Chapter 1

Introduction: Themes in the Study of Life

Lecture 1

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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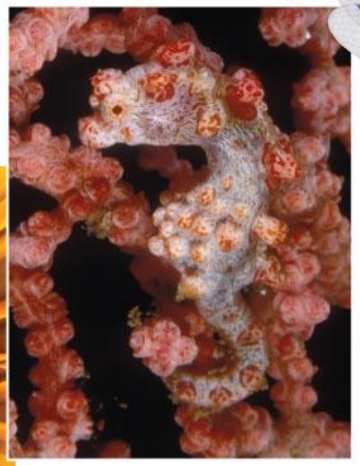
Overview: Inquiring About the World of Life

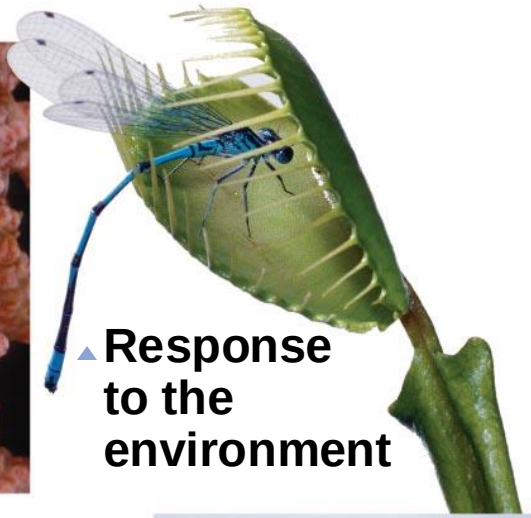
- **Evolution** is the process of change that has transformed life on Earth.
- **Biology** is the scientific study of life
- Biologists ask questions such as:
  - How a single cell develops into an organism
  - How the human mind works
  - How living things interact in communities

Fig. 1-3

Order



Evolutionary adaptation



Response to the environment

Regulation

Energy processing

Growth and development

Reproduction

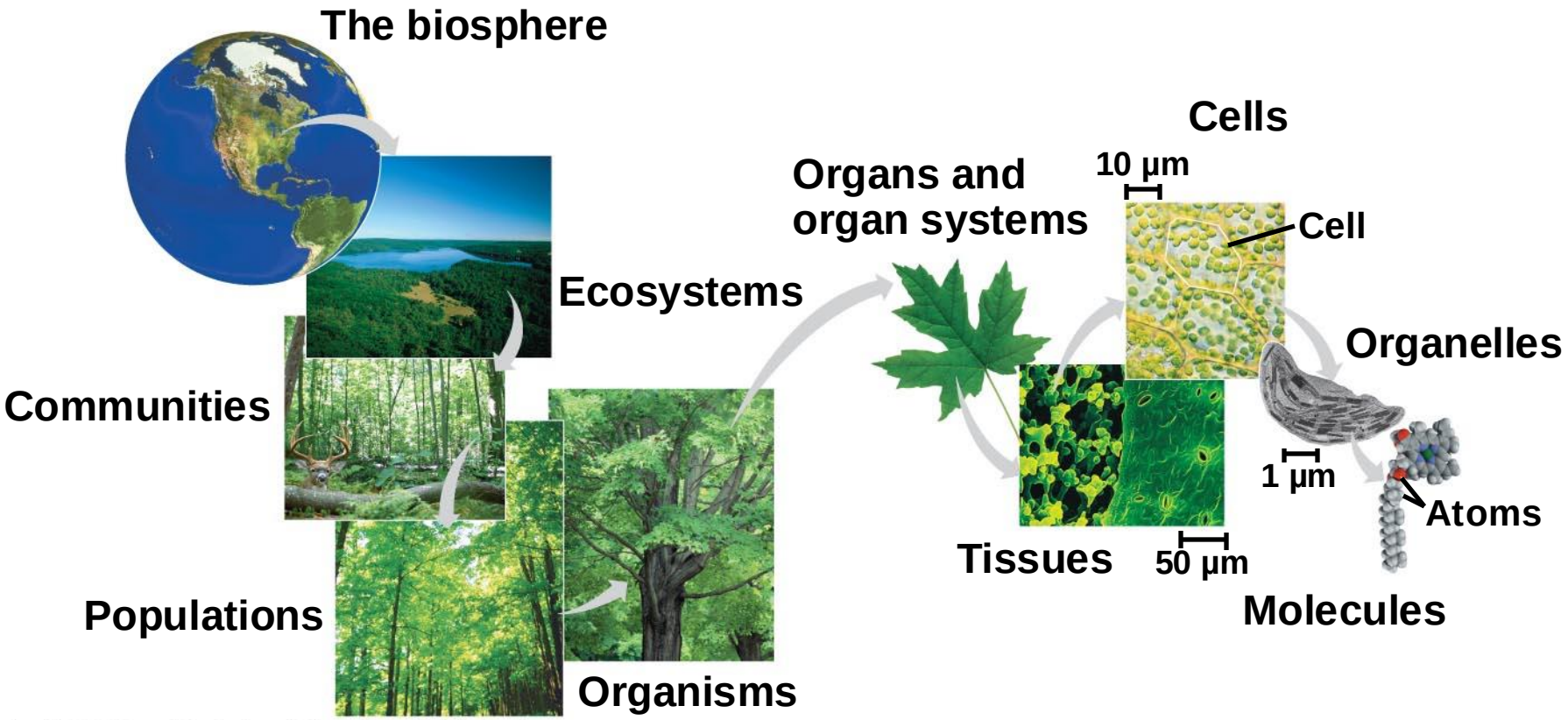
Evolution, the Overarching Theme of Biology

- **Evolution** makes sense of everything we know about living organisms.
- It's the central theory of biology.
- Evolution provides a unifying framework that explains the diversity, complexity, and adaptation of life on Earth.
- Organisms living on Earth are modified descendents of common ancestors

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

Fig. 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, the molecular structure of DNA
- An understanding of biology balances between reductionism and 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?

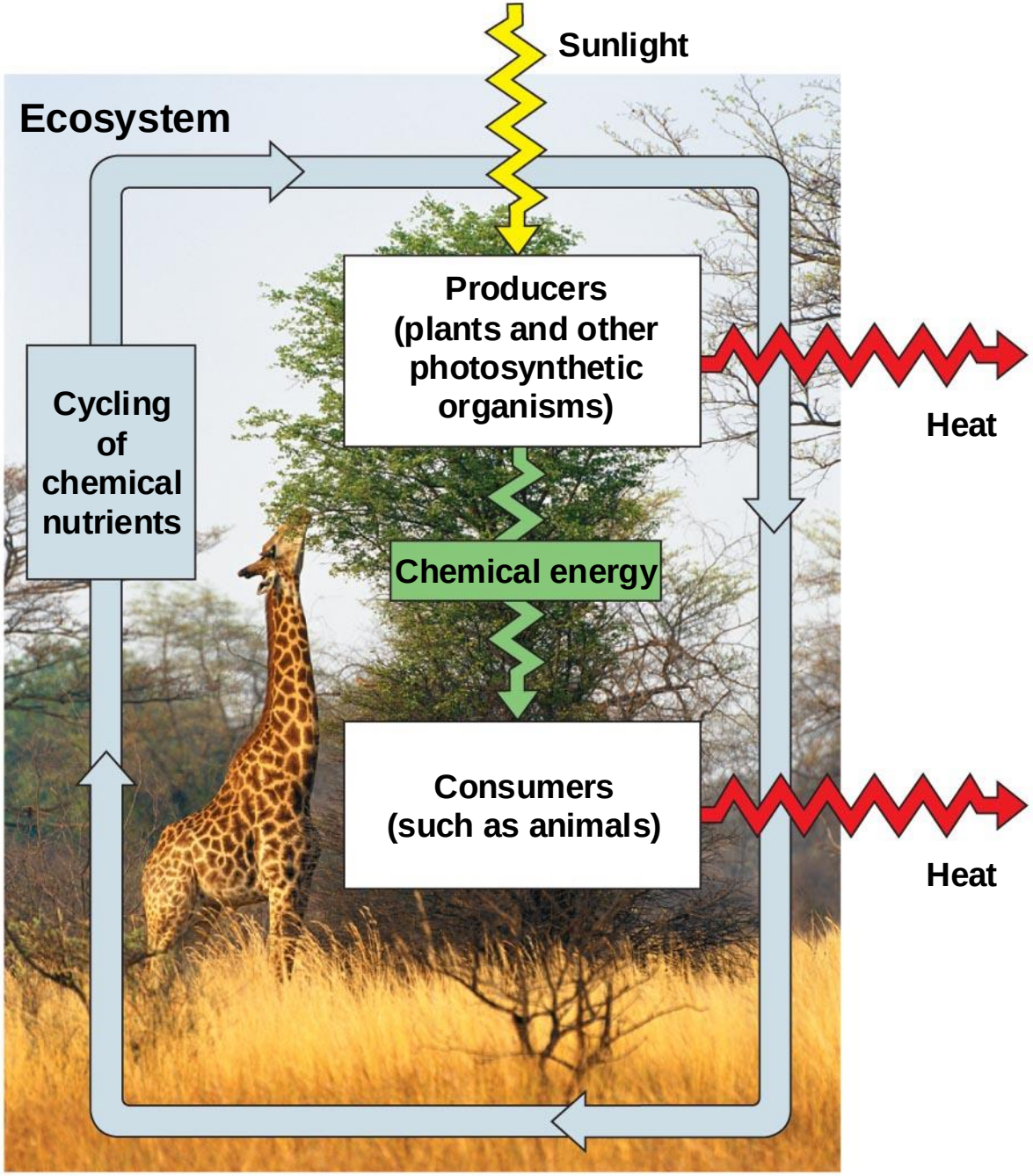
Theme: Organisms interact with their environments, exchanging matter and energy

- 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

Ecosystem Dynamics

- The dynamics of an ecosystem include two major processes:
  - **Cycling of nutrients**, in which materials acquired by plants eventually return to the soil
  - **The flow of energy** from sunlight to producers to consumers

Fig. 1-5



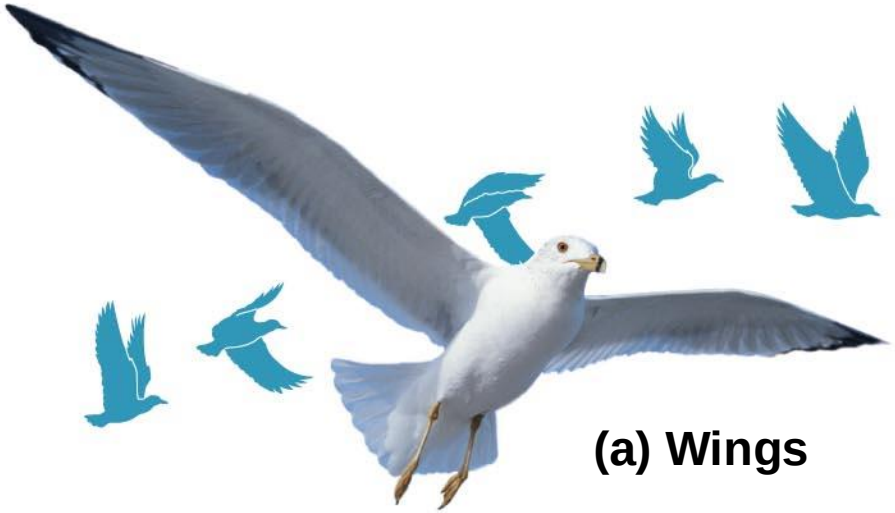
Energy Conversion

- Work requires a source of energy
- Energy can be stored in different forms, for example, light, chemical, kinetic, or thermal
- The energy exchange between an organism and its environment often involves energy transformations
- Energy flows *through* an ecosystem, usually entering as light and exiting as heat

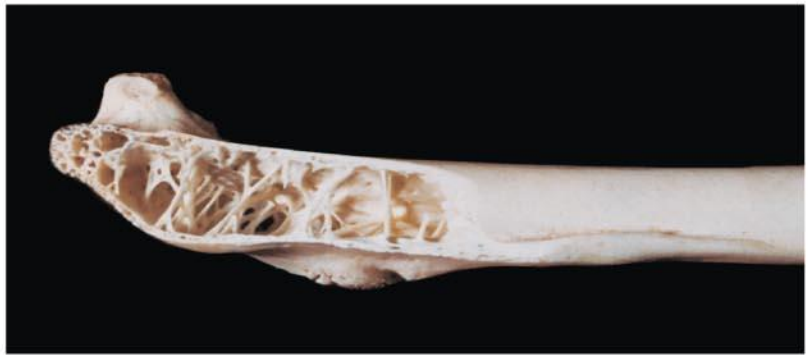
Theme: Structure and function are correlated at all levels of biological organization

- Structure and function of living organisms are closely related
  - For example, a leaf is thin and flat, maximizing the capture of light by chloroplasts

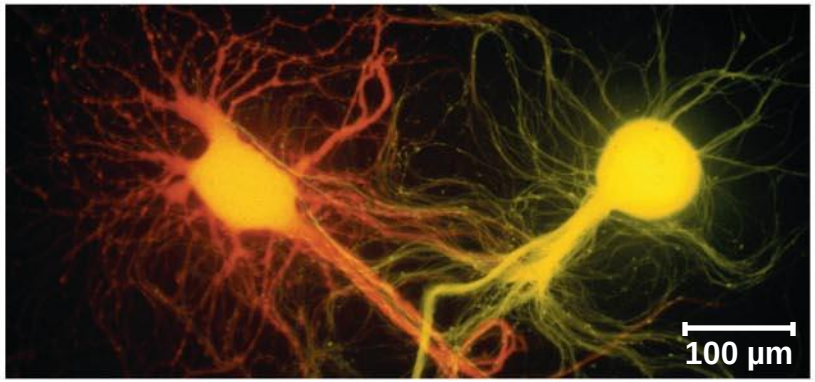
Fig. 1-6



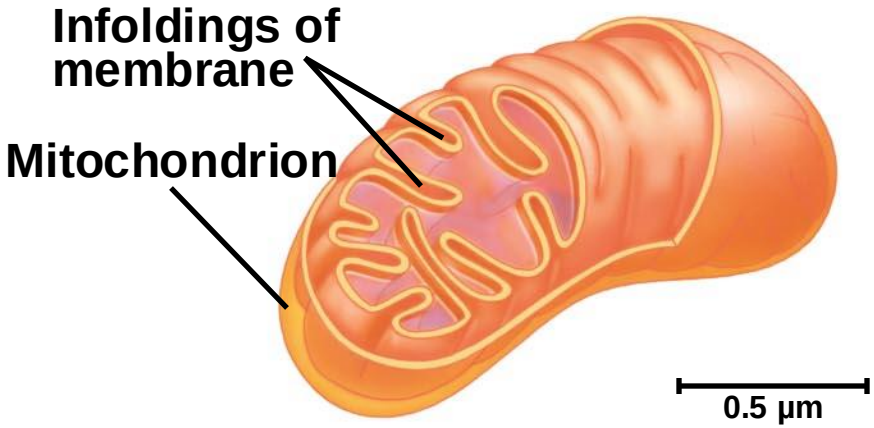
(a) Wings



(b) Bones



(c) Neurons



(d) Mitochondria

Theme: Cells are an organism's basic units 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
- The ability of cells to divide is the basis of all reproduction, growth, and repair of multicellular organisms

- Advances in **systems biology** at the cellular and molecular level depend 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

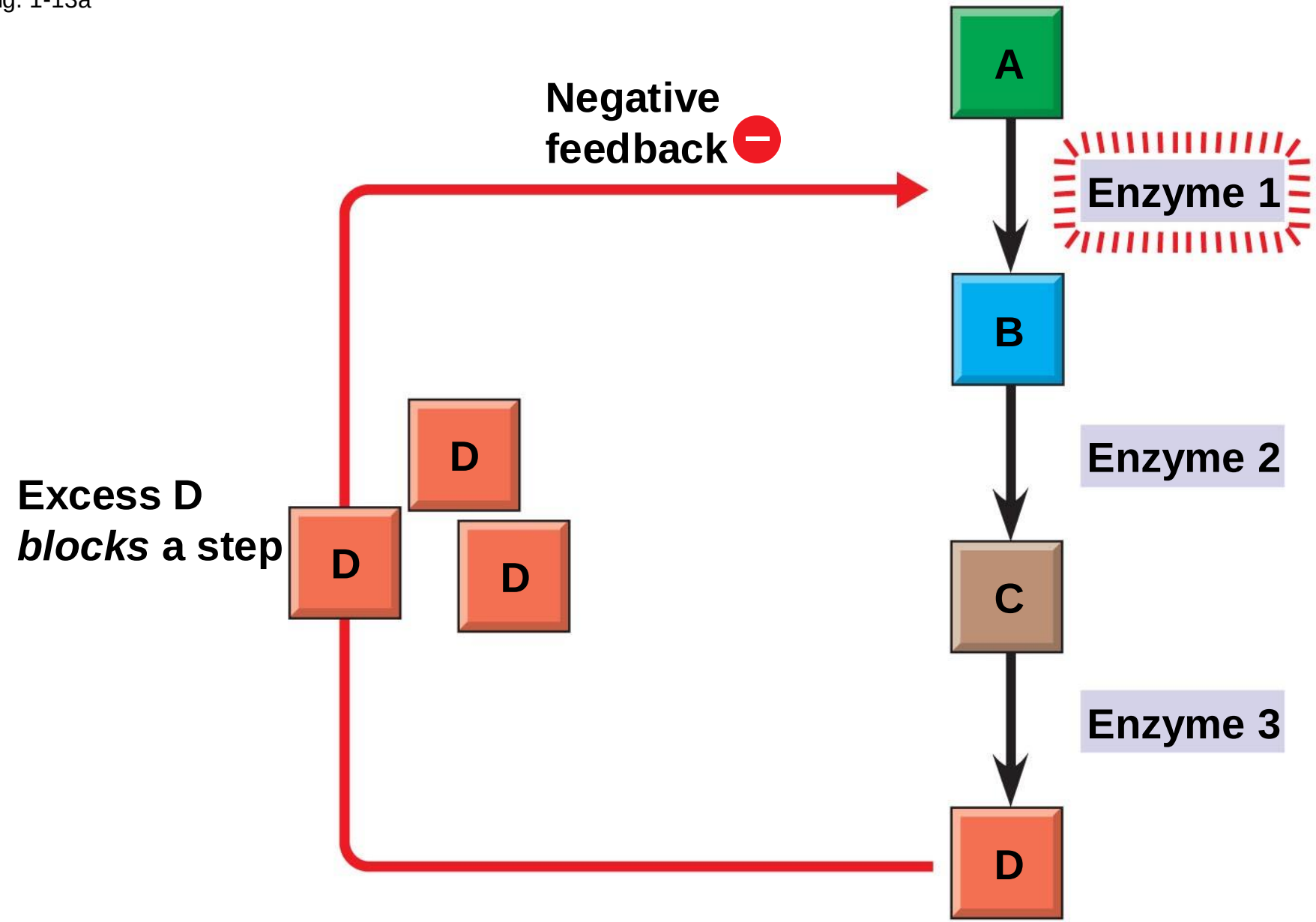
Theme: Feedback mechanisms regulate biological systems

- 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

PLAY Animation: Negative Feedback

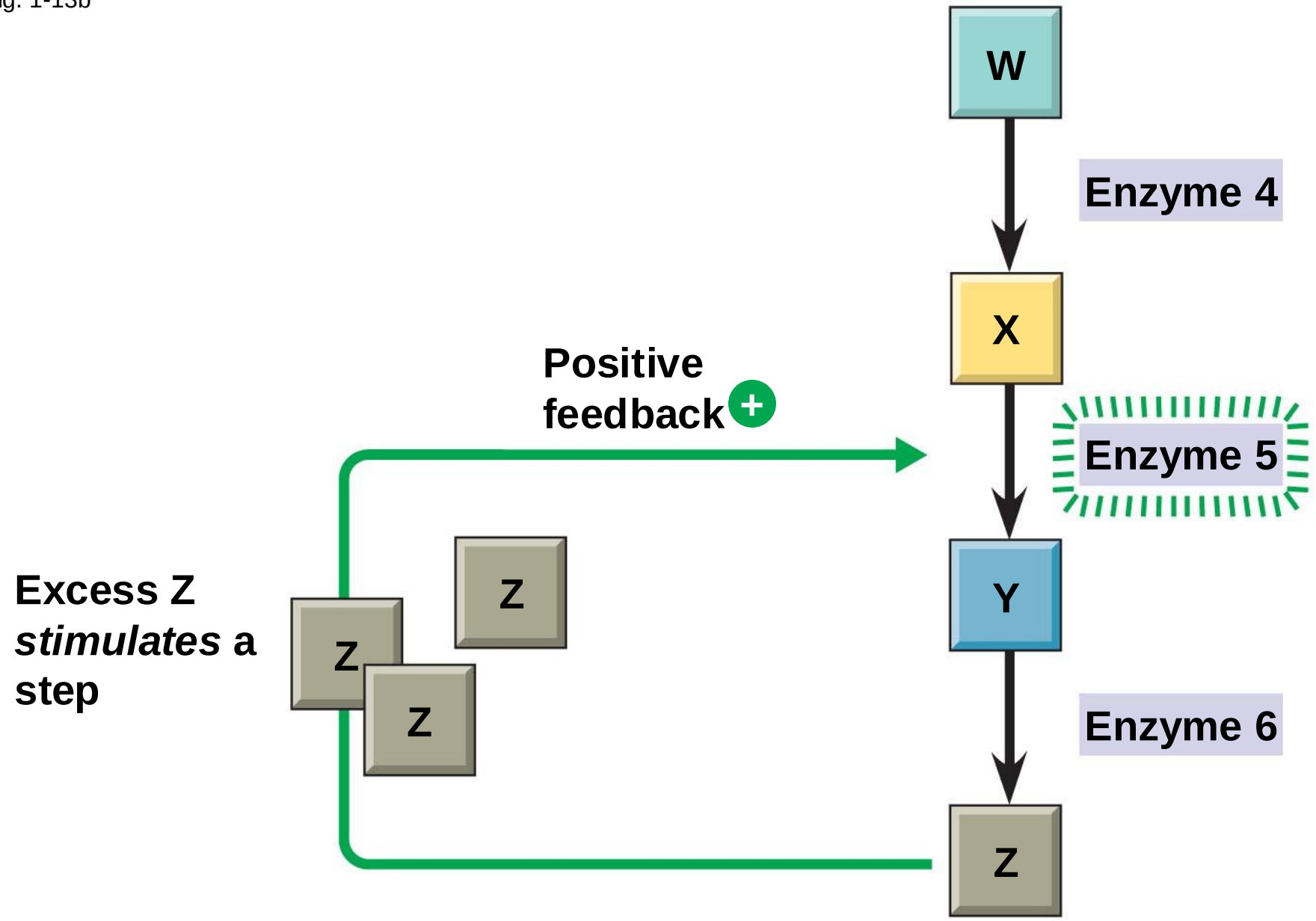
PLAY Animation: Positive Feedback

Fig. 1-13a



(a) Negative feedback

Fig. 1-13b



(b) Positive feedback

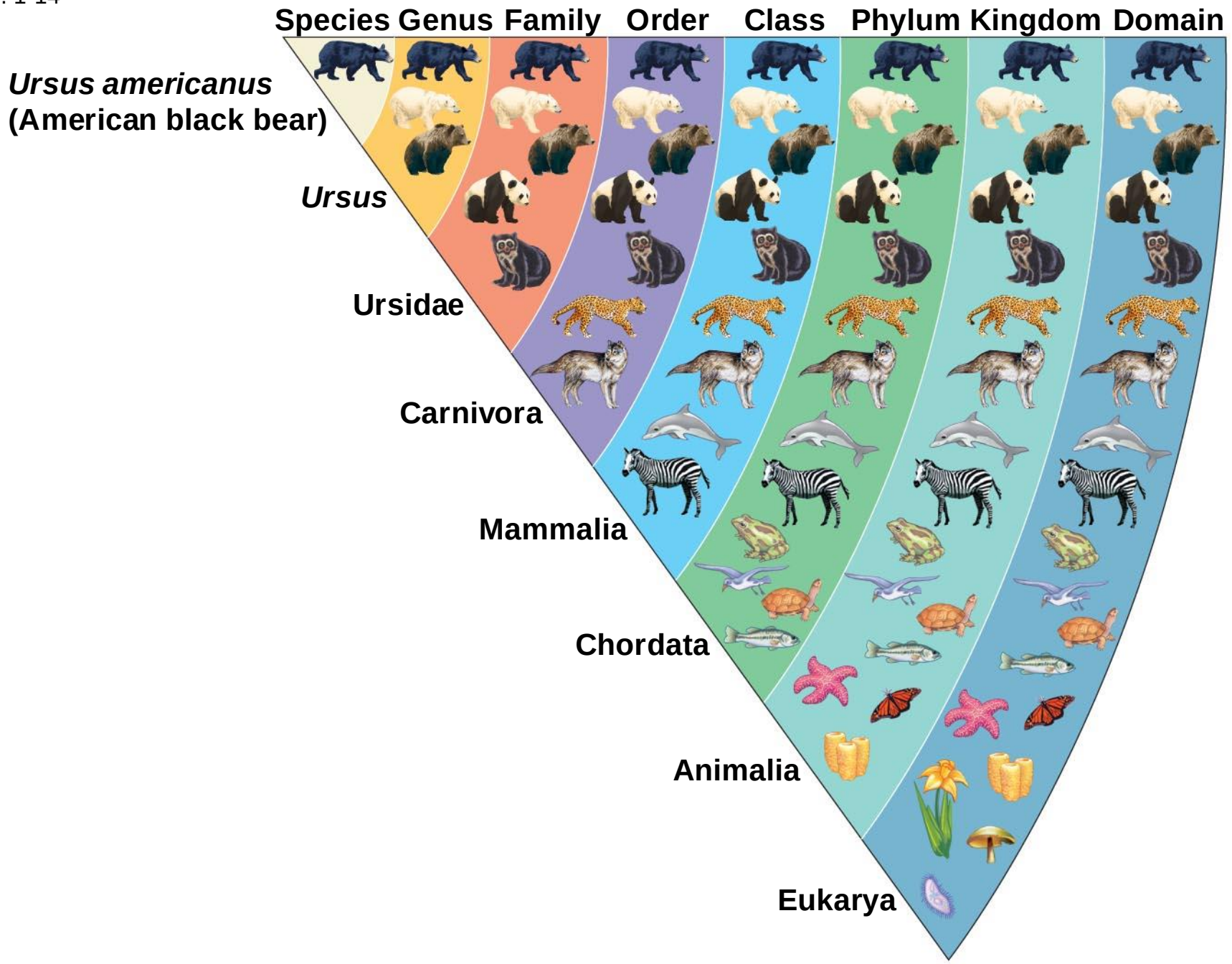
Organizing the Diversity of Life

- 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

Fig. 1-14



(Organisms with membrane-bound nucleus) **Eukarya**

(Animals) **Animalia**

(Have a backbone) **Chordata**

(Have fur & give milk) **Mammalia**

(Have nails, short snouts, large brains) **Primate**

(Great Apes) **Hominidae**

(Humans & related extinct species) ***Homo***

(Modern humans) ***sapiens***

Domain	المجال
Kingdom	المملكة
Phylum	الشعب
Class	فئات
Order	الرتبة
Family	العائلة
Genus	الجنس
Species	نوع

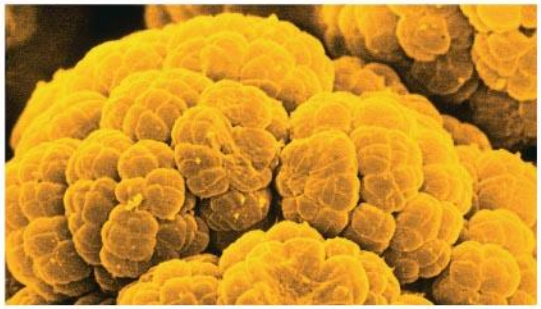
The Three Domains of Life

- The three-domain system is currently used, and replaces the old five-kingdom system which are: animal, plant, fungi, protist and monera.
- **Domain Bacteria** and **domain Archaea** comprise the prokaryotes
- **Domain Eukarya** includes all eukaryotic organisms

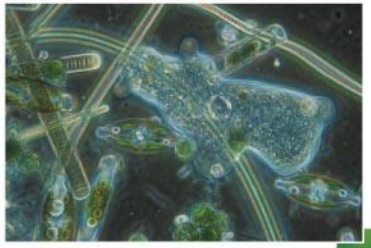
Fig. 1-15

(a) DOMAIN BACTERIA

(b) DOMAIN ARCHAEA

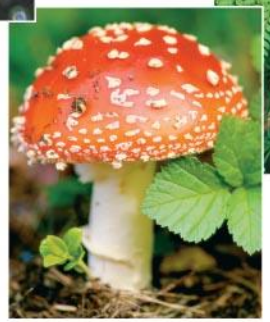


(c) DOMAIN EUKARYA



Protists

Kingdom Plantae



Kingdom Fungi

Kingdom Animalia

- The domain Eukarya includes three multicellular kingdoms:
  - Plantae
  - Fungi
  - Animalia
- Other eukaryotic organisms were formerly grouped into a kingdom called **Protista**, though these are now often grouped into many separate kingdoms

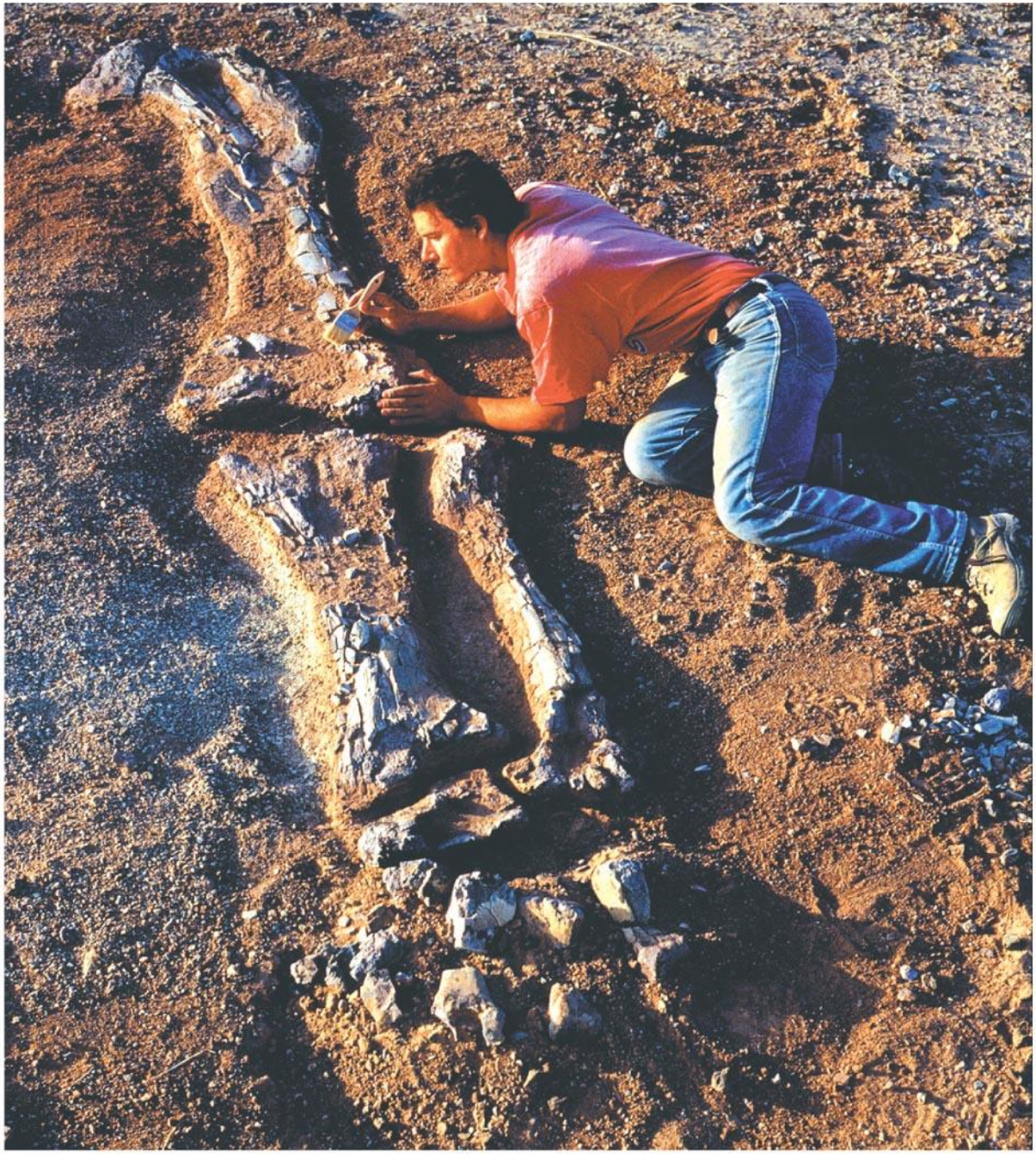
Unity in the Diversity of Life

- 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**

Charles Darwin and the Theory of Natural Selection

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

Fig. 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

Fig. 1-19

- Darwin observed that:
  - Individuals in a population have traits that vary
  - Many of these traits are heritable (passed from parents to offspring)
  - More offspring are produced than survive
  - 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
- In other words, the natural environment "selects" for beneficial traits

- Natural selection is often evident in adaptations of organisms to their way of life and environment
- Bat wings are an example of adaptation

PLAY Video: Soaring Hawk

Fig. 1-21

The Tree of Life

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

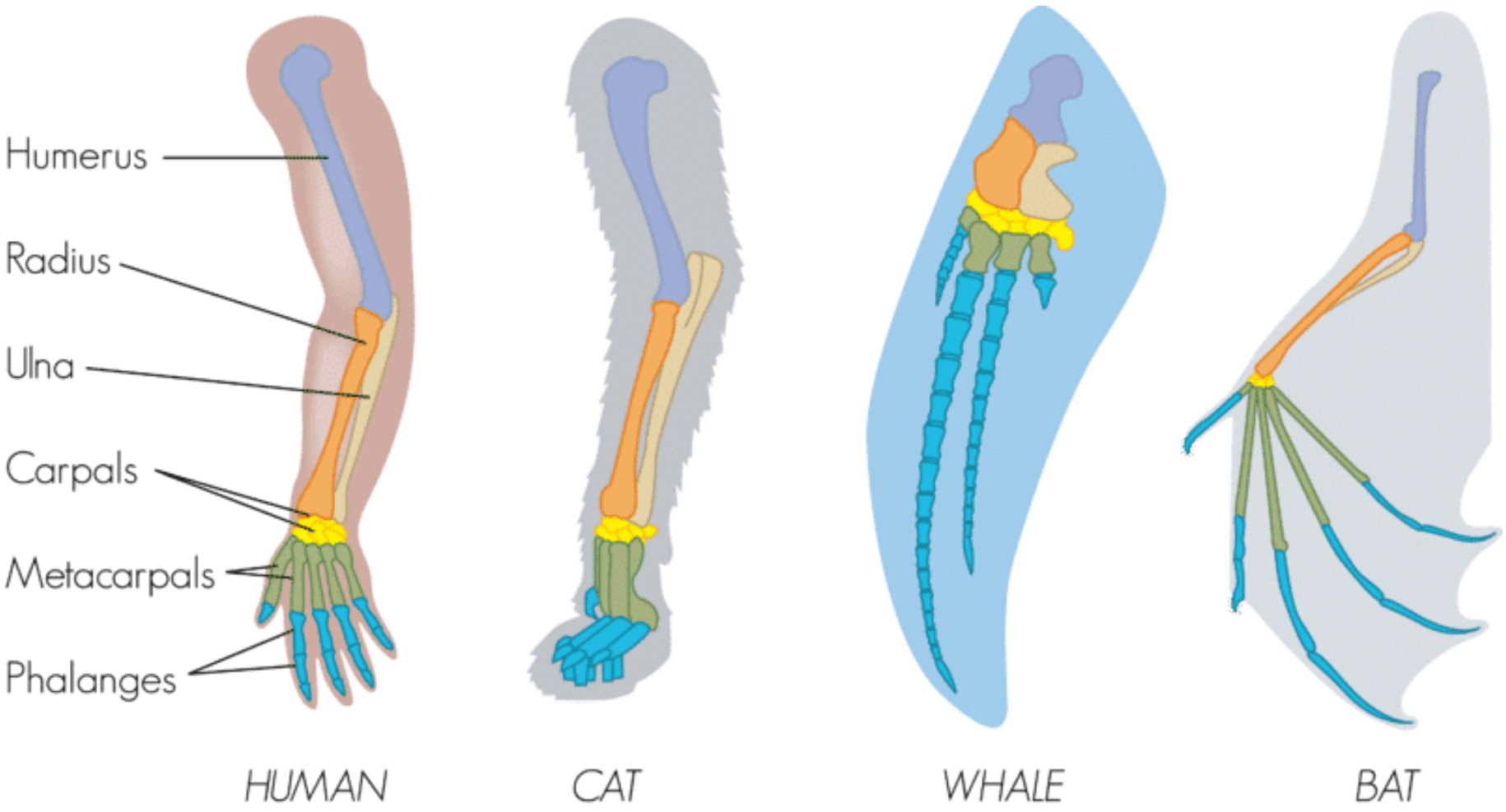
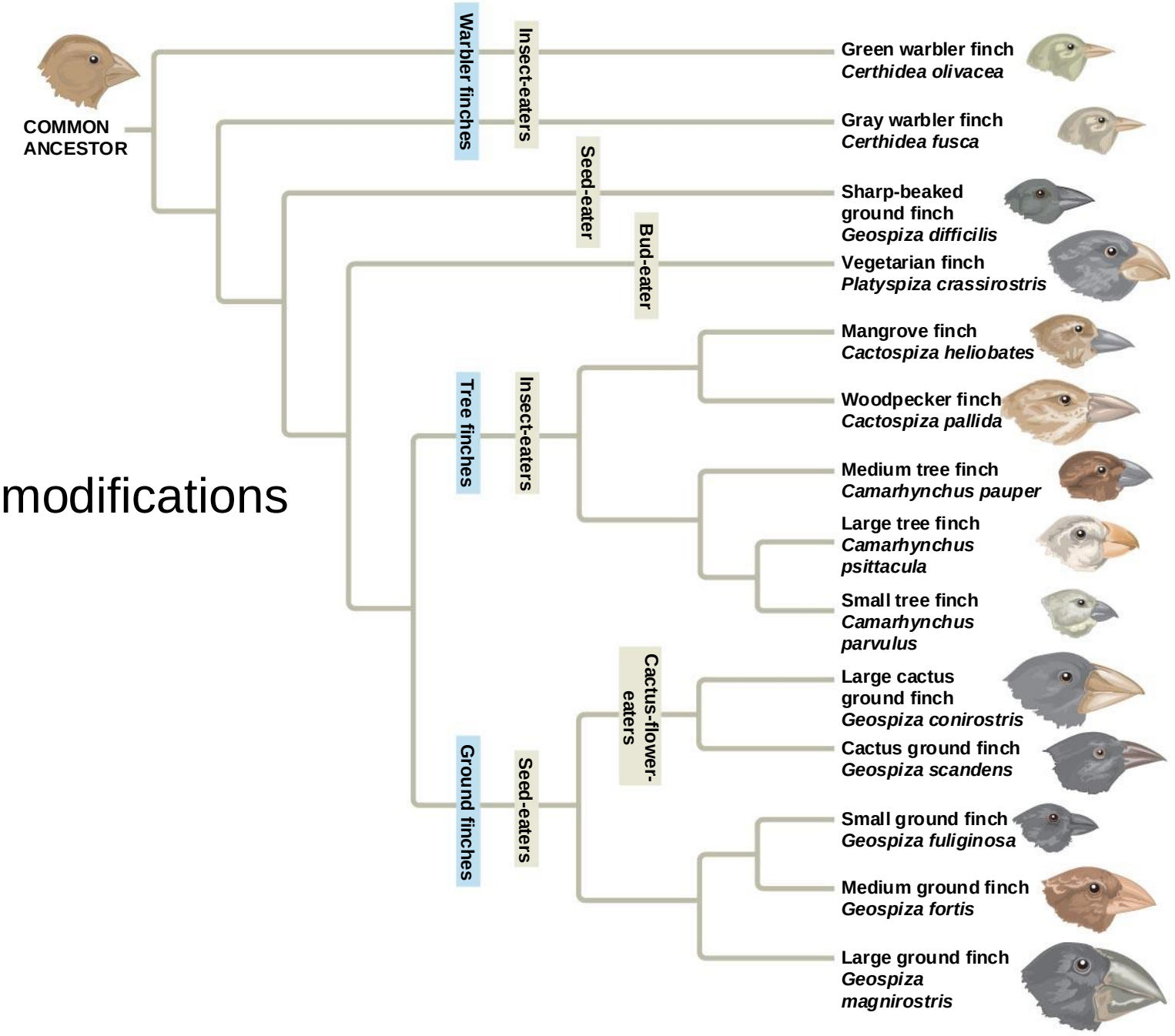

Humerus
Radius
Ulna
Carpals
Metacarpals
Phalanges
HUMAN
CAT
WHALE
BAT

Fig. 1-22



Beak modifications

Concept 1.3: Scientists use two main forms of inquiry in their study of nature

- The word *Science* is derived from Latin and means “to know”
- **Inquiry** is the search for information and explanation
- There are two main types of scientific inquiry: **discovery science** and **hypothesis-based science**

Discovery Science

- **Discovery science** describes 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
- Data fall into two categories
  - ***Qualitative***, or descriptions rather than measurements
  - ***Quantitative***, or recorded measurements, which are sometimes organized into tables and graphs

Fig. 1-23

Hypothesis-Based Science

- Observations 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

Fig. 1-24a

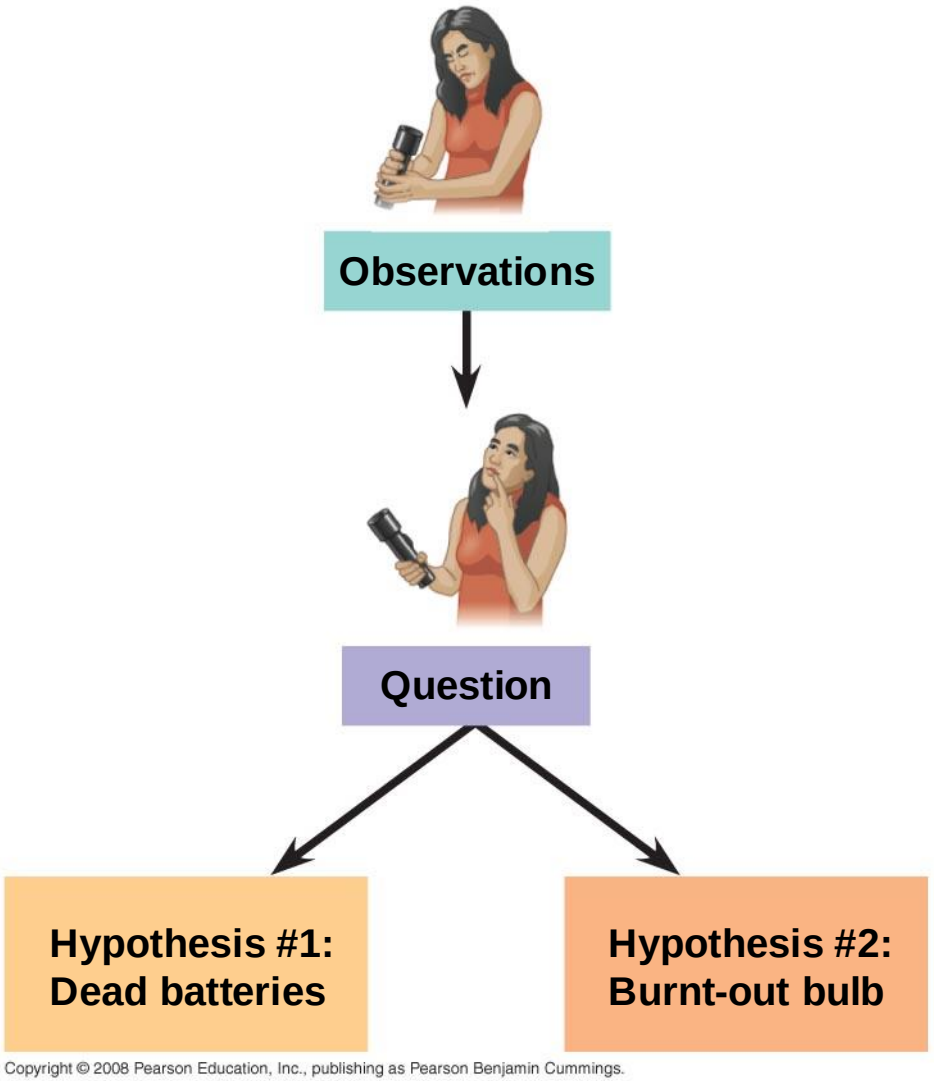
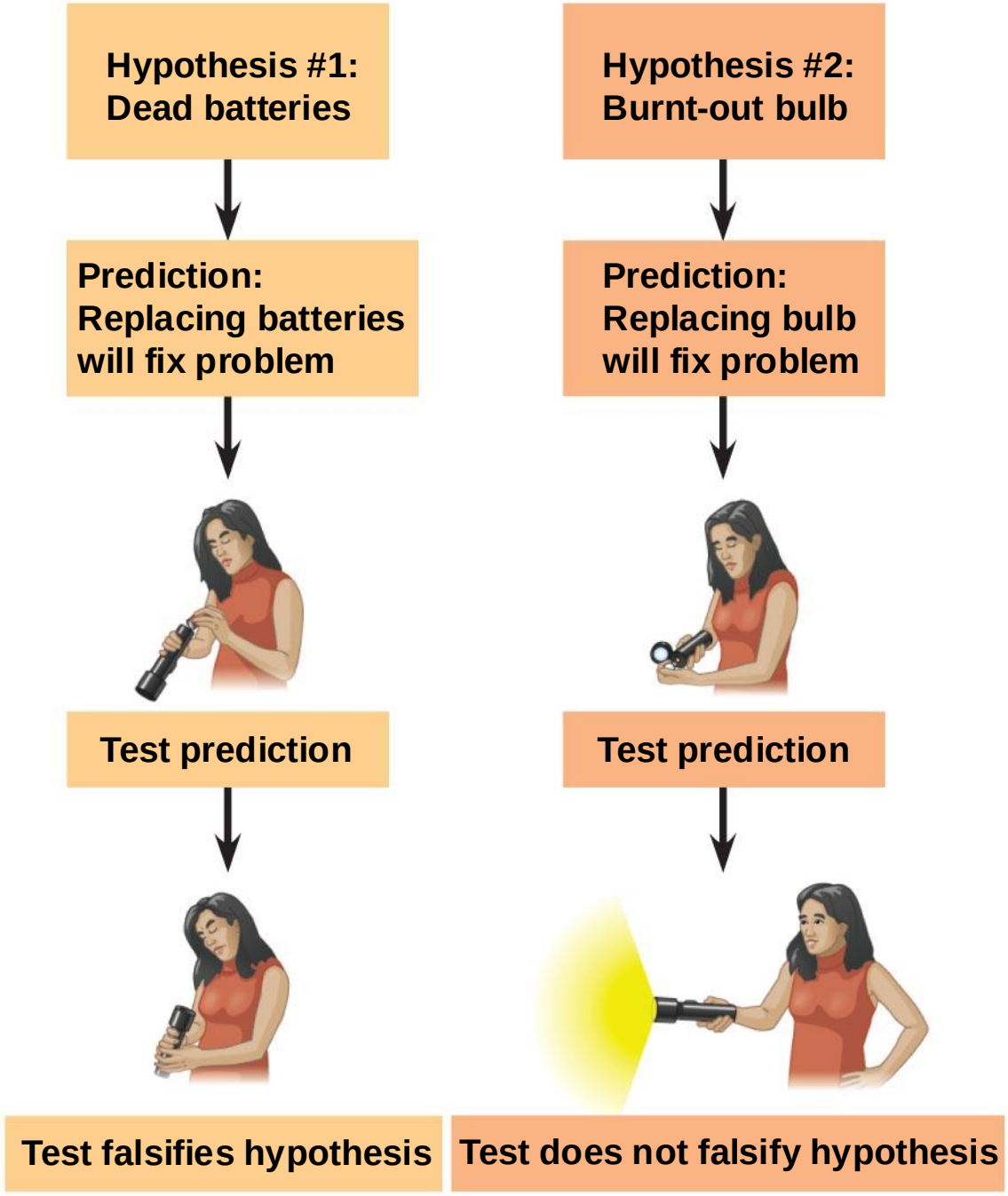


Fig. 1-24b



Deduction: The "If…Then" Logic of Hypothesis Based Science

- **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)

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

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