Chapter 1

Introduction: Themes in the Study of Life

Edited by Shawn Lester

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

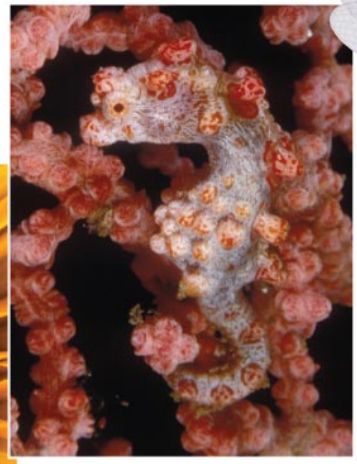
Overview: Inquiring About the World of Life

- **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

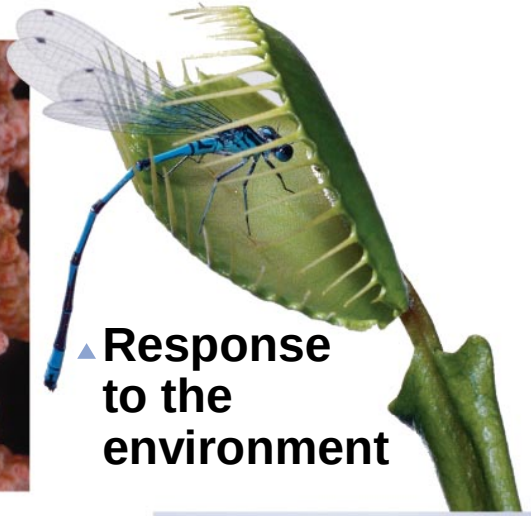
- Life defies a simple, one-sentence definition
- Life is recognized by what living things do

Fig. 1-3

Order



Evolutionary adaptation



Response to the environment

Regulation

Energy processing

Growth and development

Reproduction

Concept 1.1: Themes connect the concepts of biology

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

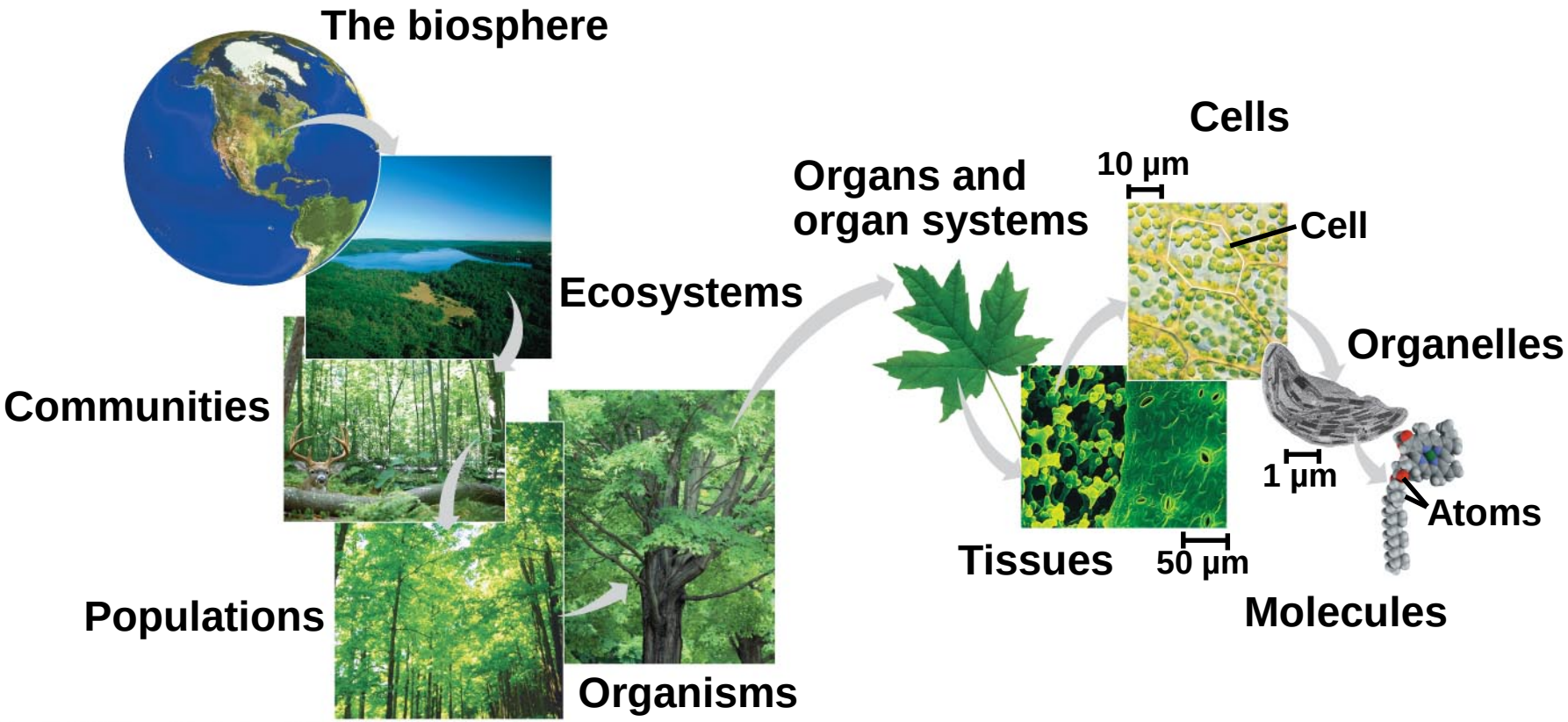
Evolution, the Overarching Theme of Biology

- Evolution makes sense of everything we know about living organisms
- 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



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
- Often for the sake of simplicity and understanding, biologists and other scientists **generalize** in order to facilitate understanding.

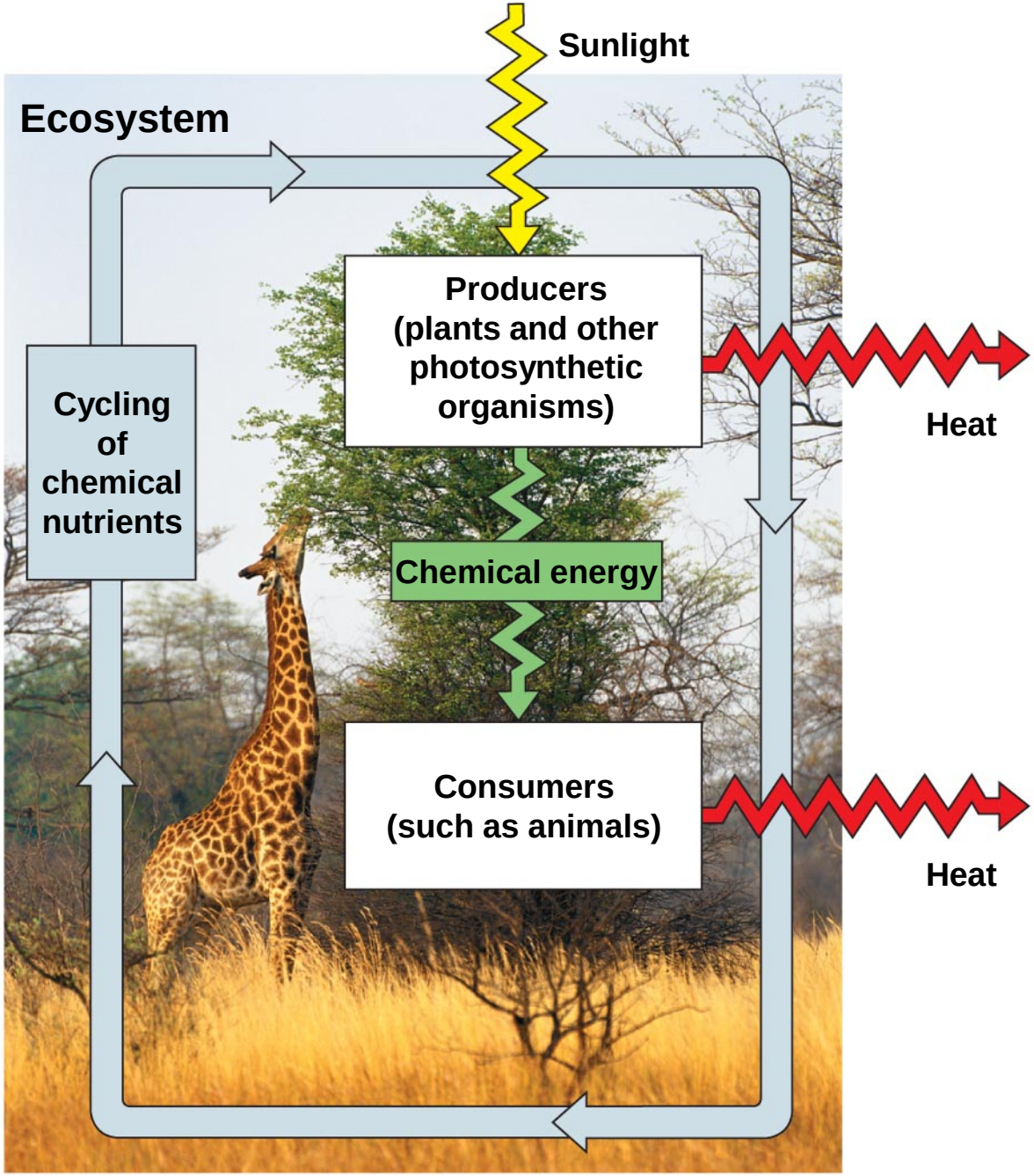
Theme: Organisms interact with their environments, exchanging matter and energy

- 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



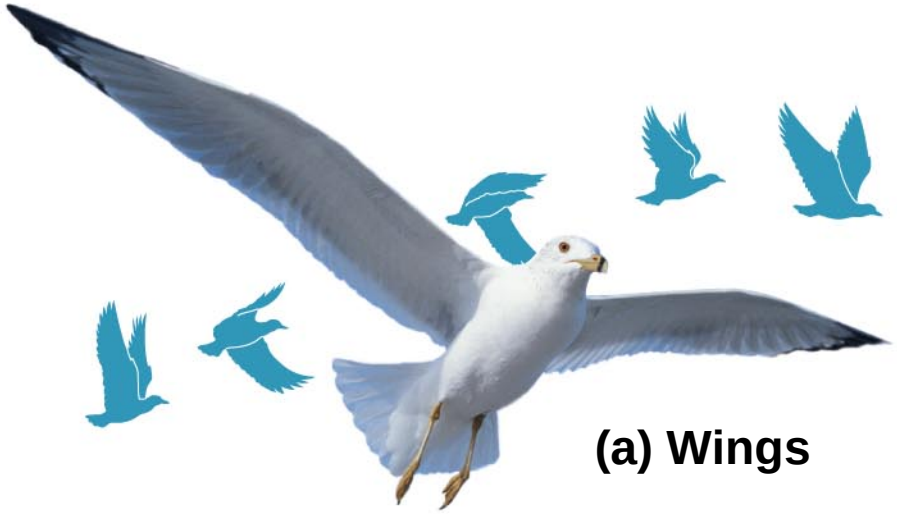
Energy Conversion

- 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

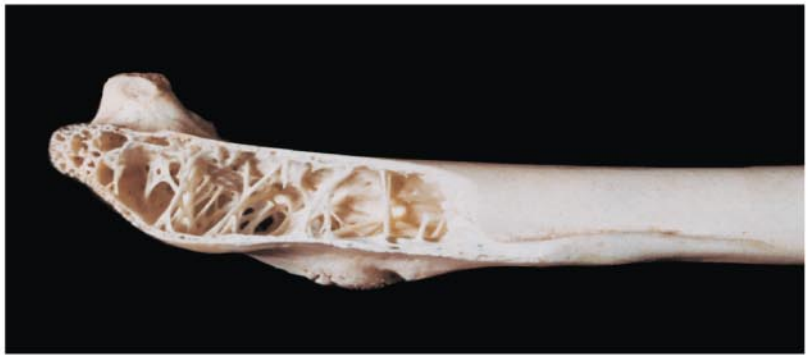
Theme: Structure and function are correlated at all levels of biological organization

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

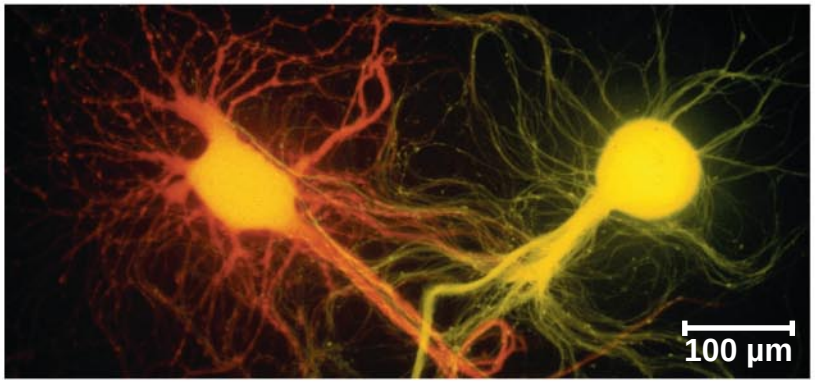
Fig. 1-6



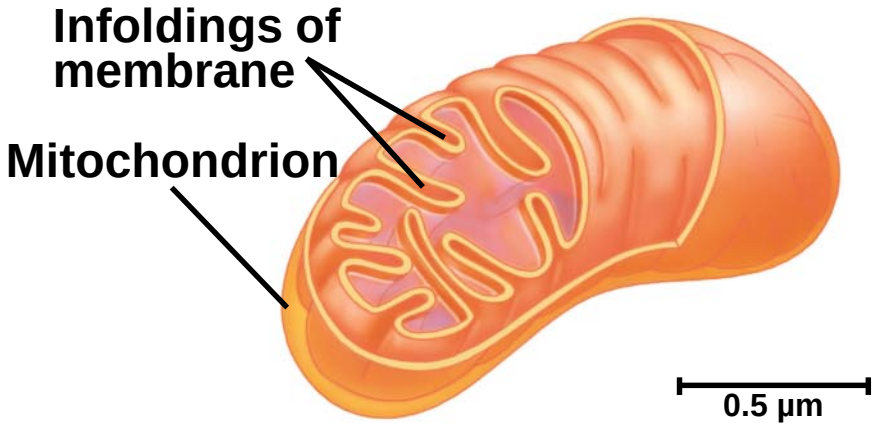
(a) Wings



(b) Bones



(c) Neurons



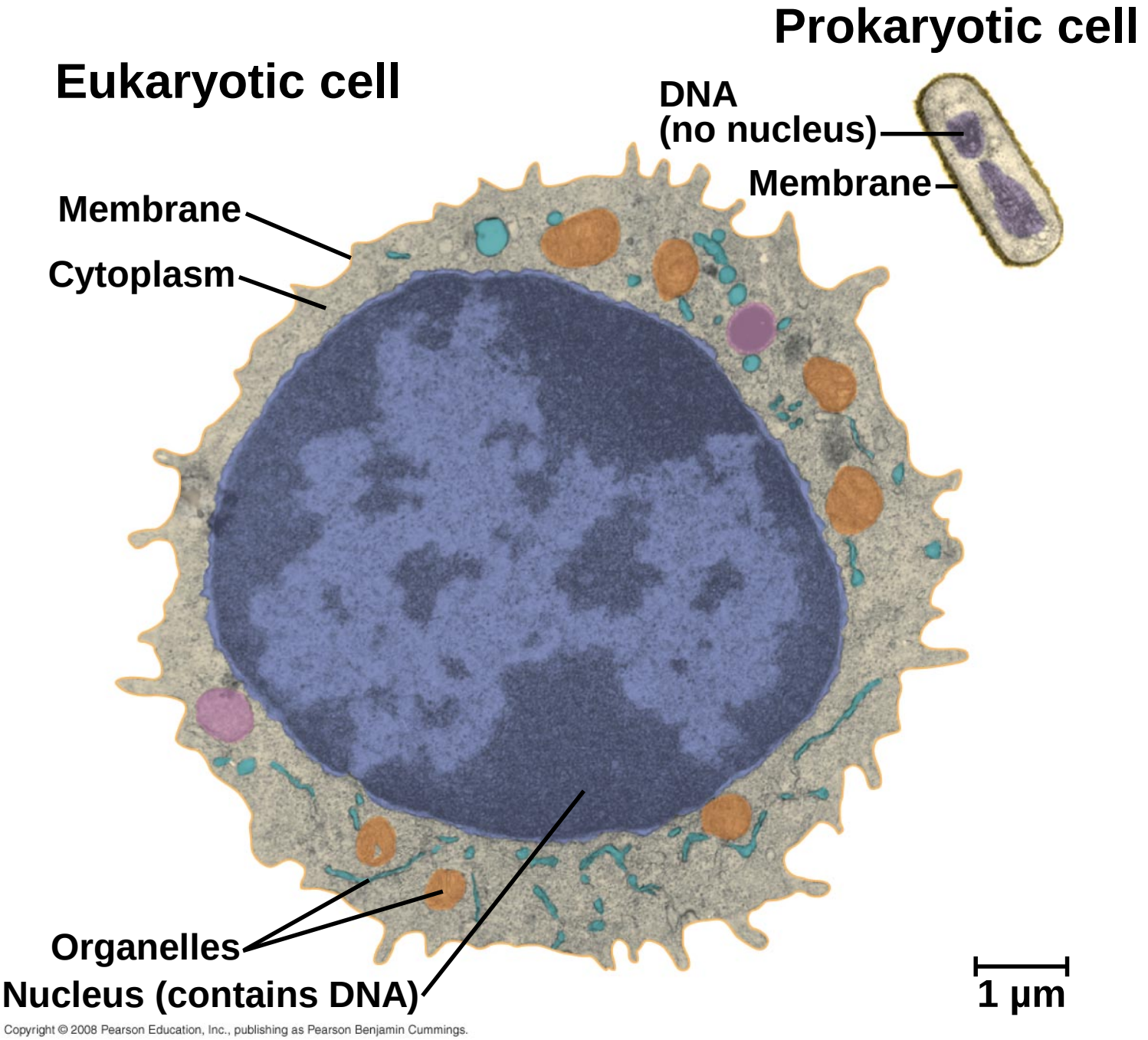
(d) Mitochondria

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

- 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
- Bacteria and Archaea are prokaryotic; plants, animals, fungi, and all other forms of life are eukaryotic

Fig. 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

DNA Structure and Function

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

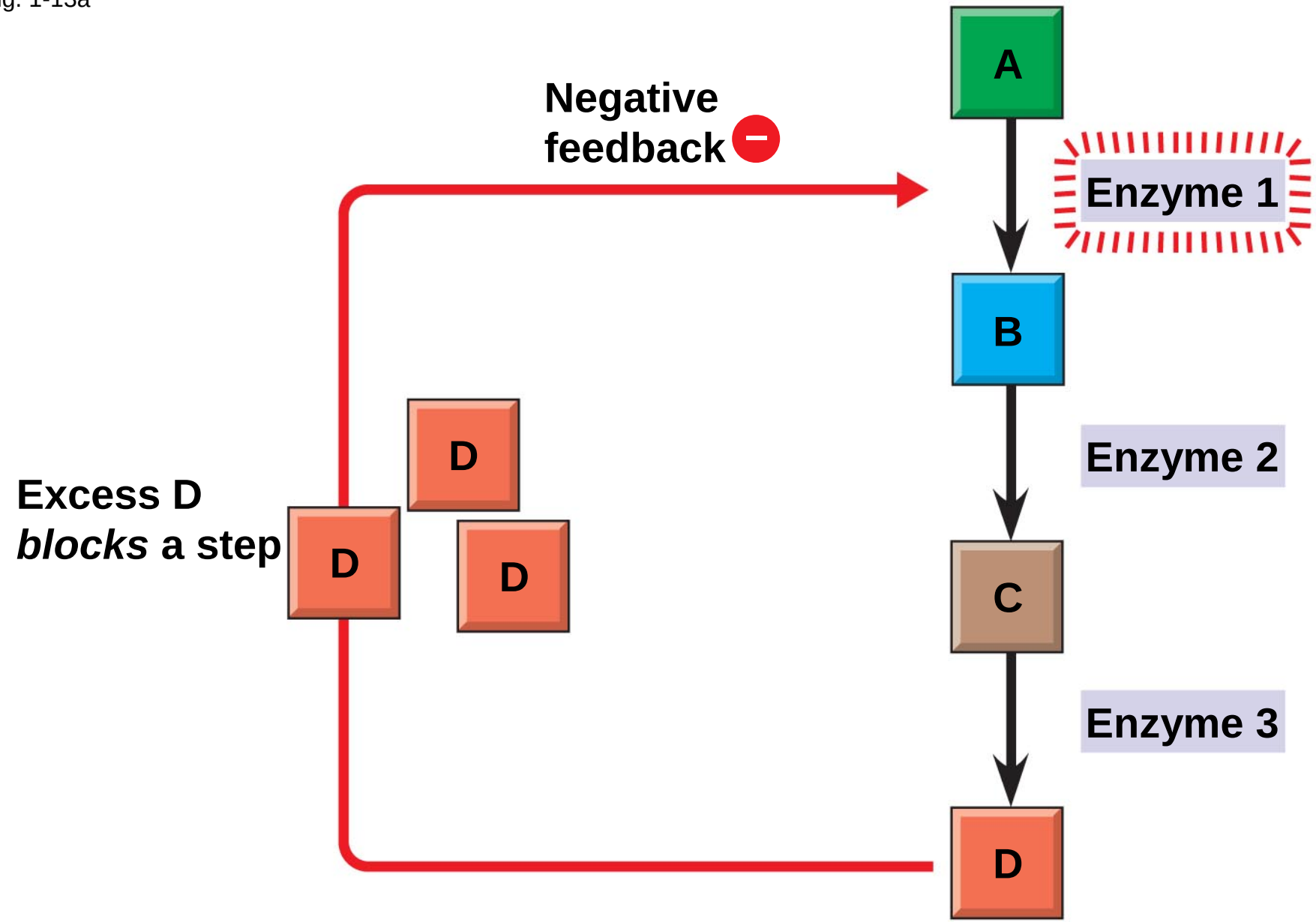
- Genes control protein production indirectly
- DNA is transcribed into RNA then translated into a protein
- An organism's **genome** is its entire set of genetic instructions

- 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

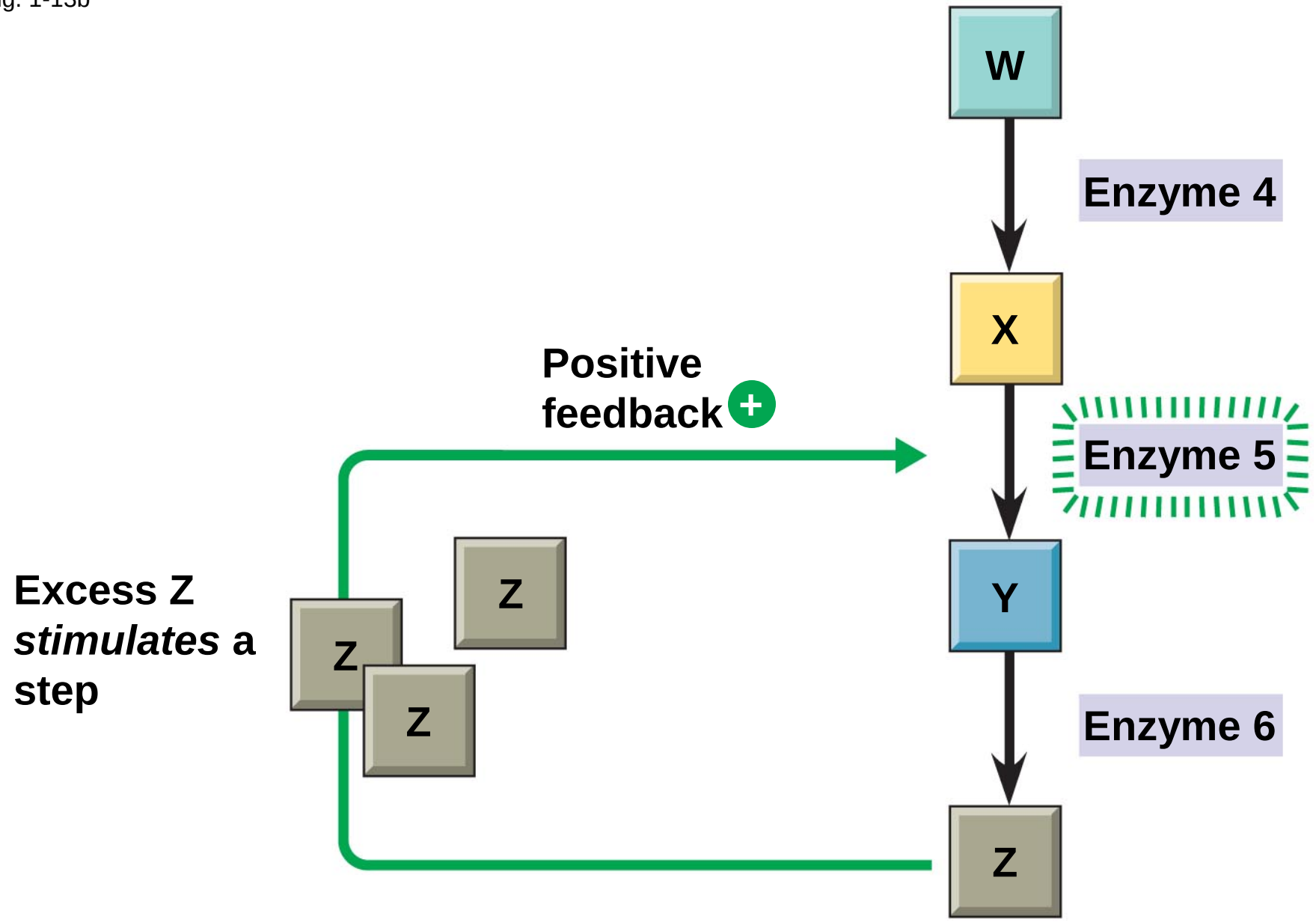
- Feedback mechanisms allow biological processes to self-regulate
- **Negative feedback** means that as more of a product accumulates, the process that creates it *slows* and *less* of the product is produced
- **Positive feedback** means that as more of a product accumulates, the process that creates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

Fig. 1-13a



(a) Negative feedback

Fig. 1-13b



(b) Positive feedback

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

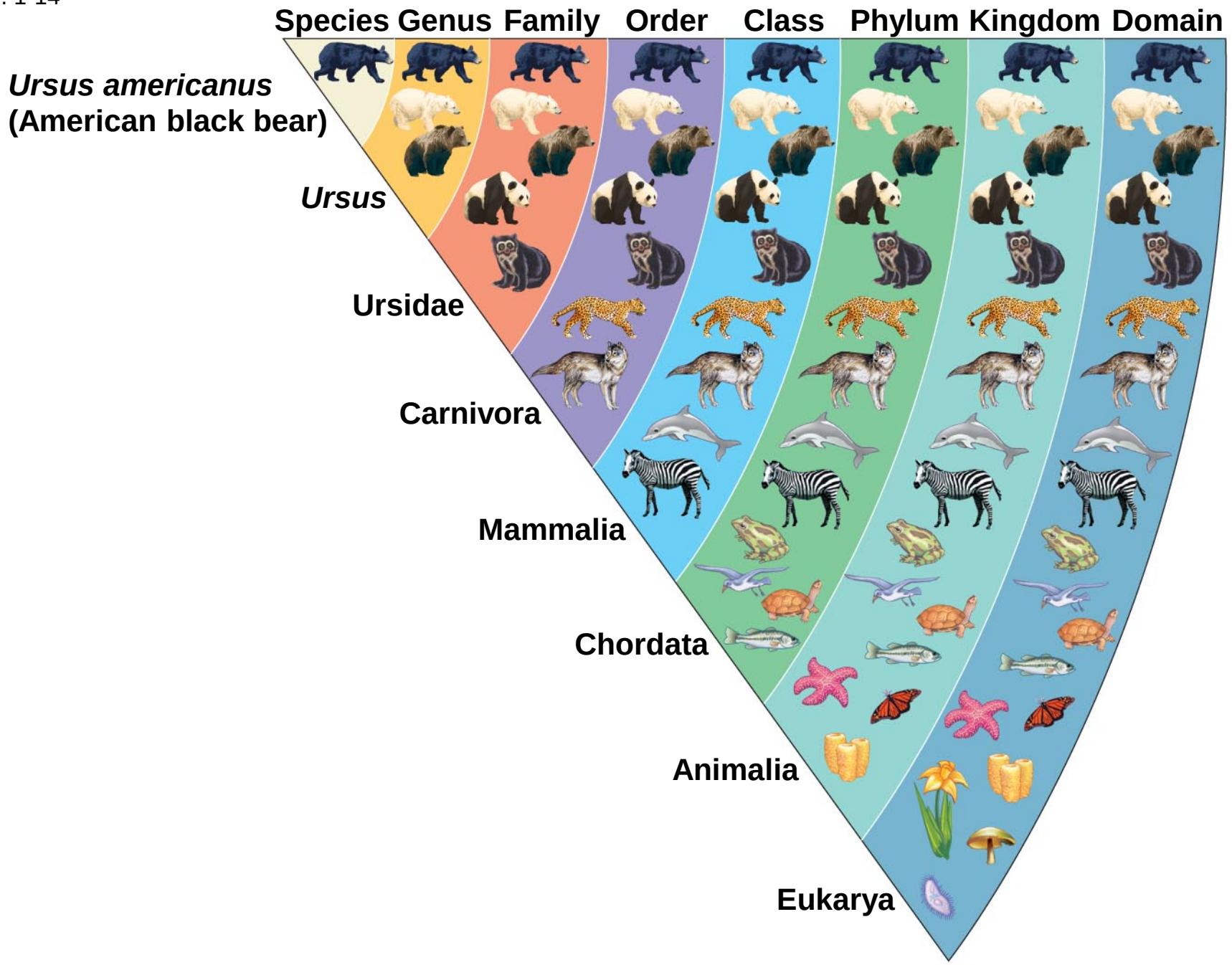
Organizing the Diversity of Life

- 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
- (All Species Inventory)

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



The Three Domains of Life

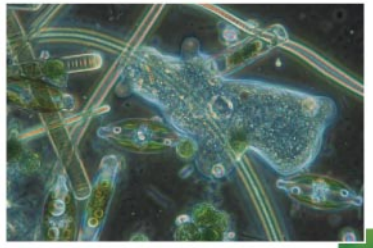
- The three-domain system is currently used, and replaces the old five-kingdom system
- **Domain Bacteria** and **domain Archaea** comprise the prokaryotes
- **Domain Eukarya** includes all eukaryotic organisms

Fig. 1-15

(a) DOMAIN BACTERIA

(b) DOMAIN ARCHAEA

(c) DOMAIN EUKARYA



Protists

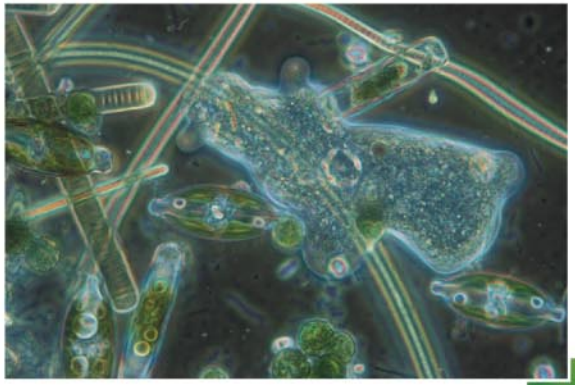
Kingdom Plantae

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

Fig. 1-15c



Protists

Kingdom Fungi

Kingdom Plantae

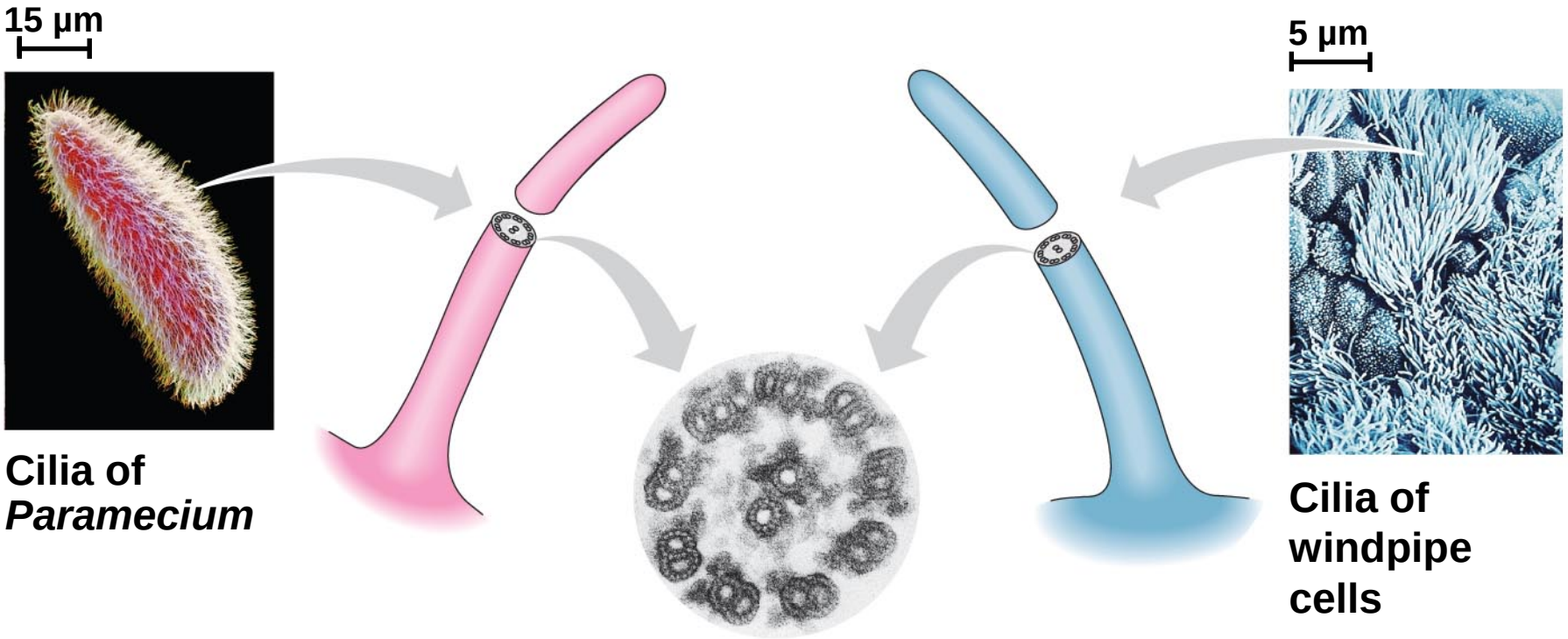
Kingdom Animalia

(c) DOMAIN EUKARYA

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

Fig. 1-16

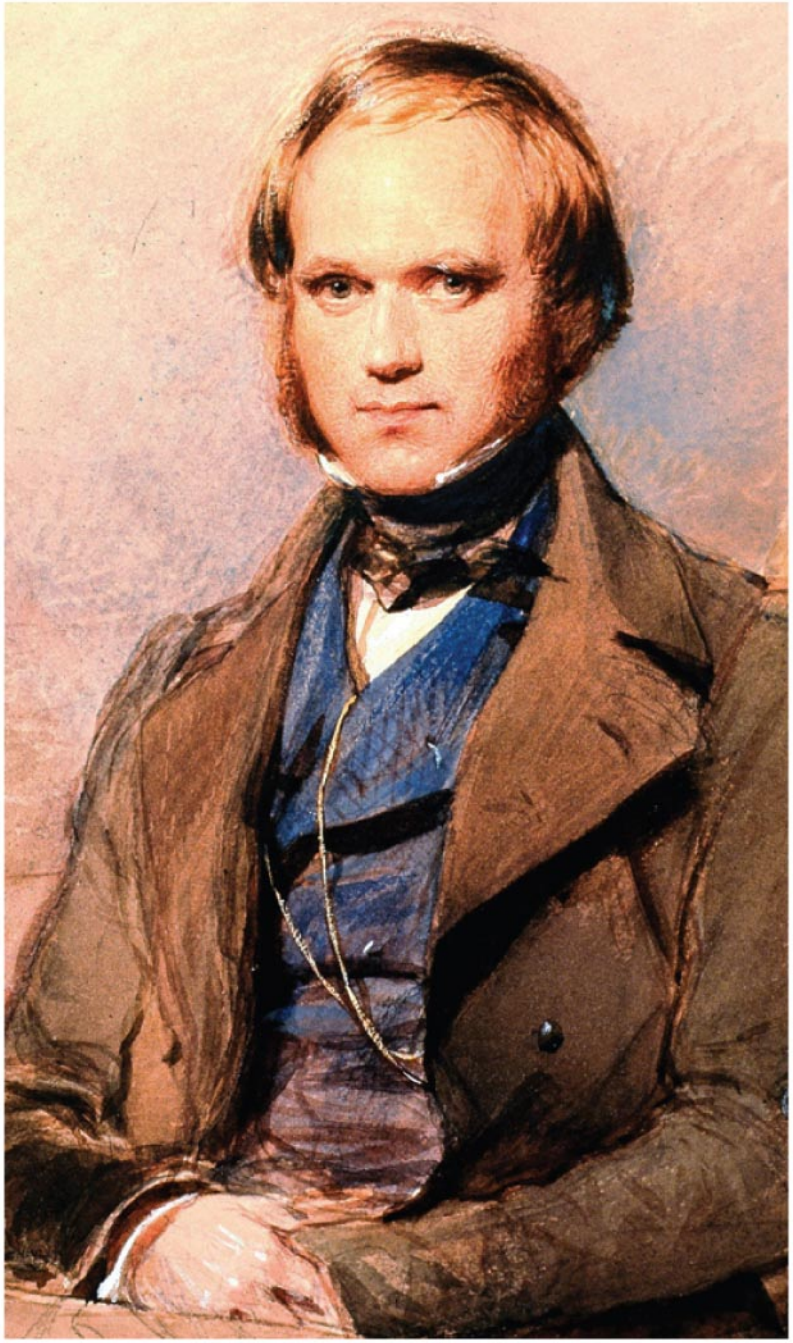


Charles Darwin and the Theory of Natural Selection

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

- 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

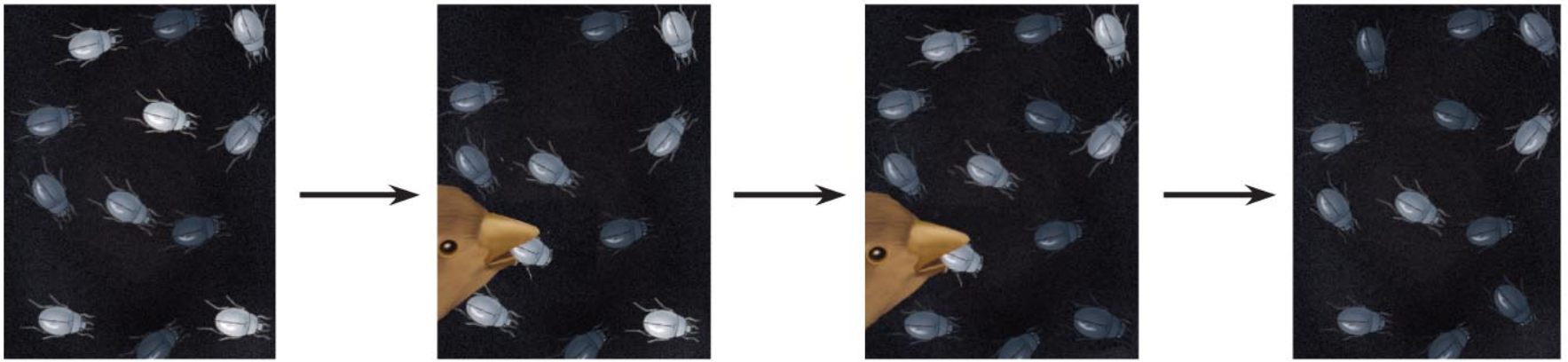
Fig. 1-18



- 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

Fig. 1-20



1 Population with varied inherited traits.

2 Elimination of individuals with certain traits.

3 Reproduction of survivors.

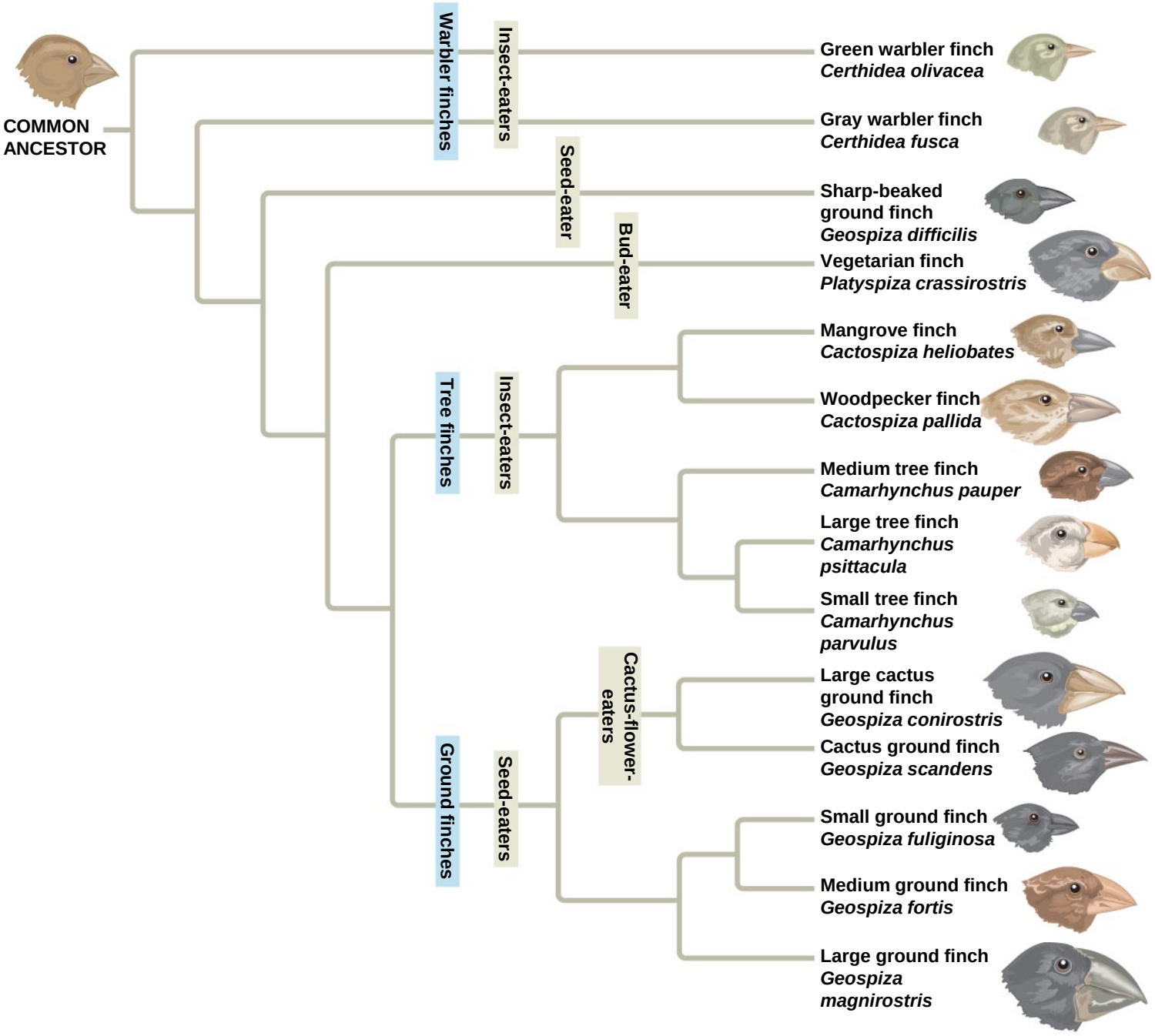
4 Increasing frequency of traits that enhance survival and reproductive success.

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

- 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
- Evolutionary relationships are often illustrated with tree-like diagrams that show ancestors and their descendents

Fig. 1-22



You should now be able to:

1. Briefly describe the unifying themes that characterize the biological sciences
2. Distinguish among the three domains of life, and the eukaryotic kingdoms
3. Distinguish between the following pairs of terms: discovery science and hypothesis-based science, quantitative and qualitative data, inductive and deductive reasoning, science and technology