

FUNDAMENTAL PRINCIPLES and CONCEPTS for the BIOLOGIST

Understanding the unity and diversity of life requires mastery of a set of fundamental concepts.

Committee on Undergraduate Biology Education NATIONAL RESEARCH COUNCIL

Biological systems show remarkable unity at the molecular and cellular levels, reflecting their common ancestry. Variations on this unity lead to the extraordinary diversity of individual organisms. **Biology students should understand the unifying features of Life by acquiring the biological concepts listed below.** Biology faculty should consider the various points in their courses at which the concepts will fit. They should also consider the concept lists for chemistry, physics, and mathematics that follow and the ways in which those ideas could be incorporated into biology courses.

The whole notion of emergent behavior, pattern formation, and dynamical networks is central to understanding biology.

Significant Concepts of Biology Every Student Should Learn

18 Central Themes

1. All living things have evolved from a **common ancestor**, through processes that include natural selection and genetic drift acting on heritable genetic variation.
2. Biological systems **obey the laws of chemistry and physics**.
3. Structural complexity and information content are built up by **combining simpler subunits** into multiple complex combinations.
4. Understanding biological systems requires **both reductionist and holistic** thinking because **novel properties emerge** as simpler units assemble into more complex structures.
5. **Living systems are far from equilibrium**. They utilize energy, largely derived from photosynthesis, which is stored in high-energy bonds or ionic concentration gradients. The release of this energy is coupled to thermodynamically unfavorable reactions to drive biological processes.
6. Although fundamental **molecular and cellular processes are conserved**, biological systems and organisms are extraordinarily diverse. Unlike atoms and simple molecules studied in chemistry and physics, no two cells are identical due to **molecular complexity**.
7. Biological systems maintain **homeostasis** by the action of complex regulatory systems. These are often networks of interconnecting partially redundant systems to make them stable to internal or external changes and **antagonistic actions**.
8. **Cells are fundamental units of living systems**. Three fundamental cell types have evolved: bacteria, archaea, and eukaryotes - **Domains**.
9. *Living organisms have behavior, which can be altered by experience in many species.*
10. **Information encoded in DNA is organized into genes**. These heritable units use RNA as informational intermediates to encode protein sequences, which become functional on folding into distinctive three-dimensional structures. In some situations RNA itself has catalytic activity.
11. Most biological processes are controlled by multiple proteins, which assemble into modular units to carry out and coordinate complex functions – **Enzymatic Pathways**.
12. Lipids assemble with proteins to form **membranes**, which surround cells to separate them from their environment. Membranes also form distinct compartments within eukaryotic cells.
13. **Communication networks** within and between cells, and between organisms, enable multicellular organisms to coordinate development and function – **Signal Transduction**.

14. In multicellular organisms, **cells divide and differentiate** to form tissues, organs, and organ systems with distinct functions. These differences arise primarily from changes in gene expression.
15. Many **diseases arise from disruption of cellular communication** and coordination by infection, mutation, chemical insult, or trauma.
16. *Groups of organisms exist as species, which include interbreeding populations sharing a gene pool.*
17. *Populations of species interact with one another and the environment to form interdependent ecosystems with flow of energy and materials between multiple levels.*
18. *Humans, as well as many other species, are members of multiple ecosystems. They have the capacity to disrupt or preserve the ecosystems upon which they depend.*