

Chapter 1: Introduction – The Science of Biology

1. Discuss in your group how the scientific method works, and the difference between inductive and deductive reasoning. Come up with examples of inductive and deductive reasoning. Do NOT worry about learning the scientific method as “step one – step two – etc.”
2. Discuss testable models, including terms for them and why “testable” matters. How does this relate to the supernatural?
3. Explain the characteristics of living matter to each other. Answer the “Fido” question (will be given in class).
4. Discuss the role of information in life, and how it is dealt with (on the molecular level).
5. Explain to each other the binomial system and taxonomic hierarchy. What is a species name? What do the two words in a species name represent, and how do you write them? How will you memorize the hierarchy?
6. What are the three domains and six kingdoms? How do you decide which kingdom to put a eukaryote into?
7. What is the importance of energy in living systems? What are autotrophs and heterotrophs?

I. Biology is Studied Using the Scientific Method

A. Science is based on a systematic thought process.

1. **Deductive reasoning** - Summarize the information at hand and draw conclusions from that information; proceeds from the general to the specific.
2. **Inductive reasoning** - Drawing a generalization from several specific observations; proceeds from the specific to the general. Must be careful, because it is **impossible to prove** the accuracy of the generalization.

B. Observations, testable models, and experiments

1. The scientific method is a recursive process for discovering knowledge that involves making observations, making testable models, and conducting experiments.
2. First step involves collecting information and/or **summarizing existing observations** about the phenomenon under study.

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3. This permits the formulation of a **hypothesis**, a **testable model** that explains the existing observations and makes predictions that can be tested.
 4. An **experiment** is conducted to test the correctness of the hypothesis
 - **Experimental or treatment group** - the individuals given the specific treatment or condition being tested
 - **Control group** - the individuals not given the specific treatment
 5. Observation and measurement of the experimental and control groups and comparison of the data obtained provides evidence to either support or reject the hypothesis.
 6. Care must be taken that the experimental and control groups receive the same treatments except for the specific effect being tested. Example: the **placebo effect**.
 7. The recursive nature of the process: experiments provide more observations, and at any time more observations may be added in and more testable models may be produced; this may in turn lead to more experiments, and the process continues. This generally leads to progress towards more and more reliable models of how nature works. Creative thinking often plays a major role when rapid progress occurs.
- C. Hypothesis, theory, and law
1. A well supported hypothesis that links together a large body of observations is considered a **theory**.
 2. A theory that links together significant bodies of thought and yields unvarying and uniform predictions over a long period of time becomes considered a **principle** or **law**.
- D. The supernatural, by definition, is outside the bounds of science. Supernatural causes and effects cannot be proved or disproved.
- E. science and technology – the goal of science is to *understand* nature; the goal of technology is to *apply* scientific knowledge for a specific purpose

II. Characteristics of Living Matter

- A. Living things are **composed of cells**.
1. **Cell** - The basic structural and functional unit of life consisting of living material bounded by a membrane. The smallest unit of living things capable of growth and development.
 2. Unicellular - An organism consisting of a single cell.
 3. Multicellular - An organism consisting of more than one cell.
- B. Living things **grow and develop**.
1. Growth-increase in size because number of cells or size of cells increases.
 2. Development-changes in roles of cells during the life cycle of an organism.

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- C. **Metabolism** includes the chemical processes essential to growth and repair.
1. Metabolism - the sum of the chemical reactions and energy transformations that take place within a cell.
 2. **Homeostasis** - the tendency of an organism to maintain a relatively constant internal environment.
- D. Living things **respond to stimuli** (stimulus - physical or chemical changes in the internal or external environment of an organism)
- E. Living things **reproduce**.
1. Asexual reproduction – copying; reproduction not involving sex (genetic recombination); resulting from only cell division.
 2. Sexual reproduction – reproduction involving sex; typically involves the formation of specialized egg and sperm cells and their fusion to produce a zygote which grows and develops into a new organism.

III. Information Transfer in Living Systems

- A. Information must be transferred from one generation to the next.
1. **DNA** (deoxyribonucleic acid) is responsible for information transfer from one generation to the next.
 2. DNA is the chemical substance that makes up **genes**, the units of heredity.
- B. Information must be transferred from one cell generation to the next.
- C. Information is exchanged between cells.
1. **Hormones** are chemical signals used for intercellular signaling.
 2. Physical signals also lead to intercellular communication, e.g. nerve cells.

IV. Biological Organisms Show Great Diversity

- A. Biologists use a **binomial system** for classifying organisms.
1. **Taxonomy** - the science of classifying and naming organisms.
 2. **Carolus Linnaeus** (18th century Swedish botanist) developed a system of classification that is the basis of what is used today
 3. **Species** - basic unit of classification or taxonomy
 - if sexual, a group of organisms that can interbreed and produce fertile offspring
 - if asexual, grouped based on similarities (DNA sequence is best)
 - about 1.8 million living species have been described, likely millions more
 4. **Genus** - a group of closely related species.
 5. Together the **genus and specific epithet names make up the binomial name** used to name a species

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- The Genus name is always capitalized, and the specific epithet is never capitalized.
- The Genus and specific epithet are always together, and italicized (or underlined).
- Example: *Homo sapiens* or Homo sapiens

B. Taxonomic classification is hierarchical.

1. A group of related genera make up a **Family**.
2. Related families make up an **Order**.
3. Related orders are grouped into a **Class**.
4. Related classes are grouped into a **Phylum** or **Division**.
5. Related phyla or divisions are grouped into a **Kingdom**.
6. Related kingdoms are grouped into a **Domain**, the highest level of classification in the modern system.
7. The gold standard for “related” is based on DNA sequence similarities, but other criteria are used as well (we don’t have the complete DNA sequence of all known species)

C. The most widely accepted classification system today includes three domains and six kingdoms

1. Two domains consist of **prokaryotes**, organisms with no true cellular nucleus
 - Domain **Archaea** – Kingdom **Archaeobacteria** – bacteria typically found in extreme environments; distinguished from other bacteria mainly by ribosomal RNA sequence; include methanogens, extreme halophiles, and extreme thermophiles
 - Domain **Bacteria** – Kingdom **Eubacteria** – very diverse group of bacteria; examples: blue-green algae, *Escherichia coli*
2. One domain, **Eukarya**, consists of **eukaryotes**, organisms with a discrete cellular nucleus; it is divided into four kingdoms:
 - Kingdom **Protista** – Single celled and simple multicellular organisms having nuclei, and not fitting into the other three eukaryotic kingdoms. Includes protozoa, algae, water molds, and slime molds.
 - Kingdom **Plantae** – Plants are complex multicellular organisms having tissues and organs. Plant cells have walls containing **cellulose** as the main structural component. Most are photosynthetic, and those that are have **chlorophyll** in chloroplasts.
 - Kingdom **Fungi** – Organisms with cell walls containing **chitin** as the main structural component. Most are multicellular. Most are decomposers. Includes molds and yeasts as well as mushrooms, etc.
 - Kingdom **Animalia** – Complex multicellular organisms that must eat other organisms for nourishment. No cells walls. Typically have organs and organ systems. Most forms are motile.

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V. Life Depends on a Continuous Input of Energy

- A. At the cellular level part of the energy that is obtained from nutrients is utilized to synthesize new cellular components.
1. Used for maintenance of existing cellular structures and components (replacement of damaged or worn out materials within the cell)
 2. Used to produce materials to support growth, development, and reproduction
- B. Part of the energy obtained from nutrients is used to support:
1. Movement, either of cell itself or of materials into and out of the cell
 2. Signaling responses, such as hormone production and perception, nerve impulses, etc.
 3. Other forms of cell work, such as symbiotic relationships with other organisms, defense against pathogens
- C. Energy flows through ecosystems (the concept of a food chain or food web).
1. **Producers (autotrophs)** manufacture their own food from simple materials
 - usually produce food by the process of photosynthesis:
$$\text{Carbon dioxide} + \text{Water} + \text{light energy} \longrightarrow \text{Carbohydrate (food)} + \text{Oxygen}$$
 - use such food by oxidative **respiration**
$$\text{Carbohydrate (food)} + \text{Oxygen} \longrightarrow \text{Carbon dioxide} + \text{Water} + \text{energy}$$
 - overall, producers use carbon dioxide and water and release food and oxygen
 2. **Consumers (heterotrophs)** obtain energy by eating other organisms (ultimate source of food is producers); use food and oxygen, and release carbon dioxide and water
 3. **Decomposers** obtain energy by breaking down the waste products, by products, and dead bodies of producers and consumers. Usually bacteria and fungi.

VI. Themes that pervade biology

- A. **The cell**
- B. **Information management (heritable information, regulation, and interaction with the environment)**
- C. **Energy management**
- D. **Structure and function**
- E. **Unity and diversity**
- F. **Emergent properties**
- G. **Evolution** – the core unifying theme that explains much of the observations connected with the other themes
- H. In addition, an awareness of the process scientific inquiry and the application of science (technology) are important aspects of any study of biology.