**LECTURE PRESENTATIONS**

For CAMPBELL BIOLOGY, NINTH EDITION

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# Chapter 1

# Introduction: Themes in the Study of Life

**Lectures by**
**Erin Barley**
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# Overview: Inquiring About Life

- An organism's adaptations to its environment are the result of evolution
  - For example, the ghost plant is adapted to conserving water; this helps it to survive in the crevices of rock walls
- **Evolution** is the process of change that has transformed life on Earth

Figure 1.1

Figure 1.2

- **Biology** is the scientific study of life
- Biologists ask questions such as
  - How does a single cell develop into an organism?
  - How does the human mind work?
  - How do living things interact in communities?
- Life defies a simple, one-sentence definition
- Life is recognized by what living things do

Figure 1.3

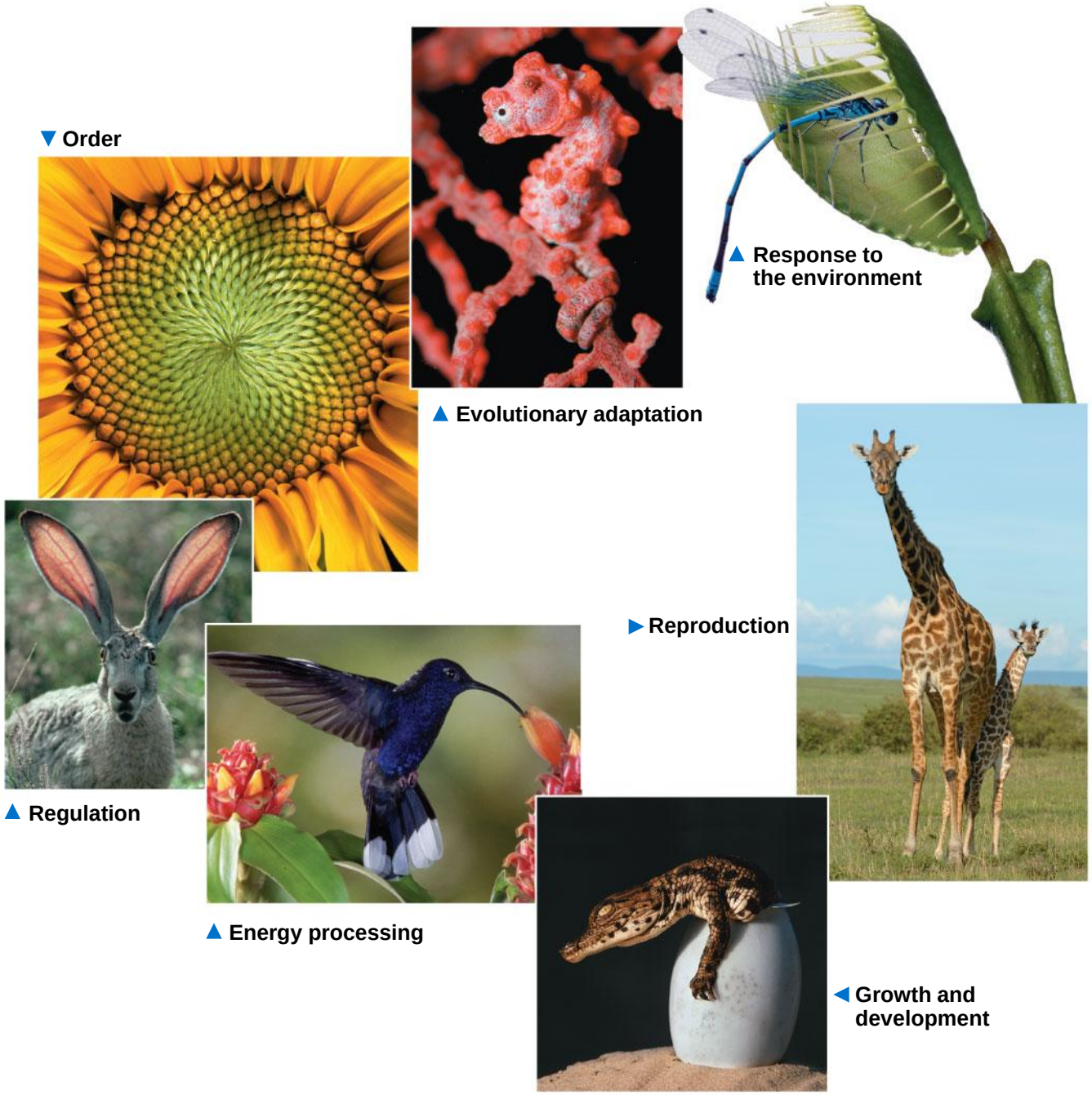


Figure 1.3a

**Evolutionary adaptation**

Figure 1.3b

**Response to the environment**

Figure 1.3c

**Reproduction**

Figure 1.3d

**Growth and development**

Figure 1.3e

**Energy processing**

Figure 1.3f

**Regulation**

Figure 1.3g

**Order**

# Concept 1.1: The themes of this book make connections across different areas of biology

- Biology consists of more than memorizing factual details
- Themes help to organize biological information

# Theme: New Properties Emerge at Each Level in the Biological Hierarchy

- Life can be studied at different levels, from molecules to the entire living planet
- The study of life can be divided into different levels of biological organization

Figure 1.4

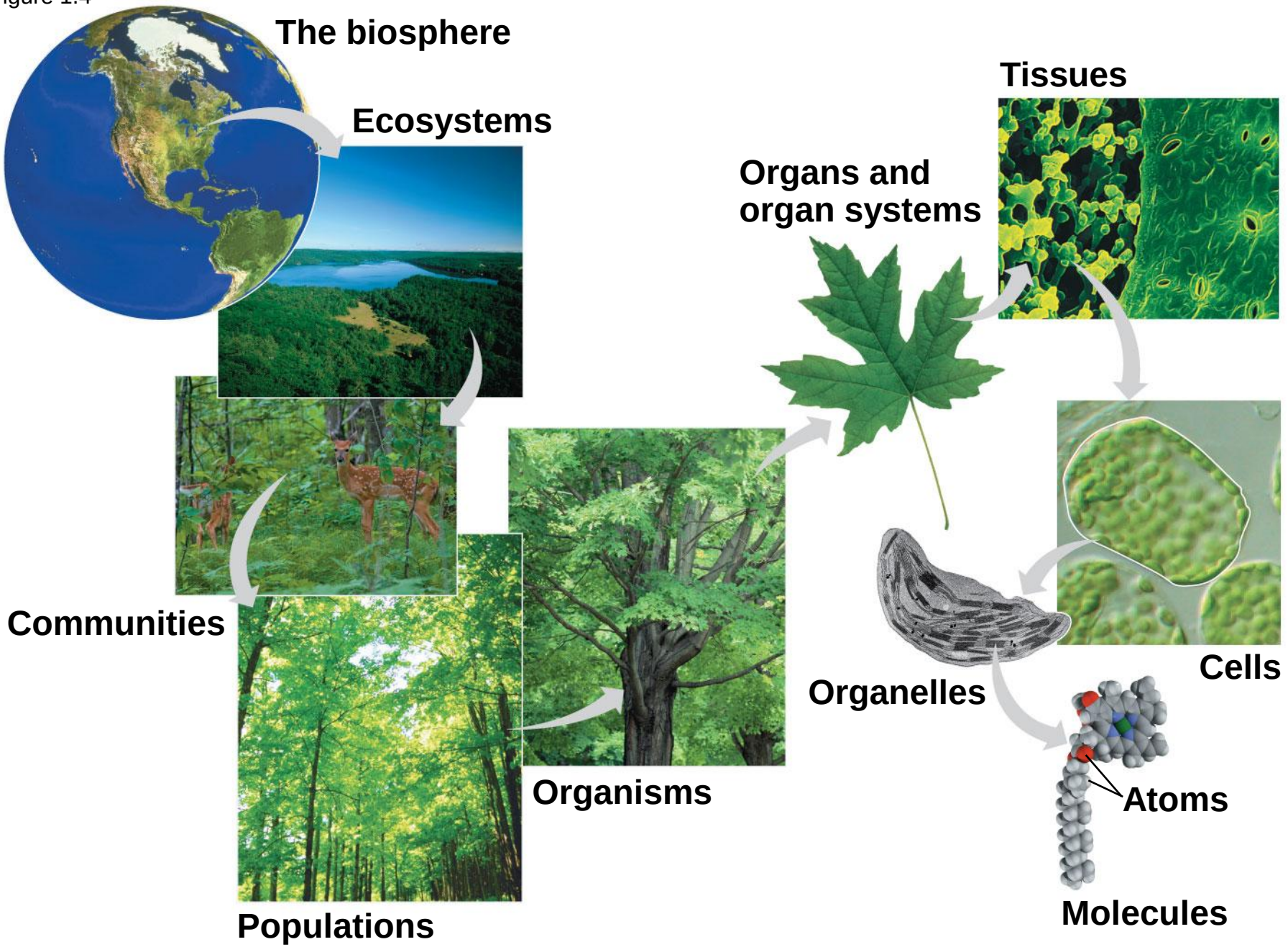


Figure 1.4a

**The biosphere**

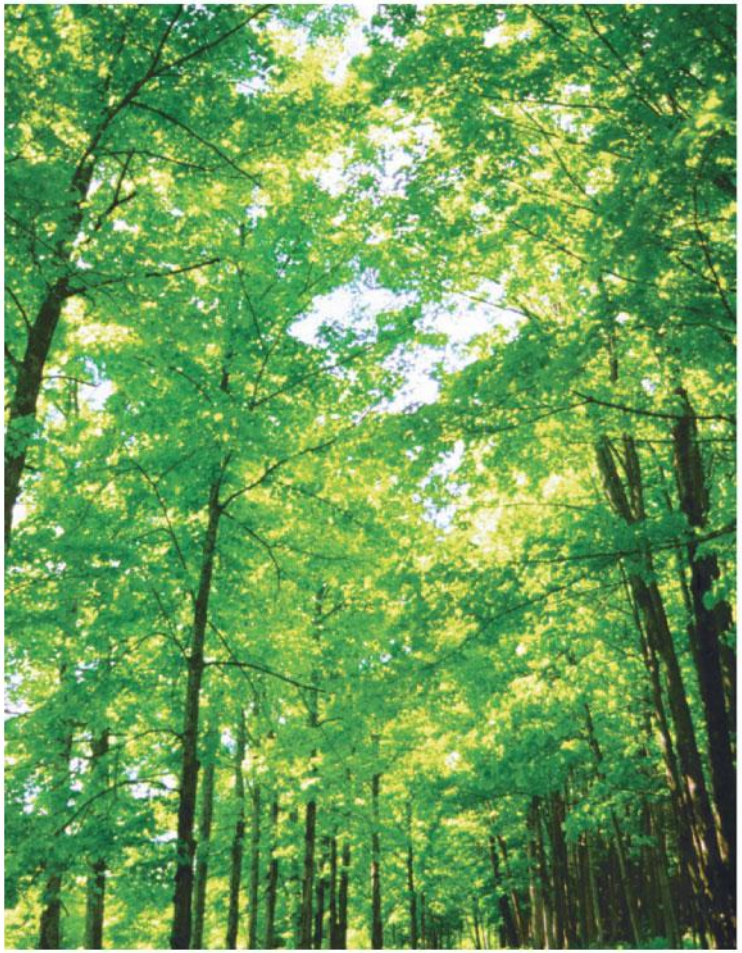
Figure 1.4b

# Ecosystems

Figure 1.4c

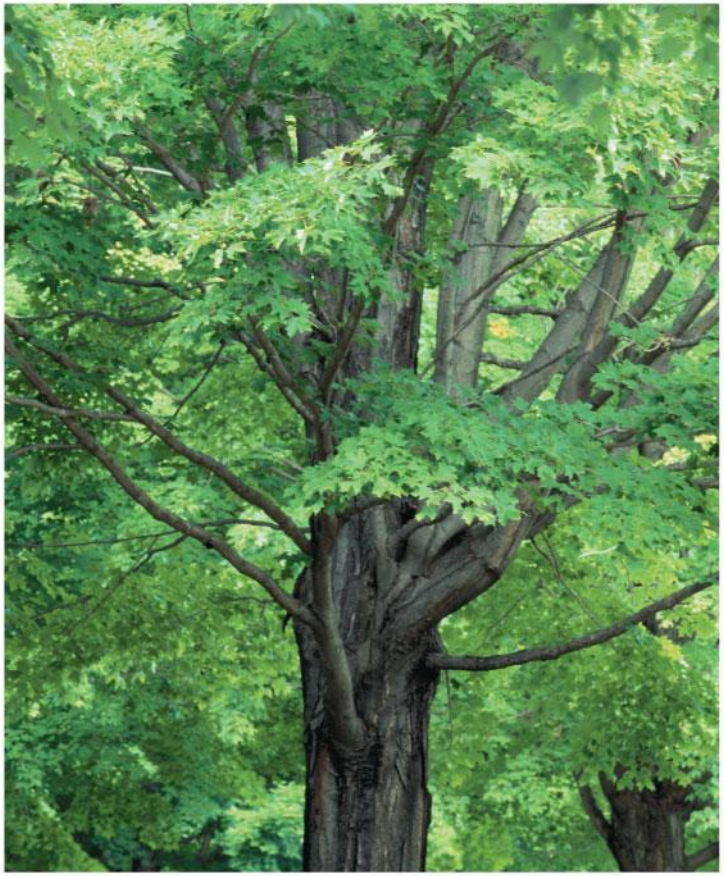
**Communities**

Figure 1.4d



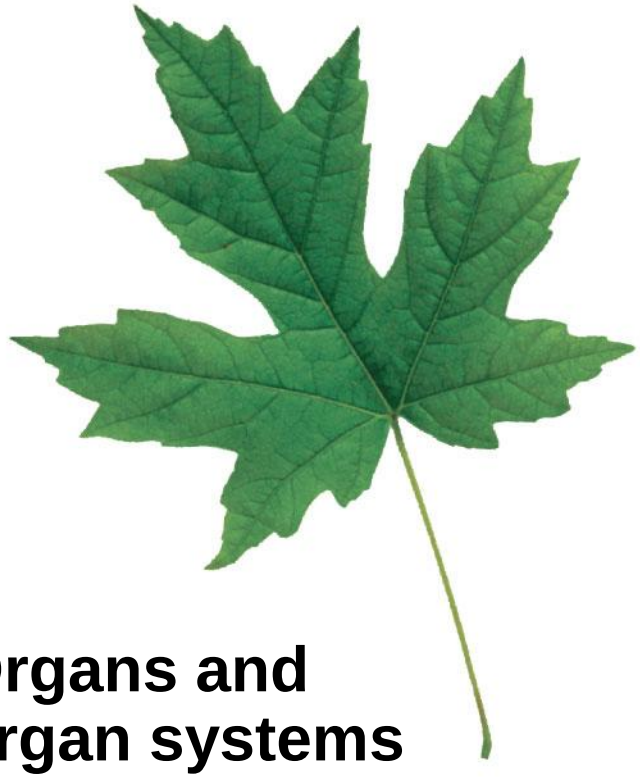
**Populations**

Figure 1.4e



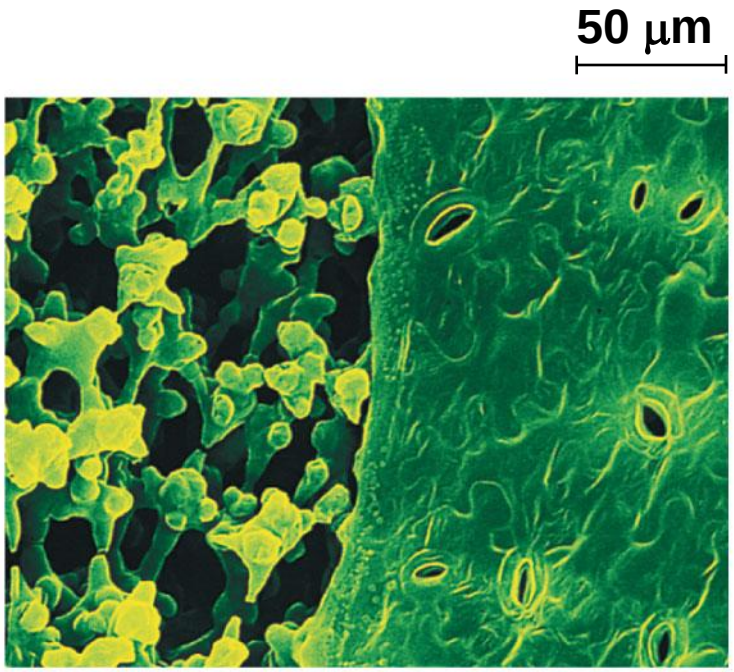
**Organisms**

Figure 1.4f



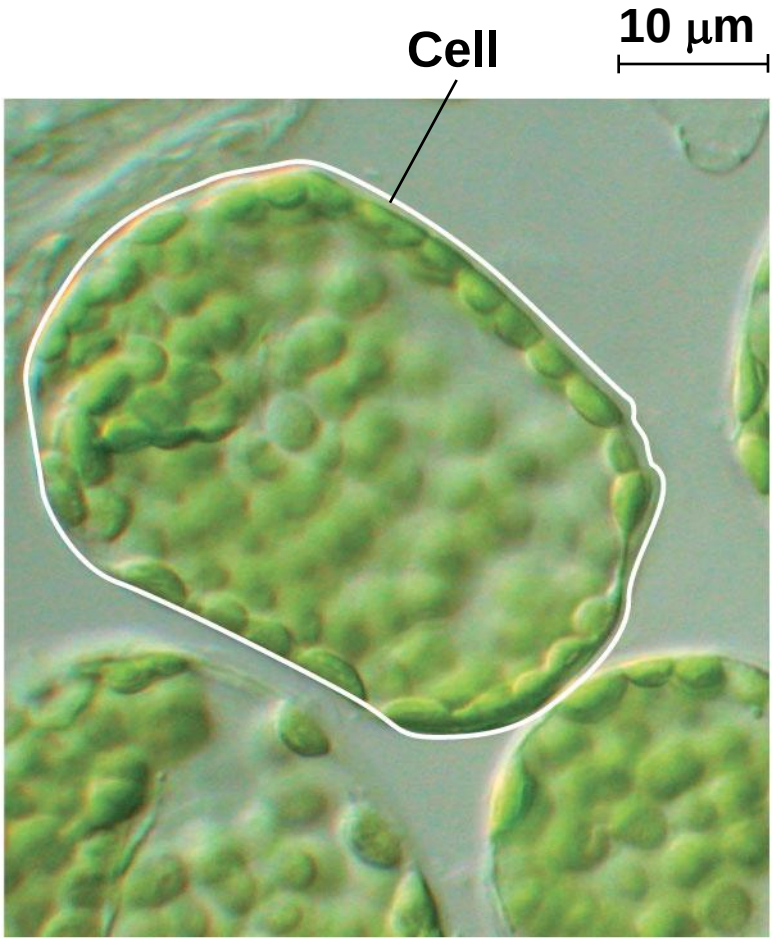
**Organs and organ systems**

Figure 1.4g



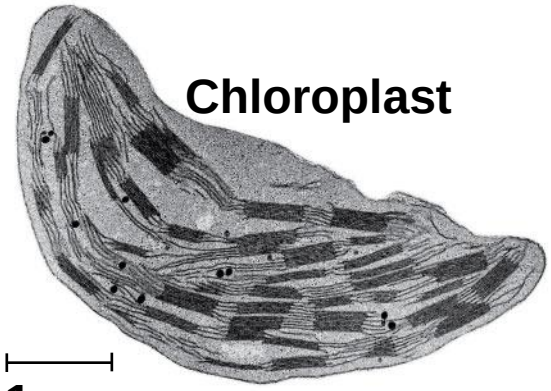

**Tissues**

Figure 1.4h



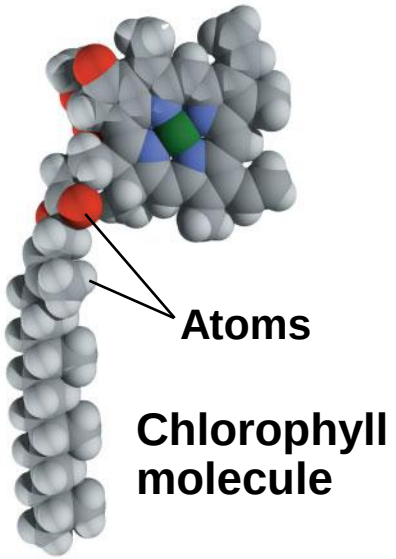

**Cells**

Figure 1.4i




**Organelles**

Figure 1.4j




**Molecules**

# *Emergent Properties*

- **Emergent properties** result from the arrangement and interaction of parts within a system
- Emergent properties characterize nonbiological entities as well
  - For example, a functioning bicycle emerges only when all of the necessary parts connect in the correct way

# *The Power and Limitations of Reductionism*

- Reductionism is the reduction of complex systems to simpler components that are more manageable to study
  - For example, studying the molecular structure of DNA helps us to understand the chemical basis of inheritance

- An understanding of biology balances reductionism with the study of emergent properties
  - For example, new understanding comes from studying the interactions of DNA with other molecules

# *Systems Biology*

- A system is a combination of components that function together
- **Systems biology** constructs models for the dynamic behavior of whole biological systems
- The systems approach poses questions such as
  - How does a drug for blood pressure affect other organs?
  - How does increasing $CO_2$ alter the biosphere?

# Theme: Organisms Interact with Other Organisms and the Physical Environment

- Every organism interacts with its environment, including nonliving factors and other organisms
- Both organisms and their environments are affected by the interactions between them
  - For example, a tree takes up water and minerals from the soil and carbon dioxide from the air; the tree releases oxygen to the air and roots help form soil

Figure 1.5

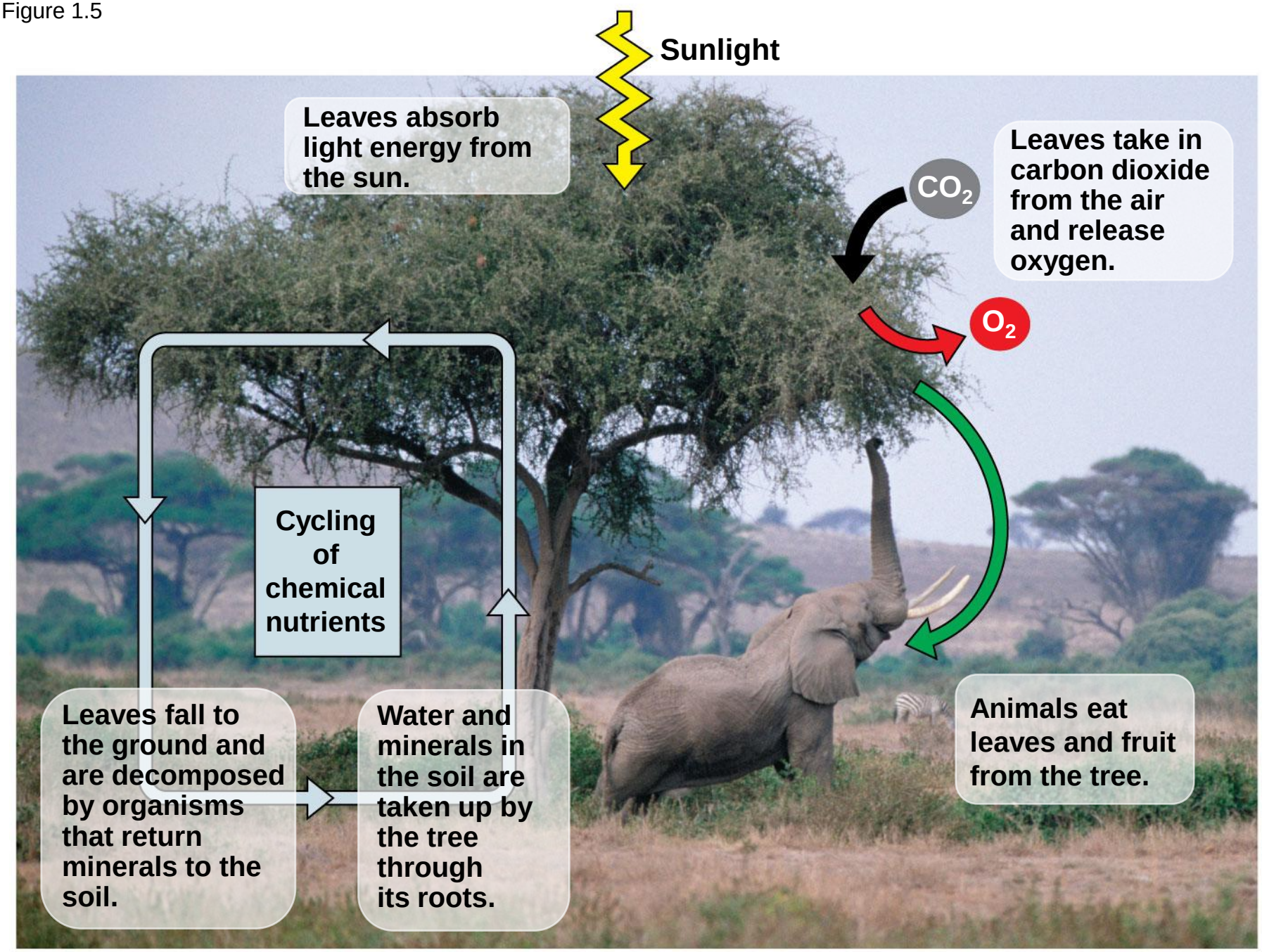


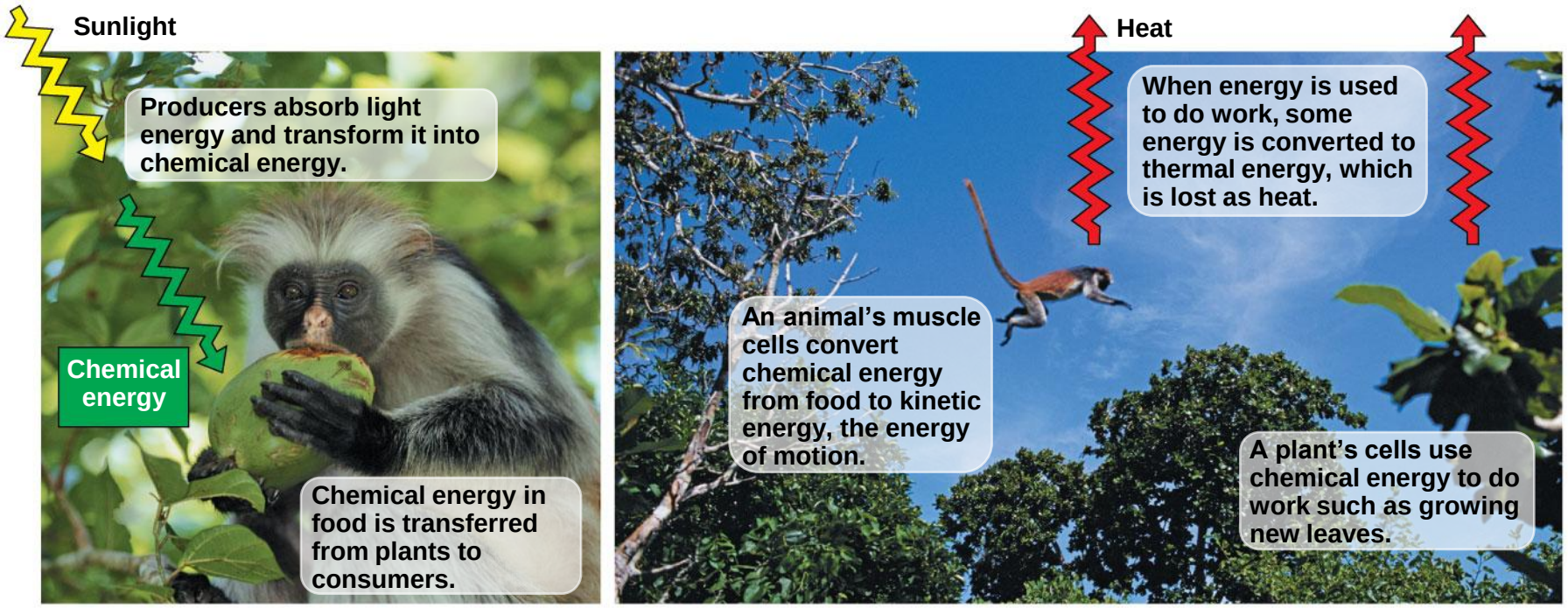
Figure 1.5a

- Humans have modified our environment
  - For example, half the human-generated $CO_2$ stays in the atmosphere and contributes to global warming
- Global warming is a major aspect of **global climate change**
- It is important to understand the effects of global climate change on the Earth and its populations

# Theme: Life Requires Energy Transfer and Transformation

- A fundamental characteristic of living organisms is their use of energy to carry out life's activities
- Work, including moving, growing, and reproducing, requires a source of energy
- Living organisms transform energy from one form to another
  - For example, light energy is converted to chemical energy, then kinetic energy
- Energy flows through an ecosystem, usually entering as light and exiting as heat

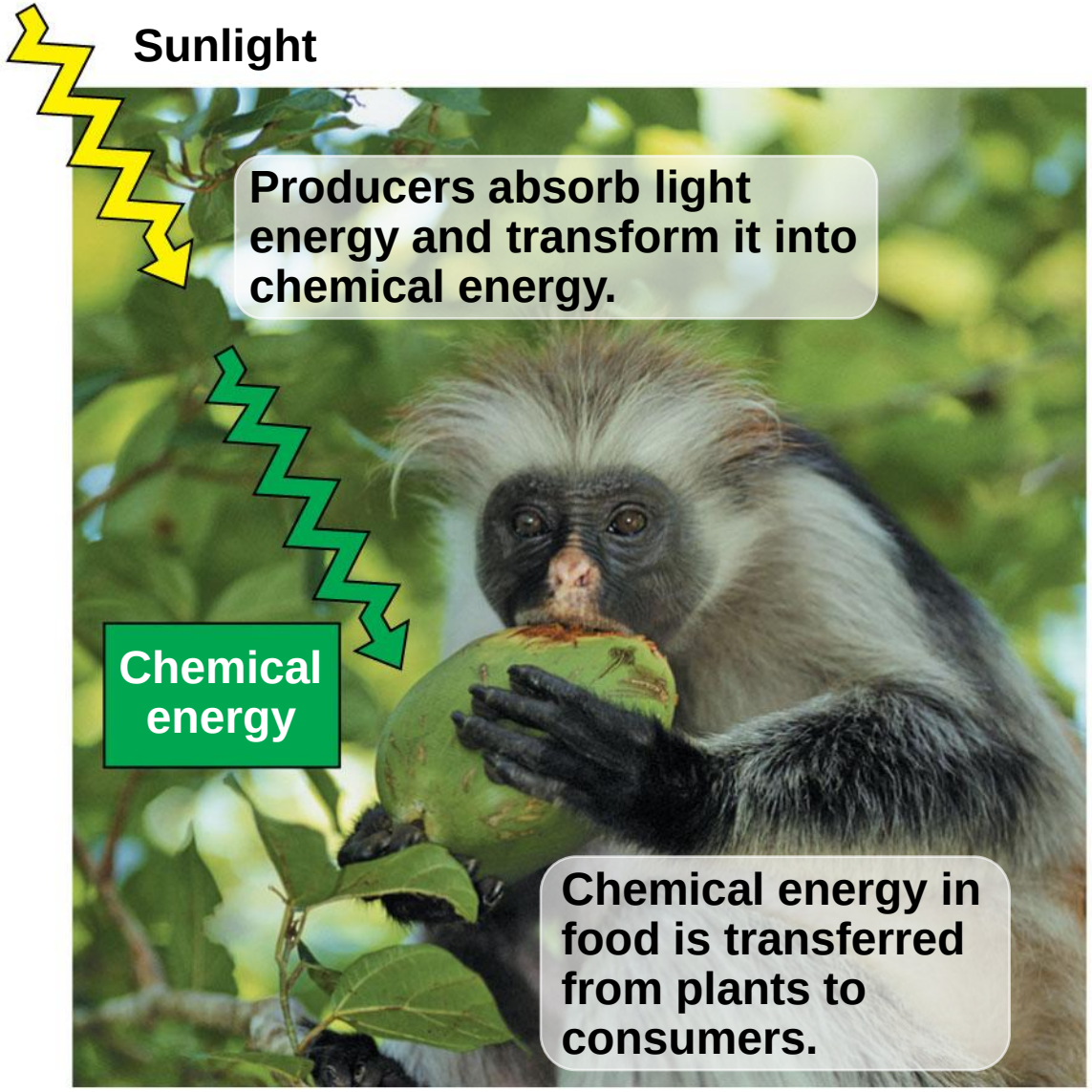
Figure 1.6




(a) Energy flow from sunlight to producers to consumers

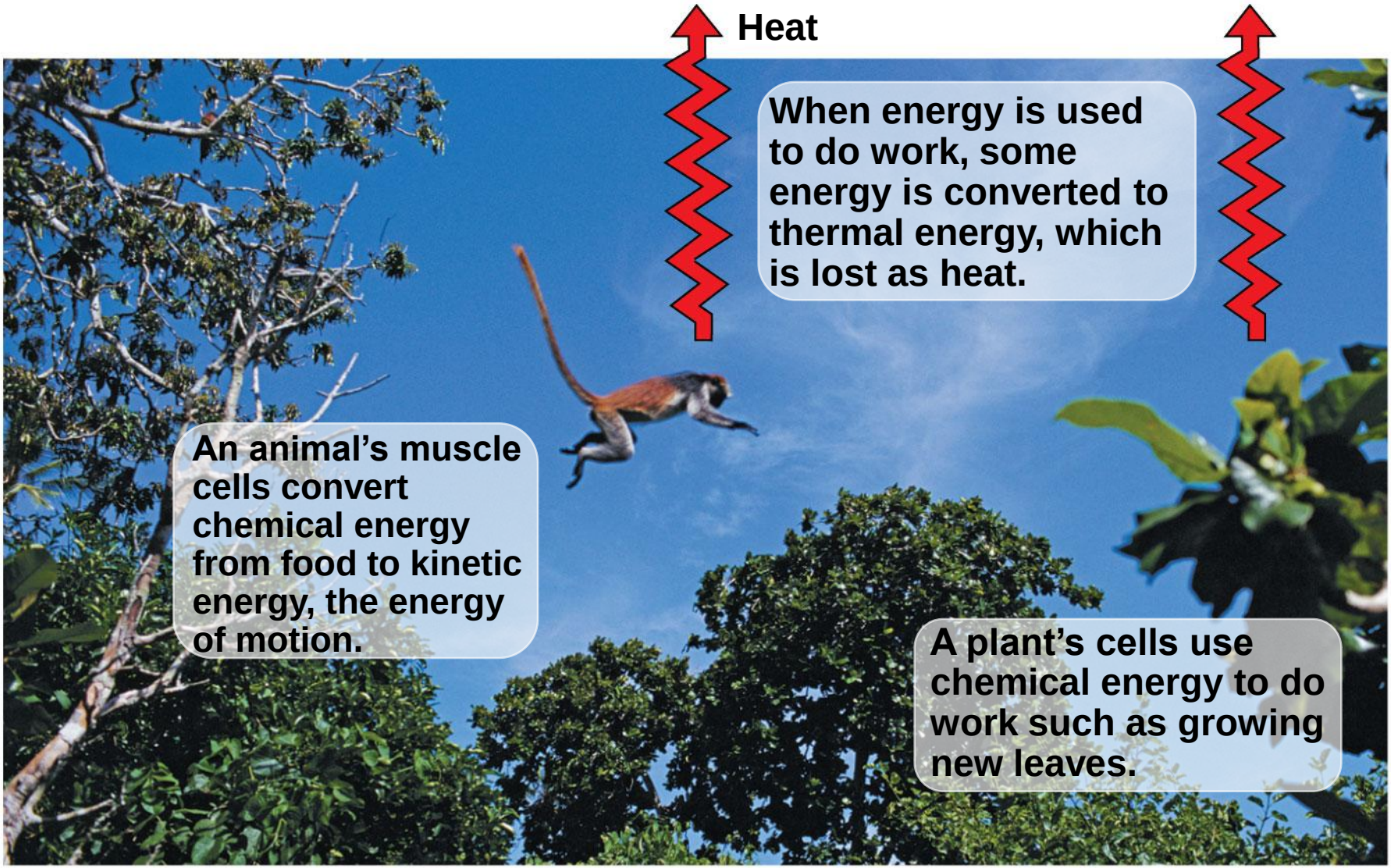
(b) Using energy to do work

Figure 1.6a




**(a) Energy flow from sunlight to producers to consumers**

Figure 1.6b




**(b) Using energy to do work**

Figure 1.6c

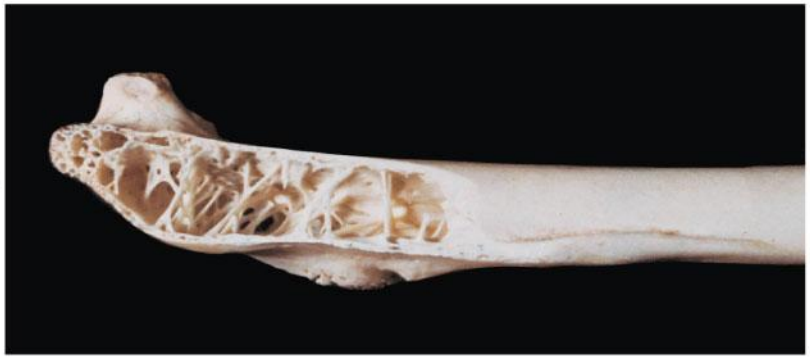
Figure 1.6d

# Theme: Structure and Function Are Correlated at All Levels of Biological Organization

- Structure and function of living organisms are closely related
  - For example, a leaf is thin and flat, maximizing the capture of light by chloroplasts
  - For example, the structure of a bird's wing is adapted to flight

Figure 1.7

(a) Wings

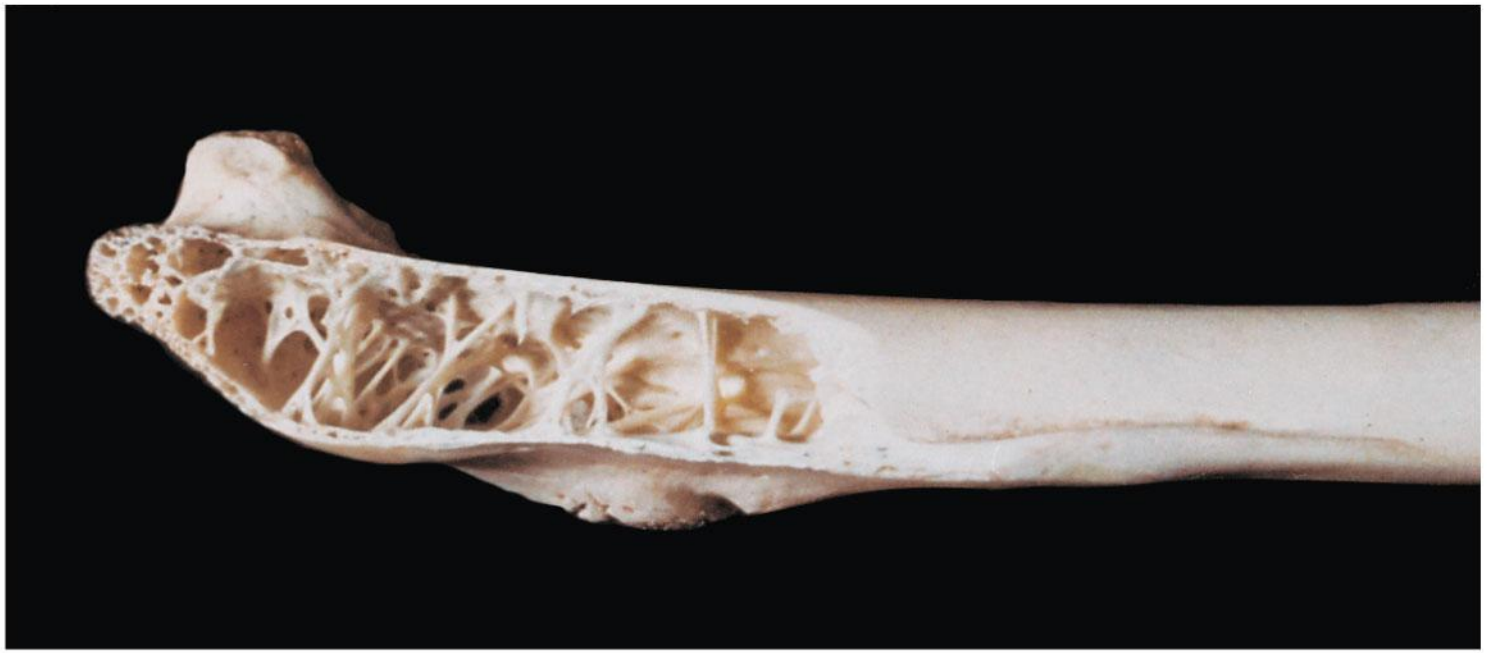


(b) Wing bones

Figure 1.7a

**(a) Wings**

Figure 1.7b



**(b) Wing bones**

Figure 1.7c

# Theme: The Cell Is an Organism's Basic Unit of Structure and Function

- The cell is the lowest level of organization that can perform all activities required for life
- All cells
  - Are enclosed by a membrane
  - Use DNA as their genetic information

- A **eukaryotic cell** has membrane-enclosed organelles, the largest of which is usually the nucleus
- By comparison, a **prokaryotic cell** is simpler and usually smaller, and does not contain a nucleus or other membrane-enclosed organelles

Figure 1.8

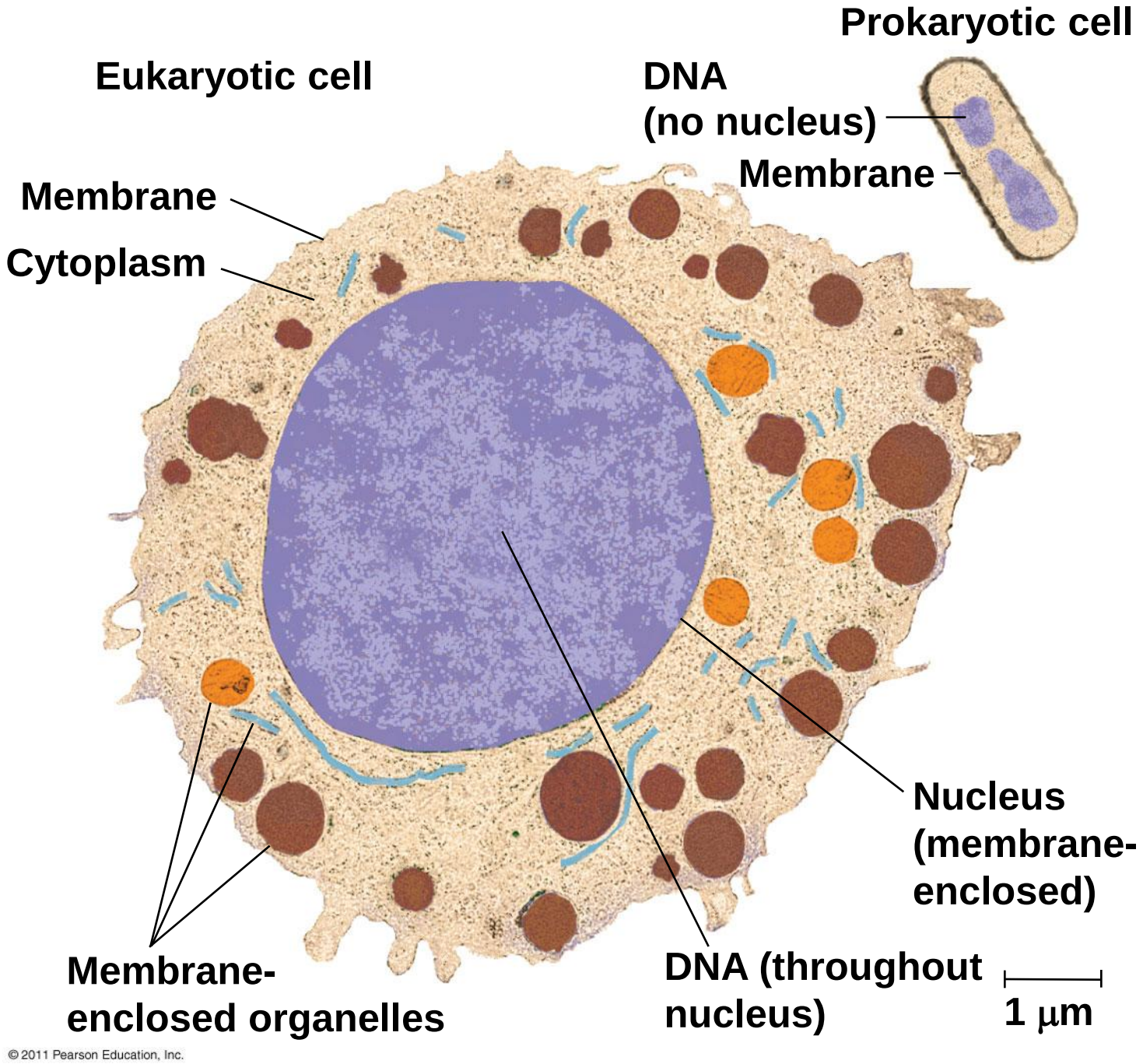


Figure 1.8a

# Eukaryotic cell

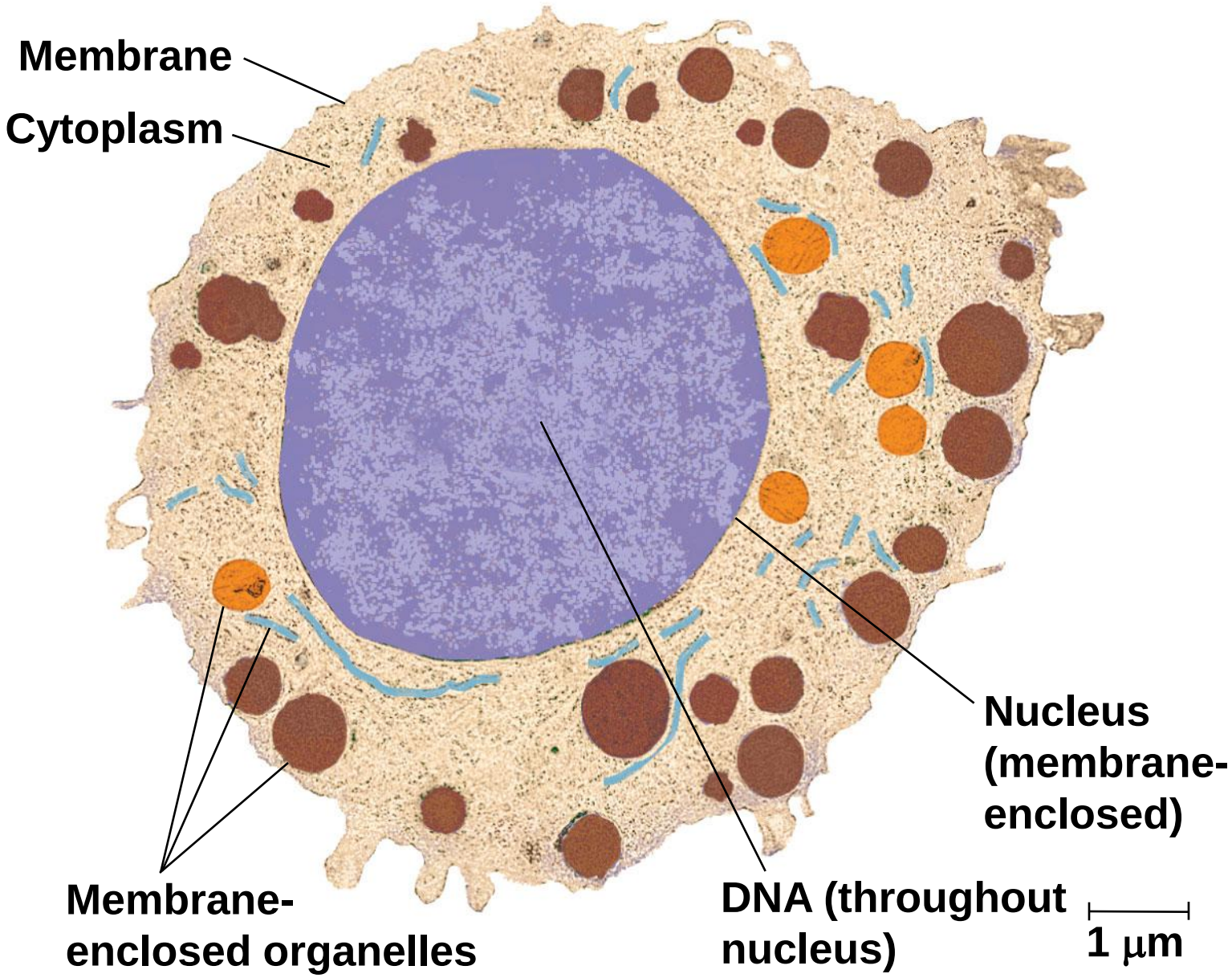
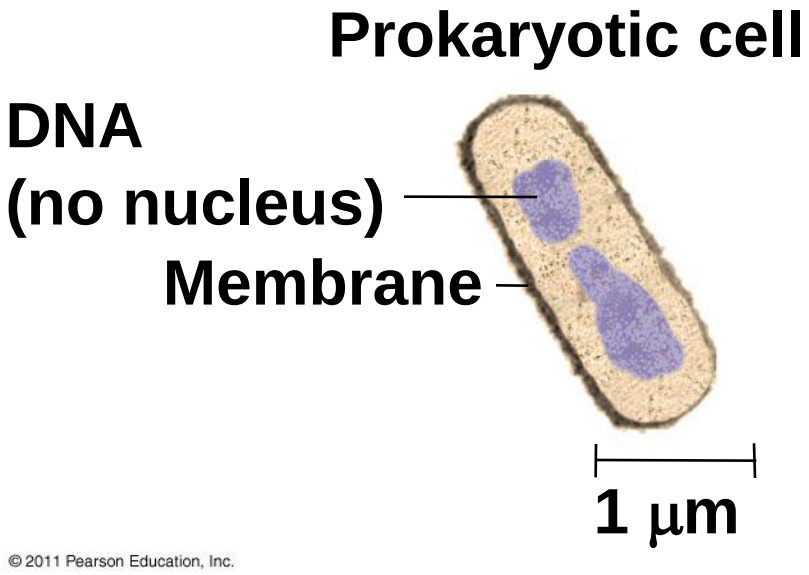


Figure 1.8b



# Theme: The Continuity of Life Is Based on Heritable Information in the Form of DNA

- Chromosomes contain most of a cell's genetic material in the form of **DNA** (deoxyribonucleic acid)
- DNA is the substance of genes
- **Genes** are the units of inheritance that transmit information from parents to offspring
- The ability of cells to divide is the basis of all reproduction, growth, and repair of multicellular organisms

Figure 1.9

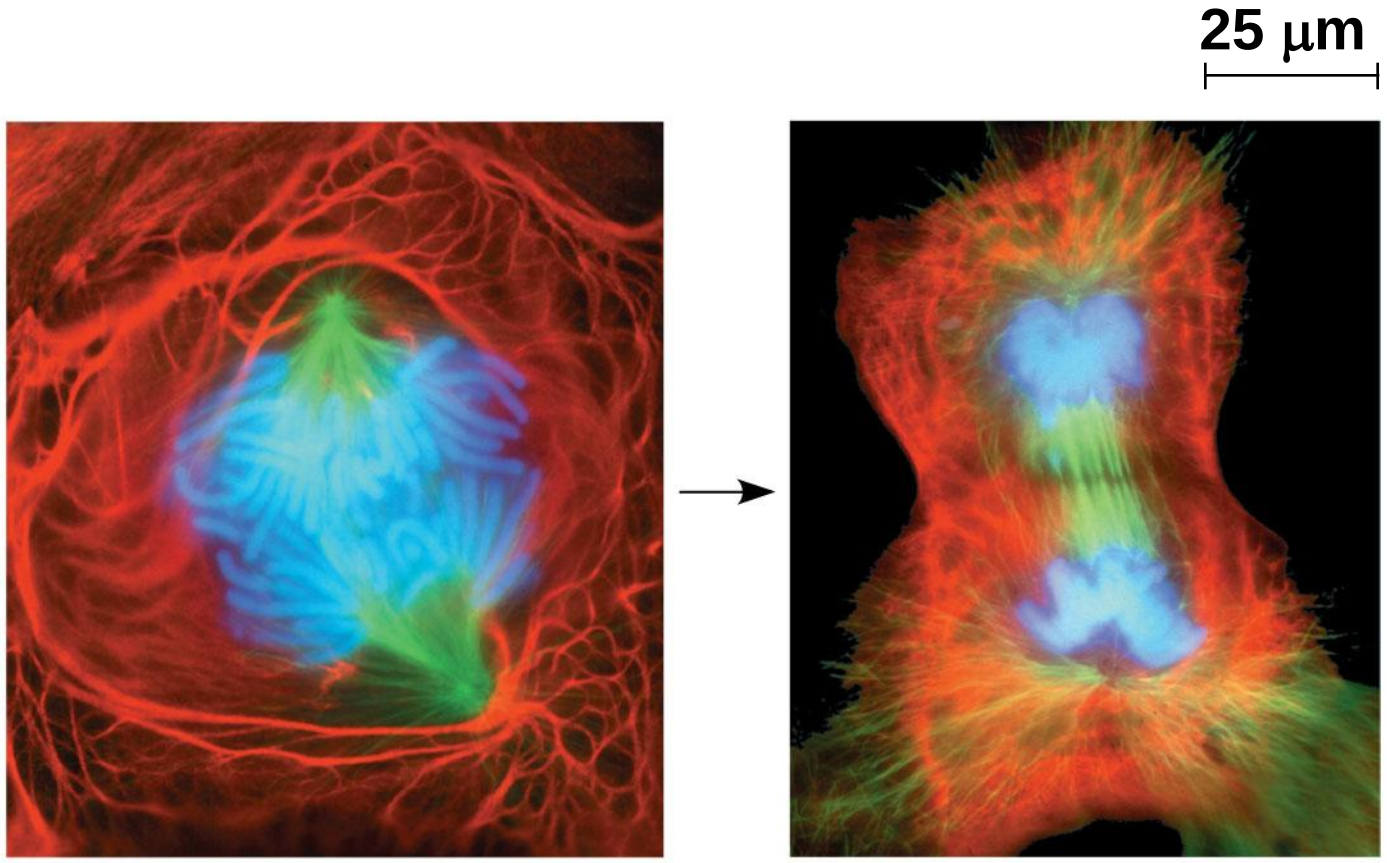


Figure 1.9a

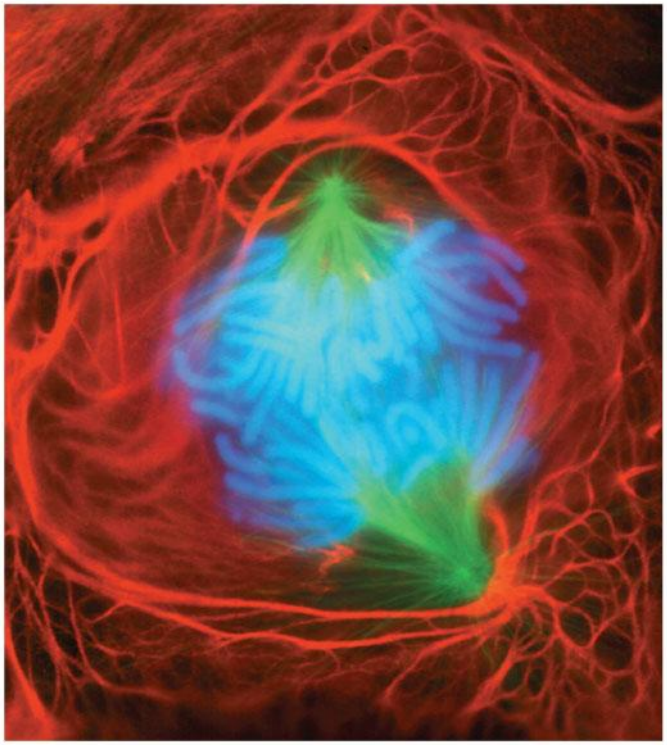
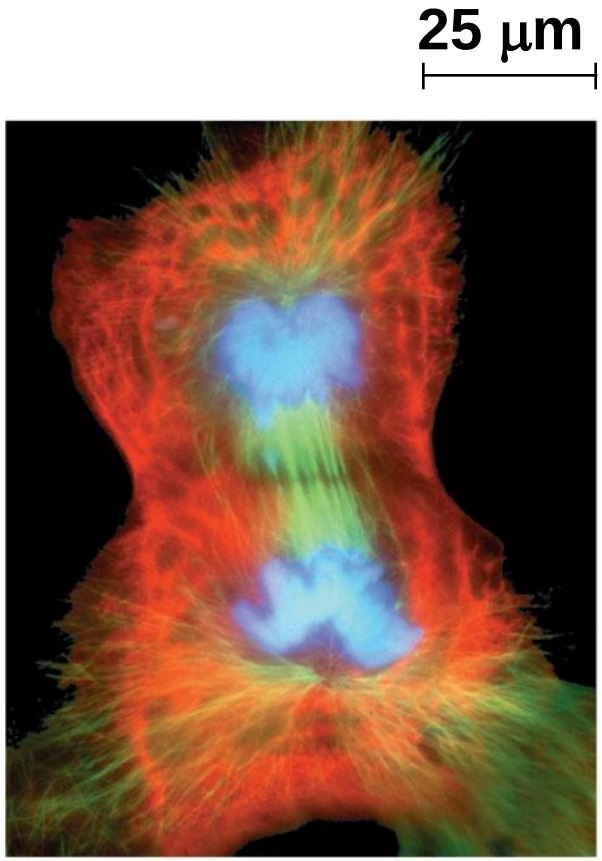


Figure 1.9b



# *DNA Structure and Function*

- Each chromosome has one long DNA molecule with hundreds or thousands of genes
- Genes encode information for building proteins
- DNA is inherited by offspring from their parents
- DNA controls the development and maintenance of organisms

Figure 1.10

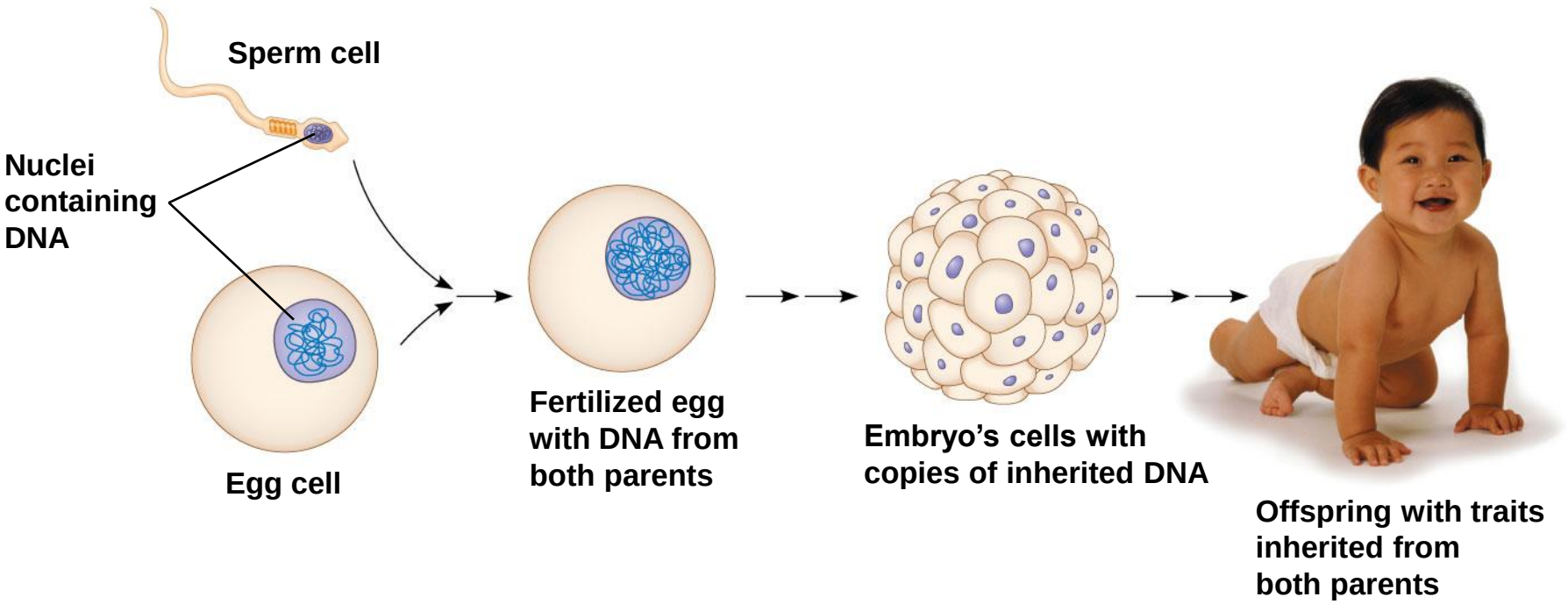


Figure 1.10a

- Each DNA molecule is made up of two long chains arranged in a double helix
- Each link of a chain is one of four kinds of chemical building blocks called nucleotides and nicknamed A, G, C, and T

Figure 1.11

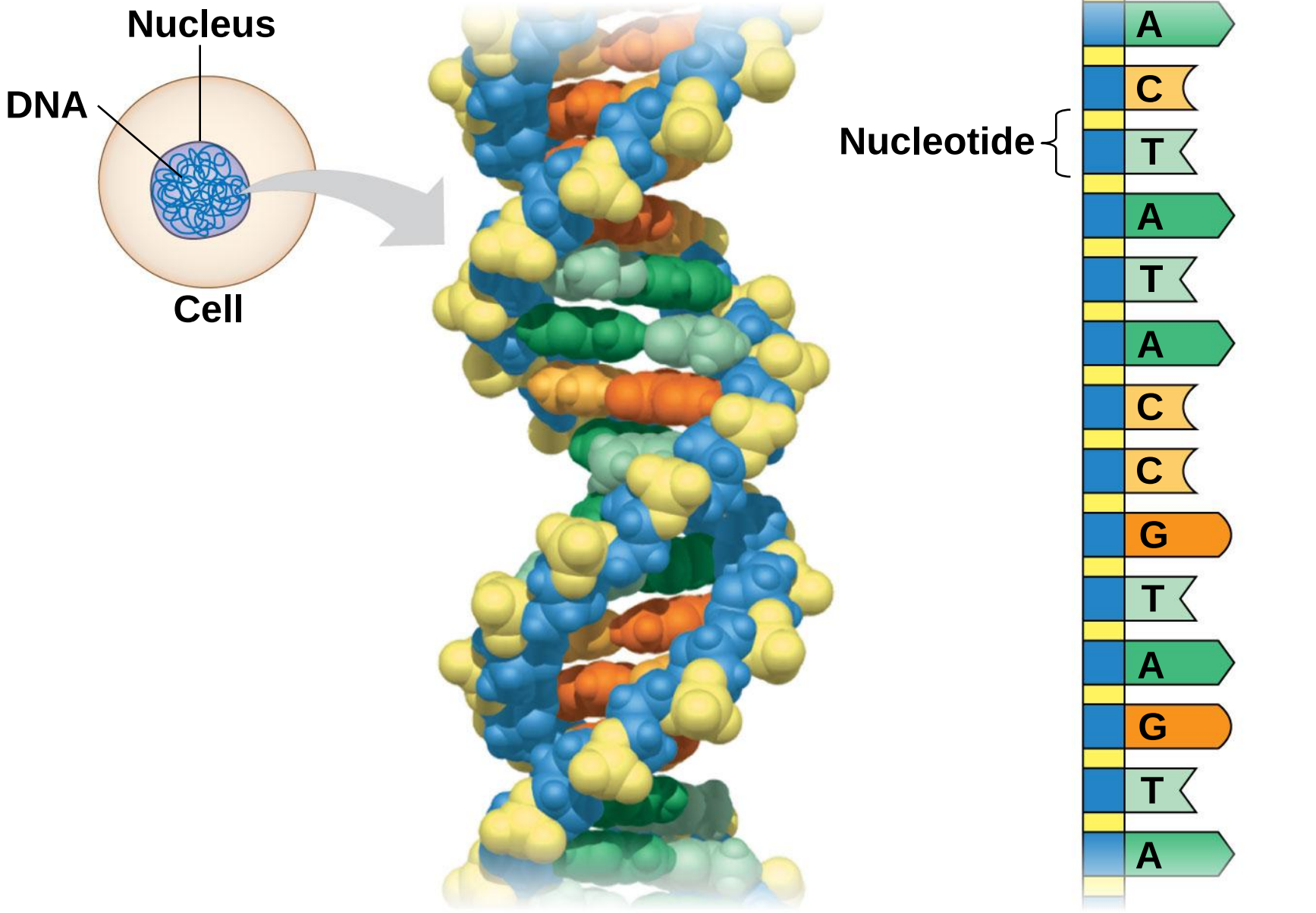
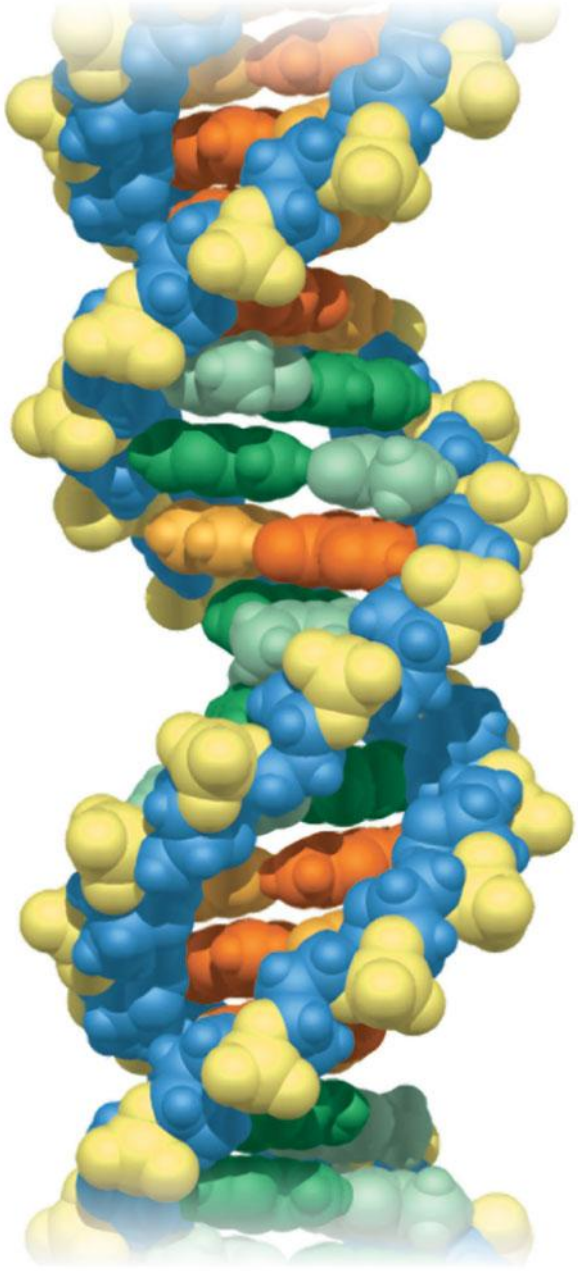


Figure 1.11a



- Genes control protein production indirectly
- DNA is transcribed into RNA then translated into a protein
- **Gene expression** is the process of converting information from gene to cellular product

# *Genomics: Large-Scale Analysis of DNA Sequences*

- An organism's **genome** is its entire set of genetic instructions
- The human genome and those of many other organisms have been sequenced using DNA-sequencing machines
- **Genomics** is the study of sets of genes within and between species

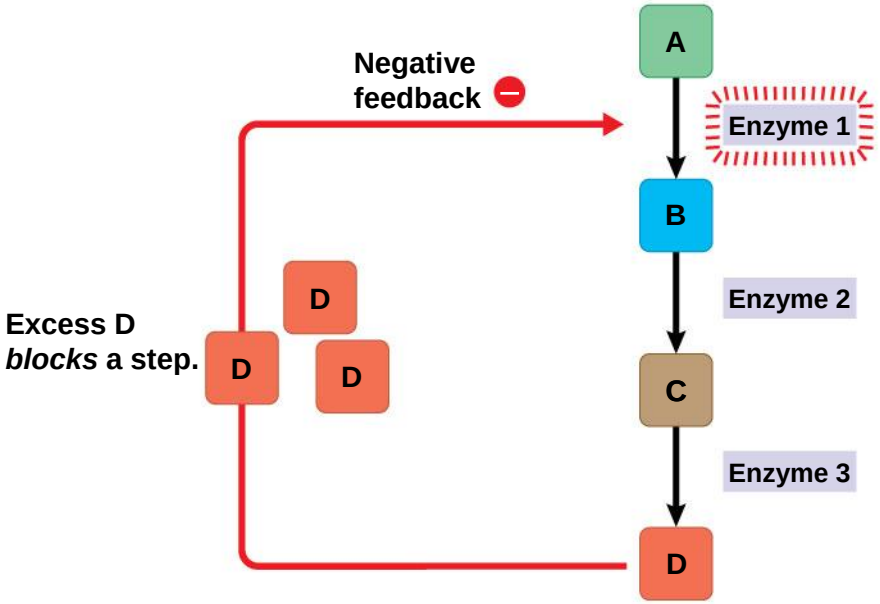
Figure 1.12

- The genomics approach depends on
  - "High-throughput" technology, which yields enormous amounts of data
  - **Bioinformatics,** which is the use of computational tools to process a large volume of data
  - Interdisciplinary research teams

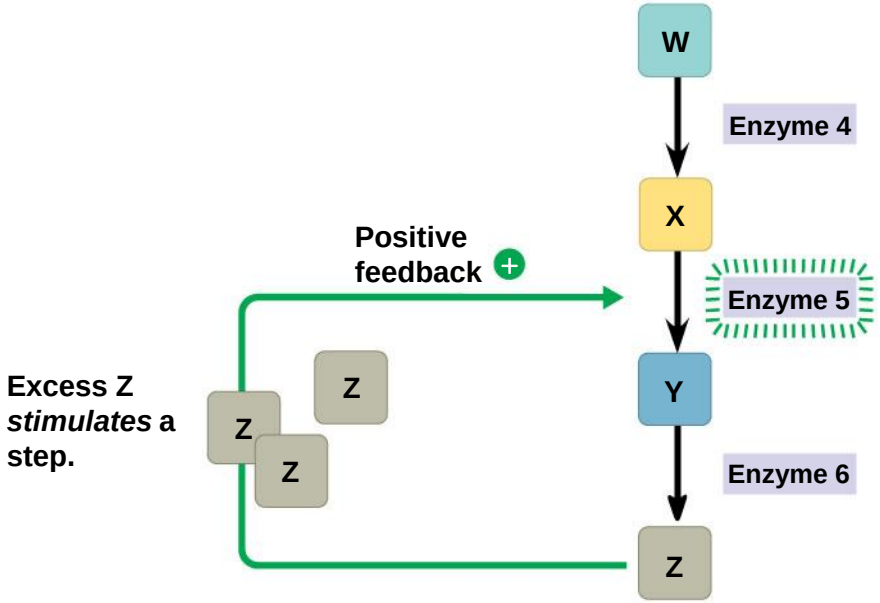
# Theme: Feedback Mechanisms Regulate Biological Systems

- Feedback mechanisms allow biological processes to self-regulate
- **Negative feedback** means that as more of a product accumulates, the process that creates it slows and less of the product is produced
- **Positive feedback** means that as more of a product accumulates, the process that creates it speeds up and more of the product is produced

Figure 1.13

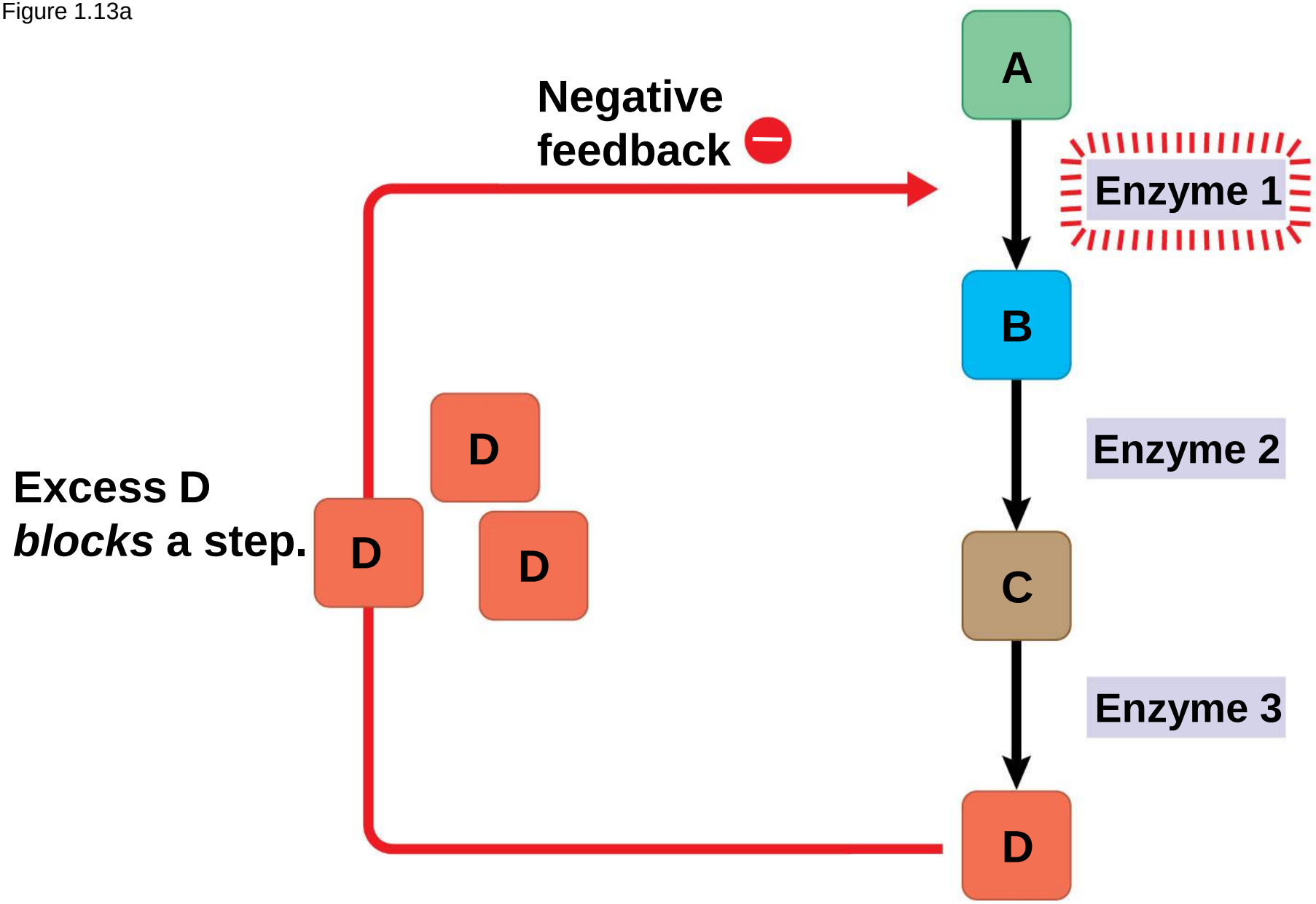



(a) Negative feedback



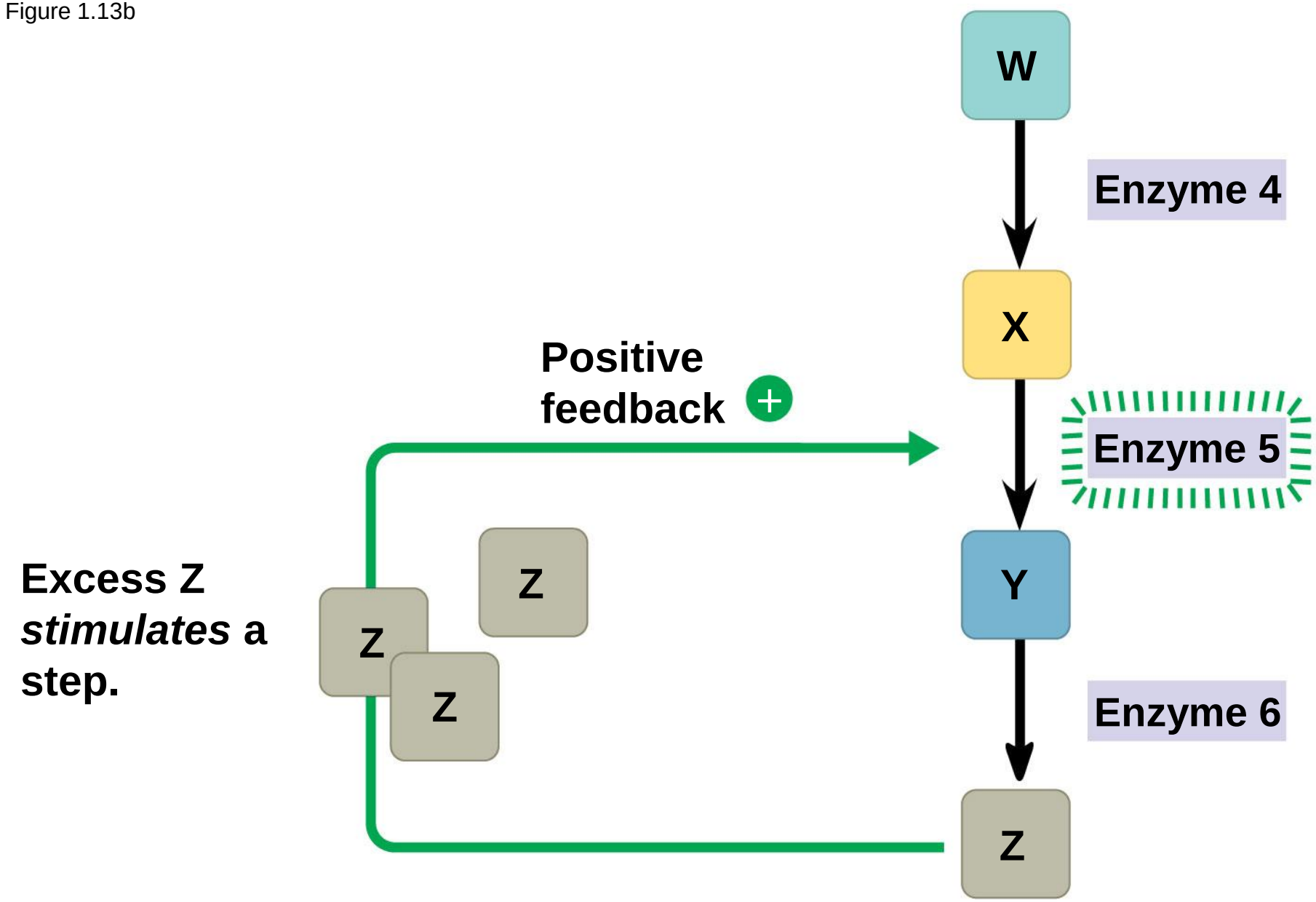

(b) Positive feedback

Figure 1.13a




(a) Negative feedback

Figure 1.13b




**(b) Positive feedback**

# Evolution, the Overarching Theme of Biology

- Evolution makes sense of everything we know about biology
- Organisms are modified descendants of common ancestors

- Evolution explains patterns of unity and diversity in living organisms
- Similar traits among organisms are explained by descent from common ancestors
- Differences among organisms are explained by the accumulation of heritable changes

# Concept 1.2: The Core Theme: Evolution accounts for the unity and diversity of life

- "Nothing in biology makes sense except in the light of evolution"—Theodosius Dobzhansky
- Evolution unifies biology at different scales of size throughout the history of life on Earth

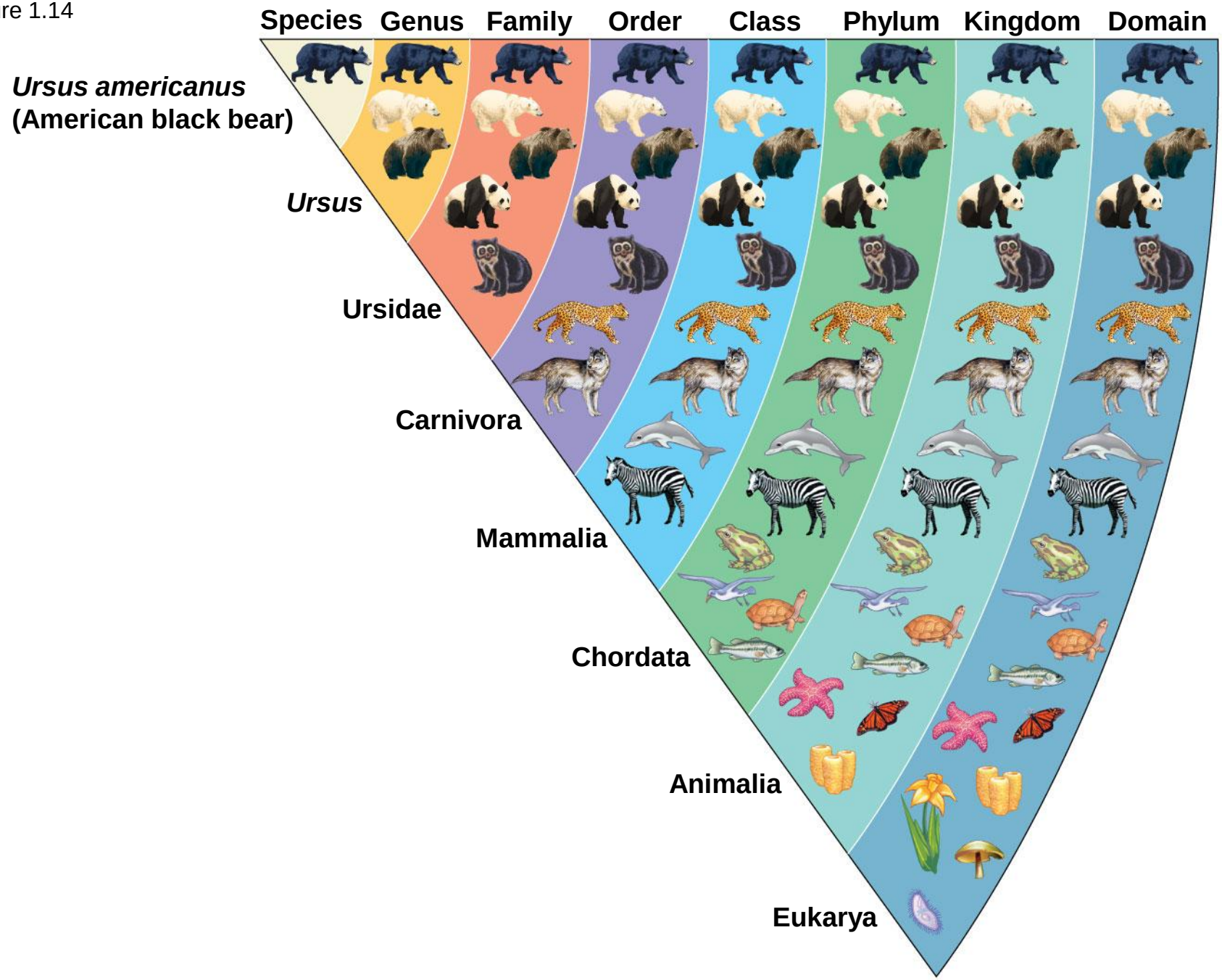
# Classifying the Diversity of Life

- Approximately 1.8 million species have been identified and named to date, and thousands more are identified each year
- Estimates of the total number of species that actually exist range from 10 million to over 100 million

# *Grouping Species: The Basic Idea*

- Taxonomy is the branch of biology that names and classifies species into groups of increasing breadth
- Domains, followed by kingdoms, are the broadest units of classification

Figure 1.14



# *The Three Domains of Life*

- Organisms are divided into three domains
- Domain **Bacteria** and domain **Archaea** compose the prokaryotes
- Most prokaryotes are single-celled and microscopic

Figure 1.15

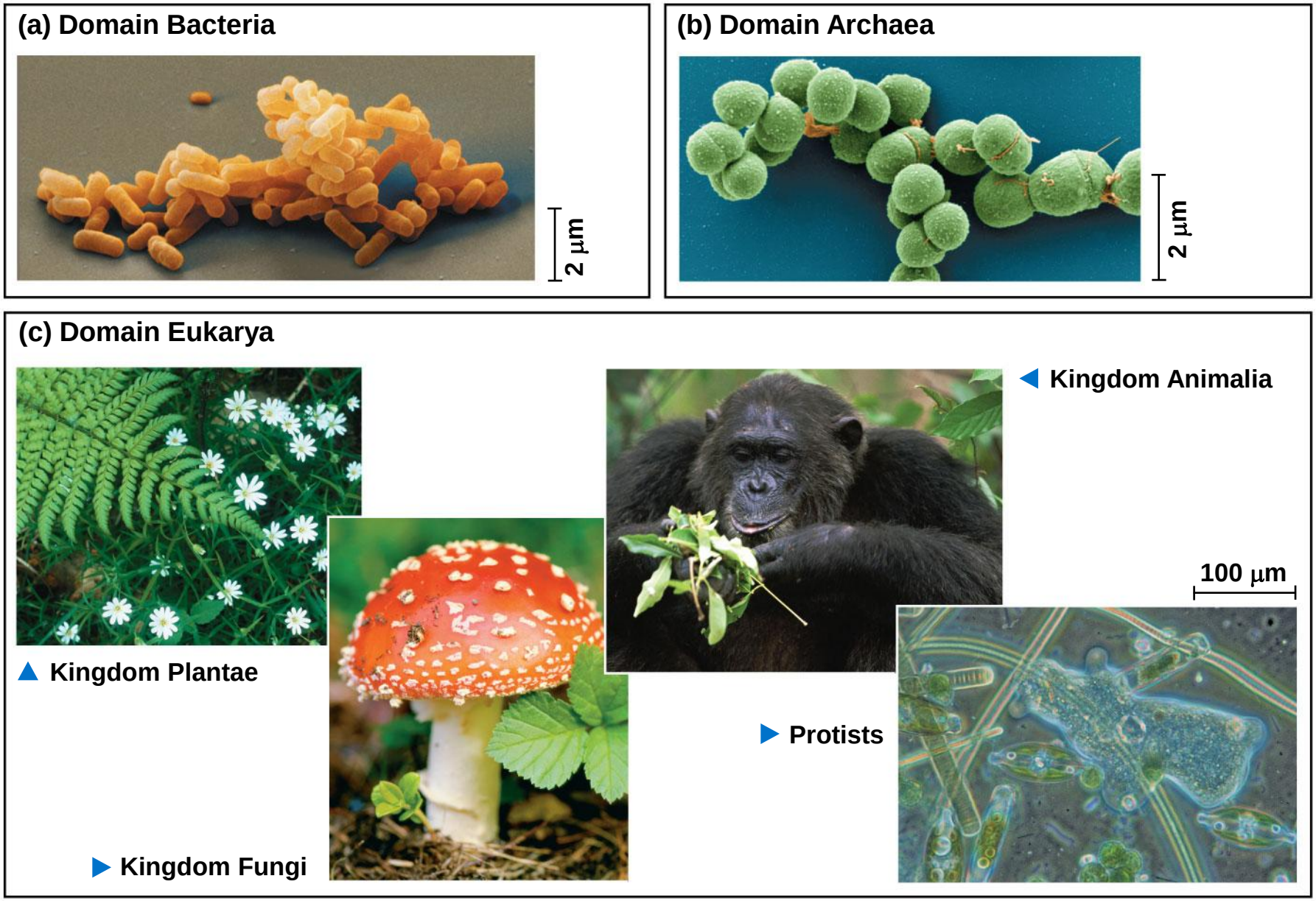


Figure 1.15a

## (a) Domain Bacteria

Figure 1.15b

## (b) Domain Archaea

- Domain **Eukarya** includes all eukaryotic organisms
- Domain Eukarya includes three multicellular kingdoms
  - Plants, which produce their own food by photosynthesis
  - Fungi, which absorb nutrients
  - Animals, which ingest their food

- Other eukaryotic organisms were formerly grouped into the Protist kingdom, though these are now often grouped into many separate groups

Figure 1.15c

**(c) Domain Eukarya**

▲ **Kingdom Plantae**

▶ **Kingdom Fungi**

◀ **Kingdom Animalia**

**100 μm**

▶ **Protists**

Figure 1.15ca

**Kingdom Plantae**

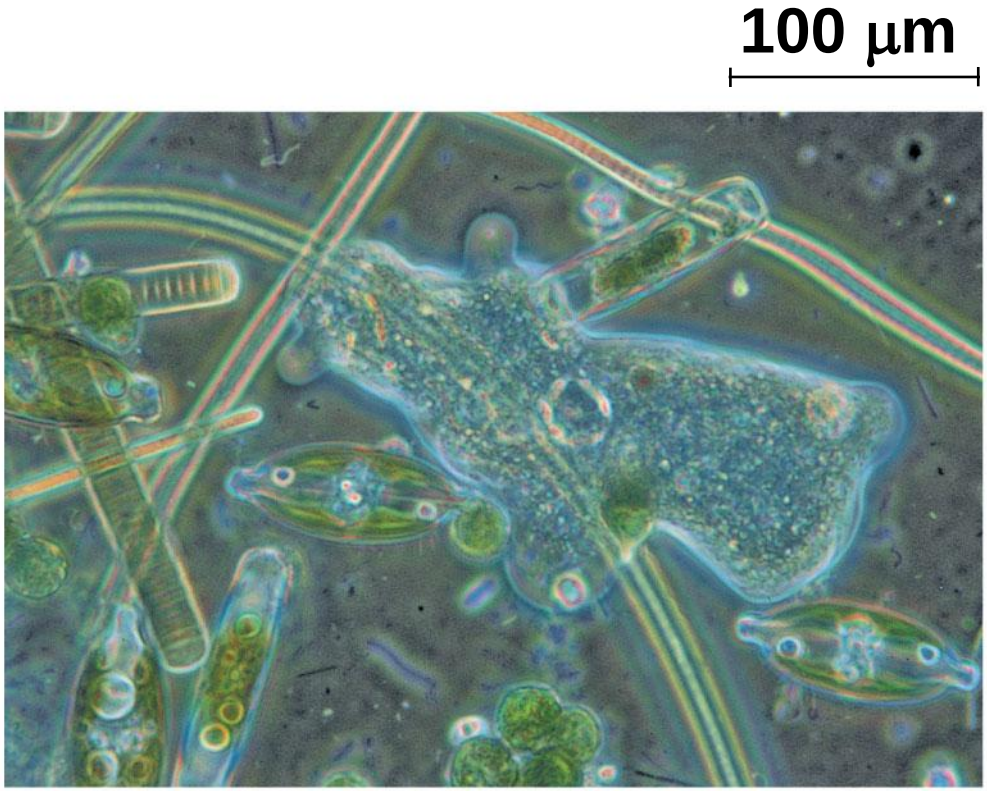
Figure 1.15cb

**Kingdom Fungi**

Figure 1.15cc

**Kingdom Animalia**

Figure 1.15cd




**Protists**

# *Unity in the Diversity of Life*

- A striking unity underlies the diversity of life; for example
  - DNA is the universal genetic language common to all organisms
  - Unity is evident in many features of cell structure

Figure 1.16

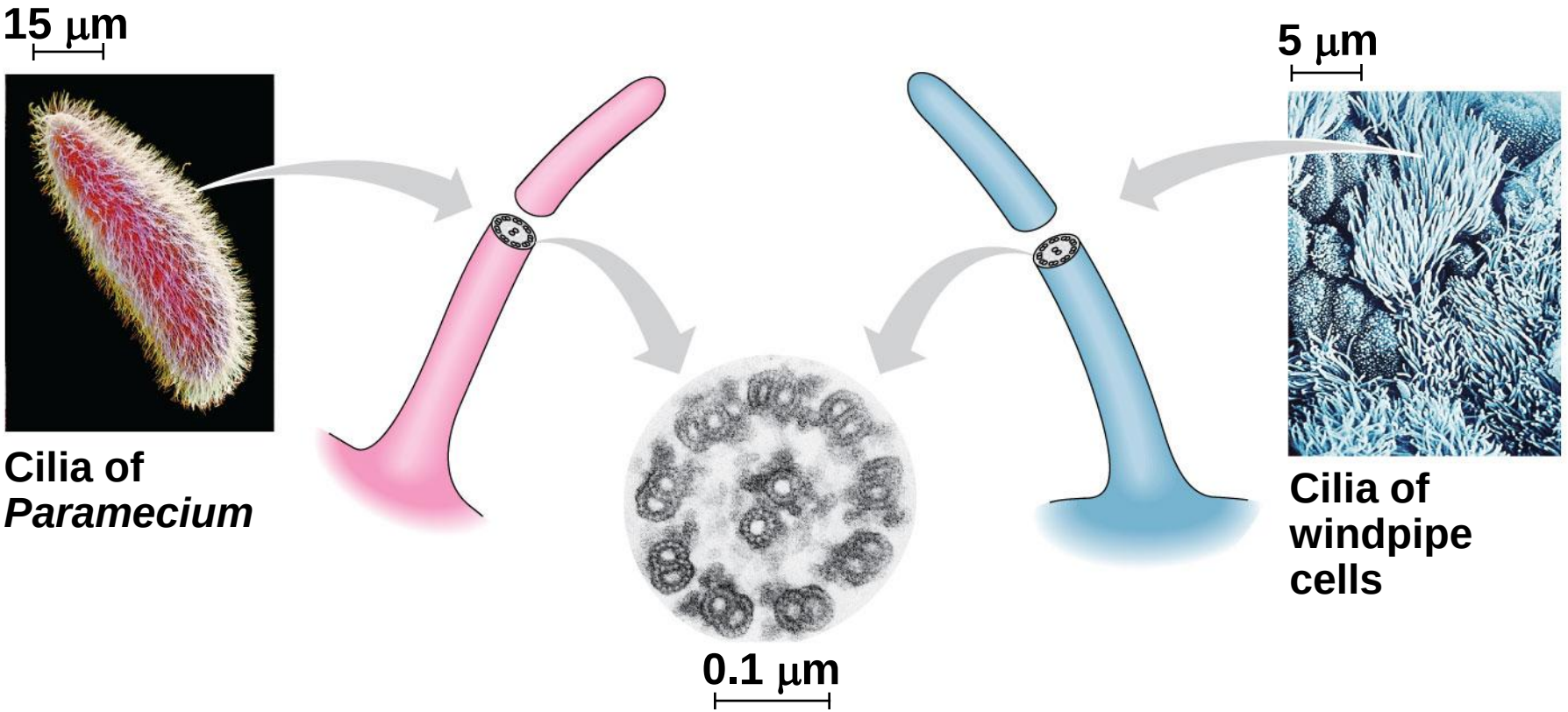
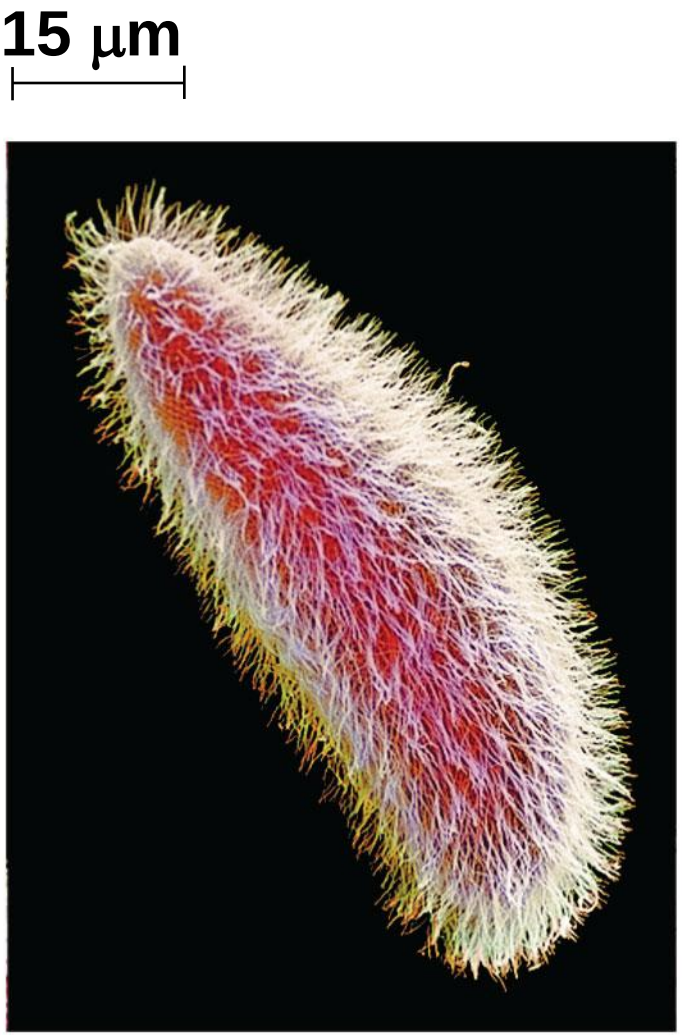


Figure 1.16a




**Cilia of *Paramecium***

Figure 1.16b


Cilia of windpipe cells

Figure 1.16c


**Cross section of a cilium, as viewed with an electron microscope**

# Charles Darwin and the Theory of Natural Selection

- Fossils and other evidence document the evolution of life on Earth over billions of years

Figure 1.17

- Charles Darwin published *On the Origin of Species by Means of Natural Selection* in 1859
- Darwin made two main points
  - Species showed evidence of "descent with modification" from common ancestors
  - Natural selection is the mechanism behind "descent with modification"
- Darwin's theory explained the duality of unity and diversity

Figure 1.18

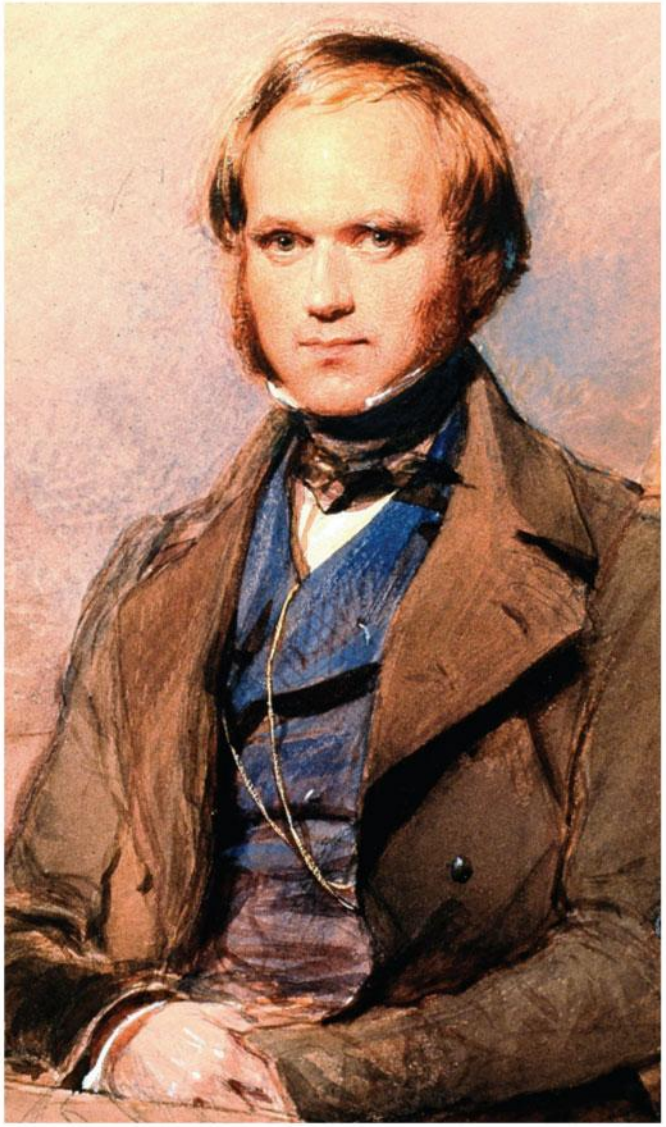


Figure 1.19

Figure 1.19a

Figure 1.19b

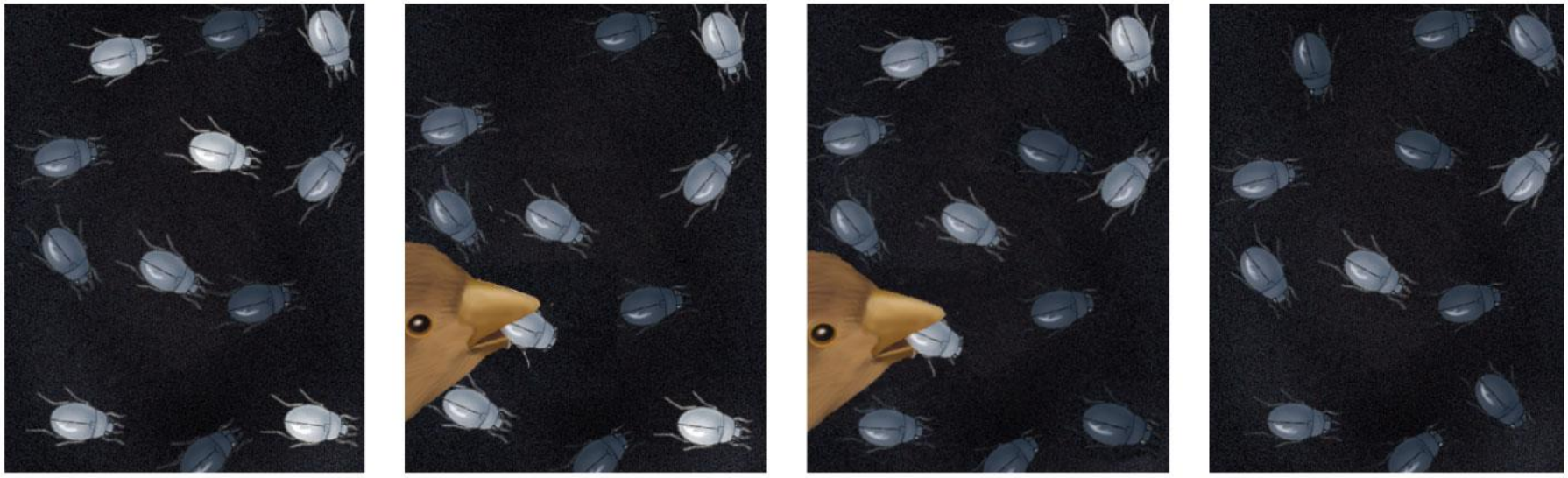
Figure 1.19c

- Darwin observed that
  - Individuals in a population vary in their traits, many of which are heritable
  - More offspring are produced than survive, and competition is inevitable
  - Species generally suit their environment

- Darwin inferred that
  - Individuals that are best suited to their environment are more likely to survive and reproduce
  - Over time, more individuals in a population will have the advantageous traits
- Evolution occurs as the unequal reproductive success of individuals

- In other words, the environment “selects” for the propagation of beneficial traits
- Darwin called this process **natural selection**

Figure 1.20



1 Population with varied inherited traits

2 Elimination of individuals with certain traits

3 Reproduction of survivors

4 Increasing frequency of traits that enhance survival and reproductive success

- Natural selection results in the adaptation of organisms to their environment
  - For example, bat wings are an example of adaptation

Figure 1.21

# The Tree of Life

- "Unity in diversity" arises from "descent with modification"
  - For example, the forelimb of the bat, human, and horse and the whale flipper all share a common skeletal architecture
- Fossils provide additional evidence of anatomical unity from descent with modification

- Darwin proposed that natural selection could cause an ancestral species to give rise to two or more descendent species
  - For example, the finch species of the Galápagos Islands are descended from a common ancestor
- Evolutionary relationships are often illustrated with treelike diagrams that show ancestors and their descendants

Figure 1.22

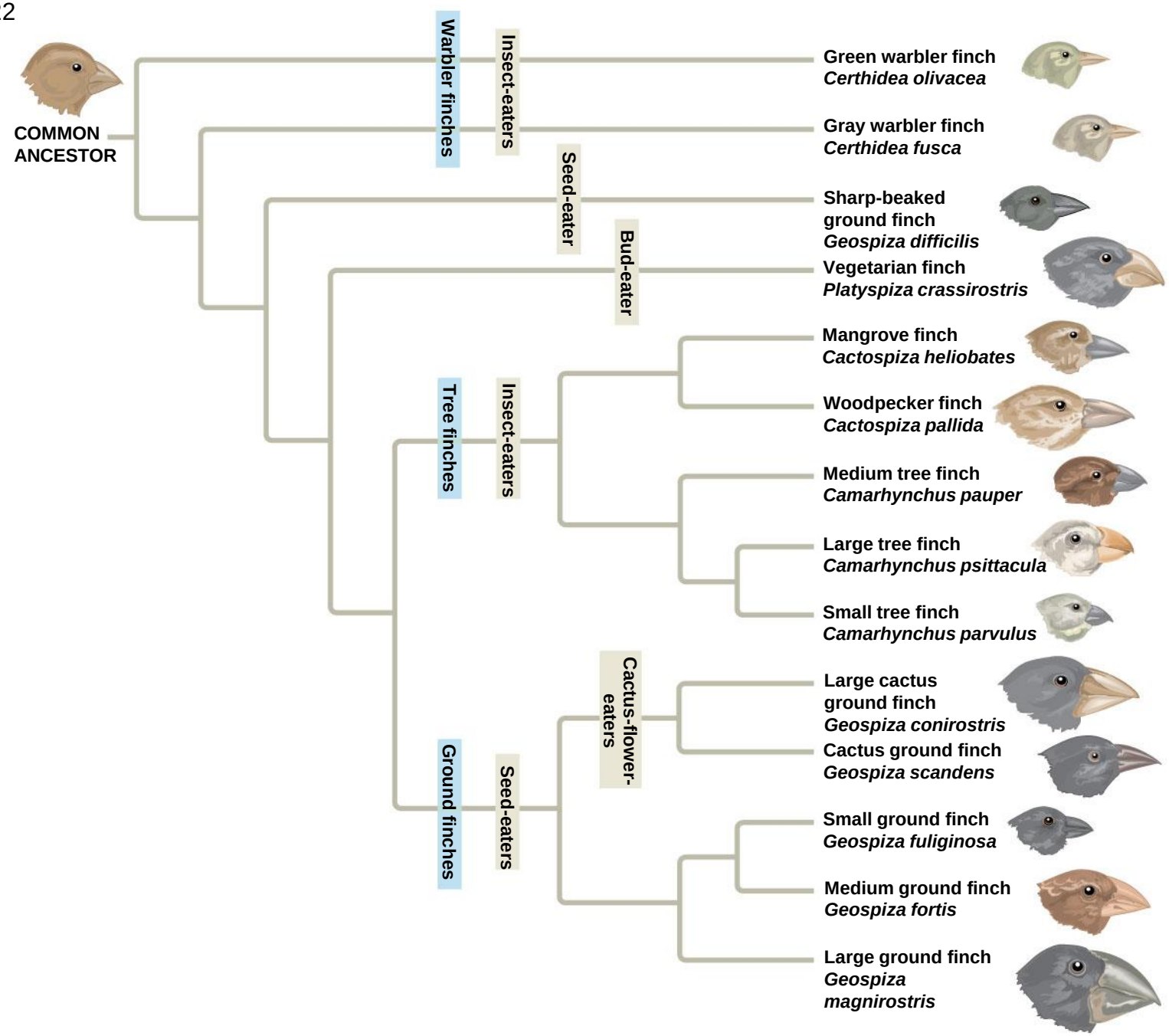


Figure 1.22a

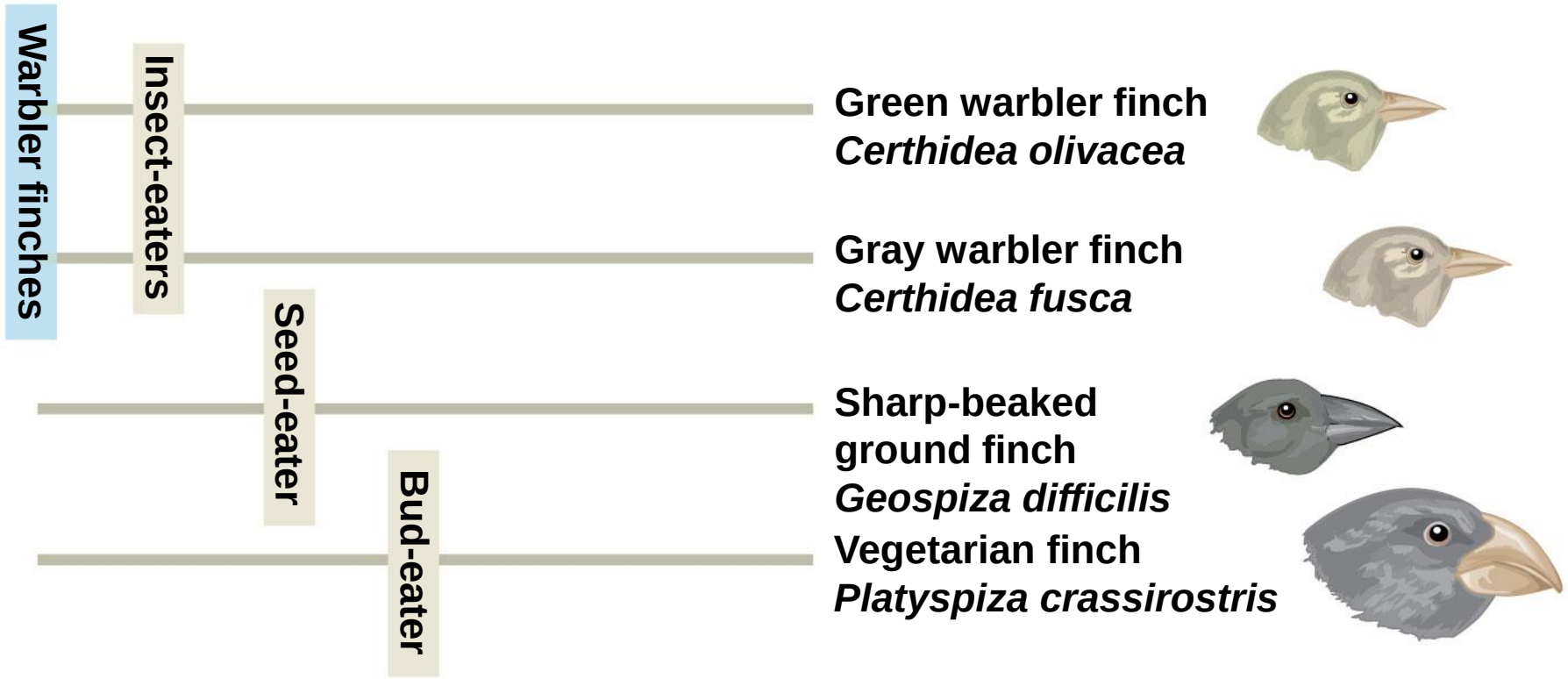


Figure 1.22b

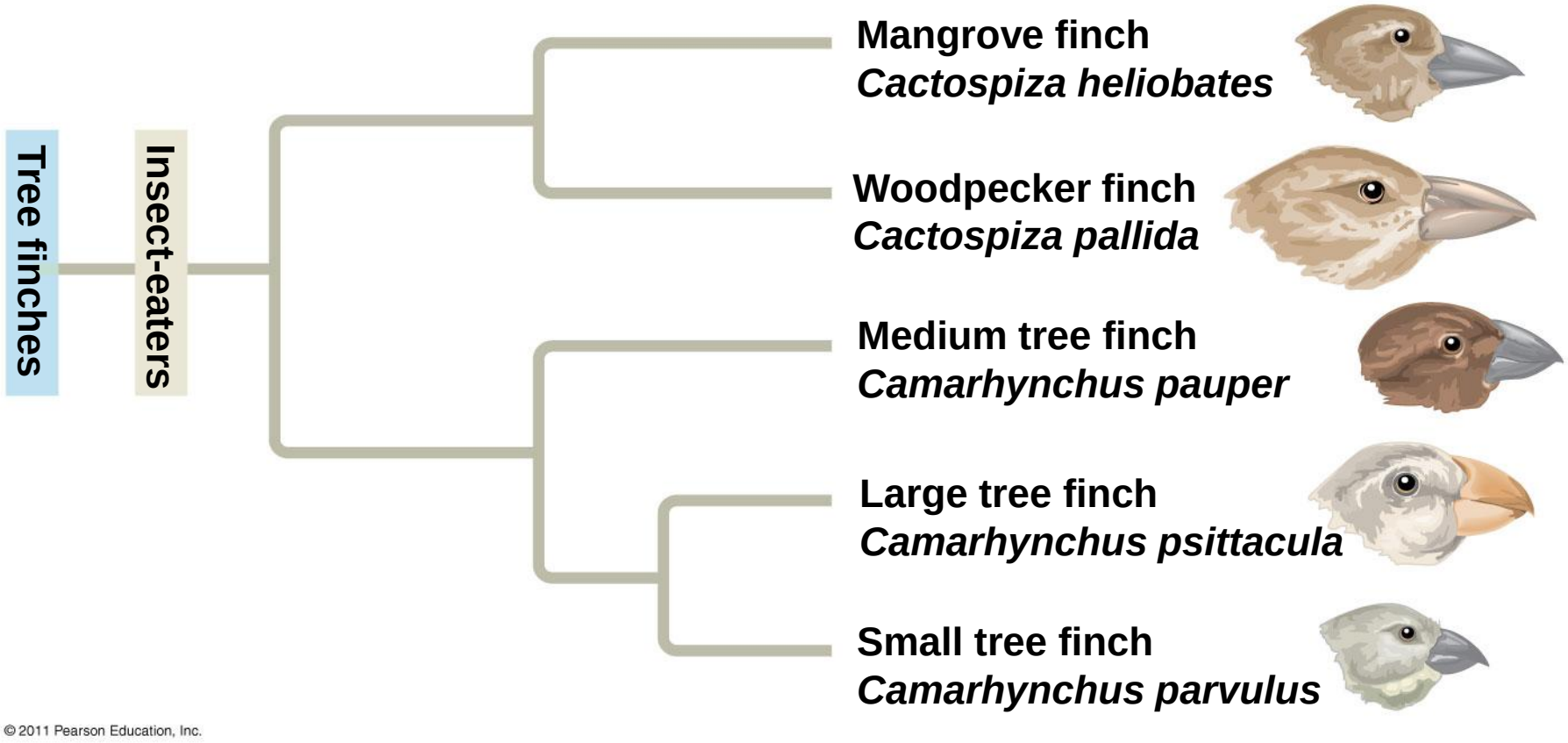


Figure 1.22c