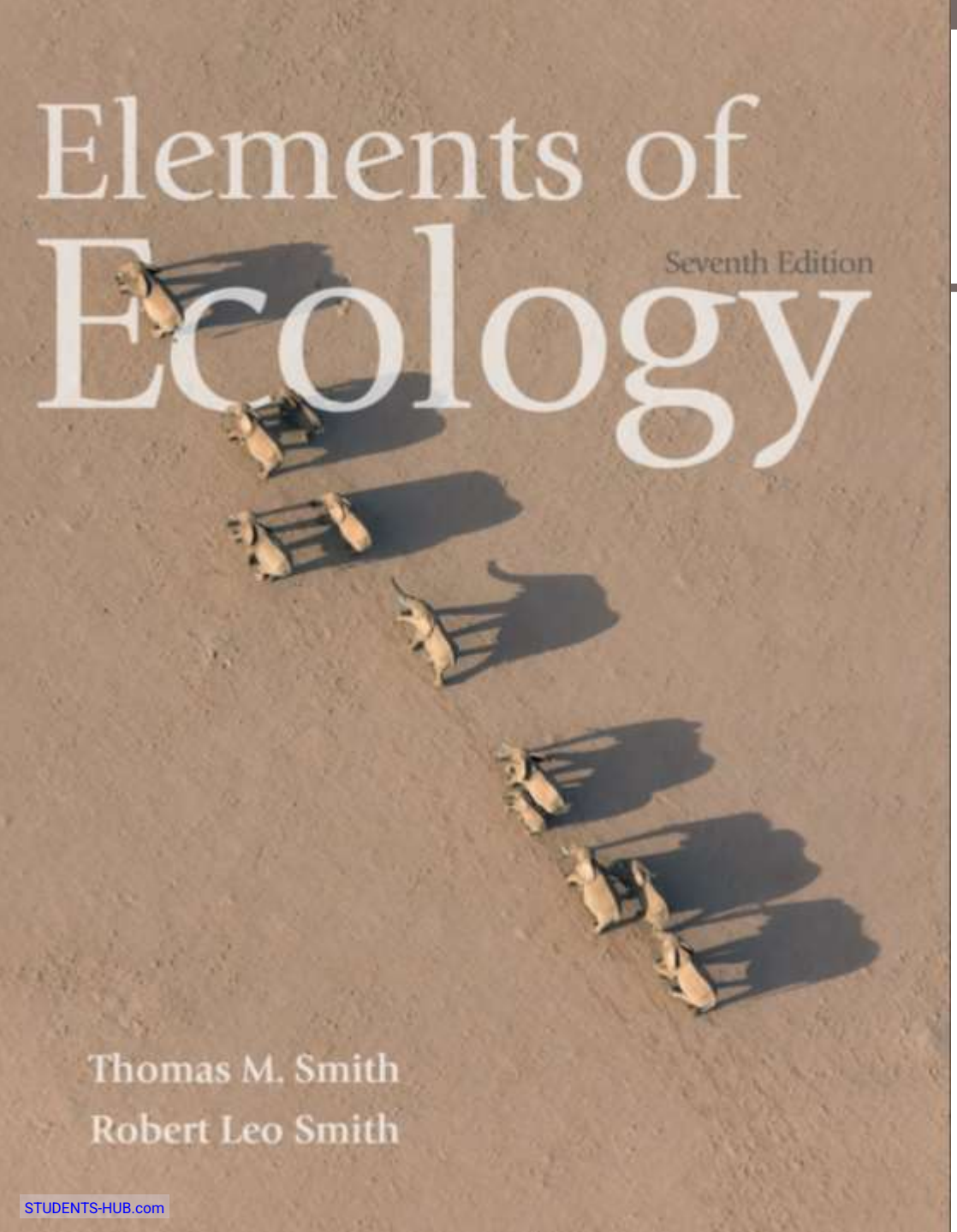

Chapter 7

Animal Adaptations to the Environment

Lecture prepared by
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Chapter 7 Animal Adaptations to the Environment

- **Animals are heterotrophs** and derive their energy and most nutrients from consuming organic compounds contained in other plants and animals
- **Key processes common to all animals:**
  - Acquire and digest food
  - Absorb oxygen
  - Maintain body temperature and water balance
  - Adapt to light and temperature variations
- Animals encounter different constraints in aquatic versus terrestrial environments

7.1 Size Imposes a Fundamental Constraint on the Evolution of Organisms

- Animals range in body size (2 µg to 100,000 kg)
- Morphological and physiological features change as a function of body size, a process known as **scaling**.
  - Size has consequences for structure and functional relationships in animals

(a)

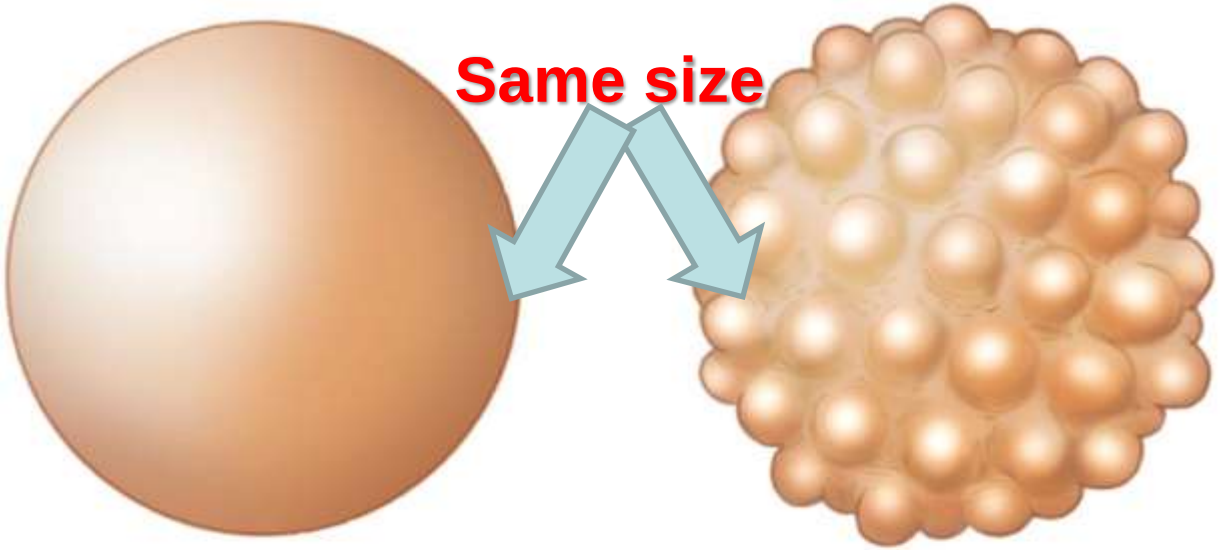
(b)

(c)

(d)

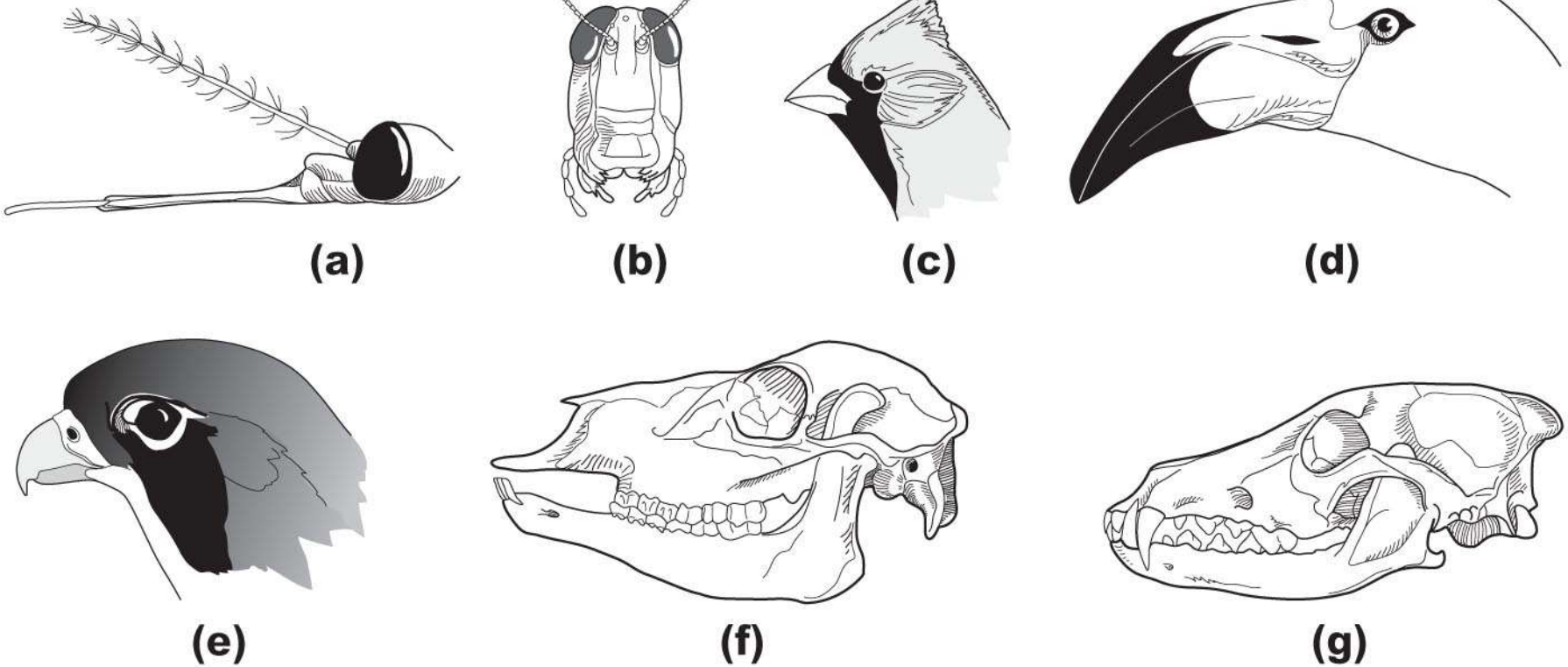
- Smaller bodies have a larger surface area relative to their volume (*SA*/*V*) than larger objects (of the same shape)
- *SA*/*V* sets a basic constraint on animal evolution
  - Every animal cell is dependent on oxygen—the rate of oxygen delivery is determined by **the diffusion gradient** and the **distance diffused**

- **As the size of an organism increases**, the surface area decreases relative to interior body volume
- This constraint may be overcome by a body plan that somehow can increase surface area in another way:
  - Change shape to increase external surface area
  - Actively transport oxygen into the interior of the body and increase internal surface area
    - **Lungs**
    - **Circulatory system**



7.2 Animals Have Various Ways of Acquiring Energy and Nutrients

- **Herbivores** feed exclusively on plant tissues
- **Carnivores** feed exclusively on the tissues of other animals
- **Omnivores** feed on both plant and animal tissues
- **Detritivores** are those that feed on **detritus** (dead plant and animal matter)



7.3 Animals Have Various Nutritional Needs

- Animals require a **variety of mineral elements and amino acids:**
  - **Essential amino acids** must be supplied by the diet; the animal cannot synthesize these.
- **Nutritional needs vary little among vertebrates and invertebrates.**

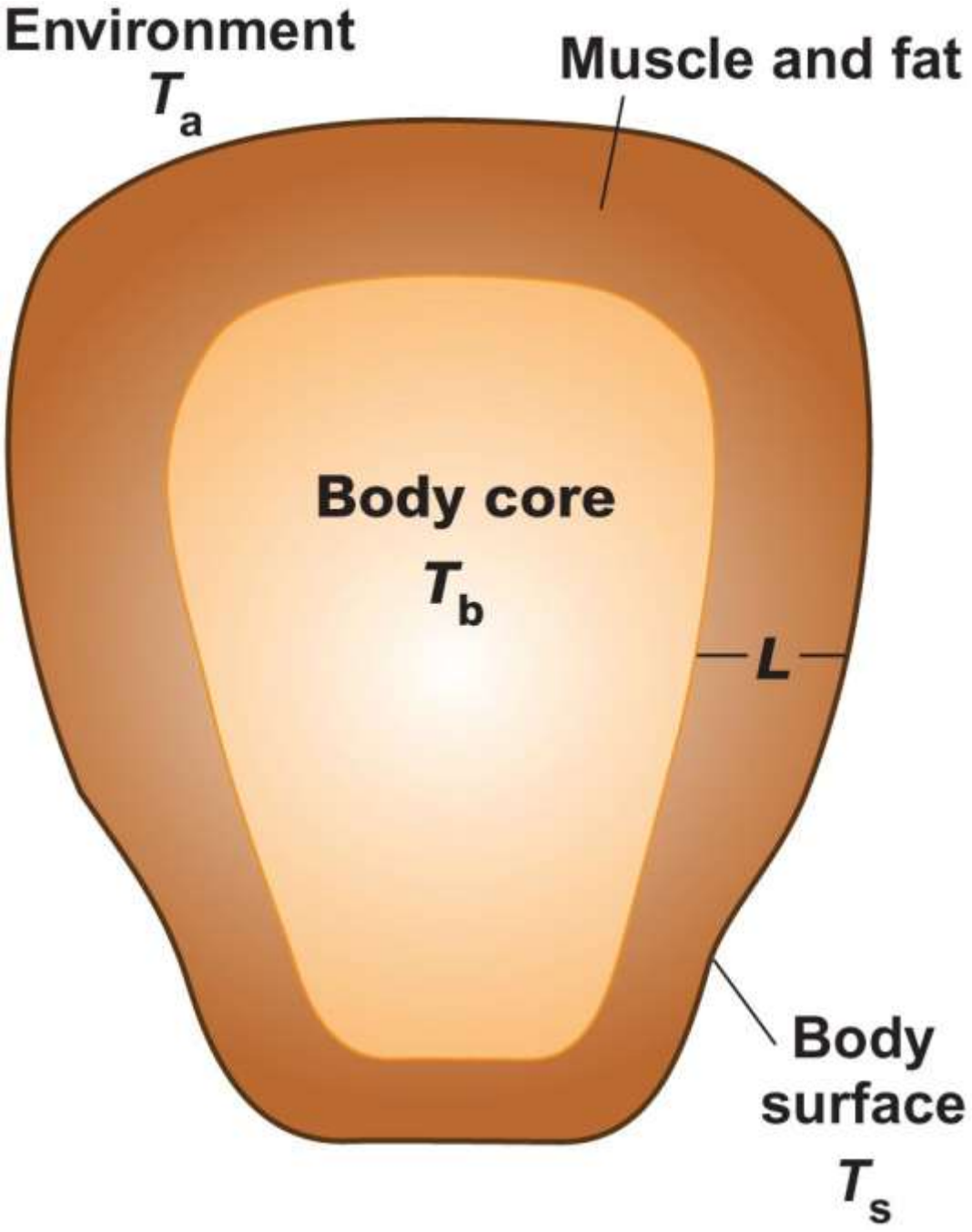
Table 7.1 | Essential Minerals in Animals

Element	Role
Carbon (C) Hydrogen (H) Oxygen (O)	Basic constituents of all organic matter.
Nitrogen (N)	Building block of protein.
Calcium (Ca)	Needed for acid–base relationships, clotting of blood, contraction and relaxation of heart muscles. Controls movement of fluid through cells; gives rigidity to skeletons of vertebrates; forms shells of mollusks, arthropods, and one-celled Foraminifera.
Phosphorus (P)	Necessary for energy transfer; major component of nuclear material of cells; acid–base balance; bone and tooth formation.
Magnesium (Mg)	Essential for maximum rates of enzymatic reactions in cells; enzyme activation.
Sulfur (S)	Basic constituent of protein.
Sodium (Na)	Maintenance of acid–base balance, osmotic homeostasis, formation and flow of gastric and intestinal secretions, nerve transmission, lactation, growth, and maintenance of body weight.
Potassium (K)	Involved in synthesis of protein, growth, and carbohydrate metabolism.
Chlorine (Cl)	Role is similar to that of sodium, which it is associated with in salt (NaCl).
Fluorine (F)	Maintenance of tooth (and probably bone) structure.
Iron (Fe)	Component of respiratory pigment hemoglobin in blood of vertebrates and hemolymph of insects; electron carriers in energy metabolism.
Manganese (Mn)	Enzyme systems.
Selenium (Se)	Closely related to vitamin E in function.
Cobalt (Co)	Required by ruminants for the synthesis of vitamin B_{12} by bacteria in the rumen.
Copper (Cu)	Involved in iron metabolism; melanin synthesis; electron transport.
Molybdenum (Mo)	Enzyme systems.
Zinc (Zn)	Functions in several enzyme systems, especially the respiratory enzyme carbonic anhydrase in red blood cells, and in certain digestive enzymes.
Iodine (I)	Involved in thyroid metabolism.
Chromium (Cr)	Involved in glucose and energy metabolism.

- The ultimate **source of most nutrients** needed by animals is **plants**
- **Plant quantity and quality affect herbivorous consumers:**
  - Highest-quality plant food is high in nitrogen (protein)—growing tips, new leaves and buds
  - **Herbivores** show some preference for the most nitrogen-rich plants.
  - **For carnivores**, **quantity is more important than quantity**

7.7 Animals Exchange Energy with Their Surrounding Environment

- **Body structure** influences the exchange of heat between animals and external environment
  - **Body surface (boundary surface)** temperature differs from both the air (or water) and core body temperatures
- This layer of insulation (boundary surface) influences the ability to conduct or transmit heat (**conductivity**)



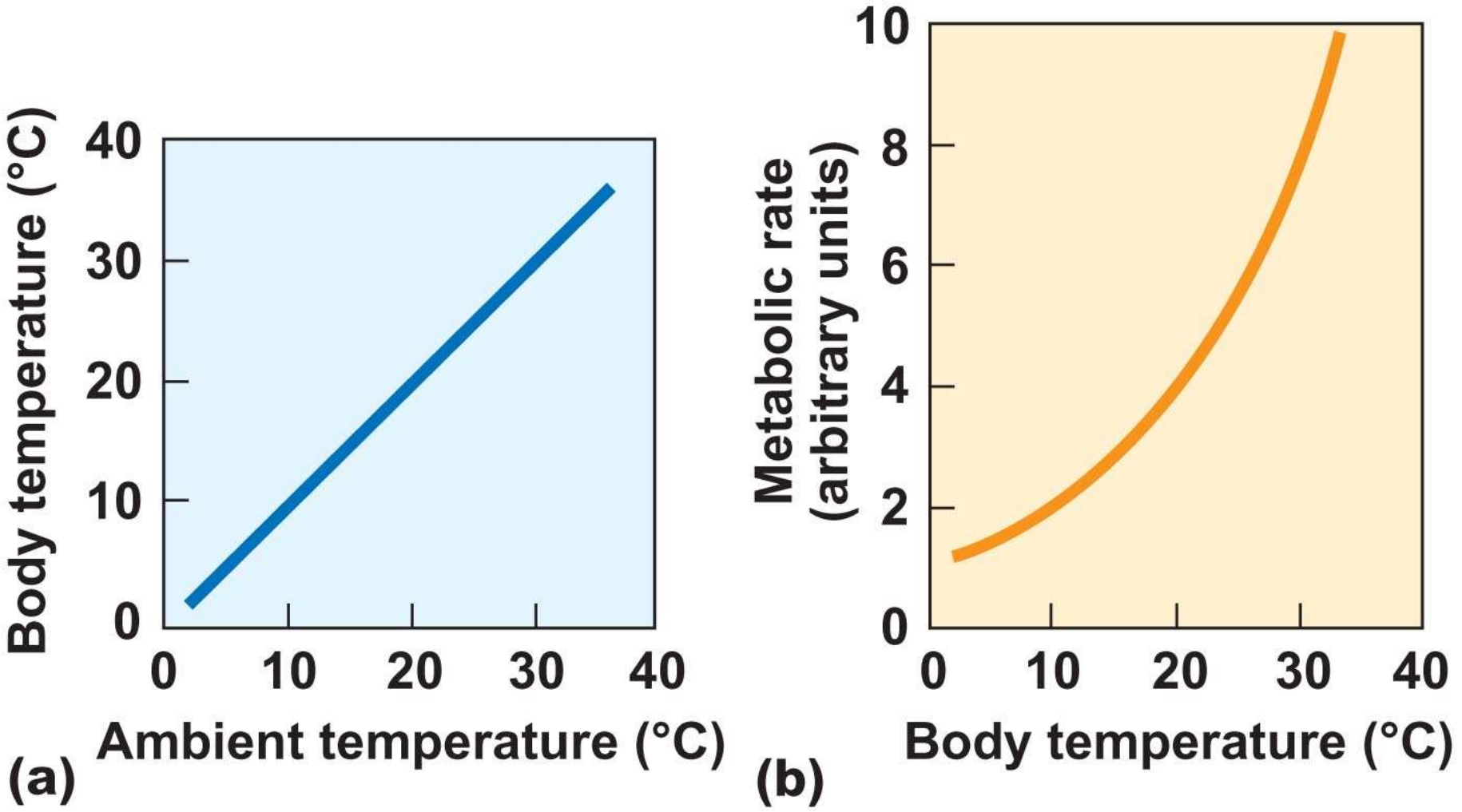
- An animal must balance *heat gain* and *loss* to maintain its core body temperature:
  - **The core** exchanges heat with the surface area by conduction
    - Influenced by thickness/conductivity of fat, movement of blood to surface
  - **The surface layer** exchanges heat with the environment via convection, conduction, radiation, and evaporation

7.8 Animals Fall into Three Groups Relative to Temperature Regulation

- In **endothermy**, animals generate heat metabolically, and this results in the maintenance of a fairly constant internal temperature independent of external temperatures (**homeothermy**).
  - Examples: Birds and mammals.
- In **ectothermy**, animals acquire heat primarily from the external environment (**poikilothermy**)
  - Fish, amphibians, reptiles, insects, and other invertebrates.
- **Heterotherms** are animals *that regulate body temperature by both endothermy and ectothermy*
  - Bats, bees, and hummingbirds

7.9 Poikilotherms Depend on Environmental Temperatures

- Environmental sources of heat control the rates of metabolism and activity among most poikilotherms
- *For every 10°C rise in temperature, the rate of metabolism in poikilotherms approximately doubles*

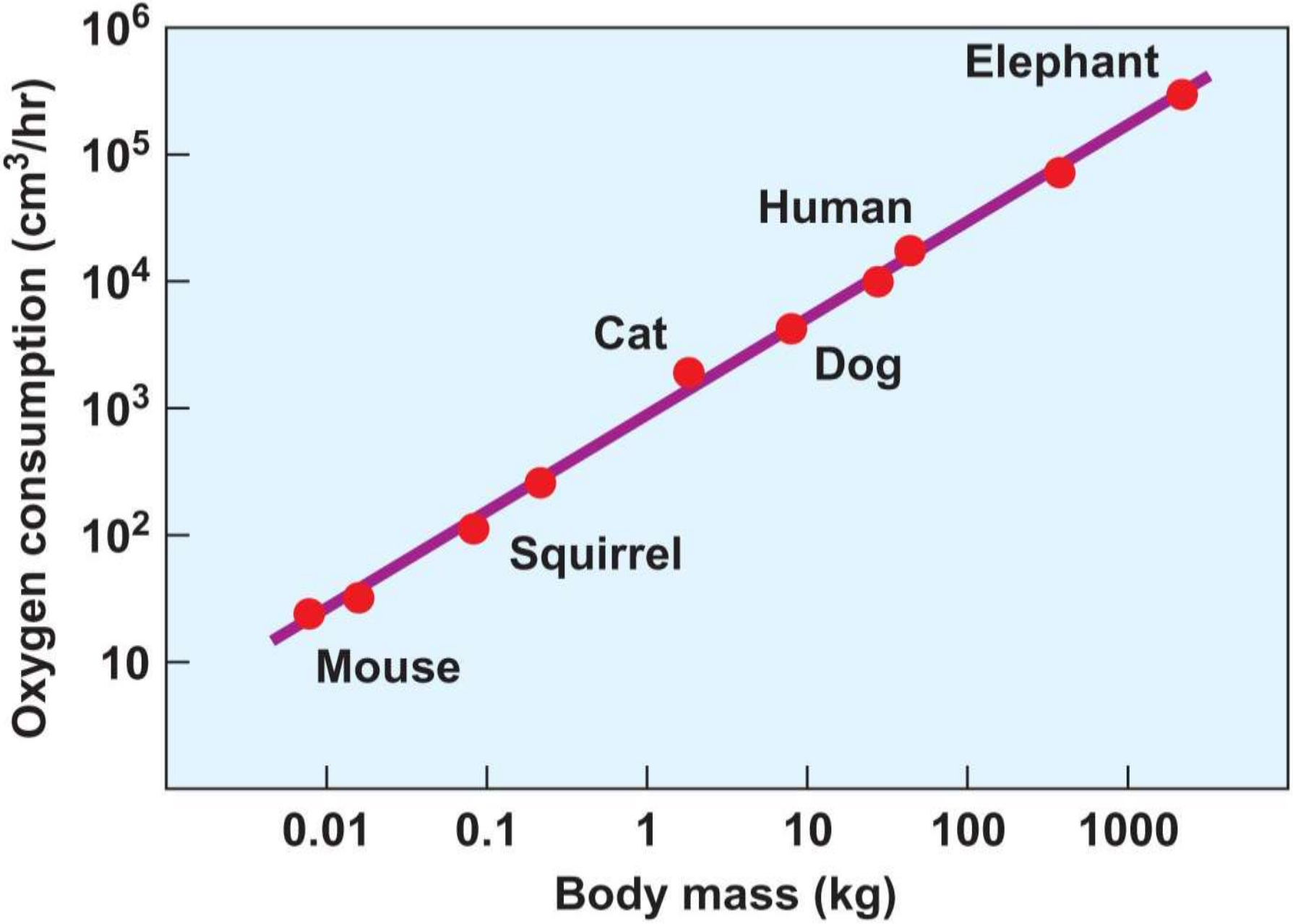


- Poikilotherms have an **upper and lower thermal limit** that they can tolerate:
  - Can maintain a relatively constant daytime body temperature by behavioral means.
- The **operative temperature range** *is that at which poikilotherms carry out their daily activities.*
- Poikilotherms have a **low metabolic rate** and a **high ability to exchange heat between body and environment**

- **Terrestrial and amphibious** poikilotherms **rely on behavioral thermoregulation** and **seek out appropriate microclimates**
  - Cooling in the shade
  - Basking in the sun
  - Seeking a warmer or cooler substrate

7.10 Homeotherms Escape the Thermal Restraints of the Environment

- Homeotherms maintain body temperature by **oxidizing glucose** in cellular respiration.
  - *Oxidation is not completely efficient and some energy is lost as heat*
- **Homeothermic respiration rate is proportional to body mass.**



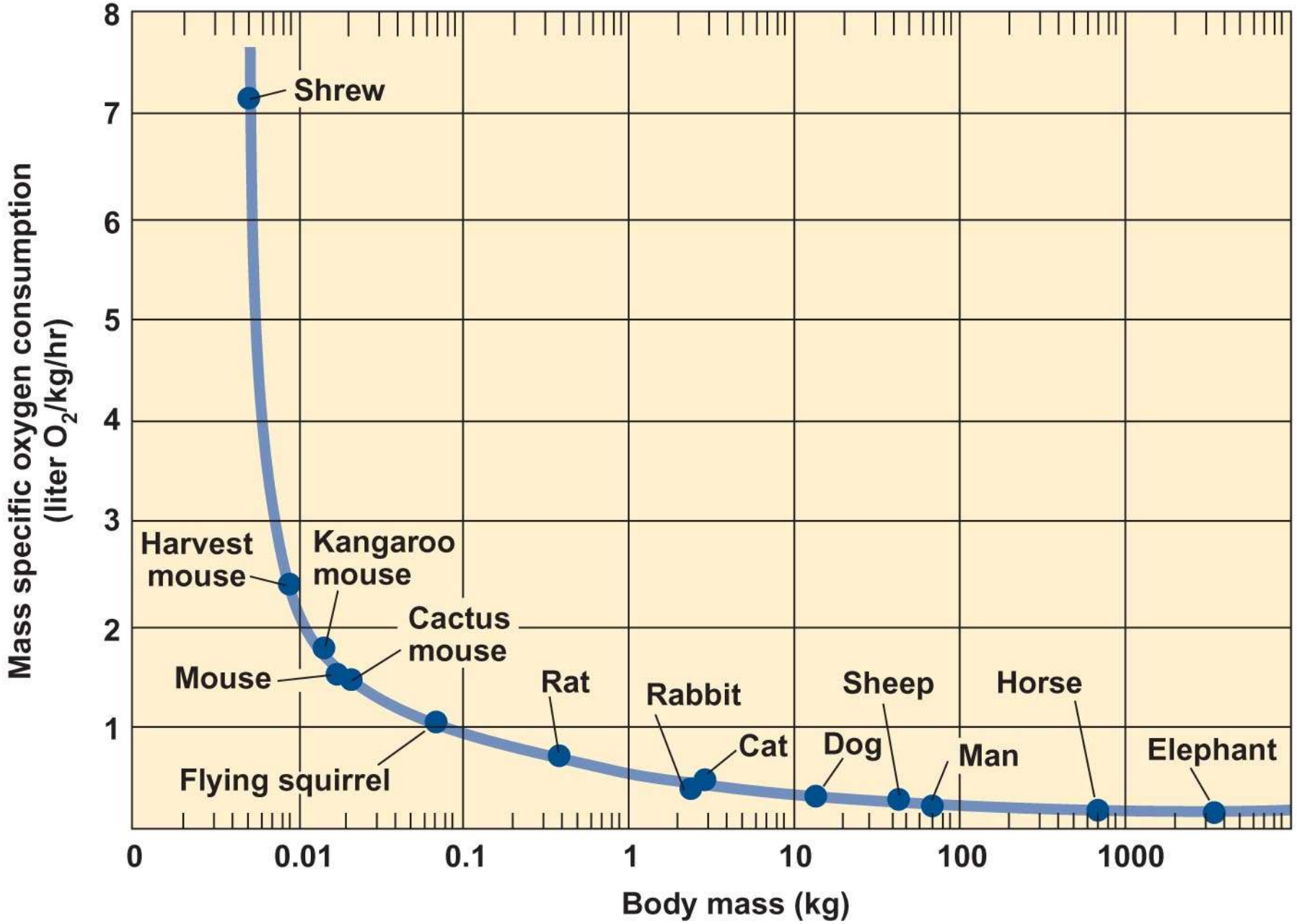
- Homeotherms maintain a high level of energy through **aerobic respiration:**
  - They can sustain **high levels of physical activity for long periods.**
- Homeotherms regulate exchange between the body and environment by **insulation**
  - **Fur**: *barrier to heat flow, insulation value varies with thickness*
    - *Fur thickness changes with the seasons*
  - **Feathers**
  - **Body fat**

- **Insulation** can **also keep heat out:**
  - *Reflection of solar radiation*
  - *Fur coat that heat cannot penetrate (example: camel)*
- Some **insects** have **a dense, fur-like coat over the thoracic region** (where flight muscles are located).
- Homeotherms regulate exchange between the body and environment by **shivering.**
- **Shivering:** *is involuntary muscular activity that increases heat production.*
  - **Brown fat oxidation** (prevalent in hibernators).

- Homeotherms regulate exchange between the body and environment by **evaporative cooling**:
  - **Sweating**
  - **Panting and gular fluttering**
  - **Wallow in water and wet mud**

7.11 Endothermy and Ectothermy Involve Trade-offs (مقايضات)

- **Endothermy:**
  - *Animals can remain active regardless of environmental temperatures* **(Advantage)**
  - *Animals must consume a lot of food to meet the energy demands of endothermy → a minor amount of energy goes to growth* **(Disadvantage)**
- **Ectothermy:**
  - *Animals can allocate more of their energy to biomass production* **(Advantage)**
  - *Animals require fewer calories per gram of body weight and so can colonize areas of limited food and water* **(Advantage)**
  - *Animals cannot be active under all environmental conditions* ***(disadvantage).***



7.12 Heterotherms Take On Characteristics of Ectotherms and Endotherms

- **Temporal heterotherms:** *are those that sometimes regulate their body temperature.*
- **Many species of insect** are heterothermic in the adult stage:
  - **Pre-flight warm up of flight muscles** → wing beating: moths, butterflies).
  - Orientation of wings to the sun (butterflies, dragonflies).

7.13 Torpor Helps Some Animals Conserve Energy

- Daily **torpor (سبات)** *is the dropping of body temperature to approximately ambient temperature for a part of each day, regardless of the season:*
  - *Temperature drops near to ambient.*
  - *Hummingbirds, bats, pocket mice, kangaroo mice … etc.*

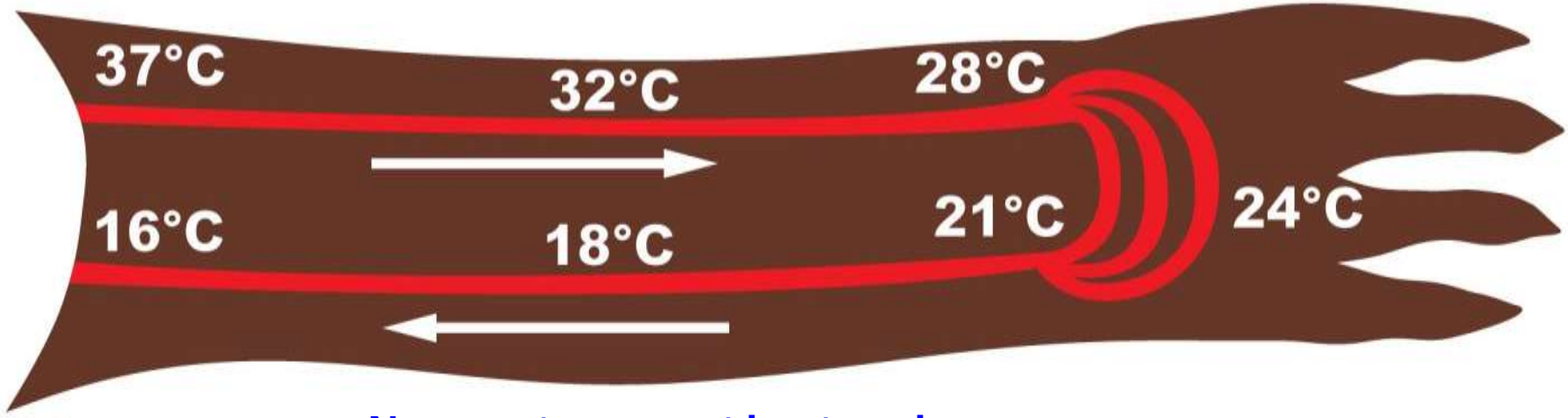
- **Hibernation (سبات فصلي)** *is a long, seasonal torpor characterized by cessation of activity:*
  - Common in terrestrial poikilotherms.
  - And some heterothermic mammals.
    - *Heart rate, respiration, and total metabolism fall, body temperature sinks below 10°C.*

- **Black bears, grizzly bears**, and **female polar bears** **do not hibernate:**
  - A unique **winter sleep** from which they *easily* rouse!
  - Body temperature is only a few degrees below normal
- These mammals *do not eat, drink, urinate, or defecate.*
- Females give birth to and nurse young during their sleep.

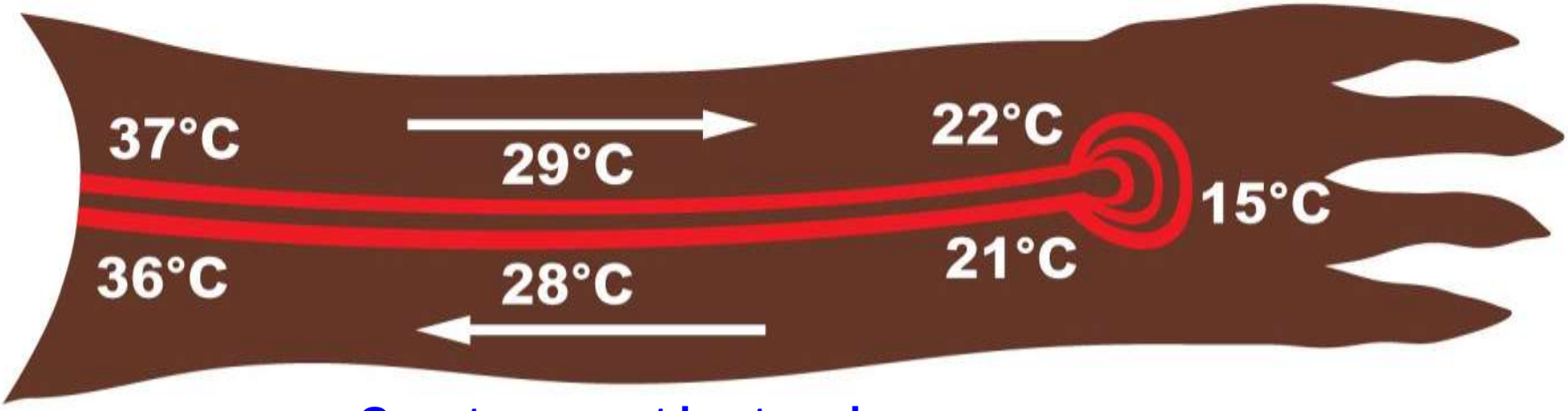
7.14 Some Animals Use Unique Physiological Means for Thermal Balance

- **Supercooling** of body fluids takes place when the body temperature falls below the freezing point without actually freezing
- The presence of **solutes** (e.g., **glycerol**) in body fluids functions to lower the freezing point of water.
  - Characteristic of **arctic marine fish, some insects, reptiles, and amphibians.**

- **Countercurrent heat exchange** can **conserve heat in a cold environment** or can **cool vital parts of the body under heat stress.**



(a) No countercurrent heat exchange



(b) Countercurrent heat exchange

7.18 Daily and Seasonal Light and Dark Cycles Influence Animal Activity

- **Biological clocks** *are the internal mechanisms in organisms that control the periodicity of functions and activities.*
- Biological processes fluctuate in cycles:
  - *A daily rhythm is a biological process that cycles in 24-hour intervals.*
  - A **circadian rhythm** *is a daily rhythm (cycle) that results from a physiological response to the diurnal environment.*
    - *Example: melatonin secretion.*

- **Adaptive value of biological clocks (Advantages):**
  - Time-dependent mechanism that allows an organism to prepare for periodic changes in the environment
  - Predators can match their feeding activity to the activity rhythm of their prey
  - Allows for orientation based on the Sun's position (in birds, reptiles and insects)

7.19 Critical Day Lengths Trigger Seasonal Responses

- **Critical day length** signals certain animal responses (e.g., reproduction)
  - Usually between 10 and 14 hours
- **Day neutral** *organisms are not controlled by day length but by something else.*
- **Short-day** *organisms are those whose response is stimulated by day lengths shorter than their critical day length.*
- **Long-day** *organisms are those whose response is stimulated by day lengths longer than their critical day length.*

- **Circannual rhythms** *are those activities of animals that reflect the seasonal response to changing day length:*
  - Reproductive cycle of white-tailed deer : *starts in autumn so that the young are born in spring when food is available.*