherms and ectotherms
- In general, the maximum metabolic rate an animal can sustain is inversely related to the duration of the activity

Energy Budgets

- Different species use energy and materials in food in different ways, depending on their environment
- Use of energy is partitioned to BMR (or SMR), activity, thermoregulation, growth, and reproduction

Figure 40.20



Torpor and Energy Conservation

- **Torpor** is a physiological state in which activity is low and metabolism decreases
- Torpor enables animals to save energy while avoiding difficult and dangerous conditions
- **Hibernation** is long-term torpor that is an adaptation to winter cold and food scarcity