



Science Assessment Item Collaborative

High School Item Cluster Prototype

for assessment of the

Next Generation Science Standards

December 2015

Developed by WestEd in collaboration with CCSSO Science Assessment Item Collaborative state members and content experts.



Introduction

On behalf of the Council of Chief State School Officers (CCSSO) Science Assessment Item Collaborative (SAIC) state members, WestEd's science content and assessment specialists are pleased to present this High School Item Cluster Prototype for assessment of the Next Generation Science Standards (NGSS). This prototype is designed to follow the principles and recommendations set forth in the SAIC Assessment Framework and Item Specifications Guidelines for an NGSS-aligned large-scale summative assessment item cluster. Its developers are optimistic that, if it is considered in conjunction with key sections of the Assessment Framework, it will serve as an initial building block for the development of large-scale summative assessments measuring the NGSS.

As with the previously released Grade 5 Item Cluster Prototype, development of the High School Item Cluster Prototype was a collaborative effort that depended upon the significant expertise and experience of SAIC state members, science content experts, and assessment designers and developers. This first iteration has undergone many rounds of refinement based on their feedback. It is anticipated that future iterations of item clusters will be informed by this foundational work and by future work from the wider science research and assessment community. Overall, the goal of this initiative is to provide states and other jurisdictions with a vetted approach to ensuring that emerging NGSS-based assessments are fair, meet the highest standards for technical quality, and are aligned to the principles of responsible testing articulated in the report *Developing Assessments for the Next Generation Science Standards* (hereafter "the BOTA report") (NRC, 2014).

Intended Uses of This Prototype

1. To serve as an initial model for measuring the three-dimensional science learning called for in the NGSS (NGSS Lead States, 2013) and in *A Framework for K–12 Science Education* (hereafter "the K–12 Framework") (NRC, 2012).
2. To support states in guiding their test vendors with the design and development of NGSS-aligned assessments. *This may be accomplished by presenting the prototype as a model that can be customized for each state's unique context.*

Issues of feasibility must be considered by the state and by the vendor, as these issues will affect implementation. These issues include platform capability, practicality, cost, time to develop, time to administer, number of constructed-response (CR) items, and scoring methods.

3. To promote ongoing dialogue, in the science education and assessment communities, about the vision for a truly next-generation science assessment and the opportunity to develop a research-supported, innovative, large-scale assessment for measuring the NGSS.

The High School Item Cluster Prototype is aligned to two Life Sciences Performance Expectations (PEs). As such, states may choose to use the prototype as a model

for the base unit of assessment for an end-of-course assessment and/or an end-of-year assessment.

The following sections outline the working assumptions under which the High School Item Cluster Prototype was developed and provide a summary of the decisions and accompanying rationales for features of the prototype that warranted additional discussion during development.

Prototype Assumptions

1. The prototype was developed with the intent to show how the Assessment Framework could be implemented for the purpose of development of an NGSS-aligned large-scale summative assessment. As such, the Assessment Framework, the *K–12 Framework*, the BOTA report, the NGSS, and the NGSS Evidence Statements (NGSS Network, 2015a, 2015b) are at the foundation of the prototype. Those seeking to use this approach will benefit from deep familiarity with these resources.
2. The prototype was developed with input from SAIC state members. The prototype development process did not require full consensus on every issue, but does represent the best thinking of state members.
3. The Assessment Framework was written prior to development of the prototype. Thus, some minor discrepancies emerged between the prototype and recommendations in the Assessment Framework.
4. The prototype is presented as a series of static item cards, not as functional items. This is indicative of the SAIC's focus on alignment rather than on system functionality. The annotations and metadata provided in the item cards are necessary to understand the intent of the items and the overall scaffolding in the item cluster.
5. The prototype was designed to be delivery system-agnostic. General principles of computer-based assessment delivery systems were used in developing the prototype, but the item structure and functionality described in the prototype are not meant to be representative of any specific delivery system. User interface (UI) notes are presented to help guide the interpretation of the intended system functionality.

Design Decisions, Execution, and Process Summary

Template Structure. The overall design of an item card includes student view (left), UI notes (right), and alignment information and item part metadata (at the bottom).

In addition, stimulus slides consist of the student view (left) and UI notes (right). Item overview slides are provided to show the complete presentation of each item to the student, inclusive of all item parts but without UI notes.

Alignment. The item cluster, when taken in its entirety, is intended to achieve three-dimensional alignment to the targeted NGSS PEs. As stated in the NGSS Evidence Statements Executive Summary (NGSS Network, 2015a),

Each PE represents the integration of three “dimensions” of science education: scientific and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs). As such, both student learning and assessment around the NGSS should be “three dimensional.” (p. 1)

Items, inclusive of all their parts, are intended to align at the PE and dimension (SEP, DCI, and CCC) levels.¹ Discrete item parts are aligned to one or more Evidence Statements associated with the target PEs. This organization is intended to directly support overall item alignment to PEs and dimensions. Information on this level of alignment is provided on the item card pages and in the comprehensive [metadata table](#) included in the prototype. As stated in the NGSS Evidence Statements Executive Summary (NGSS Network, 2015a),

The evidence statements are meant to show what it looks like for students to fully satisfy the PE [and] . . . were designed to articulate how students can use the practices to demonstrate their understanding of the DCIs through the lens of the CCCs, and thus, demonstrate proficiency on each PE. (p. 1)

Color coding for the high school Evidence Statements was not available at the time of prototype development. WestEd content specialists applied a methodology, similar to the methodology used by Achieve, Inc., during the color-coding of the K–8 Evidence Statements, to provide color coding for the high school Evidence Statements.

Scaffolding. The High School Item Cluster Prototype is designed to assess students along a range of proficiency and across an appropriate range of cognitive complexity. The intent of scaffolding in this context is to provide a structure that allows students of all abilities to demonstrate their level of proficiency through progressively built item parts and purposeful sequencing of items. The NGSS Evidence Statements were written to describe student evidence at a single proficiency level and to cover a range of cognitive complexity. In order to serve the needs of a large-scale summative assessment, the item cluster provides scaffolding with respect to anticipated item difficulty, independent from alignment to the sequence of the Evidence Statements, and in order to effectively collect a range of information along a proficiency continuum.

Items and Item Parts. Most items within the item cluster prototype have multiple parts. This allows for more complex interactions and deeper thinking—and allows for the employment of science practices on the part of the student. The presumed navigational control that is offered

by online administration is leveraged in order to scaffold the items within the item cluster. Students may navigate freely to the stimulus at any time (preferably through a tabbed structure) and can navigate freely between parts within an item. *The overall design of the item cluster is predicated on a navigation strategy in which students cannot navigate back to items that they have previously submitted.* For example, students can change their responses to Part (a) and Part (b) of a single item at will, but cannot change their response to a previous item once the item is submitted and the student has navigated to the next item in the sequence. This limits cueing within the item cluster while supporting the intended scaffolding for the assessment of students along a broader learning continuum.

Item Types and Scoring Considerations. SAIC member states believe that the effort and time needed to score CR items must be considered when selecting item types for inclusion in a cluster. In order to balance this consideration with the overall alignment goals, every effort was made to select items of appropriate types—i.e., those item types that offered the ideal functionality for the measurement purpose—while limiting the number of likely hand-scored items (e.g., CR items). While CR items can be an effective means of measuring complex three-dimensional learning, technology-enhanced items (TEIs) and selected-response items (SRs) were included when they were deemed effective at achieving alignment and serving as a valid measure of the intended constructs.

Content-Related Decisions. During the development process, certain choices were deemed necessary by the SAIC in order to satisfy the majority of its members. For example, the decision was made to reduce the number of assessed PEs in the high school item cluster from three to two, in order to more fully assess the targeted PEs. This resulted in alignment to thirteen of fourteen Evidence Statements associated with the two PEs. While complete or near-complete coverage of the Evidence Statements is ideal, it is not intended that all item clusters can or will include alignment to all of the Evidence Statements that are associated with the targeted PEs in an item cluster.

Per the clarification statements provided for the targeted PEs (HS-LS1-5 and HS-LS1-7), emphasis of the item cluster was on “illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms” and “the conceptual understanding of the inputs and outputs of the process of cellular respiration.” As such, the focus of the phenomenon (students observe a stable pond ecosystem) is on the movement of matter and energy in an ecosystem, and not on the food chain(s) present in the ecosystem. Further, emphasis is placed on conceptual understanding of the outcomes of the chemical reactions that are involved in the transfer of matter and energy in the system, rather than on the underlying biochemical processes.

Use of Prototype to Emphasize Various Design Elements. The SAIC members wanted a range of Assessment Framework design elements to be reflected in the prototypes that emerged from their collaboration. These ranges of design elements will be evident in two significant ways: (1) via stimulus innovation, interaction, and item dependency, and (2) via the relative number of CR items in the item cluster. These ranges reflect the intended utility of the prototypes.

¹ See the Assessment Framework and the appendix of this prototype for a more in-depth description of item cluster alignment expectations. Additional information also can be found on the Item Overview slide pages and in the comprehensive metadata table that immediately follows the last item in the item cluster.

Level:	High School
Primary Target Domain:	Life Sciences
Target PEs:	HS-LS1-5, HS-LS1-7
Crosscutting Concept(s) Focus:	Energy and Matter
Science and Engineering Practice(s) Focus:	Developing and Using Models
Phenomenon:	A pond ecosystem has remained stable for several years.
Allowable Item Types:	SR, TE, CR

	HS-LS1-5	HS-LS1-7
Performance Expectations:	Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
Target Clarifications:	Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.	Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.
Assessment Boundary:	Assessment does not include specific biochemical steps.	Assessment should not include identification of the steps or specific processes involved in cellular respiration.

Disciplinary Core Idea(s):	LS1.C: Organization for Matter and Energy Flow in Organisms <ul style="list-style-type: none"> The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. 	LS1.C: Organization for Matter and Energy Flow in Organisms <ul style="list-style-type: none"> As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
Science and Engineering Practice(s):	Developing and Using Models <p>Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.</p> <ul style="list-style-type: none"> Use a model based on evidence to illustrate the relationships between systems or between components of a system. 	Developing and Using Models <p>Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.</p> <ul style="list-style-type: none"> Use a model based on evidence to illustrate the relationships between systems or between components of a system.
Crosscutting Concept(s):	Energy and Matter <ul style="list-style-type: none"> Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. 	Energy and Matter <ul style="list-style-type: none"> Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

ITEM CLUSTER



Stimulus



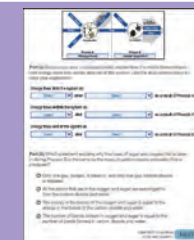
Item 1a:
Drag-and-Drop
(TEI)

HS-LS1-5
HS-LS1-7

DCI

SEP

CCC



Item 2a:
Drop-Down
Menu (TEI)

HS-LS1-5
HS-LS1-7

DCI

SEP

CCC

Item 2b:
Multiple
Choice



Item 3:
Hot Spot (TEI)
with Multiple
Select

HS-LS1-5

DCI

SEP

CCC



Item 4a:
Multiple
Select

HS-LS1-5
HS-LS1-7

DCI

SEP

CCC

Item 4b:
Multiple
Choice



Item 5a:
Drag-and-Drop
w/Fill-in
Labeling (TEI)

HS-LS1-5
HS-LS1-7

DCI

SEP

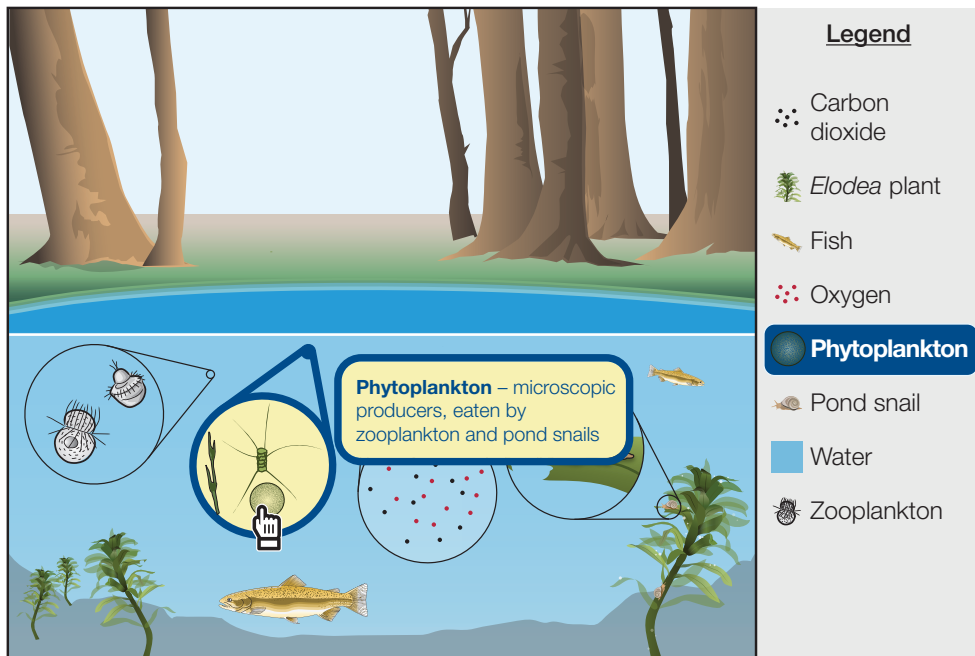
CCC

Item 5b:
Constructed
Response

Each year, in the spring, a teacher takes her students on a field trip to the same pond to observe the pond ecosystem. The students measure and observe different components of the pond ecosystem, including the numbers and types of organisms present and the concentrations of gases in the water.

Scroll over the parts of the Interactive Pond Exploration image to explore the different components.

Interactive Pond Exploration



Click NEXT to continue.

NEXT

Stimulus

Information adapted from the following source:

http://www.fws.gov/columbiariver/ANS/Activities/A4_food_web_crashers_cards.pdf

Interactive graphic: As student scrolls over a component in the diagram, the component receives an outer glow, the corresponding label in the Legend is highlighted, and hovering text appears that provides a brief explanation of the component.

Language for hovering text:

Carbon dioxide – gas dissolved in water; concentration changes throughout the day

Elodea plant – eaten by pond snails and fish

Fish – eat Elodea, pond snails, and zooplankton

Oxygen – gas dissolved in water; concentration changes throughout the day

Phytoplankton – microscopic producers, eaten by zooplankton and pond snails

Pond snail – eats Elodea and phytoplankton, eaten by fish

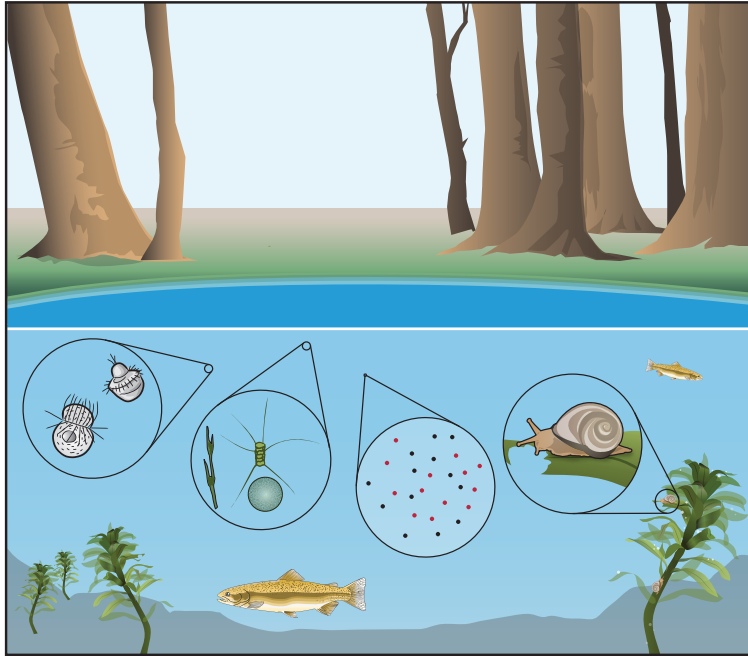
Water – contains all organisms in the pond ecosystem

Zooplankton – microscopic organisms, eaten by fish, eat phytoplankton

Optional functionality: An alternative to hovering text would be to include all of the hovering text language in the Legend, to the right of each Legend image.

Platform prompt and student control

The students compare their measurements and observations with the notes left by previous classes and notice that the pond ecosystem has remained relatively stable for the past several years. The teacher asks her students to think about the factors that affect stability in pond ecosystems, including the processes that transfer energy and matter. She asks her students to develop a model that can be used to explain how the flow of energy and matter relate to stability in the pond ecosystem.



Stimulus

Graphic

BACK

Click BACK to go back.

Click NEXT to continue.

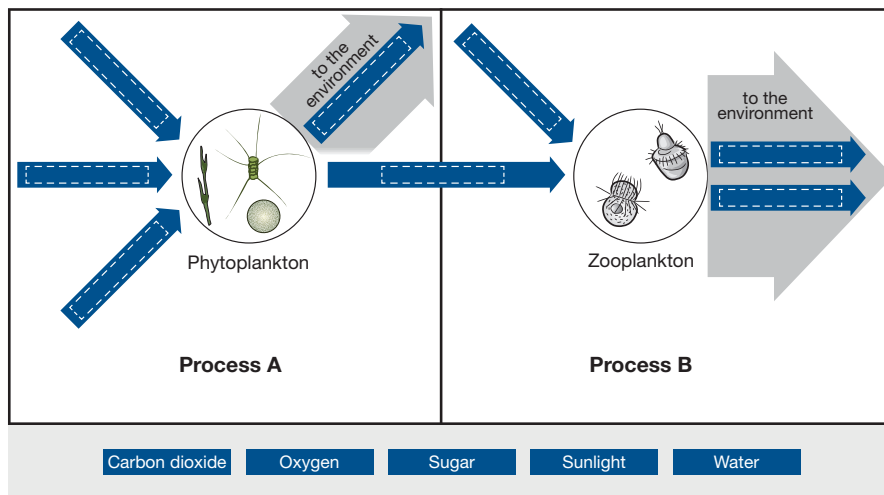
NEXT

Platform prompt and student control

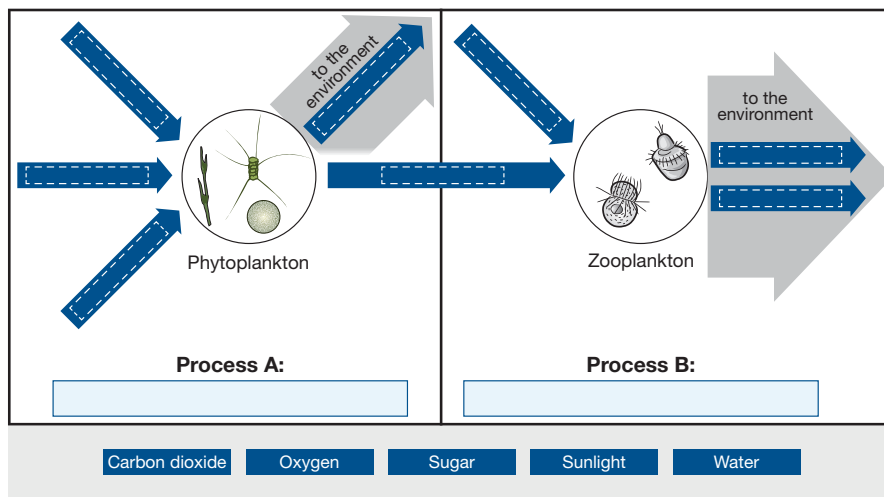
Part (a) Complete a model to represent the two main processes by which energy and matter are transferred among the various components of the pond ecosystem.

Drag the correct labels into the blue arrows in the model to identify the reactants, products, and energy involved in each of these processes.

Every arrow must be labeled. Some labels may be used more than once.



Part (b) Type the name of Process A and the name of Process B into the appropriate boxes.



Click NEXT to continue to the next question.

NEXT

HS-LS1-5

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-7

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

Alignment to the PE and targeted dimensions is intended through the entirety of the item cluster. Partial to strong alignment to the dimensions for each item is achieved through alignment to the evidence statements, and is inclusive of all item parts for any given item.

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

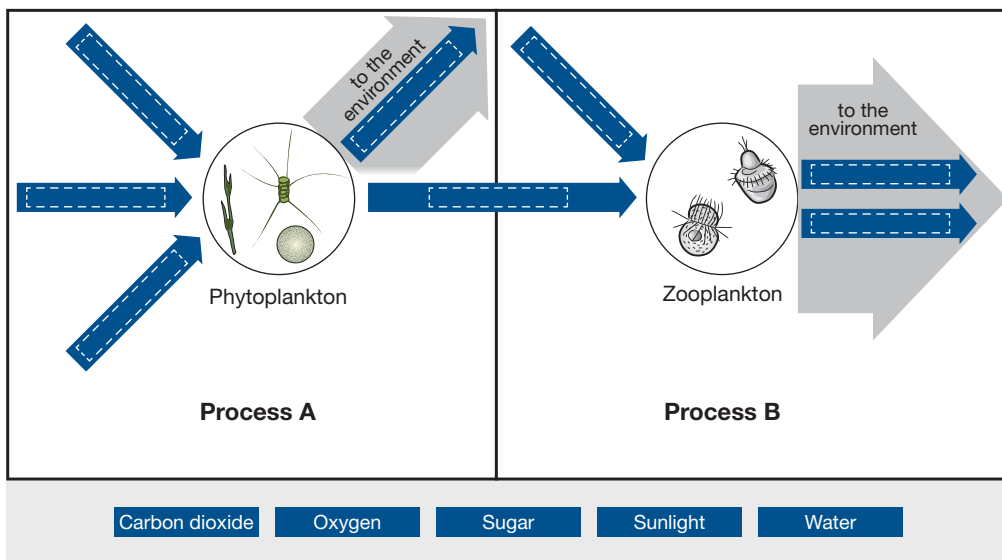
Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Part (a) Complete a model to represent the two main processes by which energy and matter are transferred among the various components of the pond ecosystem.

Drag the correct labels into the blue arrows in the model to identify the reactants, products, and energy involved in each of these processes.

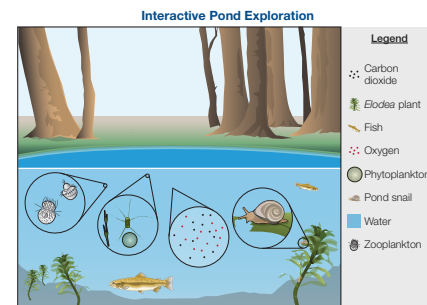
Every arrow must be labeled. Some labels may be used more than once.



Click NEXT to continue to the next question.

NEXT

(Stimulus graphic viewable by student)



Stem

Targets will expand to fit the selected drag-and-drop object.

Optional functionality: To increase rigor, students may be prompted to select organisms from the ecosystem to populate the model.

Drag-and-drop objects available for student use (objects replenish). Objects will snap to the orientation of the chosen target.

Platform prompt and student control

Item Type: Drag-and-Drop Model

Estimated Time: 2 min

Evidence Statement Alignment:

(HS-LS1-5)

(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including: (i) Energy in the form of light; and (iv) Matter in the form of carbon dioxide, water, sugar, and oxygen.

(HS-LS1-7)

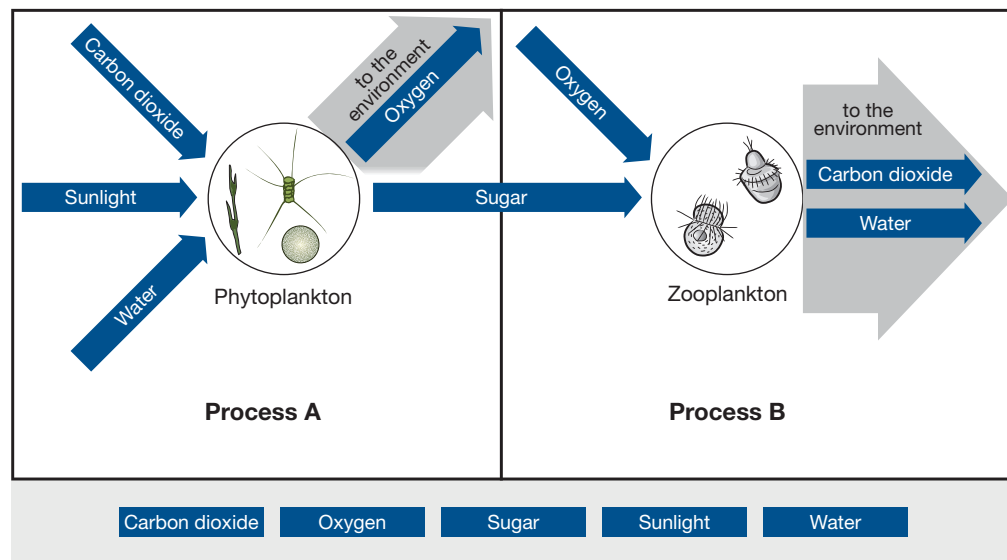
(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including: (i) Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO₂).

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and organize the major reactants, products, and energy involved in photosynthesis and cellular respiration (light energy, carbon dioxide, oxygen, sugar, and water) to demonstrate an understanding of the relationships between the reactants and products. The student's mental model of the two processes is used to complete Part (a) and the explicit naming of the processes (photosynthesis and cellular respiration) is completed in Part (b).

Part (a) Complete a model to represent the two main processes by which energy and matter are transferred among the various components of the pond ecosystem.

Drag the correct labels into the blue arrows in the model to identify the reactants, products, and energy involved in each of these processes.

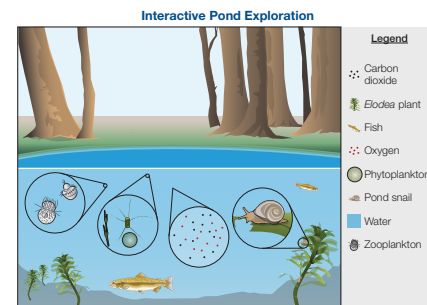
Every arrow must be labeled. Some labels may be used more than once.



Click NEXT to continue to the next question.

NEXT

(Stimulus graphic viewable by student)



Stem

Targets will expand to fit the selected drag-and-drop object.

Optional functionality: To increase rigor, students may be prompted to select organisms from the ecosystem to populate the model.

Drag-and-drop objects available for student use (objects replenish). Objects will snap to the orientation of the chosen target.

Platform prompt and student control

Item Type: Drag-and-Drop Model

Estimated Time: 2 min

Evidence Statement Alignment:

(HS-LS1-5)

(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including: (i) Energy in the form of light; and (iv) Matter in the form of carbon dioxide, water, sugar, and oxygen.

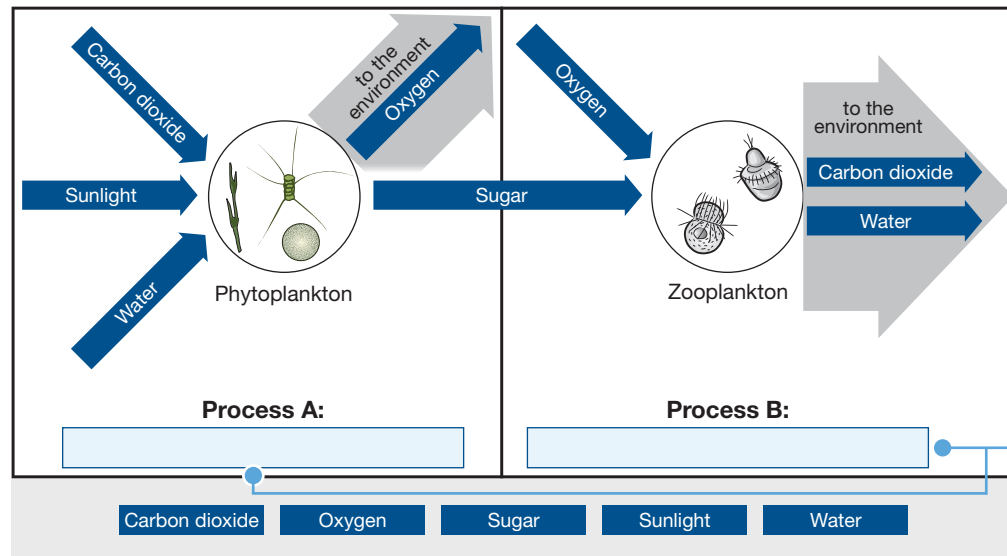
(HS-LS1-7)

(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including: (i) Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO₂).

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and organize the major reactants, products, and energy involved in photosynthesis and cellular respiration (light energy, carbon dioxide, oxygen, sugar, and water) to demonstrate an understanding of the relationships between the reactants and products. The student's mental model of the two processes is used to complete Part (a) and the explicit naming of the processes (photosynthesis and cellular respiration) is completed in Part (b).

Scoring Notes: 2 points are awarded for 8 correct arrow labels; 1 point is awarded for 7 correct arrow labels. The order of the inputs for photosynthesis can be interchanged with no effect on scoring. The order of the outputs of cellular respiration can be interchanged with no effect on scoring.

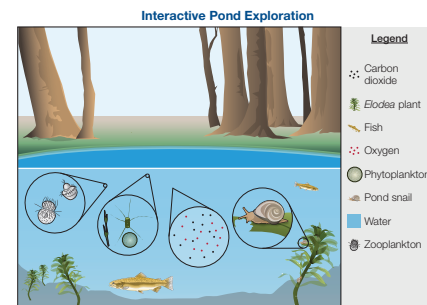
Part (b) Type the name of Process A and the name of Process B into the appropriate boxes.



Click NEXT to continue to the next question.

NEXT

(Stimulus graphic viewable by student)



Once the student populates all of the targets in Part (a), the platform will introduce Part (b), prompting the student to type in a label for each process. Students may change their responses to Part (a) and Part (b) at their discretion before clicking NEXT and continuing to Item 2.

The student types a response in each of the text entry fields.

Platform prompt and student control

Item Type: Text Entry
Estimated Time: 1 min

Evidence Statement Alignment:

(HS-LS1-5)

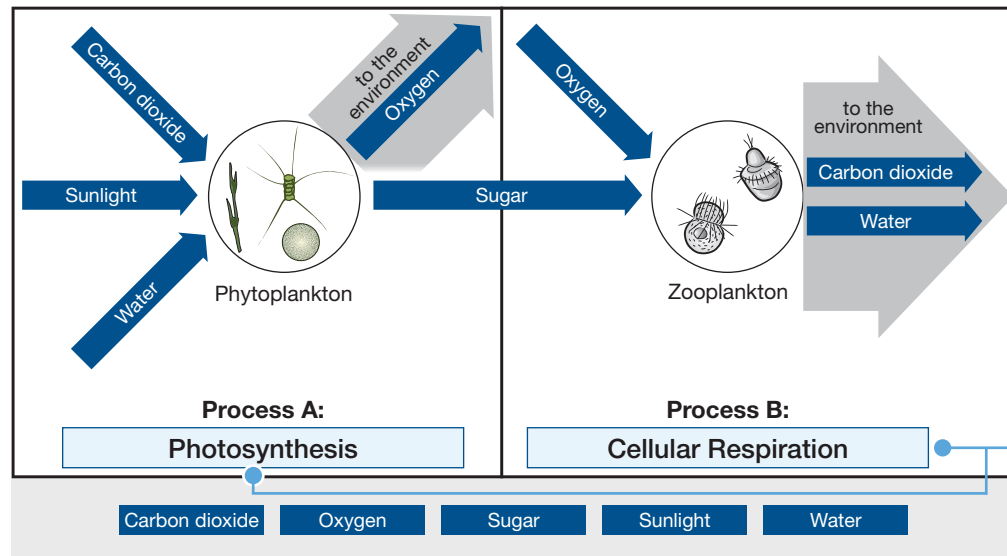
(2) **Relationships:** (a) Students identify the following relationship between components of the given model: Sugar and oxygen are produced by carbon dioxide and water by the process of photosynthesis.

(HS-LS1-7)

(2) **Relationships:** (a) From the given model, students describe the relationships between components, including: (i) Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration.

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and organize the major reactants, products, and energy involved in photosynthesis and cellular respiration (light energy, carbon dioxide, oxygen, sugar, and water) to demonstrate an understanding of the relationships between the reactants and products. The student's mental model of the two processes is used to complete Part (a) and the explicit naming of the processes (photosynthesis and cellular respiration) is completed in Part (b).

Part (b) Type the name of Process A and the name of Process B into the appropriate boxes.

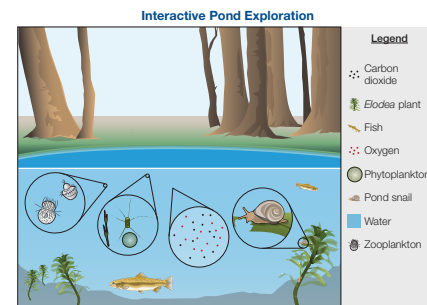


Click NEXT to continue to the next question.

NEXT

Stem

(Stimulus graphic viewable by student)



Once the student populates all of the targets in Part (a), the platform will introduce Part (b), prompting the student to type in a label for each process. Students may change their responses to Part (a) and Part (b) at their discretion before clicking NEXT and continuing to Item 2.

The student typed a response in each of the text entry fields.

Platform prompt and student control

Item Type: Text Entry
Estimated Time: 1 min

Evidence Statement Alignment:

(HS-LS1-5)

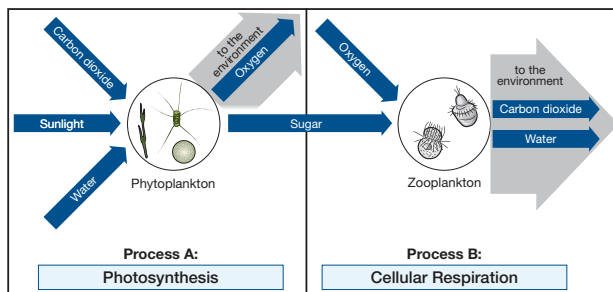
(2) **Relationships:** (a) Students identify the following relationship between components of the given model: Sugar and oxygen are produced by carbon dioxide and water by the process of photosynthesis.

(HS-LS1-7)

(2) **Relationships:** (a) From the given model, students describe the relationships between components, including: (i) Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration.

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and organize the major reactants, products, and energy involved in photosynthesis and cellular respiration (light energy, carbon dioxide, oxygen, sugar, and water) to demonstrate an understanding of the relationships between the reactants and products. The student's mental model of the two processes is used to complete Part (a) and the explicit naming of the processes (photosynthesis and cellular respiration) is completed in Part (b).

Scoring Notes: 1 point is awarded for entering "Photosynthesis" for Process A and "Cellular Respiration" for Process B. Automatic scoring is feasible, and spelling variations can be accepted, if preferred.



Part (a) Based upon your completed model, explain how the model demonstrates how energy flows into, within, and out of this system. Use the drop-down menus to write your explanation.

Energy flows **into** the system as

when as a result of Process A.

Energy flows **within** the system as

after as a result of Process A.

Energy flows **out of** the system as

after as a result of Process B.

Part (b) Which statement explains why the mass of sugar and oxygen that is taken in during Process B is the same as the mass of carbon dioxide and water that is produced?

- ☐ Only one gas, oxygen, is taken in, and only one gas, carbon dioxide, is released.
- ☐ All the atoms that are in the oxygen and sugar are rearranged to form the carbon dioxide and water.
- ☐ The energy in the bonds of the oxygen and sugar is equal to the energy in the bonds of the carbon dioxide and water.
- ☐ The number of bonds broken in oxygen and sugar is equal to the number of bonds formed in carbon dioxide and water.

Click NEXT to continue to the next question.

NEXT

HS-LS1-5

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-7

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

Alignment to the PE and targeted dimensions is intended through the entirety of the item cluster. Partial to strong alignment to the dimensions for each item is achieved through alignment to the evidence statements, and is inclusive of all item parts for any given item.

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Part (a) Based upon your completed model, explain how the model demonstrates how energy flows into, within, and out of this system. Use the drop-down menus to write your explanation.

Energy flows **into** the system as

<input type="text" value="Select"/>	when	<input type="text" value="Select"/>	as a result of Process A.
chemical energy		energy is converted into matter	
heat energy		bonds break in sugar	
light energy		sunlight is absorbed	
		bonds form in sugar	

Energy flows **within** the system as

<input type="text" value="Select"/>	after	<input type="text" value="Select"/>	as a result of Process A.
chemical energy		energy is converted into matter	
heat energy		bonds break in sugar	
light energy		sunlight is absorbed	
		bonds form in sugar	

Energy flows **out of** the system as

<input type="text" value="Select"/>	after	<input type="text" value="Select"/>	as a result of Process B.
chemical energy		energy is converted into matter	
heat energy		bonds break in sugar	
light energy		sunlight is absorbed	
		bonds form in sugar	

Click NEXT to continue to the next question.

NEXT

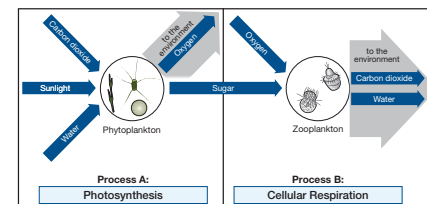
Stem

Student selects one response from each drop-down menu.

Item 2 Parts (a) and (b) will appear together on the same screen, and students may change their responses to Part (a) or Part (b) at their discretion before clicking NEXT and continuing to Item 3. Students may not return to Item 1 at this stage in the administration.

Platform prompt and student control

(Student's model viewable by student)



Item Type: Drop-Down Menu

Estimated Time: 2 min

Evidence Statement Alignment:

(HS-LS1-5)

(3) **Connections:** (a) Students use the given model to illustrate: (ii) Photosynthesis as resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).

(HS-LS1-7)

(2) **Relationships:** (a) From the given model, students describe the relationships between components, including: (ii) The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO₂ and water is greater than the energy required to break the bonds of sugar and oxygen.

Note on Alignment: What is being elicited from the student (evidence)? The student explains how energy flows into the pond ecosystem, is transferred between organisms, and flows out of the system. The student also explains how energy is stored and then transferred between organisms in the form of sugar.

Part (a) Based upon your completed model, explain how the model demonstrates how energy flows into, within, and out of this system. Use the drop-down menus to write your explanation.

Energy flows **into** the system as
 when as a result of Process A.

Energy flows **within** the system as
 after as a result of Process A.

Energy flows **out of** the system as
 after as a result of Process B.

Click NEXT to continue to the next question.

NEXT

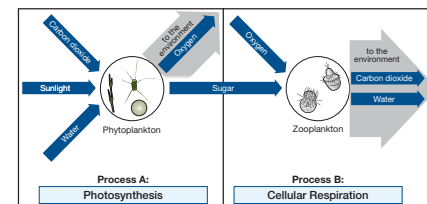
Stem

Student selected one response from each drop-down menu.

Item 2 Parts (a) and (b) will appear together on the same screen, and students may change their responses to Part (a) or Part (b) at their discretion before clicking NEXT and continuing to Item 3. Students may not return to Item 1 at this stage in the administration.

Platform prompt and student control

(Student's model viewable by student)



Item Type: Drop-Down Menu

Estimated Time: 2 min

Evidence Statement Alignment:

(HS-LS1-5)

(3) **Connections:** (a) Students use the given model to illustrate: (ii) Photosynthesis as resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).

(HS-LS1-7)

(2) **Relationships:** (a) From the given model, students describe the relationships between components, including: (ii) The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO₂ and water is greater than the energy required to break the bonds of sugar and oxygen.

Note on Alignment: What is being elicited from the student (evidence)? The student explains how energy flows into the pond ecosystem, is transferred between organisms, and flows out of the system. The student also explains how energy is stored and then transferred between organisms in the form of sugar.

Scoring Notes: 2 points are awarded if all drop-down selections are correct; partial credit (1 point) is awarded if two of the three sentences are correct.

Part (b) Which statement explains why the mass of sugar and oxygen that is taken in during Process B is the same as the mass of carbon dioxide and water that is produced?

- ☐ Only one gas, oxygen, is taken in, and only one gas, carbon dioxide, is released.
- ☐ All the atoms that are in the oxygen and sugar are rearranged to form the carbon dioxide and water.
- ☐ The energy in the bonds of the oxygen and sugar is equal to the energy in the bonds of the carbon dioxide and water.
- ☐ The number of bonds broken in oxygen and sugar is equal to the number of bonds formed in carbon dioxide and water.

Click NEXT to continue to the next question.

NEXT

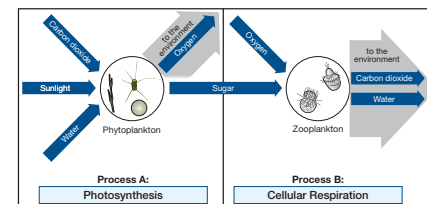
Stem

Student selects one response from the choices.

Item 2 Parts (a) and (b) will appear together on the same screen, and students may change their responses to Part (a) or Part (b) at their discretion before clicking NEXT and continuing to Item 3. Students may not return to Item 1 at this stage in the administration.

Platform prompt and student control

(Student's model viewable by student)



Item Type: Multiple Choice

Estimated Time: 1 min

Evidence Statement Alignment:

(HS-LS1-7)

(3) **Connections:** (a) Students use the given model to illustrate: (i) The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed; and (ii) Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment.

Note on Alignment: *What is being elicited from the student (evidence)?* The student understands that all the atoms in the reactants are rearranged and used to form the products, and that the law of conservation of mass applies.

Part (b) Which statement explains why the mass of sugar and oxygen that is taken in during Process B is the same as the mass of carbon dioxide and water that is produced?

- ☐ Only one gas, oxygen, is taken in, and only one gas, carbon dioxide, is released.
- ☒ All the atoms that are in the oxygen and sugar are rearranged to form the carbon dioxide and water.
- ☐ The energy in the bonds of the oxygen and sugar is equal to the energy in the bonds of the carbon dioxide and water.
- ☐ The number of bonds broken in oxygen and sugar is equal to the number of bonds formed in carbon dioxide and water.

Click NEXT to continue to the next question.

NEXT

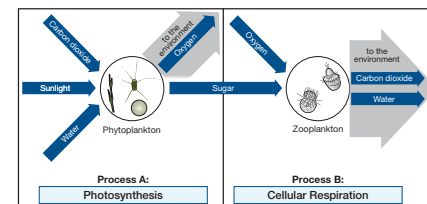
Stem

Student selected one response from the choices.

Item 2 Parts (a) and (b) will appear together on the same screen, and students may change their responses to Part (a) or Part (b) at their discretion before clicking NEXT and continuing to Item 3. Students may not return to Item 1 at this stage in the administration.

Platform prompt and student control

(Student's model viewable by student)



Item Type: Multiple Choice

Estimated Time: 1 min

Evidence Statement Alignment:

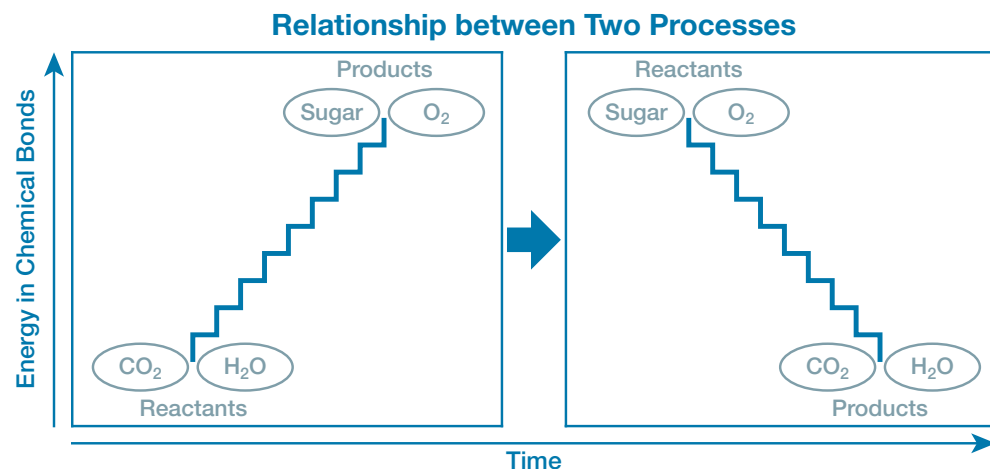
(HS-LS1-7)

(3) **Connections:** (a) Students use the given model to illustrate: (i) The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed; and (ii) Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment.

Note on Alignment: *What is being elicited from the student (evidence)?* The student understands that all the atoms in the reactants are rearranged and used to form the products, and that the law of conservation of mass applies.

Scoring Notes: 1 point is awarded for the correct response.

A student in class develops the graph below to represent the two main processes by which matter and energy are transferred within this pond ecosystem.



Click NEXT to continue.

NEXT

Stimulus

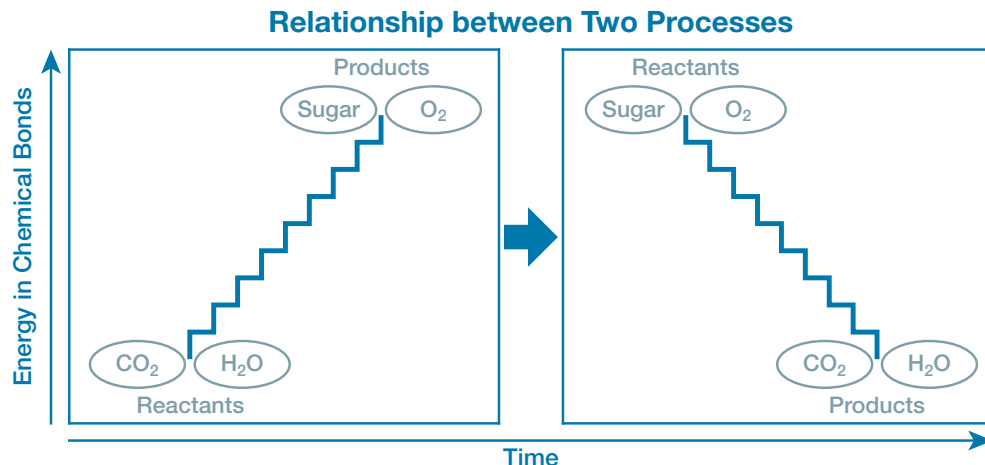
Graphic

Platform prompt and student control

Energy graph adapted from the following sources:

- The release of energy from sugar:
<http://www.nature.com/scitable/topicpage/cell-energy-and-cell-functions-14024533>
- The photosynthesis-respiration free energy cycle:
http://chemwiki.ucdavis.edu/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3ALower's_Chem1/23%3A_Thermodynamics_of_Chemical_Equilibrium/23.6%3A_Some_Applications_of_Entropy_and_Free_Energy
- An overview of transformation of energy in living systems:
<https://www.khanacademy.org/test-prep/mcat/biological-sciences-practice/biological-sciences-practice-tut/e/free-energy--photosynthesis--and-cellular-respiration->

Click on the box in the graph that represents **photosynthesis**, and then select the statements that **best** explain the reasoning for selecting that part of the graph. Select all the statements that apply.



- ☐ More energy is released than is stored during photosynthesis.
- ☐ Energy is absorbed when the bonds in the reactants are broken.
- ☐ Energy is created during photosynthesis, resulting in high-energy sugar molecules.
- ☐ The total amounts of energy in the molecules of the reactants and in the molecules of the products are equal.
- ☐ The amount of energy in the bonds of the products formed is greater than the amount of energy in the bonds of the reactants.

Click NEXT to continue to the next question.

NEXT

HS-LS1-5

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

Alignment to the PE and targeted dimensions is intended through the entirety of the item cluster. Partial to strong alignment to the dimensions for each item is achieved through alignment to the evidence statements, and is inclusive of all item parts for any given item.

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

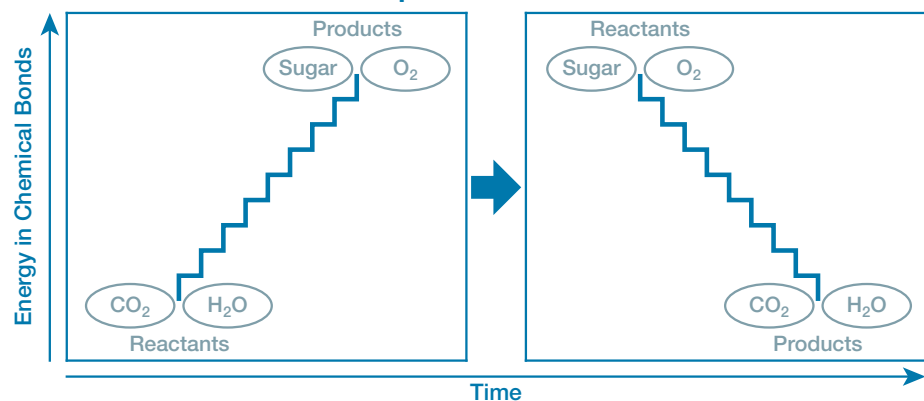
- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Click on the box in the graph that represents **photosynthesis**, and then select the statements that **best** explain the reasoning for selecting that part of the graph. Select all the statements that apply.

Relationship between Two Processes



- ☐ More energy is released than is stored during photosynthesis.
- ☐ Energy is absorbed when the bonds in the reactants are broken.
- ☐ Energy is created during photosynthesis, resulting in high-energy sugar molecules.
- ☐ The total amounts of energy in the molecules of the reactants and in the molecules of the products are equal.
- ☐ The amount of energy in the bonds of the products formed is greater than the amount of energy in the bonds of the reactants.

Click NEXT to continue to the next question.

NEXT

Stem

Interactive graphic: As a student scrolls over one side of the graph, that side glows green-blue and "Photosynthesis" appears as the label. The student locks in the answer by clicking.

Student selects from the choices.

Platform prompt and student control

Item Type: Hot Spot / Multiple Select

Estimated Time: 2 min

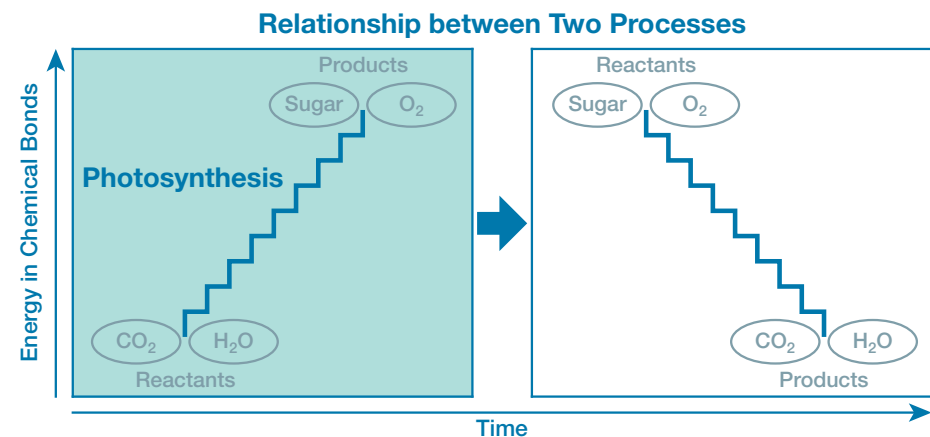
Evidence Statement Alignment:

(HS-LS1-5)

(3) **Connections:** (a) Students use the given model to illustrate: (ii) Photosynthesis as resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).

Note on Alignment: *What is being elicited from the student (evidence)?* The student can identify that the left box in the graph represents photosynthesis because sugar is a main product of photosynthesis and the energy stored in the bonds of the reactants is less than the energy stored in the bonds of the products (sugar).

Click on the box in the graph that represents **photosynthesis**, and then select the statements that **best** explain the reasoning for selecting that part of the graph. Select all the statements that apply.



Stem

Interactive graphic: As a student scrolls over one side of the graph, that side glows green-blue and "Photosynthesis" appears as the label. The student locks in the answer by clicking.

- ☐ More energy is released than is stored during photosynthesis.
- ☒ Energy is absorbed when the bonds in the reactants are broken.
- ☐ Energy is created during photosynthesis, resulting in high-energy sugar molecules.
- ☐ The total amounts of energy in the molecules of the reactants and in the molecules of the products are equal.
- ☒ The amount of energy in the bonds of the products formed is greater than the amount of energy in the bonds of the reactants.

Student selected two responses from the choices.

Click NEXT to continue to the next question.

NEXT

Platform prompt and student control

Item Type: Hot Spot / Multiple Select

Estimated Time: 2 min

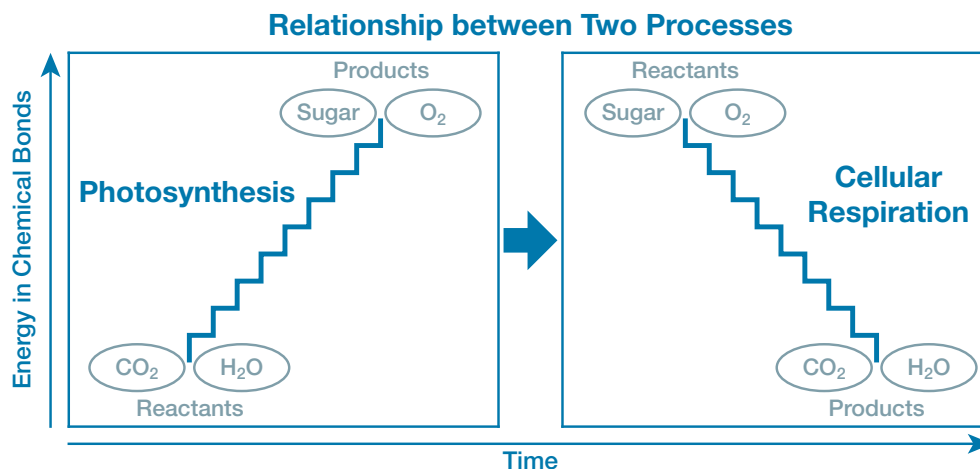
Evidence Statement Alignment:

(HS-LS1-5)

(3) **Connections:** (a) Students use the given model to illustrate: (ii) Photosynthesis as resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).

Note on Alignment: *What is being elicited from the student (evidence)?* The student can identify that the left box in the graph represents photosynthesis because sugar is a main product of photosynthesis and the energy stored in the bonds of the reactants is less than the energy stored in the bonds of the products (sugar).

Scoring Notes: 2 points— 1 point is awarded for selecting the correct side of the graph, and 1 point is awarded for selecting both correct reasoning statements.



Part (a) What do the steps in the box labeled “Photosynthesis” represent? Select all that apply.

- ☐ the conversion of energy into matter
- ☐ the formation of chemical bonds that store energy
- ☐ the transformation of matter, which releases energy
- ☐ the destruction of matter, a process that releases energy
- ☐ the breaking of chemical bonds, a process that absorbs energy

Part (b) What do the steps in the box labeled “Cellular Respiration” represent?

- ☐ a decrease in energy as heat is converted into the reactants
- ☐ a decrease in energy as chemical bonds of the products form
- ☐ a decrease in matter as molecules are transferred to the environment
- ☐ a decrease in matter as atoms are rearranged to form smaller molecules

Click NEXT to continue
to the next question.

NEXT

HS-LS1-5

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-7

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

Alignment to the PE and targeted dimensions is intended through the entirety of the item cluster. Partial to strong alignment to the dimensions for each item is achieved through alignment to the evidence statements, and is inclusive of all item parts for any given item.

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Part (a) What do the steps in the box labeled “Photosynthesis” represent?
Select all that apply.

- ☐ the conversion of energy into matter
- ☐ the formation of chemical bonds that store energy
- ☐ the transformation of matter, which releases energy
- ☐ the destruction of matter, a process that releases energy
- ☐ the breaking of chemical bonds, a process that absorbs energy

Click NEXT to continue
to the next question.

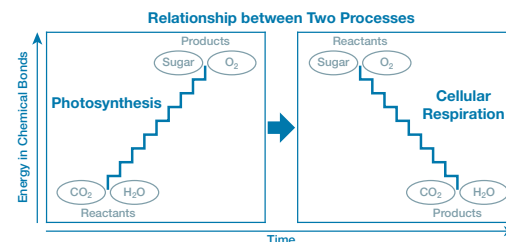
NEXT

Stem

*Student selects
from the choices.*

Platform prompt and student control

(Stimulus graphic viewable by student)



Item Type: Multiple Select

Estimated Time: 1 min

Evidence Statement Alignment:

(HS-LS1-5)

(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including: (ii) Breaking of chemical bonds to absorb energy.

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and demonstrate an understanding that energy is stored when chemical bonds are formed during photosynthesis.

Part (a) What do the steps in the box labeled “Photosynthesis” represent?
Select all that apply.

- ☐ the conversion of energy into matter
- ☒ the formation of chemical bonds that store energy
- ☐ the transformation of matter, which releases energy
- ☐ the destruction of matter, a process that releases energy
- ☒ the breaking of chemical bonds, a process that absorbs energy

Click NEXT to continue
to the next question.

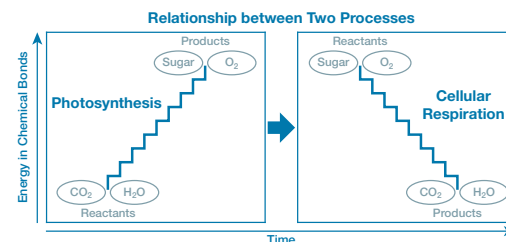
NEXT

Stem

*Student selected
two responses from
the choices.*

Platform prompt and student control

(Stimulus graphic viewable by student)



Item Type: Multiple Select

Estimated Time: 1 min

Evidence Statement Alignment:

(HS-LS1-5)

(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including: (ii) Breaking of chemical bonds to absorb energy.

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and demonstrate an understanding that energy is stored when chemical bonds are formed during photosynthesis.

Scoring Notes: 1 point is awarded for both correct responses to Part (a).

Part (b) What do the steps in the box labeled “Cellular Respiration” represent?

- ☐ a decrease in energy as heat is converted into the reactants
- ☐ a decrease in energy as chemical bonds of the products form
- ☐ a decrease in matter as molecules are transferred to the environment
- ☐ a decrease in matter as atoms are rearranged to form smaller molecules

Click NEXT to continue to the next question.

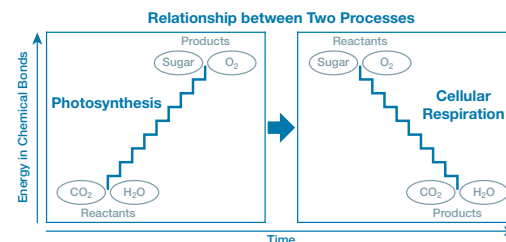
NEXT

Stem

Student selects one response from the choices.

Platform prompt and student control

(Stimulus graphic viewable by student)



Item Type: Multiple Choice

Estimated Time: 1 min

Evidence Statement Alignment:

(HS-LS1-7)

(1) **Components of the model:** (a) From the given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including: (ii) The breaking and formation of chemical bonds; and (iii) Energy from the chemical reactions.

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and demonstrate an understanding that energy is released when products form during cellular respiration.

Part (b) What do the steps in the box labeled “Cellular Respiration” represent?

- ☐ a decrease in energy as heat is converted into the reactants
- ☒ a decrease in energy as chemical bonds of the products form
- ☐ a decrease in matter as molecules are transferred to the environment
- ☐ a decrease in matter as atoms are rearranged to form smaller molecules

Click NEXT to continue to the next question.

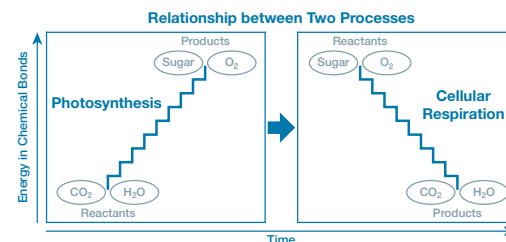
NEXT

Stem

Student selected one response from the choices.

Platform prompt and student control

(Stimulus graphic viewable by student)



Item Type: Multiple Choice

Estimated Time: 1 min

Evidence Statement Alignment:

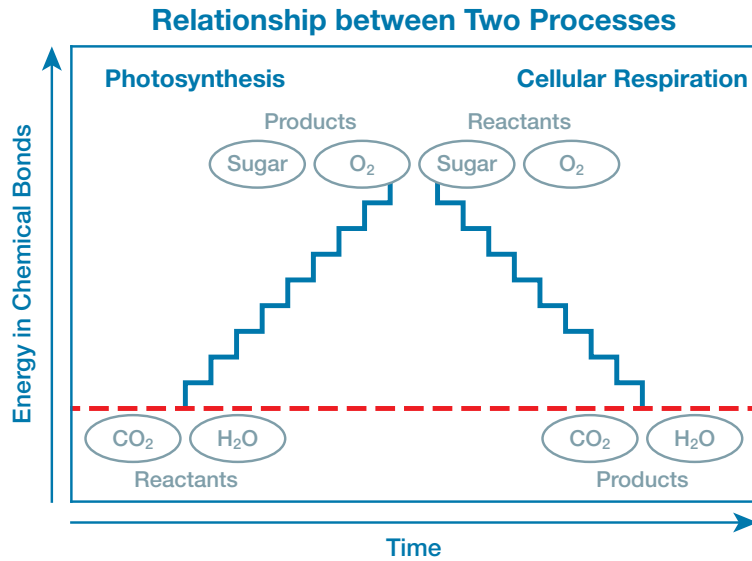
(HS-LS1-7)

(1) Components of the model: (a) From the given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including: (ii) The breaking and formation of chemical bonds; and (iii) Energy from the chemical reactions.

Note on Alignment: What is being elicited from the student (evidence)? The student can identify and demonstrate an understanding that energy is released when products form during cellular respiration.

Scoring Notes: 1 point is awarded for the correct response to Part (b).

Some of the students in the class argue that the pond ecosystem has remained stable for the past several years because the same amount of energy that is created in the ecosystem is later destroyed. The students add the red dotted line to the model to show that the same amount of energy exists at the beginning of photosynthesis as at the end of cellular respiration.



Stimulus

Graphic: animation of red line being drawn will be included to call attention to the change in the graph.

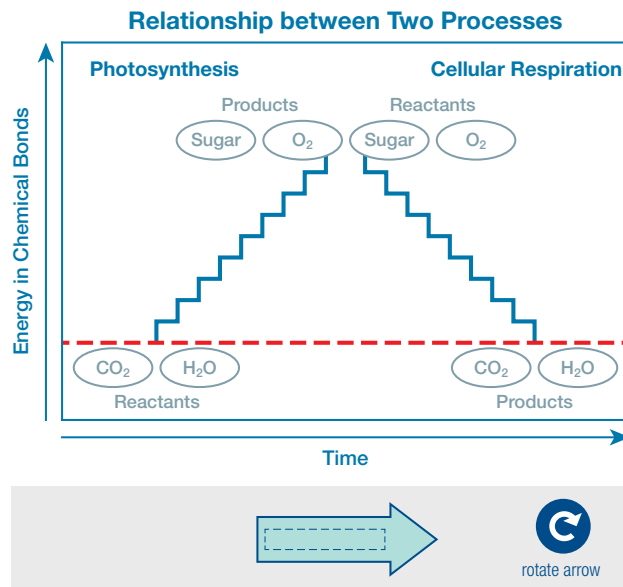
Click NEXT to continue.

NEXT

Platform prompt and student control

Part (a) Refute the students' argument by refining the model to show how energy is transferred into and within the pond ecosystem during photosynthesis and cellular respiration.

Drag arrow(s) onto the model and position the arrow(s) to show where energy is transferred into and within the pond system. Label your arrow(s) with the form that energy takes when it is being transferred.



Part (b) Explain how the modifications that you made to the model help refute the students' argument that the pond has remained stable because equal amounts of energy are created and destroyed in the pond ecosystem. In your explanation, describe how the model relates to the relationship between photosynthesis and cellular respiration.

Click NEXT to continue to the next question.

NEXT

HS-LS1-5

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-7

Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

Alignment to the PE and targeted dimensions is intended through the entirety of the item cluster. Partial to strong alignment to the dimensions for each item is achieved through alignment to the evidence statements, and is inclusive of all item parts for any given item.

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

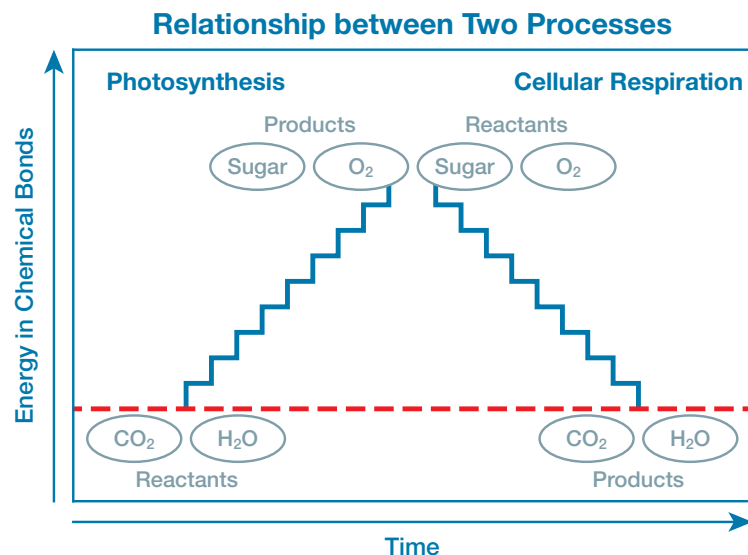
- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Part (a) Refute the students' argument by refining the model to show how energy is transferred into and within the pond ecosystem during photosynthesis and cellular respiration.

Drag arrow(s) onto the model and position the arrow(s) to show where energy is transferred into and within the pond system. Label your arrow(s) with the form that energy takes when it is being transferred.



Click NEXT to continue to the next question.

NEXT

Stem

Student may drag objects to any location on the graph. Student will be prompted to label the arrow once it is placed on the model.

Optional functionality: Pre-labeled arrows can also be used in this item part.

Drag-and-drop object (arrow) with text entry fill-in (object replenishes) and rotation control (object rotates in increments of 45 degrees)

Platform prompt and student control

Item Type: Drag-and-Drop / Fill-in Labeling

Estimated Time: 2 min

Evidence Statement Alignment:

(HS-LS1-5)

(3) Connections: (a) Students use the given model to illustrate: (i) The transfer of matter and flow of energy between the organism and its environment during photosynthesis.

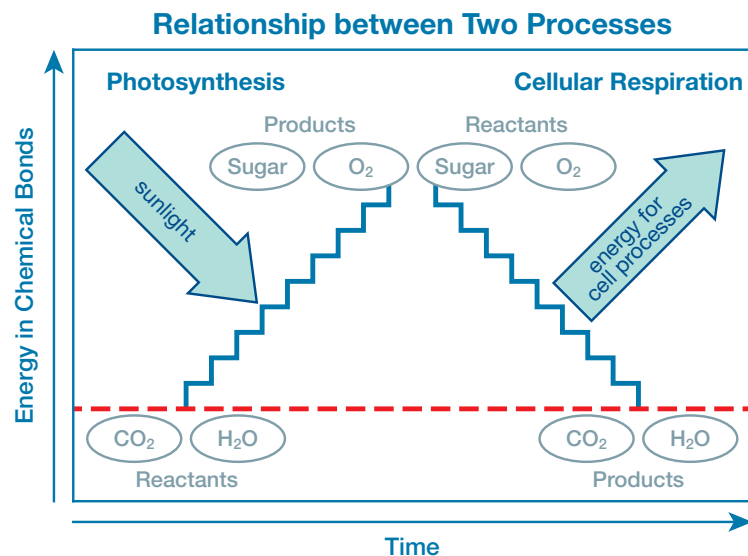
(HS-LS1-7)

(3) Connections: (a) Students use the given model to illustrate: (ii) Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment.

Note on Alignment: What is being elicited from the student (evidence)? The student can use and revise the given model to illustrate the flow of energy between the environment and organisms, both during photosynthesis, in the form of sunlight, and during cellular respiration, when energy from food molecules (sugar) is released and transferred to the cell and eventually to the environment (as heat).

Part (a) Refute the students' argument by refining the model to show how energy is transferred into and within the pond ecosystem during photosynthesis and cellular respiration.

Drag arrow(s) onto the model and position the arrow(s) to show where energy is transferred into and within the pond system. Label your arrow(s) with the form that energy takes when it is being transferred.



Click NEXT to continue to the next question.

NEXT

Stem

Student dragged objects to the correct locations on the model and typed in labels.

Optional functionality: Pre-labeled arrows can also be used in this item part.

Drag-and-drop object (arrow) with text entry fill-in (object replenishes) and rotation control (object rotates in increments of 45 degrees)

Platform prompt and student control

Item Type: Drag-and-Drop / Fill-in Labeling

Estimated Time: 2 min

Evidence Statement Alignment:

(HS-LS1-5)

(3) **Connections:** (a) Students use the given model to illustrate: (i) The transfer of matter and flow of energy between the organism and its environment during photosynthesis.

(HS-LS1-7)

(3) **Connections:** (a) Students use the given model to illustrate: (ii) Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment.

Note on Alignment: *What is being elicited from the student (evidence)?* The student can use and revise the given model to illustrate the flow of energy between the environment and organisms, both during photosynthesis, in the form of sunlight, and during cellular respiration, when energy from food molecules (sugar) is released and transferred to the cell and eventually to the environment (as heat).

Scoring Notes: 2 points—1 point is awarded for the correct number of arrows and positioning of arrows, and 1 point is awarded for the correct labeling of arrows. Accept labeling variations: for photosynthesis, accept "sunlight," "energy from sun," "solar energy," or acceptable variations; for cellular respiration, accept "energy for cell processes," "energy for life's processes," "energy for maintenance and repair," "ATP," "heat energy," or other acceptable variations. Students can receive full credit if one or two arrows are included pointing away from the stepped line for cellular respiration if labeled correctly (e.g., "heat" and "ATP").

Part (b) Explain how the modifications that you made to the model help refute the students' argument that the pond has remained stable because equal amounts of energy are created and destroyed in the pond ecosystem. In your explanation, describe how the model relates to the relationship between photosynthesis and cellular respiration.

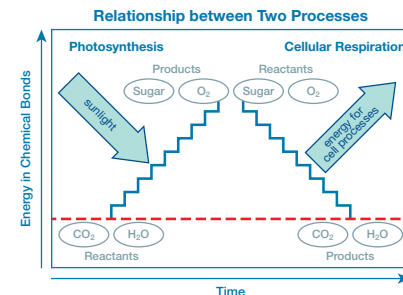
Click NEXT to continue to the next question.

NEXT

Stem

Student types response in this field. Field expands as needed.

(Student graphic viewable by student)



Sample Student Response

The arrow added to the photosynthesis side of the graph shows that energy in the form of sunlight entered the pond ecosystem, rather than being created. The energy from sunlight was stored in the chemical bonds of the products (sugar) during photosynthesis. The arrow added to the cellular respiration side of the graph shows that energy was then released during cellular respiration, not destroyed. The energy released during cellular respiration was used by cells and transferred to the surrounding environment in the form of heat. The pond ecosystem remained stable because the populations of organisms undergoing each process remained stable. The input of energy from sunlight has remained stable in the pond ecosystem and provides the energy necessary for each process to occur. Photosynthesis and cellular respiration each provide the matter necessary for the other to occur. Energy and matter are neither created nor destroyed; they are transferred into, out of, or within the system.

Platform prompt and student control

Item Type: Constructed Response

Estimated Time: 5 min

Evidence Statement Alignment:

(HS-LS1-5)

(3) **Connections:** (a) Students use the given model to illustrate: (i) The transfer of matter and flow of energy between the organism and its environment during photosynthesis.

(HS-LS1-7)

(3) **Connections:** (a) Students use the given model to illustrate: (i) The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed.

Note on Alignment: *What is being elicited from the student (evidence)?* The student can describe the complementary relationship and the cycling of matter and energy between photosynthesis and cellular respiration in order to explain the pattern reflected in the graph and support sense-making of the phenomenon.

Scoring Notes: 4 points—1 point is awarded for the correct rationale when explaining each modification (arrow) added to the graph (2 points total); 1 point is awarded for explaining that energy and matter are neither created nor destroyed; 1 point is awarded for describing the complementary relationship between photosynthesis and cellular respiration; see Sample Student Response.

Item	Item Part	Brief Description	Item Type	PE	DCI	SEP	CCC	EV Level	EVs	Points	Estimated Time (min)	Hand or Automated Scoring
Stimulus		Interactive Pond Exploration	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	N/A
1	1a	Complete a model of photosynthesis and cellular respiration	Drag-and-Drop	HS-LS1-5	LS1.C	2	5	1	1.a.i 1.a.iv	2	2	A
				HS-LS1-7				1	1.a.i			
	1b	Identify processes in model	Text Entry	HS-LS1-5				2	2.a	1	1	A
				HS-LS1-7				2	2.a.i			
2	2a	Explain transfer of energy in model	Drop-Down Menu	HS-LS1-5	LS1.C	2	5	3	3.a.ii	2	2	A
				HS-LS1-7				2	2.a.ii			
	2b	Conservation of mass	Multiple Choice	HS-LS1-7				3	3.a.i 3.a.ii	1	1	A
Stimulus		Relationship between Two Processes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A
3		Identification of photosynthesis based on energy	Hot Spot with Multiple Select	HS-LS1-5	LS1.C	2	5	3	3.a.ii	2	2	A
4	4a	Energy storage in bonds	Multiple Select	HS-LS1-5	LS1.C	2	5	1	1.a.ii	1	1	A
	4b	Energy released when products form	Multiple Choice	HS-LS1-7				1	1.a.ii 1.a.iii	1	1	A
Stimulus		Relationship between Two Processes, Starting and Ending	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A
5	5a	Energy transfer and refuting a claim	Drag-and-Drop w/ Fill-in Labeling	HS-LS1-5	LS1.C	2	5	3	3.a.i	2	2	A or H
				HS-LS1-7				3	3.a.ii			
	5b	Explanation of interdependence of photosynthesis and cellular respiration	Constructed Response	HS-LS1-5				3	3.a.i	4	5	H
				HS-LS1-7				3	3.a.i			
Total:								13 of 14	16	24		

HS-LS1-5	HS-LS1-7
<p>1. Components of the model</p> <p>a. From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis <u>transforms light energy into stored chemical energy</u> by converting carbon dioxide plus water into sugars plus released oxygen, including:</p> <ul style="list-style-type: none"> i. <u>Energy in the form of light.</u> ii. <u>Breaking of chemical bonds to absorb energy.</u> iii. Formation of chemical bonds to release energy. iv. <u>Matter in the form of carbon dioxide, water, sugar, and oxygen.</u> 	<p>1. Components of the model</p> <p>a. From the given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including:</p> <ul style="list-style-type: none"> i. Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO₂). ii. <u>The breaking and formation of chemical bonds.</u> iii. <u>Energy from the chemical reactions.</u>
<p>2. Relationships</p> <p>a. Students identify the following relationship between components of the given model: <u>Sugar and oxygen are produced by carbon dioxide and water</u> by the process of photosynthesis.</p>	<p>2. Relationships</p> <p>a. From the given model, students describe the relationships between components, including:</p> <ul style="list-style-type: none"> i. Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration. ii. <u>The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO₂ and water is greater than the energy required to break the bonds of sugar and oxygen.</u>
<p>3. Connections</p> <p>a. Students use the given model to illustrate:</p> <ul style="list-style-type: none"> i. <u>The transfer of matter and flow of energy between the organism and its environment</u> during photosynthesis. ii. Photosynthesis as resulting in the <u>storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).</u> 	<p>3. Connections</p> <p>a. Students use the given model to illustrate:</p> <ul style="list-style-type: none"> i. <u>The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed.</u> ii. Food molecules and oxygen <u>transfer energy to the cell</u> to sustain life's processes, including the maintenance of body temperature <u>despite ongoing energy transfer to the surrounding environment.</u>

Excerpts from the SAIC Assessment Framework

The following sections of this document were taken directly from the SAIC Assessment Framework and are included to provide a high-level overview of item cluster expectations. Assessment Framework page references are provided in parentheses. The SAIC Assessment Framework and Item Specifications Guidelines, respectively, can be accessed, in their entirety, at the following locations:

- http://www.ccsso.org/Resources/Publications/Science_Assessment_Item_Collaborative_Assessment_Framework.html
- <http://www.csai-online.org/spotlight/science-assessment-item-collaborative>

Preface (p. 1)

The Science Assessment Item Collaborative (SAIC) Assessment Framework (“Assessment Framework”) provides a range of options and accompanying rationales for the development of Next Generation Science Standards (NGSS)-aligned items and summative assessments. The Assessment Framework is designed to be used in concert with the *Item Specifications Guidelines* to aid state education agencies (SEAs) and other entities in documenting the processes needed to drive the development of NGSS-aligned items and assessments. Due to the interrelated nature of the documents, elements of the Assessment Framework that specifically detail the characteristics of the assessments and associated development considerations may also appear in the *Item Specifications Guidelines*.

The Assessment Framework principally draws on the following three seminal resources:

- the National Research Council (NRC)’s *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), hereafter referred to as the “*K–12 Framework*”;
- the Next Generation Science Standards: For States, by States (NGSS Lead States, 2013), hereafter referred to as the “NGSS”; and
- the NRC Board on Testing and Assessment (BOTA)’s report *Developing Assessments for the Next Generation Science Standards* (NRC, 2014), hereafter referred to as the “BOTA report.”

The research-supported recommendations and evidence base for practice that are embodied in these reports are foundational to the approach to development of next-generation science assessments (NGSAs) that is endorsed in the Assessment Framework.

Chapter One: Introduction (p. 4)

A new approach to K–12 science education was presented in the National Research Council (NRC)’s *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). The *K–12 Framework* articulates a broad set of rigorous expectations to support all students in achieving scientific literacy, and provided guidelines on how to prepare students to be able to pursue science, technology, engineering, and mathematics (STEM) careers. The *K–12 Framework* organizes science learning around three main dimensions: Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs). It emphasizes that these three dimensions must be interwoven into every aspect of science education—curriculum, instruction, and assessment—in order to fully achieve the vision set forth for science education.

The *K–12 Framework* was subsequently used as the research-supported foundation for the development of the NGSS. The NGSS and the *K–12 Framework* present a holistic approach to science education in maintaining that students must, in both instruction and assessment, “engage in scientific and engineering practices in the context of disciplinary core ideas, and make connections across topics through the crosscutting ideas” (NRC, 2014, p. 4). This multidimensional approach to science education presents both opportunities and challenges for states as they begin to implement the rigorous new standards and develop NGSS-aligned assessments.

Chapter One: An Assessment Framework (pp. 4–6)

A primary purpose of the SAIC is to support states in the development of a pool of high-quality items for large-scale summative assessment. To achieve this goal, the SAIC is initially developing guidance documents outlining a systematic, methodical, and research-based approach to the design and development of NGSS-aligned summative assessments. This approach begins with the development of an assessment framework, aimed at state science assessment coordinators and assessment developers, and serving as a bridge between the NGSS and methods of assessing those standards.

[. . .] It is anticipated that states will use the Assessment Framework for a number of purposes. Along with the Item Specifications Guidelines, the Assessment Framework will be the guiding document to inform the development of requests for proposals (RFPs) that will be used to select and guide assessment vendors in the development of NGSS-aligned assessments. It will also serve as a guiding document for the development of state and local test specifications and blueprints. The Assessment Framework may also be a valuable communication tool, providing information to key stakeholders and professional development providers.

Chapter One: Assessment Framework Development Process (pp. 7–8)

Development of the NGSS-based Assessment Framework described in this report was led by the SAIC, with WestEd as the primary author. This effort entailed a comprehensive state survey, multiple rounds of member and expert reviews, and strategic refinement of the emerging recommendations. Members of Achieve Inc.—including Dr. Stephen Pruitt, Senior Vice President of Achieve Inc., who coordinated development of the NGSS—and other experts in assessment design and psychometrics provided valuable feedback on drafts of the Assessment Framework and provided consultation during its development. Further details on the development process can be found in Appendix G.

The members of the SAIC are a diverse group of states and other jurisdictions. Some are members of one of the two major Race to the Top assessment consortia (the Smarter Balanced Assessment Consortium [Smarter Balanced] and the Partnership for Assessment of Readiness for College and Careers [PARCC]); others do not participate in either consortium. Some members adopted the NGSS by name, while others adopted the full NGSS but with a name change or opted for a partial adoption. Some members plan for a full computer-based administration of NGSS-based assessments, while others plan to use a mix of computer-based delivery and paper-and-pencil delivery. Finally, some members fully embrace the recommendations in the BOTA report (NRC, 2014), while other members support a more state-mediated approach to the transition to the NGSS. Despite these differences, all members of the SAIC have worked together to achieve the goals that they established as a team.

Chapter One: Context of the Assessment Framework (pp. 9–10)

The primary focus of this Assessment Framework is to build a basis of item development for NGSS large-scale assessment within the context of overall test design. The Assessment Framework should be considered a starting point for the implementation of a large-scale assessment measuring the NGSS, rather than being considered the final model. It should be noted that the item cluster model presented in the Assessment Framework has not been developed and fully implemented in a state testing system for science, although significant parts of it have. Lessons learned through large-scale development will present opportunities to adjust the model presented and tools recommended. The descriptions and expectations presented in the Assessment Framework should be considered a starting point, rather than the definitive end product. In addition, there are psychometric challenges that will need to be addressed (and limits pushed) for tests built using the item cluster model as the basic building component. These issues include acceptable content coverage, pilot testing, score generalizability, and number of score points to achieve reporting expectations. Matrix sampling is considered an important test design consideration for achieving a reasonable amount of content coverage and for achieving aggregate level reporting at the school, district, and state levels. In addition, reporting for the individual student for anything other

than overall science ability will be problematic to support using only item clusters. Even for overall science ability at the individual student level, individual reliability of scores may not be as strong as is achievable with a test composed primarily of individual items. The acceptable limits for the described concerns will need to be addressed and determined by individual states through their development and implementation efforts.

The Assessment Framework's focus on large-scale assessment was an outcome of needs expressed by states to begin the conversation about how to develop such an assessment while still being true to the principles and expectations of the *K–12 Framework* (NRC, 2012), the NGSS (NGSS Lead States, 2013), and the BOTA report (NRC, 2014). The presentation of this Assessment Framework in no way espouses the use of a single test in isolation to measure and report on the full NGSS. The BOTA report (NRC, 2014) describes a comprehensive assessment program approach. Concerns previously described in this section can be lessened if the assessment is used within the context of an assessment system that provides (through other assessments) information with greater usability and generalizability at the school level.

This Assessment Framework is not intended to provide a full assessment solution for states. Its intent is to present an acceptable solution for achieving alignment to the NGSS for large-scale assessment. Many lessons remain to be learned as this solution is pursued.

Chapter Four: Context of Item Clustering (pp. 21–22)

SAIC members have come to an agreement on common terminology used to describe two components of this emerging assessment. First, an *item cluster* is a set of items (usually between four and six items, with some items having more than one part) that are based on at least one common stimulus (e.g., text, audio, video, animation, simulation, experiment). Individual items that are part of an item cluster are not intended to be separated and used independently from one another. Second, because the term *performance-based task* can be used to describe a broad family of assessment activities, the SAIC has adopted the definition outlined by Smarter Balanced: “[a] performance task involves significant interaction of students with stimulus materials and/or engagement in a problem solution, ultimately leading to an exhibition of the students’ application of knowledge and skills” (Smarter Balanced, 2012, p. 1).

The BOTA report (NRC, 2014) recommends the use of assessment tasks with multiple components, rather than more traditional, discrete, stand-alone items:

CONCLUSION 2-1 Measuring the three-dimensional science learning called for in the framework and the Next Generation Science Standards requires assessment tasks that examine students’ performance of scientific and engineering practices in the context of crosscutting concepts and disciplinary core ideas. To adequately cover the three dimensions, assessment tasks will generally need to contain

multiple components (e.g., a set of interrelated questions). It may be useful to focus on individual practices, core ideas, or crosscutting concepts in the various components of an assessment task, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given performance expectation. (p. 44)

As presented in the Assessment Framework, item clusters are the large-scale summative assessment fulfillment of the assessment tasks recommended in the BOTA report. Item clustering will be needed in order to fully and accurately assess the NGSS. Additionally, each item within an item cluster must be aligned to at least two dimensions of the NGSS, with a strong preference that every effort be made, when feasible, to develop items aligned to all three dimensions of the NGSS. The overall item cluster must demonstrate alignment to all three dimensions.

One concern with an item-cluster-only approach for item development is that if the item cluster is appropriately developed, extracting individual items for stand-alone use will not be possible due to the scaffolded and intertwined nature of the items. A final consideration is that, at present, there are no known extant NGSS items developed that are fully aligned to the NGSS. For this reason, one planned outcome of the SAIC work is two prototype item clusters. These prototypes, which will be made available as separate documents, will offer examples of the item-cluster and NGSS alignment expectations.

The Assessment Framework presents an approach to item development that takes into consideration the following premises:

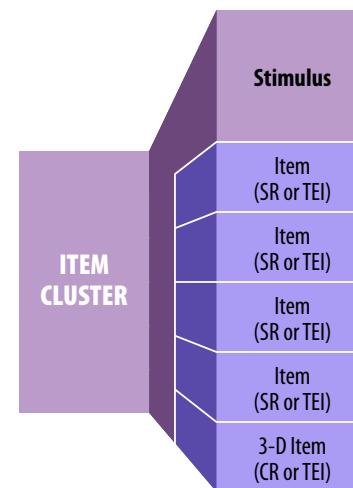
- Item clusters, not individual items, are the base unit for the SAIC test development. That is, individual items are intentionally developed to be situated within the context of an item cluster and not to be used as stand-alone items.
- Item clusters are the primary focus for developers in terms of alignment to the NGSS. That is, each item cluster must demonstrate strong three-dimensional alignment to the NGSS.
- To qualify as NGSS-aligned, item clusters must be aligned to one or more PEs and must be inclusive of all of the dimensions associated with the PE(s) (i.e., DCI, SEP, CCC).
- Each individual item within the cluster must align with at least two dimensions of the NGSS (e.g., DCI, SEP, and/or CCC) to qualify for inclusion in an item cluster.

Item clusters as described in this chapter and in the Item Specifications Guidelines fulfill these expectations.

Chapter Four: Architecture of Item Clusters (pp. 22–25)

As shown in Figure 1, the basic structure of an item cluster includes a common stimulus with an associated set of items.

Figure 1. Sample representation of the relationship of an item cluster to its component items



Each item is inextricably linked to the stimulus and to the other items within the item cluster, and the stimulus may be interspersed among the items to add information as needed. This means that student exposure to the stimulus is considered essential in order to respond correctly to any individual item, and that the item cluster must be constructed in such a way that individual performance on each item is adversely affected if an item is responded to without the context of the other items in the cluster. Testing time for each item cluster will be content dependent, but an approximation of 20 minutes of testing time per item cluster should be assumed. This time limit will allow for a reasonable overall test length while still providing an acceptable coverage of NGSS standards (i.e., PEs).

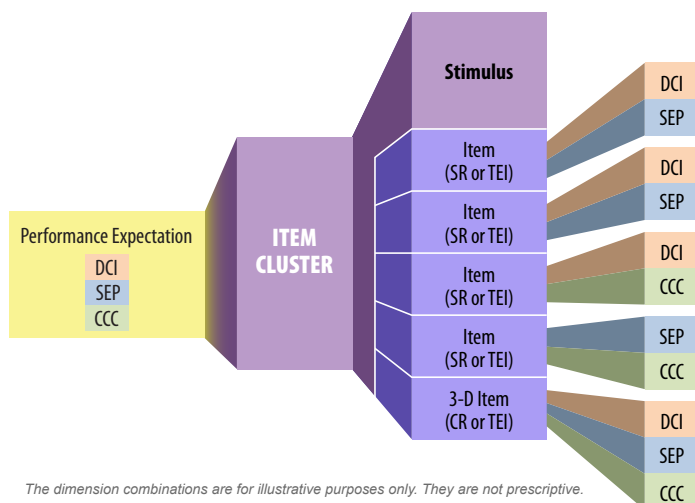
A stimulus is defined as a component of the cluster that does not directly require a student response. A stimulus can include one or more of the following:

- text;
- audio;
- video;
- discussion;
- animation/simulation;
- experimentation;
- activity; and/or
- demonstration.

Initially, stimuli will be identified or developed with the intent of inclusion on a large-scale summative assessment. States and developers should pursue creative solutions and should not allow current challenges of administration to constrain their thinking. The item cluster model is designed to allow for gradual evolution of stimuli, but still maintain NGSS alignment expectations.

An example of an item cluster's overall three-dimensional alignment is shown in Figure 2, with the dimensions of each item in a simplified single-PE cluster included.

Figure 2. Sample representation of the relationship of an item cluster aligned to a single PE to its component items, with item-aligned dimension combinations shown



- It should be noted that all items will exhibit some degree of alignment to the disciplinary context of the DCI, as all items are inextricably linked to the context, which was selected to align to the discipline(s) associated with the PEs. Therefore, every item in an item cluster will naturally fall within the content limits of the DCI, but not every item may truly call for the assessment of understanding of the content put forth in the DCI. Thus, items that only align to SEPs/CCCs are not intended to be viewed as devoid of a disciplinary context, but, rather, are intended to be viewed as items that place relatively greater emphasis on assessing an associated SEP and/or CCC than they do on assessing the underlying DCI content. Each SEP and CCC has its own knowledge that is most relevant in context of a DCI.
- If an evidence statement appears to align to a single SEP or CCC dimension, it is recommended that the evidence statement be grouped with the DCI, in order to prevent an item writer from developing an item to a single dimension in isolation (e.g., attempting to assess a science practice in isolation, without tying the item to the context and/or the DCI).

- At least one item should be aligned to all three dimensions, as shown in Figure 2, as this is the overall vision of the NGSS.
 - Each item is inextricably linked to the stimulus and to the other items within the item cluster. This means that student exposure to the stimulus is considered essential in order for the student to respond correctly to any individual item, and that the cluster of items must be constructed in such a way that individual performance on each item is adversely affected if an item is responded to without the context of the other items in the cluster. (See the Item Specifications Guidelines for more information on stimuli for item clusters.)
 - Testing time for each item cluster will be content dependent, but an estimate of 20 minutes of testing time per item cluster is assumed for summative assessment purposes. This estimate will be further refined as prototypes are completed.
 - Each item cluster will have items tied to evidence statement selections for one or more PEs. These evidence statement selections are the fundamental component of item alignment with scientific content. Item clusters aligned to more than one PE could be from the same domain (i.e., Physical Sciences, Life Sciences, Earth and Space Sciences), but could also be from related, but different, content areas (e.g., photosynthesis and chemical reactions). PEs can also be from different domains. PEs from the domain of Engineering, Technology, and Applications of Science should always be bundled with PEs from one of the science disciplines.
- The rationale for correlating the parts of a PE evidence statement with two or more of the PE's dimensions is that such a correlation provides a building block for item construction when the PE is bundled with one or more other PEs in an item cluster. Looking at the entirety of the dimensions and evidence statements for two or more PEs in an item cluster can be somewhat overwhelming in terms of the amount of information provided in relation to assessment goals. By structuring the PE and evidence statement components into natural dimensional/evidence-statement relationships that might form the basis of an item in an item cluster, the item cluster developer can better perceive how all of these PE elements fit together and how they might be used, along with the multidimensional alignment groupings for other PEs in an item cluster, to form a balanced, conceptually cohesive item cluster.
- While it may be possible to develop items within a single cluster that are collectively sufficient to assess the entirety of a single PE, this is not preferable and will not be possible in many, if not most, cases. For item clusters inclusive of more than one PE, it is not expected that a single item cluster will be able to provide the opportunity for a student to generate evidence of every aspect of each PE in the item PE bundle.

More detailed explanations of item clusters are provided in the Item Specifications Guidelines.

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