Using Physical and Life Science Ideas to Make Sense of Phenomena

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American Association for the Advancement of Science
A New Middle School Curriculum Unit

- Designed to support NGSS 3D teaching and learning (Roseman, Herrmann-Abell, & Koppal, 2017)
- Pilot and field tested in Colorado, Washington, DC, Maryland, and Massachusetts
- Results of a randomized control trial showed significant learning gains for a demographically diverse range of students using the new unit compared to those using their district curriculum (Herrmann-Abell, Koppal, & Roseman, 2016)

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Overarching Goal of the THSB Unit

To help students make sense of phenomena related to plant and animal growth, using

- Disciplinary core ideas about chemical reactions in nonliving and living systems,
- Crosscutting concept of matter conservation across physical and life science, and
- Science practices of data analysis, modeling, explanation, and communication.
The unit’s design specifications are based on learning theory and evidence from empirical studies

- **Coherent content storyline** of scientific ideas about atom rearrangement and conservation in chemical reactions in non-living and living systems
- **Phenomena** that can be explained with the science ideas
- **Models/modeling to** help students visualize underlying molecular mechanisms
- **Scaffolded explanation tasks** that accustom students to using evidence from data and logical reasoning from science ideas and models
Toward High School Biology (THSB)
Year 6 Content Storyline

1.1. When plants grow or ripe, they increase in mass. Atoms are conserved when plants grow. The increase in mass is due to the incorporation of atoms from molecules that were originally outside the plant body. (THSB Lessons 1, 2, 3, 4, 11, 15)

1.2. In animal body structures, carbon-based polymers are molecules made of glucose monomers. Different types of carbohydrates have different properties because they are made up of different numbers and arrangements of glucose monomers. (THSB Lesson 3.2)

1.3. Proteins and carbohydrates make up plant body structures. Proteins are made of amino acid monomers. Different types of proteins have different properties because they are made of different types, numbers, and arrangements of amino acid monomers. (THSB Lessons 6.1, 6.2)

1.4. The process by which plants build large structures in their environment to make glucose and other molecules is called photosynthesis. The process by which plants store energy from these molecules is called respiration. (THSB Lessons 3.2)

1.5. When animals grow or ripe, they increase in mass. Atoms are conserved when animals grow. The increase in mass is due to the incorporation of atoms from molecules that were originally outside the animal's body. (THSB Lessons 1, 2, 3, 4, 11, 15)

1.6. Water is essential for all living things. Water is a molecule composed of two hydrogen atoms and one oxygen atom. (THSB Lessons 1.2, 1.3)

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1.10. Water is essential for all living things. Water is a molecule composed of two hydrogen atoms and one oxygen atom. (THSB Lessons 1.2, 1.3)

1.11. Water is essential for all living things. Water is a molecule composed of two hydrogen atoms and one oxygen atom. (THSB Lessons 1.2, 1.3)
Phenomena: Rust forms when iron is exposed to air, and the amounts of both iron and air decrease as more rust forms.
Models of Molecules of Starting and Ending Substances

**Chemical Reaction:**
Steel Wool (Iron) and Air (Oxygen)

**Substances we start with in the container:**
- Fe (iron)
- O₂ (oxygen gas)

**Substances we end up with in the container:**
- Fe₂O₃ (iron oxide/rust)
Modeling how a new substance, rust (Fe$_2$O$_3$), could form from the starting substances iron (Fe) and oxygen (O$_2$).
Science Idea #5

During chemical reactions, atoms that make up molecules of the starting substances (called reactants) disconnect from one another and connect in different ways to form the molecules of the ending substances (called products). Because the arrangement of atoms in the products is different from the arrangement of atoms in the reactants, the products of a chemical reaction have different properties from the reactants.
Phenomena: Nylon forms when hexamethylenediamine is mixed with adipic acid, and the amount of product increases as the amounts of the reactants decrease.
Models of Molecules of Starting and Ending Substances

Chemical Reaction: Hexamethylenediamine and Adipic Acid

Substances we start with in the container:
- $C_6H_{16}N_2$ (hexamethylene diamine)
- $C_6H_{10}O_4$ (adipic acid)

Substances we end up with in the container:
- $C_{12}H_{24}O_3N$ (nylon repeating unit)
- $H_2O$ (water)
Modeling how a new substance, nylon (polymer), could form from hexamethylenediamine and adipic acid (monomers).
Phenomenon: When a herring eats brine shrimp, some of the brine shrimp protein becomes incorporated into the herring’s body.

Photo by Jiri Bohdal

Photo by Uli Harder
After 24 hours, 20% of the labeled carbon atoms are in the fish’s body (mostly muscle).

<table>
<thead>
<tr>
<th>Location</th>
<th>% of labeled carbon atoms found 24 hours after feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestive system</td>
<td>7</td>
</tr>
<tr>
<td>Rest of body (excluding digestive system)</td>
<td>20</td>
</tr>
<tr>
<td>Water (outside the fishes’ bodies)</td>
<td>73</td>
</tr>
</tbody>
</table>
Models help students visualize the reactants and products of protein digestion.
Modeling how brine shrimp proteins could become herring fish proteins
Phenomenon: Egg-eating snakes eat mostly ovalbumin (from egg white)

but need to make keratin (for skin and scales).
Currently Funded R & D Projects

• High school curriculum unit targeting ideas about matter and energy in chemical reactions in physical and life science in addressing the obesity epidemic

• High school curriculum unit targeting ideas about natural selection and common ancestry to explain similarities among diverse organisms

• Energy assessments to track students’ progress across grades 4-12

• Investigating the basis for differences in student performance on assessment items
How can we work to ensure a science literate citizenry when Halley’s Comet returns?

2061
1985
1910
1834
1758
1682