UNIT SYNOPSES

Carbon: Transformations in Matter and Energy (Carbon TIME) units focus on key carbon-transforming processes in socio-ecological systems at multiple scales. These processes:

(a) create organic materials (*photosynthesis*),
(b) transform organic materials (*biosynthesis, digestion*), and
(c) oxidize organic materials (*cellular respiration, combustion*).

The curriculum is based on learning progression research, and has been classroom tested and revised. It is aligned with *Next Generation Science Standards* practices, cross-cutting concepts, and disciplinary core ideas in life, earth, and physical science.

There are six Carbon Time Units. The first unit, **Systems and Scale**, orients students to the foundational perspectives and routines for the core concepts addressed. The next three units focus on transformations in matter and energy at the **organism level**. The last two units build on the concepts developed in the previous units focusing on a **systems level**. The units each require about three weeks of classroom time.

Systems and Scale introduces students to key ideas that form the basis for all the other units. Students develop a scientific account of organic and inorganic materials, as well as how *combustion* transforms organic materials to inorganic materials and chemical energy into heat and light.

- What do materials look like at smaller and smaller scales? Students use digital "Powers of Ten" resources to explore systems at multiple scales: large, macroscopic, microscopic, atomic-molecular.
- What happens when soda water loses its fizz? Students take mass measurements and use BTB to measure changes in CO_2 as soda water loses its fizz, and explain their results.
- What happens to ethanol as it burns? Students take mass measurements and use BTB to measure changes in CO_2 when ethanol burns, and explain their results.
- What is the difference between materials that burn and materials that don't burn? Students use knowledge of high-energy bonds to identify substances as organic or inorganic.
- Students learn to use the Three Questions (*Where are atoms moving? What is happening to carbon atoms? What is happening to chemical energy?*) to explain chemical changes.

If you are interested in participating in the Carbon TIME study or if you have questions about the program, please email our project management at (envlit@msu.edu).

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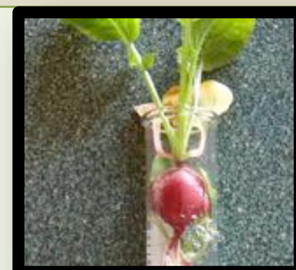
Carbon TIME - ORGANISM LEVEL UNITS

Animals cannot create organic materials, so they must find organic materials (food) and break the complex organic molecules into simpler molecules that their cells can use—the process of *digestion*. Animal cells are like plant cells in that they can grow and divide by making complex organic molecules out of simpler molecules—*biosynthesis,* again—and that they get energy by oxidizing organic materials—*cellular respiration*.

- <u>What makes up our food</u>? Students use nutrition labels to identify energy-containing and non-energy containing materials in food.
- <u>What happens when mealworms eat food</u>? Students take mass measurements and use BTB to measure changes in CO_2 when mealworms eat potatoes.
- <u>How is it true that you are what you eat</u>? Students model digestion and biosynthesis in cows using colored paperclips to represent monomers and chains of paperclips to represent large biomolecules.
- <u>How do animals have energy to move and function</u>? Students think about the "missing mass" from the mealworms experiment and create molecular models to trace matter and energy through cellular respiration.
- Students use the Three Questions to explain digestion, cellular respiration, and biosynthesis in animals.



Plants are unique in that they use the process of *photosynthesis*, using the energy from sunlight to create an organic substance (glucose) from inorganic materials (carbon dioxide and water). Plant cells grow by transforming glucose and soil minerals into all the complex organic materials that plants are made of, including fats, proteins, and complex carbohydrates—the process of *biosynthesis*. Finally, plants get the energy they need to function by oxidizing glucose—the process of *cellular respiration*.

- <u>What happens to plants in the light and dark</u>? Students use BTB to measure changes in CO_2 in the air inside containers with plants in the light and in the dark. They create molecular models to trace matter and energy through the process of photosynthesis.
- <u>How do plant cells get the energy they need to move</u>? Students create molecular models to trace matter and energy through cellular respiration.
- <u>How does a plant gain mass</u>? Students plant seeds, grow them for 4 weeks, and compare the initial and final masses of the plants and soil.
- <u>How can a potato plant make a potato</u>? Students explain how plants grow by modeling biosynthesis, using colored paperclips to represent monomers (sugars, amino acids, and fatty acids), and chains of paperclips to represent large biomolecules.
- Students use the Three Questions to explain photosynthesis, cellular respiration, and biosynthesis in plants.

Although ***Decomposers*** appear very different from animals, aerobic decomposers (fungi and aerobic decomposing bacteria) are biochemically very similar. Like animals, they rely on *digestion* (in this case, outside of the body) to break complex organic molecules into simpler organic molecules. The cells of decomposers also grow through *biosynthesis* and obtain energy through *cellular respiration*.

- <u>What happens when materials decay</u>? Students grow mold on bread, measuring mass changes and using BTB to measure changes in CO_2.
- <u>How do mushrooms grow and function</u>? Students model digestion and biosynthesis in mushrooms using colored paperclips, and use molecular models to explore cellular respiration.
- <u>How do decomposers live and grow in other places</u>? Students investigate decomposers in local soil and use the Three Questions to explain digestion, cellular respiration, and biosynthesis in decomposers.

Carbon TIME - SYSTEMS LEVEL UNITS

Ecosystems are larger systems where carbon-transforming processes – *photosynthesis*, *biosynthesis*, *digestion*, and *cellular respiration* – are constantly occurring. In combination, these processes create food chains, food webs, and organic matter pyramids—all components of the ecological carbon cycle, which cycles matter between inorganic carbon dioxide and organic materials, and energy flow through ecosystems.

- Where is the carbon located in an ecosystem? Students identify forms of organic or inorganic carbon in ecosystems.
- How do organic carbon pools change over time? Students use an online simulation to investigate changes in producer, herbivore, and carnivore organic carbon pools. They note similarities in the relative sizes of carbon pools in different ecosystems.
- How do carbon atoms and energy move through an ecosystem? In the Carbon Dice game students play the role of individual carbon atoms that move through ecosystems because of carbon-transforming processes in different organisms. . They use the Three Questions (Large Scale) to explain their results.
- How do carbon pools change over time? Students predict and follow how carbon pools change size due to carbon-transforming processes, and then chart fluxes between organic and inorganic carbon pools.
- How do humans affect carbon cycling and energy flow in ecosystems? Students use a farm ecosystem to discuss how human food choices impact the organic matter pyramid and examine satellite images of changing landscapes to assess carbon cycling in new contexts.

We depend on ***Human Energy Systems*** for many aspects of our lifestyles, from driving cars to turning on light bulbs, use carbon and energy that can be traced back to *combustion* of fossil fuels. These systems are affecting carbon cycling and energy flow on a global scale. Identifying how energy use in our lives releases CO_2 is a key for understanding the current imbalance between organic and inorganic forms of carbon in the Earth's land, oceans, and atmosphere.

- What is the Keeling Curve and why do we care about it? Students interpret data in the Keeling Curve, tracing concentrations of atmospheric CO_2 over a 50-year period. They investigate both the yearly cycle and the long-term trend in these data, learning about climate change and the Greenhouse Effect.
- How do fossil fuels form, and how do we use them? Students investigate the origins and uses of organic carbon and energy in fossil fuels using the Three Questions (Large Scale).
- How do we use organic carbon in our lives? Students calculate and compare CO_2 emissions associated with different lifestyles around the world and explore how our ways of using organic carbon drive fluxes among carbon pools.
- How does carbon move from pool to pool when we use energy? Students use a jigsaw activity to read about and discuss human consumption of fossil fuels, trace carbon in a real-world Energy Scenario Game, and return to the Keeling Curve to explain the upward trend.
- What can people do to lower carbon emissions? Students discuss individual and societal actions that reduce carbon emissions. They also learn about oceans as another carbon pool.