

Tables for “Conceptual Elements: A Detailed Framework to Support and Assess Student Learning of Biology Core Concepts” (Cary & Branchaw)

Table 1. Conceptual Elements Framework of the Vision and Change Core Concepts

Pathways and Transformations of Energy and Matter (PTEM)
PTEM1: Energy is neither created nor destroyed, but can be transformed from one form to another to generate biological activity.
PTEM2: Input of energy, which can be from different sources, is needed to build and maintain biological entities, thereby lowering entropy in the system.
PTEM3: Biological entities harness potential energy stored in electrochemical gradients and released from chemical reactions.
PTEM4: Matter is recycled through the re-arrangement of chemical bonds in biological entities.
PTEM5: Biological entities regulate the synthesis, storage and mobilization of biological compounds to meet energy demands.
PTEM6: Many chemical elements can serve as electron donors and acceptors to drive biological processes.
PTEM7: Matter can transfer between the abiotic and biotic components of biological systems.
Information Flow, Exchange and Storage (IFES)
IFES1: Information exists in many forms and is relayed within and across biological molecules, cells, tissues, organisms, populations and ecosystems.
IFES2: Genetic information is stored in nucleic acids (DNA and RNA); epigenetic information is stored in proteins that associate with DNA and in reversible DNA modifications.
IFES3: The process of protein synthesis results from the flow of genetic information through various pathways.
IFES4: Information from the environment regulates protein synthesis and activity, which control cellular processes and thereby organismal and population-level activity.
IFES5: Organisms transmit genes and epigenetic information to their offspring.
Structure and Function (S&F)
SF1: Biological structures from the molecular to the ecosystem scale and their interactions are determined by chemical and physical properties that both enable and constrain function.
SF2: Individual structures can be arranged into organized units that enable more complex functions.
SF3: Structural features of biological entities undergo changes during development that are determined by the regulation of gene expression.
SF4: Structural features are dynamic and modifications can be made in response to environmental changes that are compensatory to restore lost function, or non- compensatory to eliminate functions that are no longer needed.
SF5: Comparable changes in structure can have small or large effects on function, depending on the spatial location.
Evolution (E)
E1: All living organisms share common ancestors at some time in the past.
E2: The phenotypes of living organisms result from the gain and loss of traits along their lineage.
E3: Genetic variation within a population can be generated by mutation, which results in the generation of novel traits, and by sexual recombination, endosymbiosis and horizontal gene transfer.
E4: Phenotypes, based upon underlying genotypes and environmental factors, can be subject to selective pressure.
E5: Organisms have greater fitness if they have a phenotype that increases their ability to survive and reproduce in a particular environment.
E6: Populations are composed of individual organisms that vary in their fitness, leading to differential rates of survival and reproduction and therefore changes in allele frequency over time.
E7: Evolution in a population may be due to events not related to fitness, including genetic drift and gene flow.
E8: The rate of evolutionary change varies and is influenced by many factors, including mutation rate, generation time, and environmental variation.
E9: Speciation occurs when subpopulations can no longer exchange genetic material, allowing them to diverge over time in their physiological and ecological traits.
Systems (S)
S1: Biological entities interact through chemical and physical signals that can be transient, depend on spatial organization, and are influenced by environmental factors.
S2: Changes in one component of a biological system can affect or be regulated by other components of the same system.
S3: Biological systems can be defined at different scales, interact within and across scales, and together form complex networks.
S4: Biological systems include and are affected by biotic and abiotic factors in the environment.
S5: Interactions between and among biological entities can generate new system properties.

***ENTITY** refers to an independent thing, which contains in itself all the conditions essential to autonomy; that which forms a complete whole; **biologically**, denoting a separate and distinct structure at any scale (e.g., molecules, cells, organisms, ecosystems). Adapted from: <https://www.biology-online.org/dictionary/Entity>

Conceptual Elements Course Inventory

FOR MORE INFORMATION CONTACT:

Tawnya Cary & Janet Branchaw, University of Wisconsin - Madison

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Conceptual Elements Course Inventory

Instructions: Indicate whether each conceptual element is addressed in the course in the Y/N column. If yes, then identify the specific topic or course content that is taught and at what scale(s).

Course:	Y / N	Topic/Course Content	Scale(s)
PATHWAYS AND TRANSFORMATIONS OF ENERGY AND MATTER (PTEM)			
PTEM1: Energy is neither created nor destroyed, but can be transformed from one form to another to generate biological activity.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
PTEM2: Input of energy, which can be from different sources, is needed to build and maintain biological entities, thereby lowering entropy in the system.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
PTEM3: Biological entities harness potential energy stored in electrochemical gradients and released from chemical reactions.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
PTEM4: Matter is recycled through the re-arrangement of chemical bonds in biological entities.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
PTEM5: Biological entities regulate the synthesis, storage and mobilization of biological compounds to meet energy demands.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
PTEM6: Many chemical elements can serve as electron donors and acceptors to drive biological processes.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
PTEM7: Matter can transfer between the abiotic and biotic components of biological systems.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem

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Course:	Y / N	Topic/Course Content	Scale(s)
INFORMATION FLOW, EXCHANGE AND STORAGE (IFES)			
IFES1: Information exists in many forms and is relayed within and across biological molecules, cells, tissues, organisms, populations and ecosystems.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
IFES2: Genetic information is stored in nucleic acids (DNA and RNA); epigenetic information is stored in proteins that associate with DNA and in reversible DNA modifications.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
IFES3: The process of protein synthesis results from the flow of genetic information through various pathways.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
IFES4: Information from the environment regulates protein synthesis and activity, which control cellular processes and thereby organismal and population-level activity.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
IFES5: Organisms transmit genes and epigenetic information to their offspring.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem

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SF5: Comparable changes in structure can have small or large effects on function, depending on the spatial location.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem

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EVOLUTION (E)			
E1: All living organisms share common ancestors at some time in the past.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
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E4: Phenotypes, based upon underlying genotypes and environmental factors, can be subject to selective pressure.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E5: Organisms have greater fitness if they have a phenotype that increases their ability to survive and reproduce in a particular environment.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E6: Populations are composed of individual organisms that vary in their fitness, leading to differential rates of survival and reproduction and therefore changes in allele frequency over time.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E7: Evolution in a population may be due to events not related to fitness, including genetic drift and gene flow.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E8: The rate of evolutionary change varies and is influenced by many factors, including mutation rate, generation time, and environmental variation.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E9: Speciation occurs when subpopulations can no longer exchange genetic material, allowing them to diverge over time in their physiological and ecological traits.			<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem

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Conceptual Elements Department Inventory

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Conceptual Elements Department Inventory

Instructions: Use individual course inventories to map the conceptual elements that are covered at each scale across the curriculum.

Courses:					
PATHWAYS AND TRANSFORMATIONS OF ENERGY AND MATTER (PTEM)					
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Instructions: Use individual course inventories to map the conceptual elements that are covered at each scale across the curriculum.

Courses:					
STRUCTURE AND FUNCTION (SF)					
SF1: Biological structures from the molecular to the ecosystem scale and their interactions are determined by chemical and physical properties that both enable and constrain function.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
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E2: The phenotypes of living organisms result from the gain and loss of traits along their lineage.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
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E7: Evolution in a population may be due to events not related to fitness, including genetic drift and gene flow.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E8: The rate of evolutionary change varies and is influenced by many factors, including mutation rate, generation time, and environmental variation.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
E9: Speciation occurs when subpopulations can no longer exchange genetic material, allowing them to diverge over time in their physiological and ecological traits.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem

FOR MORE INFORMATION CONTACT:

Tawnya Cary & Janet Branchaw, University of Wisconsin - Madison

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Conceptual Elements Department Inventory

Instructions: Use individual course inventories to map the conceptual elements that are covered at each scale across the curriculum.

Courses:					
SYSTEMS (S)					
S1: Biological entities interact through chemical and physical signals that can be transient, depend on spatial organization, and are influenced by environmental factors.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
S2: Changes in one component of a biological system can affect or be regulated by other components of the same system.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
S3: Biological systems can be defined at different scales, interact within and across scales, and together form complex networks.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
S4: Biological systems include and are affected by biotic and abiotic factors in the environment.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem
S5: Interactions between and among biological entities can generate new system properties.	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem	<input type="checkbox"/> cell/molec <input type="checkbox"/> organismal <input type="checkbox"/> ecosystem

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