Chapter 40

Basic Principles of Animal Form and Function

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Key concepts

Organization of animal form and function

Homeostasis (balance): temperature, energy

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

Fig. 40-1

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

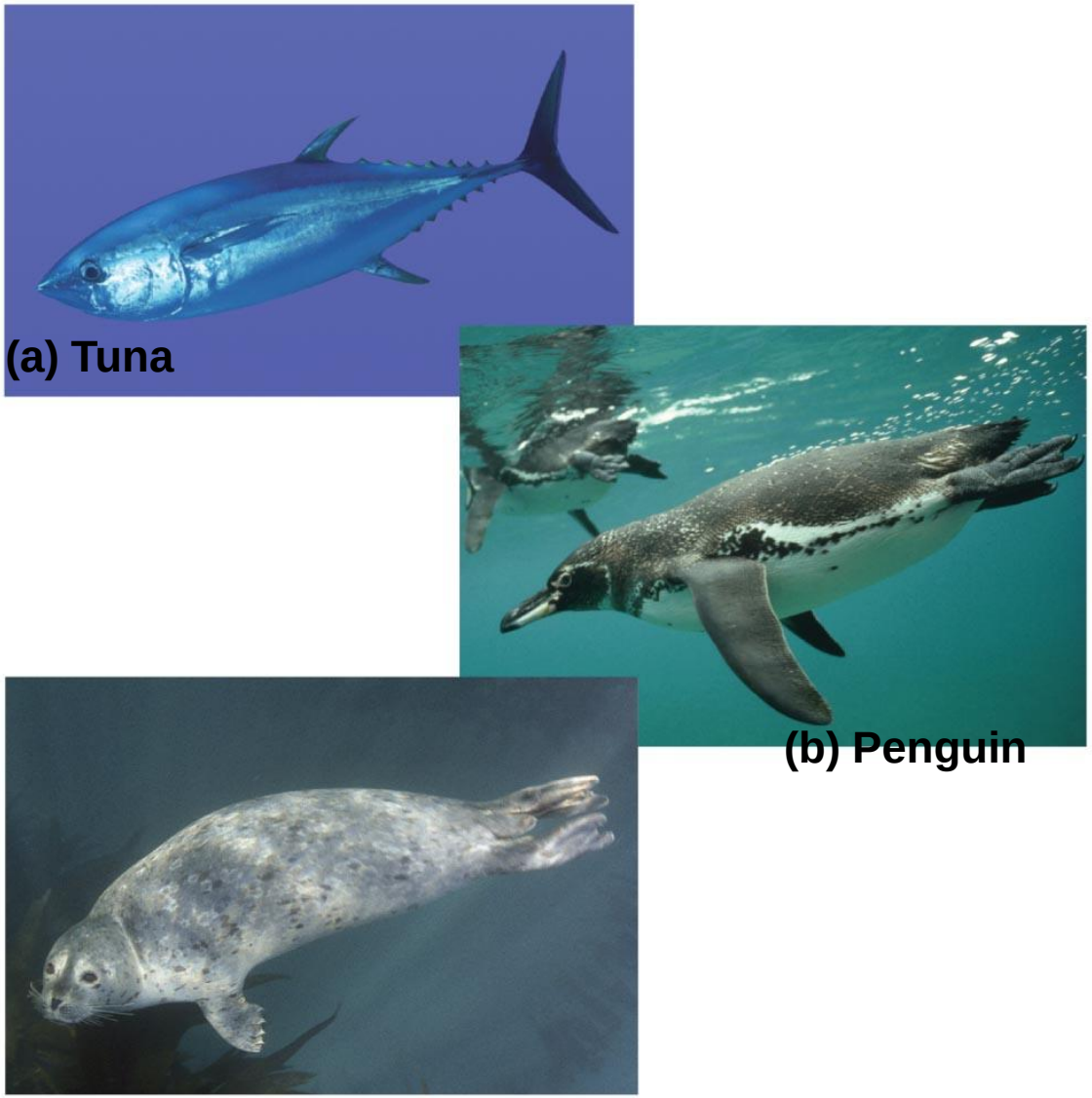
- Size and shape affect the way an animal interacts with its environment
- Many different animal body plans have evolved and are determined by the genome

Physical Constraints on Animal Size and Shape

- The ability to perform certain actions depends on an animal's shape, size, and environment
- Evolutionary convergence reflects different species' adaptations to a similar environmental challenge
- Physical laws impose constraints on animal size and shape

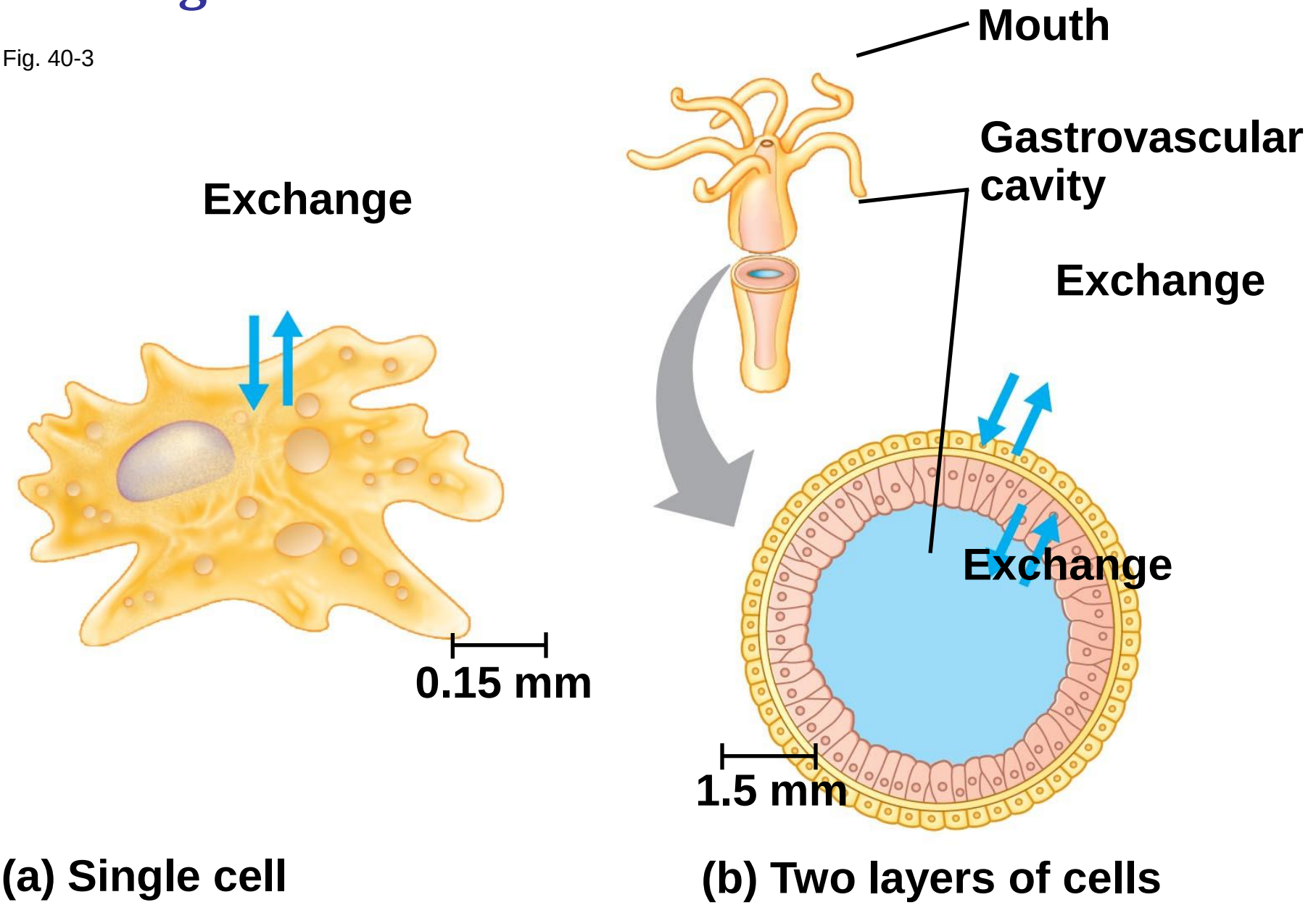
Physical Constraints on Animal Size and Shape

Fig. 40-2



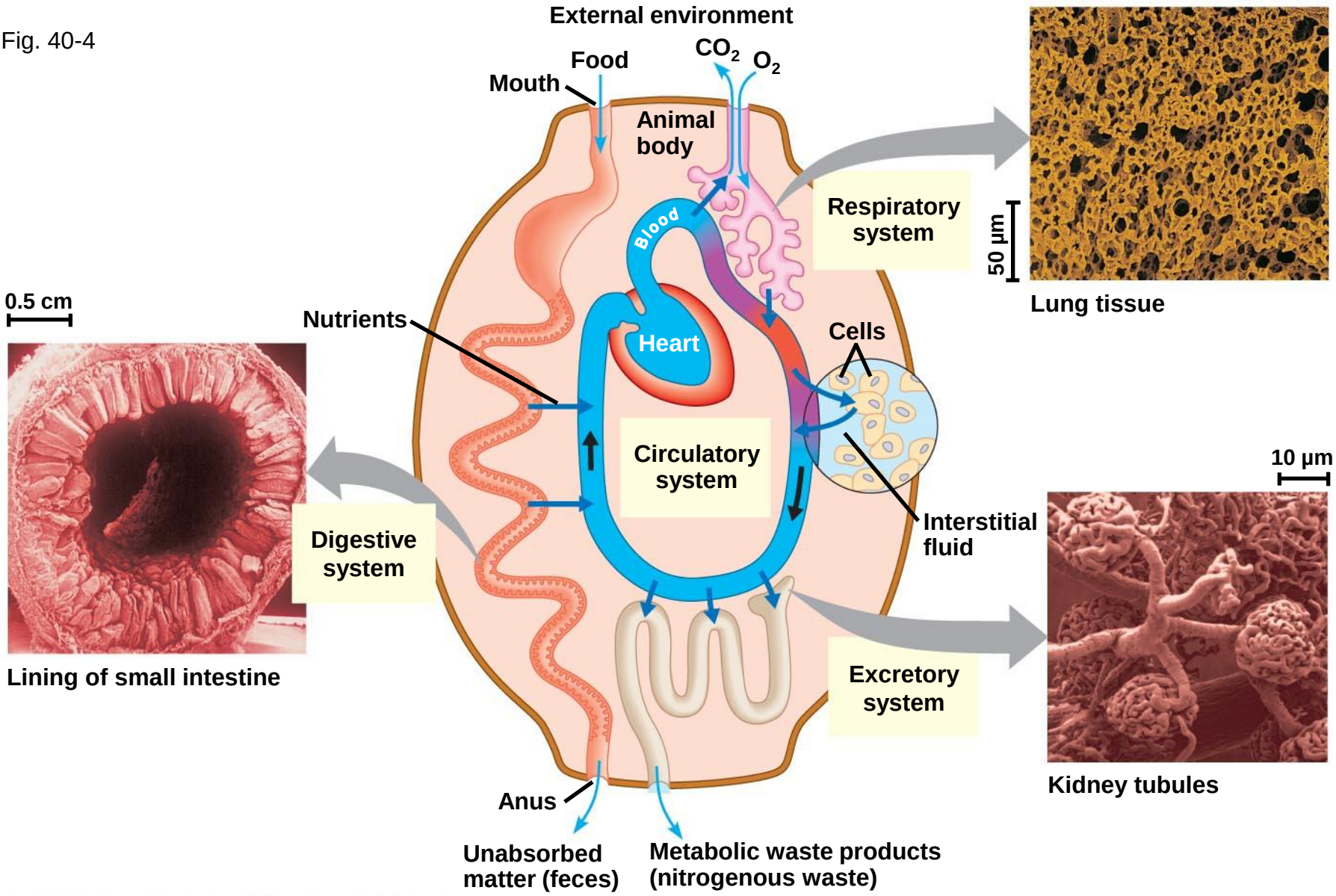
Exchange with the Environment

Fig. 40-3



More complex organisms have highly folded internal surfaces for exchanging materials

Fig. 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

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**

Table 40-1

Table 40.1 Organ Systems: Their Main Components and Functions in Mammals

Organ System	Main Components	Main Functions
Digestive	Mouth, pharynx, esophagus, stomach, intestines, liver, pancreas, anus	Food processing (ingestion, digestion, absorption, elimination)
Circulatory	Heart, blood vessels, blood	Internal distribution of materials
Respiratory	Lungs, trachea, other breathing tubes	Gas exchange (uptake of oxygen; disposal of carbon dioxide)
Immune and lymphatic	Bone marrow, lymph nodes, thymus, spleen, lymph vessels, white blood cells	Body defense (fighting infections and cancer)
Excretory	Kidneys, ureters, urinary bladder, urethra	Disposal of metabolic wastes; regulation of osmotic balance of blood
Endocrine	Pituitary, thyroid, pancreas, adrenal, and other hormone-secreting glands	Coordination of body activities (such as digestion and metabolism)
Reproductive	Ovaries or testes, and associated organs	Reproduction
Nervous	Brain, spinal cord, nerves, sensory organs	Coordination of body activities; detection of stimuli and formulation of responses to them
Integumentary	Skin and its derivatives (such as hair, claws, skin glands)	Protection against mechanical injury, infection, drying out; thermoregulation
Skeletal	Skeleton (bones, tendons, ligaments, cartilage)	Body support, protection of internal organs, movement
Muscular	Skeletal muscles	Locomotion and other movement

Tissue Structure and Function

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

Fig. 40-5a

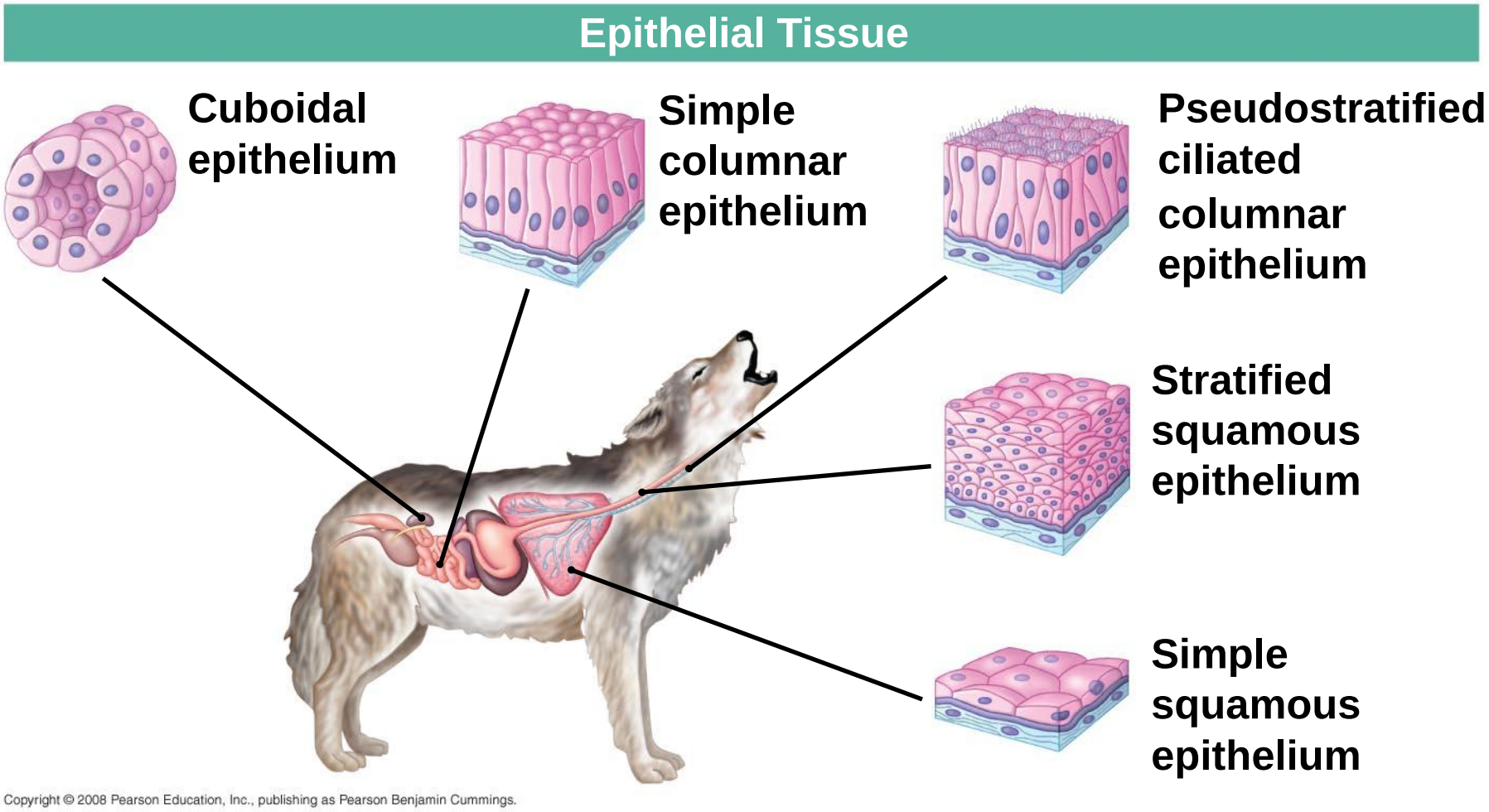


Fig. 40-5b

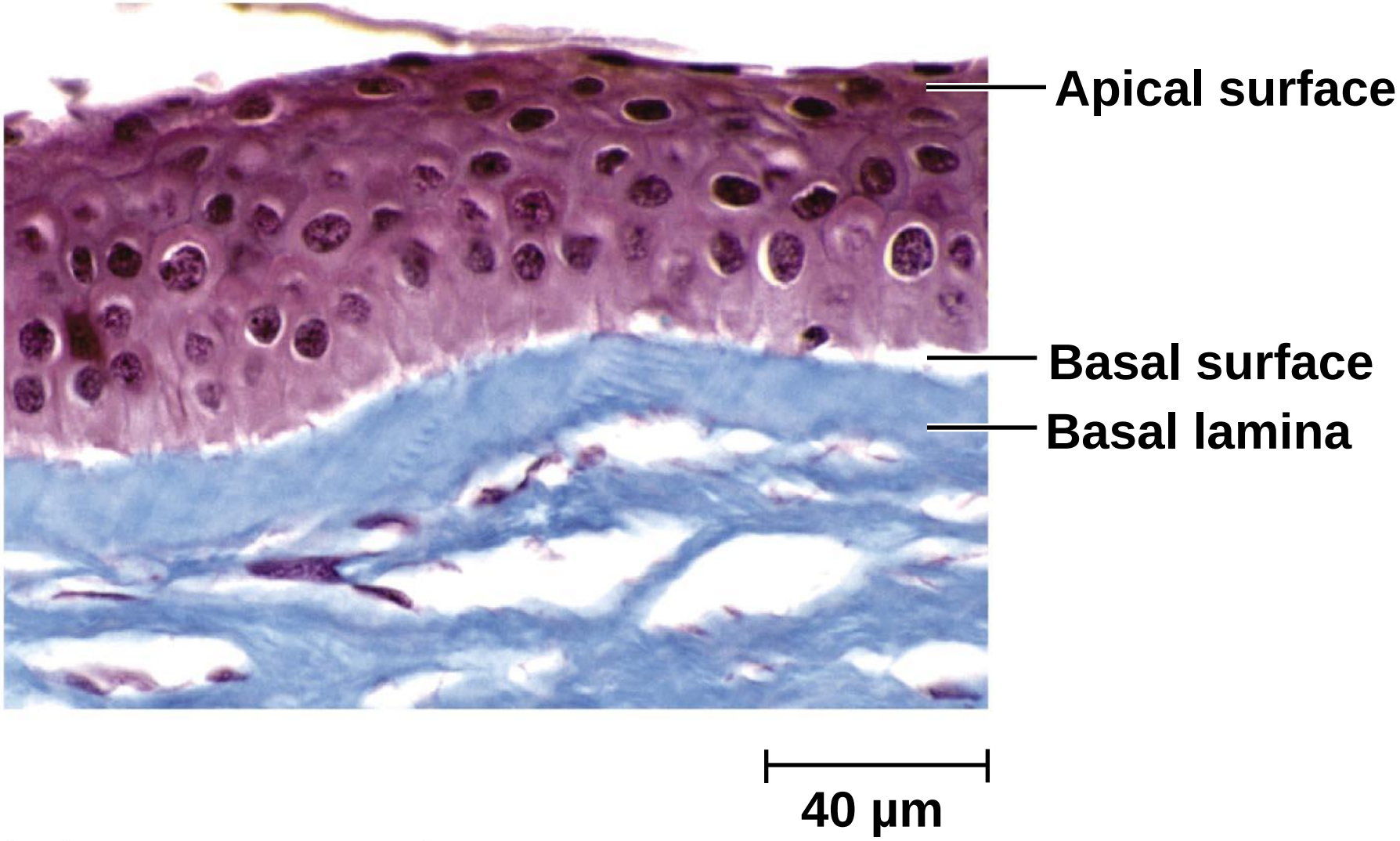


Fig. 40-5c

Connective Tissue

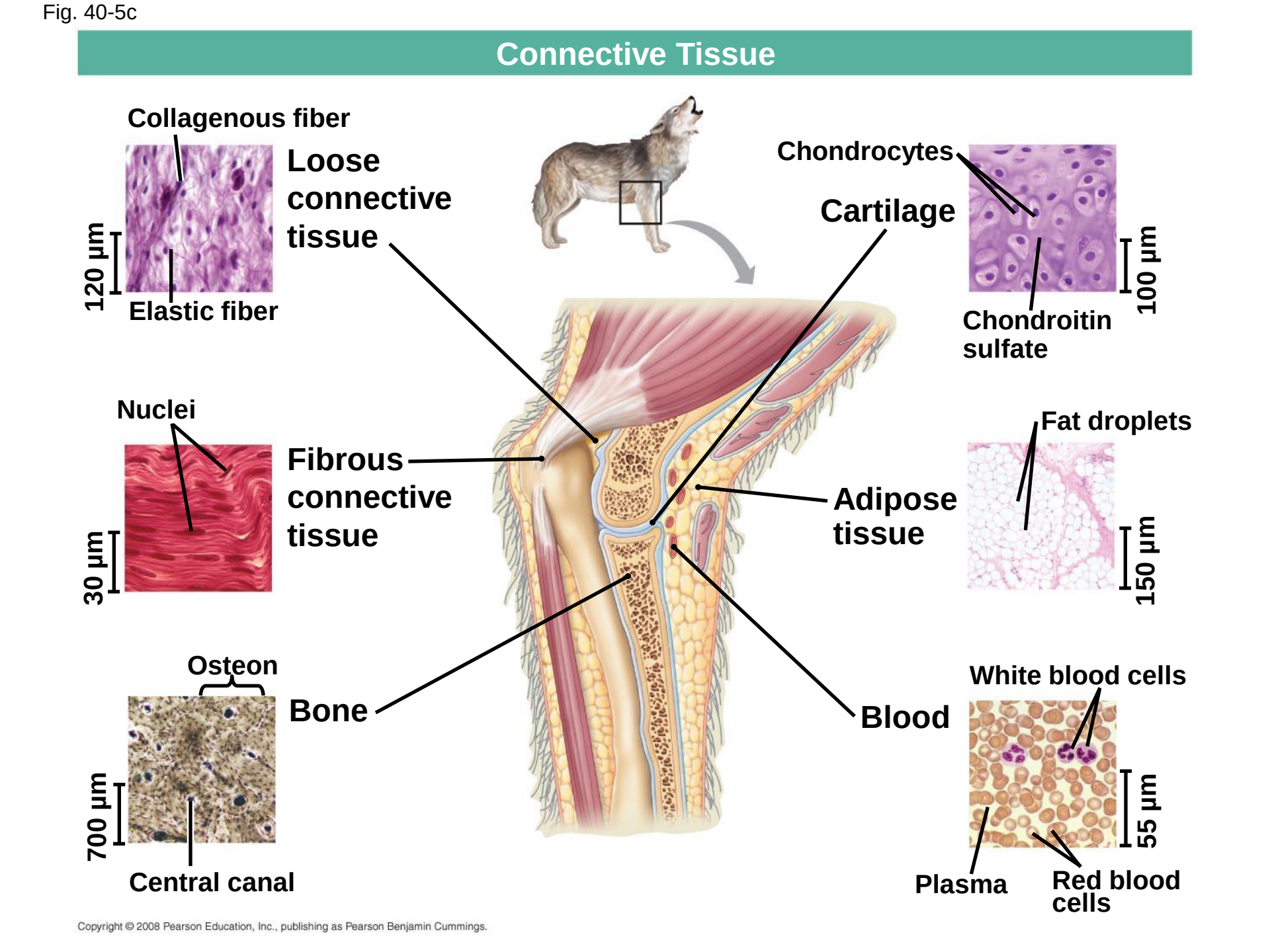
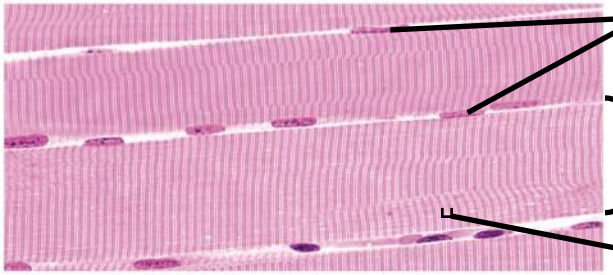
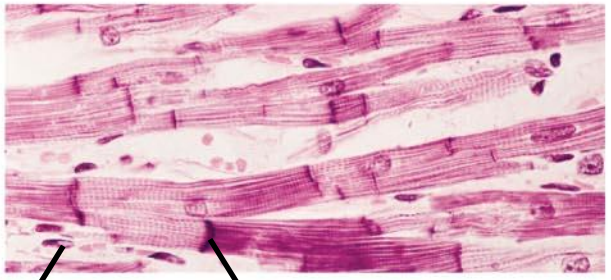


Fig. 40-5j

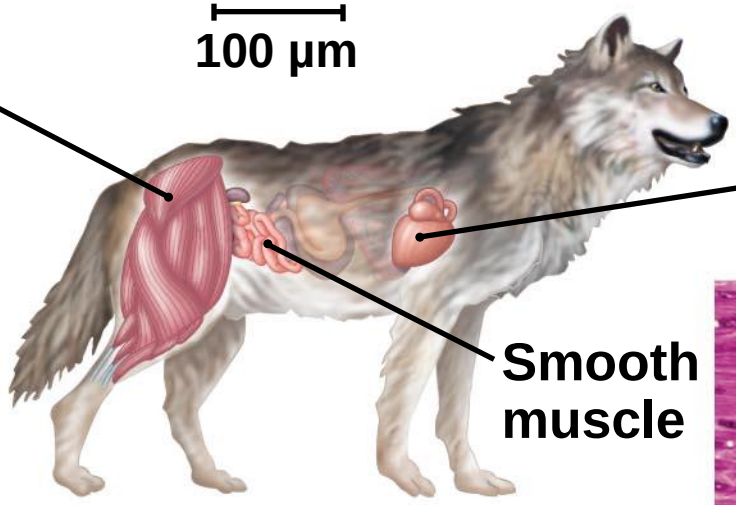
Muscle Tissue



Skeletal muscle



Cardiac muscle



Smooth muscle

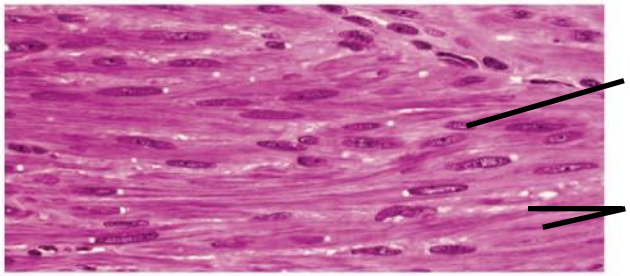
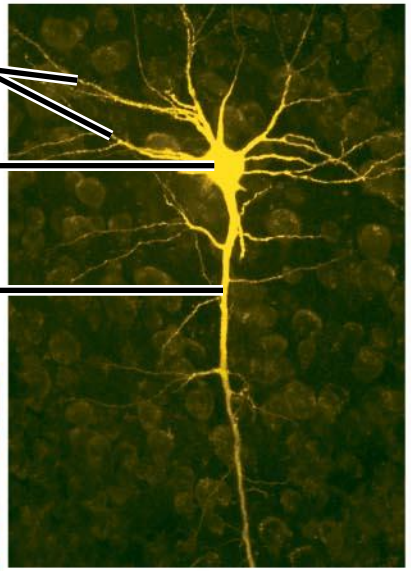


Fig. 40-5n

Nervous Tissue

40 µm



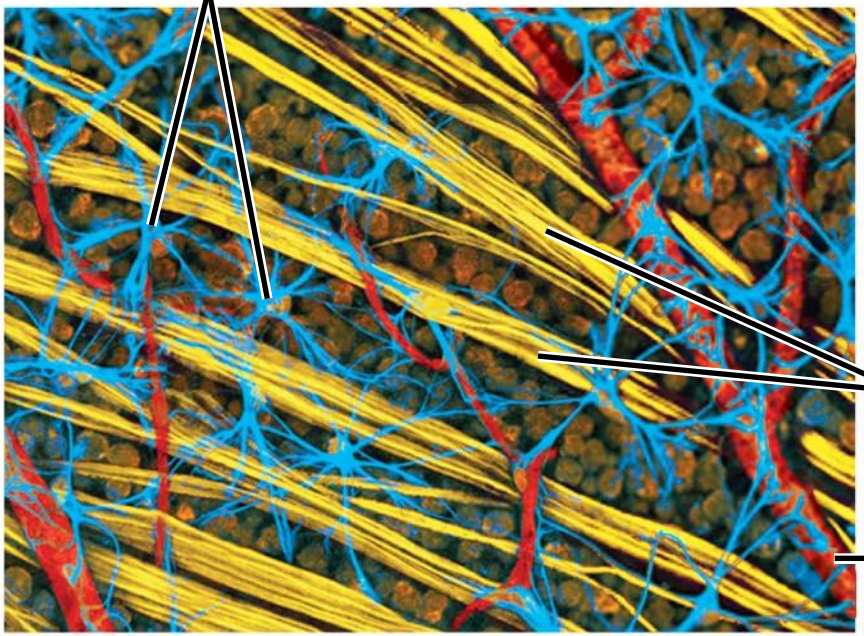
Dendrites

Cell body

Axon

Neuron

Glial cells



Axons

Blood vessel

15 µm

Fig. 40-6

Control and coordination

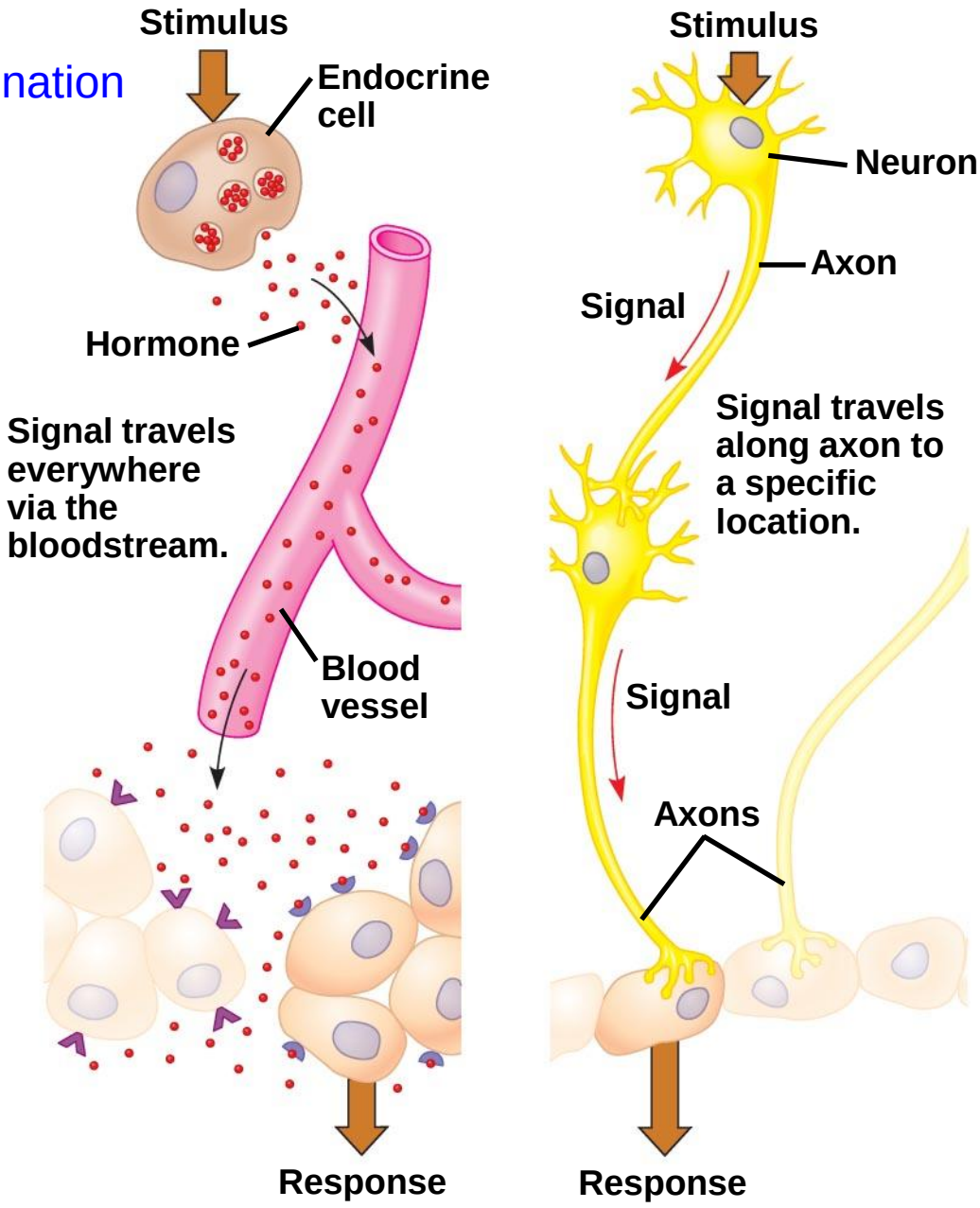
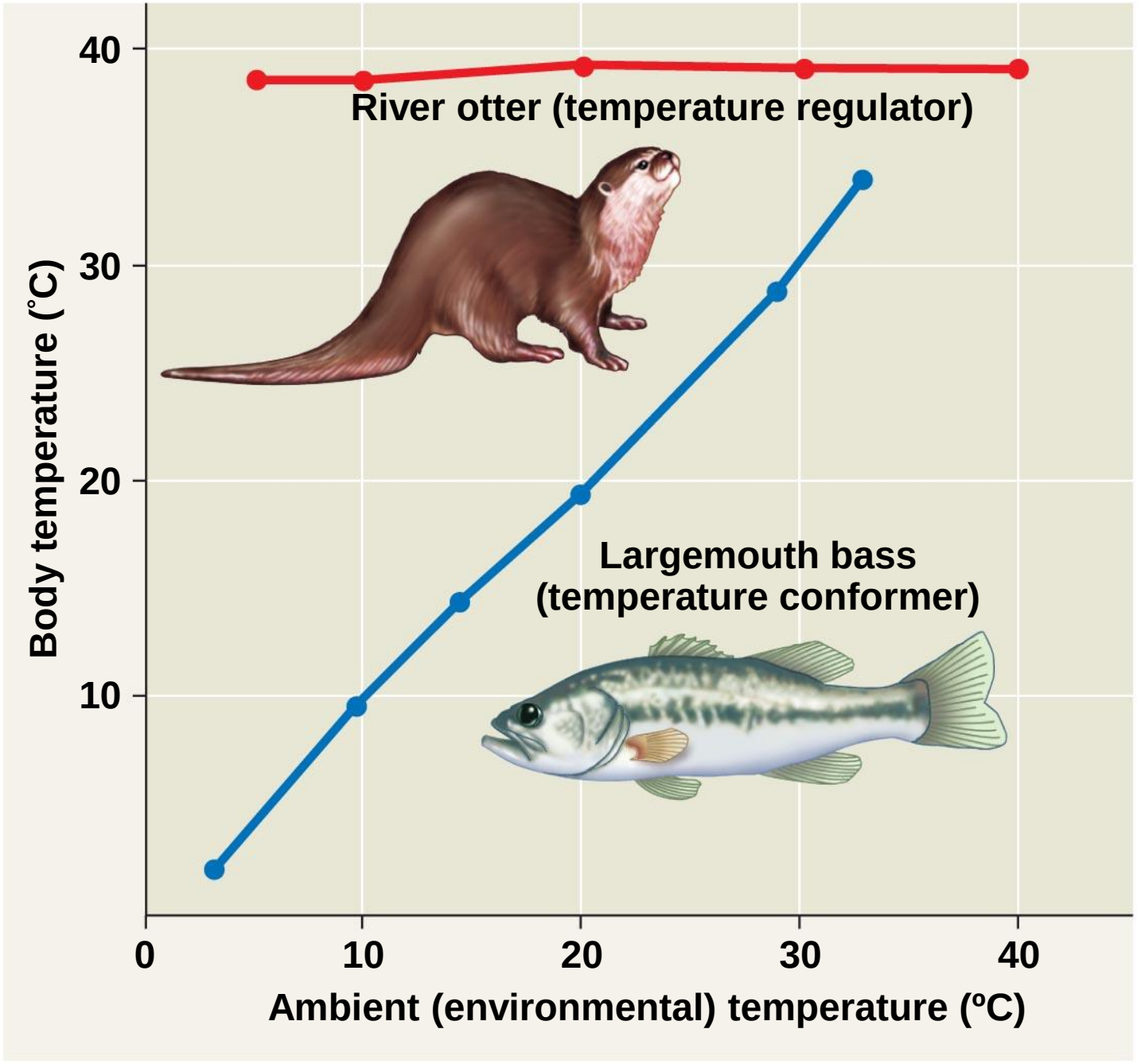


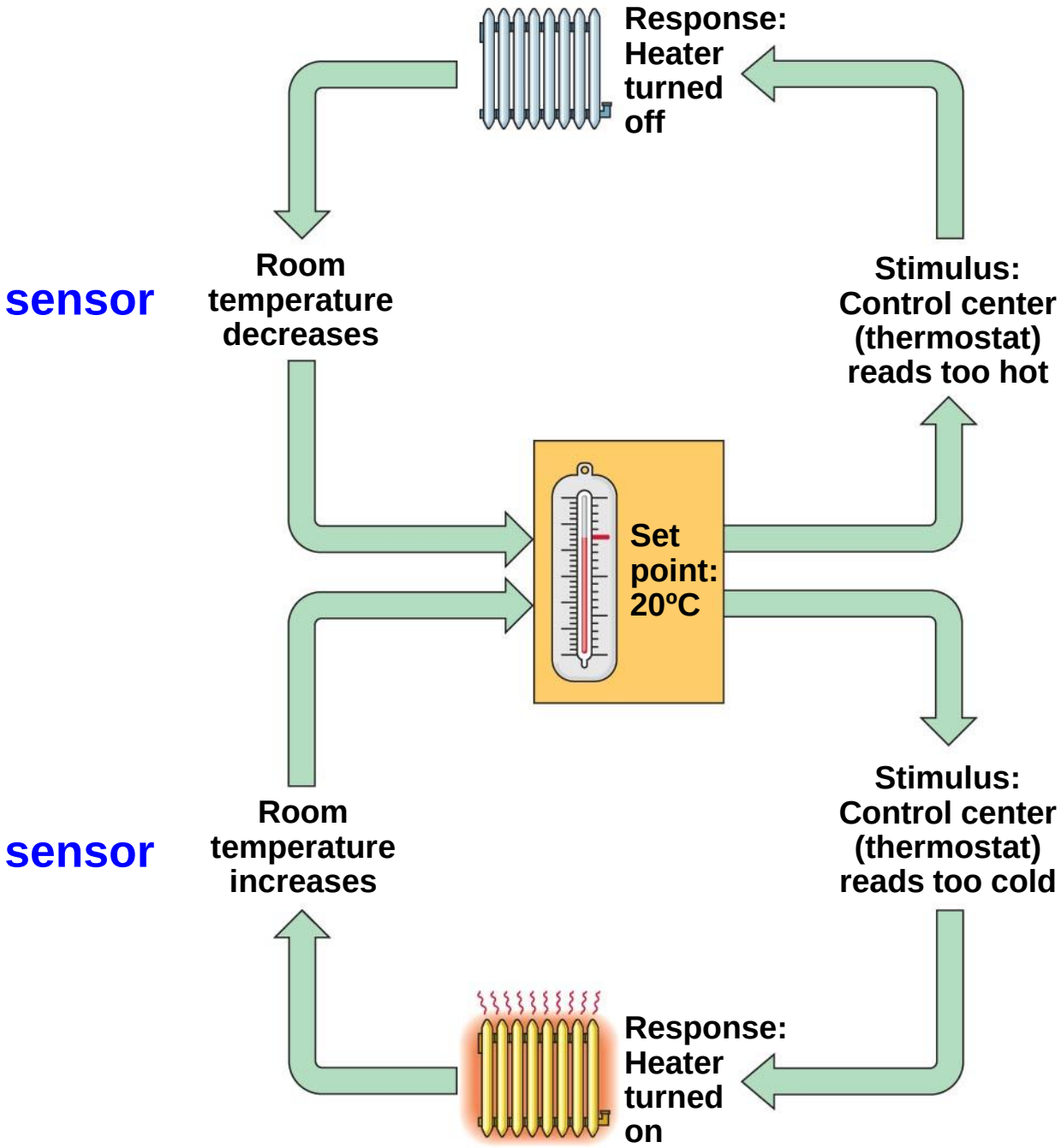
Fig. 40-7



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

Fig. 40-8



Feedback Loops in Homeostasis

- The dynamic equilibrium of homeostasis is maintained by **negative feedback,** which helps to return a variable to either a **normal range** or a set point
- Most homeostatic control systems function by negative feedback, where buildup of the end product shuts the system off
- **Positive feedback** loops occur in animals, but do not usually contribute to homeostasis

Alterations in Homeostasis

- Set points and normal ranges can change with age or show cyclic variation
- Homeostasis can adjust to changes in external environment, a process called **acclimatization**

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 non-avian reptiles

Fig. 40-9

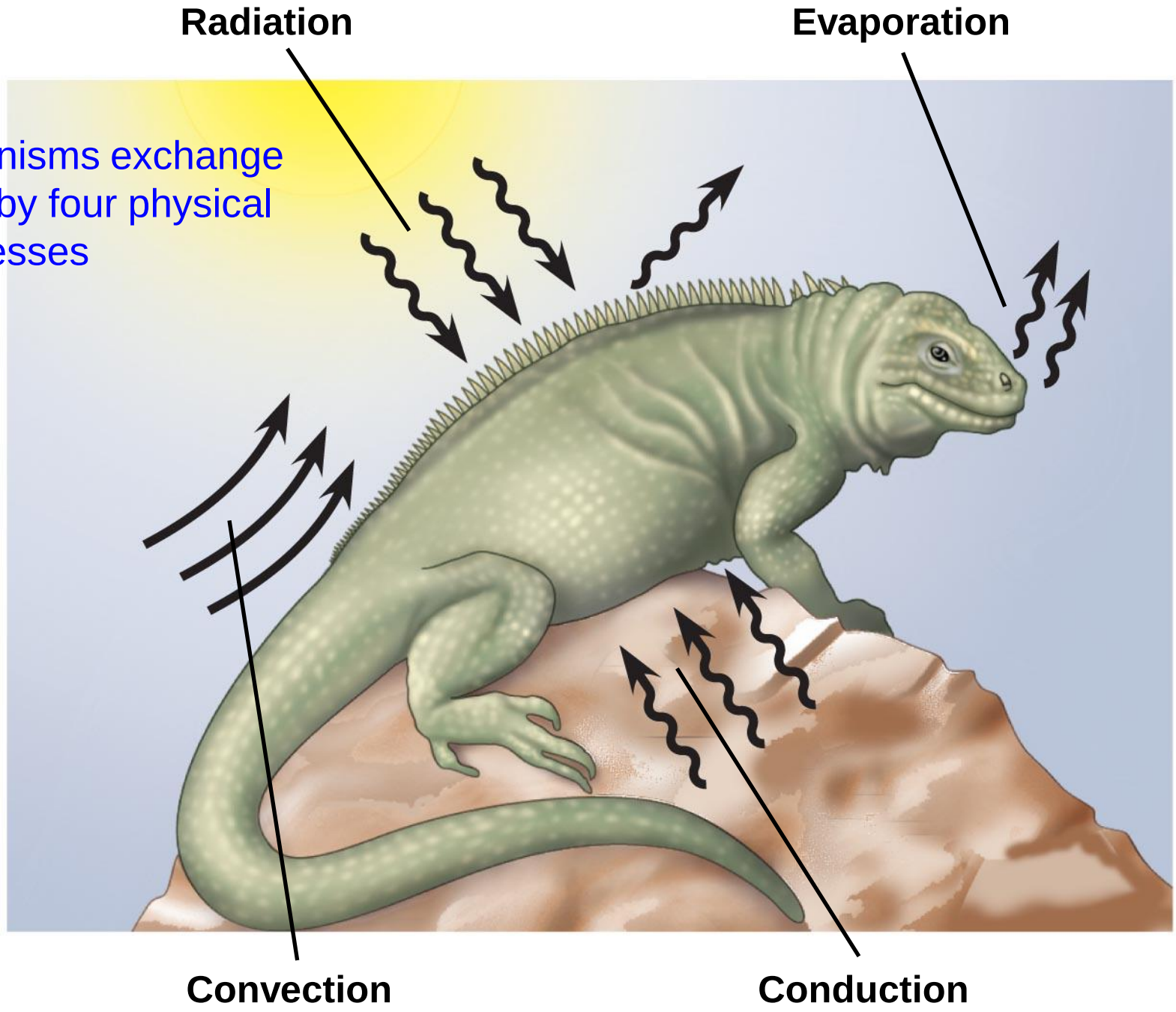
(a) A walrus, an endotherm

(b) A lizard, an ectotherm

Variation in Body Temperature

- The body temperature of a *poikilotherm* varies with its environment, while that of a *homeotherm* is relatively constant

Fig. 40-10



- Five general adaptations help animals thermoregulate:
  - Insulation
  - Circulatory adaptations
  - Cooling by evaporative heat loss
  - Behavioral responses
  - Adjusting metabolic heat production

Fig. 40-11

Heat regulation in mammals often involves the **integumentary system**: skin, hair, and nails

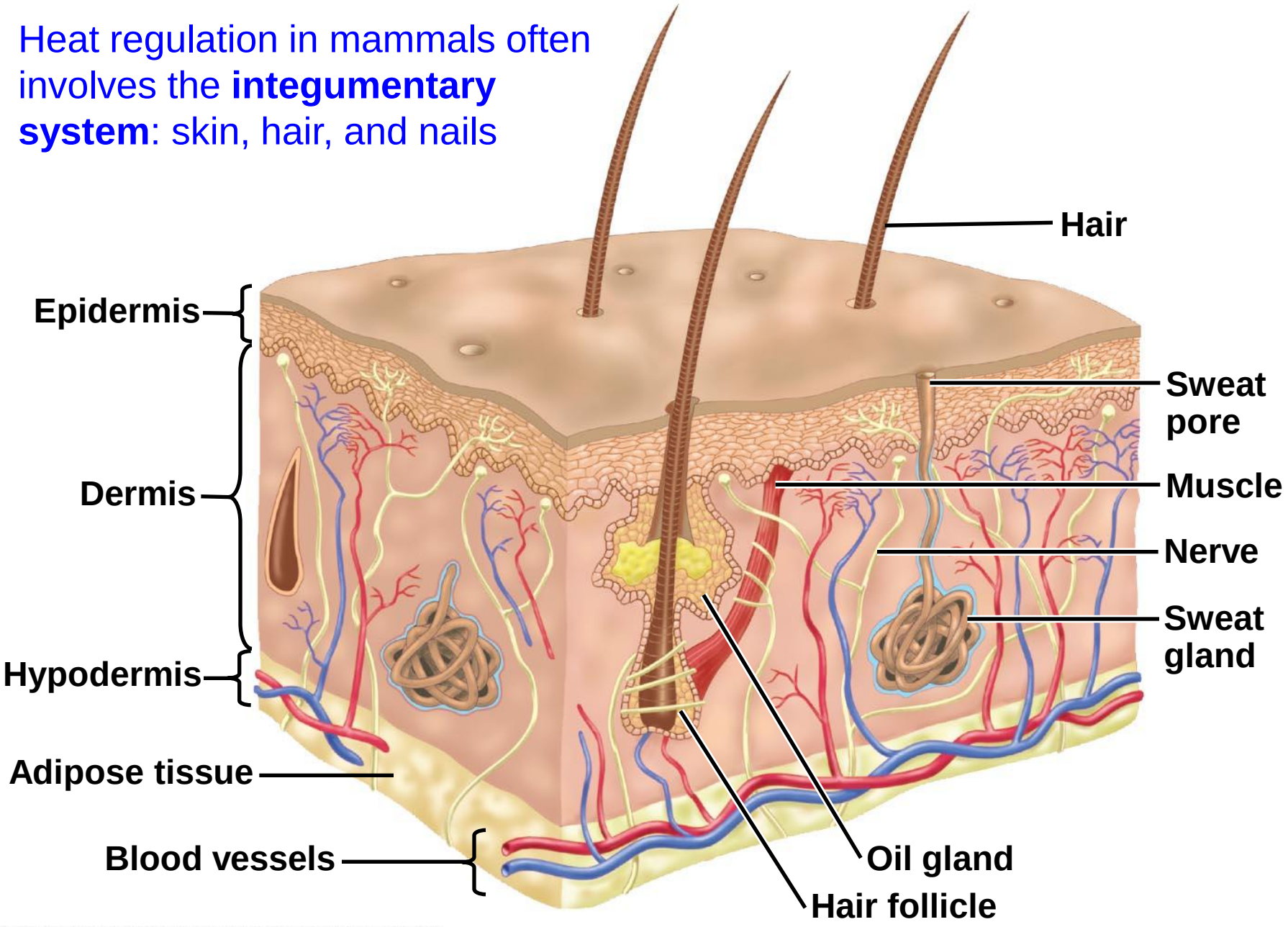


Fig. 40-12

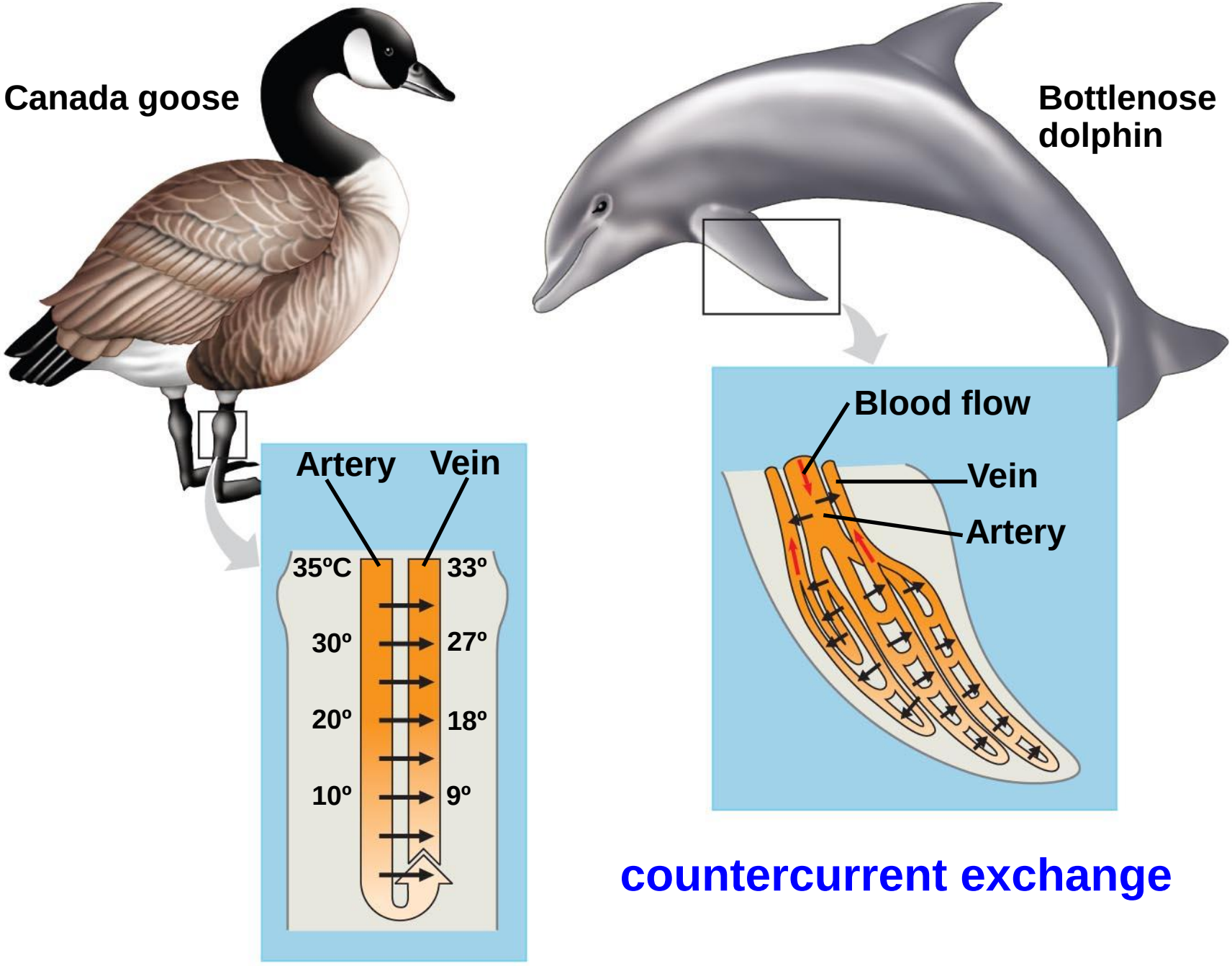


Fig. 40-13

Some terrestrial invertebrates have postures that minimize or maximize absorption of solar heat

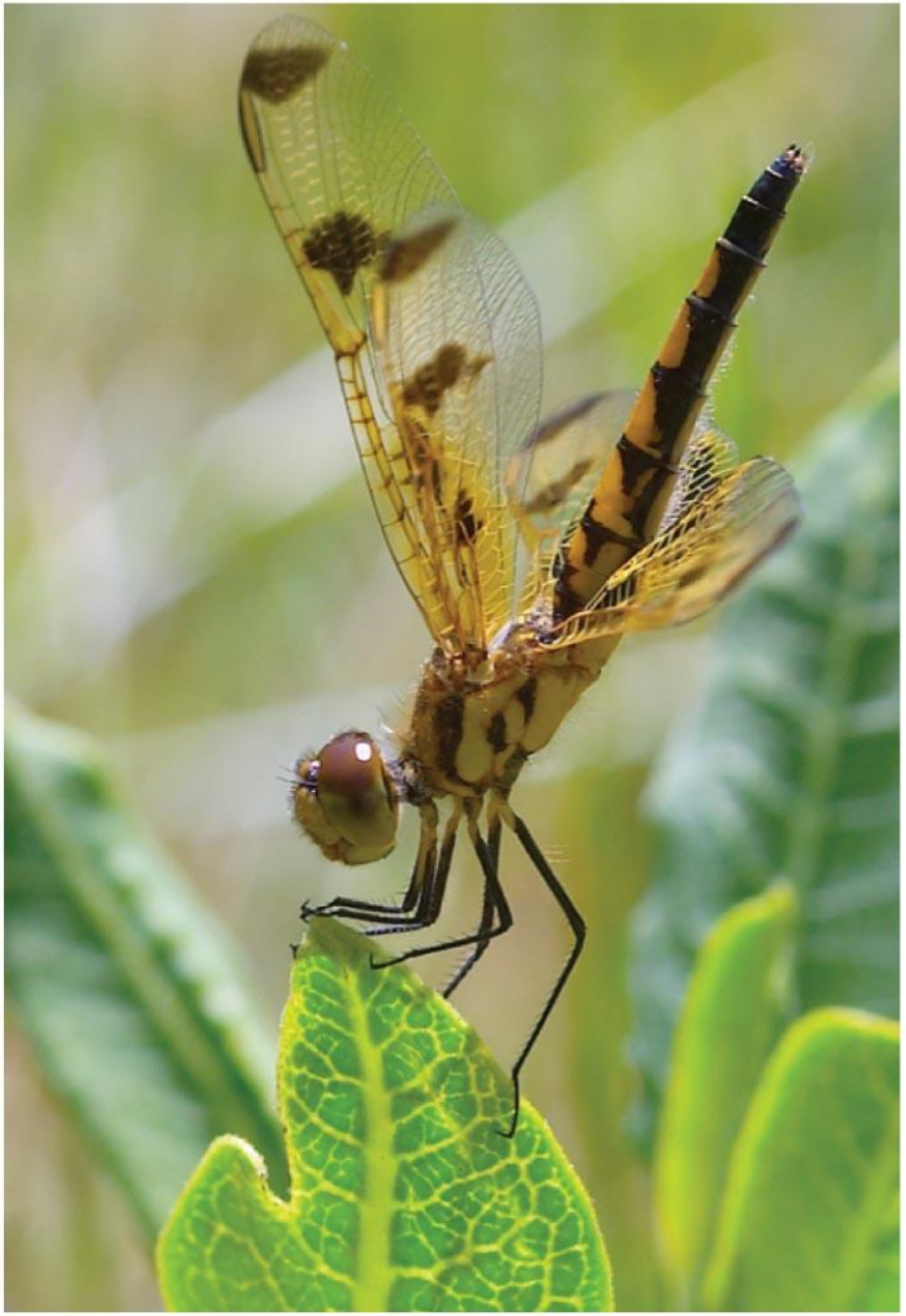


Fig. 40-14

RESULTS

animals can regulate body temperature by adjusting their rate of metabolic heat production

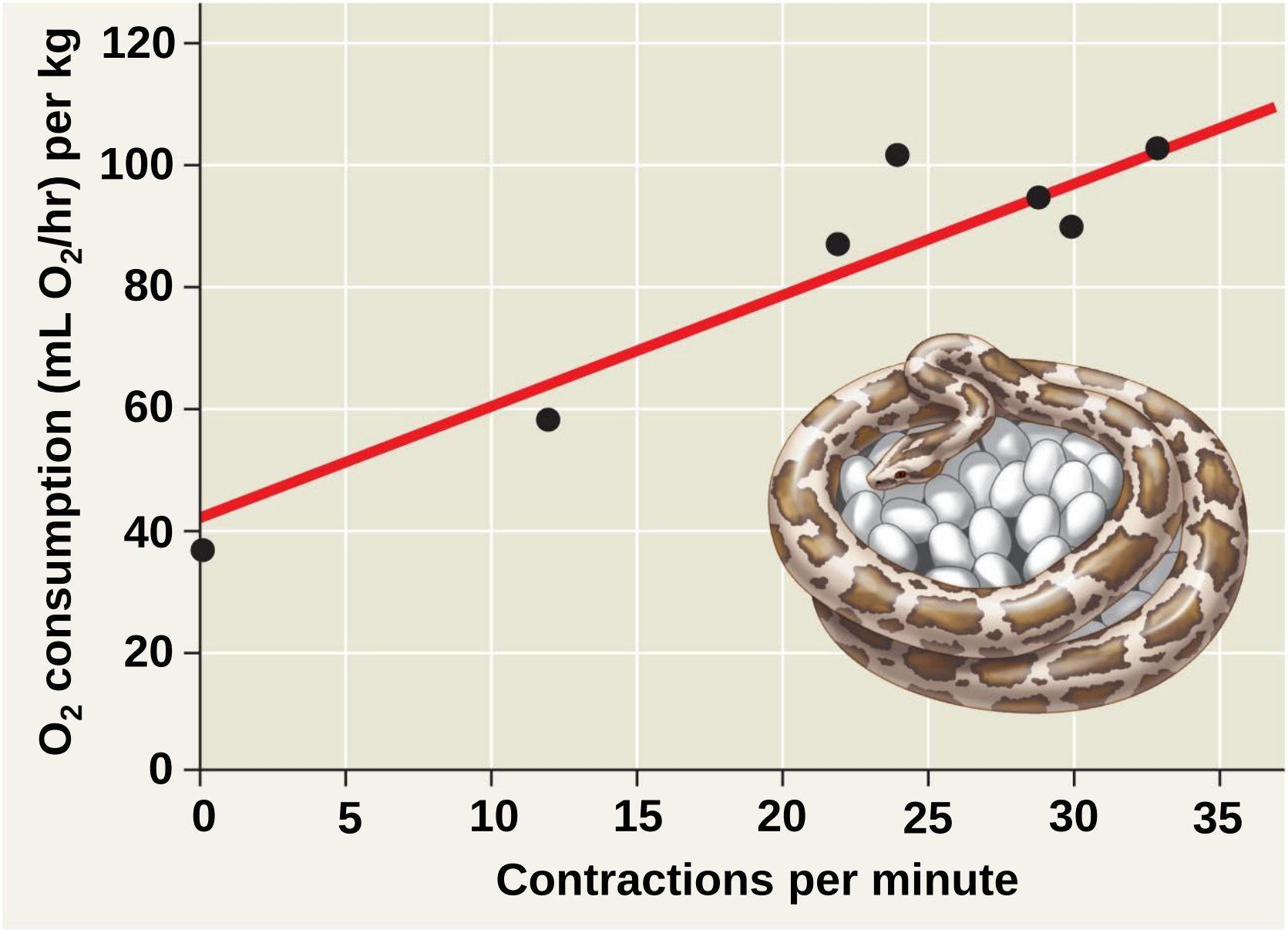
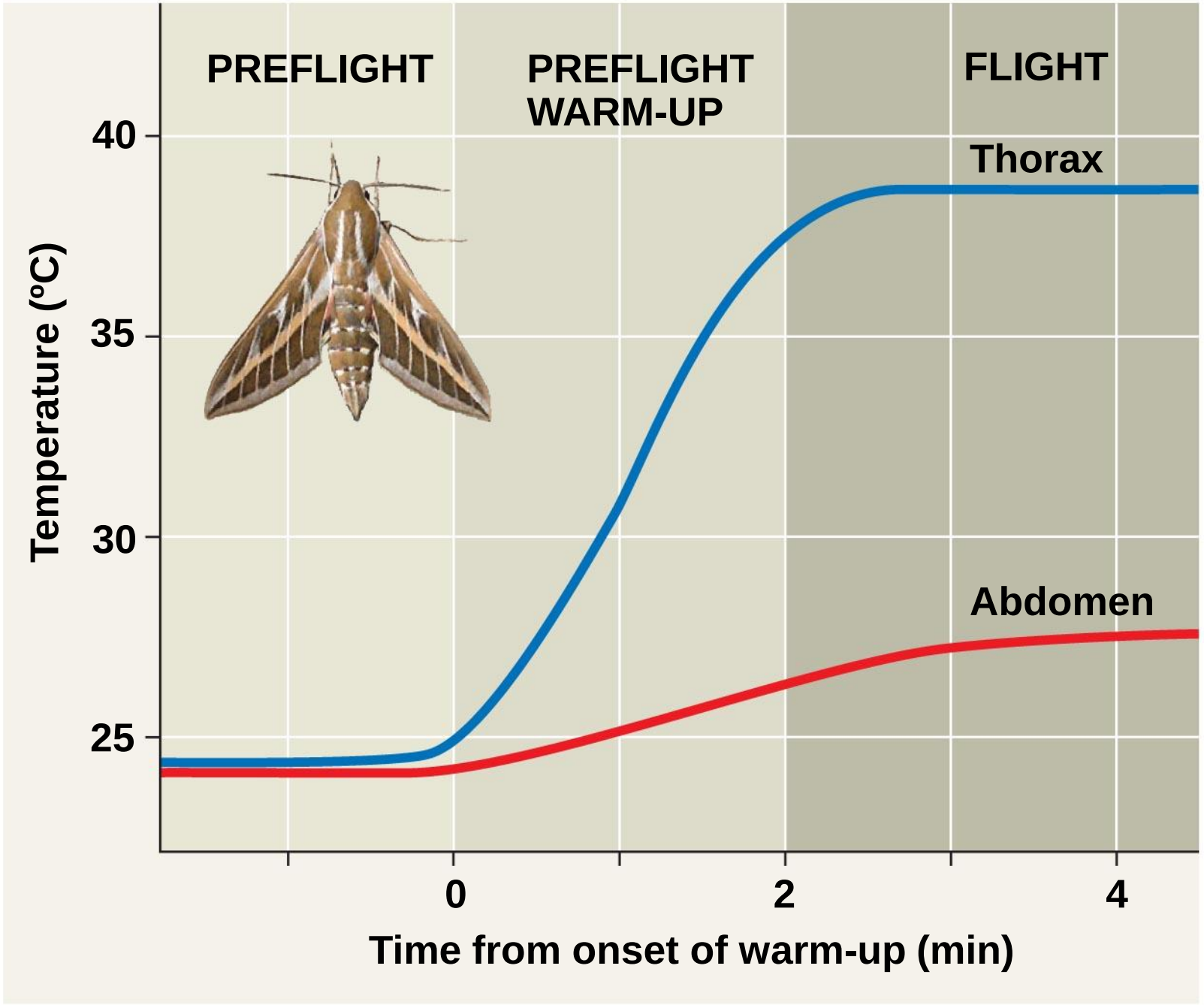


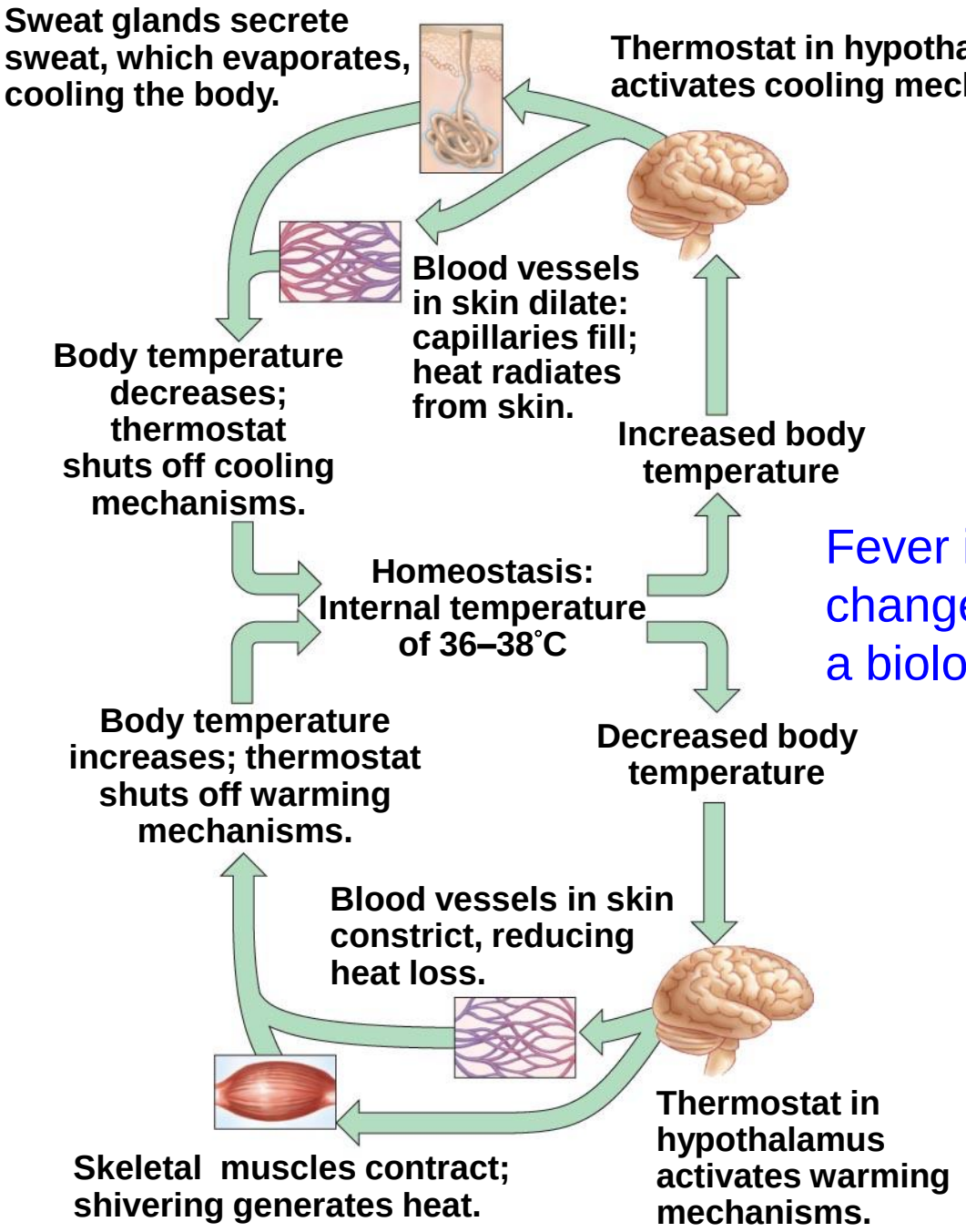
Fig. 40-15



Acclimatization in Thermoregulation

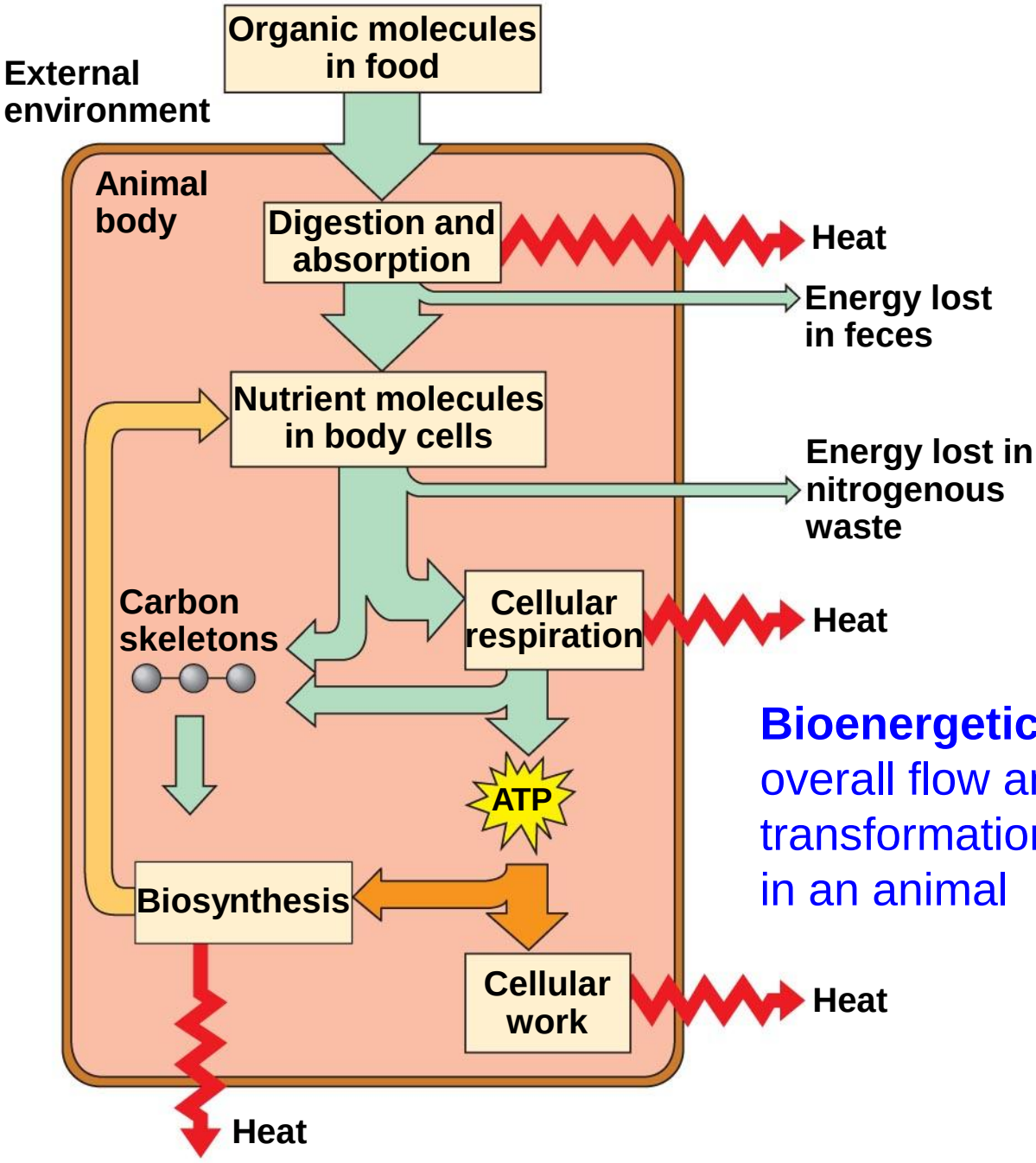
- Birds and mammals can vary their insulation to acclimatize to seasonal temperature changes
- When temperatures are subzero, some ectotherms produce "antifreeze" compounds to prevent ice formation in their cells

Fig. 40-16



Fever is the result of a change to the set point for a biological thermostat

Fig. 40-17



Bioenergetics is the overall flow and transformation of energy in an animal

Quantifying Energy Use

- **Metabolic rate** is the amount of energy an animal uses in a unit of time
- One way to measure it is to determine the amount of oxygen consumed or carbon dioxide produced

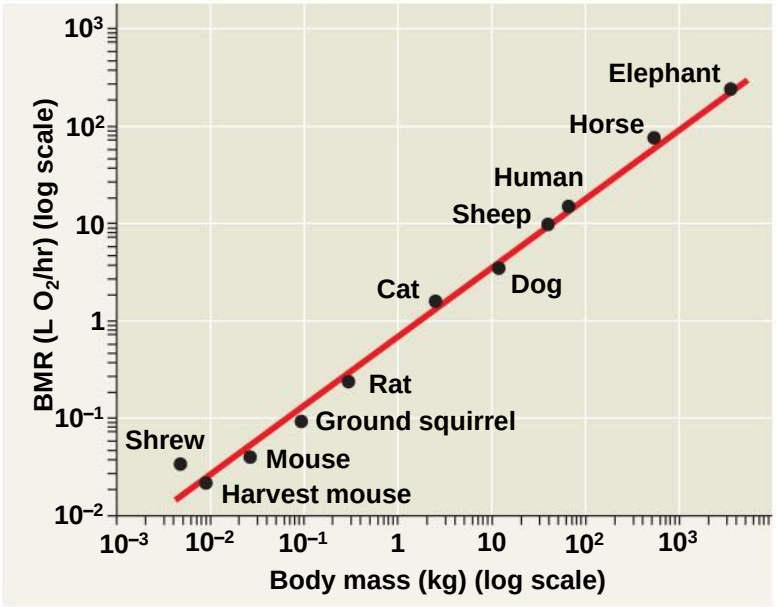
Fig. 40-18

Minimum Metabolic Rate and Thermoregulation

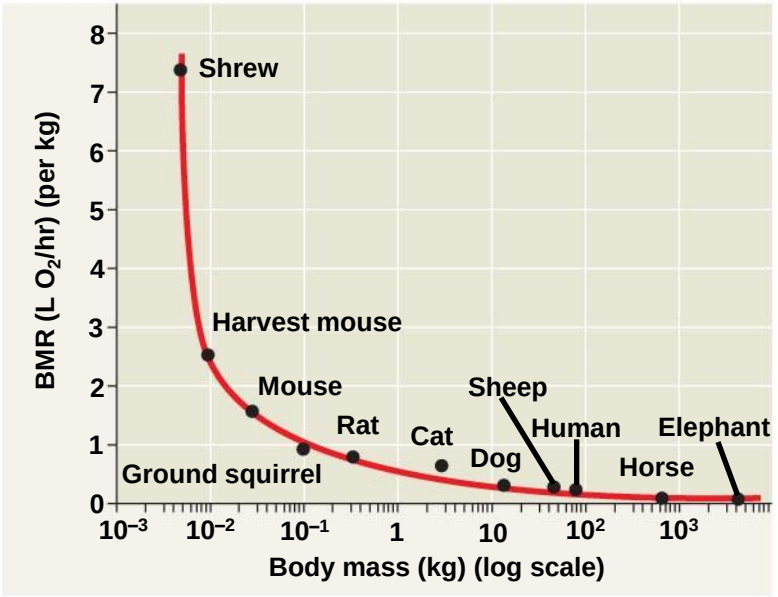
- **Basal metabolic rate (BMR)** is the metabolic rate of an endotherm at rest at a "comfortable" temperature
- **Standard metabolic rate (SMR)** is the metabolic rate of an ectotherm at rest at a specific temperature

Fig. 40-19

Size and Metabolic Rate



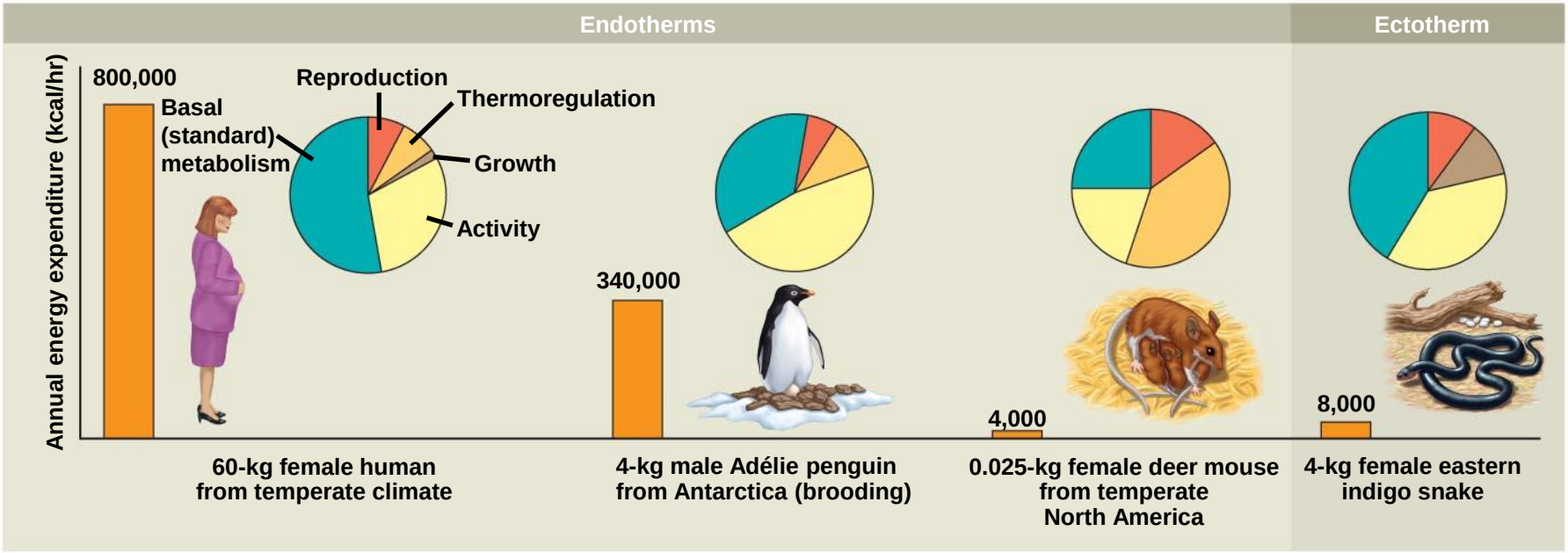
(a) Relationship of BMR to body size



(b) Relationship of BMR per kilogram of body mass to body size

Fig. 40-20

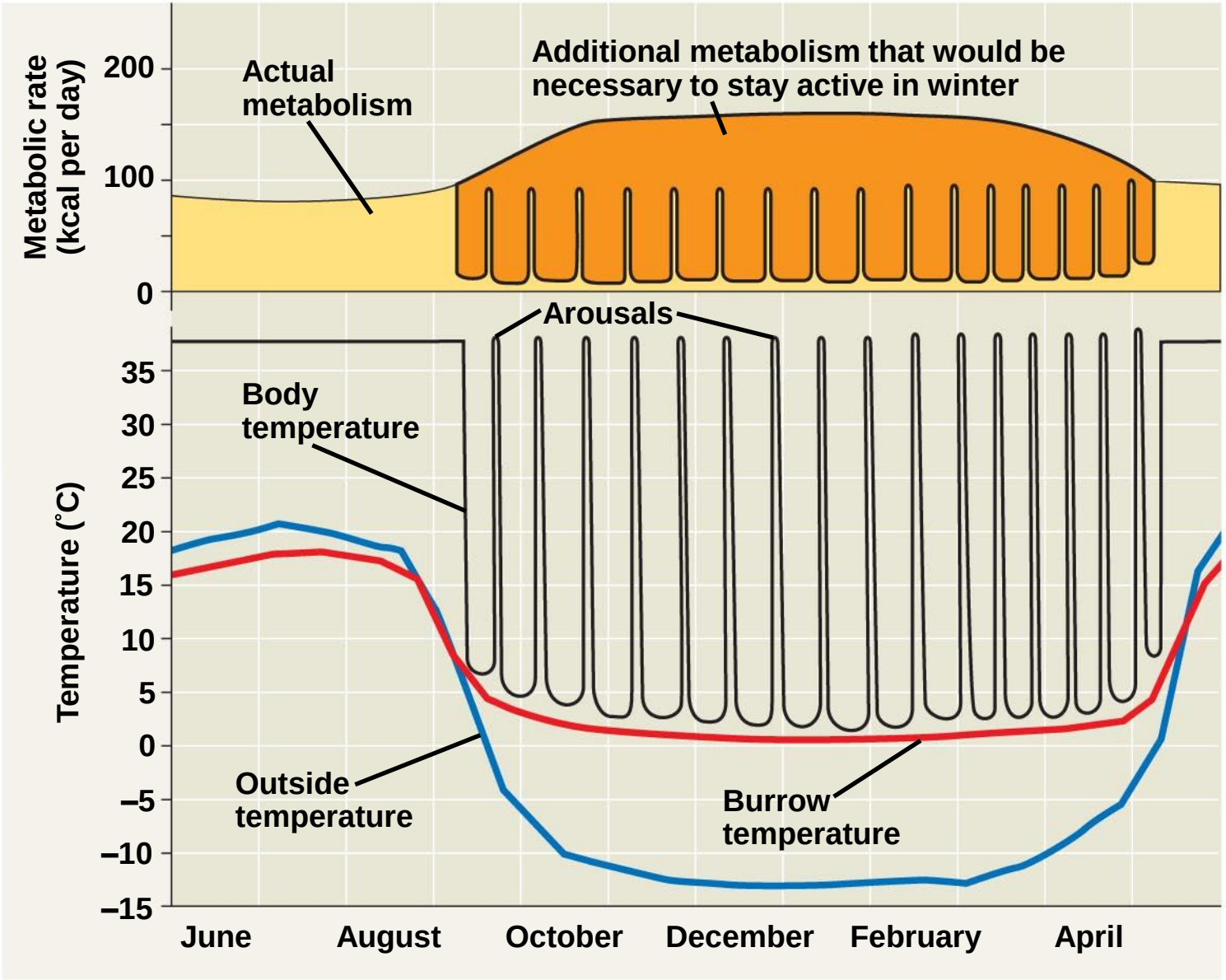
Energy Budgets



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

Fig. 40-21



- *Estivation*, or summer torpor, enables animals to survive long periods of high temperatures and scarce water supplies
- Daily torpor is exhibited by many small mammals and birds and seems adapted to feeding patterns

You should now be able to:

1. Distinguish among the following sets of terms: collagenous, elastic, and reticular fibers; regulator and conformer; positive and negative feedback; basal and standard metabolic rates; torpor, hibernation, estivation, and daily torpor

2. Relate structure with function and identify diagrams of the following animal tissues: epithelial, connective tissue (six types), muscle tissue (three types), and nervous tissue

3. Compare and contrast the nervous and endocrine systems
4. Define thermoregulation and explain how endotherms and ectotherms manage their heat budgets
5. Describe how a countercurrent heat exchanger may function to retain heat within an animal body
6. Define bioenergetics and biosynthesis
7. Define metabolic rate and explain how it can be determined for animals