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STATEMENT OF PURPOSE

The Honors Biology course of study is molecular-based and utilizes an inquiry approach to learning. Students are continually stimulated to think about biological topics and issues facing society today. Students will be expected to take the required learning to a higher level, while looking for solutions to a myriad number of problems. This is accomplished through the integration of research-based exercises, kinesthetic activities, and performance-based tasks. The students will also be expected to complete an extensive research project that is done primarily after regular school hours.

Students will learn about the chemistry of living things, the intricate workings of the cell, energy transfer systems, the cell cycle, gene expression, DNA Technology, evolutionary theories, and environmental issues.

The Honors Biology curriculum is designed to help students to develop a deeper understanding of the story of life. Units are structured using backward design principles that clearly establish what the students need to know, and then designs and implements each lesson to build upon and support that goal.

**Special Note for the 2015-16 School Year: In 2014, the New Jersey State Department of Education adopted the Next Generation Science Standards (NGSS) that set forth a vision for science education where the Science and Engineering Practices (SEPs), Disciplinary Core Ideas (DCIs) of science, and Crosscutting Concepts (CCCs) of science are blended seamlessly into a three dimensional learning environment for all students. The transition to NGSS across New Jersey and in the Parsippany Troy Hills School District will be deliberate, and full implementation of NGSS in New Jersey is planned for the 2016-17 school year. The shifts required in NGSS implementation are fundamental, and revision of curriculum requires careful consideration of these changes as well as time to develop, pilot, and implement. During this transitional period, resources in support of NGSS are being developed for teachers’ use in buildings and through Professional Development. A core team of experienced teachers attended NGSS curriculum training in July 2015, and are steadily working to build units that will be implemented throughout the 2015-16 school year, units that incorporate active learning for students, giving them the opportunities to Engage, Explore, Explain, Elaborate and Evaluate Science. As our master teachers implement these new units their experiences and feedback provide momentum for the unfolding new curricula.**
RATIONALE

Honors Biology is designed for the highly motivated science student. It is a fast-paced program in which the students must complete each assignment quickly and efficiently in order to accomplish each of the required elements established by the New Jersey Department of Education and be prepared to take the New Jersey Biology Competency Test (NJBCT) at the end of the school year. The Honors Biology program is very suitable for the student who possesses strong abstract reasoning skills, since each individual will be challenged to synthesize and assimilate information on a daily basis in order to develop a big picture understanding of each concept being studied.

This course is aligned with the New Jersey Core Curriculum Content Standards for Science (NJCCCS), the Next Generation Science Standards (NGSS), the New Jersey Core Curriculum Content Standards for Technology (NJCCCS for Technology), the New Jersey Core Curriculum Standards for Language Arts Science and Technical Subjects and the 21st Century Life and Careers Standards (NJCCCS for Career Ready Practices). Using a variety of materials, resources, and instructional methods, the course reinforces the educational skills of scientific interpretation, investigation, problem-solving, critical analysis and research. District initiatives in assessment and critical reading and writing are also being emphasized.

THE LIVING CURRICULUM

Curriculum guides are designed to be working documents. Teachers are encouraged to make notes in the margins. Written comments can serve as the basis for future revisions. In addition, the teachers and administrators are invited to discuss elements of the guides as implemented in the classroom and to work collaboratively to develop recommendations for curriculum reforms as needed.

AFFIRMATIVE ACTION

During the development of this course of study, particular attention was paid to material, which might discriminate on the basis of sex, race, religion, national origin, or creed. Every effort has been made to uphold both the letter and spirit of affirmative action mandates as applied to the content, the texts and the instruction inherent in this course.
GENERAL GOALS

The students will:

1. learn that the study of biology is based on systematic observations, hypotheses, predictions, observations, and experimental tasks, and understand how to apply the processes of scientific inquiry and technological design to investigate questions, conduct experiments, and solve problems.

2. develop an in-depth understanding of complex molecular-based biological processes.

3. explore the historical development of biological concepts and the relationships of those concepts to society and technology today.

4. learn that levels of organization in nature, and the characteristics of life emerge at the single cell level and extend through the entire biosphere.

5. learn that cells assemble, rearrange, and degrade organic compounds mainly through enzyme-mediated reactions.

6. discover that information for producing the heritable traits of single-celled and multi-celled organisms is encoded in DNA.

7. learn that the living world is immensely diverse and that each species is unique in terms of body plan, function, and behavior.

8. learn that the theories of evolution, such as natural selection, help to explain the meaning of life’s diversity.

9. learn about our place in nature in terms of how we interact with organisms in the biological system of Earth.

10. recognize the importance of science in everyday living, explore pertinent current scientific issues, and appreciate the interrelationship between science, technology, and society to become scientifically literate and knowledgeable members of society.

11. Develop problem-solving and critical thinking skills
GRADING PROCEDURES

MARKING PERIOD GRADES

Long and Short Term Assessments which may include: 90%

- Tests, quizzes, and/or worksheets
- Authentic assessments
- Technology applications
- Projects, reports, presentations
- Laboratory investigations
- Data Analysis
- Analysis of assigned readings

Daily Assessments which may include: 10%

- Active engagement in class activities
- Demonstration of knowledge and understanding of course material
- Skills and safety practices during lab investigations
- Do Now/Exit Questions
- Homework

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<th>FULL YEAR COURSE</th>
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<tr>
<td><strong>Final Grade</strong></td>
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<td>Full Year Course</td>
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Each marking period shall count as 20% of the final grade (80% total).
GENERAL PERSONAL SAFETY

The science classroom is potentially the most dangerous place in the school. However, this need not constitute a serious threat if the teacher and students have a thorough knowledge of the potential hazards, exercise prudent care and foresight, and use common sense. Accident prevention must be included in the performance of every task, and safety instruction must be an integral part of the overall science program.

1. Precautions should be taken to protect those in the classroom from injury from hot or corrosive materials.
   a. In order to reduce the danger from caustic or hot liquids, students and teachers handling such materials should wear protective aprons (plastic or neoprene), goggles, and should roll sleeves (which can absorb the liquid), tightly to above the elbow.
   b. Students should never be permitted to work with concentrated acids or bases or with boiling water while seated.
   c. Burns from either hot or caustic materials should be flooded immediately and for at least ten minutes with copious amounts of cold water. Following flooding of the burn, the victim should be escorted to the school nurse as quickly possible. Clothing which has absorbed caustic materials should be removed as soon as feasible. The school nurse should be called immediately.

2. High-speed devices such as mechanical rotators, electric drills, fans, etc., should never be operated with protective shields removed or opened. Goggles must be worn.

3. Eating anything in the laboratory should be prohibited since it entails an intolerable hazard from toxic or possible infectious materials.

4. Cleanliness and order should be maintained.
   a. Extraneous objects should be moved from work surface.
   b. Glassware and other hardware should be maintained in a clean condition. Chemical or biological residues may constitute a reactive hazard.
   c. Students should be required to thoroughly wash their hands with soap and water following a laboratory session.

5. There are several devices for protecting students and instructors against the corrosive or toxic effects of chemical reagents.
   a. Aprons should be worn by all students working in a laboratory, especially when working with corrosive reagents.
   b. Gloves should be worn by students when working with concentrated corrosive reagents. Gloves have a tendency to reduce dexterity, which may be a hazard in itself. Gloves are generally rubber or plastic.
   c. Long hair can be a serious hazard in the laboratory and should be covered or contained. Fire and reduced visibility are just two of the hazards that result from long hair.
   d. Loose clothing is another potential hazard in the laboratory. Loose clothing is less controllable than tight-fitting clothing. Glassware can be knocked off benches, clothes can come into contact with open flame, and manual dexterity can be reduced.
6. In a demonstration experiment using any flammable liquid such as alcohol, care must be taken to ensure that any flame in the room is a safe distance from the volatile liquid.

7. Demonstrations involving explosive or potentially explosive substances must be so arranged as to shield everyone from any danger. Use the safety shield to protect observers and the face shield and goggles to protect the demonstrators. Size of apparatus and quantities of reagents used in a demonstration should be consistent with safe practice.

8. Observers should be evacuated from seats directly in front of the demonstration table, even if the possibility is remote that injury to them might occur from splattering of chemicals, inhalation of fumes, etc.

9. All persons performing science activities involving hazards to the eyes must wear approved eye protection devices. All persons in dangerous proximity must likewise be equipped.

10. Chemicals should never be tasted (or placed on the tongue or lips), nor should laboratory glassware be used as drinking vessels.

11. Sandals and open-toe shoes should not be permitted in laboratory areas unless they have a protective covering.
PARSIPPANY-TROY HILLS TOWNSHIP SCHOOLS
COURSE PROFICIENCIES

Course: SCN114
Title: BIOLOGY I HONORS

In accordance with district policy as mandated by the New Jersey Administrative Code and the New Jersey Core Curriculum Content Standards, the following are proficiencies required for the successful completion of the above named course.

The student will:

1. demonstrate the ability to work in groups to safely solve biological problems and perform laboratory investigations.
2. select and safely use appropriate instrumentation to design and conduct investigations.
3. make measurements of length mass, volume and temperature using the metric system.
4. Compare and contrast living and nonliving things while describing the characteristics of living things.
5. construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
6. Develop and use a model to Illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
7. construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
8. Explain how the properties of water impact living things.
9. Diagram and explain the pH scale.
10. plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
11. use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
12. construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions
13. 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.
14. examine the structure and function of nucleic acids, and compare and contrast DNA and RNA molecules.
15. differentiate between prokaryotic and eukaryotic cells.
16. explore eukaryotic cell structure.
17. analyze transport of materials across cellular membranes.
18. explain the significance of ATP in cellular energy transfer.
19. analyze the process of aerobic respiration in plant and animal cells.
20. analyze the process of anaerobic respiration in plant and animal cells.
21. investigate the process of photosynthesis in plant cells.
22. examine the “life cycle” of a cell.
23. investigate cellular division, and the process of mitosis and cytokinesis.
24. explain the process of meiosis and compare it to the process of mitosis.
25. analyze the process of transcription and translation.
26. investigate the control of gene expression.
27. explore the causes and effects of point mutations and frameshift mutations.
28. demonstrate an understanding of Pedigree analysis for sex-linked and non sex-linked traits.
29. examine uses of karyotype analysis and explain possible interpretations.
30. investigate the use of plasmids and restriction enzymes in the generation of recombinant DNA.
31. analyze the use of electrophoresis to generate DNA fingerprints.
32. scrutinize the sequencing of the human genome and its implications in the area of bioethics.
33. examine the work of Charles Darwin and the concept of evolution as a major theme of biology.
34. explore Linnean classification and contrast it to the system of domains of life.
35. trace factors affecting ecosystems, including the flow of energy through ecosystems, and environmental issues of ecosystems.
### I. SCIENTIFIC METHODOLOGY AND SAFETY

**Essential Question(s):** How do Biologists conduct scientific investigations safely?

**Enduring Understanding(s):** Understanding and respect for the safety rules in a laboratory are vital to a successful Science experience. Safety guidelines are designed to prevent accidents from occurring, and yield quality results.

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<thead>
<tr>
<th>PROFICIENCY / OBJECTIVE</th>
<th>Standards</th>
<th>SUGGESTED ACTIVITY</th>
<th>EVALUATION/ ASSESSMENT</th>
<th>TEACHER NOTES</th>
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| The student will be able to: | **1.** Demonstrate the ability to work in groups to safely solve biological problems and perform laboratory investigations.  
CRP1,2,3,4,7,8,12  
RST.11-12.4,6,7  
NGSS Practices: Asking questions  
Developing & Using Models  
Planning & Carrying out Investigations  
Analyzing and Interpreting data  
Constructing Explanations  
Obtaining & Communicating Information | • Thoroughly review and discuss safety guidelines in a Science classroom.  
Carefully read and sign a safety contract, keep a copy in their workfolder for easy reference.  
• Work in groups to design an experiment that tests the effectiveness of over-the-counter antacids. Then, a data table and graphs will be prepared as appropriate, as well as a detailed description of the experiment and conclusions | Signed Safety contract  
Experimental design, group work, and adherence to safety guidelines will be assessed using teacher-designed rubric, and continuously monitored throughout the year. | See Teacher Resource Booklet for Antacids Lab |
| | **2.** Select and safely use appropriate instrumentation to design and conduct investigations.  
CRP1,2,3,4,7,8,12  
RST.11-12.4,6,7  
NGSS Practices: Asking questions | • perform a lab, *Using a Compound Microscope.* They will use a typed letter “e” to learn to prepare and view a wet-mount slide. | Group work, collaboration, microscope sketches, and safety awareness will be assessed during these | Miller and Levine, *Lab Manual* |
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<tr>
<td>The student will be able to:</td>
<td>Developing &amp; Using Models Planning &amp; Carrying out Investigations Analyzing and Interpreting data Constructing Explanations Obtaining &amp; Communicating Information</td>
<td>Students will: They will also view stained, prepared slides to become more comfortable with the observation process. • complete Supplementary Topic 1 – Technology for Studying Cells reading material (from BSCS Practicing Scientific Methods), which describes electron microscopy. Students will analyze diagrams, read the article, and complete discussion questions.</td>
<td>activities, and consistently through the school year.</td>
<td>Holt, Biology: Visualizing Life, “Using a Compound Light Microscope”, pp. 828-829</td>
</tr>
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3. Make measurements of length, mass, volume and temperature using the metric system. | CRP2,4,12 NGSS Practices: Carrying Out Investigations Using mathematics and Computational Thinking | • perform a lab experiment in which each individual will practice measuring length, mass and volume in the metric system. • complete Measuring with a Microscope lab activity. They will practice measuring cells using a variety of stained, prepared slides. Drawings and analysis questions will be completed | Accuracy of measurements, ability to cooperatively work with partner will be assessed. Adherence to safety guidelines will be continuously monitored and addressed throughout the year. | Miller/Levine, “Metric Scavenger Hunt” |

Mathematics connection
II. BIOCHEMISTRY

Essential Question(s):

a) How do organisms live and grow?

Enduring Understanding(s):

a) All living organisms are made of cells. While a simple definition of life can be difficult to capture, all living organisms can be characterized by common aspects of their structure and functioning.

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<td>The student will be able to:</td>
<td>Students will:</td>
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</table>
| 4. Compare and contrast living and nonliving things while describing the characteristics of living things. | HS-LS1.A  
HS-LS1-B  
HS-LS1-D  
HS-LS2-A  
8.1.12.D.1  
8.1.12.E.1  
RST.9-10.1,4,7 | • Contribute to a discussion comparing the meaning of the words biology and biochemistry, and apply these definitions to hierarchy in life.  
• In groups, utilize iPads or textbook to research and identify the organization from atom to biosphere. Model and communicate the organization of life utilizing classroom supplies. Evaluate each other’s models.  
• Observe one drop of cement glue in water, discuss whether what they observe is a living organism. Collaboratively construct and argue a list of characteristics that define a living organism. Utilize that finalized list to assess a series of station samples or | Participation in class discussion, generated characteristic list, and ultimate application in identifying living samples will be assessed for understanding.  
Models will be assessed. | Explore/Explain/Evaluate  
XCC: Scale, Proportion & Quality  
Practice: Model, construct explanations, and communication  
Classroom supplies to be given may include: paper clips, pipe cleaners, beads, construction paper, cups, wire hangers, string, etc. |
| 5. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. | Powerpoint scenario to determine living status.  
- read *Are Viruses Alive?* by Luis Villarreal. Utilize the article to explain why viruses walk the fine line of being living/nonliving and why we ultimately consider them to be nonliving. | Biology Resource binder contains “Is Sammy Alive?” activity | Comprehension and application of reading material will be assessed |
| --- | --- | --- | --- |
| HS-LS1.A  
HS-LS1-B  
HS-LS1-C  
8.1.12.E.1  
8.1.12.A.2 | Contributions to group discussion will be monitored and assessed for level of understanding.  
Utilize iPads to draw and model DNA and RNA. Construct an explanation on the interdependence of DNA, RNA, and proteins in the overall function of an organism. | Drawings and written explanations will be assessed for accuracy. |  |
| 6. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. |  
- contribute to a discussion on the structure and function of nucleic acids.  
- Utilize iPads to draw and model DNA and RNA. Construct an explanation on the interdependence of DNA, RNA, and proteins in the overall function of an organism. | Segue discussion into CHNOPS and the macromolecules |  |
| HS-LS1.A  
HS-LS1-B  
HS-LS1-C  
RST.9-10.7 | Discuss the importance of cells as the basic unit of life. Discuss the organization within internal structures that allow the cell to function. Communicate understanding that human systems are made up of a group of interacting atoms and molecules. | Models and discussion will be assessed for understanding. |  |
| 7. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. | HS-Ls1-A, HS-Ls1-C, RST.9-10.3,7, SL.9-10.1,3, 8.1.12.E1, CRP2,3,4,5, 7,8,11,12 | - Observe the following indicators:  
  o Benedict & Lugol solutions for carbohydrates  
  o Sudan solution and grease spot test for lipids  
  o Biuret solution for proteins  
- Discuss the structure and function of simple and complex carbohydrates. Observe examples of simple and complex molecular structures. Evaluate a series of molecules and argue which molecules are considered to be carbohydrates.  
- Discuss the structure and function of lipids. Be able to explain why it is important to monitor the intake of lipids in relation to their function in the body and their caloric amount per gram.  
- Discuss the structure and function of proteins. View a series of animations on the function of proteins throughout the body.  
- perform a laboratory exercise testing catalase activity under | Lab reports will be assessed using lab report format  
- Contributions to class discussion, notes will be assessed for understanding. | Engage/Explain  
* XCC: Structure & function  
* Practice: Ask questions, argue from evidence, analyze data  

Engage/Explain  
* XCC: Structure & function  
* Practice: Ask questions, analyze data
varied laboratory conditions. They will prepare data tables, construct graphs, analyze results, and complete a formal lab report.

- utilize molecular model kits to construct a model of a carbohydrate molecule, and demonstrate the process of dehydration synthesis/condensation and hydrolysis reactions. They will then verbally explain their models and draw the structures. Repeat for lipids and proteins, conclude the importance of dehydration synthesis in these reactions.
- design a lab testing a series of unknown foods to identify the macromolecules found in the food. Utilizing their findings, construct explanations on the role the food has on the function of the organism; construct the molecular formula, and describe the overall macromolecular content and value.
- communicate the importance of the organic molecules on the overall function. Use specific body system(s) to

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<th>Explore</th>
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<tr>
<td>XCC: Structure &amp; function, stability &amp; change</td>
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<tr>
<td>Practice: Model, construct explanations, argue from evidence</td>
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**Evaluate and Explain**

**Major Lab Investigation**

Students will design a lab where they will test a series of unknown foods in the effort to identify the macromolecules found in the food. Utilizing their findings, students will construct explanations on the role the food has on the function of the organism; students will describe the overall end result for the molecules in the food.

See calculating calories sheet
explain the role the organic molecule plays in homeostasis.
- Contribute to a discussion of what a calorie measures. Analyze a graph that shows different physical activities and the amount of calories they burn. Accurately interpret a nutritional label.
- Cooperatively analyze a series of nutritional labels and communicate findings regarding the nutritional importance of the food. Quantify caloric value in various foods utilizing the heat transfer formula.
- setup a calorimeter in an effort to quantify the amount of energy stored in various foods. Evaluate and explain their findings in regards to nutritional value, energy storage, and molecular size.
- model, construct explanations, and provide evidence on the location and function of the organic molecule in regards to homeostasis on the organism and cellular level.

**Summative Assessments**
- Biochemistry Unit Test

See Soda Can Calorimeter
III. **HOMEOSTASIS AND WATER BALANCE**

**Essential Question(s):**

a) How and why do organisms interact with their environment, and what are the effects of these interactions?

**Enduring Understanding(s):**

a) Ecosystems are complex, interactive systems that include both biotic and abiotic components. Organisms grow, develop and reproduce their species by obtaining necessary resources through interdependent relationships with other organisms and the physical environment.

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<td>The student will be able to:</td>
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<td>8. Explain how the properties of water impact living things.</td>
<td>HS-LS2.A</td>
<td>• Observe a demonstration of celery in water, salt water, distilled water. With a partner, predict expected results. Sketch experimental setup and record hypotheses.</td>
<td>Sketches, predictions, and participation in class discussions will be formatively assessed for understanding.</td>
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<td>HS-LS2.B</td>
<td>• Explain any observed changes using key terms (water, polarity, solution, solvent, etc.). Sketch observations, compose explanation.</td>
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<td></td>
<td>RST.9-10.4,7</td>
<td>• Discuss explanations, focusing on water’s structure, polarity, and special properties.</td>
<td>Peer analysis of group lists and class presentation</td>
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<td>SL.9-10.1,3</td>
<td>• With a partner, brainstorm/describe</td>
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## HOMEOSTATIS AND WATER BALANCE

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<td>Students will:</td>
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<tr>
<td></td>
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<td>examples of the various properties.</td>
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<td>9. diagram and explain the pH scale.</td>
<td>HS-LS2.A</td>
<td>• offer definitions of acids and bases. With lab partner, test various substances with red cabbage juice. Use results to create a color scale that can be used to test pH, compare results to other groups and to standardized pH paper. Explain any differences using understanding of cabbage juice as a solution.</td>
<td>Designed lab activities and resulting pH scales will be assessed for accuracy and understanding</td>
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<tr>
<td>10. plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td>
<td>HS-LS1.A HS-LS1.C HS-LS2.A HS-LS2.B</td>
<td>• design, implement, and report on transpiration in a plant shoot. Prepare brief proposals for their experiments, protocol for the experiment, and at the end a formal lab report.  • Hypothesize the effects of incubating a chicken egg in vinegar, share predictions, conduct experiment, analyze results.  • working in pairs/small groups define the terms solution, solute, and solvent. Discuss.</td>
<td>Lab report conclusions will be assessed for understanding.  Students can make a photo journal of examples of key terms from the unit (homeostasis, osmosis, etc.). They can take selfies of themselves with examples of each and write a short caption to explain.</td>
<td>Teacher should provide a model transpirometer, plant shoots, various substances for transpiration, light sources, heat sources, etc.  “Eggsperiment” Activity is in Biology Resource binder and Appendix</td>
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### HOMEOSTATIS AND WATER BALANCE

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<tbody>
<tr>
<td>The student will be able to:</td>
<td>Students will:</td>
<td>Predict what would happen if a plant were given a solution instead of water. Explain predictions and use evidence from Eggsperiment to justify.</td>
<td>Students can create a comic strip, cartoon, poem or other form of artistic communication to explain homeostasis and water balance. Lab report conclusion will be assessed for level of understanding</td>
<td>XCC: Stability &amp; Change; Cause and effect. Practice: Asking questions; design experiments; analyzing data</td>
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- using microscopes and various plant cells (potato, elodea, etc.), determine the impact of solutions on cell structures. Document procedures, hypotheses, and observations.
- **Extension Activity** – be challenged to restore plant cells to original size.
- discuss how plants exchange materials with their environments and why they would need to do so. Regroup as a class and share ideas. Discuss the term homeostasis, and discuss what plants might have to do to maintain homeostasis.
- Examine different types of leaves, discuss their observations ("Why is the top waxy/shiny? Why is the underside different? Etc.")

---

Extension (for advanced students) - Have students plot data to find the concentration of the original potato core. Especially advanced students may be able to compare it to a yam or sweet potato.

**Explore and Engage**

XCC: Structure and Function; Stability & Change; Practice: Asking questions;
# HOMEOSTATIS AND WATER BALANCE

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<th>PROFICIENCY / OBJECTIVE</th>
<th>Standards</th>
<th>SUGGESTED ACTIVITY</th>
<th>EVALUATION / ASSESSMENT</th>
<th>TEACHER NOTES</th>
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</table>
| The student will be able to: | Students will: | Using clear nail polish, make impressions of the underside to view under the microscope. Sketch observations - leading to the observation of guard cells/stomata. Hypothesize about their function. As a class, discuss. Explore stomata behavior under different environmental or species circumstances. • Design and implement a Transpiration Lab complete with proposals before beginning and formal lab reports upon conclusion. | **Evaluate**
Teacher designed summative Assessment for the unit - | Design experiments; Analyze data; Construct explanations; communicate This is a good time to discuss light transmission and using the microscope. |

- Lamps, fans, etc. and more leaves (including shade versus full sun varieties) can be used as exploration options.
### IV. ENERGY

**Essential Question(s):**

a) How do organisms obtain and use the matter and energy they need to live and grow?

**Enduring Understanding(s):**

a) Sustaining life requires substantial energy and material inputs. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. The results of these chemical reactions is that energy is transferred from one system of interacting molecules to another.

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<th>ENERGY</th>
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<td><strong>PROFICIENCY / OBJECTIVE</strong></td>
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<td>The student will be able to:</td>
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<td>11. use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.</td>
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- Design an investigation to explore the effects of differing conditions (sun, shade, light intensity, etc) on the rate of photosynthesis.  
- Contribute to a discussion “How Do Biological Organisms Use Energy?” ([http://serendip.brynmawr.edu/exchange/bioactivities/energy](http://serendip.brynmawr.edu/exchange/bioactivities/energy))  
- Complete activity “How Do Muscles Get the Energy They Need for Athletic Activity?” to compare aerobic and anaerobic respiration, as well as show how energy and matter are transformed. ([http://serendip.brynmawr.e](http://serendip.brynmawr.e)) | Scientific explanations will be assessed for accuracy and understanding  
Designed lab activities will be assessed for understanding. | Explore | XCC energy and matter | Practice models, analyze data, construct explanations  
Explore | XCC varies | Practice varies |
Student responses and assessments should inform instruction at this point. | Explore | XCC energy and matter | Practice argue from |
### ENERGY

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<tr>
<td>The student will be able to:</td>
<td>Students will:</td>
<td>du/exchange/bioactivities/energyathlete • Investigate how sugar concentrations influence the rate of anaerobic respiration in yeast. • Complete a diagram that compares and contrasts the amount of ATP generated by aerobic cell respiration with anaerobic fermentation. • Complete lab activity investigating fermentation by measuring molecules produced by anaerobic cells, complete analysis questions and conclusion statement.</td>
<td>evidence, construct explanations/ <a href="https://example.com">Campbell, Reese, Mitchell. Laboratory Investigations for Biology: Alcoholic Fermentation</a></td>
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<td>13. 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</td>
<td>HS-LS1.C 8.1.12.E.1 8.1.12.A.3 RST.9-10.3,4,7,12</td>
<td>• demonstrate a familiarity with the terms “activation energy”, “enzyme”, and “active site”. Perform a photosynthesis/cell respiration lab experiment that will use an indicator</td>
<td>Participation in lab activity, lab data and conclusion will be assessed for understanding. [Explore, Elaborate</td>
<td>XCC scale, proportion, quantity</td>
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<td>resulting in a net transfer of energy.</td>
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<td>Students will:</td>
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<td>solution to identify carbon dioxide production exhibited by autotrophs and heterotrophs. Compose a written lab conclusion.</td>
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<td>• participate in a “Cellular Respiration in Yeast” inquiry-based lab, developing connection between food and getting energy into cells. Observe the “Big Picture” at <a href="http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html">www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html</a>.</td>
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<td>• contribute to a class discussion of regarding the necessary components and conditions for cellular respiration. In small groups, summarize the findings of the lab, how it relates to cellular respiration, and to</td>
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<td>• open/close their dominant hand as fast as they can for as long as they can. Provide hypotheses for observed phenomena.</td>
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<td>• build connections between photosynthesis and cellular</td>
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<td>Scientific explanations will be assessed for accuracy and understanding</td>
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**Explore, Explain** | **XCC** | energy and matter, patterns, cause and effect | **Practice** | asking questions, design experiments, argue from evidence, communicate |

**Students should reach conclusion of lactic acid buildup**
**ENERGY**

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<td>The student will be able to:</td>
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<td>respiration and construct an explanation as to how these processes are connected and exhibit the cycling of matter and flow of energy.</td>
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<td><strong>CELLS PROFICIENCIES/OBJECTIVES</strong></td>
<td><strong>STANDARDS</strong></td>
<td><strong>SUGGESTED ACTIVITIES</strong></td>
<td><strong>EVALUATION/ASSESSMENT</strong></td>
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<td>The student will:</td>
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<td>14. examine the structure and function of nucleic acids, and compare and contrast the DNA and RNA molecules.</td>
<td>5.3.12.D.1 RST.9-10.2,4,7 8.1.12.F.1</td>
<td>• utilize paper and molecular model kits to build models of DNA and RNA segments while making observations and associations about each. They will then prepare drawings and complete the written analysis questions. • investigate a specific Website and complete an online activity/timeline on the discovery of the 3-dimensional structure of the DNA molecule.</td>
<td>• Teacher anecdotal notes and analysis questions assessed for accuracy and completion • Assess timelines for accuracy and completion</td>
<td>See Teacher Resource book for DNA and RNA Modeling <a href="http://www.dnai.org/timeline/index.html">http://www.dnai.org/timeline/index.html</a></td>
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<tr>
<td>15. Differentiate between prokaryotic and eukaryotic cells.</td>
<td>5.3.12.A.1</td>
<td>• examine prepared slides under the microscope and prepare accurately labeled sketches. They will then explain in writing the differences they observed</td>
<td>• Sketches and observations assessed for accuracy and completion</td>
<td><a href="http://www.cellsalive.com">http://www.cellsalive.com</a> Dickey, J. Laboratory Investigations for Biology: Observing Cells</td>
</tr>
<tr>
<td>16. explore eukaryotic cell structure.</td>
<td>5.3.12.A.3 8.1.12.F.1</td>
<td>• use a specific cell structures’ Website to prepare sketches, and they will create a comparison chart exploring various plant and animal cell structures.</td>
<td>• Teacher will assess sketches and charts for accuracy and completion</td>
<td><a href="http://www.cellsalive.com">http://www.cellsalive.com</a></td>
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### PROFICIENCIES/OBJECTIVES

The student will:

- Analyze the mechanisms of transport across cellular membranes.

#### STANDARDS

5.1.12.A.1  
5.1.12.B.1  
5.3.12.A.3  
RST.9-10.2,3,4,7  
WHST.9-10.2,4  
8.1.12.F.1

#### SUGGESTED ACTIVITIES

- prepare a labeled sketch or model of the phospholipid bilayer of the cell membrane. They will then write a statement explaining the process that is occurring.
- complete the Measuring Diffusion Rates lab and compete a formal lab report.
- complete a lab in which they measure osmosis and diffusion rates in plant cells, and then complete analysis questions.
- investigate a specified Website in order to examine examples of active and passive transport. They will electronically create graphs and charts, and answer analysis in the Homeostasis and Cell Transport WebQuest.

#### EVALUATION/ASSESSMENT

- Sketches/models and written statement assessed for accuracy and completion
- Assessed using formal lab report rubric
- Analysis questions assessed for completion and accuracy
- WebQuest analysis questions assessed for completion and accuracy

#### TEACHER NOTES

- BSCS Pre-AP Lab Manual
- BSCS Pre-AP Lab Manual: Normal and Plasmolyzed Cells
| 18. | explore the significance of ATP in cellular energy transfer. | 5.3.12.A.2  
5.3.12.A.3 | • construct a paper model of the structure and function of ATP, and then complete analysis questions. | • Analysis questions assessed for completion and accuracy | See Teacher Resource Book for ATP Structure activity. |
| 19. | analyze the process of aerobic respiration in plant and animal cells. | 5.3.12.B.6  
5.1.12.B.1  
RST.9-10.3  
WHST.9-10.2,4 | • complete a lab activity in which they will investigate the rate of yeast respiration, then complete a formal lab report. | • Assessed using formal lab report rubric | BSCS Pre-AP Lab Manual: Factors Influencing the Rate of Yeast Respiration |
| 20. | analyze the process of anaerobic respiration in plant and animal cells. | 5.1.12.B.1  
5.3.12.B.6  
RST.9-10.3  
WHST.9-10.2,4 | • complete a lab activity in which they investigate alcoholic fermentation by measuring molecules produced by anaerobic cells, then complete analysis questions and conclusion statement. | • Analysis questions and conclusion statement assessed for accuracy and completion | Campbell, Reese, Mitchell Laboratory Investigations for Biology: Alcoholic Fermentation |
| 21. | investigate the process of photosynthesis in plant cells. | 5.3.12.B.4  
5.3.12.B.5  
RST.9-10.3  
WHST.9-10.2,4 | • complete a lab activity using a spectrometer to analyze chloroplast pigment samples obtained from different types of plant leaves. Then, complete calculations, analysis, and prepare a formal lab report. | • Assessed using formal lab report rubric | BSCS Pre-AP Manual: Chloroplast Pigment Analysis |
# Genetics and Inheritance

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<td><strong>The student will be able to:</strong></td>
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<td>22. examine the “life cycle” of a cell.</td>
<td>5.3.12.A.4 8.1.12.F.1 RST.9-10.2,3,4,7,10 WHST.9-10.2,4</td>
<td>• investigate a specified Website and complete a virtual investigation regarding factors affecting the rate of photosynthesis. Then, they will complete electronic graphs and charts, and answer analysis questions.</td>
<td>• Assessed using formal lab report rubric</td>
<td><a href="http://www.cells.de/cellseng/1medienarchiv/Zellfunktionen/Memb_Vorg/Photosynthese/Photosynthesaktivitaet/PSTA_in_Blaettern/index.jsp">http://www.cells.de/cellseng/1medienarchiv/Zellfunktionen/Memb_Vorg/Photosynthese/Photosynthesaktivitaet/PSTA_in_Blaettern/index.jsp</a></td>
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<tr>
<td>23. investigate cellular division, and the processes of mitosis and cytokinesis.</td>
<td>5.3.12.A.4</td>
<td>• sketch and label cell cycle diagrams, and answer analysis questions and use information learned to engage in large group discussion.</td>
<td>• Diagram and questions assessed for completion and accuracy.</td>
<td>Liebaert, R.M., <em>Biology Concepts and Connections Study Guide: Cell Cycle Diagram.</em></td>
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<tr>
<td>24. explain the process of meiosis and compare the process to mitosis.</td>
<td>5.3.12.A.4 5.1.12.B.2 RST.9-10.2,4,6,7,8,9 WHST.9-10.2,4,7,8,9 8.1.12.A.2 8.1.12.F.1</td>
<td>• utilize a specified Website to play the <em>Cell Cycle</em> game in which they will role play as components at checkpoints of the cell cycle to save a dying cell. They will write a summary of the cell cycle and how the game helped them to understand it. • investigate selected databases in order to research the role of cell</td>
<td>• Summaries assessed for accuracy and understanding • Presentation assessed using teacher-made rubric</td>
<td><a href="http://nobelprize.org/educational_games/medicine/2001/cellcycle.html">http://nobelprize.org/educational_games/medicine/2001/cellcycle.html</a> Databases provided by media center e.g. Ebsco, Facts on File</td>
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| **The student will be able to:** | | cycle in a specified type of cancer, and prepare a multimedia presentation of their choosing. | • Sketches and analysis questions assessed for completion and accuracy | BSCS Blue version text: *Mitotic Cell Division Lab*  
Dickey, J., *Laboratory Investigations for Biology Activity A: Pop Bead Simulation of Meiosis* |
| | | • utilize the microscope to observe and identify cells in various stages of mitotic division, and prepare sketches along with analysis questions. | • Sketches and analysis questions assessed for completion and accuracy | |
| | | • work in pairs to complete a simulation of the stages of meiosis using pop beads, and prepare sketches along with completing a Venn diagram comparing mitosis and meiosis, write a summary statement describing their understanding. | | |
| 25. analyze the processes of transcription and translation. | 5.3.12.D.1  
5.3.12.D.2 | • complete a paper simulation of gene transcription and translation in which they use template DNA to make mRNA, then use tRNAs to build an amino acid sequence and form a | • Explanations and questions assessed for completion and accuracy | Glencoe Forensics and Biotechnology, Lab Manual: *How Do You Transcribe and Translate a Gene?* |
### Genetics and Inheritance

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<td>蛋白。然后，口头解释他们的模型并完成分析问题。</td>
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26. **investigate the control of gene expression.**  
5.3.12.D.2 WHST.9-10.2,4  
- play the *Gene Expression Card Game* in which they examine the roles of promoter sequences and write a reflective paragraph about how the game helped them to understand gene expression.  
- Reflections assessed for depth of understanding  

27. **explore the causes and effects of point mutations and frameshift mutations.**  
5.3.12.D.2  
- construct and utilize paper models of DNA to examine the effects of mutation on cell cycle and control, then answer analysis questions.  
- Models and questions assessed for completion and accuracy  
- Prentice Hall Biology Biotechnology, *Lab Manual: Simulation of DNA Mutations and Cancer*

28. **analyze concepts of Mendelian genetics and complete basic Punnett Squares.**  
5.3.12.D.3  
- explore inherited traits and the use of a Punnett square in predicting outcomes in offspring, and answer analysis questions.  
- Punnett squares and questions assessed for completion and accuracy  
- Dickey, J. *Laboratory Investigations for Biology Lab Topic 9: Mendelian Genetics*

29. **demonstrate an understanding of**  
5.3.12.D.3 5.1.12.B.4  
- utilize a specified Website to complete an online  
- Student Pedigrees and conclusions peer assessed  
- [http://learn.genetics.utah.edu/content/addiction/genetics/pi.html](http://learn.genetics.utah.edu/content/addiction/genetics/pi.html)
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<td>Pedigree Analysis for sex-linked and non sex-linked traits.</td>
<td>RST.9-10.2,3,4 WHST.9-10.2,4 8.1.12.F.1</td>
<td>activity entitled <em>P.I. Pedigree Investigator: On the Case of Nicotine Addiction</em> in which they role-play as a genetic detective in order to investigate the genetic components of nicotine addiction. Then, create a pedigree analysis and write a conclusion statement summarizing their findings. • complete an investigation in which they generate their own pedigree analysis, then complete a written hypothesis, protocol, and analysis of results to justify their Pedigree Results.</td>
<td>for accuracy and completion</td>
<td>BSCS Science Inquiry Lab Manual Predicting the Traits of Offspring</td>
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30. examine the uses of karyotype analysis and explain possible interpretations. | 5.3.12.D.3 RST.9-10.2,4,7 WHST.9-10.2,4 8.1.12.F.1 | • utilize a specified Website to complete an online karyotyping activity and diagnose three case histories who present abnormal karyotypes, then produce written | for accuracy and completion | [http://www.biology.arizona.edu/human_bio/activities/karyotyping/karyotyping.html](http://www.biology.arizona.edu/human_bio/activities/karyotyping/karyotyping.html) |
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<td>justification of their diagnosis.</td>
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<td>31. investigate the use of plasmids and restriction enzymes in the generation of recombinant DNA.</td>
<td>5.1.12.B.1 5.3.12.D.2</td>
<td>• construct a model plasmid and apply understanding of restriction enzymes to insert a new gene into the plasmid, then answer analysis questions.</td>
<td>Plasmid construction and analysis questions assessed for accuracy and completion</td>
<td>Prentice Hall, <em>Biology: Biotechnology Manual Modeling Gene Transfer with a Plasmid</em></td>
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<td>32. analyze the use of electrophoresis to generate DNA fingerprints.</td>
<td>5.1.12.B.2 5.3.12.D.2</td>
<td>• complete a paper simulation of the DNA fingerprinting process and explore its application to real life problems, then answer analysis questions.</td>
<td>• DNA fingerprints and analysis questions assessed for accuracy and completion</td>
<td>Prentice Hall, <em>Biology: Biotechnology Manual Analyzing DNA Fingerprints</em></td>
</tr>
<tr>
<td>33. scrutinize the sequencing of the human genome and its implications in the area of bioethics.</td>
<td>5.1.12.B.4 5.1.12.C.3 5.3.12.D.1</td>
<td>• complete a bioethical case study in which they will act as stakeholders in an investigation to study the legal and ethical implications of DNA testing and human gene therapy.</td>
<td>• Teacher anecdotal notes will be made during case study activity</td>
<td>Prentice Hall, <em>Biology: Biotechnology Manual What are the Legal and Ethical Implications of DNA Testing and Human Gene Therapy</em> Interdisciplinary connection to Social Studies.</td>
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| 34. examine the work of Charles Darwin and the concept of evolution as a major theme of biology. | 5.3.12.E.1 5.3.12.E.2 5.3.12.E.3 5.3.12.E.4 WHST.9-10.2,4 | • explore the role of adaption in survival of a species by examining data provided to them, then answer analysis questions.  
• complete a laboratory investigation of the biochemical evidence for evolutionary theories using their understanding of DNA sequences and proteins to determine evolutionary similarities and differences among species, then answer analysis questions.  
• view *HHMI Evolution* DVD, take notes, and complete a written reflection.  
• analyze characteristics of several organisms including the *barbellus* fish in order to hypothesize about the evolutionary relationship | • analysis questions assessed for completion and accuracy  
• data, observations, and analyses assessed for accuracy and completion  
• Notes and reflection assessed for accuracy and depth of understanding  
• Evolution of Barbellus evolutionary tree and conclusion statements assessed for understanding | BSCS Pre-AP Lab Manual  
How is Camouflage an Adaptive Advantage  
BSCS Pre-AP Lab Manual  
Biochemical Evidence for Evolution  
*HHMI Evolution* DVD  
## Evolution & Classification

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<td>Students will:</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>among illustrated organisms, and create an evolutionary tree, then justify their hypothesis with a written conclusion statement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 35. explore Linnean classification and contrast it to the system of domains of life. | 5.3.12.A.6 5.3.12.E.3 RST.9-10.2,4,5,7,8,9 8.1.12.F.1 | - create a cladagram / evolutionary timeline to isolate major events in Earth’s history and their affects on the evolution of organisms.  
- utilize a dichotomous key to classify similar species of sharks.  
- investigate selected databases, in cooperative learning groups, to create short presentations on the three domains of life. | - Cladogram assessed for accuracy and completion  
- Classifications assessed for accuracy  
See Teacher Resource Book for Shark Dichotomous Key activity.  
Selected databases provided by media center, e.g., Ebsco, Facts on File |
| 36. trace factors affecting ecosystems, including the flow of energy through ecosystems, and environmental issues of ecosystems. | V. 5.3.12.B.1 5.3.12.C.1 5.3.12.C.2 | - create a fictitious food pyramid and investigate the effects of population changes at different levels, then generate a written summary statement. | - Summary statements assessed for accuracy and completion  
- Solutions and justifications assessed | See Teacher Resource Book for What is a Food Pyramid activity.  
See Teacher Resource Book for What are the Effects of Human Intervention on a Food Web? |
<table>
<thead>
<tr>
<th><strong>Evolution &amp; Classification</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROFICIENCY / OBJECTIVE</strong></td>
</tr>
<tr>
<td>The student will be able to:</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY

Textbooks


Resources:


Websites:

http://www.abdn.ac.uk/~clt011/flash/samples/photosyn.swf
http://www.dnai.org/timeline/index.html
http://www.pbs.org/wgbh/aso/trvlt/dna/
http://www.eduref.org/Virtual/Lessons/Science/Genetics/GET0003.html
http://www.sciencespot.net/Media/mitosisbook.pdf
http://www.learn.genetics.utah.edu/units/biotech/get/
http://www.pbs.org/wgbh/harvest/
http://www.amnh.org/exhibitions/darwin/
http://www.biologycorner.com/worksheets/pepperedmoth.html
Bibliography (Continued):

http://www.biologycorner.com/worksheets/fossilrecord.html
http://www.streaming.discoveryeducation.com/index.cfm
http://www.staff.4j.land.edu/~whitley/ecology/units/unit01/lesson02/12a3/12a3.html
http://www.enviroliteracy.org/article.php/1191.php
http://www.ohea.org/GD/Templates/Pages/OEA/OEADetail.aspx?page=3&TopicRelationID=4&Content=9249
http://www.hhmi.org/biointeractive/Anticiotics_Attack/opening.html
http://www.actionbioscience.org/newfrontiers/eldredge2.html
http://learn.genetics.utah.edu/units/biotech/gel/
http://learn.genetics.utah.edu/units/cloning/
http://www.amnh.org/exhibitions/darwin/
http://www.aboutdarwin.com/
http://www.biologycorner.com/worksheets/pepperedmoth.html
http://www.biologycorner.com/worksheets/fossilrecord.html
http://www.pbs.org/wgbh/nova/orchid/classifying.html
http://www.unitedstreaming.com
http://www.biologycorner.com/worksheets/HIV_coloring.html
http://www.hhmi.org/biointeractive/Antibiotics_Attack/frameset.html
http://www.enviroliteracy.org/article.php/1191.php
https://kushnerkorner.wikispaces.com/WATER+WEBQUEST
http://www.dnai.org/timeline/index.html
http://www.cellsalive.com
http://mysite.cherokee.k12.ga.us/personal/gregg_schumaker/site/Important%20Class%20Documents/1/Equilibrium/Cell%20Transport%20Webquest.pdf
http://www.cells.de/cellseng/1medienarchiv/Zellfunktionen/Memb_Vorg/Photosynthese/Photosyntheseaktivitaet/PSTA_in_Blaettern/index.jsp
http://learn.genetics.utah.edu/content/addiction/genetics/pi.html
http://www.biology.arizona.edu/human_bio/activities/karyotyping/karyotyping.html

DVD / CD-ROM:

Evolution DVD, Howard Hughes Medical Institute. Chevy Chase, MD, 2006
APPENDIX A  SAMPLE AUTHENTIC ASSESSMENT
SAMPLE AUTHENTIC ASSESSMENT

BioAdventures Advertising Package

Scenario: You are a biologist and travel agent for BioAdventures International. Your job requires you to plan and advertise educational adventures to the Earth’s majestic biomes! Your brochures come in a variety of formats, all of which are colorful and enticing to your clients. Your clients are interested in learning about and touring one of Earth’s unique biomes. Your job is to use credible resources and databases to create your brochure. The brochure will inform your clients of both biotic and abiotic factors that they will encounter in the biome so that they are prepared to have a once-in-a-lifetime experience.

Each Advertising Package Must Include the Following Information:

1. Biome’s place on Earth
   - Where is it (geographical distribution)?
   - What are its abiotic factors?
   - What are the native plants and their adaptations to live there?
   - What are the native animals and their adaptations to live there?
   - Give examples of cooperation and competition between and among species

2. Attractions/Tour Packages
   - Advertise your biome’s recreational activities
   - Publicize points of interest
   - Suggest other biomes nearby for side trips

3. Weather Report (used to aid tourists in packing their gear)
   - What is the average precipitation?
   - What is the average temperature?
   - Suggest supplies/gear that tourists should bring to make their trip more enjoyable

4. Warnings
   - What are some threats to this biome?
   - Are there any endangered species?
   - Is there a fear of climate change for this biome?

5. Food Web
   - What is a sample food web for this biome?
   - Your food web must include at least 10 organisms and trophic levels (producers, primary, and secondary consumers).

6. Analysis/Evaluation
   - Why is this biome globally important?
# AUTHENTIC ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY</th>
<th>SATISFACTORY</th>
<th>NEEDS IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMPLETION OF CONTENT REQUIREMENTS</strong></td>
<td>Advertising package contains detailed descriptions of all of the following: Biome’s place on Earth, attractions, weather report, warnings, food web, and analysis.</td>
<td>Advertising package contains all of the following: Biome’s place on Earth, attractions, weather report, warnings, food web, and analysis.</td>
<td>Advertising package lacks two or more of the following: Biome’s place on Earth, attractions, weather report, warnings, food web, and analysis.</td>
</tr>
<tr>
<td><strong>ACCURACY OF BIOLOGIC INFORMATION</strong></td>
<td>Advertising package is complete and accurate with regard to all stated content. Descriptions of all components are highly detailed.</td>
<td>Advertising package is complete and accurate with regard to all stated components.</td>
<td>Advertising package contains major inaccuracies and/or little or no detail in its descriptions.</td>
</tr>
<tr>
<td><strong>INCORPORATION OF OUTSIDE SOURCES</strong></td>
<td>Advertising package contains: detailed maps, corresponding images, and a food web. All outside references are properly cited from credible sources.</td>
<td>Advertising package contains: maps, images, and a food web. All outside references are properly cited from credible sources.</td>
<td>Advertising package lacks two or more of the following: maps, images, and a food web; and/or it does not contain citation of outside sources.</td>
</tr>
<tr>
<td><strong>STYLE AND ORGANIZATION OF FINISHED PRODUCT</strong></td>
<td>Advertising package is in a highly organized format that incorporates the use of multiple pictures and color graphics. Package is carefully written with appropriate audience in mind. Package is free of grammatical or spelling errors.</td>
<td>Advertising package is formatted in an organized manner and is clearly written with colored pictures. Package is written free of grammatical or spelling errors.</td>
<td>Advertising package is not formatted at all. It is not audience appropriate and/or contains major spelling or grammatical errors.</td>
</tr>
</tbody>
</table>
APPENDIX B  SAMPLE LAB ACTIVITY
SAMPLE LAB ACTIVITY

TIME SEQUENCE COMPARING NORMAL MITOSIS TO ABNORMAL MITOSIS IN CANCER CELLS

OBJECTIVE:
What is the normal time sequence for the stages of mitosis and how is the timing altered in cancer cells?

MATERIALS:
Prepared slide of onion root tip
Compound microscope
Graph paper

PROCEDURE:

PART I
• Obtain a clean onion root tip slide and scan it under low power. Adjust the light for optimum viewing.

• Switch to high power and center your slide so that you have a field of view in which all the cells are in various stages of mitosis (including interphase).

• Start at the top right corner of the field and record the stage of each cell in Data Table 1. Count your cells in a systematic manner. This will be considered Area 1.

• After completing the count in the first area, move the slide to a new area and perform the identification and count a second time. Record this data in the table as well.

• Repeat the procedure a third time, with yet another field of view.
Sample Lab Activity (Procedures/Part I continued)

- On a separate sheet of unlined paper make a drawing of one cell in each of the various stages. Be sure to draw only what you actually see, but include all details that are visible. Your drawings will not necessarily look exactly like the ones in a textbook.

- Return to Data Table 1 and record the total numbers of cells in each phase for all three trial areas.

- Add the total number of cells viewed in each stage. Write the total count of cells viewed in all three trials in the appropriate place on the data table.

- There is a direct relationship between the number of cells counted in a given stage of mitosis and the time that that stage takes to complete. This may be calculated if the total time for mitosis in onion root tip cells is known. (The total time is measured from interphase to interphase). It is generally acknowledged that this time for onion cells is 720 minutes (12 hours). Set-up a ratio of the number of cells in each phase compared to the total number of cell counted, then multiply this fraction by the total time (720 minutes) needed to complete one mitotic division. Thus, the time for a specific phase is equal to:

\[
\text{Number of cells in a specific phase} \times \frac{\text{Total number of cells counted}}{720 \text{ minutes}} = \text{time for specific phase}
\]

- Using your data, calculate the time required for the completion of each stage. Be sure to use the totals for all three trials. Enter these results in the appropriate column of Data Table 1.

- Prepare a bar graph to illustrate your results. The vertical axis should be marked in “minutes to complete each stage.” On the horizontal axis, allow equal space for each of the stages beginning with interphase and ending with telophase.

PART II: Mitotic Cell Division In Cancer Cells

- An important characteristic of cancer cells is that they no longer follow their normal timing of mitosis. You may have heard cancer cells called “runaway cells” that have no control on their rate of reproduction. It is this characteristic that allows some cancer cells to grow and spread quite rapidly. In this section, you will analyze data to determine the differences in timing of mitosis between normal and cancerous stomach cells in a chicken.

- Study the data in Table 2. Assume that the total time needed for one normal mitotic division of these cells is 625 minutes. Calculate, in the same manner as before, the total time needed for each normal phase of mitosis. Enter this data in the appropriate column of Data Table 2.
Sample Lab Activity (Procedure/Part II continued)

- Repeat this analysis for the data in Table 3. In the case of cancer cells, however, the total time required for one mitotic division is only 448 minutes. Enter the time required for each stage in Data Table 3.

- Prepare another bar graph, similar to your first, using the data from Tables 2 and 3. Put the data for both the normal and cancer cells in each phase directly next to each other.

CONCLUSION QUESTIONS:

Refer to your data and graph from Part 1 to answer the following:

1. Which stage in the mitotic cycle takes the most time? What percentage of the total time is this?

2. Why do you think that this stage (the one in question 1) takes so long? What activities in relation to mitosis are occurring during this phase?

3. Which stage is the second longest? What percentage of the total time does this stage take? Again, what events are occurring during this stage identified in question 3?

4. List the remaining stages in order, from longest to shortest duration.

Referring to your data and graph from Part II answer the following:

1. How does the data for each phase in the normal chicken cell compare with that of the onion root tip cell? Are the percentages of time for the two longest phases similar? Can you make a general conclusion based on this information?

2. In which stages are the most dramatic differences in timing between normal and cancerous chicken cells?

3. What nuclear and cytoplasmic changes would you expect to find in cancer cells, as compared to their normal counterparts? (HINT: What events would be most affected by the alteration in the timing sequence of mitosis?)
### Data Table 1: Count and Timing of Cells in Various Stages of Mitosis

<table>
<thead>
<tr>
<th>Stage of Mitosis</th>
<th>Number of Cells in Area 1</th>
<th>Number of Cells in Area 2</th>
<th>Number of Cells in Area 3</th>
<th>Total Number of Cells</th>
<th>Time in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interphase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prophase</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Metaphase</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Anaphase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telophase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Cells Counted</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>720</td>
</tr>
</tbody>
</table>

**Total Time in Minutes:** 720
## DATA TABLE 2:
Normal Chicken Stomach

<table>
<thead>
<tr>
<th>Stage of Mitosis</th>
<th>Total Number of Cells</th>
<th>Time in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERPHASE</td>
<td>440</td>
<td></td>
</tr>
<tr>
<td>PROPHASE</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>METAPHASE</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>ANAPHASE</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>TELOPHASE</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>500</strong></td>
<td><strong>625</strong></td>
</tr>
</tbody>
</table>

## DATA TABLE 3:
Cancer Chicken Stomach

<table>
<thead>
<tr>
<th>Stage of Mitosis</th>
<th>Total Number of Cells</th>
<th>Time in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERPHASE</td>
<td>424</td>
<td></td>
</tr>
<tr>
<td>PROPHASE</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>METAPHASE</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>ANAPHASE</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TELOPHASE</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>500</strong></td>
<td><strong>448</strong></td>
</tr>
</tbody>
</table>
APPENDIX C  LAB REPORT RUBRIC
# LAB REPORT RUBRIC

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>EXEMPLARY</th>
<th>SATISFACTORY</th>
<th>NEEDS IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPERIMENTAL DESIGN</td>
<td>Experimental design is a well-constructed test of the stated hypothesis.</td>
<td>Experimental design is structured to test the hypothesis. Minor details may be lacking, but do not affect the outcome.</td>
<td>Experimental design is not relevant to the hypothesis.</td>
</tr>
<tr>
<td>PROCEDURES</td>
<td>Procedures are listed in clear steps. Each step is numbered and is a complete sentence.</td>
<td>Procedures are listed in a logical order. Generally, steps are numbered and written in complete sentences.</td>
<td>Procedures do not accurately list the steps of the experiment.</td>
</tr>
<tr>
<td>DATA COLLECTION</td>
<td>Information is relevant to the objective and is carefully organized and presented in an appropriate table format. Table has appropriate title. Measurements are accurately reported. Correct SI units given.</td>
<td>Information is relevant to the objective and is presented in an organized way. Measurements may include minor inaccuracies that do not affect the outcome.</td>
<td>Information is incomplete, irrelevant, poorly organized or presented. Measurements are mostly inaccurate and no units are used.</td>
</tr>
<tr>
<td>DATA PROCESSING &amp; PRESENTATION</td>
<td>Calculations include formula, numbers with units, answers with units and proper number of significant digits (SD) using SI units and scientific notation. Graphs include title, variables with units, curve of best fitted (CBF). Helps math sequence with written explanation when necessary.</td>
<td>Graphs and calculations are accurate. Some of the required elements are loosely provided. Minor mistakes in measurements do not affect the outcome.</td>
<td>Graphs and/or calculations are incomplete, very inaccurate, and/or include major mistakes in measurement</td>
</tr>
<tr>
<td>CONCLUSION &amp; EVALUATION</td>
<td>Accurately explains results in detail using prior knowledge. Refers to the stated problem and is supported by evidence from the data/observations. Posed questions are answered appropriately. Fully evaluates investigative procedure and makes recommendations for future work.</td>
<td>Attempts to explain results using prior knowledge. Refers to the stated problem with some evidence from the data/observations. Posed questions are basically answered. Some evaluation of investigative procedure and/or recommendations for future work is provided.</td>
<td>Refers to the stated problem only. Posed questions are mentioned but not really answered. No evaluation of investigative procedure and/or recommendations for future work.</td>
</tr>
<tr>
<td><strong>ORAL PRESENTATION RUBRIC</strong></td>
<td><strong>EXEMPLARY</strong></td>
<td><strong>ACCEPTABLE</strong></td>
<td><strong>MARGINAL</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>INFORMATION SEEKING/SELECTING AND EVALUATING</strong></td>
<td>Student gathered information from quality sources that are accurate, detailed, complete and related directly to the stated task.</td>
<td>Student gathered information from several sources; however, missed a few required elements related to the task.</td>
<td>Student gathered information from a limited range of sources and missed several required elements related to the task.</td>
</tr>
<tr>
<td><strong>SYNTHESIS</strong></td>
<td>Student developed well structured method for communicating information, which is logical and organized to deliver smooth transitions.</td>
<td>Student logically organized the information gathered and made appropriate connections among the ideas.</td>
<td>Student could have demonstrated better organization of the information. Connections among the topics were weak.</td>
</tr>
<tr>
<td><strong>ANALYSIS</strong></td>
<td>Narrative and description of topics were very succinct. Conflicting evidence is consistently acknowledged and accounted for.</td>
<td>Narrative and/or description was provided. Some conflicting evidence is acknowledged and accounted for.</td>
<td>Narrative or description takes precedence over analysis. Relatively little concern for conflicting evidence.</td>
</tr>
<tr>
<td><strong>PERSUASION</strong></td>
<td>Counter arguments are consistently anticipated and refuted.</td>
<td>Counter arguments are usually anticipated and refuted.</td>
<td>Counter arguments are incompletely expressed.</td>
</tr>
<tr>
<td><strong>GRAPHICS</strong></td>
<td>Student’s graphics explained and reinforced screen text and presentation.</td>
<td>Student’s graphics related to text and presentation.</td>
<td>Student’s graphics do not enhance the presentation.</td>
</tr>
<tr>
<td><strong>EYE CONTACT</strong></td>
<td>Student maintained eye contact with audience, seldom returning to notes.</td>
<td>Student maintained eye contact with audience, seldom returning to notes.</td>
<td>Student occasionally used eye contact, but still read most of the report.</td>
</tr>
<tr>
<td><strong>VOCAL QUALITY</strong></td>
<td>Student used a clear voice and correct, precise pronunciation of terms so that all audience members could hear presentation.</td>
<td>Student’s voice was clear. Student pronounced most words correctly. Most audience members could hear presentation.</td>
<td>Student’s voice was low. Student incorrectly pronounced terms. Audience members had difficulty hearing presentation.</td>
</tr>
</tbody>
</table>
The following are all minor infractions. Please **DO NOT** correct the mistakes, instead include:

- “sp” for spelling errors
- “punc” for grammar
- “form” for paragraphs missing, redundancy/repetition or not having at least three paragraphs
- “?” for a missing thesis statement

It is the quality and amount of data and/or facts that make it possible to present a case or draw valid conclusions. Therefore, this is the area of primary focus.
PORTFOLIO AND SELF-ASSESSMENT INSTRUCTIONS FOR STUDENT WORK FOLDER

Three pieces from last year’s portfolio will be saved and kept in this year’s portfolio. Choose these three (3) pieces based on the work you were most proud of, or that created a valuable learning experience.

A record log will be stapled to the inside of your portfolio. You are to include the following every time we add content to the portfolio.

1. Date the assignment was completed
2. Type of assignment
3. Grade
4. Skills demonstrated by the work
5. Self-assessment

**Type of assignment:** quiz, test, lab, project, extra credit, homework, etc.

**Skills demonstrated:** science content knowledge, use of scientific method, laboratory skills, problem solving/critical thinking, writing skills, math skills, cooperative learning, graphing skills, ability to follow directions, etc.

**Self assessment:** reaction to grade or feedback, quality of work, strengths and weaknesses, “Things I struggled with,” progress made, “What I would do differently to improve,” why this assignment is missing, plan for future assignments, etc.

At the end of every marking period, you are to write a self-reflection, commenting on your progress for the current marking period. Your portfolio will then be reviewed for a **quiz** grade. Your grade will be based upon organization, inclusion of all relevant work, a completed log, and a thoughtful self-reflection.
PORTFOLIO AND SELF-ASSESSMENT SHEET
FOR STUDENT WORK FOLDER

Name ______________________________ Course ____________________________

<table>
<thead>
<tr>
<th>Date Completed</th>
<th>Assignment</th>
<th>Grade</th>
<th>Skills</th>
<th>Self-Assessment</th>
</tr>
</thead>
<tbody>
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Marking Period _____________
MID-YEAR REFLECTION

After looking over your work folder with all of your assessments from this year, what are your strengths? What are your weaknesses?

How can you continue to use your strengths to be successful? Be specific and explain.

How can you improve your areas of weakness? Give yourself at least one goal in order to help you improve.

Which assessment(s) are you most proud of? Explain why.

Which assessment(s) do you think you could have done better on? Explain why and how.

We are now half-way through the school year. What will you continue to strive for? How do you plan on doing this
WORK FOLDER REFLECTION

Look through the various items in your work folder and take a moment to think about this school year. Answer the following questions in the form of a paragraph to reflect on your progress so far this year.

- What were some of your goals in the beginning of this school year? Have you made progress towards achieving them?
- What are some goals you have for the rest of this school year?
- In what areas did you have the most success? Be specific by indicating the topics in which you feel most confident.
- In what areas did you have difficulty? What are some ways you can improve in those areas?
- What can you do to prepare yourself for the final exam?
- Now that more than half of the year has passed, what are some things that you have learned that will help you next year? (i.e. study skills, putting more effort in homework, etc.)
- What are some things that you enjoy about this class? What are some things you don’t like? Do you have any suggestions as to what would make the class better?
Are Viruses Alive?

Although viruses challenge our concept of what "living" means, they are vital members of the web of life
Aug 8, 2008 |By Luis P. Villarreal

Editor's Note: This story was originally published in the December 2004 issue of Scientific American.

In an episode of the classic 1950s television comedy The Honeymooners, Brooklyn bus driver Ralph Kramden loudly explains to his wife, Alice, “You know that I know how easy you get the virus.” Half a century ago even regular folks like the Kramdens had some knowledge of viruses—as microscopic bringers of disease. Yet it is almost certain that they did not know exactly what a virus was. They were, and are, not alone.

For about 100 years, the scientific community has repeatedly changed its collective mind over what viruses are. First seen as poisons, then as life-forms, then biological chemicals, viruses today are thought of as being in a gray area between living and nonliving: they cannot replicate on their own but can do so in truly living cells and can also affect the behavior of their hosts profoundly. The categorization of viruses as nonliving during much of the modern era of biological science has had an unintended consequence: it has led most researchers to ignore viruses in the study of evolution. Finally, however, scientists are beginning to appreciate viruses as fundamental players in the history of life.

Coming to Terms

It is easy to see why viruses have been difficult to pigeonhole. They seem to vary with each lens applied to examine them. The initial interest in viruses stemmed from their association with diseases—the word “virus” has its roots in the Latin term for “poison.” In the late 19th century researchers realized that certain diseases, including rabies and foot-and-mouth, were caused by particles that seemed to behave like bacteria but were much smaller. Because they were clearly biological themselves and could be spread from one victim to another with obvious biological effects, viruses were then thought to be thesimplest of all living, gene-bearing life forms.

Their demotion to inert chemicals came after 1935, when Wendell M. Stanley and his colleagues, at what is now the Rockefeller University in New York City, crystallized a virus—tobacco mosaic virus—for the first time. They saw that it consisted of a package of complex biochemicals. But it lacked essential systems necessary for metabolic functions, the biochemical activity of life. Stanley shared the 1946 Nobel Prize—in chemistry, not in physiology or medicine—for this work.

Further research by Stanley and others established that a virus consists of nucleic acids (DNA or RNA) enclosed in a protein coat that may also shelter viral proteins involved in infection. By that description, a virus seems more like a chemistry set than an organism. But when a virus enters a cell (called a host after
infection), it is far from inactive. It sheds its coat, bares its genes and induces the cell’s own replication machinery to reproduce the intruder’s DNA or RNA and manufacture more viral protein based on the instructions in the viral nucleic acid. The newly created viral bits assemble and, voilà, more virus arises, which also may infect other cells.

These behaviors are what led many to think of viruses as existing at the border between chemistry and life. More poetically, virologists Marc H. V. van Regenmortel of the University of Strasbourg in France and Brian W. J. Mahy of the Centers for Disease Control and Prevention have recently said that with their dependence on host cells, viruses lead “a kind of borrowed life.” Interestingly, even though biologists long favored the view that viruses were mere boxes of chemicals, they took advantage of viral activity in host cells to determine how nucleic acids code for proteins: indeed, modern molecular biology rests on a foundation of information gained through viruses.

Molecular biologists went on to crystallize most of the essential components of cells and are today accustomed to thinking about cellular constituents—for example, ribosomes, mitochondria, membranes, DNA and proteins—as either chemical machinery or the stuff that the machinery uses or produces. This exposure to multiple complex chemical structures that carry out the processes of life is probably a reason that most molecular biologists do not spend a lot of time puzzling over whether viruses are alive. For them, that exercise might seem equivalent to pondering whether those individual subcellular constituents are alive on their own. This myopic view allows them to see only how viruses co-opt cells or cause disease. The more sweeping question of viral contributions to the history of life on earth, which I will address shortly, remains for the most part unanswered and even unasked.

To Be or Not to Be
The seemingly simple question of whether or not viruses are alive, which my students often ask, has probably defied a simple answer all these years because it raises a fundamental issue: What exactly defines “life?” A precise scientific definition of life is an elusive thing, but most observers would agree that life includes certain qualities in addition to an ability to replicate. For example, a living entity is in a state bounded by birth and death. Living organisms also are thought to require a degree of biochemical autonomy, carrying on the metabolic activities that produce the molecules and energy needed to sustain the organism. This level of autonomy is essential to most definitions.

Viruses, however, parasitize essentially all biomolecular aspects of life. That is, they depend on the host cell for the raw materials and energy necessary for nucleic acid synthesis, protein synthesis, processing and transport, and all other biochemical activities that allow the virus to multiply and spread. One might then conclude that even though these processes come under viral direction, viruses are simply nonliving parasites of living metabolic systems. But a spectrum may exist between what is certainly alive and what is not.

A rock is not alive. A metabolically active sack, devoid of genetic material and the potential for propagation, is also not alive. A bacterium, though, is alive. Although it is a single cell, it can generate energy and the molecules needed to sustain itself, and it can reproduce. But what about a seed? A seed might not be
considered alive. Yet it has a potential for life, and it may be destroyed. In this regard, viruses resemble seeds more than they do live cells. They have a certain potential, which can be snuffed out, but they do not attain the more autonomous state of life.

Another way to think about life is as an emergent property of a collection of certain nonliving things. Both life and consciousness are examples of emergent complex systems. They each require a critical level of complexity or interaction to achieve their respective states. A neuron by itself, or even in a network of nerves, is not conscious—whole brain complexity is needed. Yet even an intact human brain can be biologically alive but incapable of consciousness, or “brain-dead.” Similarly, neither cellular nor viral individual genes or proteins are by themselves alive. The enucleated cell is akin to the state of being braindead, in that it lacks a full critical complexity. A virus, too, fails to reach a critical complexity. So life itself is an emergent, complex state, but it is made from the same fundamental, physical building blocks that constitute a virus. Approached from this perspective, viruses, though not fully alive, may be thought of as being more than inert matter: they verge on life.

In fact, in October, French researchers announced findings that illustrate afresh just how close some viruses might come. Didier Raoult and his colleagues at the University of the Mediterranean in Marseille announced that they had sequenced the genome of the largest known virus, Mimivirus, which was discovered in 1992. The virus, about the same size as a small bacterium, infects amoebae. Sequence analysis of the virus revealed numerous genes previously thought to exist only in cellular organisms. Some of these genes are involved in making the proteins encoded by the viral DNA and may make it easier for Mimivirus to co-opt host cell replication systems. As the research team noted in its report in the journal *Science*, the enormous complexity of the Mimivirus’s genetic complement “challenges the established frontier between viruses and parasitic cellular organisms.”

**Impact on Evolution**

Debates over whether to label viruses as living lead naturally to another question: Is pondering the status of viruses as living or nonliving more than a philosophical exercise, the basis of a lively and heated rhetorical debate but with little real consequence? I think the issue is important, because how scientists regard this question influences their thinking about the mechanisms of evolution.

Viruses have their own, ancient evolutionary history, dating to the very origin of cellular life. For example, some viral repair enzymes—which excise and resynthesize damaged DNA, mend oxygen radical damage, and so on—are unique to certain viruses and have existed almost unchanged probably for billions of years.

Nevertheless, most evolutionary biologists hold that because viruses are not alive, they are unworthy of serious consideration when trying to understand evolution. They also look on viruses as coming from host genes that somehow escaped the host and acquired a protein coat. In this view, viruses are fugitive host genes that have degenerated into parasites. And with viruses thus dismissed from the web of life, important contributions they may have made to the origin of species and the maintenance of life may go unrecognized. (Indeed, only four of the 1,205 pages of the 2002 volume *The Encyclopedia of Evolution* are devoted to viruses.)
Of course, evolutionary biologists do not deny that viruses have had some role in evolution. But by viewing viruses as inanimate, these investigators place them in the same category of influences as, say, climate change. Such external influences select among individuals having varied, genetically controlled traits; those individuals most able to survive and thrive when faced with these challenges go on to reproduce most successfully and hence spread their genes to future generations.

But viruses directly exchange genetic information with living organisms—that is, within the web of life itself. A possible surprise to most physicians, and perhaps to most evolutionary biologists as well, is that most known viruses are persistent and innocuous, not pathogenic. They take up residence in cells, where they may remain dormant for long periods or take advantage of the cells’ replication apparatus to reproduce at a slow and steady rate. These viruses have developed many clever ways to avoid detection by the host immune system—essentially every step in the immune process can be altered or controlled by various genes found in one virus or another.

Furthermore, a virus genome (the entire complement of DNA or RNA) can permanently colonize its host, adding viral genes to host lineages and ultimately becoming a critical part of the host species’ genome. Viruses therefore surely have effects that are faster and more direct than those of external forces that simply select among more slowly generated, internal genetic variations. The huge population of viruses, combined with their rapid rates of replication and mutation, makes them the world’s leading source of genetic innovation: they constantly “invent” new genes. And unique genes of viral origin may travel, finding their way into other organisms and contributing to evolutionary change.

Data published by the International Human Genome Sequencing Consortium indicate that somewhere between 113 and 223 genes present in bacteria and in the human genome are absent in well-studied organisms—such as the yeast Saccharomyces cerevisiae, the fruit fly Drosophila melanogaster and the nematode Caenorhabditis elegans—that lie in between those two evolutionary extremes. Some researchers thought that these organisms, which arose after bacteria but before vertebrates, simply lost the genes in question at some point in their evolutionary history. Others suggested that these genes had been transferred directly to the human lineage by invading bacteria. My colleague Victor DeFilippis of the Vaccine and Gene Therapy Institute of the Oregon Health and Science University and I suggested a third alternative: viruses may originate genes, then colonize two different lineages—for example, bacteria and vertebrates. A gene apparently bestowed on humanity by bacteria may have been given to both by a virus.

In fact, along with other researchers, Philip Bell of Macquarie University in Sydney, Australia, and I contend that the cell nucleus itself is of viral origin. The advent of the nucleus—which differentiates eukaryotes (organisms whose cells contain a true nucleus), including humans, from prokaryotes, such as bacteria—cannot be satisfactorily explained solely by the gradual adaptation of prokaryotic cells until they became eukaryotic. Rather the nucleus may have evolved from a persisting large DNA virus that made a permanent home within prokaryotes. Some support for this idea comes from sequence data showing that the gene for a DNA polymerase (a DNA-copying enzyme) in the virus called T4, which infects bacteria, is closely related to other DNA polymerase genes in both eukaryotes and
Patrick Forterre of the University of Paris-Sud has also analyzed enzymes responsible for DNA replication and has concluded that the genes for such enzymes in eukaryotes probably have a viral origin.

From single-celled organisms to human populations, viruses affect all life on earth, often determining what will survive. But viruses themselves also evolve. New viruses, such as the AIDS-causing HIV-1, may be the only biological entities that researchers can actually witness come into being, providing a real-time example of evolution in action.

Viruses matter to life. They are the constantly changing boundary between the worlds of biology and biochemistry. As we continue to unravel the genomes of more and more organisms, the contributions from this dynamic and ancient gene pool should become apparent. Nobel laureate Salvador Luria mused about the viral influence on evolution in 1959. “May we not feel,” he wrote, “that in the virus, in their merging with the cellular genome and reemerging from them, we observe the units and process which, in the course of evolution, have created the successful genetic patterns that underlie all living cells?” Regardless of whether or not we consider viruses to be alive, it is time to acknowledge and study them in their natural context—within the web of life.
LESSON:
Protein Puzzles

Summary: Students read the *EHP Student Edition* article “The Shape of Food Allergenicity” and then learn about primary, secondary, and tertiary protein structure. Students then construct a 3-D model of an insulin protein and investigate how protein structure relates to allergens, insulin resistance, and mad cow disease. 

Graphic Organization and Modeling—This lesson has students organize information graphically (e.g., using figures, graphs, and/or webs) or by creating a model.

_EHP Article:_ “The Shape of Food Allergenicity”

Objectives: By the end of this lesson, students should be able to:
1. identify the basic building blocks of proteins;
2. differentiate between primary, secondary, and tertiary structures of proteins; and
3. list examples of how protein structure relates to its functionality.

Class Time:
- 2 hours for Steps 1 and 2
- 4 hours for Steps 1, 2, and 3

Grade Level: 9–12

Subjects Addressed: Biology, Biochemistry, Molecular Biology, Environmental Health, Health

Prepping the Lesson (20–25 minutes)

INSTRUCTIONS:
2. Make copies of the Student Instructions, including the page titled “The Insulin Protein Puzzle.”
3. Reserve computer lab space and gather the materials. If students do not have Internet access, then print and copy the webpages for students to be able to complete Step 3.
4. Review the article and Student Instructions.

MATERIALS:
- 1 copy of *EHP Student Edition*, October 2005, or 1 copy of “The Shape of Food Allergenicity” per student
- 1 copy of Student Instructions, including the page titled “The Insulin Protein Puzzle” per student
- 1 set of coloring markers per group
- Scissors, per student or group as available
- Clear tape, per group
- Computers with Internet access, or copies of the webpages listed in Step 3.

VOCABULARY:
- allergen
- alpha (α)-helix
- amino acids
- enzymes
- element
BACKGROUND INFORMATION:
The article, assessment section, and student handouts provide sufficient information.

RESOURCES:
- Principles of Protein Structure, Birbeck College, http://www.cryst.bbk.ac.uk/PPS2/top.html

Implementing the Lesson

INSTRUCTIONS:
1. Have students read the article “The Shape of Food Allergenicity.”
2. Review amino acids, proteins, and protein structure as needed.
3. Hand out the Student Instructions, including the page titled “The Insulin Protein Puzzle.”
4. Review the instructions on constructing a model of the insulin protein under Step 2. Students will build their insulin protein individually but will share scissors, tape, and markers as needed. Some tips to help the students build their model: a) Cut the strips by rows (not columns) since they are already sequentially numbered. b) Point out that there will be two separate strips labeled “a” and “b.” c) When the students make their spiral (secondary structure) they can wrap the strip around their finger loosely and then tape.
5. In order to complete Step 3, students will need either Internet access or printouts of the webpages listed under Step 3 in the Student Instructions.

NOTES & HELPFUL HINTS:
- Depending on how advanced your students are, you may consider having the class investigate the types of bonds in the primary, secondary, and tertiary protein structures. Students could even draw the chemical structure on each amino acid and properly align the areas of the amino acid that bond in each structural level.

Aligning with Standards

SKILLS USED OR DEVELOPED:
- classification
- comprehension
- critical thinking and response
- manipulation
- research

SPECIFIC CONTENT ADDRESSsed:
- amino acids
• proteins
• protein structure
• allergens
• insulin
• mad cow disease

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Unifying Concepts and Processes Standard
• Systems, order, and organization
• Evidence, models, and explanation
• Form and function

Science As Inquiry
• Abilities necessary to do scientific inquiry
• Understanding about scientific inquiry

Physical Science Standards
• Structure and properties of matter

Life Science Standards
• The cell
• Matter, energy, and organization in living systems

Science and Technology Standards
• Abilities of technical design
• Understanding about science and technology

Science in Personal and Social Perspectives Standard
• Personal and community health
• Environmental quality
• Natural and human-induced hazards

Assessing the Lesson

Step 2:  Students color, cut out, and assemble the insulin model. Make sure the amino acids are colored and are in the proper primary sequence (following the sequential numbering for each a and b strand). Check that the proper sections of the protein are spiraled in an $\alpha$-helix (amino acids are labeled with H). Check that the tertiary structure is properly “bonded” (S1, S2, and S3 labels are matched).

1.a. Which two amino acids occur the most in insulin? Spell out the full amino acid name instead of the abbreviation.
Cystine (there are 6) and Leucine (there are 6)

1.b. Which two amino acids occur only once in insulin? Spell out the full amino acid name instead of the abbreviation.
Lysine and Proline

3.a. Which protein structural level does taping the amino acids together in a linear fashion represent?
Primary

4.a. Which protein structural level does wrapping the protein around your finger represent?
Secondary

4.b. Does insulin have an $\alpha$-helix, $\beta$-sheet structure, or both?
Both

5.a. Which protein structural level does taping the S’s (sulfide bonds) together represent?
Tertiary
Step 3: Describe how the 3-D shape of a protein may be related to the following. Students will need to do research on the Internet to answer questions 2 and 3.

1. Proteins that cause allergic responses.
   This answer is found in the article “The Shape of Food Allergenicity.” The scientists hypothesize that the tertiary structure of the protein generates strong bonds, making the protein stable and resistant to digestion.

2. Insulin resistance is the cause of type 2 diabetes, the most common form of diabetes.
   Insulin works by fitting into a special insulin receptor on cells. When the insulin is on the receptor, the cell is “unlocked,” and glucose can go from the blood into the cell. Insulin resistance appears to have both a genetic component and a physical component (being overweight). In both circumstances it is believed that the shape of the receptor is altered. This relates to the 3-D structure of the protein because the protein will not fit properly into the receptor in order to give the signal to allow glucose into the cell from the blood.

3. Prions are proteins located on a cell’s plasma membrane. The highest concentration of prions are on cells in the central nervous system. The function of a normal prion is unknown. Mad cow disease is caused by a “rogue” prion.

   The secondary and tertiary structures of a rogue prion are altered (the primary structure or amino acid sequence remains the same). The secondary structure of a normal prion is an α-helix, whereas the secondary structure of a rogue prion is the β-sheet. Alterations in the secondary structure also affect the shape of the tertiary structure because bonding occurs in different places.

Authors and Reviewers

Author: Stefani Hines, University of New Mexico
Reviewers: Susan Booker, Liam O’Fallon, Lisa Pitman, Wendy Stephan, Kimberly Thigpen Tart
Images: courtesy of Tudor I. Oprea, University of New Mexico

Step 2: Read the information below and follow the instructions to build an insulin protein model.

You probably already know that atoms, the smallest representative sample of an element, bond together to form molecules. Different atoms of elements (like carbon, oxygen, and nitrogen) bond together in different amounts and different ways to form the billions of chemicals that make up everything in our universe. Living things tend to create complex molecules in order to do specific jobs to maintain life.

Some of the complex molecules that help life function are carbohydrates, fats, steroids, and proteins. Some of these molecules are used in cell structure, others are “active” compounds that move or change chemicals. Proteins are a class of chemicals that participate in every function of the living cell, including structural support for the cell, muscle movement, breaking down chemicals (these proteins are called enzymes), turning genes off or on, or cell signaling. Proteins play a very important role in biology and biochemistry. You can differentiate proteins from other chemicals in a living thing because proteins are made up of amino acids. Proteins also often have complex multidimensional structures. There are 22 amino acids. The human body uses 20 of these amino acids and can make 10 of them on its own. The other 10 we have to get through eating.

When amino acids bond together they are called peptides. “Polypeptide” is simply another name for a protein, where many amino acids are joined together (poly = many). There are proteins that are very short, such as the artificial sweetener aspartame, which is a dipeptide (two amino acids bonded). And there are proteins that contain several thousand amino acids.

When many amino acids bond together, the molecules can get quite large compared to the rest of its microscopic cellular surroundings. Imagine trying to stretch out a 50-foot rope in a 10 x 10 foot room. You would not be able to fully extend the rope into a straight position. You would need to bend or curve the rope, or pile it upon itself. Large proteins face a similar challenge, so they fold in upon themselves to generate a three-dimensional (3-D) structure.

There are three parts to this 3-D structure. The primary structure is the amino acid “chain” bonded together (Figure 1), much like the “straight” rope in our analogy. The order and type of amino acids in this primary structure are what define a specific protein. The amino acid type, order, and number are different for the hemoglobin protein (which carries oxygen in the blood) compared to the insulin protein (which manages sugar in the blood).

![Figure 1: Portion of a peptide chain, the primary protein structure.](image-url)
The secondary structure of a protein is the first step of a protein “folding in” on itself. The secondary structure folding is typically in a regular, repetitive pattern, like an alpha (α)-helix, or spiral, or a beta (β)-sheet (Figure 2). For an α-helix structure, imagine taking your rope and swirling it into a circular pile. Then imagine that where each part of the rope touches the rope above and below, they stick together or bond. For a β-sheet you would fold the rope so there are many parallel strands, like making compressed S’s or zigzags. The pieces of rope (or protein) that are parallel or next to each other would bond. The bonds are what stabilize the secondary structure.

The third part of the protein structure is called the tertiary structure (Figure 2). This is additional bending and kinking of the secondary structure to compress the protein even more. Like the primary and secondary structures, the tertiary structure is formed and held by bonds. The really interesting feature of the protein's tertiary structure is its function beyond saving space. The hills and valleys of the outside of the protein act like a key that fits to a specific lock or a puzzle piece. When the key or puzzle piece fits with its intended counterpart, the protein is doing its job—like carrying oxygen, stimulating the release of hormones, or fighting off infection.
Now you are going to build a model of a protein called insulin. Insulin helps regulate the amount of sugar in our blood. People who do not release enough insulin or whose insulin becomes less effective get a disease called diabetes. If diabetes is left untreated, the excess sugar in the body can cause blindness, kidney damage, artery damage, or death. Diabetes can be prevented or managed through a healthy diet of fruit, vegetables, “good” fats (like the fat in nuts, olives, and fish), plenty of water, and exercise. Extreme cases of diabetes require that a person inject insulin into their bodies near meal time.

Follow the steps to build a model of the protein insulin and answer the questions.

1. Refer to the handout titled “The Insulin Protein Puzzle.” Color each amino acid rectangle in Table 2 with the assigned color found in the parenthesis next to the amino acid name and abbreviation in Table 1.

1.a. Which two amino acids occur the most in insulin? Using Table 1 on the “Insulin Protein Puzzle” handout, spell out the full amino acid name instead of the abbreviation.

1.b. Which two amino acids occur only once in insulin? Spell out the full amino acid name instead of the abbreviation.

2. Cut out the colored amino acid rectangles. You will save time and effort if you cut in rows (rather than cutting out individual squares) keeping the sequential numbering.

3. Tape the amino acids in the numbered sequence for each strand (a and b). You will end up with two straight strands (1a–21a and 1b–30b).

3.a. Which protein structural level does taping the amino acids together in a linear fashion represent?

4. Spiral the paper sections that are labeled with sequential H’s (e.g., 1a–8a). Tape the helix so that it is stable. You may find it helpful to loosely wrap the paper around your finger, then tape the paper.

4.a. Which protein structural level does spiraling represent?

4.b. Does insulin have an α-helix structure, β-sheet structure, or both?
5. Next, tape together the corresponding “disulfide bonds” labeled with S in the upper right-hand corner of some of the amino acids rectangles (pair S1 with S1, S2 with S2, etc.).

5.a. Which protein structural level does taping the S’s (sulfide bonds) together represent?

Step 3: Refer to the article “The Shape of Food Allergenicity” to answer question 1 below. You will need to do research on the Internet to answer questions 2 and 3, unless your teacher made copies of the webpages. The website addresses are provided for each corresponding question. Describe how the 3-D shape of a protein may be related to the following:

1. Proteins can cause allergic responses.

Clinical course of genetic diseases of the insulin receptor (type A and Rabson-Mendenhall syndromes): a 30-year prospective. (Abstract)

Fat Cell Hormone Promotes Type 2 Diabetes, National Institute of Diabetes and Digestive and Kidney Diseases,
http://www.niddk.nih.gov/welcome/releases/1-01.htm

2. Insulin resistance in the cell is one mechanism for diabetes. Insulin resistance can be caused by genetics, obesity, or a combination of the two.

3. Prions are proteins located on a cell’s plasma membrane. The highest concentration of prions are on cells in the central nervous system. The function of a normal prion is unknown. Mad cow disease is caused by “rogue” prions.

Prions: Infectious Proteins Responsible for Mad Cow Disease, http://www.bioteach.ubc.ca/Biomedicine/Prions/
### The Insulin Protein Puzzle

#### Table 1: The Amino Acids and Their Abbreviations

<table>
<thead>
<tr>
<th>Essential Amino Acids (those the human body cannot generate on its own)</th>
<th>Nonessential Amino Acids (those the human body can generate on its own)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tryptophan—Trp (<em>not found in the insulin protein</em>)</td>
<td>Tyrosine—Tyr—(red dots)</td>
</tr>
<tr>
<td>Lysine—Lys—(blue stripes)</td>
<td>Glycine—Gly—(red)</td>
</tr>
<tr>
<td>Methionine—Met (<em>not found in the insulin protein</em>)</td>
<td>Serine—Ser—(green dots)</td>
</tr>
<tr>
<td>Phenylalanine—Phe—(orange dots) Threonine—Thr—(black dots) Valine—Val—(orange)</td>
<td>Glutamic acid—Glu—(blue)</td>
</tr>
<tr>
<td>Leucine—Leu—(green dots)</td>
<td>Aspartic acid—Asp (<em>not found in the insulin protein</em>)</td>
</tr>
<tr>
<td>Isoleucine—Ile—(yellow)</td>
<td>Cystine—Cys—(purple)</td>
</tr>
<tr>
<td>Histidine—His—(brown dots) (essential in children)</td>
<td>Proline—Pro—(purple stripes)</td>
</tr>
<tr>
<td>Arginine—Arg—(orange stripes) (essential in children)</td>
<td>Alanine—Ala—(green stripes)</td>
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#### Table 2: Insulin Amino Acids to Cut Out

<table>
<thead>
<tr>
<th>1a</th>
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<th>Gly</th>
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<td>22b</td>
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<td>23b</td>
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<td></td>
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<tr>
<td>30b</td>
<td>Ala</td>
<td></td>
</tr>
</tbody>
</table>
Is Sammy Alive Teacher Notes
Discussion Questions Using Bloom’s Taxonomy

1. **Knowledge, Identification, and Recall:** Does the student know the information?
   - What happened to Sammy?
   - Who supported the operations?
   - What events led to his injuries?
   - Identify… The injuries
   - Define…
   - List…

2. **Understanding and Comprehension:** Does the student understand?
   - In your own words define life.
   - Summarize when you believe Sammy was no longer living.
   - What does it mean to be alive?
   - How do you know when the right time is to make a life decision?

3. **Application:** Can the student use previously learned information in a new situation? Adapting and applying the seven characteristics from the Martian to Sammy.
   - Describe how you would react if you had to make the decisions for a loved one in Sammy’s case.
   - How might these decisions be viewed from others?
   - Where else might this apply?
   - Explain how one might use…
   - Use…

4. **Analysis and Synthesis:** Can the student dissect and reassemble the idea or issue? Can the student view the issue from a different perspective? Can the student examine the available facts and offer alternative interpretations and solutions?
   - What caused the ____________ to respond this way?
   - Why might medical coverage encourage or discourage the use of medicine?
   - How could the incentives be realigned to support in-home care?

5. **Evaluation:** Can the student assess, form opinions, establish appropriate standards and criteria, evaluate ethical dilemmas, and critically examine an issue or idea?
   - Which method, procedure, or solution is better?
   - Can you evaluate this idea in terms of…?
   - Which approach would you chose? Why?
   - Judge, select, or rate…
Introduction

Have you ever noticed the nutrition label located on the packaging of the food you buy? One of the first things listed on the label are the calories per serving. How is the calorie content of food determined? This activity will introduce the concept of calorimetry and investigate the caloric content of snack foods.

Concepts

- Calorimetry
- Conservation of energy
- First law of thermodynamics

Background

The law of conservation of energy states that energy cannot be created or destroyed, only converted from one form to another. This fundamental law was used by scientists to derive new laws in the field of thermodynamics—the study of heat energy, temperature, and heat transfer. The First Law of Thermodynamics states that the heat energy lost by one body is gained by another body. Heat is the energy that is transferred between objects when there is a difference in temperature. Objects contain heat as a result of the small, rapid motion (vibrations, rotational motion, electron spin, etc.) that all atoms experience. The temperature of an object is an indirect measurement of its heat. Particles in a hot object exhibit more rapid motion than particles in a colder object. When a hot and cold object are placed in contact with one another, the faster moving particles in the hot object will begin to bump into the slower moving particles in the colder object making them move faster (vice versa, the faster particles will then move slower). Eventually, the two objects will reach the same equilibrium temperature—the initially cold object will now be warmer, and the initially hot object will now be cooler. This principle is the basis for calorimetry, or the measurement of heat transfer.

In the 1770s, Joseph Black (1728–1799) was one of the first scientists to conduct calorimetry experiments with different materials. He discovered that not all materials are equal when it comes to heat transfer. He concluded that different materials have their own unique ability to retain heat energy. Some materials, like water, can gain a large amount of heat energy without a significant change in temperature, while other materials, such as metals, will have a more dramatic temperature change for the same amount of heat energy gained. This property is based mainly on the structure of the material, the size of the atoms and molecules, and the interactions between them. This is known as the specific heat of the substance. The specific heat is defined as the heat energy required to raise the temperature of one gram of a substance by one degree Celsius. The unit of energy commonly associated with heat is called a calorie. Water has a defined specific heat of 1 cal/g °C so it takes one calorie of energy to raise the temperature of one gram of water by one degree Celsius. (The reverse is also true, remove one calorie of heat from one gram of water, and the temperature will decrease by one degree Celsius.) With the specific heat of a substance known, the amount of heat energy gained or lost by a substance can then be calculated if the temperature change is measured.

In this experiment, the specific heat of water and its change in temperature will be used to determine the caloric content of a food sample. The normal unit for measuring the energy content in food is called a Calorie (with an uppercase C). A Calorie is really a kilocalorie, or 1000 calories (lowercase c). During calorimetry, food burns and its stored energy is quickly converted into heat energy and products of combustion (carbon dioxide and water). The heat energy that is released is then transferred into the water above it in the calorimeter. The temperature change in the water is then measured and used to calculate the amount of heat energy released from the burning food. The heat energy is calculated using Equation 1.

\[ Q = mC\Delta T \]  

Equation 1

\[ Q = \text{heat energy} \]
\[ m = \text{mass of the water} \]
\[ C = \text{specific heat of the water} \]
\[ \Delta T = \text{change in water temperature, } T_{\text{final}} - T_{\text{initial}} \] ("\( \Delta \)" is the Greek letter Delta which means “change in”)

**Materials**

- Balance (0.01-g precision)
- Cork stopper
- Butane safety lighter
- Graduated cylinder, 50-mL
- Metal ring with clamp
- Pin, large straight
- Ruler, metric
- Snack foods (cheese puffs, popcorn, marshmallows, etc.)
- Soda can, empty and clean
- Stirring rod, glass
- Support stand
- Thermometer
- Water, distilled or tap, 50 mL

**Safety Precautions**

*Wear safety glasses when performing this or any lab that uses chemicals, heat or glassware. Care should be taken when handling or placing food onto the pin point. Allow the food sample to cool before touching or discarding it. Use a glass stirring rod to stir the liquid; never stir with a thermometer. Students should not be allowed to eat the snack foods once they are brought into the lab. This lab should be performed in a well-ventilated room. Wash hands thoroughly with soap and water before leaving the laboratory.*

**Procedure**

1. Push the pin through the cork so that the pin head is flush with the cork. If the pin is large enough, try to go through the center. If this is hard to do, try to insert the pin at an angle through the side and top of the cork. See Figure 1. **Note:** This setup will now be referred to as the “Food Holder.”

2. Place a food sample on the food holder. Measure and record the combined mass of the food holder and sample. Place the food holder on the base of a support stand.

3. Using a graduated cylinder, measure and add 50.0 mL of water to an empty, clean soda can.

4. Bend the tab on the soda can and slide a glass stirring rod through the hole. Suspend the can on a support stand using a metal ring. See Figure 2. Adjust the height of the can so that it is about 2.5 cm above the food holder.

5. Insert a thermometer into the can. Measure and record the initial temperature of the water.

6. Light the food sample and center it under the soda can. Allow the water to be heated until the food sample stops burning. Record the maximum (final) temperature of the water in the can.

7. Measure and record the final mass of the food holder and sample.

8. Clean the bottom of the can and remove any food residue from the food holder.

9. Repeat steps 1–8 two more times with two different snack food samples.

**Disposal**
Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Burned food samples should be allowed to cool and may be disposed of in the trash according to Flinn Suggested Disposal Method #26a.

**Sample Data Table** (Student data may vary.)

**Data Table — The Experiment**

<table>
<thead>
<tr>
<th>Food Sample</th>
<th>Initial Mass (food sample and holder), g</th>
<th>Final Mass (food sample and holder), g</th>
<th>Initial Temperature of Water, °C</th>
<th>Final Temperature of Water, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese Puff</td>
<td>4.18 g</td>
<td>4.08 g</td>
<td>21.8 °C</td>
<td>27.1 °C</td>
</tr>
<tr>
<td>Marshmallow</td>
<td>6.08 g</td>
<td>6.00 g</td>
<td>22.0 °C</td>
<td>23.6 °C</td>
</tr>
<tr>
<td>Onion Ring</td>
<td>4.87 g</td>
<td>4.74 g</td>
<td>23.0 °C</td>
<td>30.1 °C</td>
</tr>
</tbody>
</table>

**Analysis and Calculations** (The sample calculations are for a cheese puff.)

1. Determine the change in temperature of the water by subtracting the initial water temperature from the final water temperature.
   \[ \Delta T = T_{\text{final}} - T_{\text{initial}} = 27.1 \degree C - 21.8 \degree C = 5.3 \degree C \]

2. Calculate the heat gained by the water using Equation 1 from the Background section. The mass of water used is 50.0 g and the specific heat of water (C) is 1.0 cal/g °C. These values will give you the heat gained in calories.
   \[ Q = m \times C \times \Delta T = 50.0 \text{ g} \times 1.0 \text{ cal/g}^\circ C \times 5.3 \degree C = 265 \text{ cal.} \]

3. Convert the heat gained from calories to food Calories (kilocalories) by dividing the answer above by 1000.
   \[ 265 \text{ cal.} \div 1000 = 0.265 \text{ Cal.} \]

4. Determine how much of the food burned by subtracting the final mass of the cork/pin/food assembly from the initial mass.
   \[ 4.18 \text{ g} - 4.08 \text{ g} = 0.10 \text{ g} \]

5. Calculate the energy content per gram of the food sample. This is done by dividing the heat gain of the water (in Calories), by the change in mass of the food sample.
   \[ 0.265 \text{ Cal.} \div 0.1 \text{ g} = 2.65 \text{ Cal/g} \]

*Note to Teacher:* The total energy content in Calories per gram for all the foods will be lower than the actual energy content listed on their nutrition label. This is due to the simplicity of the calorimeter used in this experiment. However, if the foods are ranked from highest energy content to lowest energy content based on the class results, the relative ranking should be the same as an actual ranking from the nutrition labels. You might want to summarize the results obtained above (in Cal/g) for three foods to show this is true.

**Tips**

- A butane safety lighter (Catalog No. AP8960) is recommended instead of matches because it may take about 10 seconds for the food to ignite.

- For further concept development, try the Flinn Scientific “Calorimetry Basics—Specific Heat Laboratory Kit” (Catalog No. AP5952).
• Have students pin the food piece at one of the ends so that the piece “points up” and the length is parallel to the pin.

• It may take about 10 seconds to get the food ignited, so some heat related to the burning food will be lost during this process. A small flame on the food will spread and engulf it over time.

• Be sure that when the food sample burns, it is close to but not touching the soda can. If it is too close to the bottom of the can, it may extinguish too early due to a lack of oxygen.

• Black carbon soot will deposit on the bottom of the can when the food burns. For best results, this soot should be wiped off with a little water and a paper towel between trials.

Sample Data Table (Student data may vary.)

Data Table — The Experiment

Analysis and Calculations (The sample calculations are for a cheese puff.)

1. Determine the change in temperature of the water by subtracting the initial water temperature from the final water temperature.

$$\Delta T = T_{\text{final}} - T_{\text{initial}} = 27.1 \ ^\circ C - 21.8 \ ^\circ C = 5.3 \ ^\circ C$$

2. Calculate the heat gained by the water using Equation 1 from the Background section. The mass of water used is 50.0 g and the specific heat of water (C) is 1.0 cal/g °C. These values will give you the heat gained in calories.

$$Q = m \times C \times \Delta T = 50.0 \ g \times 1.0 \ \text{cal}/g^\circ C \times 5.3 \ ^\circ C = 265 \ \text{cal}.$$  

3. Convert the heat gained from calories to food Calories (kilocalories) by dividing the answer above by 1000.

$$265 \ \text{cal} \div 1000 = 0.265 \ \text{Cal}.$$  

4. Determine how much of the food burned by subtracting the final mass of the cork/pin/food assembly from the initial mass.

$$4.18 \ g - 4.08 \ g = 0.10 \ g$$  

5. Calculate the energy content per gram of the food sample. This is done by dividing the heat gain of the water (in Calories), by the change in mass of the food sample.

$$0.265 \ \text{Cal} \div 0.1 \ g = 2.65 \ \text{Cal/g}$$

**Note to Teacher:** The total energy content in Calories per gram for all the foods will be lower than the actual energy content listed on their nutrition label. This is due to the simplicity of the calorimeter used in this experiment. However, if the foods are ranked from highest energy content to lowest energy content based on the class results, the relative ranking should be the same as an actual ranking from the nutrition labels. You might want to summarize the results obtained above (in Cal/g) for three foods to show this is true.

Tips

• A butane safety lighter (Catalog No. AP8960) is recommended instead of matches because it may take about 10 seconds for the food to ignite.

• For further concept development, try the Flinn Scientific “Calorimetry Basics—Specific Heat Laboratory Kit” (Catalog No. AP5952).

• Have students pin the food piece at one of the ends so that the piece “points up” and the length is parallel to the pin.

• It may take about 10 seconds to get the food ignited, so some heat related to the burning food will be lost during this process. A small flame on the food will spread and engulf it over time.

• Be sure that when the food sample burns, it is close to but not touching the soda can. If it is too close to the bottom of the can, it may extinguish too early due to a lack of oxygen.

• Black carbon soot will deposit on the bottom of the can when the food burns. For best results, this soot should be wiped off with a little water and a paper towel between trials.
• Have students try different samples of food in order to compare the caloric contents of different foods. Note: Avoid sugar cookies, pretzels, soda crackers or other food samples with a high sugar content. They tend to get soft as they burn and may fall off the pin. Walnuts, pecans, popped corn, and Cheetos® (or other puffed snacks) are good choices.

• Good ventilation is required since burning food can generate a large amount of smoke. Allow some time between trials so that the smoke has time to dissipate.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, conservation of energy, interactions of energy and matter

References

Cesa, I. Flinn ChemTopic™ Labs, Volume 10, Thermochemistry; Batavia, IL, 2002; pp 39–49.

Materials for Soda Can Calorimeter are available from Flinn Scientific, Inc.

<table>
<thead>
<tr>
<th>Catalog No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>OB2096</td>
<td>Flinn Scientific Electronic Balance (0.01-g precision)</td>
</tr>
<tr>
<td>AP8308</td>
<td>Cork Stopper, Size 8</td>
</tr>
<tr>
<td>AP8960</td>
<td>Butane Safety Lighter</td>
</tr>
<tr>
<td>GP2044</td>
<td>Graduated Cylinder, Borosilicate Glass, Plastic Base, 50 mL</td>
</tr>
<tr>
<td>AP8232</td>
<td>Metal Ring Support with Rod Clamp</td>
</tr>
<tr>
<td>AB1039</td>
<td>Pin, 2&quot; Dissection</td>
</tr>
<tr>
<td>GP5075</td>
<td>Stirring Rod, Glass</td>
</tr>
<tr>
<td>AP8228</td>
<td>Support Stand</td>
</tr>
<tr>
<td>AP6049</td>
<td>Flinn Digital Pocket Thermometer</td>
</tr>
</tbody>
</table>

Testing for Organic Molecules Lab

Objective
In this lab you will design and conduct a controlled experiment where you will test for the presence of organic molecules in a series of unknown foods. You will need to have the student research proposal stamped prior to the start of the lab.

Things to include
The following is a list of questions and information that must be included in your lab report. Keep in mind your lab report is not limited to the following criteria. See the lab report rubric for all essential components that are necessary in your laboratory investigation and lab report.

- As you begin testing the unknowns, make predictions on what the unknowns might be.
- For each unknown elaborate on what role the unknowns play in homeostasis.
- Include a molecular structure of the unknowns.
- Make sure you have included qualitative and quantitative data.
Calculating Food Calories

DATA CALCULATIONS:

- \( q = mC\Delta T \) (1000 cal = 1kcal = 1 nutritional Cal)
- Remember that 1 ml of water weighs 1 g
- The specific heat of water is 1 calorie/gram °C

1. How many kilocalories/gram are in cheerios if in a calorimeter experiment the 7 gram cheerio lost 3 grams when it was burned surrounding a 100 ml water bath. The temperature of the water found to increase from an initial temperature of 21.2°C to a final temperature of 24.4°C.
   a) How many Calories/gram are in cheerios?
   b) If you were to consume 47 grams of cheerios, how many calories would you be consuming?

2. How many kilocalories/gram is in a taco if in a calorimeter experiment the 53-gram taco after burned measured 52.99 grams surrounding a 100 ml water bath. The temperature of the water found to increase from an initial temperature of 21.0°C to a final temperature of 61.0°C.
   a) How many Calories/gram are in a taco?
   b) How many calories would you be consuming if you were to have three tacos?

3. Which food source overall is high in calories eating 2Tbsp (32 g) of peanut butter at 190 Calories or 9 pieces (85 g) of potato chips at 150 Calories? Explain.

4. If a candy bar has a total mass of 80.0 grams. In a calorimeter experiment, a 0.5-g sample of this candy bar was burned in a calorimeter surrounded by 500 mL of water. The temperature of the water in contact with the burning candy bar was measured and found to increase from an initial temperature of 21.2°C to a final temperature of 26.4°C.
   a) How many Calories/gram are in a candy bar?
   b) Calculate the total caloric content of the candy bar in Calories.
Sample Biochemistry Unit Plan

<table>
<thead>
<tr>
<th>NGSS Based Performance Expectation</th>
<th>Teaching Strategies</th>
<th>Assessment Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.</td>
<td>Day 1-2 Explore/Explain/Evaluate: XCC: Scale, Proportion &amp; Quality Practice: Model, construct explanations, and communication Students will take part in a discussion regarding the meaning of the word biology and biochemistry. Utilizing the definitions of both words students will discuss the hierarchy in life. In groups, students will utilize their ipads or course textbook to research and identify the organization from atom to biosphere. Students will model and communicate the organization of life utilizing classroom supplies. Students will evaluate each other’s models and explain which</td>
<td>Evaluate and Explain: Major Lab Investigation Students will design a lab where they will test a series of unknown foods in the effort to identify the macromolecules found in the food. Utilizing their findings, students will construct explanations on the role the food has on the function of the organism; students will construct the molecular formula, and describe the overall end result for the molecules in the food.</td>
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<tr>
<td>HS-LS1-2. Develop and use a model to Illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms</td>
<td></td>
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<tr>
<td>HS-LS1-6. Construct and revise an explanation based on</td>
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</tr>
</tbody>
</table>

Evaluate, Explain, and Evaluate: Major Lab Investigation Students will setup a calorimeter in an effort to quantify the amount of energy stored in various foods. Students will evaluate and explain their findings in regards to nutritional.
| Evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. | Models they found to be all encompassing. [Classroom supplies to be given include: paper clips, pipe cleaners, beads, construction paper, cups, wire hangers, string, etc.] | Value, energy storage, and molecular size.
Extension: Have students design a calorimeter or device/tracking method that people can use to monitor diet and nutrition (HS-ETS1-2). |
|---|---|---|
| **Day 3**  
**Engage/Explain**  
XCC: Stability & Change  
**Practice:** Communicate, argue from evidence, and construct explanations  
Show students the demo of what happens when you place one drop of cement glue in water and discuss whether what they observe is a living organism. Students will collaboratively construct and argue a list of characteristics that define a living organism. Utilizing a finalized list, students will view a powerpoint reading a fictitious scenario and determine if sammy is alive. [See attached resources regarding Is Sammy Alive activity]  
| **Explain**  
**XCC:** Stability & change, Structure & function, cause & effect  
**Practice:** Construct explanations,  
Students will be given Are Viruses Alive? By: Luis Villarreal to read and they will utilize the article to explain the location of all four macromolecules within a cell and explain their overall function in maintaining homeostasis.  
| **Quizzes:**  
- Organic Molecule  
- Characteristics of life/levels of organization  
| **Summative Assessments:**  
- Biochemistry Unit Test  

| Day 4  
**Explain**  
**XCC:** Stability & change, Structure & function, cause & effect  
**Practice:** Construct explanations,  
Students will be given Are Viruses Alive? By: Luis Villarreal to read and they will utilize the article to explain the role the organic molecule plays in homeostasis.  
| **Discuss**  
**XCC:** Stability & change, Structure & function, cause & effect  
**Practice:** Construct explanations,  
Students will be given Are Viruses Alive? By: Luis Villarreal to read and they will utilize the article to explain the role the organic molecule plays in homeostasis.  
| **Summative Assessments:**  
- Biochemistry Unit Test  

| Classroom supplies to be given include: paper clips, pipe cleaners, beads, construction paper, cups, wire hangers, string, etc.]
why viruses walk the fine line of being living/nonliving and why we ultimately consider them to be nonliving.

**Elaborate:**
Discuss the importance of cells and why they are considered to be the basic unit of life. Discuss that within a cell there is organization within internal structures that allow the cell to function. Students will communicate the connection between the modeling organization levels activity to the fact that we are but systems made up of a group of interacting atoms and molecules. [Segue discussion into CHNOPS and the macromolecules]

Day 5-6

**Engage/Explain:**
XCC: Structure & function
Practice: Ask questions, argue from evidence, analyze data.
Students will view a demo on the use of benedict and lugol solutions as an indicator that tests for the presence of carbohydrates. Teacher will use various foods that will test positive and negative for the presence of carbohydrates and starch. Discuss with students the structure and function of simple and complex carbohydrates. Students will be shown simple and
complex molecular structures. Students will be given a series of molecules where they will evaluate and argue which molecules are considered to be carbohydrates. [See Organic Molecule Sheet] Have the students save the sheet for later reference as they will identify all the organic molecules on the sheet as we go through them. [Characteristics of life/levels of organization/function of lipids. Students will communicate and argue why it is important to monitor the intake of lipids in relation to their function in the body and their caloric amount per gram.

Day 9
Engage/Explain:
XCC: Structure & function
Practice: Ask questions, analyze data
Students will view a demo on the use of biuret solution as an inn quiz given at this point]

Day 7-8
Engage/Explain:
XCC: Structure & function
Practice: Ask questions, argue from evidence, analyze data
Students will view a demo on the use of Sudan solution and grease spot test as indicators that test for the presence of lipids. The teacher will use various foods to demonstrate a positive and a negative test
result. Discuss with students the structure and function of proteins. Students will view a series of animations on the function of proteins throughout the body.

Day 10
Explore:
XCC: Structure & function, stability & change
Practice: Model, construct explanations, argue from evidence
Students will model and construct an insulin protein utilizing the insulin protein puzzle sheet. From the activity, students will construct an explanation on how the structure of a protein may or may not allow it to function properly. Students will utilize the class activity and additional research to support their argument.

Day 11-12
Elaborate:
XCC: Structure & function
Practice: Model, construct explanations, and communicate
Students will take part in a discussion on the structure and function of nucleic acids. Students will utilize their iPads to draw and model DNA and RNA. Students will construct an explanation on the interdependence of DNA, RNA, and proteins in the
Day 13
Evaluate and Explain:
XCC: Energy & matter, patterns
Practice: Design an experiment, analyze data, construct explanations
Students will design a lab where they will test a series of unknown foods in the effort to identify the macromolecules found in the food. Utilizing their findings, students will construct explanations on the role the food has on the function of the organism; students will construct the molecular formula, and describe the overall end result for the molecules in the food. [See Organic Molecules Lab sheet]
[Prior to the start of the lab, students will complete the organic molecules quiz]

Day 14
Explain and Evaluate
XCC: Energy & matter, patterns
Practices: Analyze data, math/computational, construct explanations
Students will take part in a discussion on what a calorie is and what it measures. Students will analyze a graph that shows different physical activities and the amount of calories they burn. Students will view a nutritional label and asked to identify what
they think the food is high and low in. Students will be instructed on how to read a nutritional label. Students will cooperatively analyze a series of nutritional labels and they will communicate their findings regarding the nutritional importance of the food. Students will quantify the amount of calories in various foods utilizing the heat transfer formula. [See calculating calories sheet]

Day 15
Explore, Evaluate, and Explain:
Major Lab Investigation
XCC: Energy & matter, patterns
Practice: Design an experiment, analyze data, construct explanations
Students will setup a calorimeter in an effort to quantify the amount of energy stored in various foods. Students will evaluate and explain their findings in regards to nutritional value, energy storage, and molecular size. [See Soda Can Calorimeter on possible setup]

Day 17
Explain and Evaluate
XCC: Structure & function, patterns, stability & change
Practice: Model, construct explanations, argue from evidence
Students will model, construct explanations, and provide
<table>
<thead>
<tr>
<th>evidence on the location and function of the organic molecule in regards to homeostasis on the organism and cellular level.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 18</td>
</tr>
<tr>
<td>Teacher generated summative assessment.</td>
</tr>
</tbody>
</table>
APPENDIX H  Teacher Resources for HOMEOSTASIS UNIT
Introduction to Osmosis “Eggsperiment”

I. What is happening to these eggs?

Most cells are tiny – much too small to see without the help of a microscope. In contrast, an unfertilized chicken egg is a giant cell. You will use a chicken egg to investigate movement of water across the cell membrane that surrounds each cell.

1. Why do you think it is important for each cell to be surrounded by a cell membrane that can prevent large molecules from leaving the cell?

2. The cell membrane allows some small molecules like oxygen and carbon dioxide to cross. Why do you think it is important for oxygen and carbon dioxide to be able to cross the cell membrane?

In this investigation you will see that water can cross the cell membrane surrounding an egg. You will investigate which way water moves across the membrane, depending on the type of liquid surrounding the egg. When water moves across the cell membrane, the egg changes in size and appearance.

Your group will be given two eggs. To begin, record the weight and/or circumference of these eggs in the day 1 row of the table. (Measure the circumference around the widest part, not lengthwise.)

Caution: Because these are raw eggs, they may carry salmonella, so you should use care when handling the eggs. If an egg should break, call for your teacher asap.

<table>
<thead>
<tr>
<th>Day</th>
<th>Egg 1</th>
<th>Egg 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (grams)</td>
<td>Circumference (cm)</td>
</tr>
<tr>
<td>1</td>
<td>(with shell)</td>
<td>Egg put into vinegar</td>
</tr>
<tr>
<td>2</td>
<td>(most of shell removed)</td>
<td>Egg put into water</td>
</tr>
</tbody>
</table>

1 By Dr. Ingrid Waldron, Dept of Biology, University of Pennsylvania, © 2014. Teachers are encouraged to copy this Student Handout for classroom use. A Word file, which can be used to prepare a modified version if desired, and Teacher Preparation Notes with background information and instructional suggestions are available at http://serendip.brynmawr.edu/sci_edu/waldron/#osmosis.
Put each egg in a container labeled Egg 1 or Egg 2 with enough vinegar to cover the egg. Cover the container. Do you see bubbles forming around the egg? These are bubbles of CO₂ which result from the chemical reaction between the acetic acid in the vinegar and the calcium carbonate in the eggshell. This reaction will dissolve most of the eggshell by day 2. Observe your eggs. Notice that most of the shell has been dissolved by the acetic acid in the vinegar. Although most of the shell is gone, each egg is still surrounded by a shell membrane outside the cell membrane. The shell membrane has protein fibers that give it much greater strength than the cell membrane. However, the egg without its shell is still fragile, so you will need to handle your eggs very gently and carefully!

Dry each egg and measure the weight and/or circumference of each egg. Record your results for day 2 in the table on page 1.

3. Did the eggs become heavier/larger ___ or lighter/smaller ___? What do you think happened to cause this change in weight/size?

Empty the vinegar from the container for egg 1 and replace it with water to cover the egg.

Empty the vinegar from the container for egg 2 and replace it with corn syrup to cover the egg. As you pour the corn syrup, notice that it is viscous (thick, sticky).

4. What do you think causes the corn syrup to be so viscous?

Day 3

5. Compare and contrast the appearance of the egg that has been in water vs. the egg that has been in corn syrup.

6. You should be able to observe a layer of water on top of the corn syrup. Where do you think this water came from?

Rinse the corn syrup off of egg 2. Dry each egg and measure and record the weight and/or circumference for day 3 in the table on page 1.

7. What happened to cause the change in weight/volume of the egg placed in corn syrup?

8. Why did the egg placed in water get bigger and heavier? Where did the additional weight/volume come from?
II. Understanding Osmosis

The cell membrane that surrounds each cell is a selectively permeable membrane. A **selectively permeable membrane** allows some types of molecules and ions to cross the membrane and prevents other types of molecules and ions from crossing the membrane.

**Osmosis** is the diffusion of water across a selectively permeable membrane.

1a. During **diffusion**, more molecules will move
   a. from regions of higher concentration to regions of lower concentration
   b. from regions of lower concentration to regions of higher concentration

1b. The reason is that:
   a. Crowded molecules want to move to an area with more room
   b. Molecules tend to keep moving until they are uniformly distributed and then they stop moving.
   c. The random motion of molecules results in their uniform distribution in the available space.

**Explanation of Osmosis**

Na\(^+\), Cl\(^-\), and the water molecules that are bound to these ions cannot cross the selectively permeable membrane (called a semipermeable membrane in this figure). Only free water molecules (water molecules that are not bound to ions or other solutes) can cross the selectively permeable membrane.

During osmosis, diffusion results in movement of free water molecules in both directions across the selectively permeable membrane, but more free water molecules move from the region of higher concentration of free water molecules to the region of lower concentration.

2. Why is the concentration of free water molecules lower in water with dissolved salt and higher in pure water?

3. Why does osmosis result in a net flow of water from the side of the tube that has pure water to the side of the tube that has water with dissolved salt? Include in your explanation the relative concentrations of free water molecules on the two sides of the tube.
This figure shows the effects of osmosis on animal and plant cells put in three different types of surrounding fluid.

4a. Which animal cell looks like the egg in corn syrup? ___

4b. Which animal cell looks like what could have happened to the egg in water, if the egg didn't have a strong shell membrane around it? ___

Inside the cell membrane, each cell contains cytosol, a watery substance with a high concentration of dissolved molecules and ions.

5. Which has a higher concentration of free water molecules – the cytosol inside a cell ___ or pure water___?

If a cell is surrounded by pure water, will more water diffuse into the cell ___ or out of the cell ___? Explain your reasoning.

Does this situation match A ___ or B ___ or C ___ in the figure?

6. If very salty water has a higher concentration of dissolved substances than cytosol, which has a higher concentration of free water molecules – the cytosol inside a cell ___ or the very salty water ___?

If a cell is surrounded by very salty water, will more water diffuse into the cell ___ or out of the cell ___? Explain your reasoning.
Does this situation match A __ or B __ or C __ in the figure?
7. Most animal cells are surrounded by a layer of water with dissolved substances. For animal cells to function normally, there should be equal amounts of water diffusing into and out of the cell, as shown in figure B on the previous page. Which type of surrounding fluid would result in equal amounts of water diffusing into and out of a cell?

- water with a higher concentration of dissolved substances than the cytosol
- water with a lower concentration of dissolved substances than the cytosol
- water with the same concentration of dissolved substances as the cytosol

8. If a person drinks a very large amount of water in a short time, this may result in confusion, seizures, coma, or even death, due to abnormal functioning of nerve cells in the brain. Explain how these problems could result from drinking too much water too rapidly.

9. Explain why the surrounding fluid has a different effect on animal cells vs. plant cells in figure C on the previous page.

10. Suppose that an animal's cells had cell walls. What problems would this cause for the animal?

Challenge Questions
What do you think is the reason that a person who is stranded at sea should not drink ocean water?
How could drinking salty water harm a person's cells?

Some archaea (single cell organisms) live in extremely salty water such as the Great Salt Lake or the Dead Sea. Most types of cells would shrivel and die in this very salty water. How do you think these archaea prevent water loss while living in very salty water?
<table>
<thead>
<tr>
<th>NGSS Based Performance Expectation</th>
<th>Teaching Strategies</th>
<th>Assessment Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HS-LS1-3</strong> Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td>
<td><strong>Day 1 Engage:</strong> XCC: Cause and Effect; Stability &amp; Change Practice: Communicate Show students demonstration of celery in water, salt water, distilled water. After placing celery into various solutions, have students talk with a partner to predict what will happen to each. Then, have them sketch the setup and write their predictions. Discuss how these predictions are hypotheses (and any specific formatting that you require for a hypothesis). When an observable change has occurred, have students turn to their partner and explain the change using key terms (water, polarity, solution, solvent, etc.). Each student should then sketch results and write their explanations. Discuss explanations, focusing on water’s structure, polarity, and special properties. End class having students turn to partners and brainstorm/describe examples of the various properties.</td>
<td><strong>Evaluate and Explain:</strong> Major Investigation Students will design, implement, and report on transpiration in a plant shoot. Teacher should provide a model transpirometer, plant shoots, various substances for transpiration, light sources, heat sources, etc. Students should prepare brief proposals for their experiments, protocol for the experiment, and at the end a formal lab report. <strong>Suggested Formative Assessments:</strong> Students can make a photo journal of examples of key terms from the unit (homeostasis, osmosis, etc.). They can take selfies of themselves with examples of each and write a short caption to explain. <strong>Quizzes:</strong></td>
</tr>
<tr>
<td><strong>HS-LS1-6</strong> Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon based molecules.</td>
<td><strong>Days 2-5 Elaborate and Explain</strong> XCC: Structure and Function; Stability &amp; Change; Practice: Construct explanations Day 2 Present students with chicken eggs (from grocery store). Have students describe where these eggs would fit into models of hierarchy of life. Discuss. Then, have students describe the function of the egg and how it differs from, say, a human egg.</td>
<td></td>
</tr>
<tr>
<td>Lead discussion to environmental conditions that the egg must withstand. Then, distribute an egg to each group. Have the groups sketch/photograph/ or otherwise document their egg and measure circumference and mass before placing it into a vinegar solution. Have the groups hypothesize about what the vinegar will do to the egg, then place them in. Have students record observations in their lab notebooks. As the eggs sit in solution, have groups research the purpose and composition of the egg shell to validate their predictions/observations. Also have them research vinegar in chemical terms. Now, they may go back and amend/modify their hypotheses (but not delete the original). Bring class discussion back to the chemical properties of vinegar and its role in this demonstration. Discuss. Day 3 Once the shells are dissolved from the eggs, allow students to observe the egg, again measuring circumference and mass. Have them hypothesize about what part of the egg they are touching and what it does. When they are done, they may place the eggs into a syrup solution and hypothesize about what will happen to the egg the next day. Then, lead a discussion regarding the plasma membrane and what it is. Have students view the fluid mosaic jarred model of phospholipids. Then, have them discuss why/how the phospholipids align the way that they do. Discuss what this means for transport into and out of the membrane. Then, have the students assemble 3-D paper models of the</td>
<td>Teacher can design and administer quizzes as he/she sees fit. One suggestion would be to have open notebook lab quizzes following investigations to reinforce scientific concepts as well as thought. Practical quiz: Teacher can set up beakers of starch solution (4-5 beakers of solutions with varied concentration). Color each beaker differently so that they can be easily differentiated, but do not tell students the concentrations. Have students put potato cores into each and monitor changes in the potato cores. Using change in mass and flaccidity, students should be able to create a scale/ranking of the concentration of the unknown solutions. Extension (for advanced students) - Have students plot data to find the concentration of the original potato core. Especially advanced students may even be able to compare it to a yam or sweet potato.</td>
<td></td>
</tr>
</tbody>
</table>
cell membrane., using sticky notes to emphasize the role of each feature.

Day 4
When students return the next day, present the term tonicity. Then, have them look for word roots and derive a definition for the word ‘hypertonic’. When they have done so, have them make observations and again record circumference and mass of their eggs. Have students explain why their eggs changed in the way that they did using their new term. Now, have them define the term ‘hypotonic’, and have them brainstorm what type of solution might be hypotonic to their eggs. Then, have them place the egg into that solution (water) and predict what they will see the following day. If time allows, have students describe the role of the membrane (and shell) in maintaining homeostasis in this case.

Day 5
On the last day, have students record data from their eggs, and write a conclusion about what happened to the egg and why the shell might be important to a developing chick. Students should then define the term ‘isotonic’ and describe what would happen to the egg in that situation, relating all three terms to ‘homeostasis’. If time allows: You may discuss the environmental differences that an internal embryo faces. You may also challenge students to return the egg to as close to its original size as possible.

Day 6 Explore:
Have students work in pairs/small groups to come up with a definition of the terms solution, solute, and solvent. Discuss. Ask groups of students to predict what would happen if a plant were given a solution instead of water. Ensure that each group explains their predictions and uses evidence from Eggsperiment to justify.

Using microscopes and various plant cells (potato, elodea, etc). Have students explore the impact of solutions on cell structures. Students should document their procedures, hypotheses, and observations. Pairs, or small groups of students, should then explain why the plant cells behaved the way they did and compare their behavior to the egg cells.

Extension activity - challenge students to restore plant cells to original size.

Discuss acids and bases to assess student preconceived ideas. Have students work in lab groups to design pH indicators using red cabbage juice. Each group should use the cabbage juice to test various substances. Then, using their results, they should create a color scale that can be used to test pH. After they finish creating their own scales, they may compare their results to other groups and to standardized pH paper. Each group should then explain any differences that they find, using their
understanding of cabbage juice as a solution.

<table>
<thead>
<tr>
<th>Day 10</th>
<th>Explore</th>
</tr>
</thead>
<tbody>
<tr>
<td>XCC: Structure and Function; Stability &amp; Change; Cause and effect.</td>
<td>Practice: Asking questions; design experiments.</td>
</tr>
<tr>
<td>Have students discuss how plants exchange materials with their environments and why they would need to do so. Regroup as a class and share ideas. Discuss the term homeostasis, and have students discuss what plants might have to do to maintain homeostasis. Present students with different types of leaves, and have them examine them for clues about whether their ideas were accurate. Lead students around the leaf, discussing their observations (“why is the top waxy/shiny? Why is the underside different? etc.”). Using clear nail polish, have students make impressions of the underside to view under the microscope. This is a good time to discuss light transmission and using the microscope. Have students sketch their observations - leading them to the observation of guard cells/stomata. Have students hypothesize about their function. As a class, discuss. Then, supply students with lamps, fans, etc. and more leaves (including shade vs. full sun varieties). Have students explore stomata behavior under different environmental or species circumstances.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days 11-12</th>
<th>Explore and Engage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>XCC: Structure and Function; Stability &amp; Change;</td>
<td>Practice: Asking questions; Design experiments; Analyze data; Construct explanations; communicate</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Transpiration Lab - student designed (see major investigation). Students should complete proposals before beginning and formal lab reports upon conclusion.</td>
<td></td>
</tr>
<tr>
<td><strong>Day 13</strong></td>
<td>Evaluate Summative Assessment for the unit - teacher designed.</td>
</tr>
</tbody>
</table>
APPENDIX I  TEACHER RESOURCES FOR ENERGY UNIT
Enzyme activity graphs

1. The table below shows the volume of oxygen gas produced during an investigation on the activity of catalase from potato tissue on hydrogen peroxide.

<table>
<thead>
<tr>
<th>Time from adding potato tissue (s)</th>
<th>Volume of oxygen gas (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>4.3</td>
</tr>
<tr>
<td>40</td>
<td>6.5</td>
</tr>
<tr>
<td>60</td>
<td>7.7</td>
</tr>
<tr>
<td>80</td>
<td>8.4</td>
</tr>
<tr>
<td>100</td>
<td>8.8</td>
</tr>
<tr>
<td>120</td>
<td>9.1</td>
</tr>
<tr>
<td>140</td>
<td>9.3</td>
</tr>
</tbody>
</table>

a. Draw a graph of the data and use it to find the rates of the reaction 10, 80 and 140 seconds after the start.

b. Describe the pattern of the graph.

c. Explain the changes to the rate of reaction during the investigation.

2. A student carried out an investigation on the effect of increasing catalase concentration on the rate of the reaction. Draw a sketch graph showing the pattern you would expect in the results.

3. Another student carried out an investigation on the effect of increasing the concentration of hydrogen peroxide on the rate of the reaction.

   a. Draw a sketch graph showing the pattern you would expect in the results.

   b. Add a second line to the graph showing the effect of adding a competitive inhibitor to the catalase, hydrogen peroxide mixture. Label the line.

   c. Add a third line to the graph showing the effect of adding a non-competitive inhibitor to the catalase, hydrogen peroxide mixture. Label the line.
Enzyme Lab

Throughout your body, at any given time, there are millions upon millions of chemical reactions occurring. Each of these reactions involves the breaking of covalent bonds formation of bonds between smaller molecules. Most of these reactions called an enzyme. **An enzyme is a protein that lowers the activation energy so that a reaction can occur within the body.** The purpose of this lab is to investigate enzymes and what type of conditions, enzymes work best.

The reaction you will be testing is the conversion of \( \text{H}_2\text{O}_2 \) into water and oxygen gas by the enzyme catalase:

\[
\text{catalase} \quad \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2
\]

**Control Trial:**

- **For all these experiments, use a number scale from 0 to 5 describe the level of activity, with 0 = no reaction and 5 = vigorous bubbling.**

a. Take two test tubes

b. Put 1 mL liver puree in the other tube, using the same method.

c. Into the first test tube put 3 mL of \( \text{H}_2\text{O}_2 \). **Describe results below.** Watch the reaction for several seconds, noting the height of the bubbles travel as well as the speed with which the reaction occurs. Assign this level of bubbling “4.” **These will be the standards by which you compare the other reactions today.**
**Trial 1: Effect of Temperature on Enzyme Activity**

- Tube 1: temperature of ice bath
- Tube 2: room temperature of enzyme
- Tube 3: 37 degrees Celsius
- Tube 4: temperature of hot water bath

a. Put 1 mL liver puree into the four clean test tubes using the method described in step 2 of the control experiment, above.
b. Place the liver puree in the appropriate bath so that it can reach the indicated temperatures above.
d. Add to the appropriate test tube 3 mL of the H$_2$O$_2$. Place the H$_2$O$_2$ in its appropriate water bath as well.
e. Add the H$_2$O$_2$ to the liver and observe the reaction rate.
f. Measure the column of bubbles generated for each test tube and give each reaction a rating.
g. Create a temperature vs. reaction rate graph and a temperature vs. column of bubbles formed in the data section of your lab report.

**Trial 2: Effect of pH on Enzyme Activity**

a. Label three test tubes with tape “Acid”, “Neutral”, and “Base”
b. Carefully put 1 mL liver puree into each tube.
c. Add 2 mL of the appropriate pH solution into each test tube.
d. Wait about 20 minutes.
e. Create a pH vs. reaction rate graph in the data section of your lab report.
f. Add 3 mL of H₂O₂ to each tube. Rate the reactions, and record your results below.

**Analysis questions**
Must be included in the conclusion.

1. Were there any results that surprised you?
2. With the various temperatures (cold, room temp, body temp, hot), which one had the greatest activity? Propose a reason why this would be.
3. For two situations where there was no reaction (or very little), propose reasons for these results. Think about how an enzyme’s shape plays a role in its ability to function.
4. What can you conclude from your graph about the relationship between temperature and reaction rate? Remember that reaction time and reaction rate are not the same thing (slower rate means longer reaction time).
5. What can you conclude from your graph about what happens to the reaction and to catalase when the temperature is too high?
6. The body’s internal pH is highly regulated to be between 7.3 and 7.4. This is true for liver cells as well. If you had a pH regulation problem, which can occur in some bacterial infections, and the pH of your liver cells dropped, hypothesize what might happen to your ability to catalyze hydrogen peroxide.
LACTASE ENZYME LAB

PURPOSE: to observe the breakdown of lactose, and only lactose, with the enzyme lactase.

INTRODUCTION
Lactose, the sugar found in milk, is a disaccharide composed of glucose and galactose (both six sided sugars). Sucrose, ordinary table sugar, is also a disaccharide composed of fructose and glucose. Glucose is a six sided sugar and fructose is a five sided sugar.

Lactase is an enzyme that breaks down lactose into galactose and glucose. Lactase can be purchased in pill form by people who are lactose intolerant. These people lack the enzyme lactase and cannot break down the sugar lactose into its component parts.

Although lactose is similar to sucrose, lactase will break down only lactose- due to the shape of the sugar.

In this lab, you will see lactase break down lactose into galactose and glucose. We will also observe what happens if the shape of lactase is changed due to heating.

MATERIALS
- Lactase Tablet
- 15 ml of Skim Milk
- Water
- Sucrose
- 100 ml Graduated Cylinder
- 10 ml Graduated Cylinder
- 3 400 ml Beakers
- 5 test tubes
- Test tube rack
- Marking pencil
- Clock
- Hot Plate with a pyrex test tube
- Glucose test strips
- Stirring Rod

PROCEDURES

Solution Preparation:
1) Enzyme Solution: Add 1 lactase tablet to 200 ml of water. Stir until the tablet has dissolved.
2) Skim Milk: this solution contains the lactose.
3) Sucrose Solution: Add 5 grams of sugar to 100 ml of water. Stir until the sugar has dissolved.
4) Denatured Enzyme Solution:
   a) Place 20 ml of Enzyme Solution into a pyrex test tube.
   b) Add 200 ml of water to a 400 ml pyrex beaker.
   c) Place the test tube in the beaker (gently laying the test tube so it rests on the side of the beaker.)
   d) Place the beaker and test tube on the hot plate.
   e) Boil the water in the beaker for 30 minutes.
   f) Let the solution cool to room temperature.

**Lab Procedures:**

1) Gather the materials.
2) Label the test tubes with the following labels:
   A) Test tube with skim milk and enzyme solution.
   B) Test tube with skim milk and water.
   C) Test tube with skim milk and denatured enzyme solution.
   D) Test tube with sucrose solution and enzyme solution.
   E) Test tube with sucrose solution and water.
3) In test tube A add 2 ml of skim milk and 1 ml of enzyme solution.
4) Time for 2 minutes and test for glucose with the glucose test tape. Record this data in table 1. If there was glucose present mark a '+' in the table. If glucose was absent, mark a '-' in the table.
5) In test tube B add 2 ml of skim milk and 1 ml of water.
6) Repeat step 4.
7) In test tube C add 2 ml of skim milk and 1 ml of denatured enzyme solution.
8) Repeat step 4.
9) In test tube D add 2 ml of the sucrose solution and 1 ml of enzyme solution.
10) Repeat step 4.
11) In test tube E add 2 ml of the sucrose solution and 1 ml of water.
12) Repeat steps 4.

**RESULTS:**

You can make this into a table 6 rows by 2 columns: In the second column, record if the glucose test is positive or negative.

Table 1: Glucose presence in the following solutions.
<table>
<thead>
<tr>
<th>Type of Solution</th>
<th>Positive or negative Glucose Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test tube A:</td>
<td></td>
</tr>
<tr>
<td>Milk and Enzyme Solution</td>
<td></td>
</tr>
<tr>
<td>Test tube B:</td>
<td></td>
</tr>
<tr>
<td>Milk and Water</td>
<td></td>
</tr>
<tr>
<td>Test tube C:</td>
<td></td>
</tr>
<tr>
<td>Milk and Denatured Enzyme Solution</td>
<td></td>
</tr>
<tr>
<td>Test Tube D:</td>
<td></td>
</tr>
<tr>
<td>Sucrose Solution and Enzyme Solution</td>
<td></td>
</tr>
<tr>
<td>Test Tube E:</td>
<td></td>
</tr>
<tr>
<td>Sucrose Solution and Water.</td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSION**

1) Diagram and describe the Lactose and Lactase reaction.

2) Why did the enzyme react to lactose but not to sucrose?

3) What happened when the enzyme was boiled?

4) Another way to affect the enzyme is by lowering the pH of the solution. However, lactase is suppose to be able to work in the stomach. Would lowering the pH of the enzyme solution affect the enzyme? Why or why not?

5) What type of reaction is this? Dehydration or Hydrolysis?
Teacher Notes for
How do biological organisms use energy?²

This analysis and discussion activity is designed to help students understand the basic principles of how biological organisms use energy, with a focus on the roles of ATP and cellular respiration. This activity provides a useful basic understanding of cellular respiration and provides an important conceptual framework for students who will be learning the complex specifics of cellular respiration. This activity concludes with a brief introduction to two important principles: conservation of energy and the inefficiency of energy transformations.

Learning Goals
All organisms use a two-step process to provide the energy needed for most of their biological processes:
• First, chemical energy from organic molecules like glucose is transferred to ATP molecules in a process called cellular respiration.
• Then, ATP provides the energy for most biological processes.

Cellular respiration of organic compounds such as glucose provides the energy required to synthesize ATP by adding a third phosphate to ADP (bringing together two negatively charged phosphates). The following pair of chemical equations gives a simplified overview of the cellular respiration of glucose:

\[
\begin{align*}
C_6H_{12}O_6 + 6O_2 & \rightarrow 6 CO_2 + 6 H_2O \\
\text{energy} & \rightarrow \sim 29 \text{ADP} + \sim 29 \text{phosphate} \rightarrow \sim 29 \text{ATP}
\end{align*}
\]

When ATP molecules break down to ADP plus phosphate, the separation of two negatively charged phosphates releases energy; this provides the energy needed for many biological processes (e.g. muscle contraction, pumping molecules and ions across cell membranes, and synthesizing biological molecules).

Energy can be transformed from one type to another, but energy cannot be created or destroyed by biological processes. All types of energy conversion are inefficient and result in the production of heat. (These principles are the first law of thermodynamics and an implication of the second law of thermodynamics, but this technical term is not used in the Student Handout.)

In accord with the Next Generation Science Standards (http://www.nextgenscience.org/next-generation-science-standards), this activity:

² By Dr. Ingrid Waldron, University of Pennsylvania, 2014. These Teacher Notes, the related Student Handout, and other activities for teaching biology are available at http://serendip.brynmawr.edu/exchange/bioactivities.
• helps students to learn the Disciplinary Core Idea LS1.C: "... Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that" can provide energy for biological processes.
• engages students in recommended scientific practices, including constructing explanations and critical thinking.
• can be used to illustrate two Crosscutting Concepts, "Cause and effect: Mechanism and explanation" and "Energy and matter: Flows, cycles and conservation".
• helps students to prepare for Performance Expectation 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 and new compounds are formed resulting in a net transfer of energy."

Suggestions for Teaching this Activity and Background Information

To maximize student participation and learning, I suggest that you have your students work in pairs (or individually or in groups of three) to complete groups of related questions and then have a class discussion after each group of related questions. In each discussion, you can probe student thinking and help them to develop a sound understanding of the concepts and information covered before moving on to the next group of related questions. You will probably want to have a class discussion after each section of the Student Handout.

The Importance of ATP

Our cells are constantly using energy from organic molecules like glucose to make ATP and using the ATP molecules to provide the energy for biological processes such as muscle contraction, synthesizing molecules, and pumping ions and molecules into and out of cells.

You may want to point out that, although different types of organisms get their energy input from different sources (e.g. food, sunlight), all biological organisms need to make ATP which provides energy in a form that can be used for cellular processes. For example, you may want to discuss with your students why plant cells need mitochondria even though they can make glucose by photosynthesis.

In this introductory section, the following additional question may be useful for middle school students:

Which molecule is like money that a cell can "earn" through cellular respiration and "spend" to get things done?

ADP ___ ATP ___ CO₂ ___ glucose ___

Students may inquire about where ADP comes from. Nucleotides like ADP are derived from digestion of nucleic acids in food and also can be synthesized by the liver.

I. Cellular Respiration – Transferring Energy from Organic Molecules to ATP

Question 3a is designed to help students understand the Disciplinary Core Idea that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed and the energy released is captured in ATP molecules which
provide the energy for biological processes.

The molecular diagrams, together with the following information will help students understand why energy is released by the reaction:

\[
\begin{align*}
\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}=\text{O} & \rightarrow 6 \text{O} \equiv \text{C} \equiv \text{O} + 6 \text{H}_2\text{O} \\
\end{align*}
\]

The potential energy stored in C-C or C-H bonds is greater than the potential energy stored in C-O, C=O or H-O bonds. In a C-O, C=O or H-O covalent bond, the pair of shared electrons is pulled closer to the oxygen nucleus. In contrast, in C-C and C-H bonds, the pair of shared electrons is shared relatively equally; therefore, these electrons are farther from a positively charged nucleus so they have more potential energy than the pairs of shared electrons in C-O, C=O and H-O bonds. Thus, molecules like glucose which have a high proportion of C-C and C-H bonds have more potential energy than CO₂ and H₂O which have only C=O and H-O bonds.

To introduce and reinforce these concepts, you may want to add the following question on page 2 of the Student Handout.

Notice that the atoms in the C₆H₁₂O₆ and O₂ molecules are reorganized as atoms in the CO₂ and H₂O molecules. Although the atoms stay the same, C₆H₁₂O₆ (the sugar glucose) has multiple C-C and C-H bonds which have more stored chemical energy than the C=O and O-H bonds in CO₂ and H₂O. In the first chemical equation in 3a, use an asterisk to mark each higher energy C-C and C-H bond, and circle each lower energy C=O and O-H bond.

Fatty acids and glycerol from fat molecules can also undergo cellular respiration. As shown in the following diagram, these molecules have an even higher proportion of high-energy C-C and C-H bonds than a glucose molecule. This is one important reason why fat provides more energy per gram than carbohydrates (9 kcal per gram vs. 4; stored fat also has less associated water). Given the mobility of animals, this greater energy density is an important advantage for fat as the main energy storage molecule in animals.
Question 3b provides the opportunity to reinforce student understanding that the glucose for cellular respiration ultimately comes from food molecules. The immediate source of glucose for cellular respiration may be glycogen (a polymer that stores glucose) or conversion of fats or amino acids to glucose. In addition, fatty acids or amino acids can be used directly in cellular respiration.

In discussing question 3c, it should be mentioned that we need to breathe, not only to bring in O₂, but also to get rid of CO₂.

The equation shown in question 4 seems to imply that there are no molecular precursors for ATP. This equation can create the impression that ATP is made from the energy released by the oxidation of glucose, but energy is not converted to matter. The energy released by cellular respiration of glucose is used to join negatively charged ADP and phosphate to produce ATP. To balance this equation, ADP and phosphate should be added to the left side. You may want to refer to the conservation of matter, which will tie in with the conservation of energy, discussed at the end of the activity. An additional point is that there should be some indication that cellular respiration of a single molecule of glucose provides the energy to produce multiple molecules of ATP.
The equations for cellular respiration provided in this activity give a very simplified overview of a very complex process. This figure summarizes the multiple steps of cellular respiration, although of course it omits many of the specific steps.

![Process: Summary of Cellular Respiration](image)

(From “Biological Science” by Scott Freeman, Benjamin Cummings, 2011)

Notice that cellular respiration generates ~29 molecules of ATP for each glucose molecule; this number is less than previously believed (and often erroneously stated in textbooks). Brief explanations are provided in:

- "Approximate Yield of ATP from Glucose, Designed by Donald Nicholson" by Brand, 2003, Biochemistry and Molecular Biology Education 31:2-4 (available at [http://www.bambed.org](http://www.bambed.org)).

These recent findings are interesting as an example of how science progresses by a series of successively more accurate approximations to the truth.

Notice also that O₂ does not interact directly with glucose, but rather combines with an electron and H+ at the end of the electron transport chain to form water.

Aerobic cellular respiration is not the only process used to make ATP. When oxygen is not available, our muscle cells, yeast cells, and many other organisms use glycolysis followed by fermentation³ which yields much less ATP per glucose molecule than aerobic respiration (as discussed further

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³ Some bacteria and archaea use a different process called anaerobic respiration in which nitrate or sulfate (instead of O₂) serve as electron acceptors at the end of the electron transport chain.
II. **Using ATP to Provide Energy for Biological Processes**

Question 5 engages students in completing a simplified diagram to show one example of how ATP is used for biological processes. For your information, the following figure shows how each molecule of ATP is used in muscle contraction.

![Diagram showing muscle contraction](Figure from Krogh, Biology – a Guide to the Natural World)

- **1.** When the muscle is in its starting state, each extension rests on a nearby filament, at a 45-degree angle to it.
- **2.** A molecule of ATP binds with the extension, setting the stage for the transfer of energy from ATP to the extension. With the ATP binding, the extension detaches from the filament.
- **3.** The ATP molecule loses its third phosphate group, thus becoming ADP. Energy released from this reaction powers both the movement of the extension to its cocked, 90-degree position and the reattachment of the extension to the filament. ADP and P (phosphate) remain bound to the extension.
- **4.** The release of P triggers the extension's power stroke, in which it pulls the bound filament to the left. ADP is then released from the extension and the cycle begins again.

(Figure from Krogh, Biology – a Guide to the Natural World)
Another example of coupled reactions in which the breakdown of ATP provides energy for important biological processes is protein synthesis:

\[
4 \text{ ATP} \rightarrow 4 \text{ ADP} + 4 \text{ phosphate} \\
\text{energy} \\
\text{polypeptide with n amino acids} \rightarrow \text{polypeptide with n +1 amino acids}
\]

**Question 6** requires students to synthesize what they have learned about:
- the role of cellular respiration in synthesizing ATP
- how ATP is used to provide energy for biological processes.

This question also helps students to understand that cells are dynamic systems with constant molecular activity. On average, each ATP molecule in our body is used and re-synthesized more than 30 times per minute when we are at rest and more than 500 times per minute during strenuous exercise.

With regard to the general principles about energy, another example of the inefficiency of energy transformation is that only about 30% of the energy released by cellular respiration of a glucose molecule is captured in the ATP molecules produced and the rest of the energy is converted to heat. To emphasize this principle, you may want to add heat to the chemical equations shown in the Student Handout as illustrated by the following:

\[
\text{many ATP} \rightarrow \text{many ADP} + \text{many phosphate} \\
\text{energy} \rightarrow \text{heat} \\
\text{muscle relaxed} \rightarrow \text{muscle contracted}
\]

With regard to **question 7a**, the mistake of claiming that cellular respiration produces or makes energy is widespread even in publications that generally maintain high standards of accuracy. The First Law of Thermodynamics states that energy can be changed from one type to another, but energy is not created or destroyed. In accord with this principle, cellular respiration does not make energy, but rather transfers energy from organic molecules like glucose to ATP, which provides energy in a form that can be used for cellular processes. A simple revision to make the sentence accurate would be to say that "Cellular respiration makes ATP which provides the energy needed for biological processes."

Questions 4 and 7a provide the opportunity to reinforce student understanding that they need to read critically and thoughtfully and not just assume that everything that appears on the web or in textbooks is accurate. Of course, high school students do not have the background to judge whether the statements in the Student Handout for this activity are more accurate than the statements in their textbook or on the web, but they can evaluate whether statements are logically consistent.
Additional Information and Activities


- Relevant follow-up activities include:
  - "Food, Energy and Body Weight" (http://serendip.brynmawr.edu/exchange/bioactivities/foodenergy)
  - "How do muscles get the energy they need for athletic activity?" (http://serendip.brynmawr.edu/exchange/bioactivities/energyathlete)
How do biological organisms use energy?

The Importance of ATP

All organisms use a two-step process to provide the energy needed for most of their biological activities.

I. First, chemical energy from organic molecules like glucose is transferred to ATP molecules. This process is called cellular respiration.

![Diagram of energy transfer from cellular respiration to ATP](Figures from Belk and Borden, Biology: Science for Life, 2007)

II. Then, ATP provides the energy for most biological processes. When ATP breaks down to ADP and a phosphate, this releases energy which is used for many different cellular processes.

![Diagram of energy usage in cellular processes](Figures from Belk and Borden, Biology: Science for Life, 2007)

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4 By Dr. Ingrid Waldron, University of Pennsylvania, 2014. Teachers are encouraged to copy this Student Handout for classroom use. A Word file (which can be used to prepare a modified version if desired), Teacher Notes with teaching suggestions, background information and alignment with Next Generation Science Standards are available at [http://serendip.brynmawr.edu/exchange/bioactivities/energy](http://serendip.brynmawr.edu/exchange/bioactivities/energy).
Notice that the role of ATP in biological organisms is somewhat similar to the role of money in our society. Most people use a two-step process to get food, clothing, etc.

I. During cellular respiration, energy is transferred from organic molecules like glucose to ATP.  
II. Then ATP provides the energy for most biological processes.

Most people work to earn money.  
Then people spend their money to buy the things they need or want.

1. Explain why the reaction, ADP + phosphate → ATP, requires energy input. (Hint: Review the top figure on the previous page and remember that like charges repel each other.)

2. Explain why all the cells in your body need to carry out the reaction, ATP → ADP + phosphate. How is this reaction useful?

I. Cellular Respiration – Transferring Energy from Organic Molecules to ATP
Cellular respiration is the process that transfers some of the chemical energy in glucose or another organic molecule to chemical energy in ATP molecules. Cellular respiration is a complex process with many steps, but the basic process is as follows:
 
Cellular respiration breaks down glucose and oxygen and produces carbon dioxide and water; this releases energy which is used to synthesize ATP from ADP and phosphate.

3a. The following pair of chemical equations shows the basic processes of cellular respiration. Write the names of each of the molecules in these chemical equations.
3b. How do our bodies get glucose for cellular respiration?

3c. Why do we need to breathe all day and all night?

4. If you search for "cellular respiration equation" on the web, some of the most popular sites give the following equation for cellular respiration of glucose.

\[ \text{C}_6\text{H}_12\text{O}_6 + 6\ \text{O}_2 \rightarrow 6\ \text{CO}_2 + 6\ \text{H}_2\text{O} + \text{ATP} \]

What is wrong with this equation? (Hint: Think about where the atoms in an ATP molecule come from.)

II. Using ATP to Provide Energy for Biological Processes

The energy released by the breakdown of ATP to ADP and phosphate is used for many biological processes. For example, muscle contraction requires ATP as an energy source.

5. Complete the following diagram to give an overview of how ATP provides the energy for muscle contraction.

\[
\begin{array}{c}
\text{many } \text{ADP} + \text{many } \text{PI}
\\ \downarrow
\\ \text{many } \text{ATP} + \text{many } \text{Pi}
\end{array}
\]
6. Inside a cell, ATP is constantly broken down to ADP plus phosphate, and ATP is constantly being made from ADP plus phosphate (labeled P in this diagram). Complete the diagram to show how the breakdown of ATP is useful and how new ATP molecules are made.

Two important general principles about energy are:

- Energy can be transformed from one type to another (e.g. the stored chemical energy in ATP can be transformed to the kinetic energy of muscle motion). However, energy can not be created or destroyed by biological processes.

- All types of energy conversion are inefficient and result in the production of heat. For example, when ATP provides the energy for muscle contraction, only about 20-25% of the chemical energy released from the ATP molecules is captured in the kinetic energy of muscle contraction. The rest of the energy from the ATP is converted to heat.

7a. Some textbooks claim that "Cellular respiration makes the energy needed for biological processes." Explain what is wrong with this sentence and give a more accurate sentence.

7b. Explain why your body gets warmer when you are physically active.
### SAMPLE UNIT PLAN FOR ENERGY

<table>
<thead>
<tr>
<th>NGSS Based Performance Expectation</th>
<th>Teaching Strategies</th>
<th>Assessment Strategies</th>
</tr>
</thead>
</table>
| HS-LS1-5  Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. | **Day 1**  
Engage | XCC  cause and effect | Practice  asking questions, design experiments, construct explanations | Students perform iodine (starch indicator) test on plant leaves. Some students will use leaves that have been exposed to light while others will use leaves that were kept in the dark. Students can work in pairs/groups and determine possible explanations for their results. |
| | **Major Investigation**  
Elaborate, Explain  Have students grow and/or care for seedlings/plants to determine the best conditions for successful growth and record said conditions. Create a professional product to summarize data as evidence of best plant care practices. |
| | **Formative Assessments**  
Evaluate  
- Responses to reading materials  
- Responses to lesson activities  
- Appropriate use of key terms  
- Laboratory activity conclusions  
| | **Summative Assessments**  
- Up to teacher discretion  
| 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. | **Day 2**  
Explain | XCC  energy and matter | Practice  models, analyze data | Give students a variety of clues (facts discovered by other scientists) to determine how plants get energy. Students should cut out and arrange the clues in groups that help develop an answer. Students should then use both key terms (water, carbon dioxide, oxygen, glucose) and scientific symbols to share their explanation with another pair/group. |
| | **Explain**  
Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. |
| HS-LS2-3  Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. | **Days 3-4**  
Explore | XCC  energy and matter | Practice  models, analyze data, construct explanations | Students punch small discs out from leaves and float them in a syringe of sodium hydrogen carbonate solution. Once the gas is evolved by photosynthesis, the leaf discs rise and fall. Students can compare the rate of photosynthesis in the |
sun and shade plants and at different light intensities, amongst many other factors. Once introduced to the basic protocol, students can develop their own investigations.

**Day 5**

**Explore** | **XCC** varies | **Practice** varies | Student responses and assessments should inform instruction at this point.

**Day 6**

**Engage** | **XCC** cause and effect, energy and matter | **Practice** asking questions, construct explanations, communicate | Analysis and discussion activity “How Do Biological Organisms Use Energy?”

(http://serendip.brynmawr.edu/exchange/bioactivities/energy) Students work to complete groups of related questions and then conclude with a class discussion to probe student thinking and help them develop an understanding of the concepts.

**Day 7**

**Explore** | **XCC** energy and matter | **Practice** argue from evidence, construct explanations | Complete activity such as “How Do Muscles Get the Energy They Need for Athletic Activity?” to compare aerobic and anaerobic respiration as well as show how energy and matter are transformed.

(http://serendip.brynmawr.edu/exchange/bioactivities/energyathlete) OR Have students test how sugar concentrations influence the rate of anaerobic respiration in yeast while learning about metabolism.

**Day 8-10**

**Explore, Elaborate** | **XCC** scale, proportion, quantity | **Practice** design experiments, models, analyze data, construct explanations, communicate | Introduce enzymes and how they relate to energy in reactions. Students should be familiar with the terms “activation energy”, “enzyme”, and “active site”. Students should complete a laboratory activity to observe the breakdown of lactose with the enzyme lactase. They can then test the effects of temperature and pH on enzyme activity.

**Day 11-12**
Elaborate | XCC varies | Practice varies | Student responses and assessments should inform instruction from this point.

Day 13-15

Explore, Explain | XCC energy and matter, patterns, cause and effect | Practice asking questions, design experiments, argue from evidence, communicate | "Cellular Respiration in Yeast" inquiry-based lab, developing connection between food and getting energy into cells. Begin by showing the "Big Picture" at www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html. Give an overview of the yeast lab. Facilitate an inquiry-based approach to this lab, supporting student questions regarding the necessary components and conditions for cellular respiration. Proceed with the lab. Students discuss the lab and what they discovered in a small group. They summarize the findings of the lab, how it relates to cellular respiration, and to energy required by living organisms. Students support their explanations by engaging in argumentation using results from their lab and connections to scientific knowledge. With their findings, students present a visual representation of this process of energy transfer.

Day 13

Engage, Explain | XCC cause and effect, energy and matter | Practice asking questions, models, construct explanations | Students open/close their dominant hand as fast as they can for as long as they can. They are asked to provide best guesses as to what is going on, but should conclude that lactic acid fermentation has built up in the forearm because that specific muscle group has used all the oxygen and glucose available.

Explain, Evaluate | XCC patterns, energy and matter | Practice constructing explanations | Students should build connections between photosynthesis and cellular respiration and construct an explanation as to how these processes are connected and exhibit the cycling of matter and flow of energy.

Days 14-15 (Intermittently)

Engage, Elaborate, Explore, Evaluate, Explain | XCC cause and effect, scale, proportion, and quantity, energy
and matter, structure and function | **Practice** models, design experiments, analyze data, argue from evidence, communicate | Students will periodically work on major investigation.
APPENDIX J  NEXT GENERATION SCIENCE STANDARDS
High School Life Sciences

Students in high school develop understanding of key concepts that will help them make sense of life science. The ideas are built upon students’ science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are four life science disciplinary core ideas in high school: 1) From Molecules to Organisms: Structures and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, 4) Biological Evolution: Unity and Diversity. The performance expectations for high school life science blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge that can be applied across the science disciplines. While the performance expectations in high school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices underlying the performance expectations.

The performance expectations in LS1: From Molecules to Organisms: Structures and Processes help students formulate an answer to the question, “How do organisms live and grow?” The LS1 Disciplinary Core Idea from the NRC Framework is presented as three sub-ideas: Structure and Function, Growth and Development of Organisms, and Organization for Matter and Energy Flow in Organisms. In these performance expectations, students demonstrate that they can use investigations and gather evidence to support explanations of cell function and reproduction. They understand the role of proteins as essential to the work of the cell and living systems. Students can use models to explain photosynthesis, respiration, and the cycling of matter and flow of energy in living organisms. The cellular processes can be used as a model for understanding of the hierarchical organization of organism. Crosscutting concepts of matter and energy, structure and function, and systems and system models provide students with insights to the structures and processes of organisms.

The performance expectations in LS2: Ecosystems: Interactions, Energy, and Dynamics help students formulate an answer to the question, “How and why do organisms interact with their environment, and what are the effects of these interactions?” The LS2 Disciplinary Core Idea includes four sub-ideas: Interdependent Relationships in Ecosystems, Cycles of Matter and Energy Transfer in Ecosystems, Ecosystem Dynamics, Functioning, and Resilience, and Social Interactions and Group Behavior. High school students can use mathematical reasoning to demonstrate understanding of fundamental concepts of carrying capacity, factors affecting biodiversity and populations, and the cycling of matter and flow of energy among organisms in an ecosystem. These mathematical models provide support of students’ conceptual understanding of systems and their ability to develop design solutions for reducing the impact of human activities on the environment and maintaining biodiversity. Crosscutting concepts of systems and system models play a central role in students’ understanding of science and engineering practices and core ideas of ecosystems.

The performance expectations in LS3: Heredity: Inheritance and Variation of Traits help students formulate answers to the questions: “How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different
characteristics?” The LS3 Disciplinary Core Idea from the NRC Framework includes two sub-ideas: Inheritance of Traits, and Variation of Traits. Students are able to ask questions, make and defend a claim, and use concepts of probability to explain the genetic variation in population. Students demonstrate understanding of why individuals of the same species vary in how they look, function, and behave. Students can explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expression. Crosscutting concepts of patterns and cause and effect are called out as organizing concepts for these core ideas.

The performance expectations in **LS4: Biological Evolution: Unity and Diversity** help students formulate an answer to the question, “What evidence shows that different species are related? The LS4 Disciplinary Core Idea involves four sub-ideas: Evidence of Common Ancestry and Diversity, Natural Selection, Adaptation, and Biodiversity and Humans. Students can construct explanations for the processes of natural selection and evolution and communicate how multiple lines of evidence support these explanations. Students can evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in populations as those trends relate to advantageous heritable traits in a specific environment. The crosscutting concepts of cause and effect and systems and system models play an important role in students’ understanding of the evolution of life on Earth.
### HS-LS1 From Molecules to Organisms: Structures and Processes

#### From Molecules to Organisms: Structures and Processes

All cells contain genetic information in the form of DNA, which is used to make amino acids and other carbon-based molecules.

- **LS1A: Structure and Function**
  - Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
  - All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)
  - Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)
  - Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3)

- **LS1B: Growth and Development of Organisms**
  - In multicellular organisms individual cells grow and divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

- **LS1C: Organization for Matter and Energy Flow in Organisms**
  - The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide and water into sugars plus released oxygen. (HS-LS1-5)
  - The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-5)
  - As matter and energy flow through different

### Science and Engineering Practices

#### Designing and Using Models

- in 9–12 builds on K–8 experiences and progresses to using, testing, and developing models to predict and show relationships between systems and their components in the natural world.

#### Investigating or Designing New Systems or Structures

and carrying out investigations 9–12 builds on K–8 experiences and uses to include investigations that provide evidence for and test real, mathematical, physical, and empirical models.

#### Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences to explain relationships between systems and their components in the natural world.

### Crosscutting Concepts

#### Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems of different scales. (HS-LS1-2), (HS-LS1-4)

#### 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. (HS-LS1-2), (HS-LS1-6)

#### Structure and Function

- Investigating or designing new systems or structures requires detailed examination of the properties of different materials, structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)

#### Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)
HS-LS1  From Molecules to Organisms: Structures and Processes

Scientific Investigations Use a Variety of Methods

- Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (HS-LS1-3)
- 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. (HS-LS1-7)

Connections to other DCIs in this grade-band: **HS.PS1.B** (HS-LS1-1), (HS-LS1-6), (HS-LS1-7); **HS.PS2.B** (HS-LS1-7); **HS.LS2.A** (HS-LS1-1); **HS.PS3.B** (HS-LS1-5), (HS-LS1-7)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-LS1-6); **MS.PS1.B** (HS-LS1-5), (HS-LS1-6), (HS-LS1-7); **HS.PS3.D** (HS-LS1-5), (HS-LS1-6), (HS-LS1-7); **MS.ESS2.E** (HS-LS1-6);

**MS.LS1.A** (HS-LS1-1), (HS-LS1-4); **MS.LS3.B** (HS-LS1-1)

Common Core State Standards Connections:

**ELA/Literacy** -

**RST.11-12.1**  Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1), (HS-LS1-6)

**WHST.9-12.2**  Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-1), (HS-LS1-6)

**WHST.9-12.5**  Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach; focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)

**WHST.9-12.7**  Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS1-3)

**WHST.9-12.8**  Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-LS1-3)

**WHST.9-12.9**  Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1), (HS-LS1-6)

**SL.11-12.5**  Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-2), (HS-LS1-4), (HS-LS1-5), (HS-LS1-7)

**Mathematics** -

**MP.4**  Model with mathematics. (HS-LS1-4)

**HSF-IF.C.7**  Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-LS1-4)

**HSF-BF.A.1**  Write a function that describes a relationship between two quantities. (HS-LS1-4)
### HS-LS2  Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

#### HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.  
[Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, maps, climate, and competition. Examples of mathematical representations could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.]  
[Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]

#### HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.  
[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]  
[Assessment Boundary: Assessment is limited to provided data.]

#### HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.  
[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]  
[Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]

#### HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.  
[Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.]  
[Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]

#### HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.  
[Clarification Statement: Examples of models could include simulations and mathematical models.]  
[Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]

#### HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.  
[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood, and extreme changes, such as volcanic eruption or sea level rise.]

#### HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*  
[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

#### HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species’ chances to survive and reproduce.  
[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]

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### Science and Engineering Practices

#### Disciplinary Core Ideas

**LS2.A: Interdependent Relationships in Ecosystems**
- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1),(HS-LS2-2)

**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4)

**LS2.C: Ecosystem Dynamics, Functioning, and Resilience**
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2),(HS-LS2-6)

**Crosscutting Concepts**

**Cause and Effect**
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8)

**Scale, Proportion, and Quantity**
- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)
- The scale of a model allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)

**Systems and System Models**
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-5)

**Energy and Matter**
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4)
- Energy drives the cycling of matter within and between systems. (HS-LS2-3)

**Stability and Change**
- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6),(HS-LS2-7)
and will continue to do so in the future. (HS-LS2-3)
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-7)

Engaging in Argument from Evidence
- Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)
- Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (HS-LS2-8)

Connections to Nature of Science

Scientific Knowledge is Open to Revisions in Light of New Evidence
- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-2),(HS-LS2-3)
- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HS-LS2-6),(HS-LS2-8)

Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7)

LS2-D: Social Interactions and Group Behavior
- Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-8)

LS4-D: Biodiversity and Humans
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-7) (Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.)

PS3-D: Energy in Chemical Processes
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)

ETS1-B: Developing Possible Solutions
- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-7)

Connections to other DCIs in this grade-band: HS.PS1.B (HS-LS2-3),(HS-LS2-5); HS.PS3.B (HS-LS2-3),(HS-LS2-4); HS.PS3.D (HS-LS2-3),(HS-LS2-4); HS.ESS2.A (HS-LS2-3); HS.ESS2.D (HS-LS2-5),(HS-LS2-7); HS.ESS3.A (HS-LS2-7); HS.ESS3.C (HS-LS2-2); HS.ESS3.D (HS-LS2-2)


Common Core State Standards Connections:

ELA/Literacy –

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS2-1),(HS-LS2-2),(HS-LS2-3),(HS-LS2-6),(HS-LS2-8)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1),(HS-LS2-2),(HS-LS2-3)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS2-3)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS2-7)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-6),(HS-LS2-7)

MP.4 Model with mathematics. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-7)

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-7)

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-1),(HS-LS2-2),(HS-LS2-4),(HS-LS2-7)

HSS-ID.A.1 Represent data with plots on the real number line. (HS-LS2-6)

HSS-IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population. (HS-LS2-6)

HSS-IC.B.6 Evaluate reports based on data. (HS-LS2-6)
# HS-LS3 Heredity: Inheritance and Variation of Traits

## Students who demonstrate understanding can:

### HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

### HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs. [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]

### HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

[Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]

## The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

### Science and Engineering Practices

**Asking Questions and Defining Problems**

- Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.
- Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1)

**Analyzing and Interpreting Data**

- Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-3)

**Engaging in Argument from Evidence**

- Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)

### Disciplinary Core Ideas

#### LS1.A: Structure and Function

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)

#### LS3.A: Inheritance of Traits

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species’ characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)

#### LS3.B: Variation of Traits

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2)
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2)

### Crosscutting Concepts

#### Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-1),(HS-LS3-2)

#### Scale, Proportion, and Quantity

- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-3)

### Connections to Nature of Science

#### Science is a Human Endeavor

- Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3)
- Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3)

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**Connections to other DQs in this grade-band:** HS.LS2.A (HS-LS3-3); HS.LS2.C (HS-LS3-3); HS.LS4.B (HS-LS3-3); HS.LS4.C (HS-LS3-3)

**Articulation across grade-bands:** MS.LS2.A (HS-LS3-3); MS.LS3.A (HS-LS3-1),(HS-LS3-2); MS.LS3.B (HS-LS3-1),(HS-LS3-2),(HS-LS3-3); MS.LS4.B (HS-LS3-3); MS.LS4.C (HS-LS3-3)

**Common Core State Standards Connections:**

- **ELA/Literacy –**
  - **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS3-1),(HS-LS3-2)
  - **RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS3-1)
- **WHST.9-12.1** Write arguments focused on discipline-specific content. (HS-LS3-2)
- **Mathematics –** **MP.2** Reason abstractly and quantitatively. (HS-LS3-2),(HS-LS3-3)
Obtaining, Evaluating, and Communicating Information

Science.

Engaging in argument from evidence in 9-12 builds on K-8 principles, and theories.

on K–8 experiences and progresses to explanations and designs obtained from a variety of sources (including students' own computational tools for statistical analysis to analyze, represent, and graphical analysis. Assessment does not include allele frequency calculations.

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Applying concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2), (HS-LS4-4)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science.

Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12
## HS-LS 4 Biological Evolution: Unity and Diversity

<table>
<thead>
<tr>
<th>Connections to other DCIs in this grade band:</th>
<th>HS.LS2.A (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); HS.LS3.A (HS-LS4-1); HS.LS3.B (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); HS.LS3.C (HS-LS4-1); HS.ESS2.D (HS-LS4-6); HS.ESS2.E (HS-LS4-2),(HS-LS4-5),(HS-LS4-6); HS.ESS3.A (HS-LS4-2),(HS-LS4-5),(HS-LS4-6); HS.ESS3.B (HS-LS2.D)</th>
<th>HS.ESS3.C (HS-LS4-2),(HS-LS4-5).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulation across grade bands:</td>
<td>MS.LS2.A (HS-LS4-2),(HS-LS4-3),(HS-LS4-5); MS.LS2.C (HS-LS4-5),(HS-LS4-6); MS.LS3.A (HS-LS4-1); MS.LS3.B (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-5); MS.LS4.A (HS-LS4-1); MS.LS4.B (HS-LS4-2),(HS-LS4-3),(HS-LS4-4); MS.LS4.C (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); MS.ESS1.C (HS-LS4-1); MS.ESS3.C (HS-LS4-5).</td>
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</tr>
<tr>
<td>Common Core State Standards Connections:</td>
<td>Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4)</td>
<td>RST.11-12.1</td>
</tr>
<tr>
<td>Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)</td>
<td>RST.11-12.8</td>
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<td>Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4)</td>
<td>WHST.9-12.2</td>
<td></td>
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<tr>
<td>Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS4-6)</td>
<td>WHST.9-12.5</td>
<td></td>
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<td>Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS4-6)</td>
<td>WHST.9-12.7</td>
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<tr>
<td>Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5)</td>
<td>WHST.9-12.9</td>
<td></td>
</tr>
<tr>
<td>Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-LS4-1),(HS-LS4-2)</td>
<td>SL.11-12.4</td>
<td></td>
</tr>
<tr>
<td>Reason abstractly and quantitatively. (HS-LS4-3),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5)</td>
<td>Mathematics – MP.2</td>
<td></td>
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<tr>
<td>Model with mathematics. (HS-LS4-2)</td>
<td>MP.4</td>
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APPENDIX K  NEW JERSEY CORE CURRICULUM CONTENT STANDARDS FOR SCIENCE
### NJCCC STANDARDS FOR SCIENCE (continued)

#### Content Area: Science

##### Standard: 5.1 Science Practices

All students will understand that science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.

##### Strand: A. Understand Scientific Explanations

Students understand core concepts and principles of science and use measurement and observation tools to assist in categorizing, representing, and interpreting the natural and designed world.

<table>
<thead>
<tr>
<th>By the end of grade</th>
<th>Content Statement</th>
<th>CPI #</th>
<th>Cumulative Progress Indicator (CPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Mathematical, physical, and computational tools are used to search for and explain core scientific concepts and principles.</td>
<td>5.1.12.A.1</td>
<td>Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations.</td>
</tr>
<tr>
<td>12</td>
<td>Interpretation and manipulation of evidence-based models are used to build and critique arguments/explanations.</td>
<td>5.1.12.A.2</td>
<td>Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories.</td>
</tr>
<tr>
<td>12</td>
<td>Revisions of predictions and explanations are based on systematic observations, accurate measurements, and structured data/evidence.</td>
<td>5.1.12.A.3</td>
<td>Use scientific principles and theories to build and refine standards for data collection, posing controls, and presenting evidence.</td>
</tr>
<tr>
<td>Content Area</td>
<td>Science</td>
<td></td>
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</tr>
<tr>
<td>Standard</td>
<td><strong>5.1 Science Practices:</strong> All students will understand that science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.</td>
<td></td>
<td></td>
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<tr>
<td>Strand</td>
<td><strong>B. Generate Scientific Evidence Through Active Investigations:</strong> Students master the conceptual, mathematical, physical, and computational tools that need to be applied when constructing and evaluating claims.</td>
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<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Logically designed investigations are needed in order to generate the evidence required to build and refine models and explanations.</td>
<td>5.1.12.B.1</td>
<td>Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/co-relational relationships, and anomalous data.</td>
</tr>
<tr>
<td>12</td>
<td>Mathematical tools and technology are used to gather, analyze, and communicate results.</td>
<td>5.1.12.B.2</td>
<td>Build, refine, and represent evidence-based models using mathematical, physical, and computational tools.</td>
</tr>
<tr>
<td>12</td>
<td>Empirical evidence is used to construct and defend arguments.</td>
<td>5.1.12.B.3</td>
<td>Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories.</td>
</tr>
<tr>
<td>12</td>
<td>Scientific reasoning is used to evaluate and interpret data patterns and scientific conclusions.</td>
<td>5.1.12.B.4</td>
<td>Develop quality controls to examine data sets and to examine evidence as a means of generating and reviewing explanations.</td>
</tr>
</tbody>
</table>
### NJCCC STANDARDS FOR SCIENCE (continued)

<table>
<thead>
<tr>
<th>Content Area</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td><strong>5.1 Science Practices</strong>: All students will understand that science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.</td>
</tr>
<tr>
<td>Strand</td>
<td><strong>C. Reflect on Scientific Knowledge</strong>: Scientific knowledge builds on itself over time.</td>
</tr>
</tbody>
</table>

### By the end of grade

<table>
<thead>
<tr>
<th>Content Statement</th>
<th>CPI #</th>
<th>Cumulative Progress Indicator (CPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinement of understandings, explanations, and models occurs as new evidence is incorporated.</td>
<td>5.1.12.C.1</td>
<td>Reflect on and revise understandings as new evidence emerges.</td>
</tr>
<tr>
<td>Data and refined models are used to revise predictions and explanations.</td>
<td>5.1.12.C.2</td>
<td>Use data representations and new models to revise predictions and explanations.</td>
</tr>
<tr>
<td>Science is a practice in which an established body of knowledge is continually revised, refined, and extended as new evidence emerges.</td>
<td>5.1.12.C.3</td>
<td>Consider alternative theories to interpret and evaluate evidence-based arguments.</td>
</tr>
</tbody>
</table>
**NJCCC STANDARDS FOR SCIENCE (continued)**

<table>
<thead>
<tr>
<th>Content Area</th>
<th>Science</th>
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</table>

**Standard**

5.1 Science Practices: All students will understand that science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.

**Strand**

D. Participate Productively in Science: The growth of scientific knowledge involves critique and communication, which are social practices that are governed by a core set of values and norms.

<table>
<thead>
<tr>
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<th>Cumulative Progress Indicator (CPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.</td>
<td>5.1.12.D.1</td>
<td>Engage in multiple forms of discussion in order to process, make sense of, and learn from others’ ideas, observations, and experiences.</td>
</tr>
<tr>
<td>12</td>
<td>Science involves using language, both oral and written, as a tool for making thinking public.</td>
<td>5.1.12.D.2</td>
<td>Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams.</td>
</tr>
<tr>
<td>12</td>
<td>Ensure that instruments and specimens are properly cared for and that animals, when used, are treated humanely, responsibly, and ethically.</td>
<td>5.1.12.D.3</td>
<td>Demonstrate how to use scientific tools and instruments and knowledge of how to handle animals with respect for their safety and welfare.</td>
</tr>
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</tr>
<tr>
<td><strong>Strand</strong></td>
<td>A. Properties of Matter: All objects and substances in the natural world are composed of matter. Matter has two fundamental properties: matter takes up space, and matter has inertia.</td>
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<td>12</td>
<td>Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons.</td>
<td>5.2.12.A.1</td>
<td>Use atomic models to predict the behaviors of atoms in interactions.</td>
</tr>
<tr>
<td>12</td>
<td>Differences in the physical properties of solids, liquids, and gases are explained by the ways in which the atoms, ions, or molecules of the substances are arranged, and by the strength of the forces of attraction between the atoms, ions, or molecules.</td>
<td>5.2.12.A.2</td>
<td>Account for the differences in the physical properties of solids, liquids, and gases.</td>
</tr>
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<tr>
<td>12</td>
<td>In the Periodic Table, elements are arranged according to the number of protons (the atomic number). This organization illustrates commonality and patterns of physical and chemical properties among the elements.</td>
<td>5.2.12.A.3</td>
<td>Predict the placement of unknown elements on the Periodic Table based on their physical and chemical properties.</td>
</tr>
<tr>
<td>12</td>
<td>In a neutral atom, the positively charged nucleus is surrounded by the same number of negatively charged electrons. Atoms of an element whose nuclei have different numbers of neutrons are called isotopes.</td>
<td>5.2.12.A.4</td>
<td>Explain how the properties of isotopes, including half-lives, decay modes, and nuclear resonances, lead to useful applications of isotopes.</td>
</tr>
<tr>
<td>12</td>
<td>Solids, liquids, and gases may dissolve to form solutions. When combining a solute and solvent to prepare a solution, exceeding a particular concentration of solute will lead to precipitation of the solute from the solution. Dynamic equilibrium occurs in saturated solutions. Concentration of solutions can be calculated in terms of molarity, molality, and percent by mass.</td>
<td>5.2.12.A.5</td>
<td>Describe the process by which solutes dissolve in solvents.</td>
</tr>
<tr>
<td>12</td>
<td>Acids and bases are important in numerous chemical processes that occur around us, from industrial to biological processes, from the laboratory to the environment.</td>
<td>5.2.12.A.6</td>
<td>Relate the pH scale to the concentrations of various acids and bases.</td>
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<td><strong>Strand</strong></td>
<td>B. Changes in Matter: Substances can undergo physical or chemical changes to form new substances. Each change involves energy.</td>
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<tr>
<td>12</td>
<td>An atom’s electron configuration, particularly of the outermost electrons, determines how the atom interacts with other atoms. Chemical bonds are the interactions between atoms that hold them together in molecules or between oppositely charged ions.</td>
<td>5.2.12.B.1</td>
<td>Model how the outermost electrons determine the reactivity of elements and the nature of the chemical bonds they tend to form.</td>
</tr>
<tr>
<td>12</td>
<td>A large number of important reactions involve the transfer of either electrons or hydrogen ions between reacting ions, molecules, or atoms. In other chemical reactions, atoms interact with one another by sharing electrons to create a bond.</td>
<td>5.2.12.B.2</td>
<td>Describe oxidation and reduction reactions, and give examples of oxidation and reduction reactions that have an impact on the environment, such as corrosion and the burning of fuel.</td>
</tr>
<tr>
<td>12</td>
<td>The conservation of atoms in chemical reactions leads to the ability to calculate the mass of products and reactants using the mole concept.</td>
<td>5.2.12.B.3</td>
<td>Balance chemical equations by applying the law of conservation of mass.</td>
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<td><strong>Strand</strong></td>
<td><strong>C. Forms of Energy:</strong> Knowing the characteristics of familiar forms of energy, including potential and kinetic energy, is useful in coming to the understanding that, for the most part, the natural world can be explained and is predictable.</td>
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<td>12</td>
<td>Gas particles move independently and are far apart relative to each other. The behavior of gases can be explained by the kinetic molecular theory. The kinetic molecular theory can be used to explain the relationship between pressure and volume, volume and temperature, pressure and temperature, and the number of particles in a gas sample. There is a natural tendency for a system to move in the direction of disorder or entropy.</td>
<td>5.2.12.C.1</td>
<td>Use the kinetic molecular theory to describe and explain the properties of solids, liquids, and gases.</td>
</tr>
<tr>
<td>12</td>
<td>Heating increases the energy of the atoms composing elements and the molecules or ions composing compounds. As the kinetic energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a pure solid increases the vibrational energy of its atoms, molecules, or ions. When the vibrational energy of the molecules of a pure substance becomes great enough, the solid melts.</td>
<td>5.2.12.C.2</td>
<td>Account for any trends in the melting points and boiling points of various compounds.</td>
</tr>
</tbody>
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<td><strong>Strand</strong></td>
<td><strong>D. Energy Transfer and Conservation</strong>: The conservation of energy can be demonstrated by keeping track of familiar forms of energy as they are transferred from one object to another.</td>
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<td>12</td>
<td>The potential energy of an object on Earth’s surface is increased when the object’s position is changed from one closer to Earth’s surface to one farther from Earth’s surface.</td>
<td>5.2.12.D.1</td>
<td>Model the relationship between the height of an object and its potential energy.</td>
</tr>
<tr>
<td>12</td>
<td>The driving forces of chemical reactions are energy and entropy. Chemical reactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic).</td>
<td>5.2.12.D.2</td>
<td>Describe the potential commercial applications of exothermic and endothermic reactions.</td>
</tr>
<tr>
<td>12</td>
<td>Nuclear reactions (fission and fusion) convert very small amounts of matter into energy.</td>
<td>5.2.12.D.3</td>
<td>Describe the products and potential applications of fission and fusion reactions.</td>
</tr>
<tr>
<td>12</td>
<td>Energy may be transferred from one object to another during collisions.</td>
<td>5.2.12.D.4</td>
<td>Measure quantitatively the energy transferred between objects during a collision.</td>
</tr>
<tr>
<td>12</td>
<td>Chemical equilibrium is a dynamic process that is significant in many systems, including biological, ecological, environmental, and geological systems. Chemical reactions occur at different rates. Factors such as temperature, mixing, concentration, particle size, and</td>
<td>5.2.12.D.5</td>
<td>Model the change in rate of a reaction by changing a factor.</td>
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Surface area affects the rates of chemical reactions.

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<td><strong>Strand</strong></td>
<td>E. Forces and Motion: It takes energy to change the motion of objects. The energy change is understood in terms of forces.</td>
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<td>12</td>
<td>The motion of an object can be described by its position and velocity as functions of time and by its average speed and average acceleration during intervals of time.</td>
<td>5.2.12.E.1</td>
<td>Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values.</td>
</tr>
<tr>
<td>12</td>
<td>Objects undergo different kinds of motion (translational, rotational, and vibrational).</td>
<td>5.2.12.E.2</td>
<td>Compare the translational and rotational motions of a thrown object and potential applications of this understanding.</td>
</tr>
<tr>
<td>12</td>
<td>The motion of an object changes only when a net force is applied.</td>
<td>5.2.12.E.3</td>
<td>Create simple models to demonstrate the benefits of seatbelts using Newton's first law of motion.</td>
</tr>
<tr>
<td>12</td>
<td>The magnitude of acceleration of an object depends directly on the strength of the net force, and inversely on the mass of the object. This relationship ( a = \frac{F_{net}}{m} ) is independent of the nature of the force.</td>
<td>5.2.12.E.4</td>
<td>Measure and describe the relationship between the force acting on an object and the resulting acceleration.</td>
</tr>
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### Content Area: Science

#### Standard

**5.3 Life Science:** All students will understand that life science principles are powerful conceptual tools for making sense of the complexity, diversity, and interconnectedness of life on Earth. Order in natural systems arises in accordance with rules that govern the physical world, and the order of natural systems can be modeled and predicted through the use of mathematics.

#### Strand

**A. Organization and Development:** Living organisms are composed of cellular units (structures) that carry out functions required for life. Cellular units are composed of molecules, which also carry out biological functions.

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<td>12</td>
<td>Cells are made of complex molecules that consist mostly of a few elements. Each class of molecules has its own building blocks and specific functions.</td>
<td>5.3.12 A.1</td>
<td>Represent and explain the relationship between the structure and function of each class of complex molecules using a variety of models.</td>
</tr>
<tr>
<td>12</td>
<td>Cellular processes are carried out by many different types of molecules, mostly by the group of proteins known as enzymes.</td>
<td>5.3.12 A.2</td>
<td>Demonstrate the properties and functions of enzymes by designing and carrying out an experiment.</td>
</tr>
<tr>
<td>12</td>
<td>Cellular function is maintained through the regulation of cellular processes in response to internal and external environmental conditions.</td>
<td>5.3.12 A.3</td>
<td>Predict a cell’s response in a given set of environmental conditions.</td>
</tr>
<tr>
<td>12</td>
<td>Cells divide through the process of mitosis, resulting in daughter cells that have the same genetic composition as the original cell.</td>
<td>5.3.12 A.4</td>
<td>Distinguish between the processes of cellular growth (cell division) and development (differentiation).</td>
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<td><strong>Strand</strong></td>
<td><strong>B. Matter and Energy Transformations</strong>: Food is required for energy and building cellular materials. Organisms in an ecosystem have different ways of obtaining food, and some organisms obtain their food directly from other organisms.</td>
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<td>12</td>
<td>As matter cycles and energy flows through different levels of organization within living systems (cells, organs, organisms, communities), and between living systems and the physical environment, chemical elements are recombined into different products.</td>
<td>5.3.12.B.1</td>
<td>Cite evidence that the transfer and transformation of matter and energy links organisms to one another and to their physical setting.</td>
</tr>
<tr>
<td>12</td>
<td>Each recombination of matter and energy results in storage and dissipation of energy into the environment as heat.</td>
<td>5.3.12.B.2</td>
<td>Use mathematical formulas to justify the concept of an efficient diet.</td>
</tr>
<tr>
<td>12</td>
<td>Continual input of energy from sunlight keeps matter and energy flowing through ecosystems.</td>
<td>5.3.12.B.3</td>
<td>Predict what would happen to an ecosystem if an energy source was removed.</td>
</tr>
<tr>
<td>12</td>
<td>Plants have the capability to take energy from light to form sugar molecules containing carbon, hydrogen, and oxygen.</td>
<td>5.3.12.B.4</td>
<td>Explain how environmental factors (such as temperature, light intensity, and the amount of water available) can affect photosynthesis as an energy storing process.</td>
</tr>
</tbody>
</table>
In both plant and animal cells, sugar is a source of energy and can be used to make other carbon-containing (organic) molecules.

| 12 | Investigate and describe the complementary relationship (cycling of matter and flow of energy) between photosynthesis and cellular respiration. |
| 12 | Explain how the process of cellular respiration is similar to the burning of fossil fuels. |
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<td><strong>Strand</strong></td>
<td><strong>C. Interdependence:</strong> All animals and most plants depend on both other organisms and their environment to meet their basic needs.</td>
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<td>12</td>
<td>X A Biological communities in ecosystems are based on stable interrelationships and interdependence of organisms.</td>
<td>5.3.12.C.1</td>
<td>Analyze the interrelationships and interdependencies among different organisms, and explain how these relationships contribute to the stability of the ecosystem.</td>
</tr>
<tr>
<td>12</td>
<td>DIX B Stability in an ecosystem can be disrupted by natural or human interactions.</td>
<td>5.3.12.C.2</td>
<td>Model how natural and human-made changes in the environment will affect individual organisms and the dynamics of populations.</td>
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<td><strong>Strand</strong></td>
<td><strong>D. Heredity and Reproduction:</strong> Organisms reproduce, develop, and have predictable life cycles. Organisms contain genetic information that influences their traits, and they pass this on to their offspring during reproduction.</td>
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<td>Genes are segments of DNA molecules located in the chromosome of each cell. DNA molecules contain information that determines a sequence of amino acids, which result in specific proteins.</td>
<td>5.3.12.D.1</td>
<td>Explain the value and potential applications of genome projects.</td>
</tr>
<tr>
<td>12</td>
<td>D Inserting, deleting, or substituting DNA segments can alter the genetic code.</td>
<td>5.3.12.D.2</td>
<td>Predict the potential impact on an organism (no impact, significant impact) given a change in a specific DNA code, and provide specific real world examples of conditions caused by mutations.</td>
</tr>
<tr>
<td>IX E</td>
<td>An altered gene may be passed on to every cell that develops from it. The</td>
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| IX E                | | | |

| IX E                | | | |
resulting features may help, harm, or have little or no effect on the offspring’s success in its environment.

| 12 | Sorting and recombination of genes in sexual reproduction result in a great variety of possible gene combinations in the offspring of any two parents. | 5.3.12.D.3 | Demonstrate through modeling how the sorting and recombination of genes during sexual reproduction has an effect on variation in offspring (meiosis, fertilization). |

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<td>Strand</td>
<td><strong>IX F  E. Evolution and Diversity:</strong> Sometimes, differences between organisms of the same kind provide advantages for surviving and reproducing in different environments. These selective differences may lead to dramatic changes in characteristics of organisms in a population over extremely long periods of time.</td>
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<td>12</td>
<td>New traits may result from new combinations of existing genes or from mutations of genes in reproductive cells within a population.</td>
<td>5.3.12.E.1</td>
<td>Account for the appearance of a novel trait that arose in a given population.</td>
</tr>
<tr>
<td>12</td>
<td>Molecular evidence (e.g., DNA, protein structures, etc.) substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched.</td>
<td>5.3.12.E.2</td>
<td>Estimate how closely related species are, based on scientific evidence (e.g., anatomical similarities, similarities of DNA base and/or amino acid sequence).</td>
</tr>
<tr>
<td>12</td>
<td>The principles of evolution (including natural selection and common descent) provide a scientific explanation for the history of life on Earth as evidenced in the fossil record and in the similarities</td>
<td>5.3.12.E.3</td>
<td>Provide a scientific explanation for the history of life on Earth using scientific evidence (e.g., fossil record, DNA, protein structures, etc.).</td>
</tr>
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</table>
that exist within the diversity of existing organisms.

| 12 | Evolution occurs as a result of a combination of the following factors:  
• Ability of a species to reproduce  
• Genetic variability of offspring due to mutation and recombination of genes  
• Finite supply of the resources required for life  
• Natural selection, due to environmental pressure, of those organisms better able to survive and leave offspring | 5.3.12.E.4 | Account for the evolution of a species by citing specific evidence of biological mechanisms. |
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<td><strong>5.4 Earth Systems Science:</strong> All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.</td>
</tr>
<tr>
<td><strong>Strand</strong></td>
<td><strong>A. Objects in the Universe:</strong> Our universe has been expanding and evolving for 13.7 billion years under the influence of gravitational and nuclear forces. As gravity governs its expansion, organizational patterns, and the movement of celestial bodies, nuclear forces within stars govern its evolution through the processes of stellar birth and death. These same processes governed the formation of our solar system 4.6 billion years ago.</td>
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<td>12</td>
<td>Prior to the work of 17th-century astronomers, scientists believed the Earth was the center of the universe (geocentric model).</td>
</tr>
<tr>
<td>12</td>
<td>The properties and characteristics of solar system objects, combined with radioactive dating of meteorites and lunar samples, provide evidence that Earth and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago.</td>
</tr>
<tr>
<td>12</td>
<td>Stars experience significant changes during their life cycles, which can be illustrated with an Hertzsprung-Russell (H-R) Diagram.</td>
</tr>
<tr>
<td>12</td>
<td>The Sun is one of an estimated two hundred billion stars in our Milky Way galaxy, which together with over one</td>
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A hundred billion other galaxies make up the universe.

| 12 | The Big Bang theory places the origin of the universe at approximately 13.7 billion years ago. Shortly after the Big Bang, matter (primarily hydrogen and helium) began to coalesce to form galaxies and stars. | 5.4.12.A.5 | Critique evidence for the theory that the universe evolved as it expanded from a single point 13.7 billion years ago. |
| 12 | According to the Big Bang theory, the universe has been expanding since its beginning, explaining the apparent movement of galaxies away from one another. | 5.4.12.A.6 | Argue, citing evidence (e.g., Hubble Diagram), the theory of an expanding universe. |
NJCCC STANDARDS FOR SCIENCE (continued)

<table>
<thead>
<tr>
<th>Content Area</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td><strong>5.4 Earth Systems Science</strong>: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.</td>
</tr>
<tr>
<td><strong>Strand</strong></td>
<td><strong>B. History of Earth</strong>: From the time that Earth formed from a nebula 4.6 billion years ago, it has been evolving as a result of geologic, biological, physical, and chemical processes.</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>By the end of grade</th>
<th>Content Statement</th>
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</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>The evolution of life caused dramatic changes in the composition of Earth’s atmosphere, which did not originally contain oxygen gas.</td>
<td>5.4.12.B.1</td>
<td>Trace the evolution of our atmosphere and relate the changes in rock types and life forms to the evolving atmosphere.</td>
</tr>
<tr>
<td>12</td>
<td>Relative dating uses index fossils and stratigraphic sequences to determine the sequence of geologic events.</td>
<td>5.4.12.B.2</td>
<td>Correlate stratigraphic columns from various locations by using index fossils and other dating techniques.</td>
</tr>
<tr>
<td>12</td>
<td>Absolute dating, using radioactive isotopes in rocks, makes it possible to determine how many years ago a given rock sample formed.</td>
<td>5.4.12.B.3</td>
<td>Account for the evolution of species by citing specific absolute-dating evidence of fossil samples.</td>
</tr>
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<td><strong>Strand</strong></td>
<td><strong>C. Properties of Earth Materials</strong>: Earth’s composition is unique, is related to the origin of our solar system, and provides us with the raw resources needed to sustain life.</td>
</tr>
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<tr>
<td>12</td>
<td>Soils are at the interface of the Earth systems, linking together the biosphere, geosphere, atmosphere, and hydrosphere.</td>
<td>5.4.12.C.1</td>
<td>Model the interrelationships among the spheres in the Earth systems by creating a flow chart.</td>
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<tr>
<td>12</td>
<td>The chemical and physical properties of the vertical structure of the atmosphere support life on Earth.</td>
<td>5.4.12.C.2</td>
<td>Analyze the vertical structure of Earth’s atmosphere, and account for the global, regional, and local variations of these characteristics and their impact on life.</td>
</tr>
</tbody>
</table>
**NJCCS STANDARDS FOR SCIENCE (continued)**

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<tr>
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<td>Science</td>
<td><strong>5.4 Earth Systems Science</strong>: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.</td>
<td><strong>D. Tectonics</strong>: The theory of plate tectonics provides a framework for understanding the dynamic processes within and on Earth.</td>
</tr>
</tbody>
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<tr>
<td>12</td>
<td>Convection currents in the upper mantle drive plate motion. Plates are pushed apart at spreading zones and pulled down into the crust at subduction zones.</td>
<td>5.4.12.D.1</td>
<td>Explain the mechanisms for plate motions using earthquake data, mathematics, and conceptual models.</td>
</tr>
<tr>
<td>12</td>
<td>Evidence from lava flows and ocean-floor rocks shows that Earth’s magnetic field reverses (North – South) over geologic time.</td>
<td>5.4.12.D.2</td>
<td>Calculate the average rate of seafloor spreading using archived geomagnetic-reversals data.</td>
</tr>
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<td>Science</td>
<td><strong>5.4 Earth Systems Science</strong>: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.</td>
<td><strong>E. Energy in Earth Systems</strong>: Internal and external sources of energy drive Earth systems.</td>
<td></td>
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<tr>
<td>12</td>
<td>The Sun is the major external source of energy for Earth’s global energy budget.</td>
<td>5.4.12.E.1</td>
<td>Model and explain the physical science principles that account for the global energy budget.</td>
</tr>
<tr>
<td>12</td>
<td>Earth systems have internal and external sources of energy, both of which create heat.</td>
<td>5.4.12.E.2</td>
<td>Predict what the impact on biogeochemical systems would be if there were an increase or decrease in internal and external energy.</td>
</tr>
</tbody>
</table>
**Content Area** | Science
---|---
**Standard** | **5.4 Earth Systems Science**: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.
**Strand** | **F. Climate and Weather**: Earth’s weather and climate systems are the result of complex interactions between land, ocean, ice, and atmosphere.

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<td>12</td>
<td>Global climate differences result from the uneven heating of Earth’s surface by the Sun. Seasonal climate variations are due to the tilt of Earth’s axis with respect to the plane of Earth’s nearly circular orbit around the Sun.</td>
<td>5.4.12.F.1</td>
<td>Explain that it is warmer in summer and colder in winter for people in New Jersey because the intensity of sunlight is greater and the days are longer in summer than in winter. Connect these seasonal changes in sunlight to the tilt of Earth’s axis with respect to the plane of its orbit around the Sun.</td>
</tr>
<tr>
<td>12</td>
<td>Climate is determined by energy transfer from the Sun at and near Earth’s surface. This energy transfer is influenced by dynamic processes, such as cloud cover and Earth’s rotation, as well as static conditions, such as proximity to mountain ranges and the ocean. Human activities, such as the burning of fossil fuels, also affect the global climate.</td>
<td>5.4.12.F.2</td>
<td>Explain how the climate in regions throughout the world is affected by seasonal weather patterns, as well as other factors, such as the addition of greenhouse gases to the atmosphere and proximity to mountain ranges and to the ocean.</td>
</tr>
<tr>
<td>12</td>
<td>Earth’s radiation budget varies globally, but is balanced. Earth’s hydrologic cycle is complex and varies globally, regionally, and locally.</td>
<td>5.4.12.F.3</td>
<td>Explain variations in the global energy budget and hydrologic cycle at the local, regional, and global scales.</td>
</tr>
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### NJCCC STANDARDS FOR SCIENCE (continued)

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<tr>
<td>Strand</td>
<td>G. Biogeochemical Cycles: The biogeochemical cycles in the Earth systems include the flow of microscopic and macroscopic resources from one reservoir in the hydrosphere, geosphere, atmosphere, or biosphere to another, are driven by Earth's internal and external sources of energy, and are impacted by human activity.</td>
</tr>
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<tr>
<td>12</td>
<td>Natural and human-made chemicals circulate with water in the hydrologic cycle.</td>
<td>5.4.12.G.1</td>
<td>Analyze and explain the sources and impact of a specific industry on a large body of water (e.g., Delaware or Chesapeake Bay).</td>
</tr>
<tr>
<td>12</td>
<td>Natural ecosystems provide an array of basic functions that affect humans. These functions include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients.</td>
<td>5.4.12.G.2</td>
<td>Explain the unintended consequences of harvesting natural resources from an ecosystem.</td>
</tr>
<tr>
<td>12</td>
<td>Movement of matter through Earth’s system is driven by Earth’s internal and external sources of energy and results in changes in the physical and chemical properties of the matter.</td>
<td>5.4.12.G.3</td>
<td>Demonstrate, using models, how internal and external sources of energy drive the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles.</td>
</tr>
<tr>
<td>12</td>
<td>Natural and human activities impact the cycling of matter and the flow of energy through ecosystems.</td>
<td>5.4.12.G.4</td>
<td>Compare over time the impact of human activity on the cycling of matter and energy through ecosystems.</td>
</tr>
<tr>
<td>12</td>
<td>Human activities have changed Earth’s land, oceans, and atmosphere, as well as its populations of plant and animal species.</td>
<td>5.4.12.G.5</td>
<td>Assess (using maps, local planning documents, and historical records) how the natural environment has changed since humans have inhabited the region.</td>
</tr>
<tr>
<td>12</td>
<td>Scientific, economic, and other data can assist in assessing environmental risks and benefits associated with societal activity.</td>
<td>5.4.12.G.6</td>
<td>Assess (using scientific, economic, and other data) the potential environmental impact of large-scale adoption of emerging technologies (e.g., wind farming, harnessing geothermal energy).</td>
</tr>
<tr>
<td>12</td>
<td>Earth is a system in which chemical elements exist in fixed amounts and move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles.</td>
<td>5.4.12.G.7</td>
<td>Relate information to detailed models of the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles, identifying major sources, sinks, fluxes, and residence times.</td>
</tr>
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</table>
APPENDIX L  NEW JERSEY CORE CURRICULUM CONTENT STANDARDS
ENGLISH LANGUAGE ARTS STANDARDS;
SCIENCE & TECHNICAL SUBJECTS, WRITING
GRADES 9-10
English Language Arts Standards
Reading: Informational Text » Grade 9-10

VI. Standards in this strand:

RI.9-10.1  RI.9-10.2  RI.9-10.3  RI.9-10.4  RI.9-10.5  RI.9-10.6  RI.9-10.7  RI.9-10.8  RI.9-10.9  RI.9-10.10

The CCR anchor standards and high school grade-specific standards work in tandem to define college and career readiness expectations—the former providing broad standards, the latter providing additional specificity.

VII. Key Ideas and Details

• RI.9-10.1. Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

• RI.9-10.2. Determine a theme or central idea of a text and analyze in detail its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.

• RI.9-10.3. Analyze how complex characters (e.g., those with multiple or conflicting motivations) develop over the course of a text, interact with other characters, and advance the plot or develop the theme.

VIII. Craft and Structure

• RI.9-10.4. Determine the meaning of words and phrases as they are used in the text, including figurative and connotative meanings; analyze the cumulative impact of specific word choices on meaning and tone (e.g., how the language evokes a sense of time and place; how it sets a formal or informal tone).

• RI.9-10.5. Analyze how an author’s choices concerning how to structure a text, order events within it (e.g., parallel plots), and manipulate time (e.g., pacing, flashbacks) create such effects as mystery, tension, or surprise.

• RI.9-10.6. Analyze a particular point of view or cultural experience reflected in a work of literature from outside the United States, drawing on a wide reading of world literature.
IX. **Integration of Knowledge and Ideas**

- **RL.9-10.7.** Analyze the representation of a subject or a key scene in two different artistic mediums, including what is emphasized or absent in each treatment (e.g., Auden’s “Musée des Beaux Arts” and Breughel’s Landscape with the Fall of Icarus).
- **RL.9-10.8.** (Not applicable to literature)
- **RL.9-10.9.** Analyze how an author draws on and transforms source material in a specific work (e.g., how Shakespeare treats a theme or topic from Ovid or the Bible or how a later author draws on a play by Shakespeare).

X. **Range of Reading and Level of Text Complexity**

- **RL.9-10.10.** By the end of grade 9, read and comprehend literature, including stories, dramas, and poems, in the grades 9–10 text complexity band proficiently, with scaffolding as needed at the high end of the range.

By the end of grade 10, read and comprehend literature, including stories, dramas, and poems, at the high end of the grades 9–10 text complexity band independently and proficiently.
 XI.  **Standards in this strand:**

| W.9-10.1 | W.9-10.2 | W.9-10.3 | W.9-10.4 | W.9-10.5 | W.9-10.6 | W.9-10.7 | W.9-10.8 | W.9-10.9 | W.9-10.10 |

The CCR anchor standards and high school grade-specific standards work in tandem to define college and career readiness expectations—the former providing broad standards, the latter providing additional specificity.

XII.  **Text Types and Purposes**

- **W.9-10.1.** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
  a. Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.
  b. Develop claim(s) and counterclaims fairly, supplying evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience’s knowledge level and concerns.
  c. Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.
  d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
  e. Provide a concluding statement or section that follows from and supports the argument presented.

- **W.9-10.2.** Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

  Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
a. Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
b. Use appropriate and varied transitions to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.
c. Use precise language and domain-specific vocabulary to manage the complexity of the topic.
d. Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
e. Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

- **W.9-10.3.** Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.
  a. Engage and orient the reader by setting out a problem, situation, or observation, establishing one or multiple point(s) of view, and introducing a narrator and/or characters; create a smooth progression of experiences or events.
  b. Use narrative techniques, such as dialogue, pacing, description, reflection, and multiple plot lines, to develop experiences, events, and/or characters.
  c. Use a variety of techniques to sequence events so that they build on one another to create a coherent whole.
  d. Use precise words and phrases, telling details, and sensory language to convey a vivid picture of the experiences, events, setting, and/or characters.
  e. Provide a conclusion that follows from and reflects on what is experienced, observed, or resolved over the course of the narrative.

**XIII. Production and Distribution of Writing**

- **W.9-10.4.** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
- **W.9-10.5.** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
- **W.9-10.6.** Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
XIV. **Research to Build and Present Knowledge**

- **W.9-10.7.** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

- **W.9-10.8.** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

- **W.9-10.9.** Draw evidence from literary or informational texts to support analysis, reflection, and research.
  
  a. Apply *grades 9–10 Reading standards* to literature (e.g., “Analyze how an author draws on and transforms source material in a specific work [e.g., how Shakespeare treats a theme or topic from Ovid or the Bible or how a later author draws on a play by Shakespeare]”).

  b. Apply *grades 9–10 Reading standards* to literary nonfiction (e.g., “Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning”).

XV. **Range of Writing**

- **W.9-10.10.** Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

The CCR anchor standards and high school grade-specific standards work in tandem to define college and career readiness expectations—the former providing broad standards, the latter providing additional specificity.
English Language Arts Standards
Speaking & Listening » Grade 9-10

XVI. Standards in this strand:

<table>
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<th>SL.9-10.1</th>
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The CCR anchor standards and high school grade-specific standards work in tandem to define college and career readiness expectations—the former providing broad standards, the latter providing additional specificity.

XVII. Comprehension and Collaboration

- SL.9-10.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
  a. Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.
  b. Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.
  c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
  d. Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.

- SL.9-10.2. Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.

- SL.9-10.3. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence.
XVIII. **Presentation of Knowledge and Ideas**

- **SL.9-10.4.** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
- **SL.9-10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.
- **SL.9-10.6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.
XIX. **Vocabulary Acquisition and Use**

- **L.9-10.4.** Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 9–10 reading and content, choosing flexibly from a range of strategies.
  a. Use context (e.g., the overall meaning of a sentence, paragraph, or text; a word’s position or function in a sentence) as a clue to the meaning of a word or phrase.
  b. Identify and correctly use patterns of word changes that indicate different meanings or parts of speech (e.g., analyze, analysis, analytical; advocate, advocacy).
  c. Consult general and specialized reference materials (e.g., dictionaries, glossaries, thesauruses), both print and digital, to find the pronunciation of a word or determine or clarify its precise meaning, its part of speech, or its etymology.
  d. Verify the preliminary determination of the meaning of a word or phrase (e.g., by checking the inferred meaning in context or in a dictionary).

- **L.9-10.5.** Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.
  a. Interpret figures of speech (e.g., euphemism, oxymoron) in context and analyze their role in the text.
  b. Analyze nuances in the meaning of words with similar denotations.

- **L.9-10.6.** Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.
English Language Arts Standards » Science & Technical Subjects » Grade 9-10

Key Ideas and Details

- **CCSS.ELA-Literacy.RST.9-10.1** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- **CCSS.ELA-Literacy.RST.9-10.2** Determine the central ideas or conclusions of a text; trace the text’s explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **CCSS.ELA-Literacy.RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

Craft and Structure

- **CCSS.ELA-Literacy.RST.9-10.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.
- **CCSS.ELA-Literacy.RST.9-10.5** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
- **CCSS.ELA-Literacy.RST.9-10.6** Analyze the author’s purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

Integration of Knowledge and Ideas

- **CCSS.ELA-Literacy.RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **CCSS.ELA-Literacy.RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem.
- **CCSS.ELA-Literacy.RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Range of Reading and Level of Text Complexity

- **CCSS.ELA-Literacy.RST.9-10.10** By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.
English Language Arts Standards » Writing » Grade 9-10

Text Types and Purposes

- **CCSS.ELA-Literacy.WHST.9-10.1** Write arguments focused on discipline-specific content.
  - **CCSS.ELA-Literacy.WHST.9-10.1a** Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.
  - **CCSS.ELA-Literacy.WHST.9-10.1b** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.
  - **CCSS.ELA-Literacy.WHST.9-10.1c** Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.
  - **CCSS.ELA-Literacy.WHST.9-10.1d** Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
  - **CCSS.ELA-Literacy.WHST.9-10.1e** Provide a concluding statement or section that follows from or supports the argument presented.
- **CCSS.ELA-Literacy.WHST.9-10.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
  - **CCSS.ELA-Literacy.WHST.9-10.2a** Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
  - **CCSS.ELA-Literacy.WHST.9-10.2b** Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience’s knowledge of the topic.
  - **CCSS.ELA-Literacy.WHST.9-10.2c** Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts.
  - **CCSS.ELA-Literacy.WHST.9-10.2d** Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.
APPENDIX M  -NEW JERSEY CORE CURRICULUM CONTENT STANDARDS FOR TECHNOLOGY
<table>
<thead>
<tr>
<th>Grade Level bands</th>
<th>Content Area</th>
<th>Technology Standard</th>
<th>Indicator</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.</td>
<td>A. Technology Operations and Concepts: Students demonstrate a sound understanding of technology concepts, systems and operations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content Area</strong></td>
<td><strong>Strand</strong></td>
<td><strong>Technology Standard</strong></td>
<td><strong>Indicator</strong></td>
<td><strong>Indicator</strong></td>
</tr>
<tr>
<td><strong>K-2</strong></td>
<td>Understand and use technology systems.</td>
<td>8.1.2.A.1</td>
<td>Identify the basic features of a digital device and explain its purpose.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Select and use applications effectively and productively.</td>
<td>8.1.2.A.2</td>
<td>Create a document using a word processing application.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>8.1.2.A.3</td>
<td>Compare the common uses of at least two different digital applications and identify the advantages and disadvantages of using each.</td>
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<tr>
<td></td>
<td></td>
<td>8.1.2.A.4</td>
<td>Demonstrate developmentally appropriate navigation skills in virtual environments (i.e. games, museums).</td>
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<tr>
<td></td>
<td></td>
<td>8.1.2.A.5</td>
<td>Enter information into a spreadsheet and sort the information.</td>
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<tr>
<td></td>
<td></td>
<td>8.1.2.A.6</td>
<td>Identify the structure and components of a database.</td>
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<tr>
<td></td>
<td></td>
<td>8.1.2.A.7</td>
<td>Enter information into a database or spreadsheet and filter the information.</td>
<td></td>
</tr>
<tr>
<td><strong>P</strong></td>
<td>Understand and use technology systems.</td>
<td>8.1.P.A.1</td>
<td>Use an input device to select an item and navigate the screen.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Select and use applications effectively and productively.</td>
<td>8.1.P.A.2</td>
<td>Navigate the basic functions of a browser.</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>8.1.P.A.3</td>
<td>Use digital devices to create stories with pictures, numbers, letters and words.</td>
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<tr>
<td></td>
<td></td>
<td>8.1.P.A.4</td>
<td>Use basic technology terms in the proper context in conversation with peers and teachers (e.g., camera, tablet, Internet, mouse, keyboard, and printer).</td>
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<tr>
<td></td>
<td></td>
<td>8.1.P.A.5</td>
<td>Demonstrate the ability to access and use resources on a computing device.</td>
<td></td>
</tr>
<tr>
<td><strong>3-5</strong></td>
<td>Understand and use technology systems.</td>
<td>8.1.5.A.1</td>
<td>Select and use the appropriate digital tools and resources to accomplish a variety of tasks including solving problems.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Select and use applications effectively and productively.</td>
<td>8.1.5.A.2</td>
<td>Format a document using a word processing application to enhance text and include graphics, symbols and/ or pictures.</td>
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</tr>
<tr>
<td>Content Area</td>
<td>Technology</td>
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</tr>
<tr>
<td><strong>Standard</strong></td>
<td>8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.</td>
<td></td>
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</tr>
<tr>
<td>8.1.5.A.3</td>
<td>Use a graphic organizer to organize information about problem or issue.</td>
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<tr>
<td>8.1.5.A.4</td>
<td>Graph data using a spreadsheet, analyze and produce a report that explains the analysis of the data.</td>
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<tr>
<td>8.1.5.A.5</td>
<td>Create and use a database to answer basic questions.</td>
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<tr>
<td>8.1.5.A.6</td>
<td>Export data from a database into a spreadsheet; analyze and produce a report that explains the analysis of the data.</td>
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<tr>
<td><strong>6-8</strong></td>
<td>Understand and use technology systems.</td>
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<tr>
<td>8.1.8.A.1</td>
<td>Demonstrate knowledge of a real world problem using digital tools.</td>
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<tr>
<td>Select and use applications effectively and productively.</td>
<td>8.1.8.A.2</td>
<td>Create a document (e.g. newsletter, reports, personalized learning plan, business letters or flyers) using one or more digital applications to be critiqued by professionals for usability.</td>
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<td></td>
<td>8.1.8.A.3</td>
<td>Use and/or develop a simulation that provides an environment to solve a real world problem or theory.</td>
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<tr>
<td></td>
<td>8.1.8.A.4</td>
<td>Graph and calculate data within a spreadsheet and present a summary of the results.</td>
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<td></td>
<td>8.1.8.A.5</td>
<td>Create a database query, sort and create a report and describe the process, and explain the report results.</td>
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</tr>
<tr>
<td><strong>9-12</strong></td>
<td>Understand and use technology systems.</td>
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</tr>
<tr>
<td>8.1.12.A.1</td>
<td>Create a personal digital portfolio which reflects personal and academic interests, achievements, and career aspirations by using a variety of digital tools and resources.</td>
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</tr>
<tr>
<td>Select and use applications effectively and productively.</td>
<td>8.1.12.A.2</td>
<td>Produce and edit a multi-page digital document for a commercial or professional audience and present it to peers and/or professionals in that related area for review.</td>
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<tr>
<td></td>
<td>8.1.12.A.3</td>
<td>Collaborate in online courses, learning communities, social networks or virtual worlds to discuss a resolution to a problem or issue.</td>
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<tr>
<td></td>
<td>8.1.12.A.4</td>
<td>Construct a spreadsheet workbook with multiple worksheets, rename tabs to reflect the data on the worksheet, and use mathematical or logical functions, charts and data from all worksheets to convey the results.</td>
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<tr>
<td></td>
<td>8.1.12.A.5</td>
<td>Create a report from a relational database consisting of at least two tables and describe the process, and explain the report results.</td>
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</tbody>
</table>
### Strand: B. Creativity and Innovation

*Students demonstrate creative thinking, construct knowledge and develop innovative products and process using technology.*

<table>
<thead>
<tr>
<th>Grade Level bands</th>
<th>Content Statement</th>
<th>Indicator</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Apply existing knowledge to generate new ideas, products, or processes.</td>
<td>8.1.P.B.1</td>
<td>Create a story about a picture taken by the student on a digital camera or mobile device.</td>
</tr>
<tr>
<td>K-2</td>
<td>Create original works as a means of personal or group expression.</td>
<td>8.1.2.B.1</td>
<td>Illustrate and communicate original ideas and stories using multiple digital tools and resources.</td>
</tr>
<tr>
<td>3-5</td>
<td></td>
<td>8.1.5.B.1</td>
<td>Collaborative to produce a digital story about a significant local event or issue based on first-person interviews.</td>
</tr>
<tr>
<td>6-8</td>
<td></td>
<td>8.1.8.B.1</td>
<td>Synthesize and publish information about a local or global issue or event (ex. telecollaborative project, blog, school web).</td>
</tr>
<tr>
<td>9-12</td>
<td></td>
<td>8.1.12.B.2</td>
<td>Apply previous content knowledge by creating and piloting a digital learning game or tutorial.</td>
</tr>
</tbody>
</table>

### Content Area: Technology

#### Standard: 8.1 Educational Technology

*All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.*

### Strand: C. Communication and Collaboration

*Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.*

<table>
<thead>
<tr>
<th>Grade Level bands</th>
<th>Content Statement</th>
<th>Indicator</th>
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</thead>
<tbody>
<tr>
<td>P</td>
<td>Interact, collaborate, and publish with peers, experts, or others by employing a variety of digital environments and media. Communicate information and ideas to multiple audiences using a variety of media and formats.</td>
<td>8.1.P.C.1</td>
<td>Collaborate with peers by participating in interactive digital games or activities.</td>
</tr>
<tr>
<td>K-2</td>
<td></td>
<td>8.1.2.C.1</td>
<td>Engage in a variety of developmentally appropriate learning activities with students in other classes, schools, or countries using various media formats such as online collaborative tools, and social media.</td>
</tr>
<tr>
<td>3-5</td>
<td></td>
<td>8.1.5.C.1</td>
<td>Engage in online discussions with learners of other cultures to investigate a worldwide issue from multiple perspectives and sources, evaluate findings and present possible solutions, using digital tools and online resources for all steps.</td>
</tr>
<tr>
<td>Grade Level bands</td>
<td>Content Statement</td>
<td>Indicator</td>
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<tr>
<td>6-8</td>
<td>Develop cultural understanding and global awareness by engaging with learners of other cultures.</td>
<td>8.1.8.C.1</td>
<td>Collaborate to develop and publish work that provides perspectives on a global problem for discussions with learners from other countries.</td>
</tr>
<tr>
<td>9-12</td>
<td>Contribute to project teams to produce original works or solve problems.</td>
<td>8.1.12.C.1</td>
<td>Develop an innovative solution to a real world problem or issue in collaboration with peers and experts, and present ideas for feedback through social media or in an online community.</td>
</tr>
</tbody>
</table>

**Content Area** | **Technology**
---|---
**Standard** | 8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.

**Strand** | D. Digital Citizenship: Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.

<table>
<thead>
<tr>
<th>Grade Level bands</th>
<th>Content Statement</th>
<th>Indicator</th>
<th>Indicator</th>
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</thead>
<tbody>
<tr>
<td>K-2</td>
<td>Advocate and practice safe, legal, and responsible use of information and technology.</td>
<td>8.1.2.D.1</td>
<td>Develop an understanding of ownership of print and nonprint information.</td>
</tr>
<tr>
<td>3-5</td>
<td>Advocate and practice safe, legal, and responsible use of information and technology.</td>
<td>8.1.5.D.1</td>
<td>Understand the need for and use of copyrights.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.1.5.D.2</td>
<td>Analyze the resource citations in online materials for proper use.</td>
</tr>
<tr>
<td></td>
<td>Demonstrate personal responsibility for lifelong learning.</td>
<td>8.1.5.D.3</td>
<td>Demonstrate an understanding of the need to practice cyber safety, cyber security, and cyber ethics when using technologies and social media.</td>
</tr>
<tr>
<td></td>
<td>Exhibit leadership for digital citizenship.</td>
<td>8.1.5.D.4</td>
<td>Understand digital citizenship and demonstrate an understanding of the personal consequences of inappropriate use of technology and social media.</td>
</tr>
<tr>
<td>6-8</td>
<td>Advocate and practice safe, legal, and responsible use of information and technology.</td>
<td>8.1.8.D.1</td>
<td>Understand and model appropriate online behaviors related to cyber safety, cyber bullying, cyber security, and cyber ethics including appropriate use of social media.</td>
</tr>
<tr>
<td></td>
<td>Demonstrate personal responsibility for lifelong learning.</td>
<td>8.1.8.D.2</td>
<td>Demonstrate the application of appropriate citations to digital content.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.1.8.D.3</td>
<td>Demonstrate an understanding of fair use and Creative Commons to intellectual property.</td>
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<tr>
<td>Content Area</td>
<td>Technology</td>
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<tr>
<td><strong>Standard</strong></td>
<td>8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.</td>
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<td></td>
</tr>
<tr>
<td><strong>Strand</strong></td>
<td>E: Research and Information Fluency: Students apply digital tools to gather, evaluate, and use information.</td>
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</table>

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<thead>
<tr>
<th>Grade Level bands</th>
<th>Content Statement</th>
<th>Indicator</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P</strong></td>
<td>Plan strategies to guide inquiry.</td>
<td>8.1.P.E.1</td>
<td>Use the Internet to explore and investigate questions with a teacher’s support.</td>
</tr>
<tr>
<td><strong>K-2</strong></td>
<td>Plan strategies to guide inquiry&lt;br&gt;Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.&lt;br&gt;Evaluate and select information sources and digital tools based on the appropriateness for specific tasks.</td>
<td>8.1.2.E.1</td>
<td>Use digital tools and online resources to explore a problem or issue.</td>
</tr>
</tbody>
</table>
### Content Area: Technology

<table>
<thead>
<tr>
<th>Grade Level bands</th>
<th>Content Statement</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks.</td>
<td>8.1.5.E.1 Use digital tools to research and evaluate the accuracy of, relevance to, and appropriateness of using print and non-print electronic information sources to complete a variety of tasks.</td>
</tr>
<tr>
<td>6-8</td>
<td>Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks.</td>
<td>8.1.8.E.1 Effectively use a variety of search tools and filters in professional public databases to find information to solve a real world problem.</td>
</tr>
<tr>
<td>9-12</td>
<td>Plan strategies to guide inquiry. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media. Evaluate and select information sources and digital tools based on the appropriateness for specific tasks. Process data and report results.</td>
<td>8.1.12.E.1 Produce a position statement about a real world problem by developing a systematic plan of investigation with peers and experts synthesizing information from multiple sources. 8.1.12.E.2 Research and evaluate the impact on society of the unethical use of digital tools and present your research to peers.</td>
</tr>
</tbody>
</table>

**Content Area:** Technology

**Standard:** 8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.

**Strand:** F: Critical thinking, problem solving, and decision making: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.
<table>
<thead>
<tr>
<th>K-2</th>
<th>Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.</th>
<th>8.1.2.F.1</th>
<th>Use geographic mapping tools to plan and solve problems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.</td>
<td>8.1.5.F.1</td>
<td>Apply digital tools to collect, organize, and analyze data that support a scientific finding.</td>
</tr>
<tr>
<td>6-8</td>
<td>Identify and define authentic problems and significant questions for investigation. Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.</td>
<td>8.1.8.F.1</td>
<td>Explore a local issue, by using digital tools to collect and analyze data to identify a solution and make an informed decision.</td>
</tr>
<tr>
<td>9-12</td>
<td>Identify and define authentic problems and significant questions for investigation.</td>
<td>8.1.12.F.1</td>
<td>Evaluate the strengths and limitations of emerging technologies and their impact on educational, career, personal and or social needs.</td>
</tr>
</tbody>
</table>
Plan and manage activities to develop a solution or complete a project. Collect and analyze data to identify solutions and/or make informed decisions. Use multiple processes and diverse perspectives to explore alternative solutions.

<table>
<thead>
<tr>
<th>Content Area</th>
<th>Technology</th>
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<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming: All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.</td>
</tr>
<tr>
<td><strong>Strand</strong></td>
<td>A. The Nature of Technology: Creativity and Innovation Technology systems impact every aspect of the world in which we live.</td>
</tr>
<tr>
<td><strong>Grade Level bands</strong></td>
<td><strong>Content Statement Students will be able to understand:</strong></td>
</tr>
<tr>
<td><strong>K-2</strong></td>
<td>The characteristics and scope of technology.</td>
</tr>
<tr>
<td></td>
<td>8.2.2.A.1 Define products produced as a result of technology or of nature.</td>
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<tr>
<td></td>
<td>8.2.2.A.2 Describe how designed products and systems are useful at school, home and work.</td>
</tr>
<tr>
<td></td>
<td>The core concepts of technology.</td>
</tr>
<tr>
<td></td>
<td>8.2.2.A.3 Identify a system and the components that work together to accomplish its purpose.</td>
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<tr>
<td></td>
<td>8.2.2.A.4 Choose a product to make and plan the tools and materials needed.</td>
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<tr>
<td></td>
<td>The relationships among technologies and the connections between technology and other fields of study.</td>
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<tr>
<td></td>
<td>8.2.2.A.5 Collaborate to design a solution to a problem affecting the community.</td>
</tr>
<tr>
<td><strong>3-5</strong></td>
<td>The characteristics and scope of technology.</td>
</tr>
<tr>
<td></td>
<td>8.2.5.A.1 Compare and contrast how products made in nature differ from products that are human made in how they are produced and used.</td>
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<tr>
<td></td>
<td>8.2.5.A.2 Investigate and present factors that influence the development and function of a product and a system.</td>
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<tr>
<td><strong>Standard</strong></td>
<td>8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming: All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.</td>
</tr>
<tr>
<td><strong>Strand</strong></td>
<td>B. Technology and Society: Knowledge and understanding of human, cultural and society values are fundamental when designing technology systems and products in the global society.</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td><strong>Content Statement</strong></td>
</tr>
<tr>
<td><strong>6-8</strong></td>
<td>The core concepts of technology.</td>
</tr>
<tr>
<td></td>
<td>The relationships among technologies and the connections between technology and other fields of study.</td>
</tr>
<tr>
<td></td>
<td>8.2.5.A.5</td>
</tr>
<tr>
<td><strong>6-8</strong></td>
<td>The characteristics and scope of technology.</td>
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<tr>
<td></td>
<td>The core concepts of technology.</td>
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<tr>
<td></td>
<td>8.2.8.A.3</td>
</tr>
<tr>
<td><strong>6-8</strong></td>
<td>The relationships among technologies and the connections between technology and other fields of study.</td>
</tr>
<tr>
<td></td>
<td>8.2.8.A.5</td>
</tr>
<tr>
<td><strong>9-12</strong></td>
<td>The characteristics and scope of technology.</td>
</tr>
<tr>
<td></td>
<td>The core concepts of technology.</td>
</tr>
<tr>
<td></td>
<td>The relationships among technologies and the connections between technology and other fields of study.</td>
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<tr>
<td>Level bands</td>
<td>Students will be able to understand:</td>
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</tr>
<tr>
<td>K-2</td>
<td>The cultural, social, economic and political effects of technology.</td>
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<td></td>
<td>The effects of technology on the environment.</td>
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<tr>
<td></td>
<td>The role of society in the development and use of technology.</td>
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<td>3-5</td>
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<tr>
<td>Strand</td>
<td>C. Design: The design process is a systematic approach to solving problems.</td>
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<tr>
<td>Grade Level</td>
<td>Content Statement</td>
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<tr>
<td>bands</td>
<td>Students will be able to understand:</td>
</tr>
<tr>
<td>K-2</td>
<td>The attributes of design.</td>
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<tr>
<td></td>
<td>8.2.2.C.2 Create a drawing of a product or device that communicates its function to peers and discuss.</td>
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<td>8.2.2.C.3 Explain why we need to make new products.</td>
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<td>The application of engineering design.</td>
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<td>The role of troubleshooting, research and development, invention and innovation and experimentation in problem solving.</td>
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<tr>
<td>The role of troubleshooting, research and development, invention and innovation and experimentation in problem solving.</td>
<td>8.2.8.C.6</td>
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<td>8.2.8.C.7</td>
<td>Collaborate with peers and experts in the field to research and develop a product using the design process, data analysis and trends, and maintain a design log with annotated sketches to record the developmental cycle.</td>
</tr>
<tr>
<td>8.2.8.C.8</td>
<td>Develop a proposal for a chosen solution that include models (physical, graphical or mathematical) to communicate the solution to peers.</td>
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</table>

9-12 | The attributes of design. | 8.2.12.C.1 | Explain how open source technologies follow the design process. |
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<tbody>
<tr>
<td>8.2.12.C.2</td>
<td>Analyze a product and how it has changed or might change over time to meet human needs and wants.</td>
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</tbody>
</table>

The application of engineering design. | 8.2.12.C.3 | Analyze a product or system for factors such as safety, reliability, economic considerations, quality control, environmental concerns, manufacturability, maintenance and repair, and human factors engineering (ergonomics). |
| 8.2.12.C.4 | Explain and identify interdependent systems and their functions. |
| 8.2.12.C.5 | Create scaled engineering drawings of products both manually and digitally with materials and measurements labeled. |

The role of troubleshooting, research and development, invention and innovation and experimentation in problem solving. | 8.2.12.C.6 | Research an existing product, reverse engineer and redesign it to improve form and function. |
| 8.2.12.C.7 | Use a design process to devise a technological product or system that addresses a global problem, provide research, identify trade-offs and constraints, and document the process through drawings that include data and materials. |

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<tr>
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<tr>
<td>Content Statement</td>
<td>Students will understand how to:</td>
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<tr>
<td>Indicator</td>
<td>Indicator</td>
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</tbody>
</table>

**Grade Level bands**

**K-2**

Apply the design process. | 8.2.2.D.1 | Collaborate and apply a design process to solve a simple problem from everyday experiences. |

**Standard**

8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming: All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.

**Strand**

D. Abilities for a Technological World: The designed world is the product of a design process that provides the means to convert resources into products and systems.
<p>| Use and maintain technological products and systems. | <strong>8.2.2.D.2</strong> | Discover how a product works by taking it apart, sketching how parts fit, and putting it back together. |
| Assess the impact of products and systems. | <strong>8.2.2.D.3</strong> | Identify the strengths and weaknesses in a product or system. |
| | <strong>8.2.2.D.4</strong> | Identify the resources needed to create technological products or systems. |
| 3-5 | <strong>8.2.2.D.5</strong> | Identify how using a tool (such as a bucket or wagon) aids in reducing work. |
| Apply the design process. | <strong>8.2.5.D.1</strong> | Identify and collect information about a problem that can be solved by technology, generate ideas to solve the problem, and identify constraints and trade-offs to be considered. |
| | <strong>8.2.5.D.2</strong> | Evaluate and test alternative solutions to a problem using the constraints and trade-offs identified in the design process to evaluate potential solutions. |
| Use and maintain technological products and systems. | <strong>8.2.5.D.3</strong> | Follow step by step directions to assemble a product or solve a problem. |
| | <strong>8.2.5.D.4</strong> | Explain why human-designed systems, products, and environments need to be constantly monitored, maintained, and improved. |
| | <strong>8.2.5.D.5</strong> | Describe how resources such as material, energy, information, time, tools, people and capital are used in products or systems. |
| Assess the impact of products and systems. | <strong>8.2.5.D.6</strong> | Explain the positive and negative effect of products and systems on humans, other species and the environment, and when the product or system should be used. |
| | <strong>8.2.5.D.7</strong> | Explain the impact that resources such as energy and materials used in a process to produce products or system have on the environment. |
| 6-8 | <strong>8.2.8.D.1</strong> | Design and create a product that addresses a real world problem using a design process under specific constraints. |
| | <strong>8.2.8.D.2</strong> | Identify the design constraints and trade-offs involved in designing a prototype (e.g., how the prototype might fail and how it might be improved) by completing a design problem and reporting results in a multimedia presentation, design portfolio or engineering notebook. |
| | <strong>8.2.8.D.3</strong> | Build a prototype that meets a STEM-based design challenge using science, engineering, and math principles that validate a solution. |
| Use and maintain technological products and systems. | <strong>8.2.8.D.4</strong> | Research and publish the steps for using and maintaining a product or system and incorporate diagrams or images throughout to enhance user comprehension. |</p>
<table>
<thead>
<tr>
<th>Content Area</th>
<th>Technology</th>
<th>8.2.8.D.5</th>
<th>Explain the impact of resource selection and the production process in the development of a common or technological product or system.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2.8.D.6</td>
<td>Identify and explain how the resources and processes used in the production of a current technological product can be modified to have a more positive impact on the environment.</td>
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<tr>
<td>9-12</td>
<td>Apply the design process.</td>
<td>8.2.12.D.1</td>
<td>Design and create a prototype to solve a real world problem using a design process, identify constraints addressed during the creation of the prototype, identify trade-offs made, and present the solution for peer review.</td>
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<td>8.2.12.D.2</td>
<td>Write a feasibility study of a product to include: economic, market, technical, financial, and management factors, and provide recommendations for implementation.</td>
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<tr>
<td>Use and maintain technological products and systems.</td>
<td>8.2.12.D.3</td>
<td>Determine and use the appropriate resources (e.g., CNC (Computer Numerical Control) equipment, 3D printers, CAD software) in the design, development and creation of a technological product or system.</td>
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<tr>
<td>Assess the impact of products and systems.</td>
<td>8.2.12.D.4</td>
<td>Assess the impacts of emerging technologies on developing countries.</td>
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<td>8.2.12.D.5</td>
<td>Explain how material processing impacts the quality of engineered and fabricated products.</td>
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<td>8.2.12.D.6</td>
<td>Synthesize data, analyze trends and draw conclusions regarding the effect of a technology on the individual, society, or the environment and publish conclusions.</td>
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### Content Area Technology

#### Standard

8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming:

All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.

#### Strand

E. Computational Thinking: Programming: Computational thinking builds and enhances problem solving, allowing students to move beyond using knowledge to creating knowledge.

#### Grade Level bands

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<tr>
<td>8.2.12.E.4</td>
<td>Use appropriate terms in conversation (e.g., troubleshooting, peripherals, diagnostic software, GUI, abstraction, variables, data types and conditional statements).</td>
</tr>
</tbody>
</table>
CAREER READY PRACTICES

Career Ready Practices describe the career-ready skills that all educators in all content areas should seek to develop in their students. They are practices that have been linked to increase college, career, and life success. Career Ready Practices should be taught and reinforced in all career exploration and preparation programs with increasingly higher levels of complexity and expectation as a student advances through a program of study.

CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP3. Attend to personal health and financial well being.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP10. Plan education and career paths aligned to personal goals.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

CRP1. Act as a responsible and contributing citizen and employee
Career-ready individuals understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.

CRP2. Apply appropriate academic and technical skills.
Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.

CRP3. Attend to personal health and financial well-being.
Career-ready individuals understand the relationship between personal health, workplace performance and personal well-being; they act on that understanding to regularly practice healthy diet, exercise and mental health activities. Career-ready individuals also take regular action to contribute to their personal financial well-being, understanding that personal financial security provides the peace of mind required to contribute more fully to their own career success.
CRP4. Communicate clearly and effectively and with reason.

Career-ready individuals communicate thoughts, ideas, and action plans with clarity, whether using written, verbal and/or visual methods. They communicate in the workplace with clarity and purpose to make maximum use of their own and others' time. They are excellent writers; they master conventions, word choice, and organization, and use effective tone and presentation skills to articulate ideas. They are skilled at interacting with others; they are active listeners and speak clearly and with purpose. Career-ready individuals think about the audience for their communication and prepare accordingly to ensure the desired outcome.

CRP5. Consider the environmental, social and economic impacts of decisions.

Career-ready individuals understand the interrelated nature of their actions and regularly make decisions that positively impact and/or mitigate negative impact on other people, organization, and the environment. They are aware of and utilize new technologies, understandings, procedures, materials, and regulations affecting the nature of their work as it relates to the impact on the social condition, the environment and the profitability of the organization.

CRP6. Demonstrate creativity and innovation.

Career-ready individuals regularly think of ideas that solve problems in new and different ways, and they contribute those ideas in a useful and productive manner to improve their organization. They can consider unconventional ideas and suggestions as solutions to issues, tasks or problems, and they discern which ideas and suggestions will add greatest value. They seek new methods, practices, and ideas from a variety of sources and seek to apply those ideas to their own workplace. They take action on their ideas and understand how to bring innovation to an organization.

CRP7. Employ valid and reliable research strategies.

Career-ready individuals are discerning in accepting and using new information to make decisions, change practices or inform strategies. They use reliable research process to search for new information. They evaluate the validity of sources when considering the use and adoption of external information or practices in their workplace situation.

CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.

Career-ready individuals readily recognize problems in the workplace, understand the nature of the problem, and devise effective plans to solve the problem. They are aware of problems when they occur and take action quickly to address the problem; they thoughtfully investigate the root cause of the problem prior to introducing solutions. They carefully consider the options to solve the problem. Once a solution is agreed upon, they follow through to ensure the problem is solved, whether through their own actions or the actions of others.
CRP9. Model integrity, ethical leadership and effective management.
Career-ready individuals consistently act in ways that align personal and community-held ideals and principles while employing strategies to positively influence others in the workplace. They have a clear understanding of integrity and act on this understanding in every decision. They use a variety of means to positively impact the directions and actions of a team or organization, and they apply insights into human behavior to change others’ action, attitudes and/or beliefs. They recognize the near-term and long-term effects that management’s actions and attitudes can have on productivity, morals and organizational culture.

CRP10. Plan education and career paths aligned to personal goals.
Career-ready individuals take personal ownership of their own education and career goals, and they regularly act on a plan to attain these goals. They understand their own career interests, preferences, goals, and requirements. They have perspective regarding the pathways available to them and the time, effort, experience and other requirements to pursue each, including a path of entrepreneurship. They recognize the value of each step in the education and experiential process, and they recognize that nearly all career paths require ongoing education and experience. They seek counselors, mentors, and other experts to assist in the planning and execution of career and personal goals.

CRP11. Use technology to enhance productivity.
Career-ready individuals find and maximize the productive value of existing and new technology to accomplish workplace tasks and solve workplace problems. They are flexible and adaptive in acquiring new technology. They are proficient with ubiquitous technology applications. They understand the inherent risks-personal and organizational-of technology applications, and they take actions to prevent or mitigate these risks.

CRP12. Work productively in teams while using cultural global competence.
Career-ready individuals positively contribute to every team, whether formal or informal. They apply an awareness of cultural difference to avoid barriers to productive and positive interaction. They find ways to increase the engagement and contribution of all team members. They plan and facilitate effective team meetings.