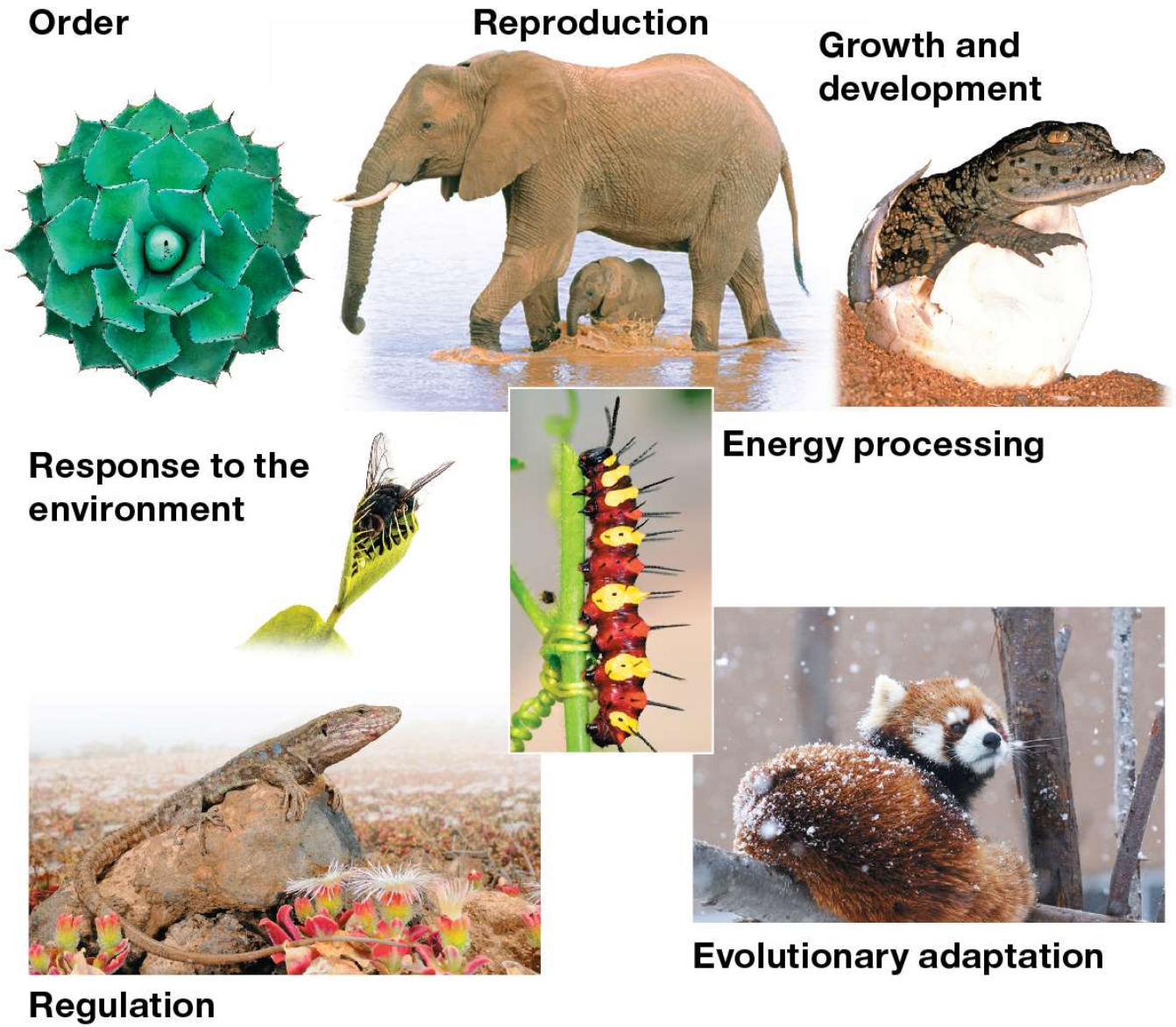
Biology: The Scientific Study of Life

1.1 Biology is the Scientific Study of Life (1 of 2)

- **Biology** is the scientific study of life.
- But what is *life*? Properties of life include order, reproduction, growth and development, energy processing, regulation, response to the environment, and evolutionary adaptation.
- The **cell** is the structural and functional unit of life.

Figure 1.1



1.1 Biology is the Scientific Study of Life (2 of 2)

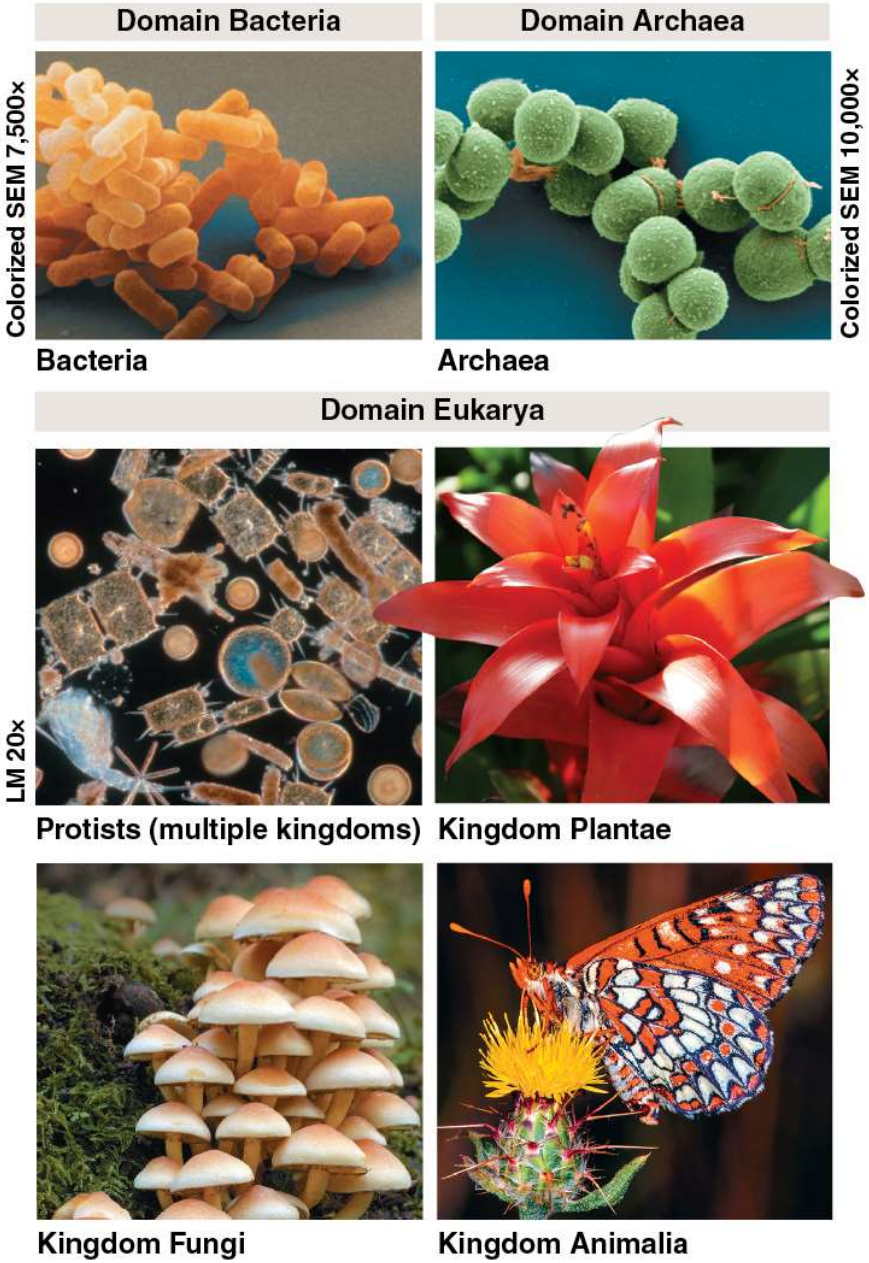
Checkpoint question How is life recognized?

Life can be characterized by its properties listed in Figure 1.1.

1.2 Biologists Arrange the Diversity of Life into Three Domains (1 of 2)

- Taxonomists name species and classify them into broader groups.
- Although the debate continues, there is consensus among biologists that life can be organized into three higher levels called **domains**.
  - Domains Bacteria and Archaea contain organisms with simple cells.
  - Domain Eukarya includes various protists and the kingdoms Fungi, Plantae, and Animalia.

Figure 1.2



1.2 Biologists Arrange the Diversity of Life into Three Domains (2 of 2)

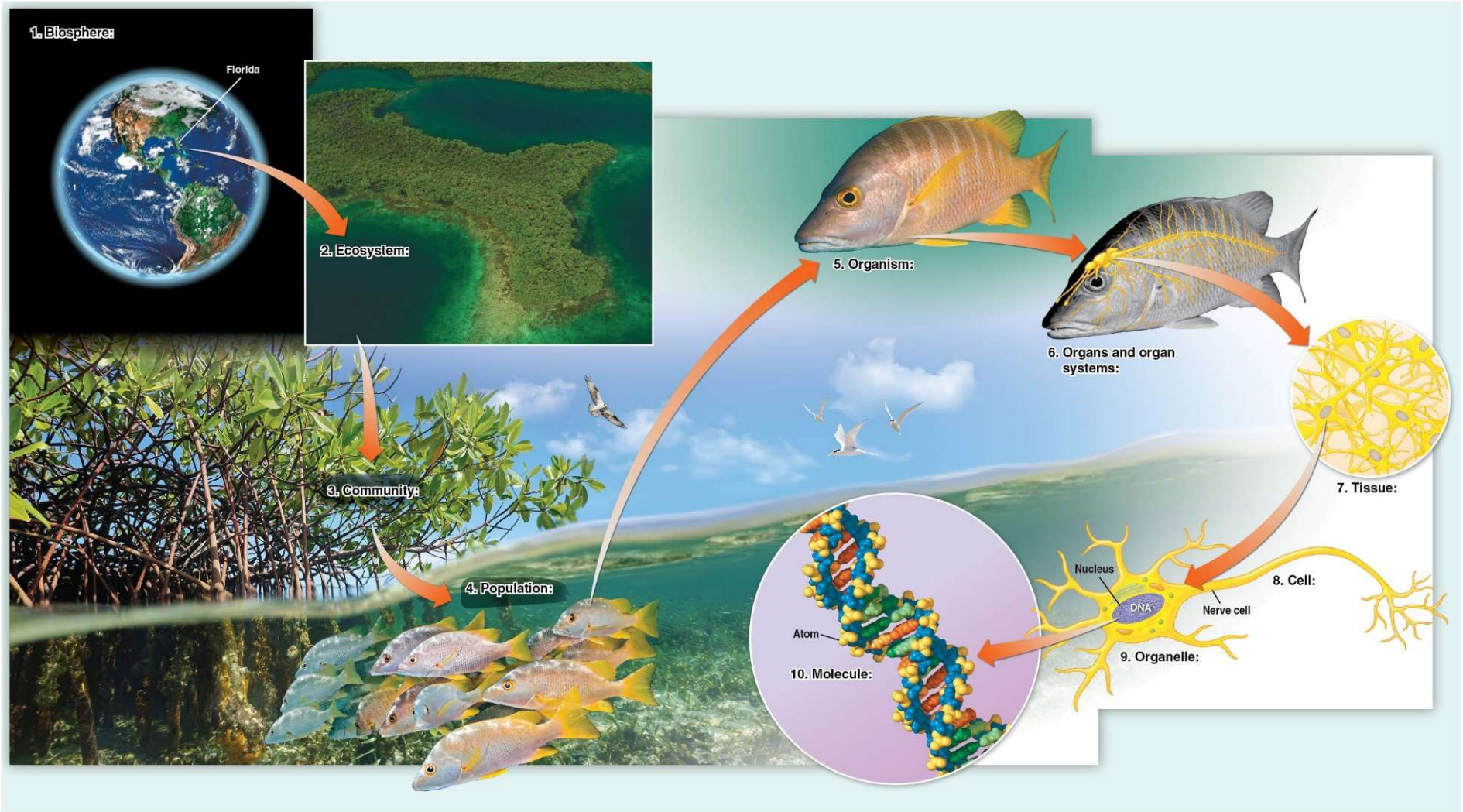
Checkpoint question To which of the three domains of life do we belong?

Eukarya

1.3 Visualizing the Concept: In Life's Hierarchy of Organization, New Properties Emerge at Each Level (1 of 2)

- Biologists study life across a very broad range of scales, from the molecules in a cell to the entire living planet.
- They divide this vast scope of biology into a series of structural levels.
- **Emergent properties** result from the specific arrangement and interactions among component parts.

Figure 1.3



1.3 Visualizing the Concept: In Life's Hierarchy of Organization, New Properties Emerge at Each Level (2 of 2)

Checkpoint question Which of these levels of biological organization includes all of the others in the list: cell, molecule, organ, tissue?

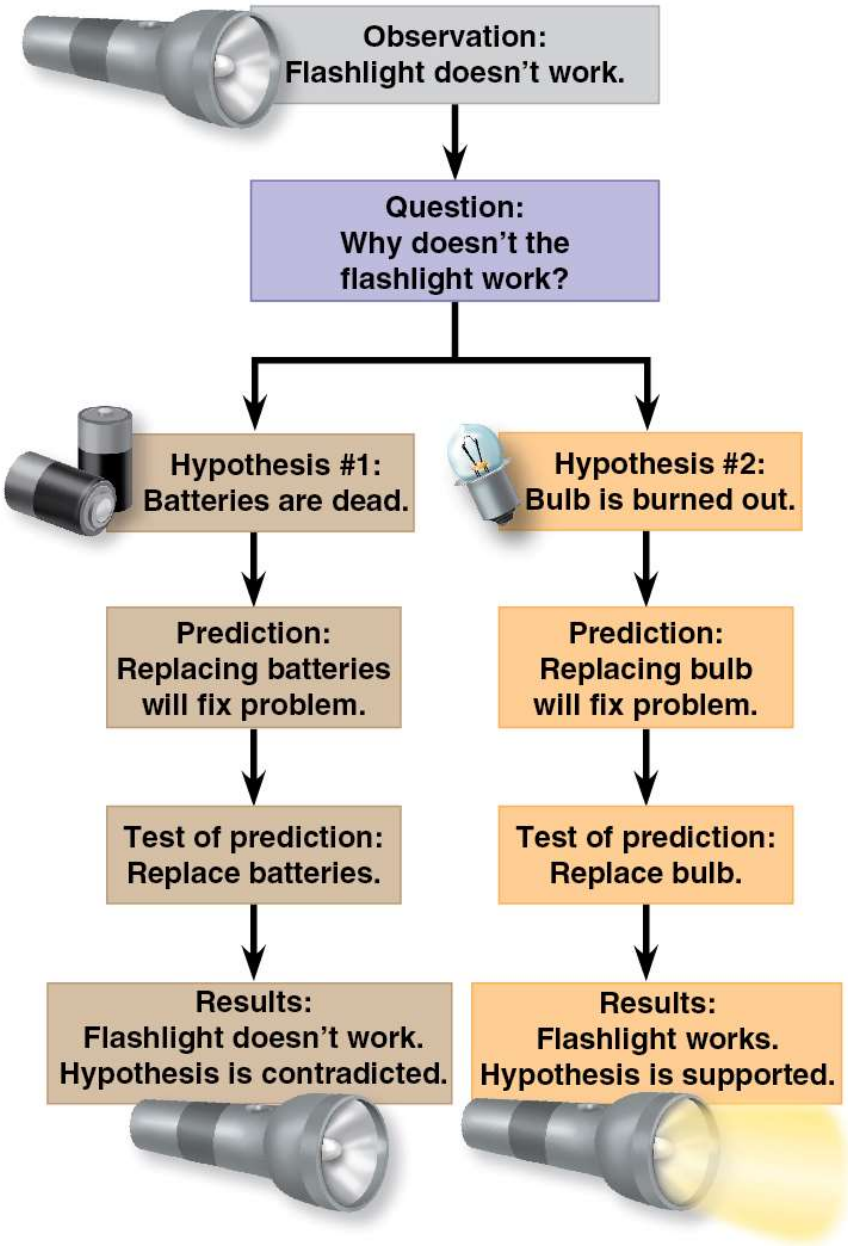
Organ

The Process of Science

1.4 What Is Science? (1 of 2)

- **Science** is a way of knowing—an approach to understanding the natural world.
  - Science uses an evidence-based process of inquiry to investigate the natural world.
  - The scientific approach involves observations, **hypotheses**, predictions, tests of hypotheses via **experiments** or additional observations, and analysis of **data**.
  - A scientific **theory** is broad in scope and supported by a large body of evidence.

Figure 1.4_3



1.4 What Is Science? (2 of 2)

Checkpoint question What is the main requirement for a scientific hypothesis?

It must generate predictions that can be tested by experiments or gathering further observations.

1.5 Hypotheses Can Be Tested Using Controlled Experiments (1 of 3)

- In an experimental test of a hypothesis, researchers often manipulate one component in a system and observe the effects of this change.
  - The factor that is manipulated is called the **independent variable**.
  - The measure used to judge the outcome of the experiment is called the **dependent variable**. This variable depends on the manipulated variable.
  - A **controlled experiment** compares an experimental group with a control group.

1.5 Hypotheses Can Be Tested Using Controlled Experiments (2 of 3)

- The use of control and experimental groups can demonstrate the effect of a single variable. For example, researchers found that mice models that did not match their habitat had higher predation rates than camouflaged models.
- Hypotheses can be tested in humans with clinical trials, as well as retrospective or prospective observational studies.

Figure 1.5

Table 1.5 Results from Camouflage Experiment

Habitat	Number of Attacks on Camouflaged Models	Number of Attacks on Noncamouflaged Models	% Attacks on Noncamouflaged Models
Beach (light habitat)	2	5	71%
Inland (dark habitat)	5	16	76%

Data from S. N. Vignieri et al., The selective advantage of crypsis in mice, *Evolution* 64: 2153–8 (2010).

1.5 Hypotheses Can Be Tested Using Controlled Experiments (3 of 3)

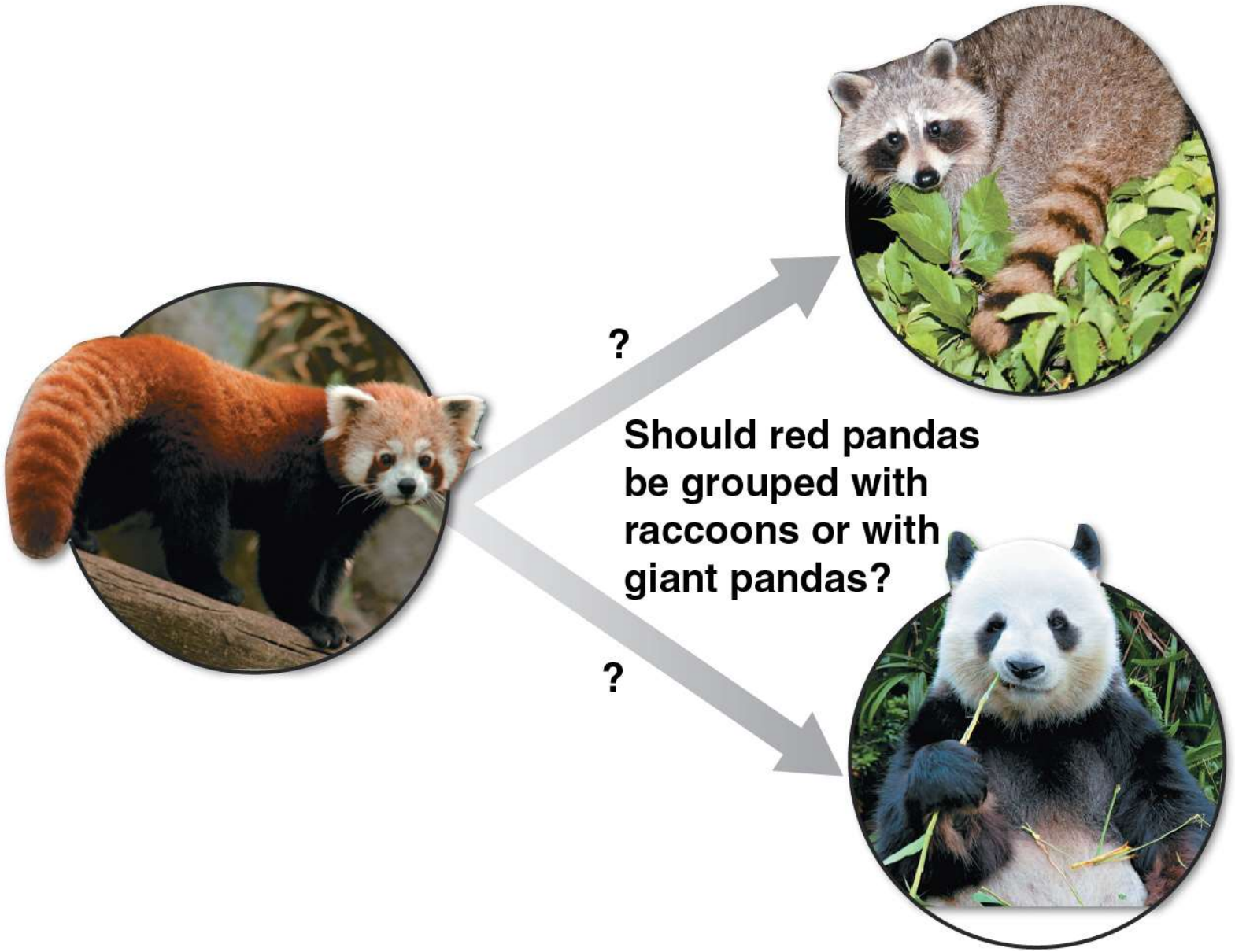
Checkpoint question In some studies, researchers try to match factors such as sex, age, and general health for subjects in the control and experimental groups. What is this experimental design trying to do?

Ensure that the two groups differ only in the one variable the experiment is designed to test.

1.6 Scientific Thinking: Hypotheses Can Be Tested Using Observational Data (1 of 2)

- Scientists tested hypotheses about the evolutionary relationships of red pandas.
  - Based on observations of physical similarities, scientists initially hypothesized that the red panda was most closely related to raccoons.
  - Other scientists, observing that the diet and habitat of red pandas were similar to those of giant pandas, placed the two pandas together in their own family.
  - But recent studies comparing DNA sequences led scientists to classify red pandas as the only living species of their own family.

Figure 1.6



1.6 Scientific Thinking: Hypotheses Can Be Tested Using Observational Data (2 of 2)

Checkpoint question Explain why comparisons of DNA sequences are considered observational and not experimental data.

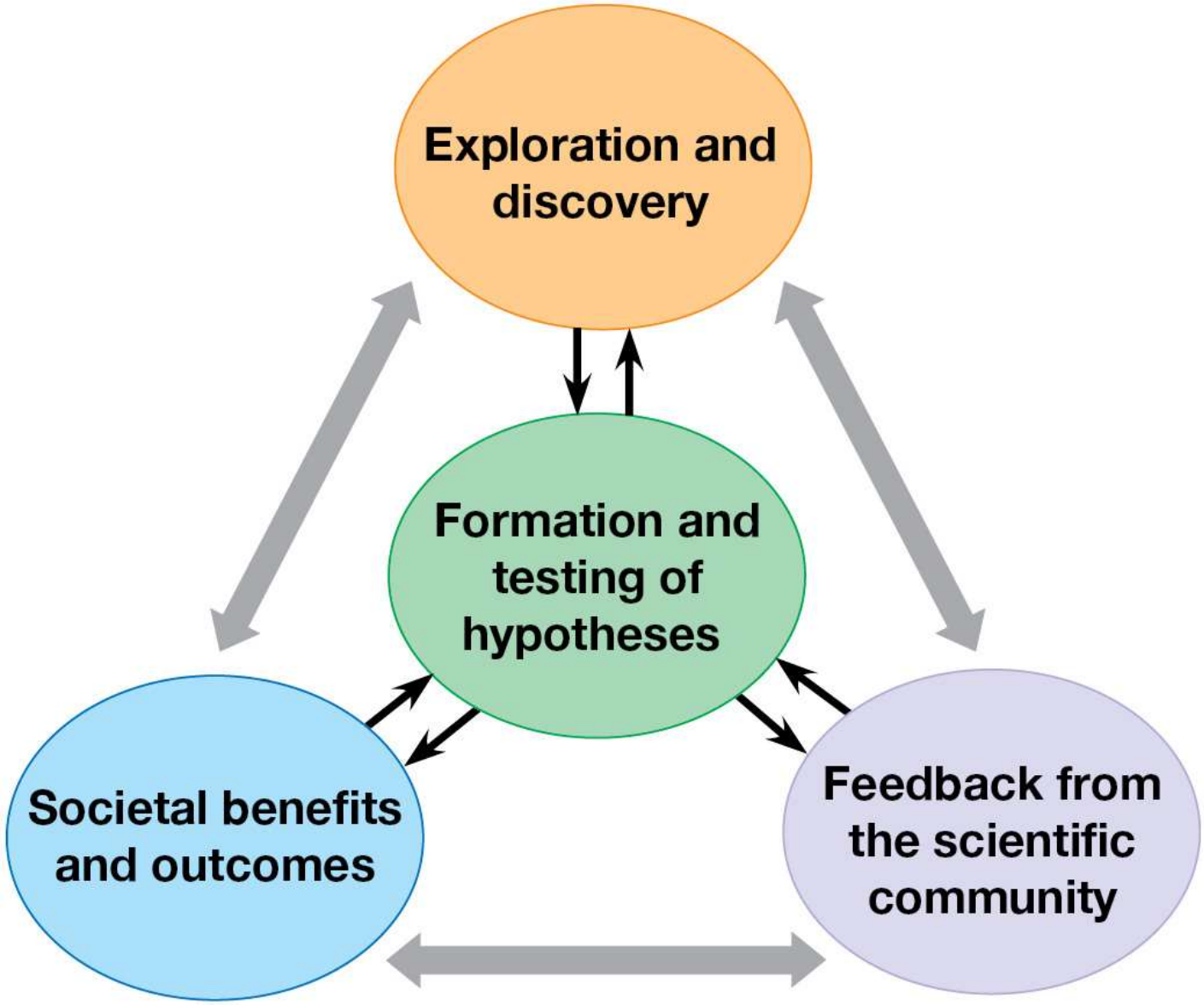
Scientists are not manipulating DNA sequences in any type of experiment but are simply recording and comparing the differences in sequences that they observe.

1.7 The Process of Science Is Repetitive, Nonlinear, and Collaborative (1 of 2)

- Forming and testing hypotheses are at the core of science. This endeavor is influenced by three spheres:

  1. exploration and discovery,
  2. analysis and feedback from the scientific community, and
  3. societal benefits and outcomes.

Figure 1.7



1.7 The Process of Science Is Repetitive, Nonlinear, and Collaborative (2 of 2)

Checkpoint question Why is hypothesis testing at the center of the process of science?

Hypothesis testing is central because a core component of science is testable explanations of nature.

1.8 Connection: Biology, Technology, and Society Are Connected in Important Ways

- The goal of science is to understand natural phenomena.
- In contrast, the goal of **technology** is to apply scientific knowledge for some specific purpose.
- These two fields, however, are interdependent. Technological advances stem from scientific research, and research benefits from new technologies.

Five Unifying Themes in Biology

1.9 Theme: Evolution Is the Core Theme of Biology (1 of 4)

- Life is distinguished by its unity and its diversity.
- The scientific explanation for this unity and diversity is **evolution**, the process of change that has transformed life on Earth from its earliest forms to the vast array of organisms living today.

Figure 1.9a

1.9 Theme: Evolution Is the Core Theme of Biology (2 of 4)

- Darwin synthesized the theory of evolution by **natural selection**.

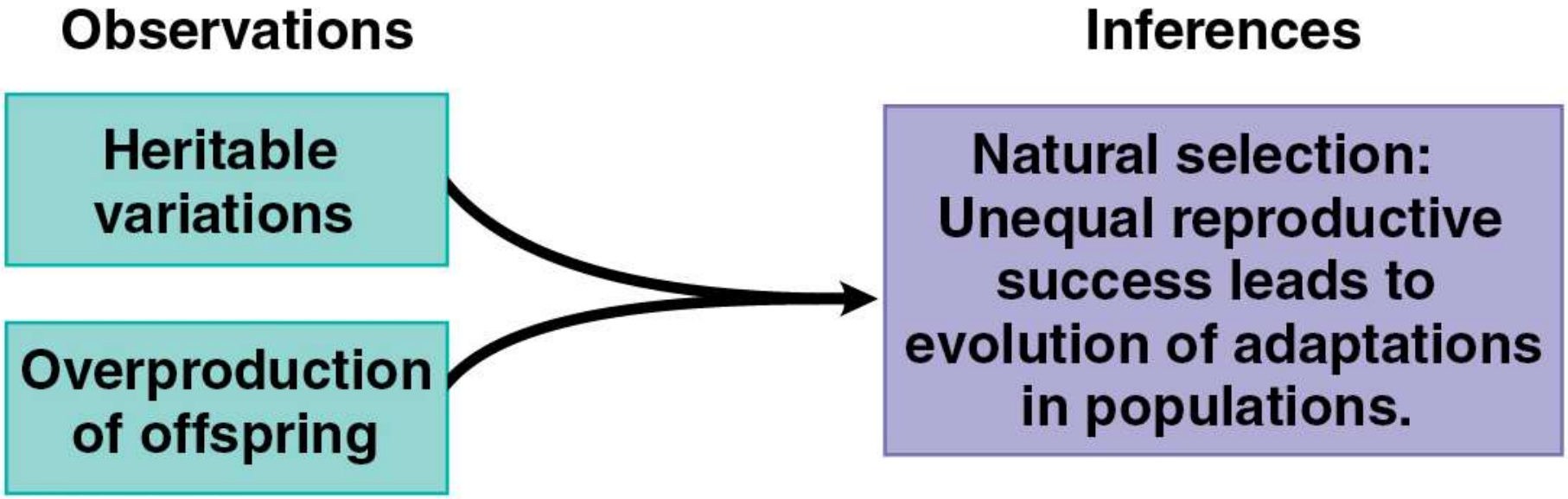


Figure 1.9b_3

1 Population with varied inherited traits.

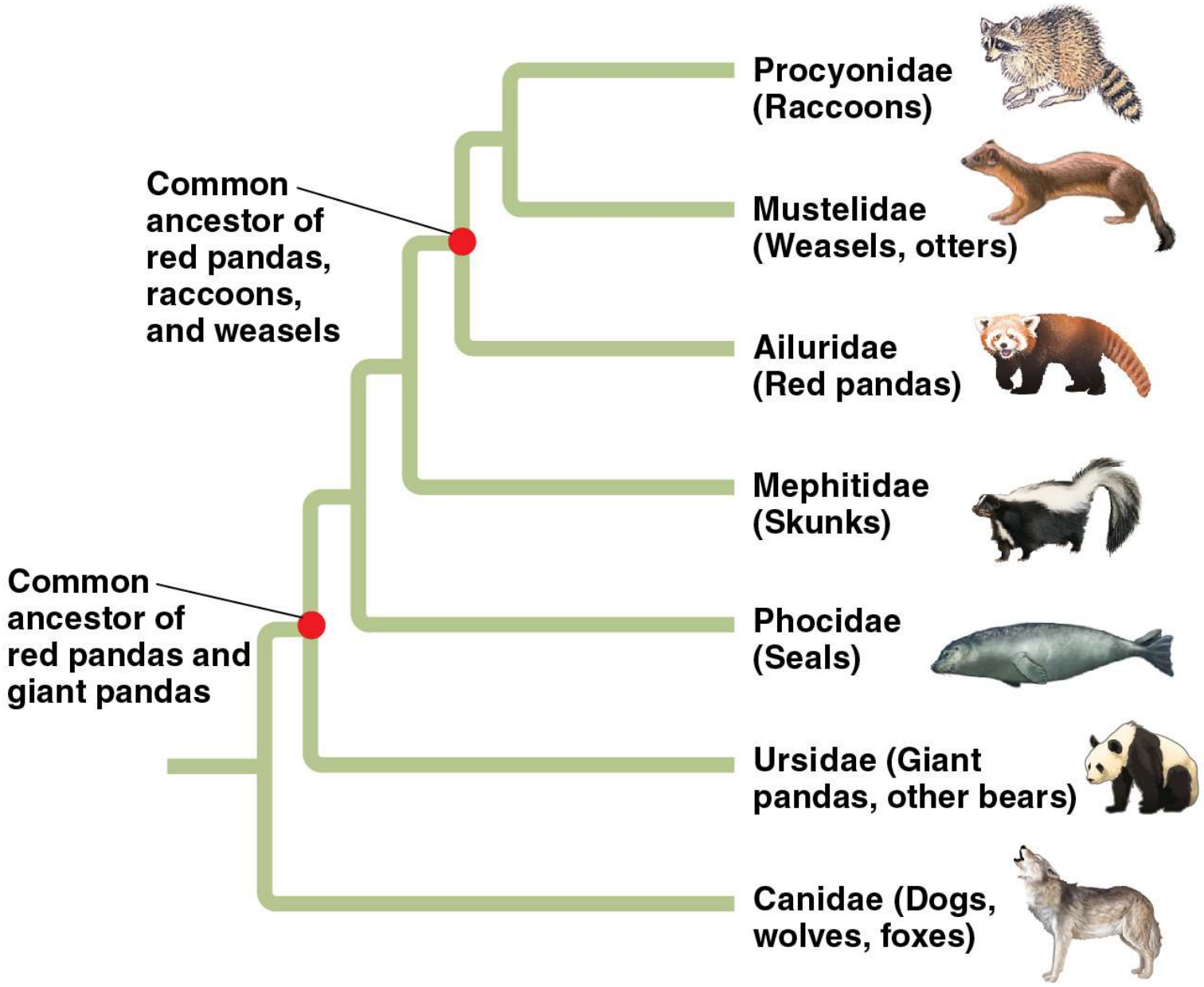
2 Elimination of individuals with certain traits and reproduction of survivors.

3 Increasing frequency of traits that enhance survival and reproductive success.

1.9 Theme: Evolution Is the Core Theme of Biology (3 of 4)

- Each species on Earth today has a family history.
- A species represents one twig on a branching tree of life that extends back in time through ancestral species more and more remote.

Figure 1.9c



1.9 Theme: Evolution Is the Core Theme of Biology (4 of 4)

Checkpoint question Explain the cause and effect of unequal reproductive success.

Those individuals with heritable traits best suited to the local environment produce the greatest number of offspring. Over many generations, the proportion of these adaptive traits increases in the population.

1.10 Evolution Connection: Evolution Is Connected to Our Everyday Lives (1 of 2)

- Evolutionary theory is useful in medicine, conservation, and agriculture.
- Through the selective breeding of plants and animals, humans also act as agents of evolution.
- As a result of **artificial selection**, our crops, livestock, and pets bear little resemblance to their wild ancestors.

1.10 Evolution Connection: Evolution Is Connected to Our Everyday Lives (2 of 2)

Checkpoint question Explain how humans are agents of both artificial selection and natural selection.

We use artificial selection when choosing specific traits or genes in organisms that we breed. Our intentional and unintentional manipulations change the environment and thus affect natural selection.

1.11 Theme: Life Depends on the Flow of Information (1 of 2)

- The processes of life depend on the transmission and use of information.
  - DNA is responsible for heredity and for programming the activities of a cell by providing the blueprint for proteins.
  - Information from the external and internal environment includes the stimuli, signals, and pathways that regulate body processes and gene expression.

Figure 1.11a

Figure 1.11b

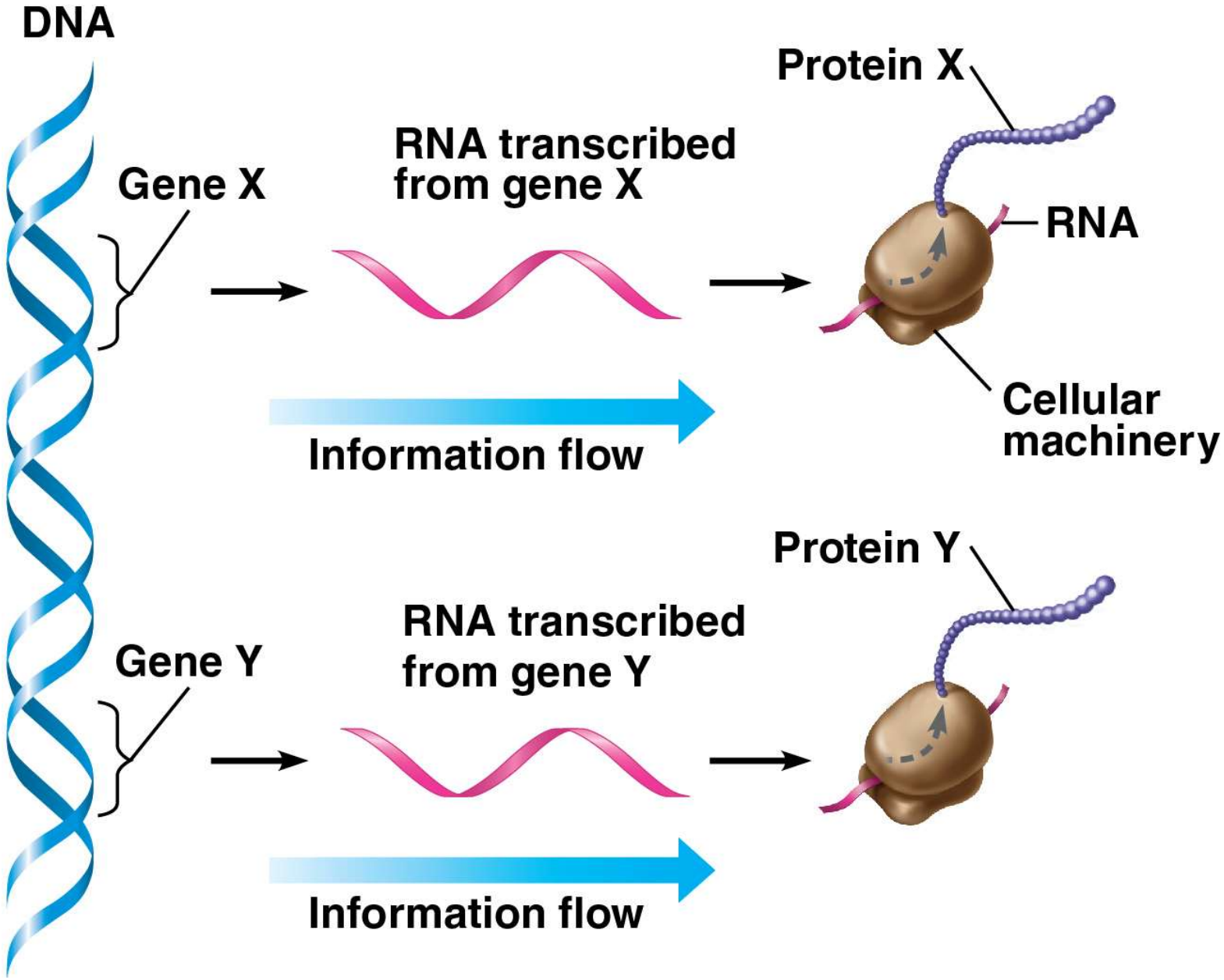
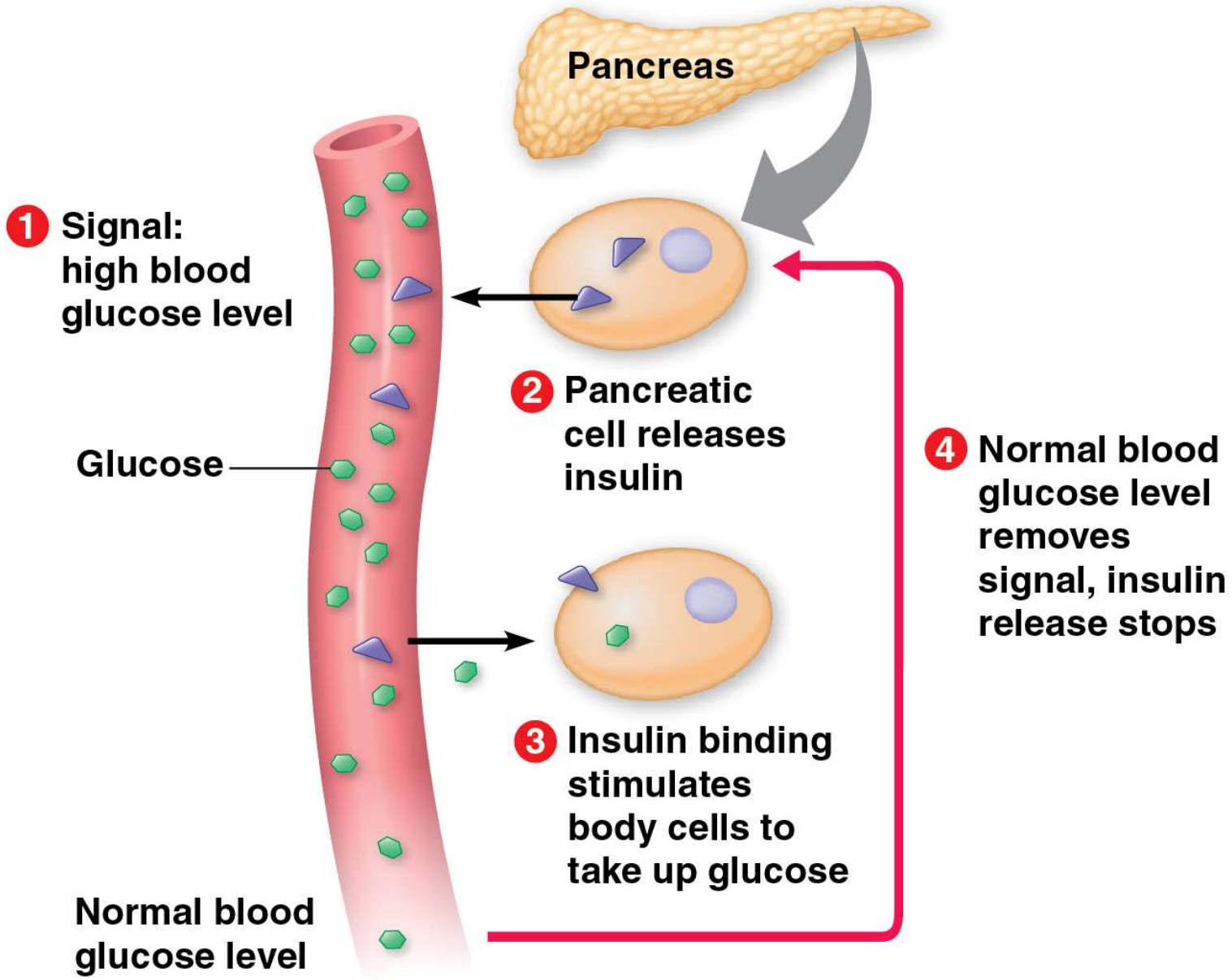


Figure 1.11c



1.11 Theme: Life Depends on the Flow of Information (2 of 2)

Checkpoint question How is signaling information involved in the expression of genetic information?

Information from the internal and external environment affects gene expression—where and when particular genes are activated and proteins made.

1.12 Theme: Structure and Function Are Related (1 of 2)

- The relationship between structure and function can be observed at every level of life.
- At the molecular level, the structure of a protein correlates with its function. For example, hemoglobin molecules transport oxygen in blood.
- On the cellular level, the long extensions of nerve cells enable them to transmit impulses from your spinal cord to your toes.

Figure 1.12a

1.12a Structural adaptations in the form of plant cell walls and insect exoskeletons that function in physical support

Figure 1.12b

1.12 Theme: Structure and Function Are Related (2 of 2)

Checkpoint question Look at the structure of your hand and explain how its structure supports its function.

The finger joints and opposable digits allow you to manipulate objects.

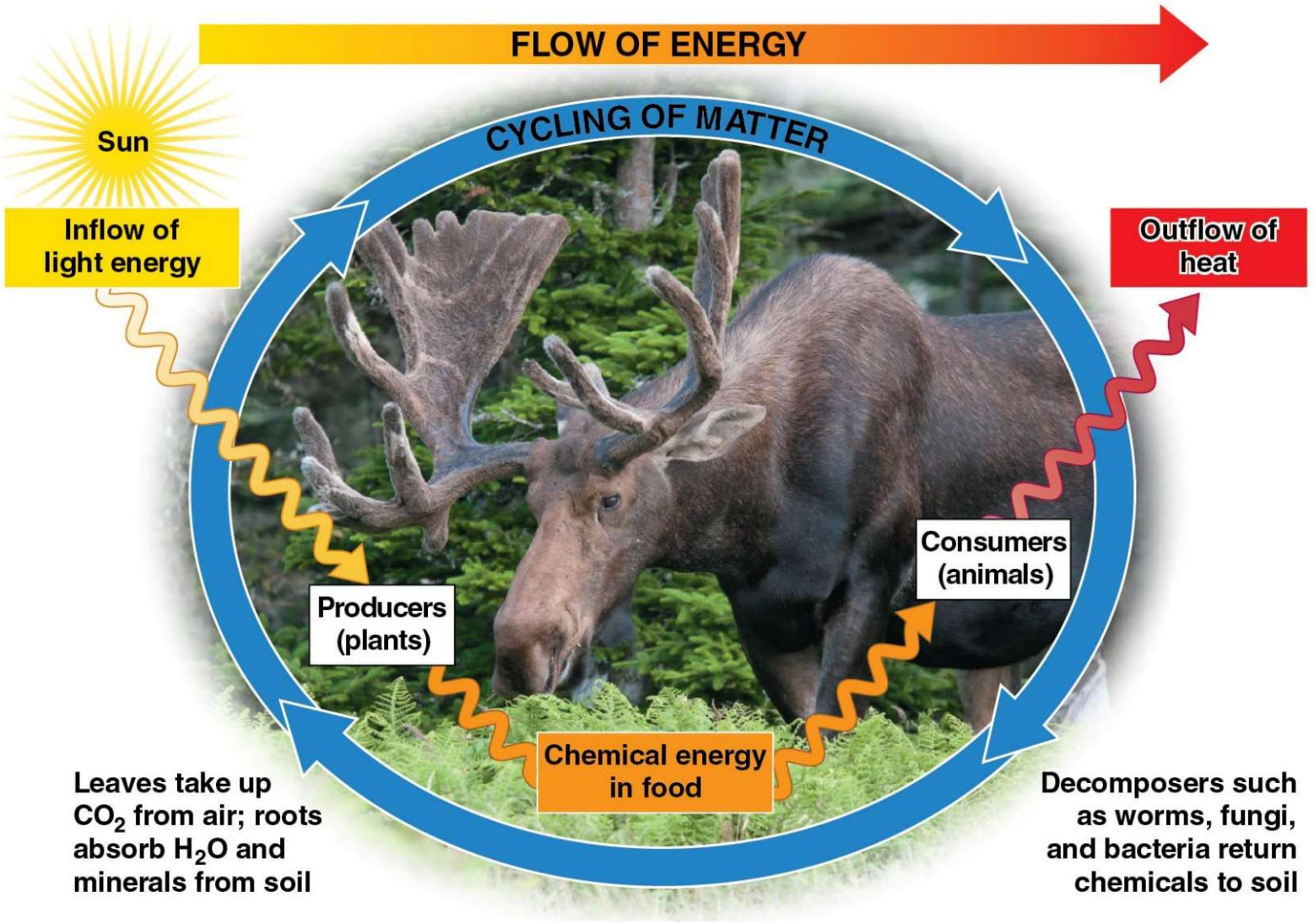
1.13 Theme: Life Depends on the Transfer and Transformation of Energy and Matter (1 of 3)

- Energy flows through an ecosystem in one direction
  - entering as sunlight,
  - converted to chemical energy by producers,
  - passed on to consumers, and
  - exiting as heat.

1.13 Theme: Life Depends on the Transfer and Transformation of Energy and Matter (2 of 3)

- Ecosystems are characterized by the cycling of matter
  - from the atmosphere and soil,
  - through producers, consumers, and decomposers,
  - then back to the environment.

Figure 1.13



1.13 Theme: Life Depends on the Transfer and Transformation of Energy and Matter (3 of 3)

Checkpoint question Describe how photosynthesis transforms energy and matter.

Using the energy of sunlight, CO_2 and H_2O (matter) are converted into sugar molecules with stored chemical energy.

1.14 Theme: Life Depends on Interactions Within and Between Systems (1 of 2)

- The study of life extends from the microscopic scale of the molecules and cells that make up an organism to the global scale of the living planet.
- Emergent properties are the result of interactions between the components of a system.
- Using an approach called **systems biology**, scientists attempt to model the behavior of biological systems by analyzing the interactions among their parts.

1.14 Theme: Life Depends on Interactions Within and Between Systems (2 of 2)

Checkpoint question A box of bicycle parts won't do anything, but if the parts are properly assembled, you can take a ride. What does this illustrate?

Emergent properties of the interacting components of a system

Figure 1.UN03