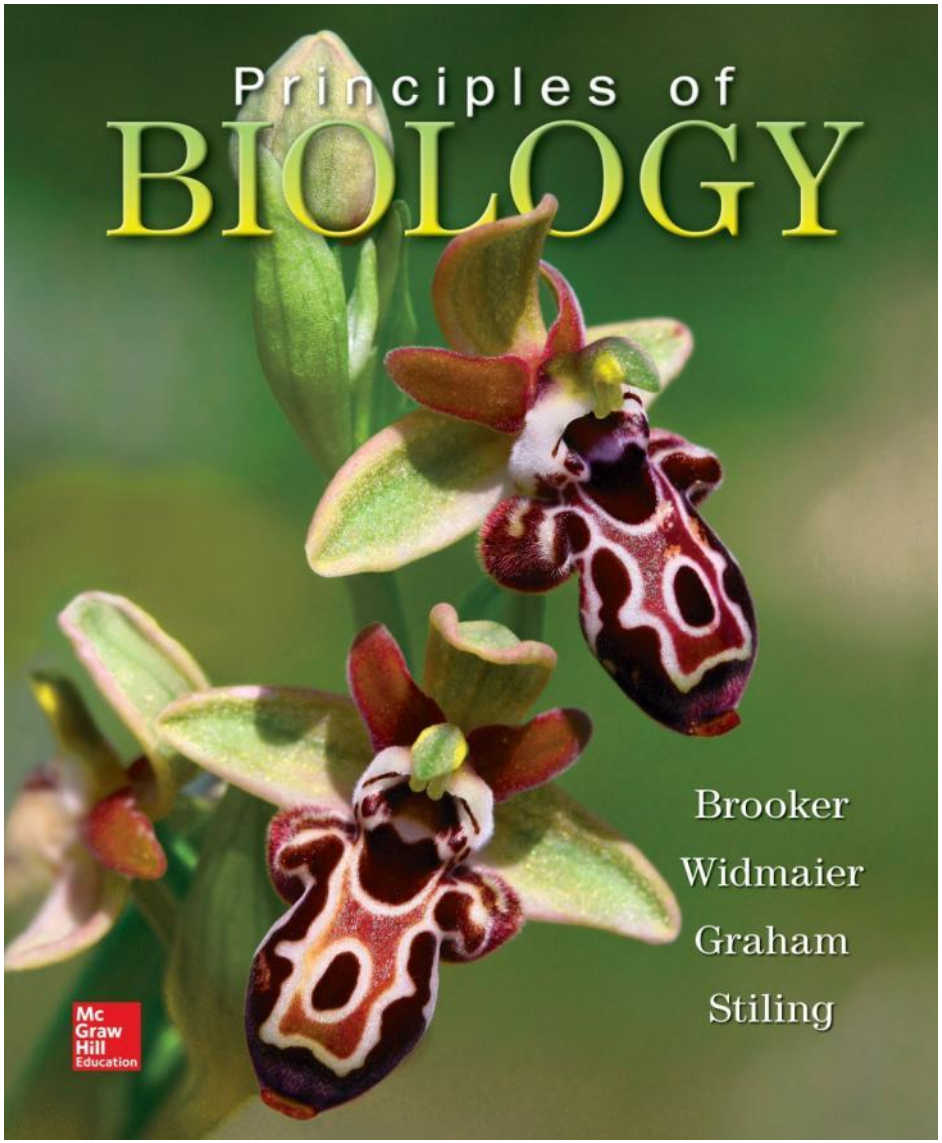
Chapter 01
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.



Chapter 1

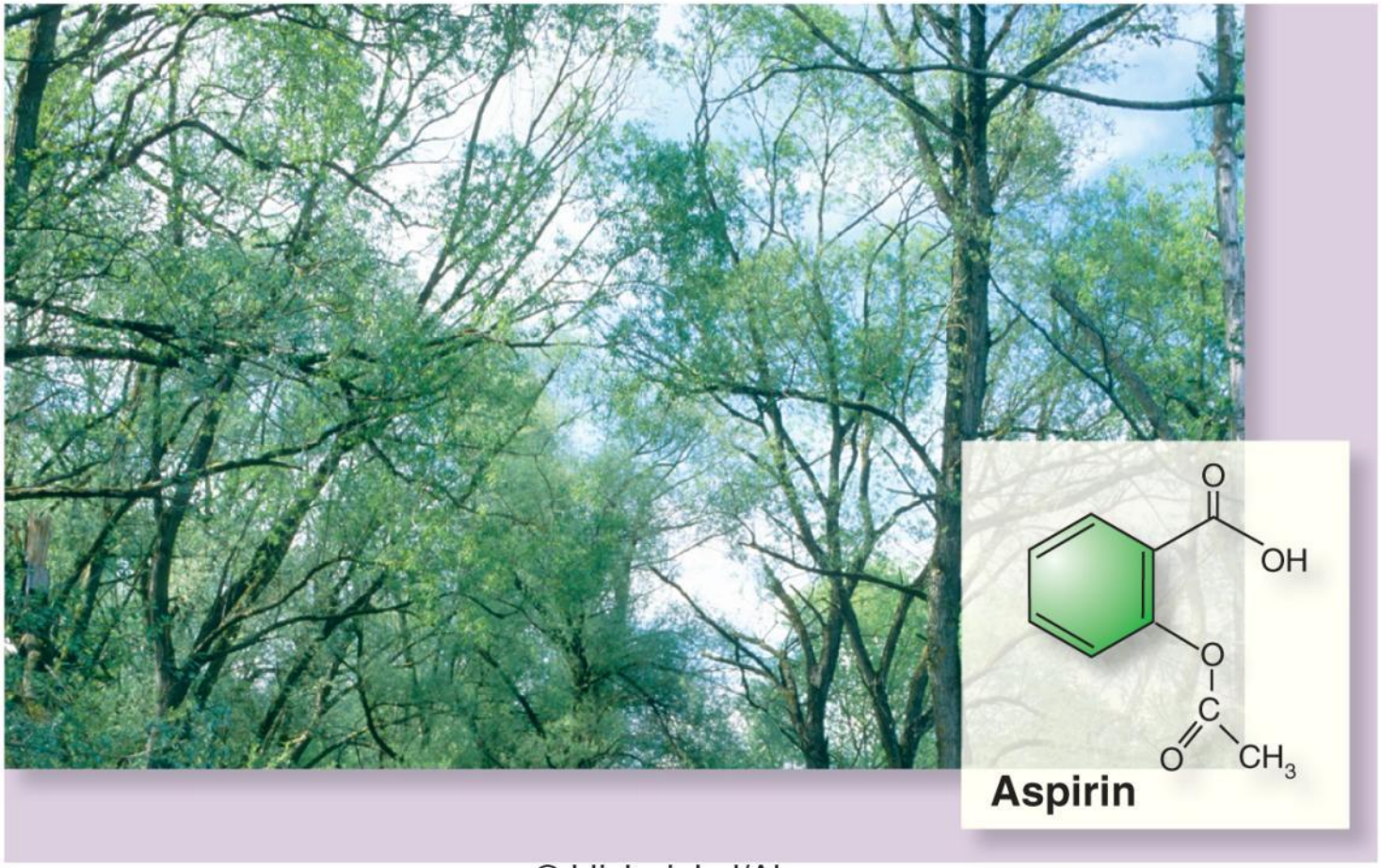
An Introduction to Biology

Chapter Outline:

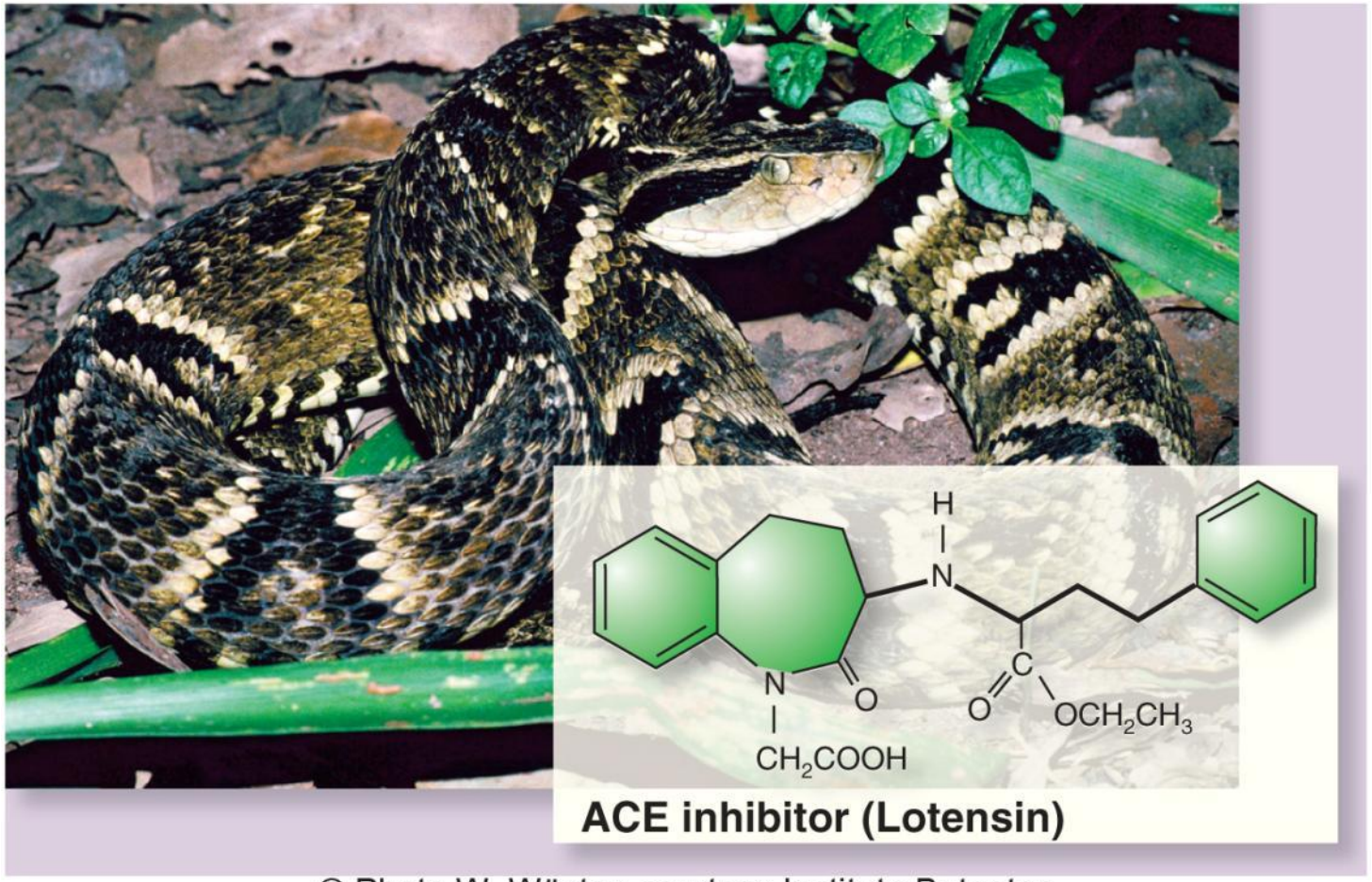
- **Principles of Biology**
- **Levels of Biological Organization**
- **Unity and Diversity of Life**
- **Biology as a Scientific Discipline**

Biological discoveries

- Biology is **the study of life**
- Investigation of living things can lead to discoveries with **far-reaching benefits**
- Examples:
  - **Salicylic acid** (aspirin) from the willow tree
  - **Blood pressure medicine** from poisonous snakes



Aspirin was developed after analysis of a chemical found in the bark of the white willow tree



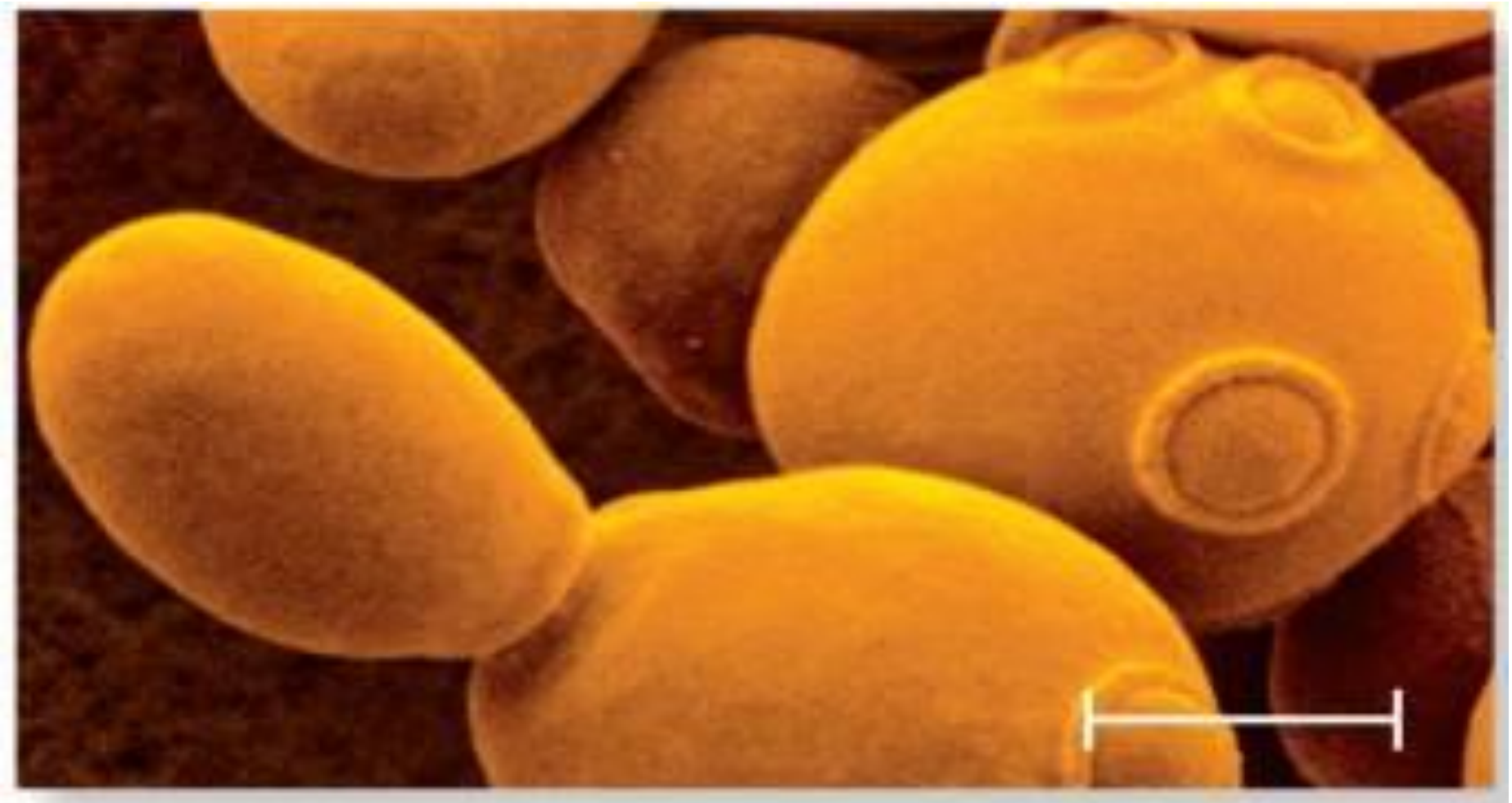
ACE inhibitors (for treating high blood pressure) were originally found in the Brazilian arrowhead viper

Principles of Biology

1. **Cells** are the simplest units of life.
2. Living organisms use **energy.**
3. Living organisms interact with their **environment.**
4. Living organisms maintain **homeostasis.**
5. Living organisms grow and **develop.**
6. The **genetic material** provides a blueprint for reproduction.

Principles of Biology

7. Populations of organisms **evolve** from one generation to the next.
8. All species (past and present) are **related** by an evolutionary history.
9. **Structure** determines function.
10. New properties of life **emerge** from complex interactions.
11. Biology is an **experimental** science.
12. Biology affects our **society.**



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1. Cells are the simplest units of life.

© Alexis Rosenfeld/Photo Researchers

2. Living organisms use energy.

c: © Cathlyn Melloan/Stone/Getty Images

3. Living organisms interact with their environment.

© Adam Jones/Visuals Unlimited

4. Living organisms maintain homeostasis.

© Patti Murray/Animals Animals

5. Living organisms grow and develop.

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6. The genetic material provides a blueprint for reproduction.

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7. Populations of organisms evolve from one generation to the next.

8. All species (past and present) are related by an evolutionary history.

© Louise Pemberton

9. Structure determines function.

j: © Maria Teijeiro/Getty Images RF

10. New properties of life emerge from complex interactions.

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11. Biology is an experimental science.

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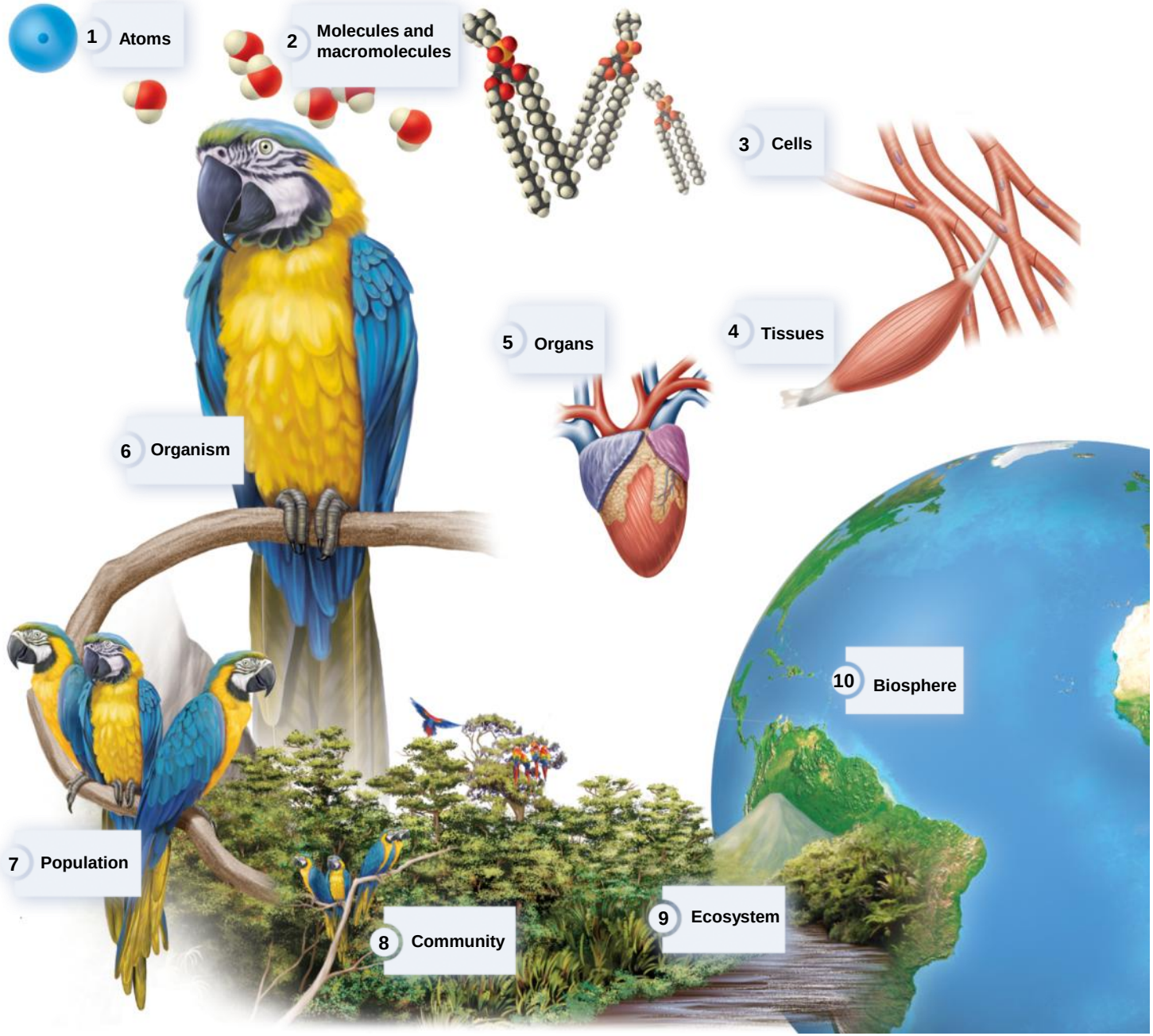
12. Biology affects our society.

Levels of Biological Organization

1. Atoms
2. Molecules
3. Cells
4. Tissues
5. Organs
6. Organism
7. Population
8. Community
9. Ecosystem
10. Biosphere



Unity and Diversity of Life

- Unity
  - All life displays a **common set of characteristics** (see Principles #1-8)
  - United by a shared **evolutionary history**
- Diversity
  - Life has a **diversity of form** in diverse environments

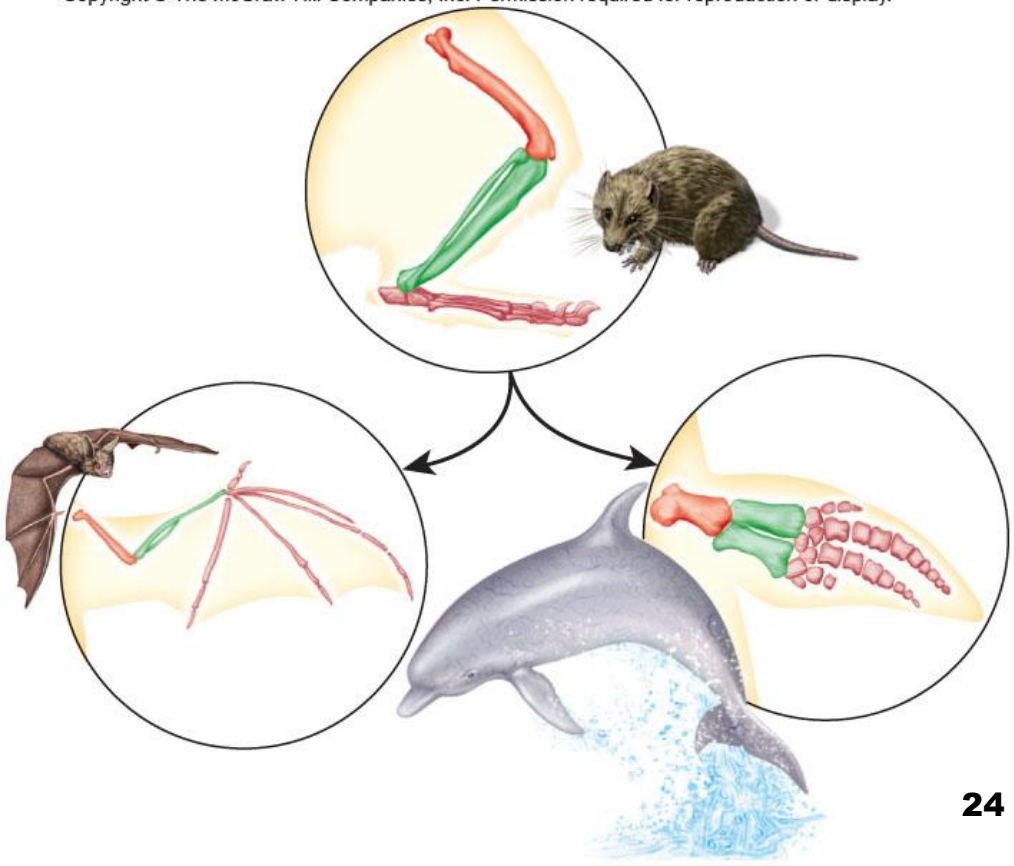
Evolutionary History

- Life began on Earth as primitive cells between **3.5 - 4 billion years ago** (bya)
- Those primitive cells underwent **evolutionary changes** to give rise to the species of today
- Evolutionary history helps us understand the **structure and function** of an organism

- Evolutionary change involves **modifications** of pre-existing characteristics
- Structures may be modified to **serve new purposes**

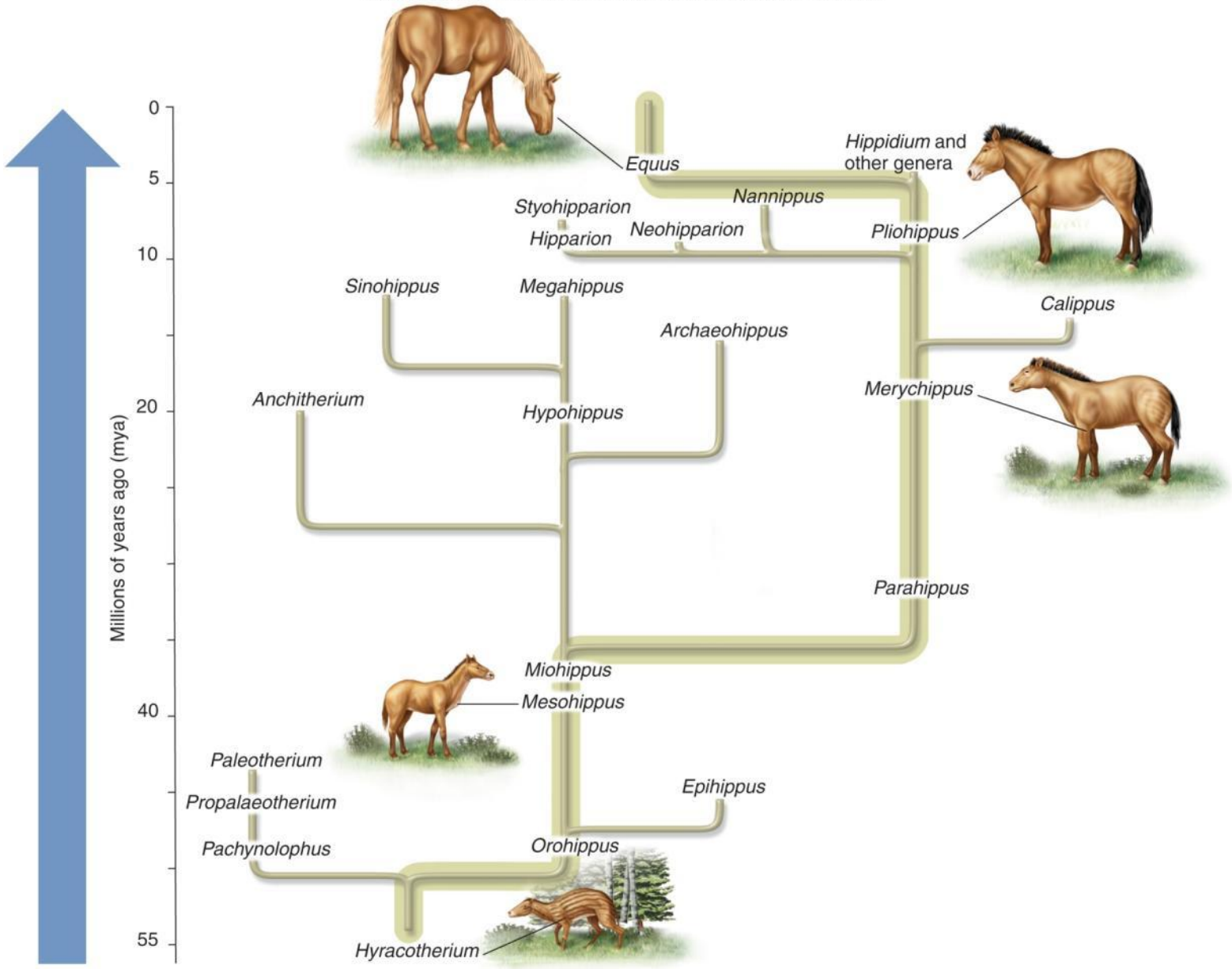
- Example:

Walking limbs were modified into a **dolphin's flipper** or a **bat's wing**



Two mechanisms of evolutionary change

1. **Vertical descent with modification**
   - **Progression** of changes in a lineage
   - New species evolve from pre-existing species by the **accumulation** of mutations
   - **Natural selection** takes advantage of beneficial mutations



2. Horizontal gene transfer

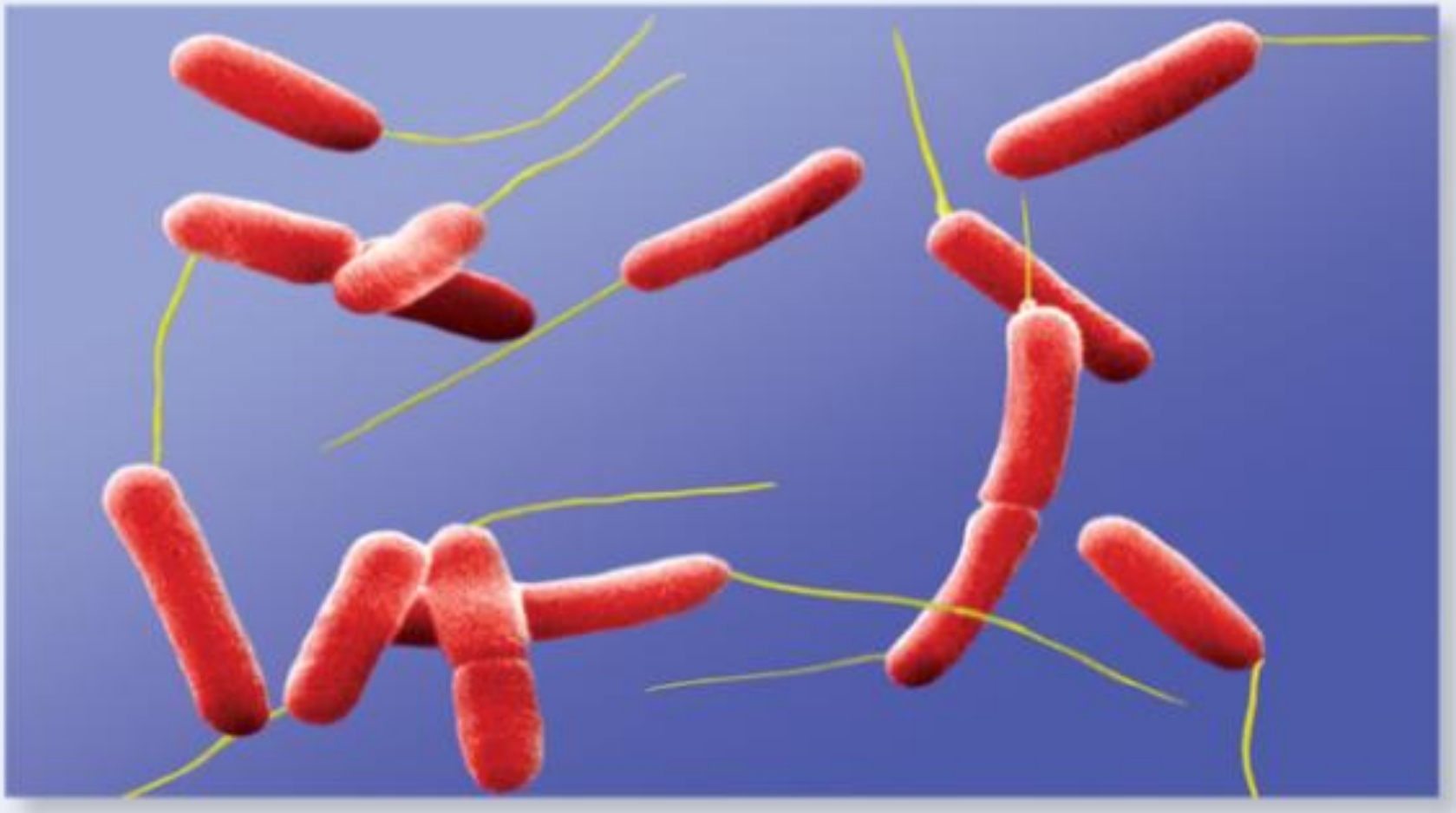
- **Genetic exchange** between different species
- Relatively **rare**
- Genes that confer **antibiotic resistance** are sometimes transferred between different bacteria species

Tree or web of life?

- **Horizontal gene transfer** was an important part of the process that gave rise to modern species
- **Tree of life** focuses on vertical evolution
- **Web of life** includes the contribution of horizontal gene transfer

Classification

- **Taxonomy** is the grouping of species based on common ancestry
- **Three domains** of life
  - **Bacteria-** unicellular prokaryote
  - **Archaea-** unicellular prokaryote
  - **Eukarya-** unicellular and multicellular eukaryotes
    - Complex cells with a **nucleus**
    - Three kingdoms + Protista
      - **Plantae, Fungi, Animalia**
      - **Protista** – not really a kingdom, 7 supergroups



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Domain Bacteria: Mostly unicellular prokaryotes that inhabit many diverse environments on Earth.

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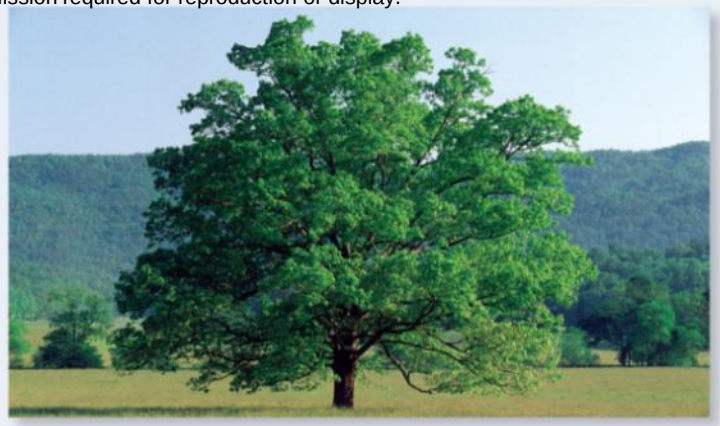
Domain Archaea: Unicellular prokaryotes that often live in extreme environments, such as hot springs.

Protists



Plants

Fungi

Animals

Domain Eukarya: Unicellular and multicellular organisms having cells with internal compartments that serve various functions.

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Protists: Unicellular and small multicellular organisms divided into seven broad groups based on evolutionary relationships.

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Plants: Multicellular organisms that can carry out photosynthesis.

© Carl Schmidt-uchs/Photo Researchers

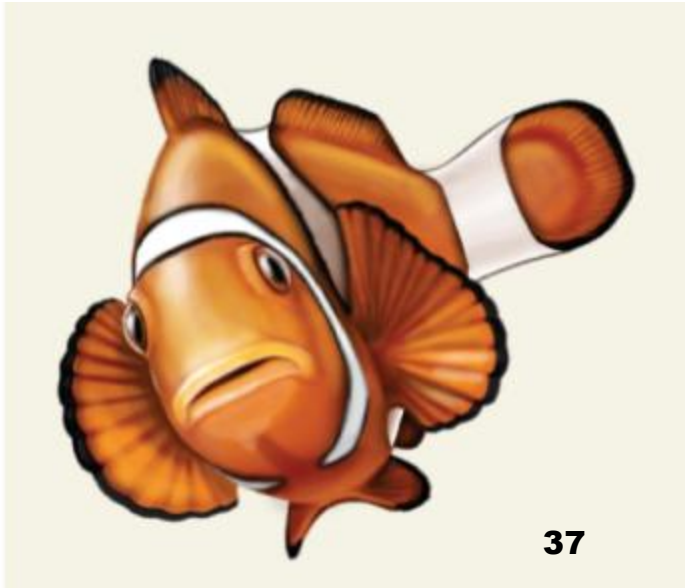
Fungi: Unicellular and multicellular organisms that have a cell wall but cannot carry out photosynthesis. Fungi usually survive on decaying organic material.

© Fritz Polking/Visuals Unlimited

Animals: **Multicellular organisms that usually have a nervous system and are capable of locomotion. They must eat other organisms or the products of other organisms to live.**

Classification

- A species is placed into progressively smaller groups that are more **closely related**
- Emphasizes the **unity and diversity** of different species
- Example:
  - Clownfish (*Amphiprion ocellaris*)



Taxonomic group	Clown anemonefish is found in	Approximate time when the common ancestor for this group arose	Approximate number of modern species in this group	Examples
Domain	Eukarya	2,000 mya	> 5,000,000	
Kingdom	Animalia	600 mya	> 1,000,000	
Phylum	Chordata	525 mya	50,000	
Class	Actinopterygii	420 mya	30,000	
Order	Perciformes	80 mya	7,000	
Family	Pomacentridae	~ 40 mya	360	
Genus	Amphiprion	~ 9 mya	28	
Species	ocellaris	> 3 mya	1	

- Binomial nomenclature
  - Each species has a **unique scientific name**
  - Genus name **capitalized**
  - Species descriptor is **not capitalized**
  - Both names are **italicized**

Amphiprion ocellaris = Ocellaris clownfish

The study of evolution allows us to appreciate the unity and diversity among different species

- Evolutionary adaptations to specific environments explain life's diversity
- Example: **Bee orchid** (*Ophrys apifera*)
  - Flower looks and smells like a female bee
  - Male bees "pseudocopulate" and transfer pollen

(a) Cyprus bee orchid (b) Pseudocopulation

Cyprus bee orchid **Pseudocopulation**

Biology as a Scientific Discipline

- **Science** is the observation, identification, experimental investigation, and theoretical explanation of natural phenomena
- Many scientists focus research on the same **model organisms**
- **The Scientific Method** is used to test theories
- Some scientists also **gather information**
  - "Fact-finding mission"

Biologists investigate life at different levels

- Different branches of biology study life at **different levels** using a variety of tools
  - Ecology, anatomy, physiology, cell biology, molecular biology, and systems biology
- As **new tools** become available, they allow scientists to ask new questions
- **Systems biology** aims to understand how emergent properties arise from complex interactions, at any level

Ecologists study species in their native environments.

(a) Ecology—population/ community/ecosystem levels

Anatomists and physiologists study how the structures of organisms are related to their functions.

(b) Anatomy and physiology—tissue/organ/organism levels

Cell biologists often use microscopes to learn how cells function.

(c) Cell biology—cellular levels

Molecular biologists and biochemists study the molecules and macromolecules that make up cells.

(d) Molecular biology—atomic/molecular levels

Systems biologists may study groups of molecules. The microarray shown in the inset determines the expression of many genes simultaneously.

(e) Systems biology—all levels, shown here at the molecular level

Hypothesis or Theory?

- **Hypothesis**
  - A **proposed explanation** for a natural phenomenon
  - Based on **previous observations** or experiments
  - Hypotheses must **make predictions** that can be shown to be correct or incorrect (must be testable)
  - Additional observations or experiments can **support or reject** a hypothesis, but a hypothesis is never really proven
- Example:
  - “Maple trees drop their leaves in autumn because of shortened hours of sunlight”

- **Theory**
  - Broad explanation of some aspect of the natural world that is substantiated by a **large body of evidence**
  - Allows us to make **many predictions**
  - Also can never be proved true, but due to overwhelming evidence, may be **very likely** to be true
- **Two key attributes** of a theory:
  1. **Consistent** with a vast amount of known data
  2. Able to make many **correct predictions**
- Example
  - "DNA is the genetic material"
  - Overwhelming body of evidence supports this theory

Understanding biology

- Curiosity is the key
- No rigid set of steps
- Two general approaches
  1. **Discovery-based science**
  2. **Hypothesis testing**

Discovery-based science

- Collection and analysis of data without the need for a preconceived hypothesis
- Goal is to **gather information**
- Examples:
  - Testing drugs to look for action against disease
  - Sequencing genomes and proteomes
- Often **leads to** hypothesis testing

Hypothesis Testing

- Five steps
  1. **Observations** are made regarding natural phenomena.
  2. These observations lead to a **testable hypothesis** that tries to explain the phenomena.
  3. **Experiments** are conducted to determine if the predictions are correct.
  4. The **data** are analyzed.
  5. The hypothesis is **accepted** or **rejected**.
- These steps comprise the **Scientific Method**

Hypothesis Testing

- Data are often collected in parallel
  - **Control** and **experimental** groups
  - Differ by only **a single variable**
- Data analysis
  - Apply **statistical analysis** to determine if the control and experimental groups are different because of the single variable that is different
  - Are differences **statistically significant?**
  - If the two sets are found *not* to be significantly different, we must **reject our hypothesis**
  - If the two sets of data *are* significantly different, we **accept our hypothesis** (though it is not proven)

1 **OBSERVATIONS** The leaves on maple trees fall in autumn when the days get colder and shorter.

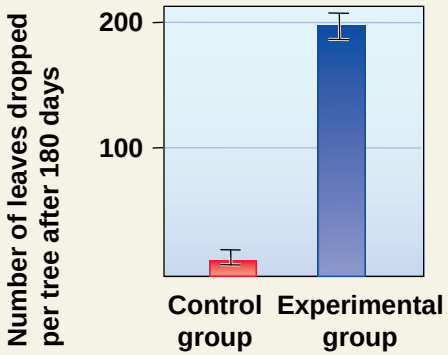
2 **HYPOTHESIS** The shorter amount of daylight causes the leaves to fall.

3 **EXPERIMENTATION**
Small maple trees are grown in 2 greenhouses where the only variable is the length of light.

Control group:
Amount of daily light remains constant for 180 days.

Experimental group:
Amount of daily light becomes progressively shorter for 180 days.

4 **THE DATA**



A statistical analysis can determine if the control and the experimental data are significantly different. In this case, they are.

5 **CONCLUSION** The hypothesis cannot be rejected.

example: **Cystic Fibrosis**

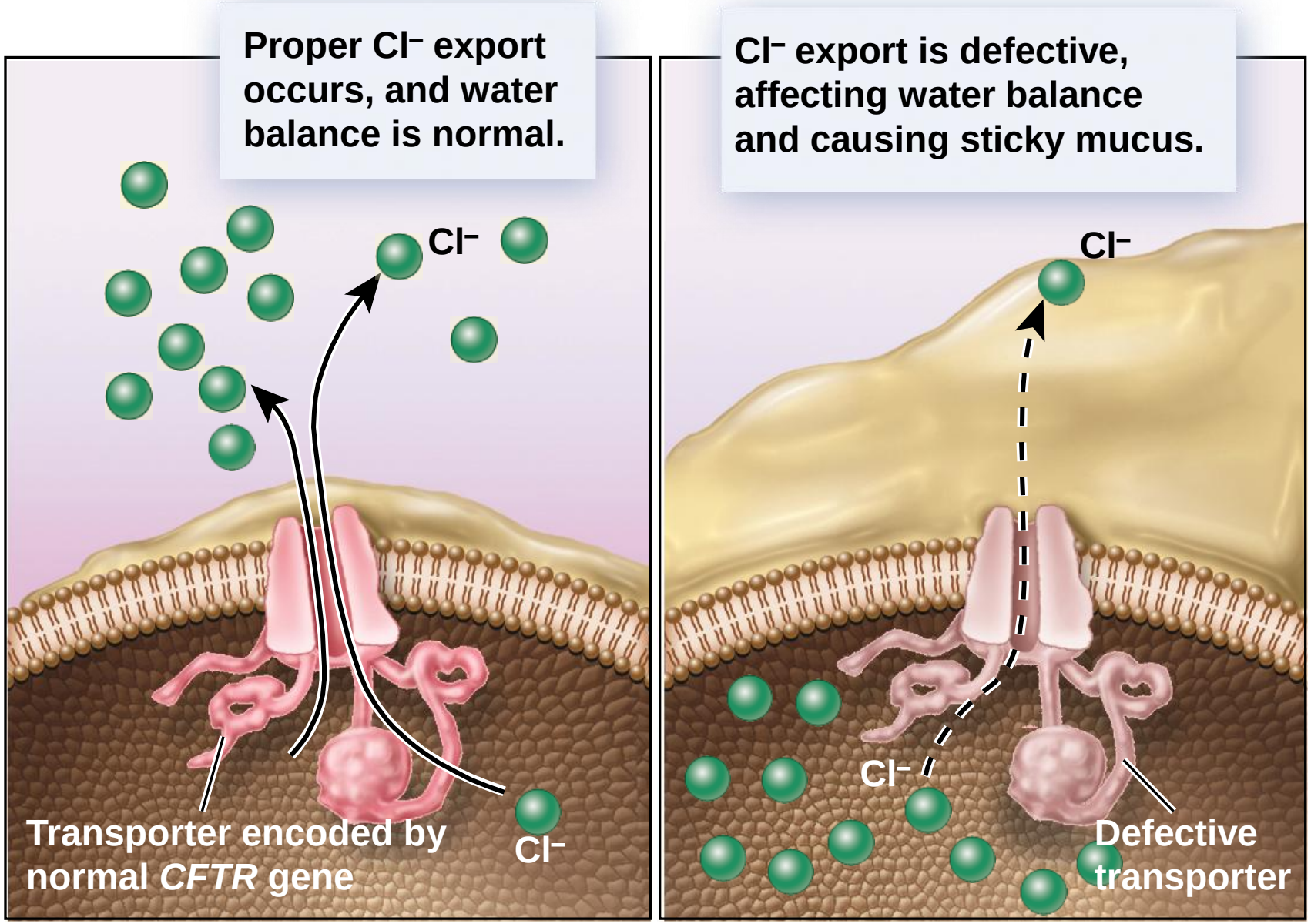
- Affects about **1 in every 3,500** Americans
- Persons with CF produce abnormally thick and **sticky mucus** that obstructs the lungs and pancreas
- Average **lifespan** for people with CF is currently in their late 30s
- Lifespan has **increased** due to advances in treatment

example: **Cystic Fibrosis**

- In 1945, Dorothy Anderson determined that cystic fibrosis is a **genetic disorder**
- In 1989, research groups headed by Lap-Chi Tsui, Francis Collins, and John Riordan identified the *CFTR* gene
- **Discovery-based science,** not hypothesis-testing, found the gene that causes CF

Hypothesis for function of CF gene

- **Hypothesis:** The *CFTR* gene encodes a protein that transports chloride ions (Cl^-) across the membrane of cells
- Led to **experiments** to test normal cells and cells from CF patients for ability to transport Cl^-
  - CF cells were found **defective in chloride transport**
  - Transferring a normal *CFTR* gene into cells in the lab **corrects** this defect
- Chloride transport hypothesis is **accepted**



Lung cell with normal *CFTR* gene

Lung cell with faulty *CFTR* gene

- Results **supported** the hypothesis that the *CFTR* gene encodes a protein that transports Cl^- across the plasma membrane
- A mutation in this gene causes it to encode a **defective transporter protein,** leading to a salt imbalance
- This imbalance affects **water levels** outside the cell, which explains the thick and sticky mucus in CF patients
- In this example, **hypothesis testing** has provided a way to accept or reject an idea regarding how a disease is caused by a genetic change

Science is social

- Within a lab, students, postdocs, technicians, and the Principal Investigator (PI) **work together**
- Different labs **collaborate**
- Research papers are **peer-reviewed**
- At **meetings,** scientists discuss new data – and debate!
- You can **discuss** science without having “all the answers”
- Science is a **never-ending series of questions**