**LECTURE PRESENTATIONS**

For CAMPBELL BIOLOGY, NINTH EDITION

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# Chapter 1

# Introduction: Themes in the Study of Life

**Lectures by**
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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

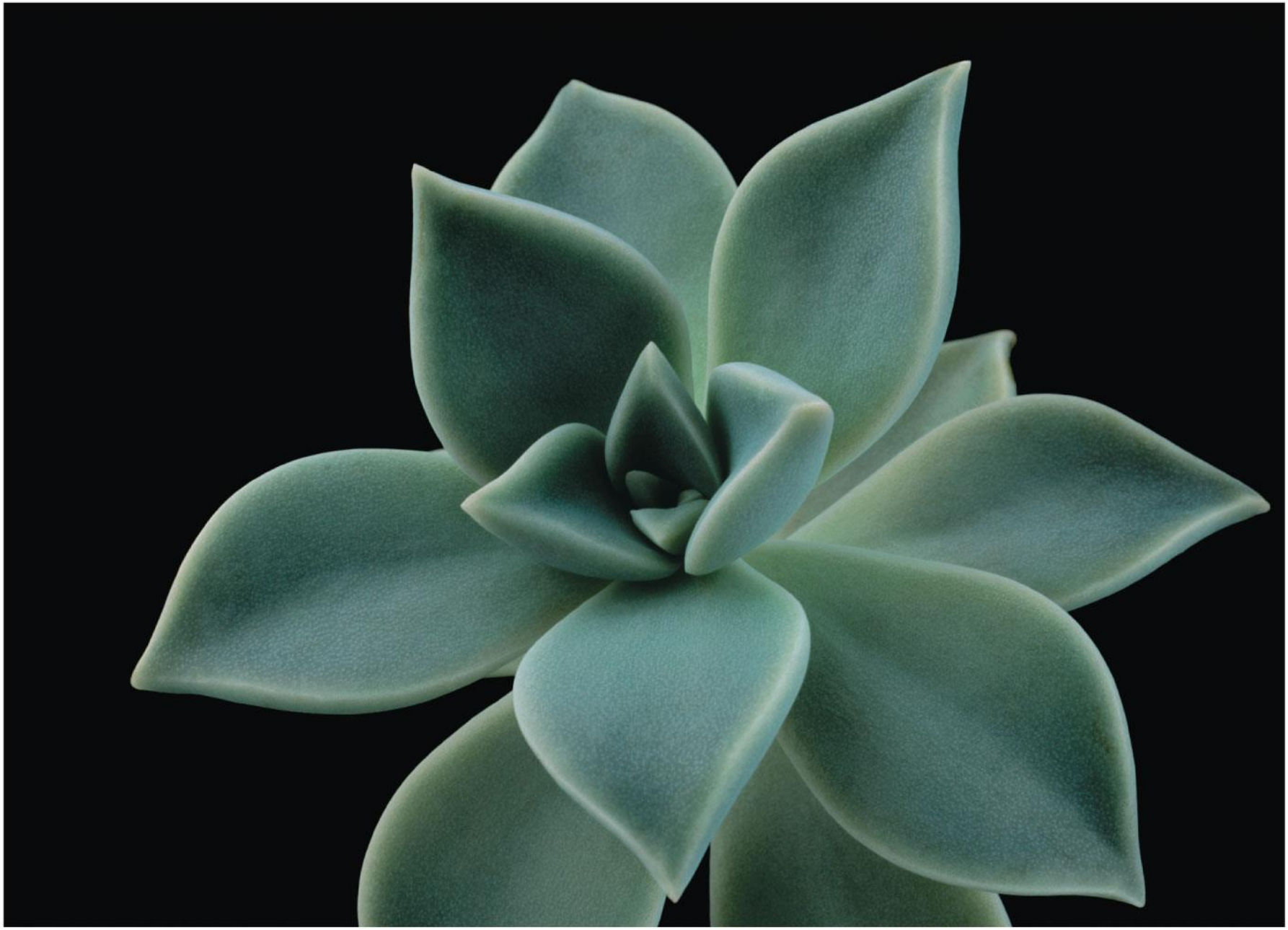
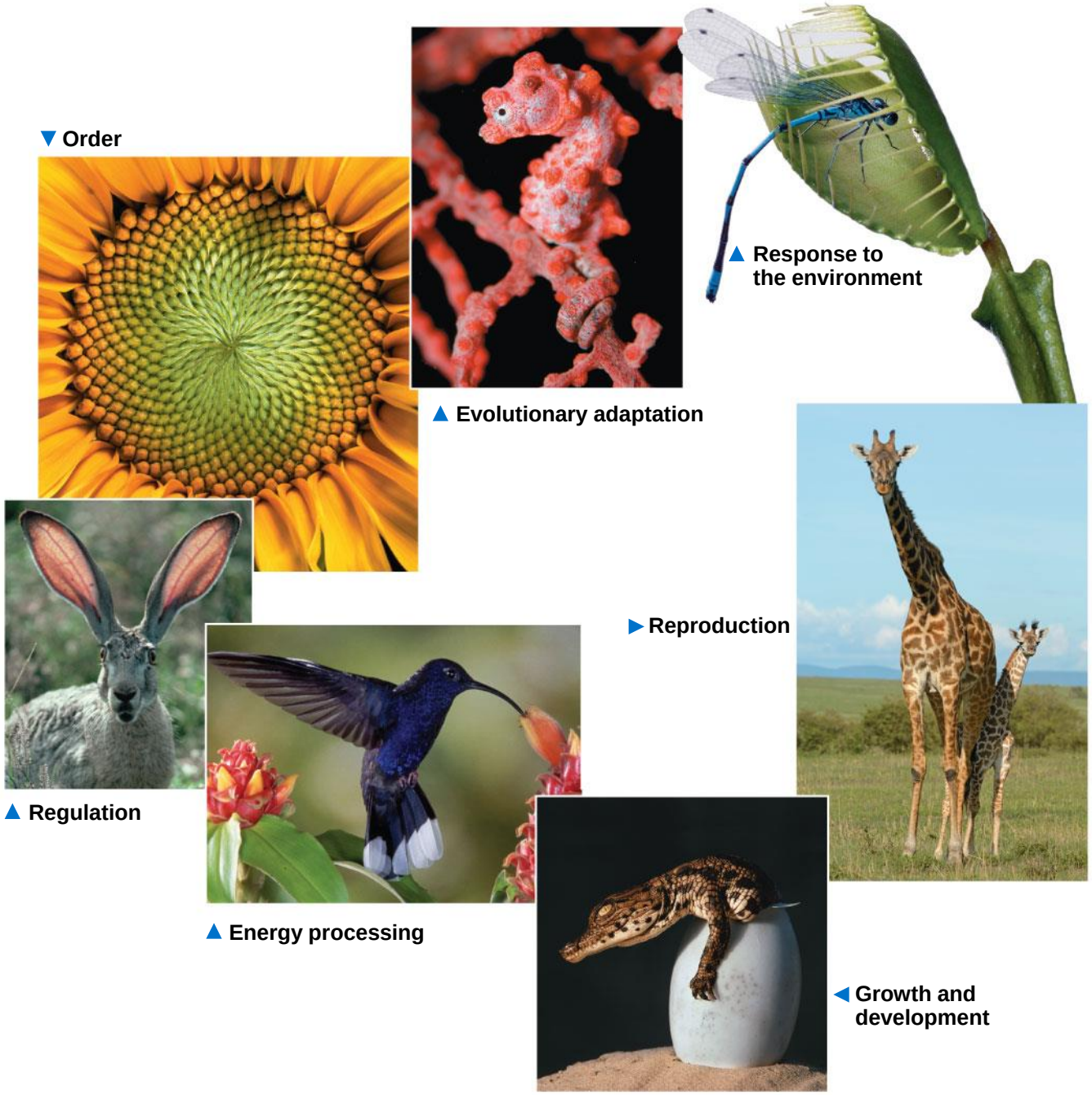


Figure 1.2

- **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



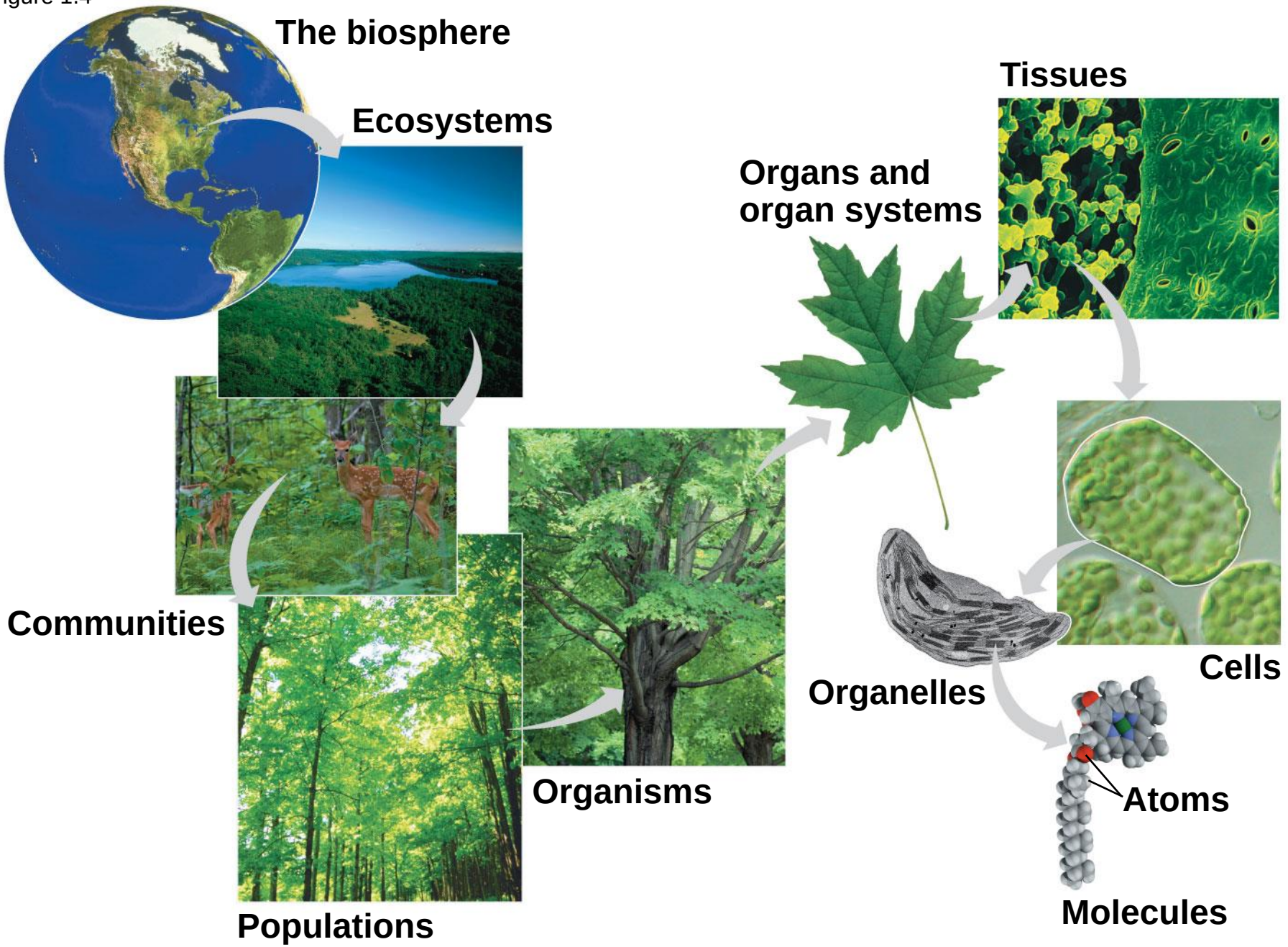
# Concept 1.1: The themes of this book make connections across different areas of biology

- 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



# *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

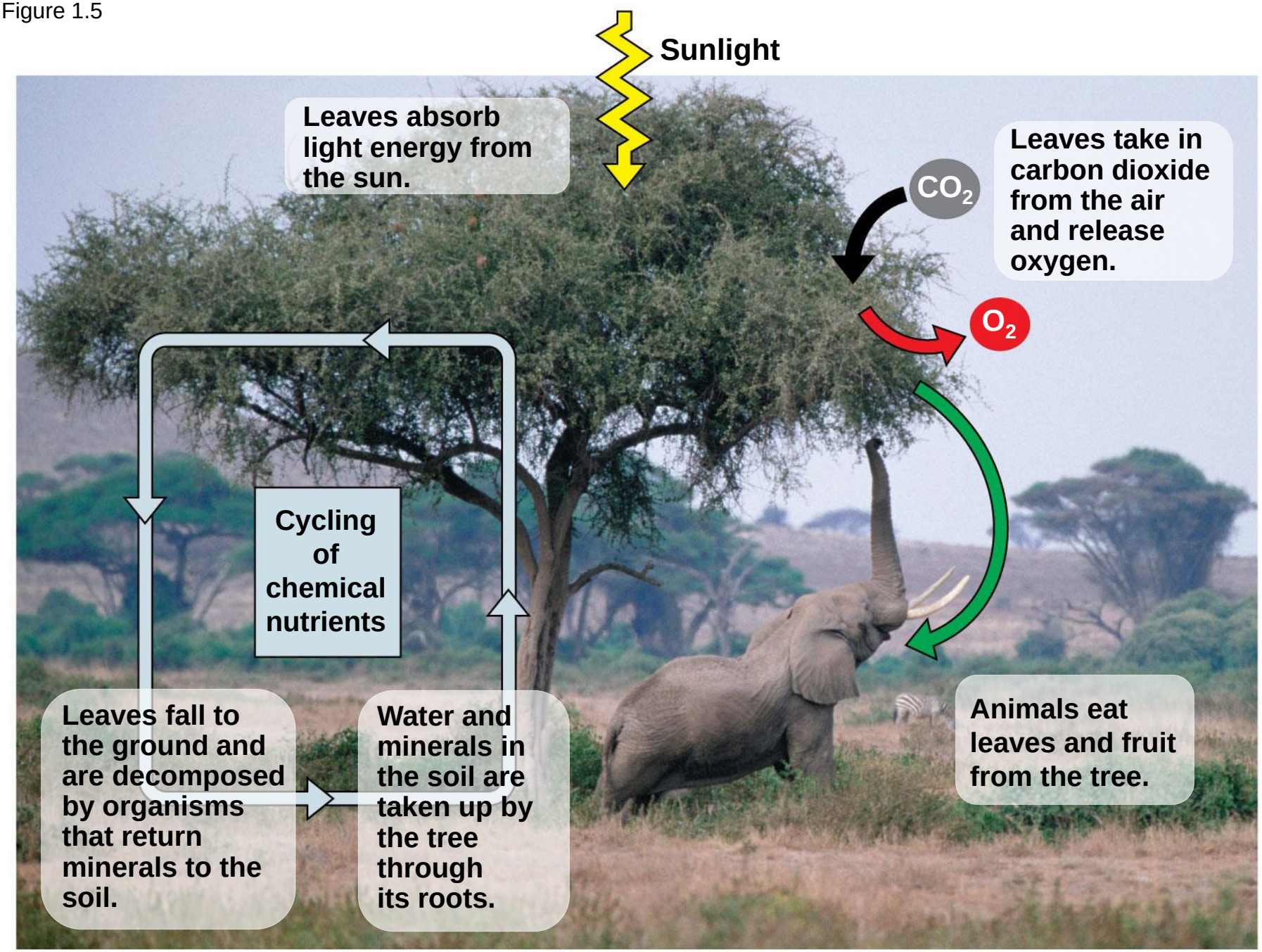
# *Systems Biology*

- 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

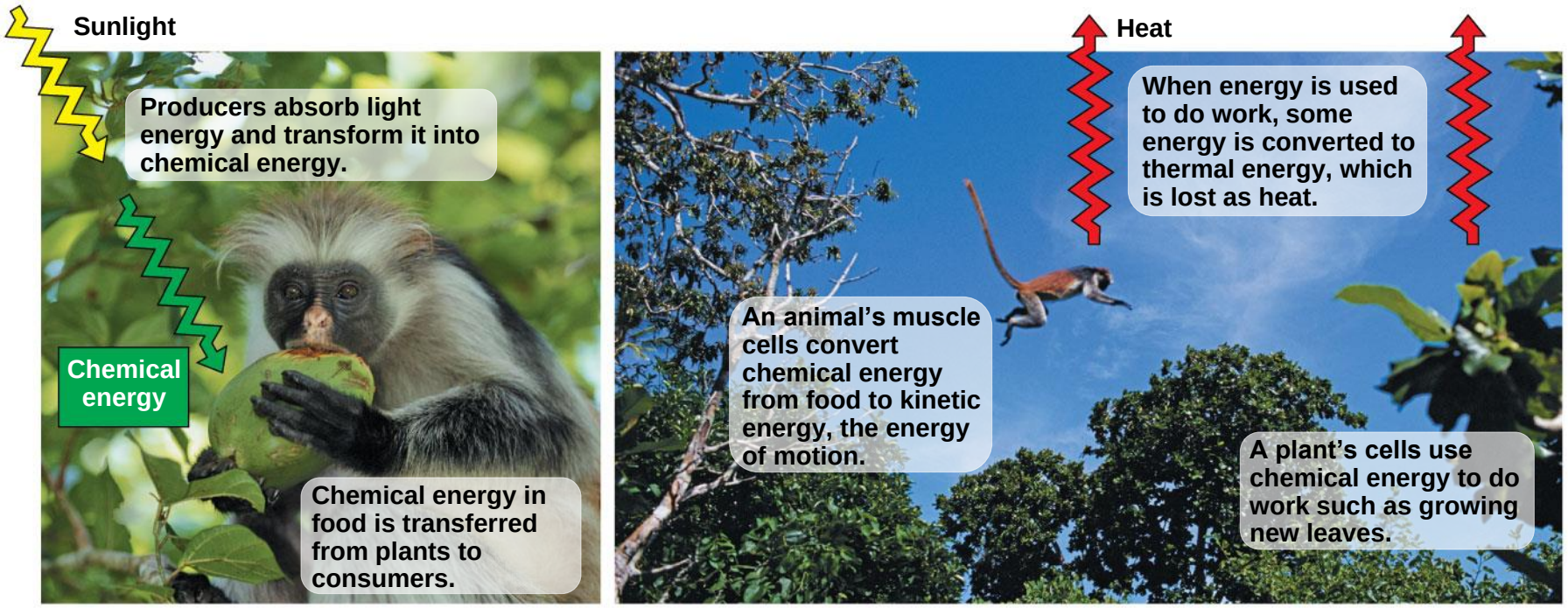


- Humans have modified our environment
  - For example, half the human-generated $CO_2$ stays in the atmosphere and contributes to global warming
- Global warming is a major aspect of **global climate change**
- It is important to understand the effects of global climate change on the Earth and its populations

# 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



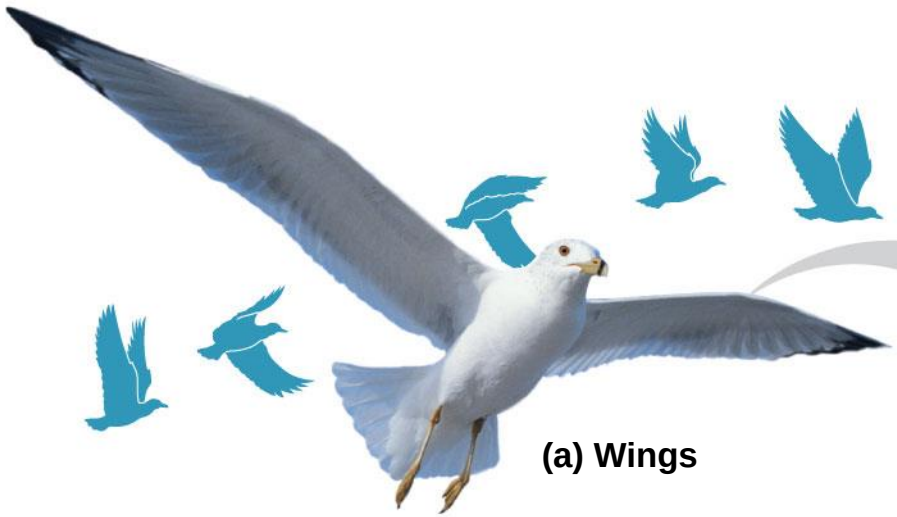

(a) Energy flow from sunlight to producers to consumers

(b) Using energy to do work

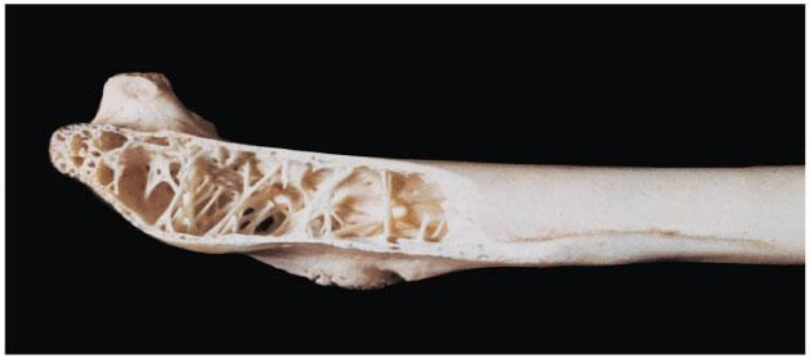
# Theme: Structure and Function Are Correlated at All Levels of Biological Organization

- 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



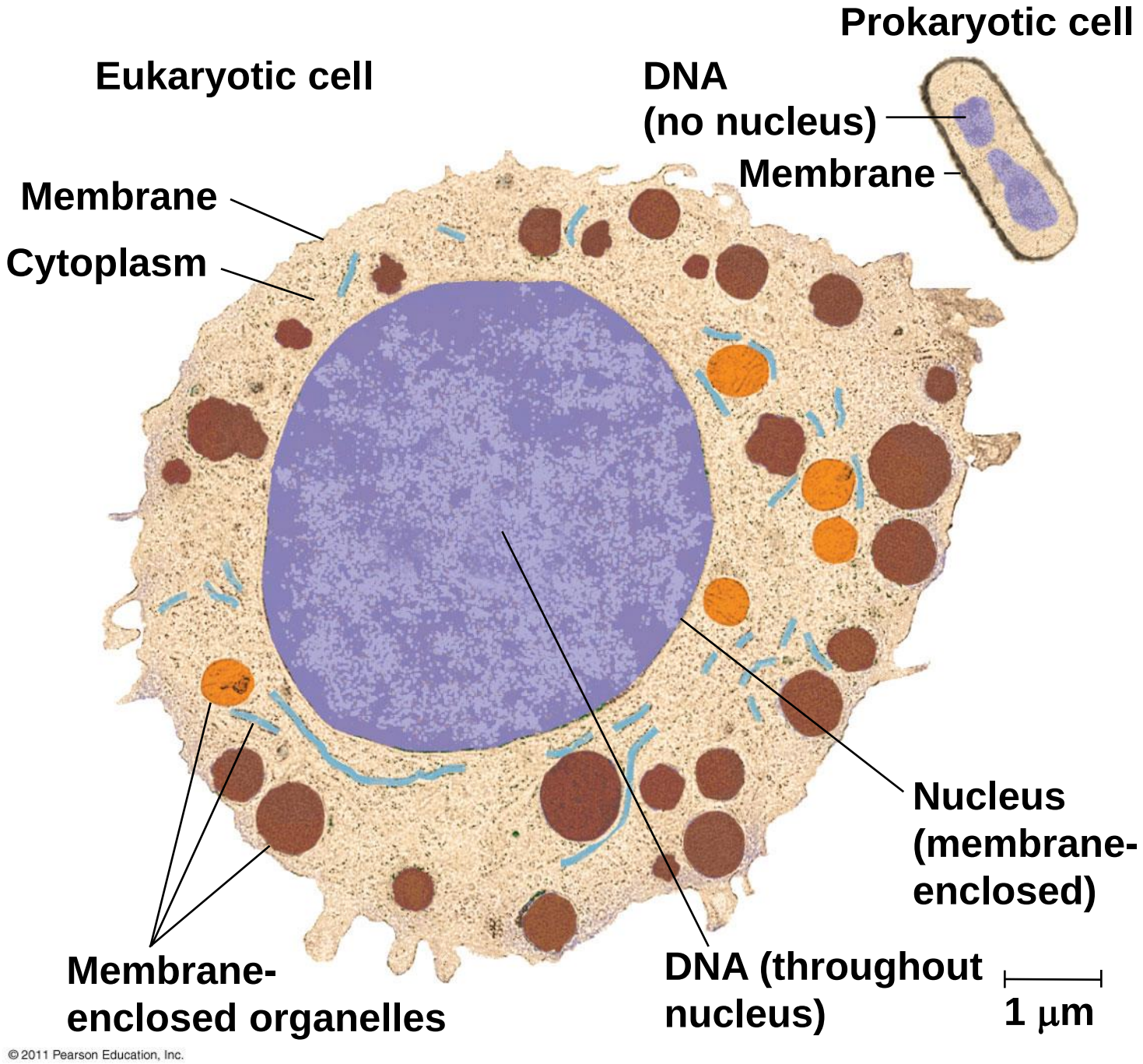
(b) Wing bones

# 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

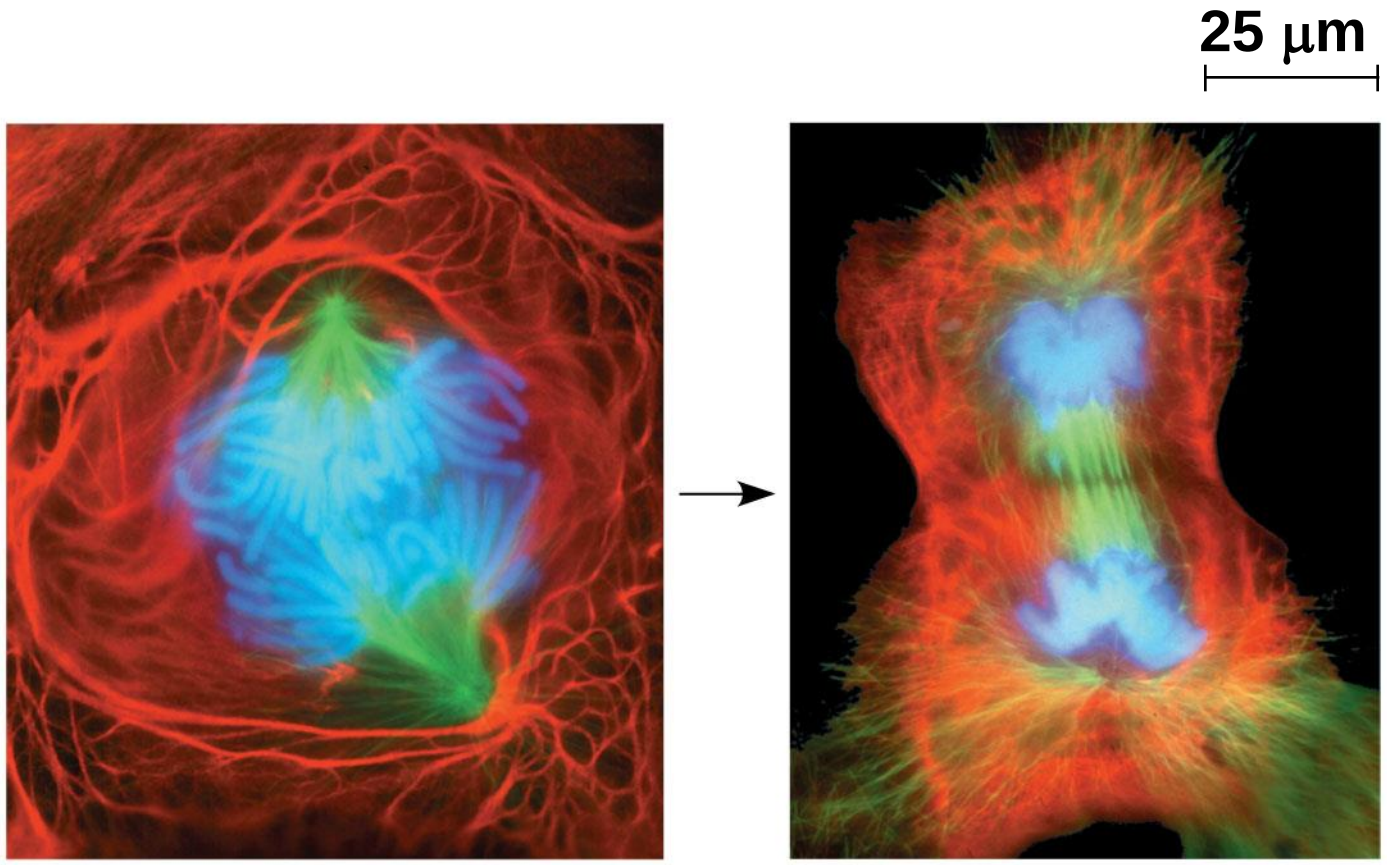
Figure 1.8



# 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

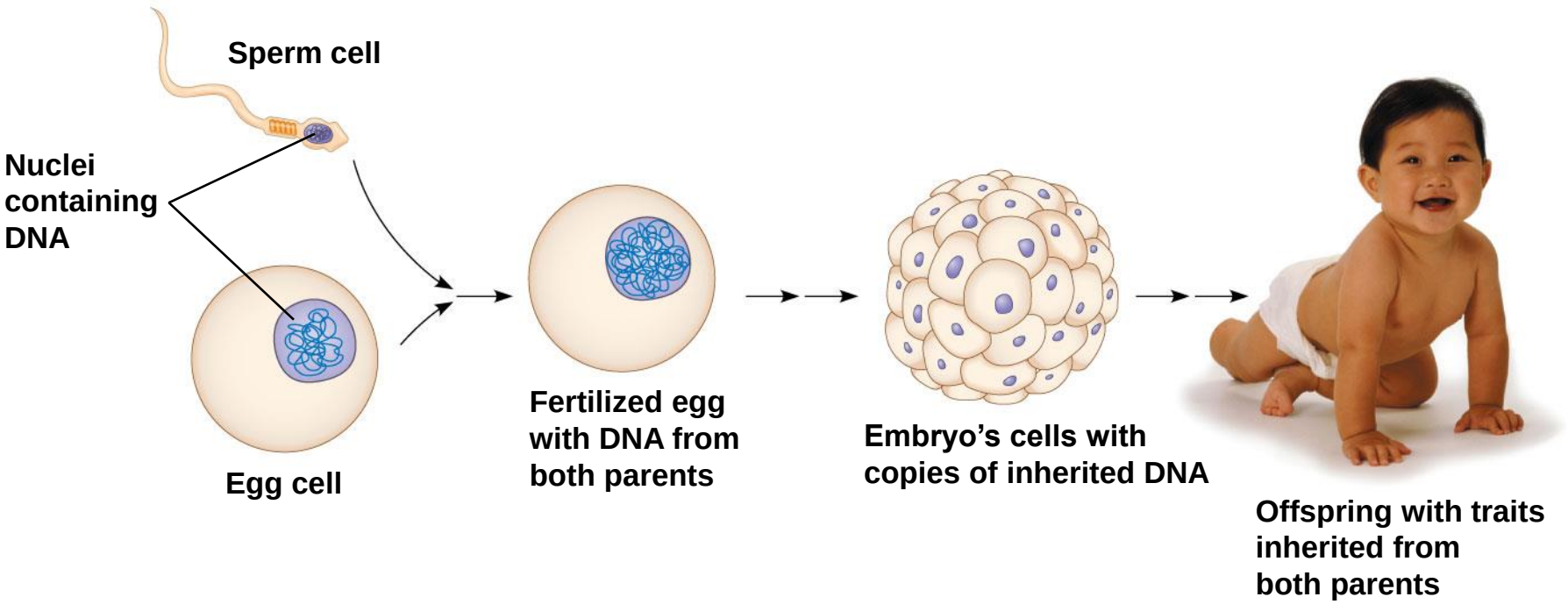
Figure 1.9



# *DNA Structure and Function*

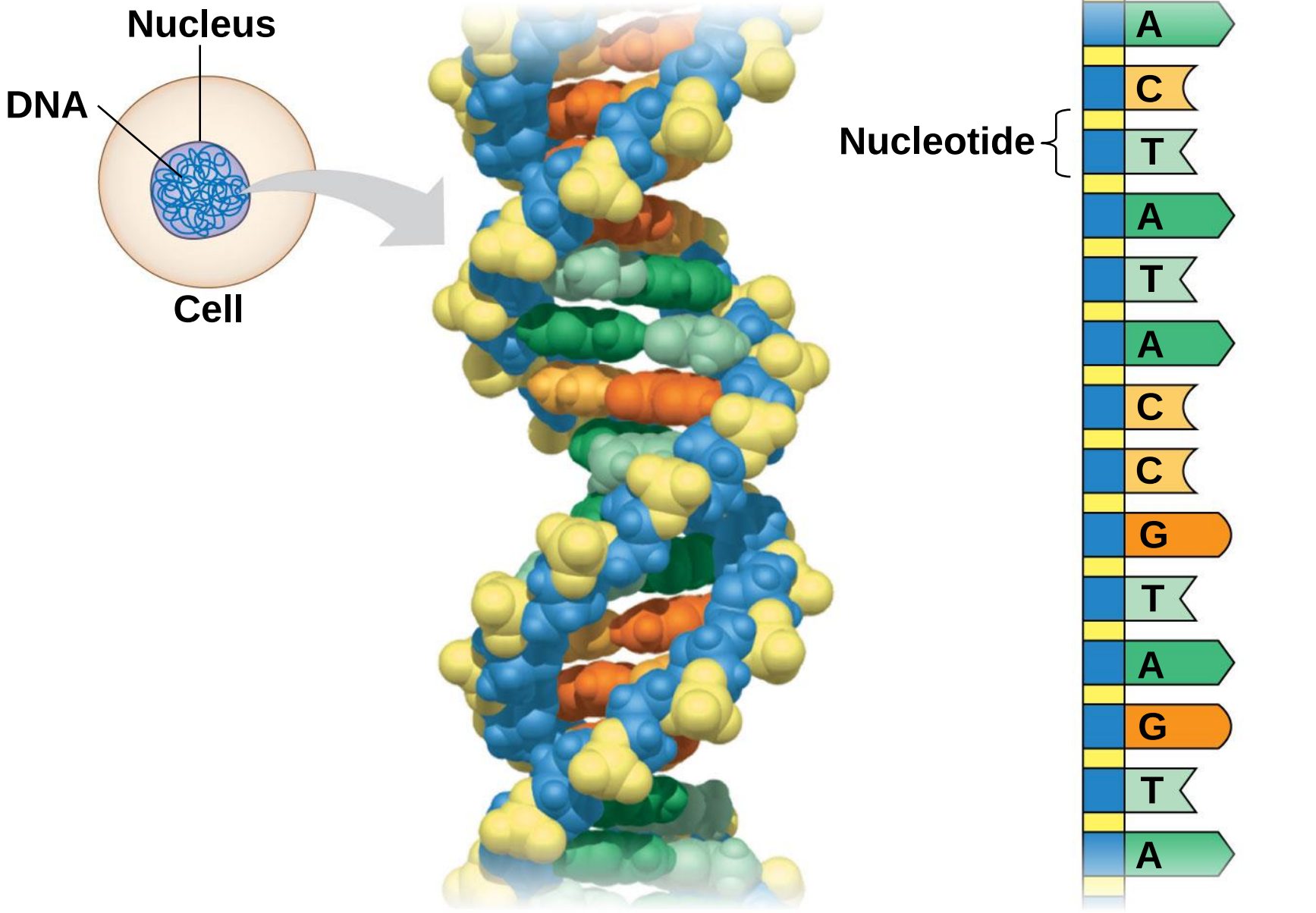
- Each chromosome has one long DNA molecule with hundreds or thousands of genes
- Genes encode information for building proteins
- DNA is inherited by offspring from their parents
- DNA controls the development and maintenance of organisms

Figure 1.10



- 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



- 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

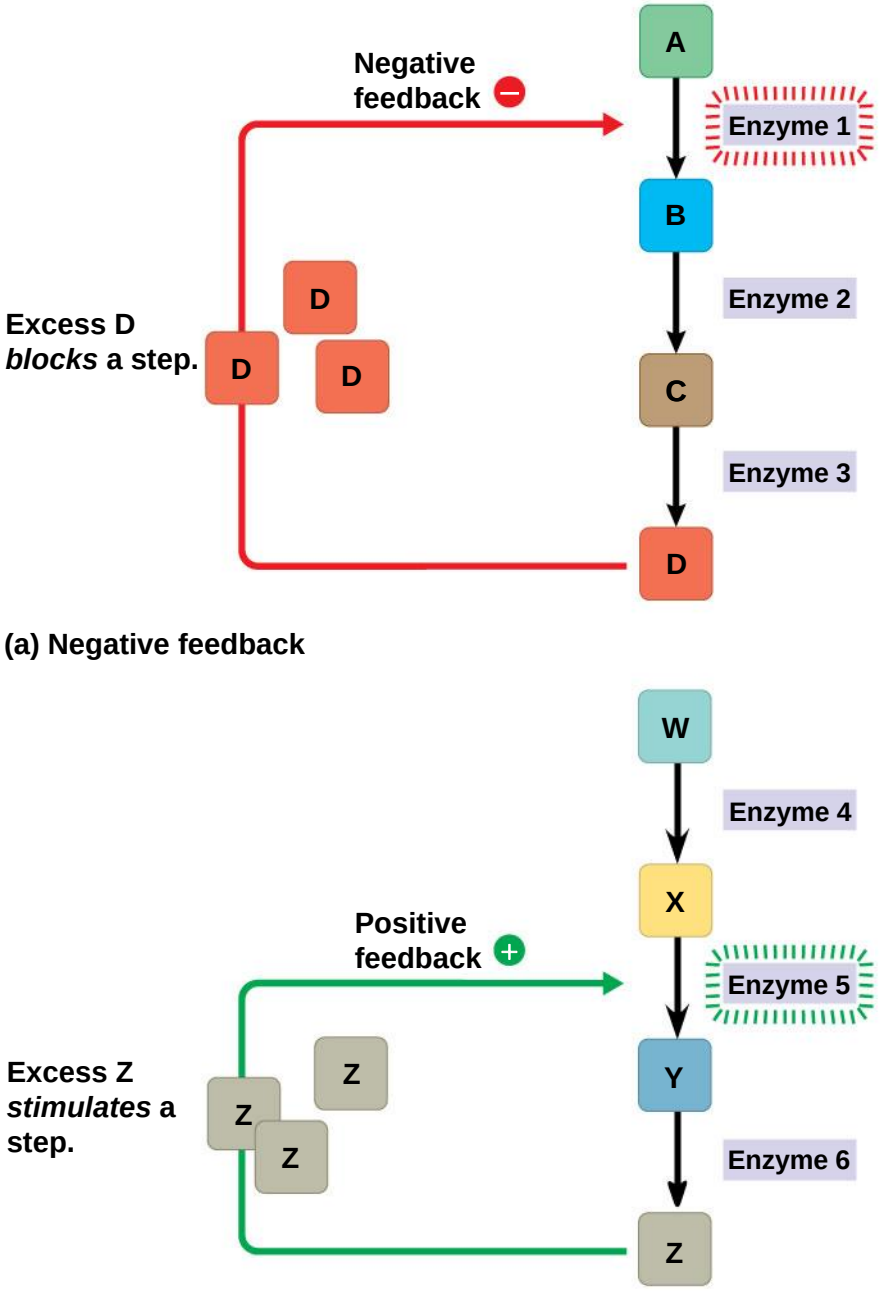
Figure 1.12

- 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



# 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

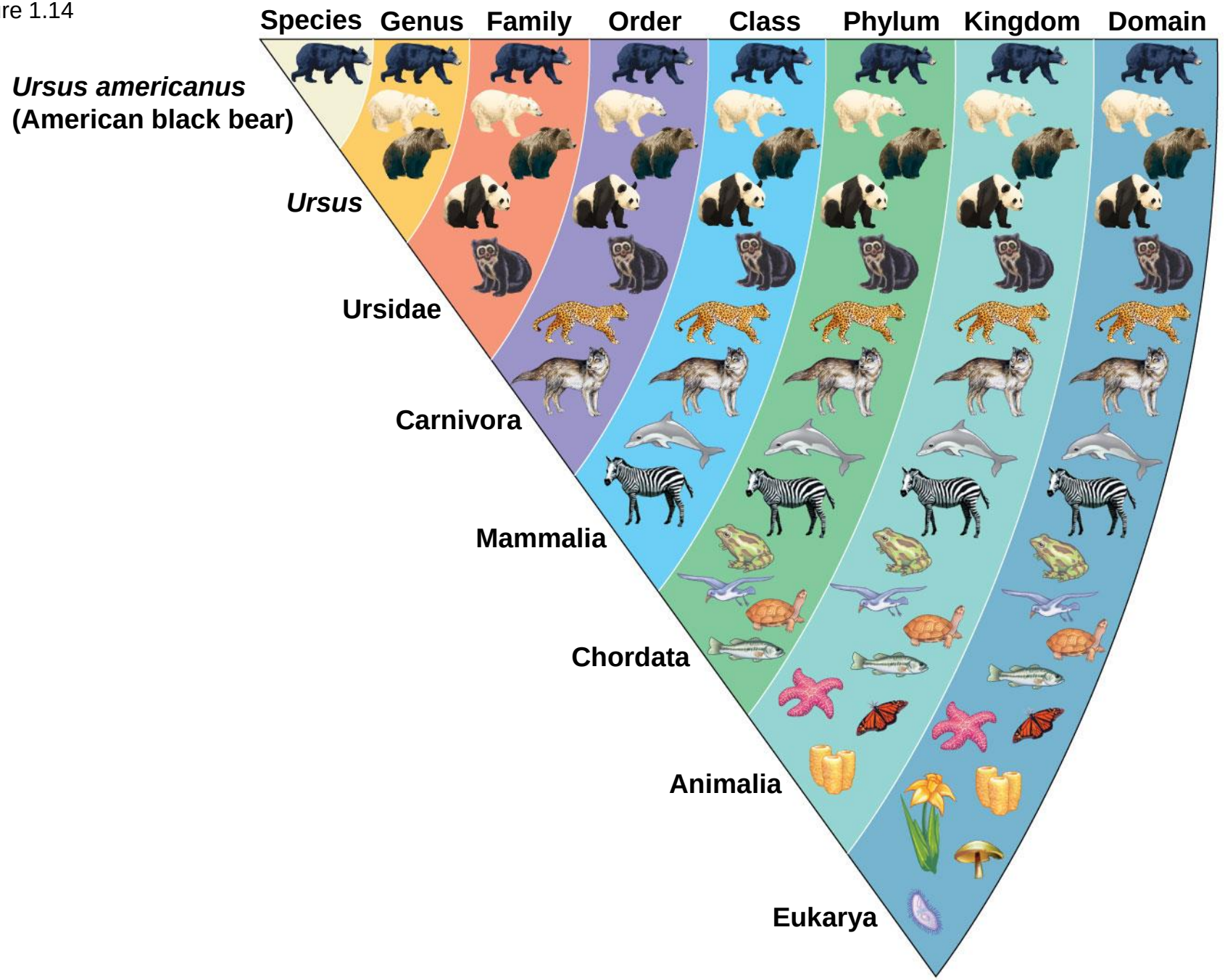
# Classifying the Diversity of Life

- 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

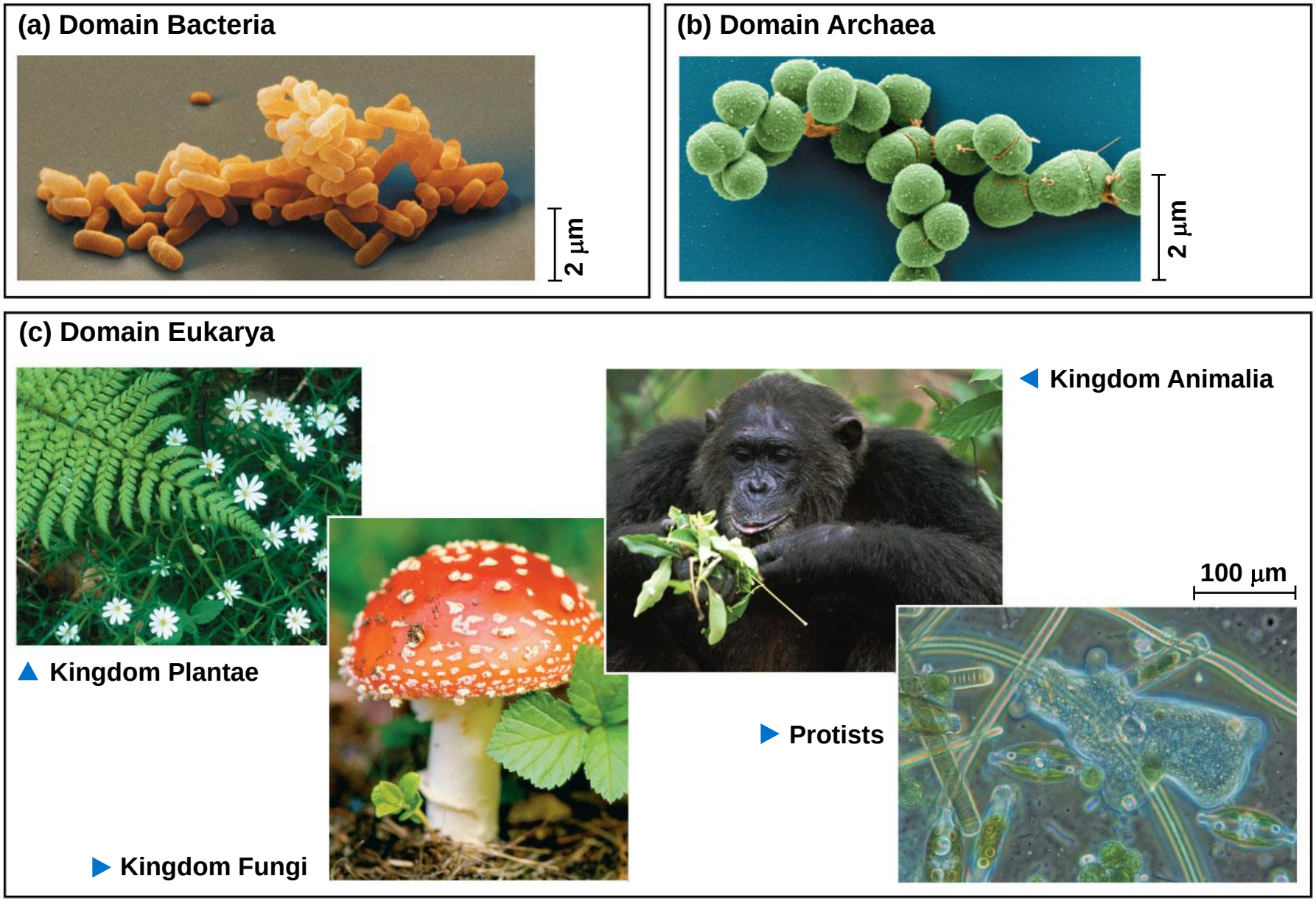
Figure 1.14



# *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

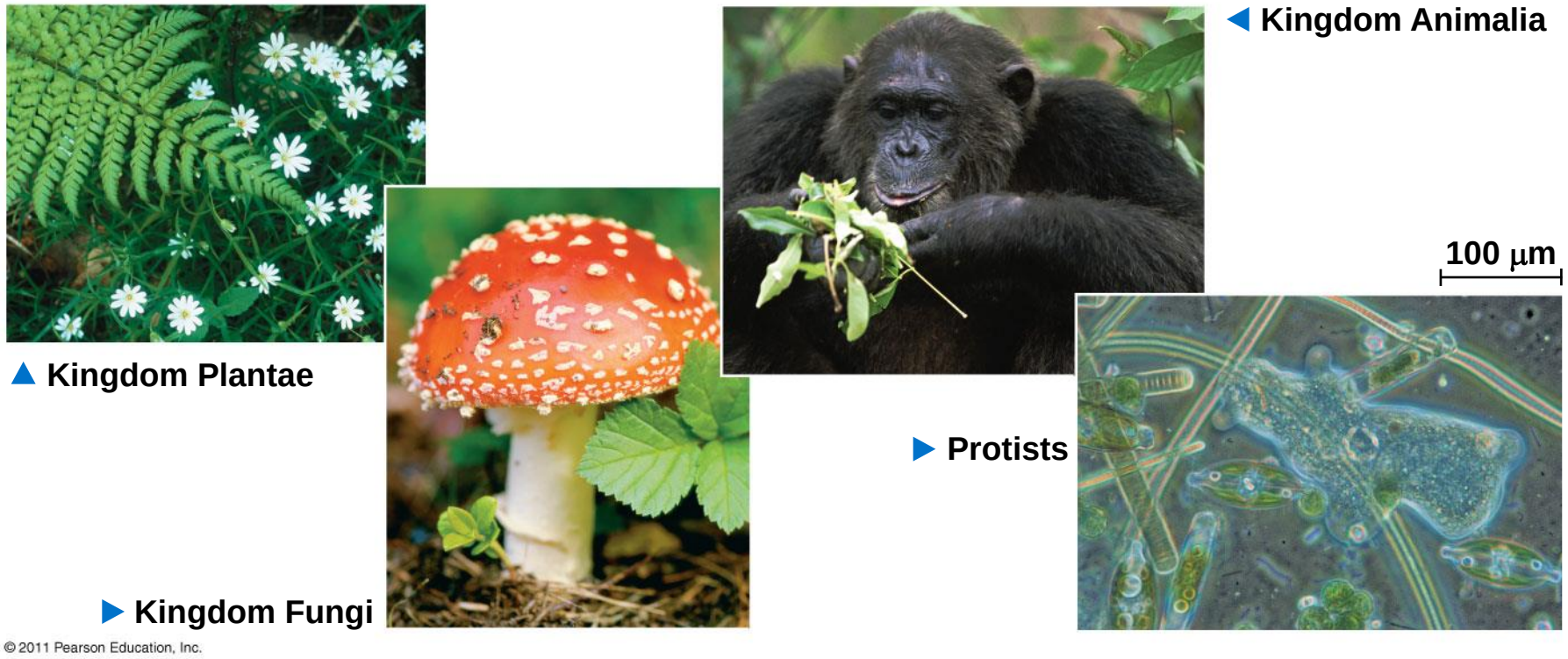
Figure 1.15



- 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

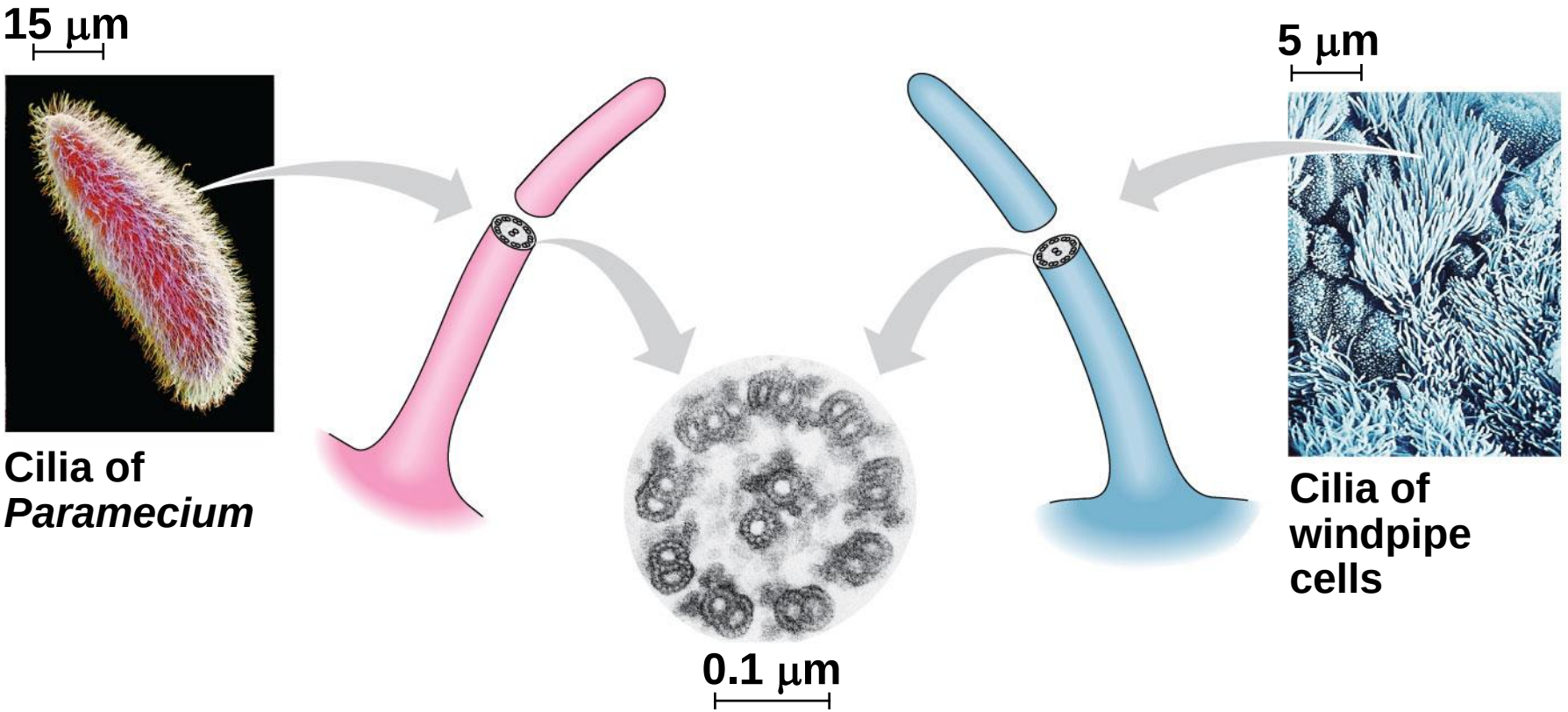
Figure 1.15c



# *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



# 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

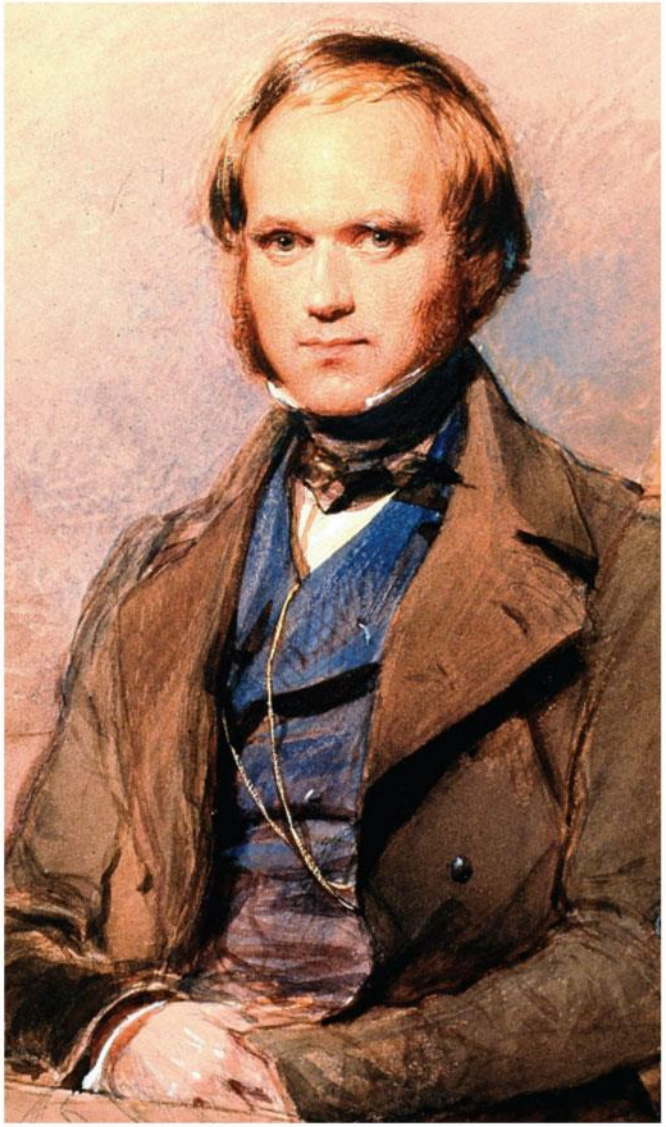


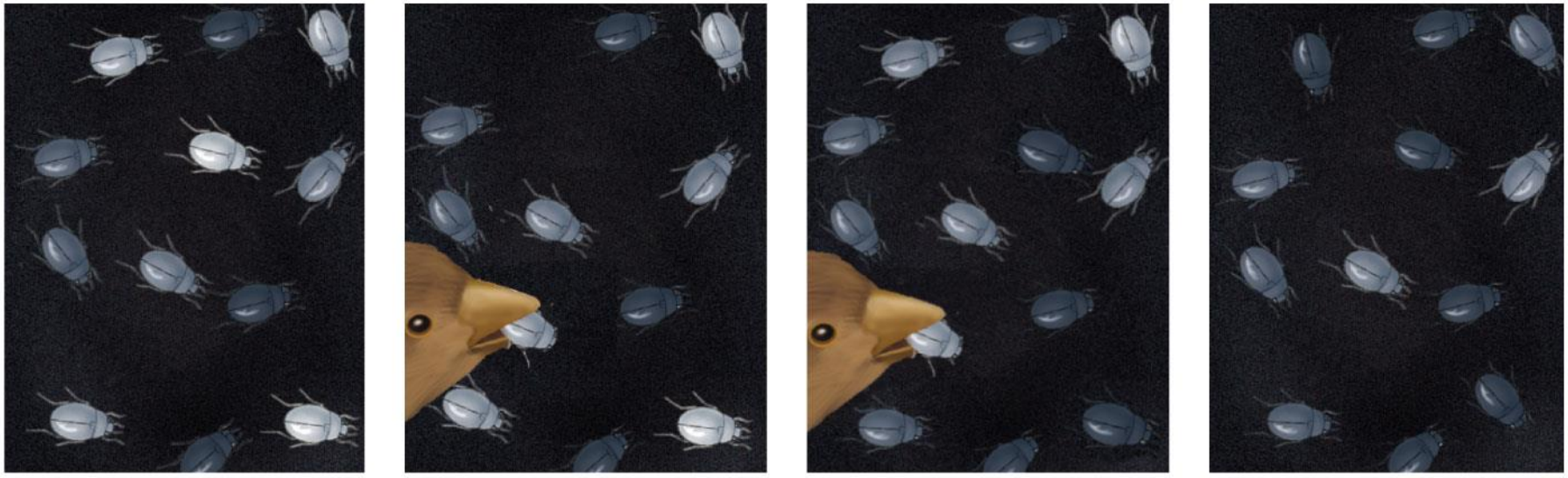
Figure 1.19

- 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

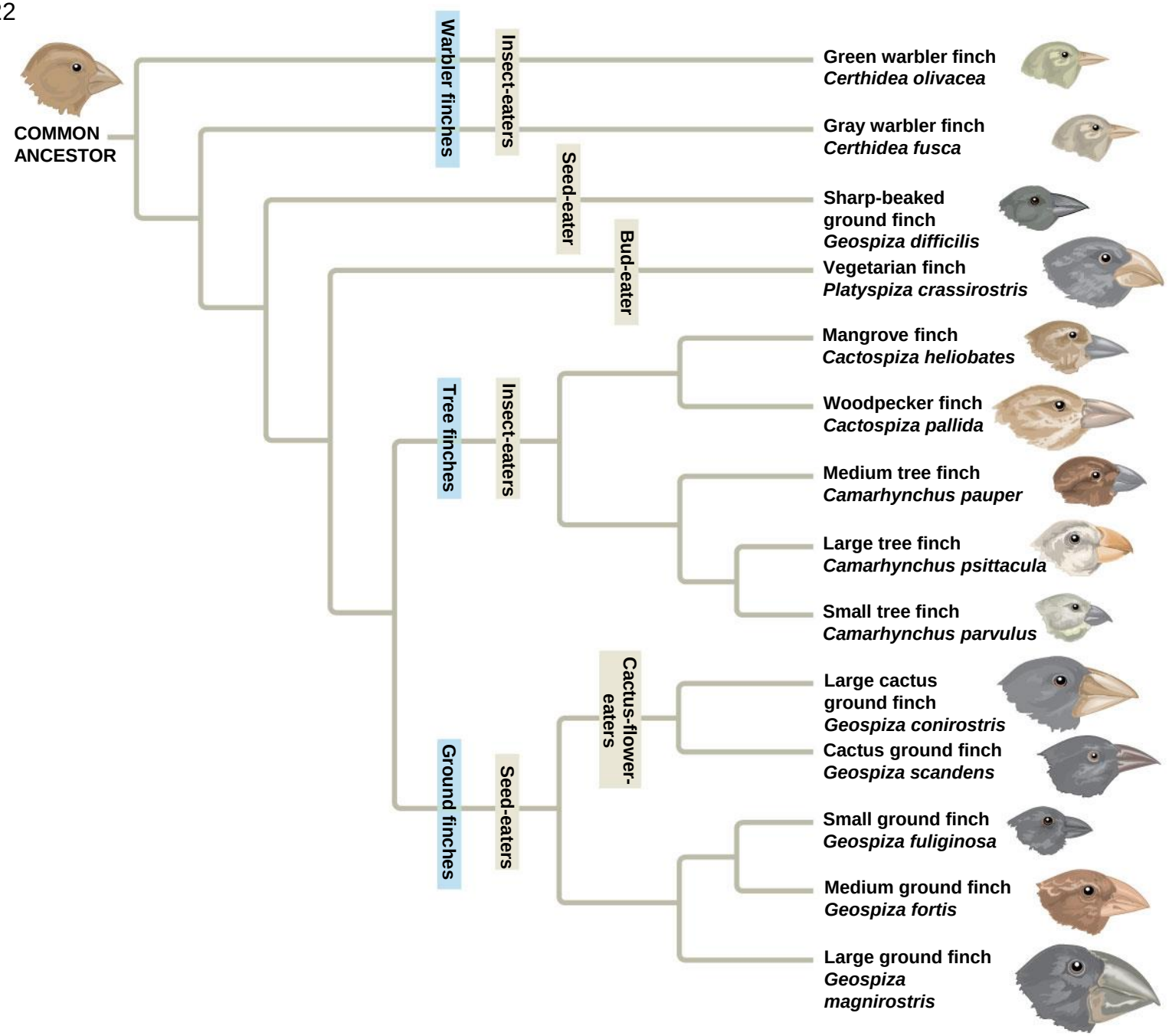
Figure 1.21

# 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



# Concept 1.3: In studying nature, scientists make observations and then form and test hypotheses

- The word **science** is derived from Latin and means “to know”
- **Inquiry** is the search for information and explanation
- The scientific process includes making observations, forming logical hypotheses, and testing them

# Making Observations

- Biologists describe natural structures and processes
- This approach is based on observation and the analysis of data

# *Types of Data*

- **Data** are recorded observations or items of information; these fall into two categories
  - Qualitative data, or descriptions rather than measurements
    - For example, Jane Goodall's observations of chimpanzee behavior
  - Quantitative data, or recorded measurements, which are sometimes organized into tables and graphs

Figure 1.23

# *Inductive Reasoning*

- **Inductive reasoning** draws conclusions through the logical process of induction
- Repeating specific observations can lead to important generalizations
  - For example, “the sun always rises in the east”

# Forming and Testing Hypotheses

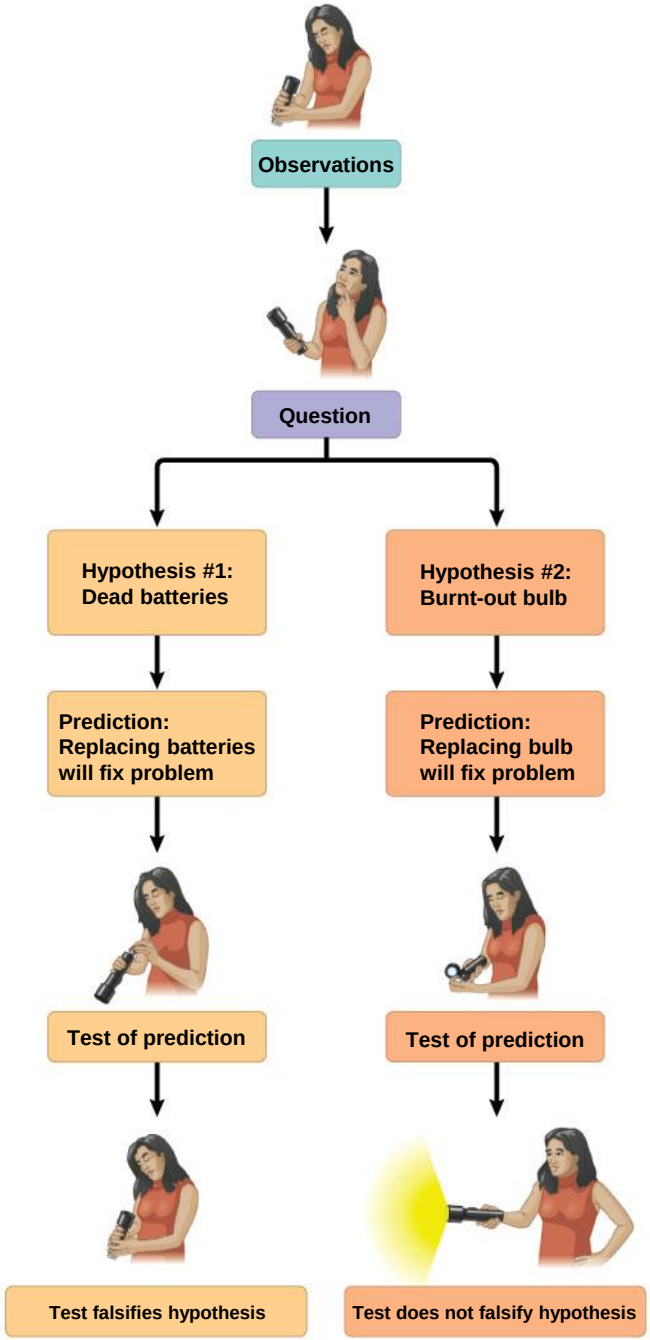
- Observations and inductive reasoning can lead us to ask questions and propose hypothetical explanations called hypotheses

# *The Role of Hypotheses in Inquiry*

- A **hypothesis** is a tentative answer to a well-framed question
- A scientific hypothesis leads to predictions that can be tested by observation or experimentation

- For example,
  - Observation: Your flashlight doesn’t work
  - Question: Why doesn’t your flashlight work?
  - Hypothesis 1: The batteries are dead
  - Hypothesis 2: The bulb is burnt out
- Both these hypotheses are testable

Figure 1.24



# *Deductive Reasoning and Hypothesis Testing*

- **Deductive reasoning** uses general premises to make specific predictions
- For example, if organisms are made of cells (premise 1), and humans are organisms (premise 2), then humans are composed of cells (deductive prediction)

- Hypothesis-based science often makes use of two or more alternative hypotheses
- Failure to falsify a hypothesis does not prove that hypothesis
  - For example, you replace your flashlight bulb, and it now works; this supports the hypothesis that your bulb was burnt out, but does not prove it (perhaps the first bulb was inserted incorrectly)

# *Questions That Can and Cannot Be Addressed by Science*

- A hypothesis must be testable and falsifiable
  - For example, a hypothesis that ghosts fooled with the flashlight cannot be tested
- Supernatural and religious explanations are outside the bounds of science

# The Flexibility of the Scientific Method

- The scientific method is an idealized process of inquiry
- Hypothesis-based science is based on the "textbook" scientific method but rarely follows all the ordered steps

# A Case Study in Scientific Inquiry: Investigating Mimicry in Snake Populations

- Many poisonous species are brightly colored, which warns potential predators
- Mimics are harmless species that closely resemble poisonous species
- Henry Bates hypothesized that this mimicry evolved in harmless species as an evolutionary adaptation that reduces their chances of being eaten

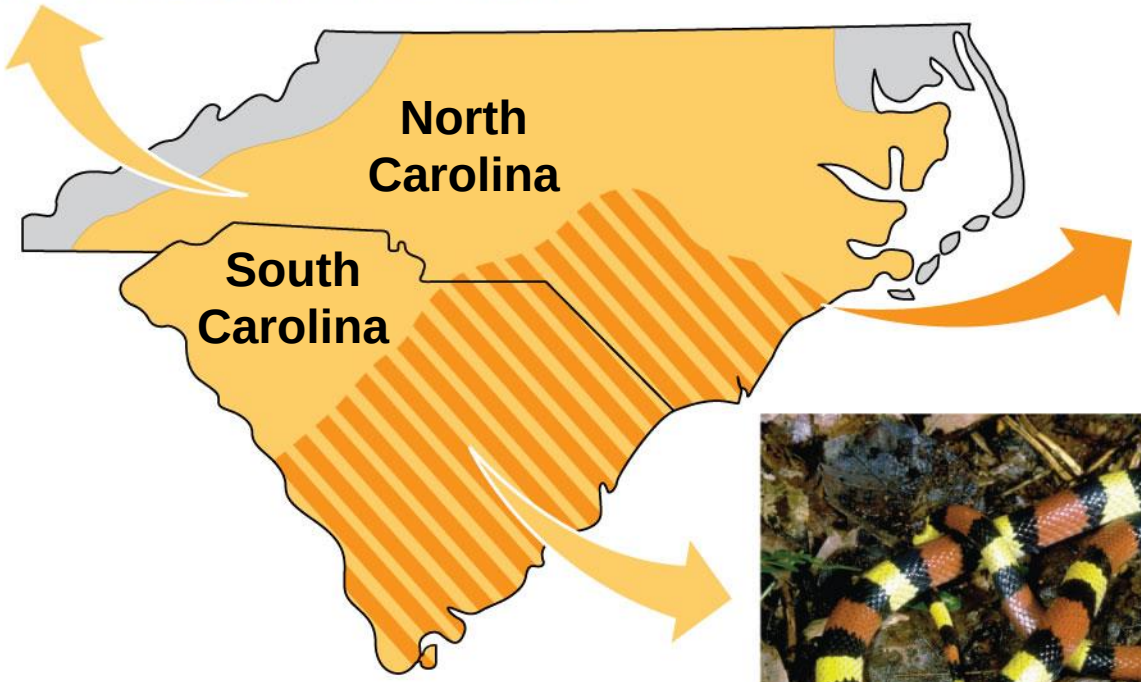
- This hypothesis was tested with the venomous eastern coral snake and its mimic the nonvenomous scarlet kingsnake
- Both species live in the Carolinas, but the kingsnake is also found in regions without venomous coral snakes
- If predators inherit an avoidance of the coral snake's coloration, then the colorful kingsnake will be attacked less often in the regions where coral snakes are present

Figure 1.25

## Scarlet kingsnake (nonvenomous)

**Key**

- Range of scarlet kingsnake only
- Overlapping ranges of scarlet kingsnake and eastern coral snake




Eastern coral snake (venomous)

Scarlet kingsnake (nonvenomous)

# *Field Experiments with Artificial Snakes*

- To test this mimicry hypothesis, researchers made hundreds of artificial snakes:
  - An experimental group resembling kingsnakes
  - A control group resembling plain brown snakes
- Equal numbers of both types were placed at field sites, including areas without poisonous coral snakes

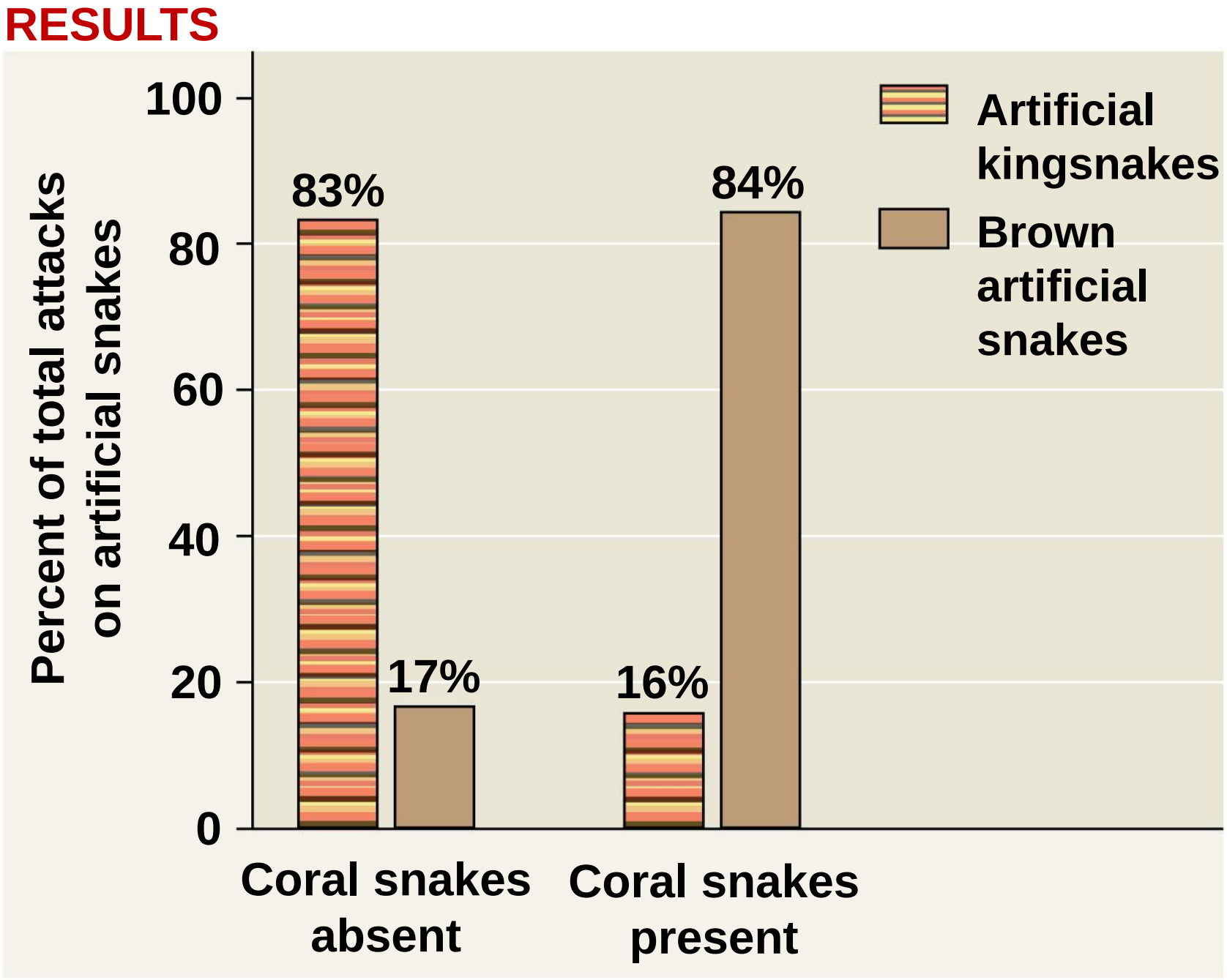
Figure 1.26

**(a) Artificial kingsnake**

**(b) Brown artificial snake that has been attacked**

- After four weeks, the scientists retrieved the artificial snakes and counted bite or claw marks
- The data fit the predictions of the mimicry hypothesis: the ringed snakes were attacked less frequently in the geographic region where coral snakes were found

Figure 1.27



# *Experimental Controls and Repeatability*

- A **controlled experiment** compares an experimental group (the artificial kingsnakes) with a control group (the artificial brown snakes)
- Ideally, only the variable of interest (the effect of coloration on the behavior of predators) differs between the control and experimental groups
- A controlled experiment means that control groups are used to cancel the effects of unwanted variables
- A controlled experiment does not mean that all unwanted variables are kept constant

- In science, observations and experimental results must be repeatable

# Theories in Science

- In the context of science, a **theory** is
  - Broader in scope than a hypothesis
  - General, and can lead to new testable hypotheses
  - Supported by a large body of evidence in comparison to a hypothesis

# Concept 1.4: Science benefits from a cooperative approach and diverse viewpoints

- Most scientists work in teams, which often include graduate and undergraduate students
- Good communication is important in order to share results through seminars, publications, and websites

Figure 1.28

# Building on the Work of Others

- Scientists check each others' claims by performing similar experiments
- It is not unusual for different scientists to work on the same research question
- Scientists cooperate by sharing data about **model organisms** (e.g., the fruit fly *Drosophila melanogaster*)

# Science, Technology, and Society

- The goal of science is to understand natural phenomena
- The goal of **technology** is to apply scientific knowledge for some specific purpose
- Science and technology are interdependent
- Biology is marked by “discoveries,” while technology is marked by “inventions”

- The combination of science and technology has dramatic effects on society
  - For example, the discovery of DNA by James Watson and Francis Crick allowed for advances in DNA technology such as testing for hereditary diseases
- Ethical issues can arise from new technology, but have as much to do with politics, economics, and cultural values as with science and technology

# The Value of Diverse Viewpoints in Science

- Many important inventions have occurred where different cultures and ideas mix
  - For example, the printing press relied on innovations from China (paper and ink) and Europe (mass production in mills)
- Science benefits from diverse views from different racial and ethnic groups, and from both women and men

Figure 1.UN09

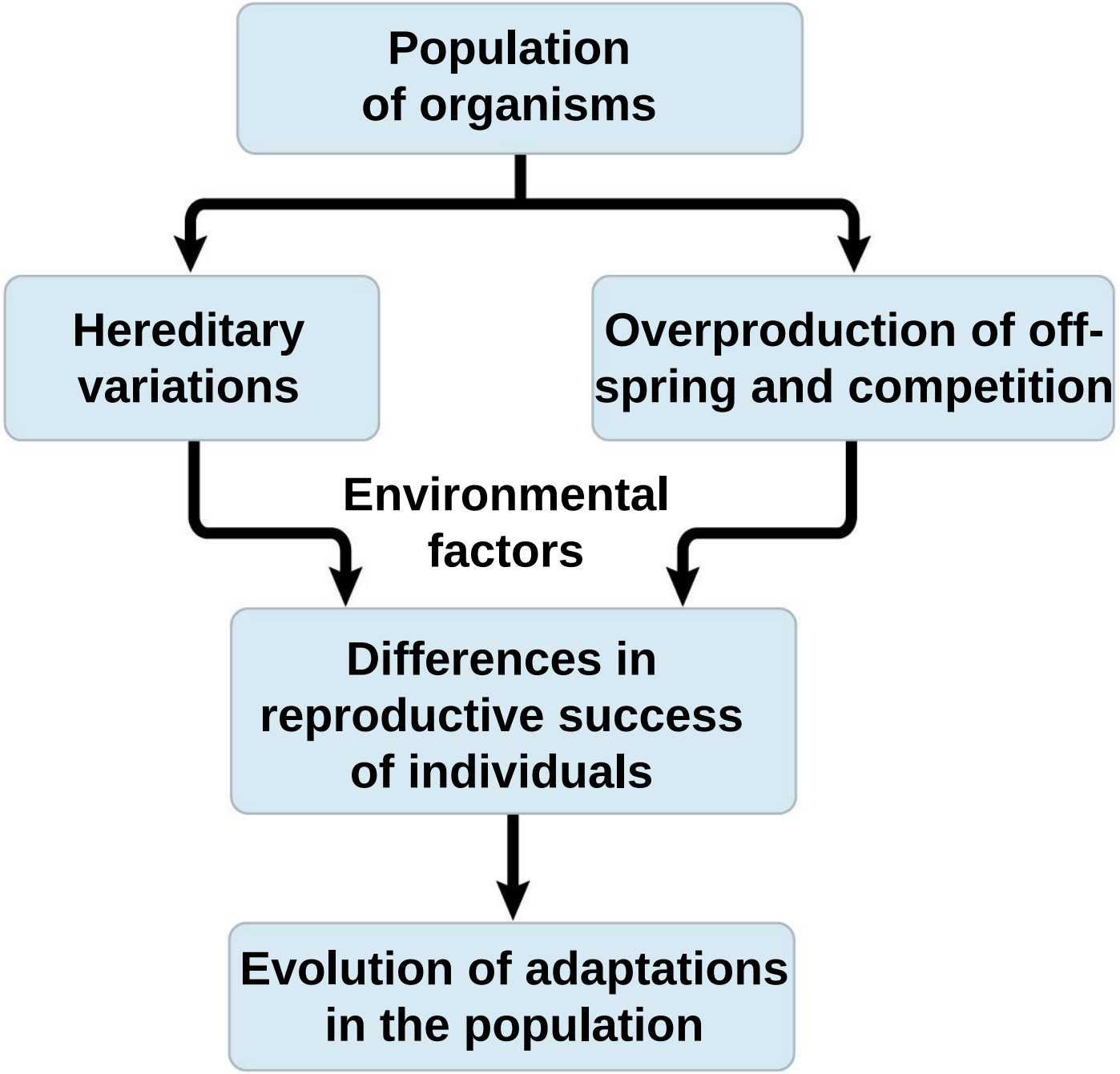


Figure 1.UN10