Supplemental Material

CBE—Life Sciences Education

Brownell ***et al.***

MAJOR SUBDISCIPLINES OF BIOLOGY

EVOLUTION

Principles: All living organisms share a common ancestor. Species evolve over time, and new species can arise, when allele frequencies change due to mutation, natural selection, gene flow, & genetic drift.

Molecular / Cellular/ Developmental Biology	Physiology	Ecology / Evolutionary Biology
Multiple molecular mechanisms, including DNA damage and errors in replication, lead to the generation of random mutations. These mutations create new alleles that can be inherited via mitosis, meiosis, or cell division.	Mutations that change protein structure and/or regulation can impact anatomy and physiological function at all levels of organization.	The characteristics of populations change over time due to changes in allele frequencies. Changes in allele frequencies are caused by random and nonrandom processes--specifically mutation, natural selection, gene flow, and genetic drift. Not all of these changes are adaptive.
Mutations and epigenetic modifications can impact the regulation of gene expression and/or the structure and function of the gene product. If mutations affect phenotype and lead to increased reproductive success, the frequency of those alleles will tend to increase in the population.	Most organisms have anatomical and physiological traits that tend to increase their fitness for a particular environment.	All species alive today are derived from the same common ancestor. New species arise when populations become genetically isolated and diverge due to mutation, natural selection, and genetic drift. Phylogenetic trees depict relationships among ancestral and descendant species, and are estimated based on data.
	Physiological systems are constrained by ancestral structures, physical limits, and the requirements of other physiological systems, leading to trade-offs that affect fitness.	Fitness is an individual's ability to survive and reproduce. It is environment-specific and depends on both abiotic and biotic factors. Evolution of optimal fitness is constrained by existing variation, trade-offs and other factors.

INFORMATION FLOW

Principles: Organisms inherit genetic and epigenetic information that influences the location, timing, and intensity of gene expression. Cells/organs/organisms have multiple mechanisms to perceive and respond to changing environmental conditions.

Molecular / Cellular/ Developmental Biology	Physiology	Ecology / Evolutionary Biology
In most cases, genetic information flows from DNA to mRNA to protein,but there are important exceptions.	Information stored in DNA is expressed as RNA and proteins. These gene products impact anatomical structures and physiological function.	Individuals transmit genetic information to their offspring; some alleles confer higher fitness than others in a particular environment.
Gene expression and protein activity are regulated by intracellular and extracellular signaling molecules. Signal transduction pathways are crucial in relaying these signals.	Organisms have sophisticated mechanisms for sensing changes in the internal or external environment. They use chemical, electrical, or other forms of signaling to coordinate responses at the cellular, tissue, organ, and/or system level.	A genotype influences the range of possible phenotypes in an individual; the actual phenotype results from interactions between alleles and the environment.
The signals that a cell receives depend on its location, and may change through time. As a result, different types of cells express different genes, even though they contain the same DNA.		

Molecules (smaller and faster) ⟶ Ecosystems (larger and slower)

BIOLOGICAL SCALE

MAJOR SUBDISCIPLINES OF BIOLOGY

STRUCTURE FUNCTION

Principles: Biological structures exist at all levels of organization, from molecules to ecosystems. A structure's physical and chemical characteristics influence its interactions with other structures, and therefore its function. Natural selection leads to the evolution of structures that tend to increase fitness within the context of evolutionary, developmental, and environmental constraints.

Molecular / Cellular/ Developmental Biology	Physiology	Ecology / Evolutionary Biology
The structure of a cell--its shape, membrane, organelles, cytoskeleton, and polarity--impacts its function.	Physiological functions are often compartmentalized into different cells, tissues, organs, and systems, which have structures that support specialized activities.	Natural selection has favored structures whose shape and composition contribute to their ecological function.
The three dimensional structure of a molecule and its subcellular localization impact its function, including the ability to catalyze reactions or interact with other molecules. Function can be regulated through reversible alterations of structure e.g. phosphorylation.	The size, shape, and physical properties of organs and organisms all affect function. The ratio of surface area to volume is particularly critical for structures that function in transport or exchange of materials and heat.	Competition, mutualism, and other interactions are mediated by each species' morphological, physiological, and behavioral traits.
The structure of molecules or organisms may be similar due to common ancestry or selection for similar function.	Structure constrains function in physiology; specialization for one function may limit a structure's ability to perform another function.	

TRANSFORMATIONS of ENERGY & MATTER

Principles: Energy and matter cannot be created or destroyed, but can be changed from one form to another. Energy captured by primary producers is necessary to support the maintenance, growth and reproduction of all organisms. Natural selection leads to the evolution of efficient use of resources within constraints.

Molecular / Cellular/ Developmental Biology	Physiology	Ecology / Evolutionary Biology
Energy captured by primary producers is stored as chemical energy. This stored energy can be converted through a series of biochemical reactions into ATP for immediate use in the cell.	Energy captured by primary producers is stored as chemical energy. This stored energy can be converted into ATP, which is required for energetically demanding activities necessary for life, including synthesis, transport, and movement.	Energy captured by primary producers is stored as chemical energy. At each trophic level, most of this energy is used for maintenance, with a relatively small fraction available for growth and reproduction. As a consequence, each trophic level in an ecosystem has less energy available than the preceding level.
In cells, the synthesis and breakdown of molecules is highly regulated. Biochemical pathways usually involve multiple reactions catalyzed by enzymes that lower activation energies. Energetically unfavorable reactions are driven by coupling to energetically favorable reactions such as ATP hydrolysis.	Due to the inefficiency of biochemical reactions and other constraints, physiological processes are never 100% efficient.	Chemical elements are transferred among the abiotic and biotic components of an ecosystem; changes in the amount and distribution of chemical elements can impact the ecosystem.
Intracellular and intercellular movement of molecules occurs via 1) energy-demanding transport processes and 2) random motion. A molecule's movement is affected by its thermal energy, size,electro-chemical gradient, and biochemical properties.	Organisms have limited energetic and material resources which must be distributed across competing functional demands. These include movement of material across gradients, growth, maintenance, and reproduction, inevitably leading to trade-offs.	

Molecules (smaller and faster) ⟶ Ecosystems (larger and slower)

BIOLOGICAL SCALE

MAJOR SUBDISCIPLINES OF BIOLOGY

SYSTEMS

Principles: Biological molecules, genes, cells, tissues, organs, individuals, and ecosystems interact to form complex networks. A change in one component of the network can affect many other components. Organisms have complex systems that integrate internal and external information, incorporate feedback control, and allow them to respond to changes in the environment.

Molecular / Cellular/ Developmental Biology	Physiology	Ecology / Evolutionary Biology
Cells receive a complex array of chemical and physical signals that vary in time, location, and intensity over the lifespan of the organism; a cell's response depends on integration and coordination of these various signals.	Organ systems are not isolated, but interact with each other through chemical and physical signals at the level of cells, tissues, and organs.	The size and structure of populations are dynamic. A species' abundance and distribution is limited by available resources and by interactions between biotic and abiotic factors.
During development, the signals a cell receives depend on its spatial orientation within the embryo and its intercellular interactions. As a consequence, cells adopt different cell fates depending on their local environment and/or cell lineage.	An individual's physiological traits affect its interactions with other organisms and with its physical environment.	Ecosystems are not isolated and static--they respond to change, both as a result of intrinsic changes to networks of species and as a result of extrinsic environmental drivers. Within an ecosystem, interactions among individuals form networks; changes in one node of a network can cause changes in other nodes--directly or indirectly.
Alteration of a single gene or molecule in a signaling network may have complex impacts at the cell, tissue or whole-organism level.	In the face of environmental changes, organisms may maintain homeostasis through control mechanisms that often use negative feedback; others have adaptations that allow them to acclimate to environmental variation.	Biodiversity impacts many aspects of ecosystems.

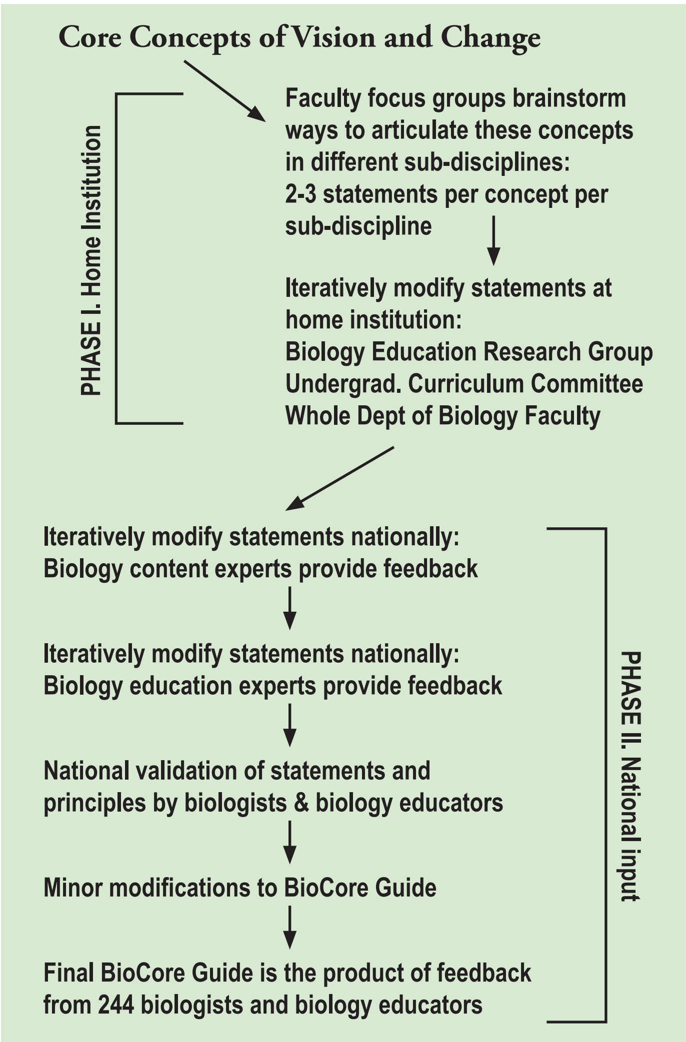
Molecules (smaller and faster) ⟶ Ecosystems (larger and slower)

BIOLOGICAL SCALE

FOR MORE INFORMATION:

Brownell SE, Freeman S, Wenderoth MP, Crowe AJ (2014). BioCore Guide: A Tool for Interpreting the Core Concepts of Vision and Change for Biology Majors. *CBE Life Sci Educ* 13, 200-211.

We used a grassroots approach to generate the BioCore Guide. We began with faculty ideas and engaged in an iterative process that incorporated feedback from over 240 biologists and biology educators at a diverse range of academic institutions throughout the U.S. The final validation step demonstrated strong national consensus, with over 90% of respondents agreeing with the importance and scientific accuracy of the statements.



DEPARTMENT OF BIOLOGY

UNIVERSITY of WASHINGTON

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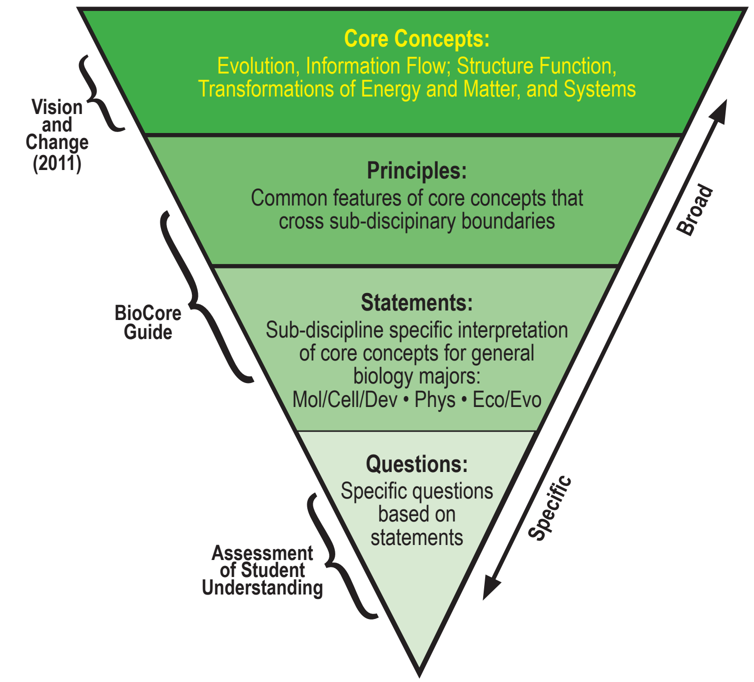
BIOCORE GUIDE:

A TOOL FOR INTERPRETING THE CORE CONCEPTS OF VISION AND CHANGE FOR BIOLOGY MAJORS



The BioCore Guide is a set of general principles and specific statements that expand upon the five core concepts outlined in *Vision and Change,* creating a framework that biology departments can use to align with the goals of Vision and Change.

It is our hope that the BioCore Guide will serve as an agent of change for biology departments as we move towards transforming undergraduate biology education.