1 _ Exploring Life

Themes in the Study of Biology

Evolution, the Core Theme of Biology

The Process of Science

After completing this topic, you should be able to:

1) **Describe** seven properties common to all life.
2) **Describe** the levels of biological organization from molecules to the biosphere, noting the interrelationships between levels.
3) **Explain** why cells are a special level in biological organization.
4) **Compare** the dynamics of nutrients and in an ecosystem.
5) **Compare** the three domains of life.
6) **Describe** the process and products of natural selection.
7) **Distinguish** between quantitative and qualitative data.
8) **Distinguish** between discovery and hypothesis-based science.
9) **Compare** the definitions and use of inductive and deductive reasoning in scientific investigations.
10) **Distinguish** between a scientific theory and a hypothesis.
11) **Describe** the structure of the process of science

THEMES IN THE STUDY OF BIOLOGY

- Common Properties of Life
- Hierarchy of Life
- Cells - the Structural & Functional Units of Life
- Organisms Interact with Their Environment

All forms of life share common properties

- **Biology** is the scientific study of life
- Life properties are the characteristics shared by all living things
- Properties of life include:
  1. **Order**—the highly ordered structure that typifies life
  2. **Reproduction**—the ability of organisms to reproduce their own kind
  3. **Growth and development**—consistent growth and development controlled by inherited DNA
  4. **Energy processing**—the use of chemical energy to power an organism's activities and chemical reactions
  5. **Regulation**—an ability to control an organism's internal environment within limits that sustain life

6. **Response to the environment**—an ability to respond to environmental stimuli
7. **Evolutionary adaptation**—adaptations evolve over many generations, as individuals with traits best suited to their environments have greater reproductive success and pass their traits to offspring

(1) Order

(2) Reproduction

(3) Growth and development

(4) Energy processing

(5) Regulation

(6) Response to the environment

(7) Evolutionary adaptation

In life's hierarchy of organization, new properties emerge at each level

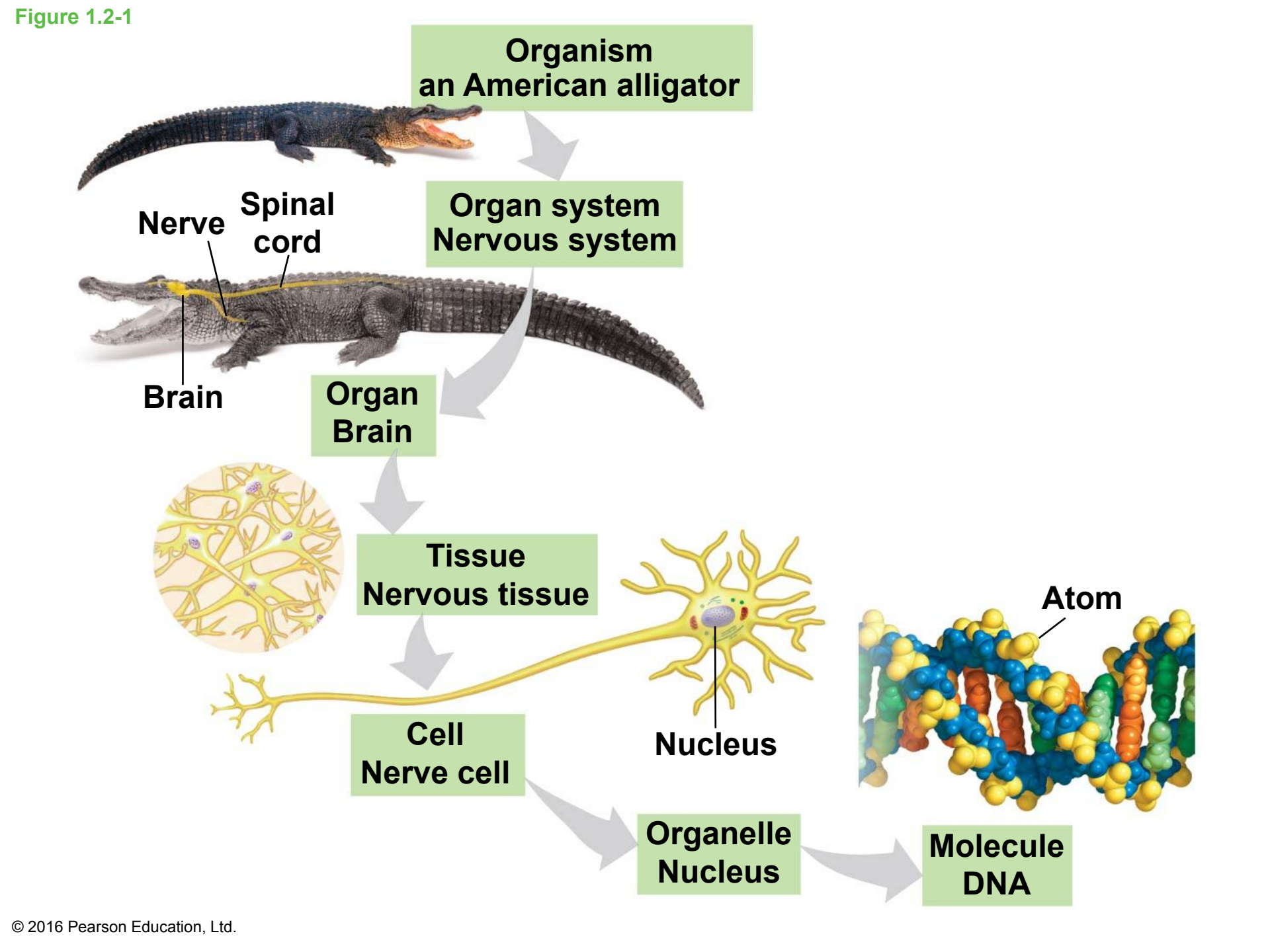
- **Biological organization** unfolds as follows (from the complex to simple):
  - **Biosphere**—all of the environments on Earth that support life
  - **Ecosystem**—all the organisms living in a particular area and the physical components with which the organisms interact
  - **Community**—the entire array of organisms living in a particular ecosystem
  - **Population**—all the individuals of a species living in a specific area
  - **Organism**—an individual living thing

- **Organ system**—several organs that cooperate in a specific function
- **Organ**—a structure that is composed of tissues
- **Tissue**—a group of similar cells that perform a specific function
- **Cell**—the fundamental unit of life
- **Organelle**—a membrane-enclosed structure that performs a specific function within a cell
- **Molecule**—a cluster of small chemical units called atoms held together by chemical bonds

Emergent properties are new properties that arise in each step upward in the hierarchy of life from the arrangement and interactions among component parts

Figure 1.2-0

Figure 1.2-1



Cells are the structural and functional units of life

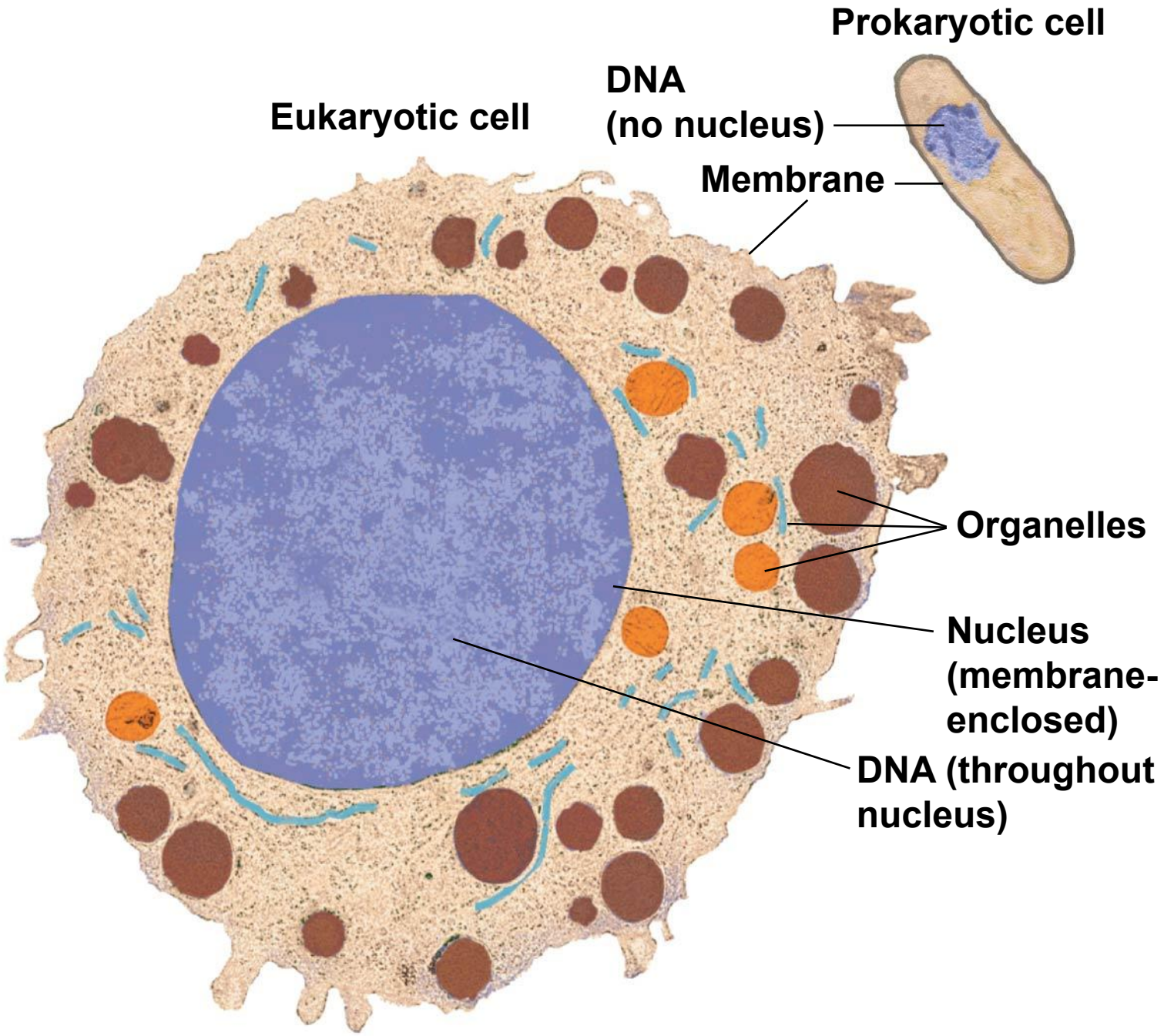
- **Cell**s are the level at which the properties of life emerge – **basic unit of life**
- A cell can:
  - regulate its internal environment
  - take in and use energy
  - respond to its environment
  - develop and maintain its complex organization
  - give rise to new cells
- All cells:
  - are enclosed by a membrane that regulates the passage of materials between the cell and its surroundings
  - use DNA as their genetic information

Two basic forms of cells:

There are two basic forms of cells

1. **Prokaryotic cells**
   - were the first to evolve
   - are found in bacteria and archaea
   - are simpler
   - are usually smaller than eukaryotic cells
2. **Eukaryotic cells**
   - are found in plants, animals, fungi, and protists
   - are subdivided by membranes into various functional compartments, or organelles, including a nucleus that houses the DNA

Figure 1.3



Organisms interact with their environment, exchanging matter and energy

- Living organisms interact with their environments, which include
  - other organisms
  - physical factors
- In most ecosystems,
  - plants are the "***producers"*** that provide the food
  - animals are ***"consumers"*** that eat plants & other animals
  - ***"decomposers"*** act as recyclers, changing complex matter into simpler chemicals that plants can absorb and use

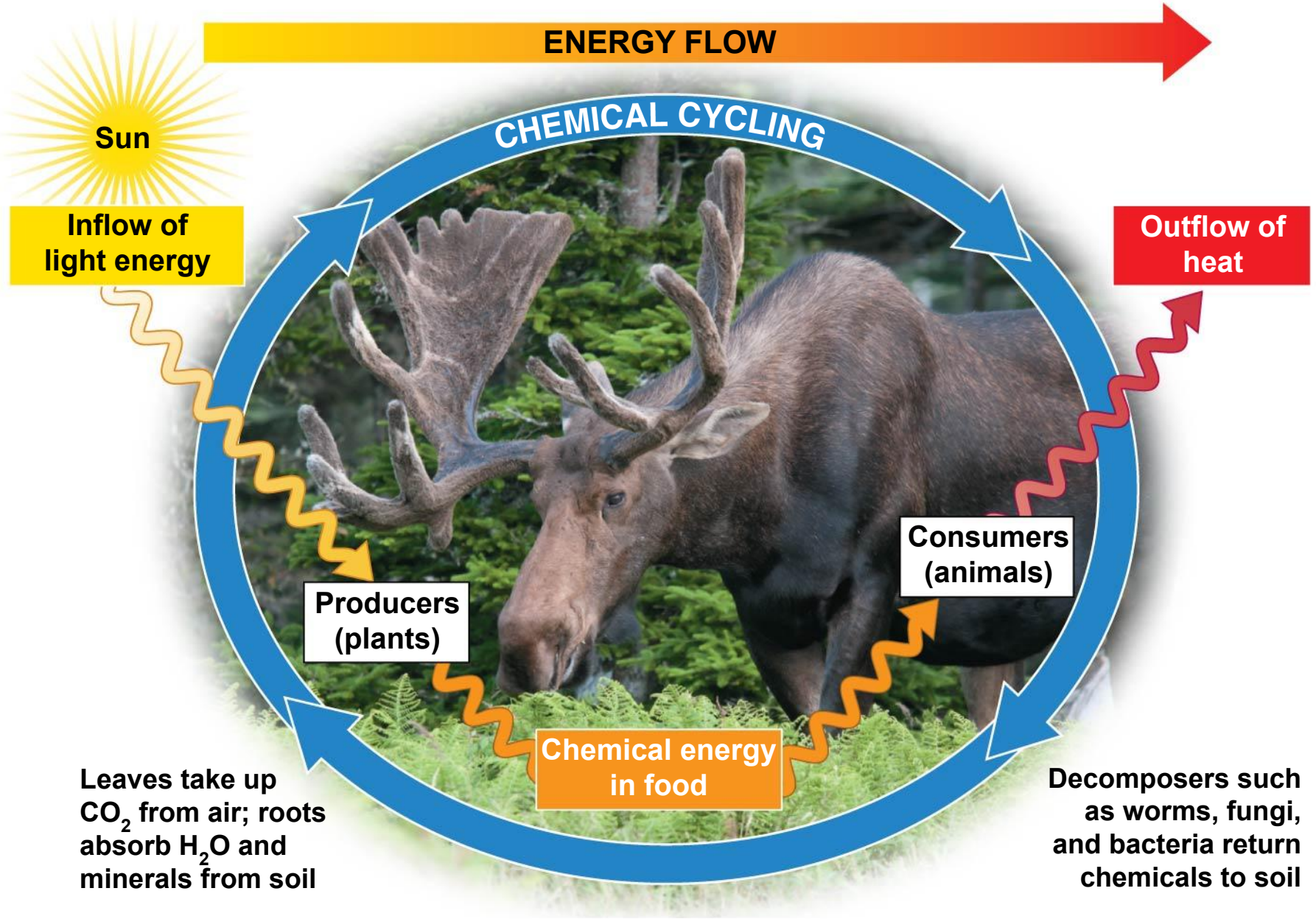
Dynamics of ecosystems

- The dynamics of ecosystems include two major processes:

1. the **recycling of chemical nutrients** from the atmosphere and soil through producers, consumers, and decomposers back to the air and soil

2. the **one-way flow of energy through an ecosystem**, entering as sunlight and exiting as heat

Figure 1.4



Evolution, the Core Theme of Biology

- The Unity of Life
- The Diversity of Life
- Process of Natural Selection

The unity of life is based on DNA and a common genetic code

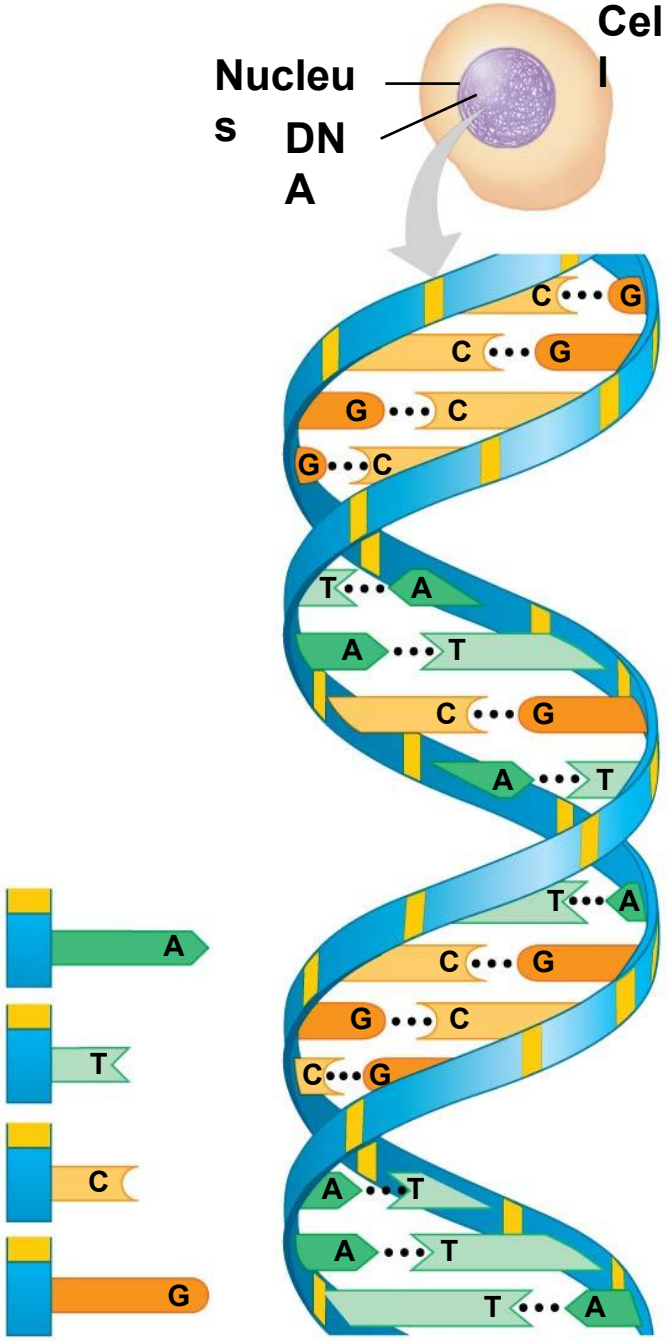
- All cells have **DNA**, the chemical substance of genes

Genes:

- are the **unit of inheritance** that transmit information from parents to offspring
- are grouped into very long DNA molecules called chromosomes
- control the activities of a cell

- A species' genes are coded in the sequences of the four kinds of building blocks making up DNA's double helix.
  - All forms of life use essentially the same code to translate the information stored in DNA into proteins
  - The diversity of life arises from differences in DNA sequences
- The entire "library" of genetic instructions that an organism inherits is called its **genome**
- In recent years, scientists have determined the entire sequence of nucleotides in the human genome

(~ 3 billions base pairs)



The diversity of life

- We can think of biology's enormous scope as having two dimensions
  1. The "**vertical**" dimension is the size scale that stretches from molecules to the biosphere
  2. The "**horizontal**" dimension spans across the great diversity of organisms existing now and over the long history of life on Earth
     - Biologists have identified about 1.8 million species
     - Estimates of the actual number of species range from 10 million to over 100 million

Taxonomy is the branch of biology that

- names species
- classifies species into a hierarchy of broader groups: genus, family, order, class, phylum, and kingdom

The members increases from the "genus" group to the "kingdom" group

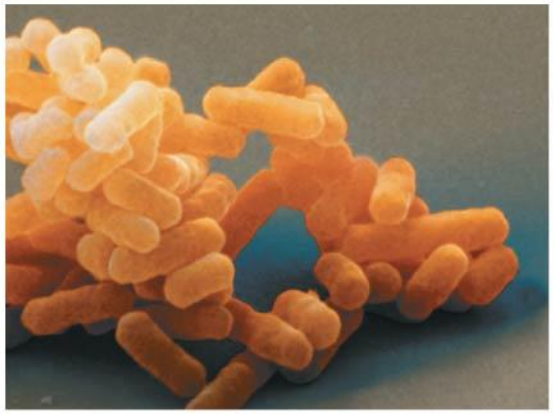
The diversity of life can be arranged into three domains

- The diversity of life can be arranged into three higher levels called **domains**

1. **Bacteria** are the most diverse and widespread prokaryotes
2. **Archaea** are prokaryotes that often live in Earth's extreme environments
3. **Eukarya** have eukaryotic cells and include
   - single-celled protists
   - multicellular fungi, animals, and plants.

Figure 1.6

Domain Bacteria

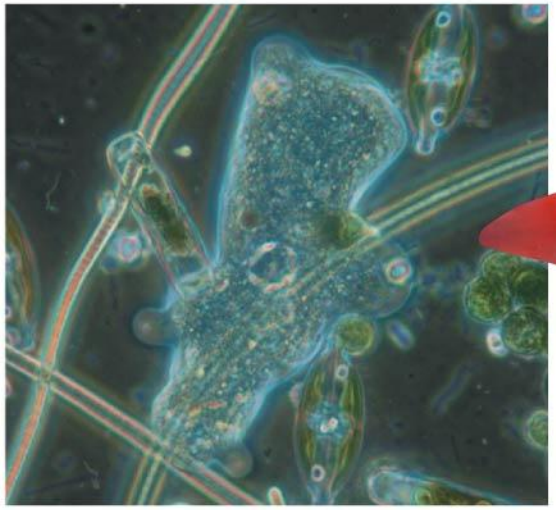


Bacteria

Domain Archaea

Archaea

Domain Eukarya



Protists
(multiple kingdoms)

Kingdom Plantae

Kingdom Fungi

Kingdom Animalia

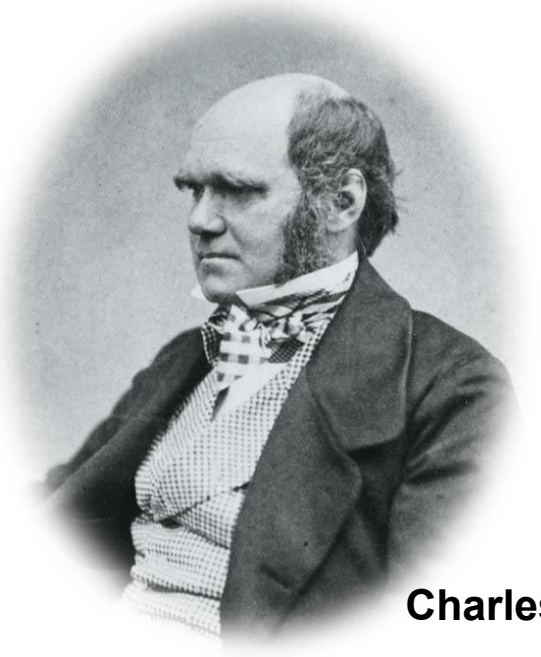
Evolution explains the unity and diversity of life

- **Evolution** can be defined as the process of change that has transformed life on Earth from its earliest beginnings to the diversity of organisms living today
- The fossil record tell us
  - that life has been evolving on Earth for billions of years
  - the pattern of ancestry

Excavation of fossilized mammoth bones

- In 1859, Charles Darwin published the book "*On the Origin of Species by Means of Natural Selection*", which explained two main points:

1. Species living today descended from ancestral species - "**descent with modification**"
2. **Natural selection** is a mechanism for evolution



Charles Darwin in 1859

Natural Selection

- Natural selection was inferred by connecting <u>two observations</u>

1. **Individual variation**: Individuals in a population vary in their traits, many of which are passed on from parents to offspring

2. **Overproduction of offspring**: A population can produce far more offspring than the environment can support

Individual variation

- From these observations, Darwin drew two conclusions

1. **Unequal reproductive success**: Individuals with heritable traits best suited to the environment are more likely to survive and reproduce than less well-suited individuals

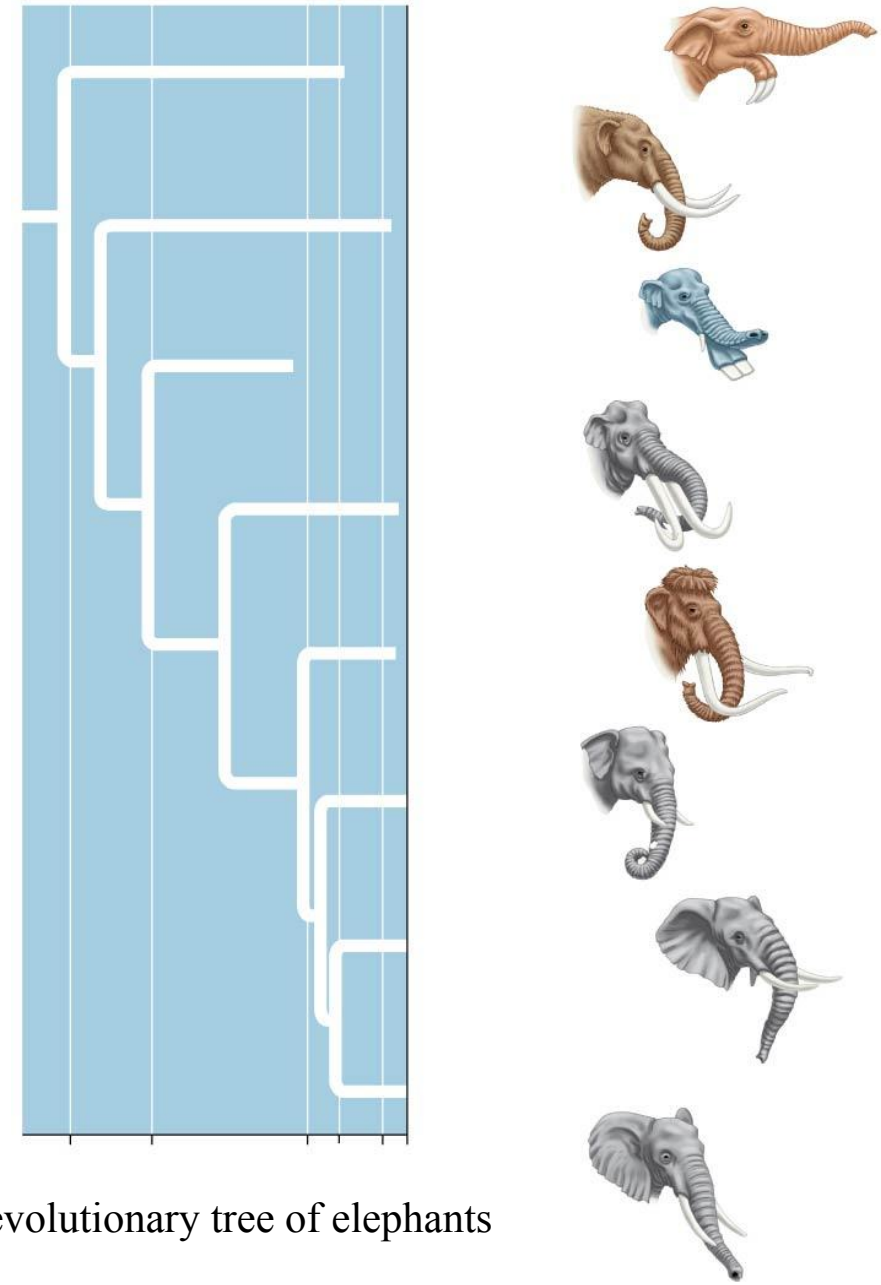
2. **Accumulation of favorable traits over time**: As a result of this unequal reproductive success over many generations, an increasing proportion of individuals in a population will have the advantageous traits

Unequal reproductive success

Accumulation of favorable traits over time

- Darwin realized that numerous small changes in populations as a result of natural selection could eventually lead to major alterations of species.

- The fossil record provides evidence of such diversification of species from ancestral species.



An evolutionary tree of elephants

The Process of Science

- Scientific Approaches
- Scientific Thinking

Scientific Approaches

- The word "**SCIENCE"** is derived from a Latin verb meaning "**to know**"
- Science is a way of knowing that stems from our curiosity about ourselves and the world around us
- Science is based upon inquiry, the search for information and explanations of natural phenomena
- Scientists typically
  - make observations
  - form **hypotheses** by proposing explanations for a set of observations, and test them

Scientists uses **two forms of inquiry**

1. **Discovery Science** which is mostly about **describing nature**
   - Verifiable observations and measurements are the data of discovery science
   - In biology, discovery science describe life at its many levels, from ecosystems down to cells and molecules

2. **Hypothesis-based Science** which is mostly about **explaining nature**
   - The observations of discovery science stimulate us to seek natural causes and explanations for those observations

- **Two types of data** are frequently collected in scientific investigations
  1. **Qualitative** data is “descriptive”
  2. **Quantitative** data includes “numerical measurements”

- Scientists use **two types of reasoning**

  1. **Inductive reasoning** makes generalizations based on collecting and analyzing a large number of specific observations

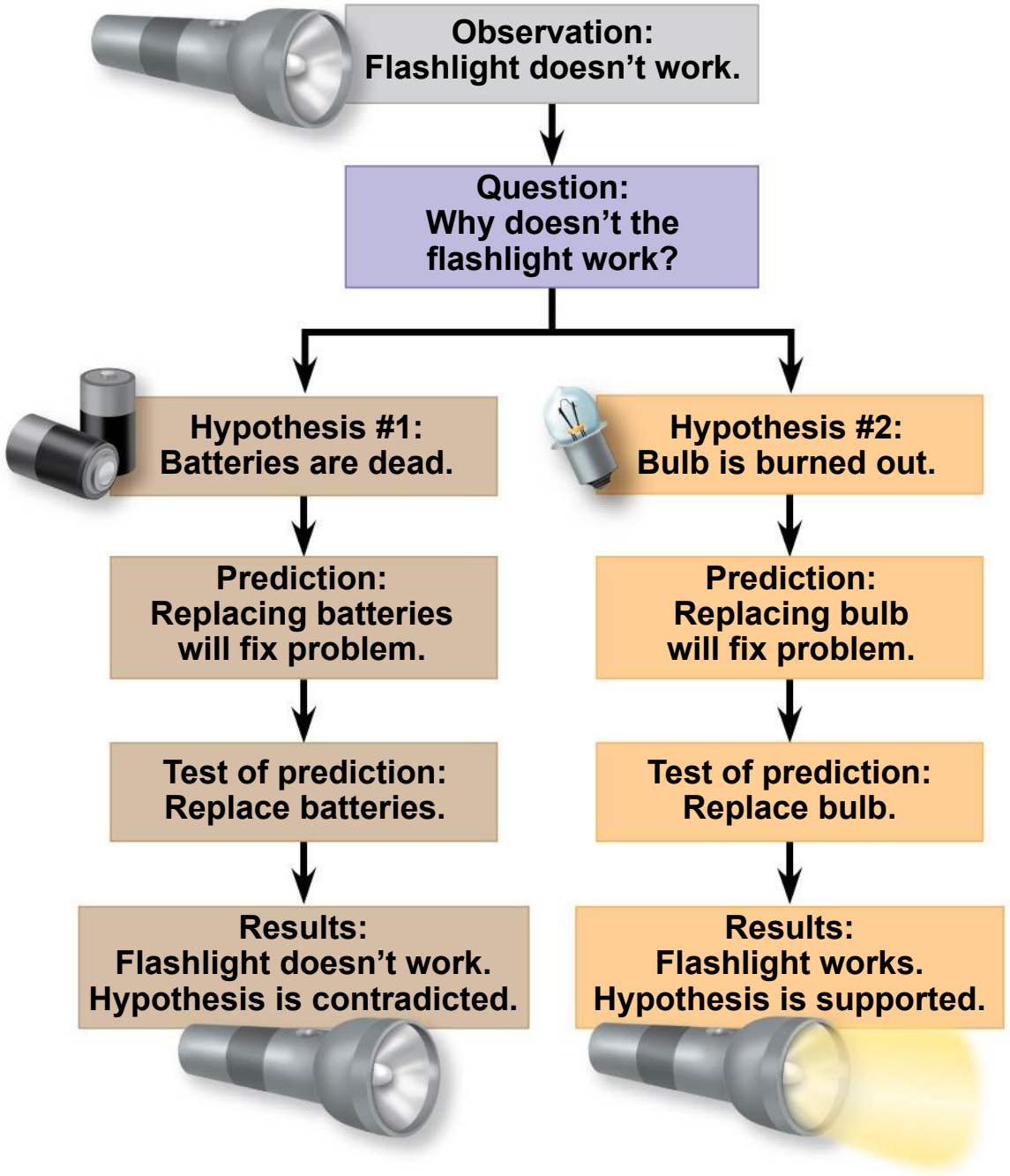
  2. **Deductive reasoning** flows from general premises to predicted and specific results

In studying nature, scientists make observations, then form and test hypotheses

We solve everyday problems by using hypotheses

- A common example would be the reasoning we use to answer the question, “Why doesn’t a flashlight work?”
- Two reasonable hypotheses are that
  1. the batteries are dead
  2. the bulb is burned out

Figure 1.8 An everyday example of forming and testing hypotheses



- A **scientific theory** is
  - much broader in scope than a hypothesis
  - supported by a large and usually growing body of evidence

- Science is a social activity in which scientists
  - work in teams
  - share information through peer-reviewed publications, meetings, and personal communication
  - build on and confirm each other's work

SCIENTIFIC THINKING: Hypotheses can be tested using controlled studies

- Scientists conducted a **controlled experiment** to test the hypothesis
- The experiment compared
  - Experimental group
  - Control group
- The groups differed by only one factor, the factor to be tested by the hypothesis
- Experiments need repetition to get closer to the best estimation