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Chapter 1

Evolution, the Themes of Biology, and Scientific Inquiry

Lecture Presentations by
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Inquiring About Life

- An organism's adaptations to its environment are the result of **evolution**
 - For example, the color of the beach mouse has come to be well matched, or **adapted**, to its local background
- *Evolution is the process of change that has transformed life on Earth*



An inland mouse of the species *Peromyscus polionotus*

- **Biology** is the scientific study of life
- Biologists ask questions, such as: How does a single cell develop into an organism?
- Biology is an ongoing **inquiry** about the nature of life
- Life does not have *a simple, one-sentence definition*
- Life is recognized by **what living things do**

- *Some properties of life are as follows:*

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Characteristics of living organisms

Figure 1.2a



Order

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Figure 1.2b



Evolutionary adaptation

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Figure 1.2c



Regulation

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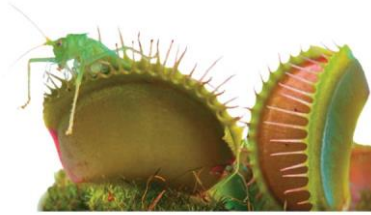
Figure 1.2d



Reproduction

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Figure 1.2e



Response to the environment

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Figure 1.2f



Growth and development

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Figure 1.2g



Energy processing

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Video: Seahorse Camouflage



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Concept 1.1: The study of life reveals unifying themes

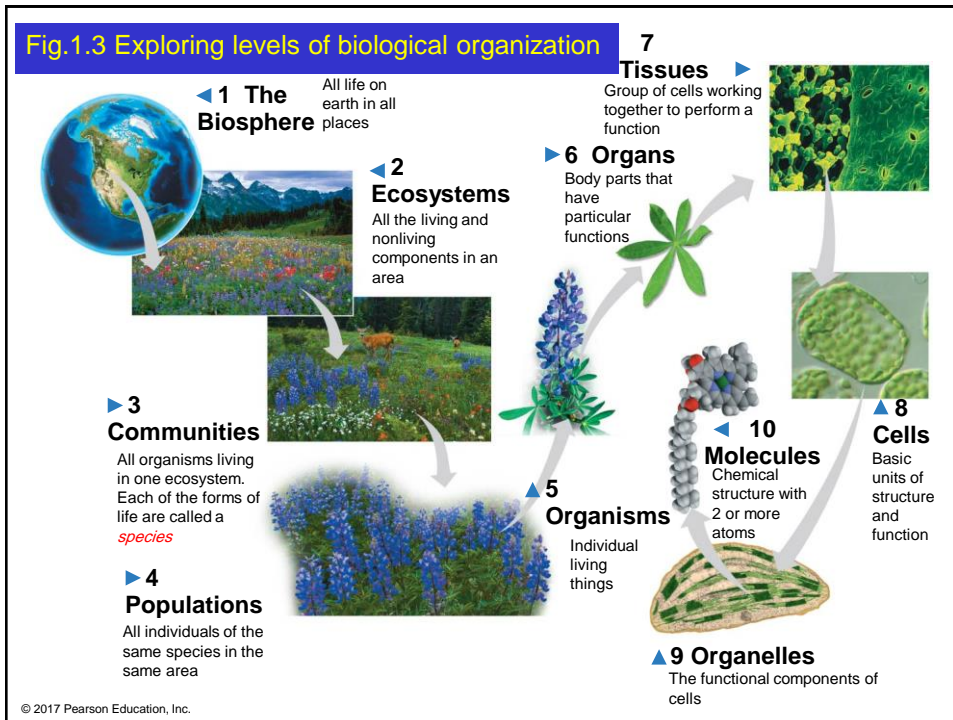
- Biology is a *very large* subject
- Memorizing facts is not the way to learn it
- There are five general **unifying themes**
 - Organization
 - Information
 - Energy and Matter
 - Interactions
 - Evolution

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Theme: New Properties Emerge at Successive Levels of Biological Organization

- Life can be studied at **different levels**, from molecules to the entire living planet
- This very large range **can be divided into different levels of biological organization**

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Emergent Properties

- **Emergent properties** result from the arrangement and interaction of parts within a system
- Emergent properties characterize non-biological entities as well
 - For example, a functioning bicycle emerges only when all of the necessary parts connect in the correct way
 - Table salt (NaCl) is made from toxic components (Na + Cl)

Structure and Function

- At each level of the **biological hierarchy** we find a **correlation between structure and function**
- Analyzing a biological structure gives us clues about what it does and how it works
- Also, knowing the function of something may give indications of its structure and organization

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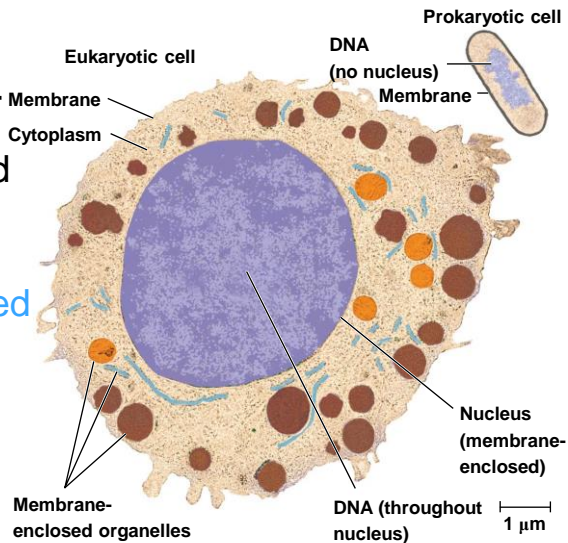
The Cell: An Organism's Basic Unit of Structure and Function

- The cell is the **smallest unit of organization** that can **perform all activities required for life**
- Every cell is enclosed by a **membrane** that regulates passage of materials between the cell and its environment
- The cells of bacteria and archaea are ***prokaryotic***, while all other forms of life are composed of ***eukaryotic*** cells

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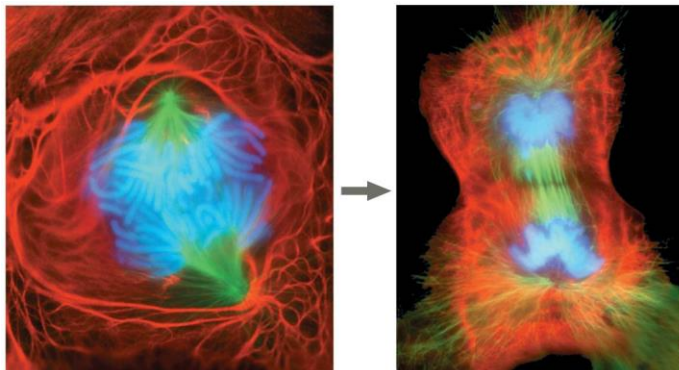
- A **eukaryotic cell** has membrane-enclosed **organelles**, the largest of which is usually the **nucleus**

- A **prokaryotic cell** is simpler and usually smaller and does not contain a nucleus or other membrane-enclosed organelles



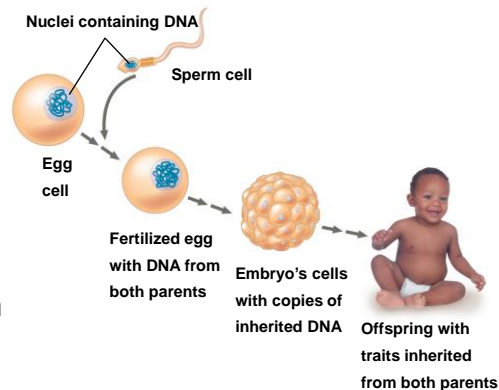
Theme: Life's Processes Involve the Expression and Transmission of Genetic Information

- Within cells, structures called **chromosomes** contain **genetic material** in the form of **DNA (deoxyribonucleic acid)**



DNA, the Genetic Material

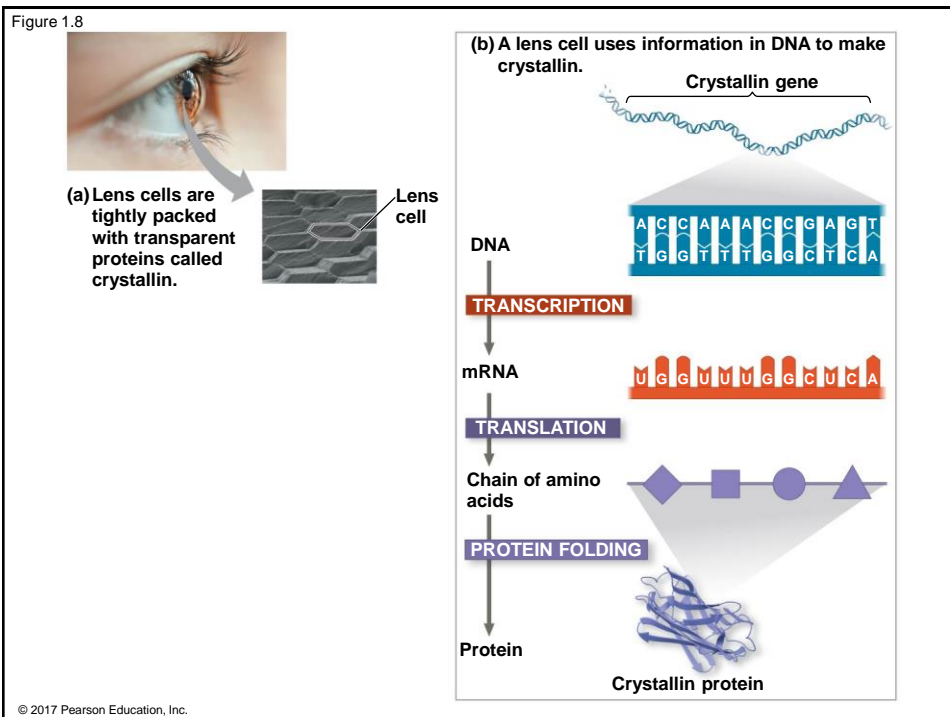
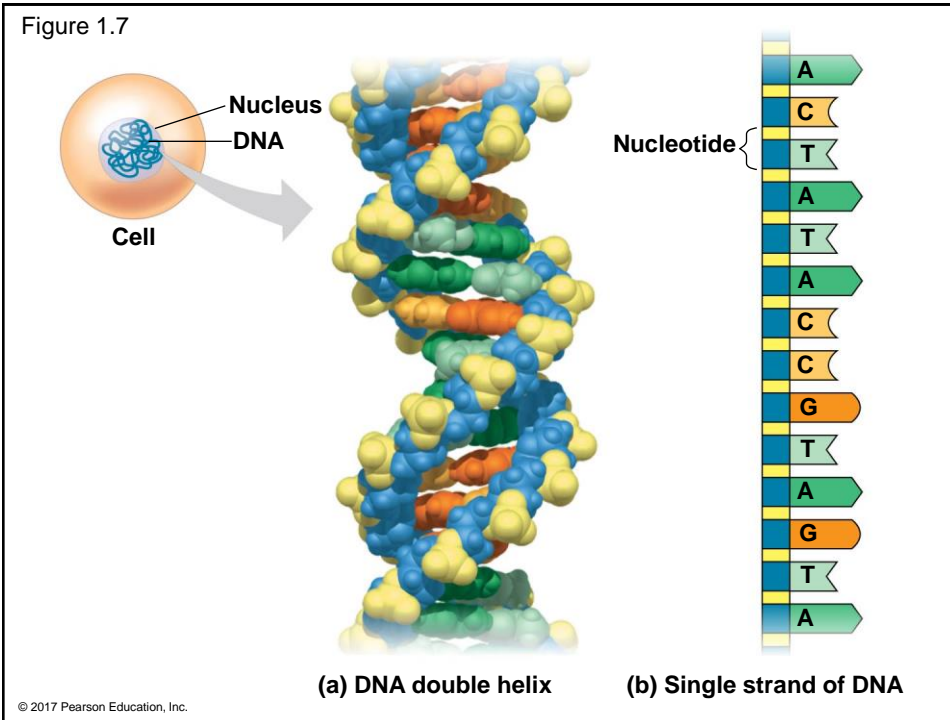
- Each chromosome contains one long DNA molecule with hundreds or thousands of genes
- **Genes** are the *units of inheritance*
- They encode **information** for building the molecules synthesized within the cell
- The genetic information encoded by DNA directs the **development** of an organism



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- The molecular structure of DNA accounts for its ability to store information
- Each DNA molecule is made up of **two long chains arranged in a double helix**
- Each chain is made up of four kinds of chemical building blocks called **nucleotides** (A, G, C, and T)
- The sequence of nucleotides has the information for making a protein
- DNA is **transcribed** into **RNA**, which is then **translated** into a **protein**
- **Gene expression** is the process of converting information from gene to cellular product

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Genomics: Large-Scale Analysis of DNA Sequences

- An organism's **genome** is its entire “library” of genetic instructions
- **Genomics** is the study of sets of genes in one or more species
- **Proteomics** is the study of whole sets of proteins and their properties
- The entire set of proteins expressed by a given cell, tissue, or organ is called a **proteome**

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- The genomics approach depends on
 - “High-throughput” technology, which yields very large amounts of **data**
 - **Bioinformatics**, which is the use of *computational* tools to process a large volume of data
 - **Interdisciplinary research teams**, especially computer scientists, physicists and biologists

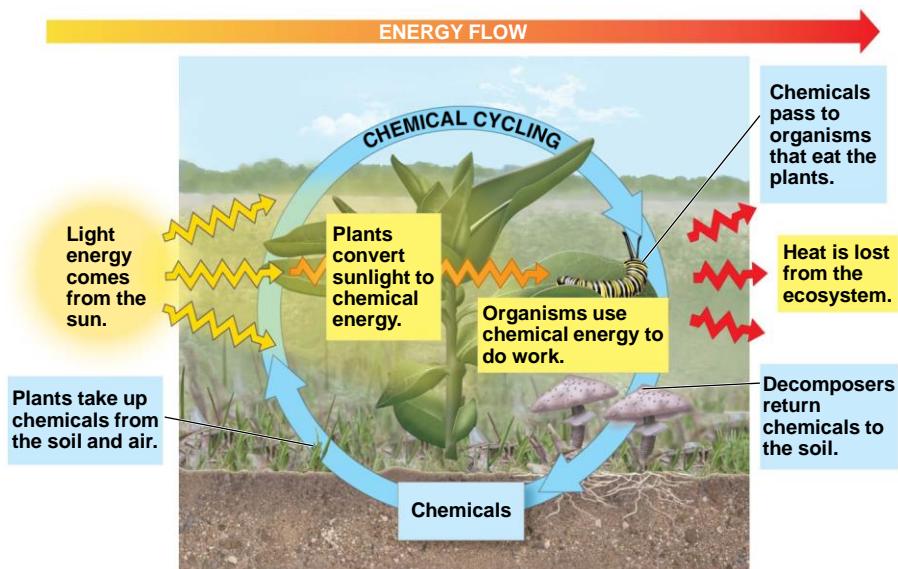
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Theme: Life Requires the Transfer and Transformation of Energy and Matter

- The input of energy from the sun and the transformation of energy from one form to another make life possible
- The chemical energy generated by plants and other photosynthetic organisms (**producers**) is passed along to consumers
- **Consumers** are organisms that feed on other organisms or their remains

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Figure 1.9



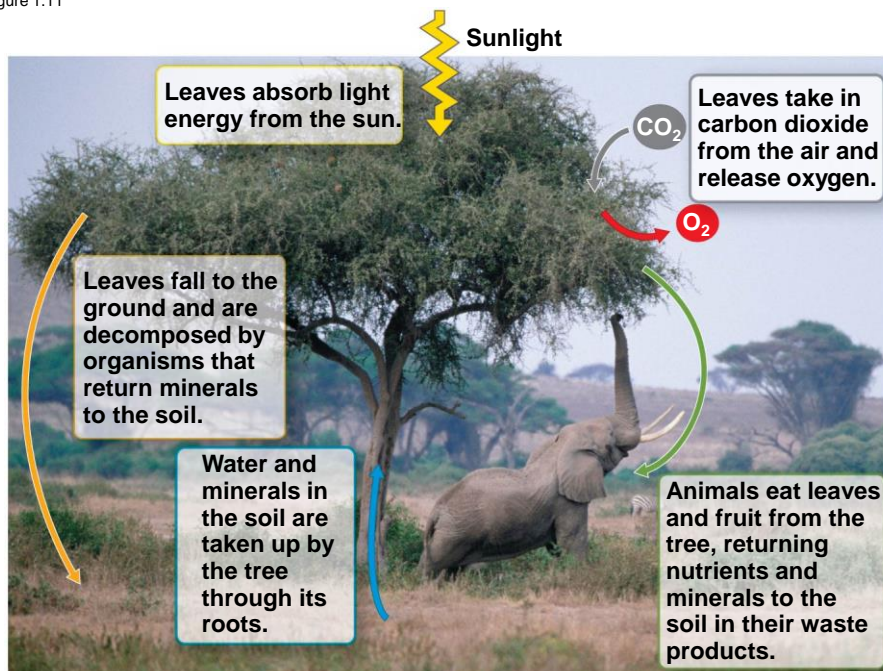
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Ecosystems: An Organism's Interactions with Other Organisms and the Physical Environment

- At the ecosystem level, each organism **interacts** with other organisms
- These interactions may be **beneficial** or **harmful** to one or both of the organisms
- Organisms also interact continuously with the physical factors in their environment, and the environment is affected by the organisms living there

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Figure 1.11



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- Each organism interacts continuously with physical factors in its environment
- Humans interact with our environment, sometimes with very bad consequences
- Over the past 150 years, humans have greatly increased the burning of **fossil fuels** and the release of carbon dioxide (CO₂) into the atmosphere
- The resulting global warming is just one aspect of **climate change**

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- Wind and rain patterns are also changing
- Extreme weather events such as storms and droughts are happening more often
- As **habitats** deteriorate, plant and animal species shift their ranges **to more suitable locations**
- *Populations of many species are shrinking in size or even disappearing*



Threatened by global warming

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

- Evolution is the one idea that makes logical sense of everything we know about living organisms
- *“Nothing in biology makes sense except in the light of evolution”—Theodosius Dobzhansky*
- The scientific explanation for both the unity and diversity of organisms is **evolution**, the concept that **living organisms are modified descendants of common ancestors**
- An abundance of evidence supports the occurrence of evolution

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Classifying the Diversity of Life

- Approximately 1.8 million species have been identified and named to date
- Each species is given a two-part name: The **genus**, to which the species belongs, and a **species** name unique to that species
- E.g., *Homo sapiens* (*H. sapiens*), the name of our species
- Other examples: *Escherichia coli* (*E. coli*)
- Estimates of the total number of species that actually exist range from 10 million to over 100 million

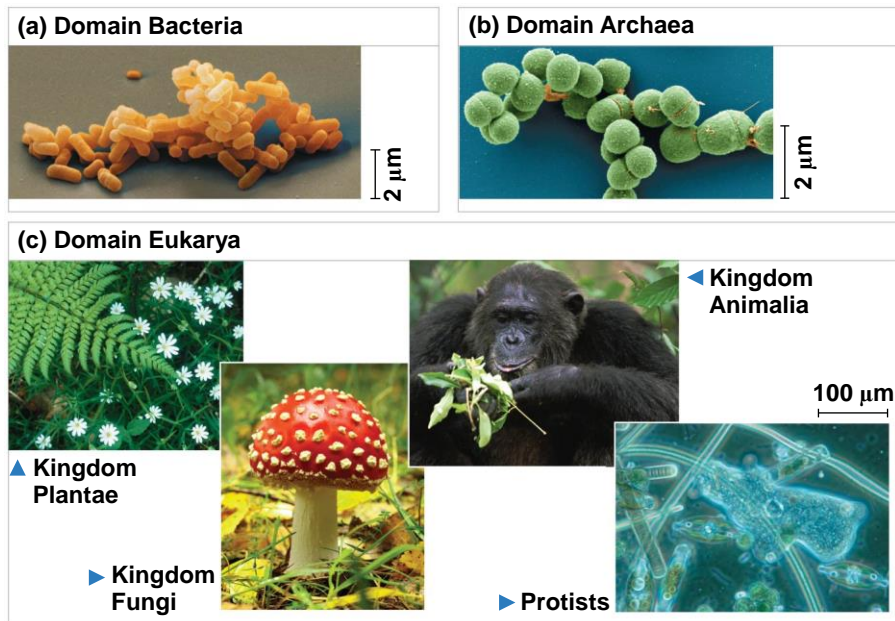
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The Three Domains of Life

- Organisms are currently divided into three **domains**: [Bacteria](#), [Archaea](#), and [Eukarya](#)
- **Bacteria** and **Archaea** are *prokaryotes*
- Domain **Eukarya** includes all eukaryotic organisms
- Domain Eukarya includes the *protists* and three *kingdoms*
 - **Plants**, which produce their own food by photosynthesis
 - **Fungi**, which absorb nutrients
 - **Animals**, which ingest their food

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Figure 1.13



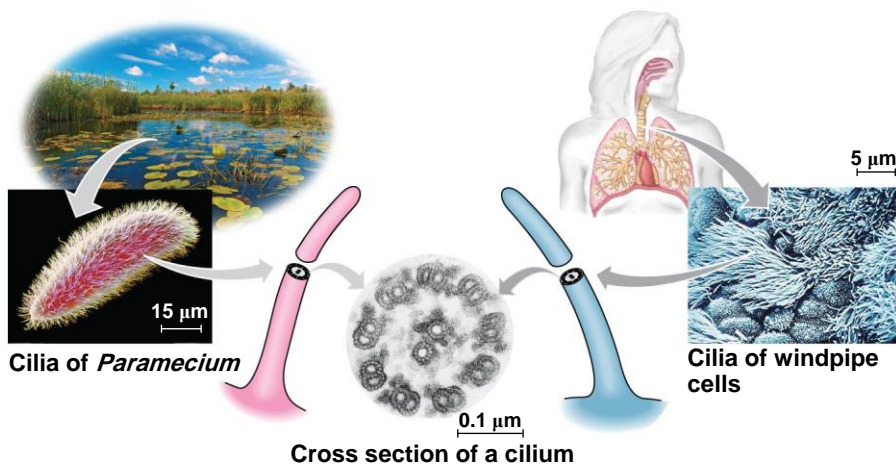
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Unity in the Diversity of Life

- 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 (e.g., all cells have membranes)

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Figure 1.14



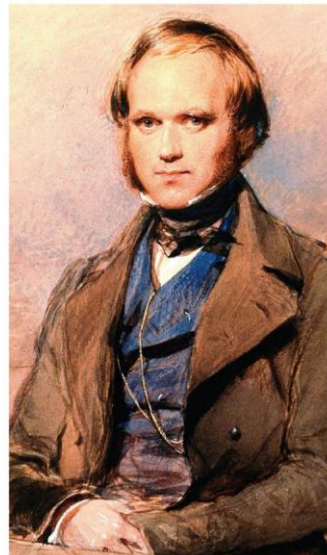
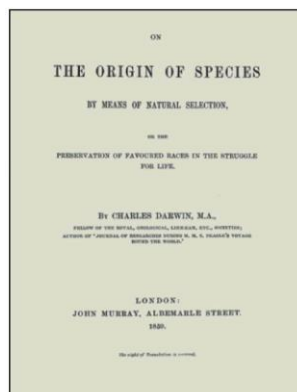
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Charles Darwin and the Theory of Natural Selection

- 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
(*descent* – unity; *modification* – modification)

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Figure 1.16



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

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- Darwin reasoned 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
- The natural environment “selects” for the propagation of beneficial traits
- Darwin called this process **natural selection**

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Figure 1.18_1



1 Population with varied inherited traits

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Figure 1.18_2



1 Population with varied inherited traits



2 Elimination of individuals with certain traits

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Figure 1.18_3



1 Population with varied inherited traits



2 Elimination of individuals with certain traits



3 Reproduction of survivors

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Figure 1.18_4



1 Population with varied inherited traits



2 Elimination of individuals with certain traits



3 Reproduction of survivors



4 Increased frequency of traits that enhance survival

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- Natural selection results in the **adaptation** of organisms to the circumstances of their way of life and their environment
- For example, bat wings are an example of adaptation (the only mammal to be able to fly; has webbing between long fingers)



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The Tree of Life

- The shared anatomy of mammalian limbs (أطراف) reflects the inheritance of the limb structure from a common ancestor
- **Fossils** provide additional evidence of anatomical unity from descent with modification



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- 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

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