We are living in a golden age of biology.

Scientists are studying a myriad of questions that are relevant to our lives.

- How can errors in cell growth lead to cancer?
- How do plants trap solar energy?
- How do living creatures form ecological networks and how do human activities disrupt them?
- How can DNA—the molecular basis of heredity—be used in forensic investigations?
- How do mutations in genes lead to disease?
STUDY OF LIFE: The Process of Science

- **Biology** is the *scientific* study of life

- The word *science* is derived from a Latin verb meaning “to know.”
  - *Science* is a way of knowing, based on inquiry.
    - *Inquiry*: a search for information & explanations
  - Science developed from our curiosity about ourselves and the world around us.

- There are two main scientific approaches:
  - *Discovery science* is mostly about *describing* nature.
  - *Hypothesis-driven science* is mostly about *explaining* nature.
Science seeks natural causes for natural phenomena. Limited to the study of structures and processes that we can observe and measure directly or indirectly.

Verifiable observations and measurements are the data of discovery science. Enables us to describe life at its many levels, from ecosystems down to cells and molecules.
DISCOVERY SCIENCE

- Discovery Science...
  - Can stimulate us to ask questions and seek explanations
  - Lead to important conclusions based on inductive reasoning
    - Inductive Conclusion: A generalization that summarizes many concurrent observations
  - Prompt the use of the Scientific Method for further studies
- Scientific Method: “Step-by-step” procedure which uses experiments and observations to find an answer to a question or solve a problem.
Most modern scientific studies can be described as **hypothesis-driven**

- A **hypothesis** is a *tentative* answer to a question—”an explanation on trial”
- We use this process every day. It’s called **problem solving**.
- Observation → Question → Hypothesis → Prediction → Experiment

- What’s the problem? → What do you know about it? → What do you think the cause is? (Hypothesis) → “If I do ___, then ___ will happen” (Prediction) → Test it out

**HYPOTHESIS-DRIVEN SCIENCE**
Observation: The remote doesn’t work.

Question: What’s wrong?

Hypothesis: The batteries are dead.

Prediction: With new batteries, it will work.

Experiment: Replace batteries.

Experiment does not support hypothesis.

Revise.

Experiment supports hypothesis; make more predictions and test.
The Scientific Method (AKA Problem Solving)

1. Observation
   - Observe a phenomenon, aspect of an organism, or discover a problem
   - Ex. Your remote stopped working

2. Question
   - Question the observation/problem. Must be simple and testable, like How, What, or Why?
   - Ex. What made it stop working?
The Scientific Method (AKA Problem Solving)

3. Hypothesis
   - Possible explanation based on previous knowledge; “educated guess”
   - General or Specific
   - Ex. The batteries are the source of the problem

4. Prediction
   - “If/then” statement
   - Ex. If the batteries are dead, then replacing them will make the remote work.
5. Experiment (play time): test your hypothesis

- **Independent variable**: factor that is changed
- **Dependent variable**: factor that is measured
- **Controlled variable**: factors kept the same
- **Continuous**: range of variations; ex: height & weight. Also known as “quantitative”.
- **Discrete**: categorical; ex: color & shape. Also known as “qualitative”.
- **Sample Size**: # samples; the more samples, the more accurate
6. Conclusion
- Interpret and discuss your results
- Accept or reject your hypothesis

Theories: only accepted if they are supported by an accumulation of extensive evidence
CASE STUDY
Are Trans Fats Bad for You?

- **Case Study**: in-depth examination of real-world investigation
- Dietary fat comes in different forms
- Trans fats ≠ natural
  - Manufacture through hydrogenation
  - Add texture, ↑ shelf life, and are cheap
- Study found that a diet high in trans fats nearly doubled risk of heart disease
A hypothesis-driven study published in 2004

Started with the observation: human body fat retains traces of consumed dietary fat

Asked the question: Would the fat tissue of heart attack patients be different from a similar group of healthy patients?

Formed the hypothesis: healthy patients’ body fat would contain less trans fats than the body fat in heart attack victims
CASE STUDY
Are Trans Fats Bad for You?

- **Experiment**: determine the amounts of trans fat in the tissue of 79 patients who had experienced a heart attack (Experimental Group).
- Compared these patients to 167 patients who had **not** experienced a heart attack (Control Group).
  - **Controlled experiment**: the control and experimental groups differ only in one variable—the occurrence of a heart attack.

- **Results**: Significantly higher amount of trans fats in heart attack patients
Scientists build on what has been learned from earlier research.

- They pay close attention to contemporary scientists working on the same problem.

Cooperation and competition characterize the scientific culture.

- Scientists check the conclusions of others by attempting to repeat experiments.
- Scientists are generally skeptics, but also open to possibilities given evidence.
- Truth-seekers at heart
STUDY OF LIFE: Properties of Life

- **Biology** is the scientific *study of life*.
- Encompasses a vast scale of size & variety…
  - From microscopic viruses to global ecosystems
- …and millions of years in the past & the calculated future
- But what is *life*?
7 Properties of Life – must have ALL 7 to be “alive”

1. Order
2. Regulation
3. Growth & Development
4. Energy Processing/Metabolism
5. Response to Environment
6. Reproduction
7. Evolution
STUDY OF LIFE: Properties of Life

- **Order** – complex organization, or pattern
  - Pinecones, body symmetry, flower petals, fish scales
STUDY OF LIFE: Properties of Life

- **Regulation** – change internal environment to maintain homeostasis
  - Blood flow to ears, sun bathing, panting
STUDY OF LIFE: Properties of Life

- **Growth & Development**
  - DNA controls how an organism grows & develops with age

- **Energy Processing/Metabolism**
  - Use energy source (food/sunlight) to power biological processes and physical activities
STUDY OF LIFE: Properties of Life

- **Response to Environment**
  - Respond to external stimuli

- **Reproduction**
  - Pass genetic material to the next generation thru sexual or asexual means
Evolution – Populations change over time by successful reproduction of those best suited to their environment.
Diversity is a hallmark of life.

The diversity of known life includes about 1.8 million species that biologists have identified and named.

Estimates of the total number of species range from 10 million to over 100 million.

This diversity can be both beautiful, and overwhelming.
Categorizing life into groups helps deal with this complexity

**Taxonomy** – the branch of biology that *names & classifies* species
- Formalizes hierarchical ordering of organisms

**Species** – a group of organisms that 1) live in the same place & time, 2) can interbreed, 3) to make fertile offspring
Three Domains of Life

1. Bacteria
   - Prokaryotic (no nucleus)
   - Most diverse & widespread prokaryotes

2. Archaea
   - Prokaryotic
   - Many live in Earth’s extreme environments (salty lakes, hot springs, thermal oceanic vents)

3. Eukarya
   - Contain nuclei & are typically multicellular
   - Divided into 4 Kingdoms based on how they obtain energy (food)
1. Plantae
   - Autotrophs – create own sugars thru photosynthesis

2. Fungi
   - Decomposers – digest dead organic matter

3. Animalia
   - Heterotrophs – consume other organisms

4. Protists
   - Single-celled eukaryotes like amoebas & some multi-cellular seaweeds
5 Unifying Themes

1. Evolution
2. Structure & Function
3. Information Flow
4. Energy Transformations
5. Interconnected Systems
Life evolves.

Each species is one twig of a branching tree of life extending back in time through ancestral species.

Species that are very similar, such as the brown bear and polar bear, share a more recent common ancestor.

Mammals share mammary glands $\rightarrow$ vertebrates share a backbone $\rightarrow$ cells have outer membranes & make proteins $\rightarrow$ DNA codes for all proteins
Millions of years ago, the common ancestor of all modern bears diverged into several lines. The common ancestor of polar bears and brown bears lived about 20 million years ago. The common ancestor of all modern bears lived about 25 million years ago. The giant panda diverged from the common ancestor of all modern bears about 10 million years ago. The spectacled bear, sloth bear, sun bear, American black bear, Asiatic black bear, polar bear, and brown bear all diverged from the common ancestor of all modern bears within the last 10 million years.
The evolutionary view of life came into focus in 1859 when Charles Darwin published *On the Origin of Species by Means of Natural Selection.*
Darwin’s book developed two main points:

1. **“Descent with Modification”** - species living today descended from a succession of ancestral species.
   - Captures the duality of life’s:
     - Unity (descent)
     - Diversity (modification)

2. **Natural selection** is the mechanism for descent with modification.
Darwin’s book developed two main points:
1. **“Descent with Modification”** - species living today descended from a succession of ancestral species
   - Captures the duality of life’s:
     - Unity (shared descent)
     - Diversity (gradual modification)
2. **Natural selection** is the mechanism for descent with modification.
   - Individuals best suited to their env’t survive better
   - Produce more offspring than those less suited
Natural Selection requires 4 things:
1. More offspring are made than survive
2. Individuals compete for resources (food, mates…)
3. Traits vary between individuals
4. These traits are heritable

Results: Unequal reproductive success, or “natural selection”

The product = adaptation
Increasing frequency of traits that enhance survival and reproductive success

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
Humans have been using selection for centuries.

Artificial Selection – purposeful breeding of domesticated plants & animals

- Dogs
- Livestock
- Agriculture
- Eugenics
(a) Vegetables descended from wild mustard

- Cabbage from end buds
- Brussels sprouts from side buds
- Kohlrabi from stems
- Kale from leaves
- Broccoli from flowers and stems
- Cauliflower from flower clusters
MAJOR THEMES: Structure & Function

- The **structure** (shape) of something correlates with its **function** (what it does)

- Your lungs
  - Branched structure = high surface area = efficient gas exchange

- Red blood cells
  - Concave shape = higher surface area
MAJOR THEMES: Information Flow

- Information is transmitted, received, and used at every level of organization
- DNA itself is a code that instructs the building of proteins
- Proteins allow cells to communicate and maintain homeostasis
MAJOR THEMES: Energy Transformations

- Life runs on Dunkin energy.
  - Movement, growth, reproduction all require energy
- Energy & Matter can't be created, only transferred and transformed
  - Energy flows in and out
  - Matter is recycled
- Life is solar-powered
- Sun → Plants (sugars) → Consumers (proteins) → Heat & organic matter → Decomposers (minerals) → Plants
ECOSYSTEM

Inflow of light energy

Producers (plants and other photosynthetic organisms)

Chemical energy (food)

Cycling of nutrients

Consumers (animals)

Decomposers (in soil)

Outflow of heat energy
MAJOR THEMES: Interconnected Systems

- There are several levels of biological systems, and all are connected.