Biology is about the nature of life and living organisms. By studying biology we can satisfy much of the curiosity we have about the world we live in, and the connections we humans make with other organisms with whom we share this earth.

Biologists ask, and try to answer, questions about the diversity of life and about the common characteristics of living organisms from molecules to entire ecosystems. To accomplish this, some biologists study organisms in their habitats; others work in laboratories to examine life on the cell and molecular level. Biologists study the history of life through fossils and use bioinformatics to determine evolutionary relationships based on DNA sequences. Ecologists use computer modeling to evaluate critical environmental issues. The study of biology encompasses so much that it's almost impossible to not be a biologist!

During the three terms of biology (211-212-213) this year, you will look at much of what and how biology is and be introduced to the **language** of biology. (*At times it may seem that all we do is memorize vocabulary. In reality, to be able to work with and process the information of biology, we must know the vocabulary – it's an essential first step in learning.*)

In Biology 211, we shall look most closely at life on the cellular and molecular level. The study of life encompasses broad themes (the characteristics of life) that apply to all organisms, generally in the context of the overarching theme of **evolution**, the process of expression of genetic change through time. These **connecting themes** or properties of life are addressed in the introductory chapter of your textbook, and include:

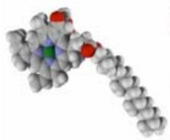
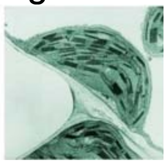
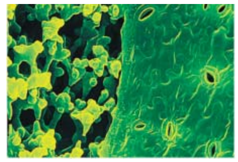
- Biological Organization
- Common evolutionary history
- Continuity of life based on the inheritable information of DNA
- Use of nutrients for energy and structure
- Regulation of biological systems
- Interaction with the living and non-living environment
- Processes of science: discovery and hypothesis-based science

In addition, we will briefly look at the way in which the vast diversity of organisms are categorized or classified based on cell structure and metabolism – a "tree of life". *Note: Diversity of Organisms is covered in Biology 212 and 213.*

Properties of Life

Living Organisms are virtually everywhere on earth, and are found in all sizes, shapes, patterns and, to our eyes, complexity. There is a remarkable array of living organisms to catalog (or classify) and observe on earth. Yet, all organisms, no matter how small or how large, share common properties that are associated with life. One definition of life is: "an organized genetic unit capable of metabolism, reproduction and evolution". Let's look a bit at some of the properties of life.

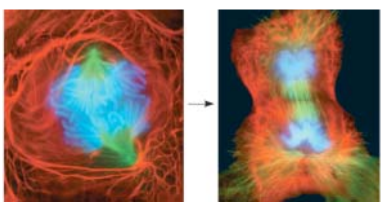
Biological Organization

Molecule Organelle Cells Tissues Organ Organism Community

Living organisms have an **organized** structure, or hierarchy, with each level of biological structure building on the level below it. Atoms form molecules that are organized into macromolecules that form cell components, called organelles, found within the cell, the basic unit of life. Organisms may be unicellular or multicellular. Multicellular organisms have structural levels above the cell: tissues, organs and organ systems.

The same hierarchy of life is seen in the interactions between different organisms and between organisms and their environment – the **structure and processes** of populations and communities within **ecosystems** is a critical component of our study of life.



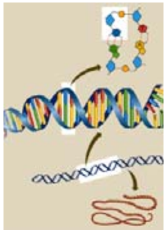
The Basic Unit of Life: The Cell

The cell is the fundamental unit of life. It holds this place in the hierarchy of organization because it is the lowest level that can perform all the activities of life. As we will discuss, all cells share some features in common, as well as a diversity of specialized cell components.

Structure and Function

The structure and function of organisms is correlated at all levels of biological organization. There is a strong relationship between form and function in living organisms. We appreciate the relationship of structure to function when we look at the processes of life. Although a biologist may focus on one level of organization, to gain perspective, one must integrate those specifics with processes occurring at higher and lower levels of the hierarchy of life.

Reproduction, Development and DNA

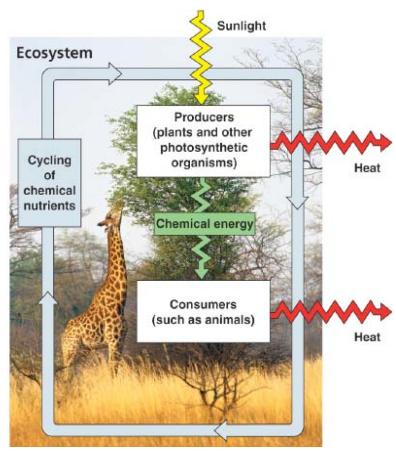
The continuity of life on earth is based on the inheritable information of the genetic molecule, **DNA.** DNA molecules contain the instructions needed for the organization and structure of organisms. Using the information contained in DNA, living organisms have the capacity for reproduction on both the cellular level for growth, development and maintenance and on the organism level, providing variation among populations to ensure the diversity of life from generation to generation.

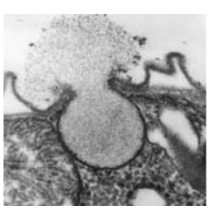
 

Energy, Matter and Metabolism

Thousands of chemical reactions that convert matter and energy occur within an organism so the organism can function. Metabolism is under the control of DNA, the genes.

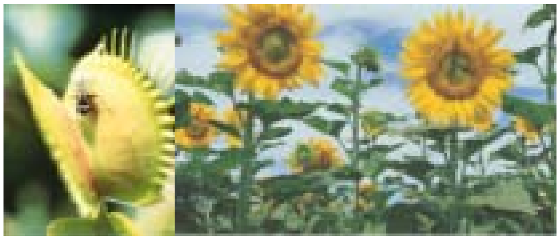
Organisms are open systems that interact with their environments. Organisms continuously exchange materials and energy with their surroundings. The field of ecology emphasizes the relationships of living organisms to each other and to their surrounding non-living environment.



Regulation and Communication

The internal functions of cells and organisms are coordinated through regulatory mechanisms. Such regulation on the cellular level includes moving materials through membranes, transporting nutrients and wastes to, within and from cells and cell-to-cell communication. Intercellular communication is fostered by chemical signals.

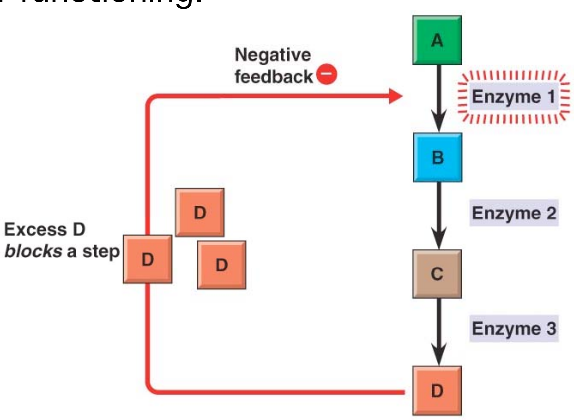


Sensitivity

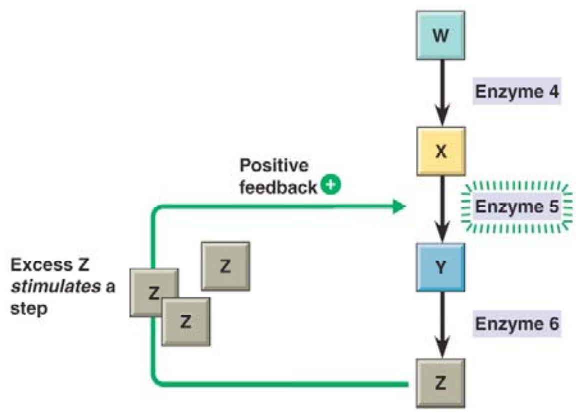
Organisms respond to environmental stimuli. We readily see this with ourselves and other animals, but we may have less experience noting how other organisms respond to stimuli, whether it is a flower tracking the sun, a cellular slime mold aggregating in response to a chemical signal, or a Venus Fly-trap capturing prey.

Homeostasis and Feedback Mechanisms

Regulatory systems help living organisms adjust to changing conditions by actively maintaining their structure and internal environment, a process called homeostasis, to ensure a dynamic balance. Organisms have a variety of regulatory and feedback systems, both positive and negative, in place to provide for order and functioning.



Negative Feedback Pathway



Positive Feedback Pathway

Evolution and the Unity and Diversity of Life

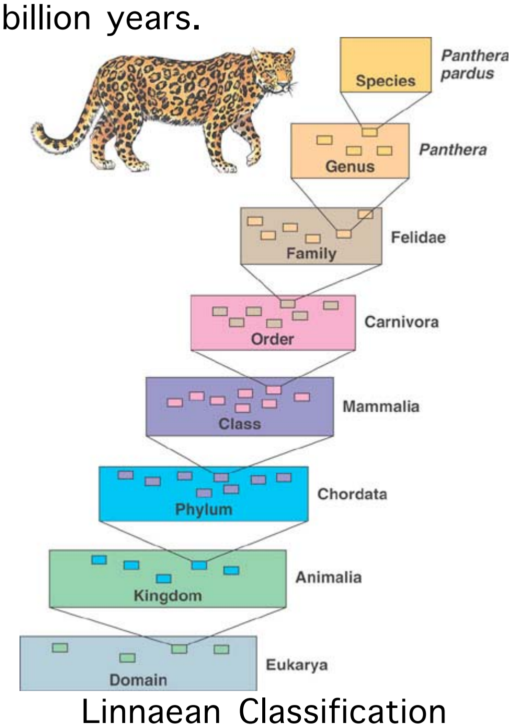
Evolution is the core of biology. Life has the capacity to change genetically from generation to generation – to evolve. The processes of evolution are fundamental to life on earth. The natural genetic variation found among members of a species provides for the capacity of organisms to respond to changing environmental conditions from generation to generation. Those who have characteristics, or **adaptations**, more favorable in the environment will reproduce more offspring that those with less successful characteristics.

Camouflage Adaptations

These statements, first presented by Charles Darwin and Albert Wallace in the mid-1800s are fundamental to all that we do in biology and our understanding of life. The mechanisms of evolution are discussed in Biology 212.

Diversity and unity are the two faces of life on earth. Biologists have described more than 1.8 million different kinds of organisms, including more than 1,000,000 insects alone. There may be as many as 30 million total species, including over 6000 prokaryotes, 100,000 fungi, 90,000 plants and 52,000 vertebrates (the animals with which we are most comfortable).

Taxonomy is the field of biology that organizes and groups different species into related categories, building a classification hierarchy – the "tree of life". In the 1700's, Linnaeus proposed a hierarchical scheme, which we continue to follow, in which each kind of organism is given a **species** name, a binomial. Similar species are grouped into **genera**, which are grouped into **families**, **orders**, **classes**, **phylums** (Phyla) and then into **Kingdoms**, based on broad general features (which are not so easy to see all of the time). In the 1990's, biologists added a category above the level of Kingdom, the **Domain.** The use of domains results from studies on cellular organization. Organisms within the three domains have been evolving separately for perhaps a billion years.



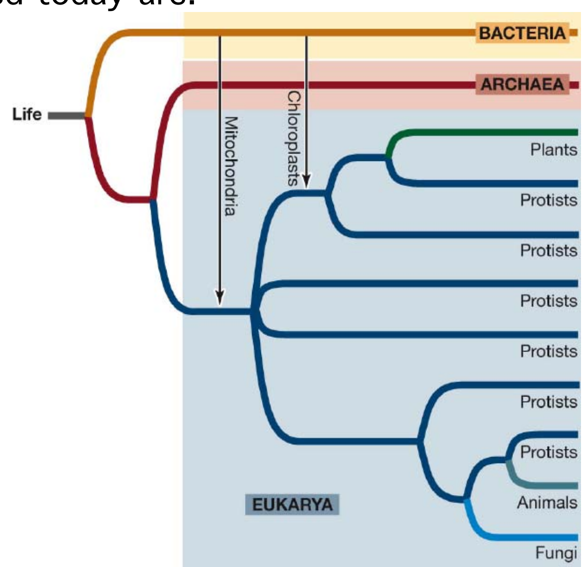
Linnaean Classification

The world of life is currently organized into three domains and six Kingdoms, although we continue to revise and modify even as new textbooks are published. Two of the domains, **Archaea** and **Bacteria** have a prokaryotic cell organization. The Domain, **Eukarya**, is comprised of several Kingdoms whose members have a eukaryotic cell organization: **Fungi, Plantae**, **Animalia** and a number of Kingdoms of **Protists,** eukaryotic organisms that lack tissue and organ development. The Bacteria and Archaea are also being separated in multiple Kingdoms, as well. Some protists are allied with other Kingdoms in the Eukarya. *(See Appendix A of your text for one current classification scheme.)*

We will discuss a bit about the cellular differences and distinctions are the basis of classification when we discuss cell structure and function.

The Domains and Kingdoms commonly used today are:

Domain Archaea
    Kingdom Archaea
Domain Bacteria
    Kingdom Bacteria
Domain Eukarya
    Kingdoms: Plantae
        Animalia
        Fungi
        Protista (Several Kingdoms)



Science Research into the Complexity of Life

The complexity of life challenges biologists who try to unravel the whole to view the component parts for research and learning. To do so, we most often must dissemble the whole, and in doing so, may disrupt its function. The human genome project – the attempt to discern the DNA sequences of the human chromosomes, was a daunting project – and biologists are still determining what those sequences mean in terms of gene function and products.

Alternatively, biologists also approach the study of life through **systems analysis** – using models to alter one or more variables and predict the outcomes. Ecologists use models to predict the consequences of our environmental actions. Cell biologists use models to predict the impact of drugs on nerve cell function, and how that impacts other physiological functions of the organism.

Observation remains a critical research skill in biology, even as our observational tools have advanced with electron microscopes, DNA chips, and satellite tracking in ecosystem studies. Such observation is essential for the objectivity of science.

Biologists do not work in isolation. Much research is now interdisciplinary. Animals are routinely tracked with computer-assisted monitoring to better understand how other organisms move in our world. The field of bioinformatics requires knowledge of database management and the biology expertise to determine what to extract from the huge biology databases that are accumulating.

DNA Sequencing Laboratory

Tracking Tuna

Science as a Process

Scientists view life as a set of natural processes that have natural explanations. Those explanations result from gathering evidence to support hypotheses or predictions. With **Discovery Science**, we gather and describe as accurately as possible what we observe and try to draw conclusions from our observations, using both **controlled** and **comparative** experimentation.

Much of science is an "if ... then" exercise, one **process of inquiry**. By taking hypotheses and testing them, scientists are able to eliminate those for which evidence is lacking or are refuted by evidence, and gather evidence to support those that have validity. But science is not a field of absolute certainty. The hypotheses we form and test are based on our past experiences, and validated with what we know today.

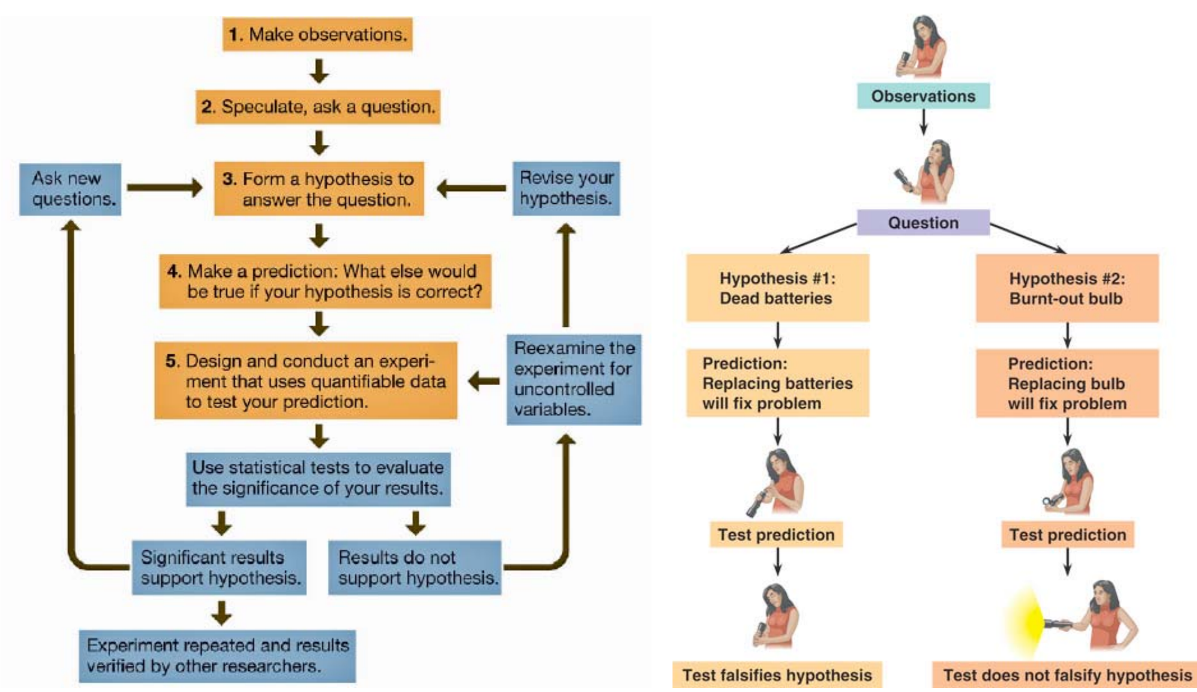
Science relies on both deductive and inductive reasoning to make hypotheses. With **deductive reasoning**, general principles are used to predict specific results. Such reasoning is used to validate general ideas in science as well as in all fields of study. **Inductive reasoning** uses specific observations to construct general principles, often using a process loosely called the scientific method, or sometimes the **hypothesis-prediction** approach *(see below)*.

Doing Science:

To succeed in science it helps to be curious. Find something to be curious about.

- Make observations and ask questions based on your observations to produce a "model" or preliminary explanation for your question.
- Based on your observations and model, make a **testable** hypothesis (reasoned guess) by using the information available to make a general statement (called the hypothesis).
- Predict what will happen if the hypothesis is correct
- Test the hypothesis by models, experiments and/or observations. When possible, science uses **controlled** experiments.

  Science also uses **comparative data**, looking for patterns in nature that are consistent with predictions. Data may be **quantitative**, such as measurements, or **qualitative**, in the form of descriptions of phenomena observed.
- Repeat tests to see if results are consistent with the hypothesis.
- Objectively note results and draw conclusions. Conclusions may support the hypothesis or not support the hypothesis. The purpose of scientific inquiry is to find answers, but not to find only those answers that support the original idea.
- Examine alternative hypotheses in the same manner.



Experimental Design Using Hypothesis-Based Inquiry

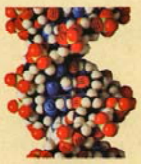
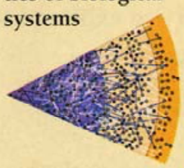
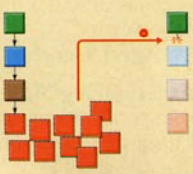
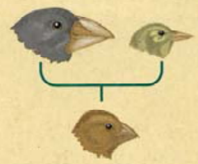
Science is limited to hypotheses that can be tested. The process used in science is self-correcting; if evidence does not support a prediction, the hypothesis is modified and subjected to more testing or rejected. Other fields may look at issues and ideas that are untestable through the hypothesis-prediction approach. Such issues or ideas are not appropriate for science.
Science and technology are both processes of our human society. Often the work of science can be applied in technological fields, but that is not the purpose of science. Technological “need” should not be the driving force for science research. Nor should we stop science research for fear of how the results might be used, which does not mean that we should not be concerned about the potential applications of the knowledge gained through scientific research. It does mean that it is incumbent upon each of us to be as educated as possible about science, so that we can make informed decisions about the use of science knowledge.

For example, the field of DNA technology today follows the discovery of the structure of DNA by Watson and Crick in the 1950’s. It would be hard to imagine that Watson and Crick envisioned at that time the impact of their discovery on biotechnology today. We are living in a time when our ability to manipulate DNA within and between organisms has broad consequences for life on earth. Perhaps more importantly, we are living in a time when human alterations of the environment affect not just those displaced by habitat but the earth's climate for centuries.

Biology is multi-disciplinary. To best understand the multitude of processes that are a part of living organisms, one needs to have knowledge of chemistry, physics and math as well. Not only does biology interface with other sciences; biology is allied with the humanities, and the vast array of human activities that celebrate life. Scientific literacy may be the most critical knowledge each of us needs in our world today. From the DNA-based technology, agricultural practices and medicine to the environmental impacts of human activities, being able to discern valid science-based statements will be critical to decisions we and those responsible for enacting legislation make.

The introductory chapter of your textbook addresses further methods and processes used in science and the applications of science to public policy. It would be beneficial to carefully review this material.

Themes of Biology

Theme	Description
The cell 	Cells are every organism's basic units of structure and function. The two main types of cells are prokaryotic cells (in bacteria and archaea) and eukaryotic cells (in protists, plants, fungi, and animals).
Heritable information 	The continuity of life depends on the inheritance of biological information in the form of DNA molecules. This genetic information is encoded in the nucleotide sequences of the DNA.
Emergent properties of biological systems 	The living world has a hierarchical organization, extending from molecules to the biosphere. With each step upward in level, system properties emerge as a result of interactions among components at the lower levels.
Regulation 	Feedback mechanisms regulate biological systems. In some cases, the regulation maintains a relatively steady state for internal factors such as body temperature.
Interaction with the environment 	Organisms are open systems that exchange materials and energy with their surroundings. An organism's environment includes other organisms as well as nonliving factors.
Energy and life 	All organisms must perform work, which requires energy. Energy flows from sunlight to producers to consumers.
Unity and diversity 	Biologists group the diversity of life into three domains: Bacteria, Archaea, and Eukarya. As diverse as life is, we can also find unity, such as a universal genetic code. The more closely related two species are, the more characteristics they share.
Evolution 	Evolution, biology's core theme, explains both the unity and diversity of life. The Darwinian theory of natural selection accounts for adaptation of populations to their environment through the differential reproductive success of varying individuals.
Structure and function 	Form and function are correlated at all levels of biological organization.
Scientific inquiry 	The process of science includes observation-based discovery and the testing of explanations through hypothesis-based inquiry. Scientific credibility depends on the repeatability of observations and experiments.
Science, technology, and society 	Many technologies are goal-oriented applications of science. The relationships of science and technology to society are now more crucial to understand than ever before.