This Module for Interactive Teaching (MINT) may be found online at
https://ivv.rit.edu/dt-mint.php

Respiration Carbon Cycle

- The carbon link between decomposition and plants exists via gaseous carbon dioxide.

Contents:

MINT Learning Objectives

- Outline several potential pathways that a carbon molecule can get from a dead organism into the biomass of a plant.
- Correlate trophic levels to metabolic pathways and to carbon cycling.
- Outline the cycle of energy transformation; how waste products from photosynthesis are used during the process of respiration and vice versa.

National Standards Alignments:

- Vision and Change Core Concepts and Competencies (http://visionandchange.org)
    - Core Concept:
        - Pathways and transformations of energy and matter: Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics.
        - Systems: Living systems are interconnected and interacting.
    - Core Competencies:
        - Ability to apply process of science: Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.
- Biocore Guide (Brownell et al., https://doi.org/10.1187/cbe.13-12-0233)
    - Transformations of Energy and Matter: Chemical elements are transferred among the abiotic and biotic components of an ecosystem; changes in the amount and distribution of chemical elements can impact the ecosystem.
- American Society for Microbiology Curriculum Guidelines (https://www.asm.org/)
    - Microbes are essential for life as we know it and the processes that support life (e.g., in biogeochemical cycles and plant and/or animal microbiota).
- Next Gen Science Standards (http://www.nextgenscience.org/)

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus 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-LS1-6)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different
- products. (HS-LS1-6),(HS-LS1-7)
- 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)
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)

- ASPB – BSA Core Concepts and Learning Objectives in Plant Biology for Undergraduate: https://aspb.org/wp-content/uploads/2016/05/ASPB-BSA-CoreConcepts.pdf
  - Plants capture light energy to assimilate inorganic carbon dioxide into organic compounds.
  - Plants take up and transport inorganic materials from their surroundings.
  - Plants capture and use energy from sunlight. Almost all other organisms on the planet eat plants as a source of energy.
  - Plants photosynthesize and respire.
  - Plants are the primary food and oxygen producers on Earth.
- Process of Science Skills, Pelaez, N, *et al*. "The Basic Competencies of Biological Experimentation: Concept-Skill Statements" (2017). PIBERG Instructional Innovation Materials. Paper 4. http://docs.lib.purdue.edu/pibergiim/4
  - Posing problems
    - Transfer of knowledge
  - Generating hypotheses
  - Designing experiments
    - Identification of proper controls
    - Comparison requires varying only one thing at a time
  - Testing hypotheses
  - Interpreting/evaluating data
    - New knowledge incorporated with old

Interactive Video Vignette Information

IVV Title: *Dead Thing by a Tree*

IVV URL for students: https://ivv.rit.edu/DT/2/
Copy the URL to the Clipboard. Either paste it into an email to your students, or use it to create a link in your course management system.

IVV description:
Students collecting data in a field course discover a dead, decomposing animal under a tree in the field. The students and their instructor have a discussion about decomposition, and the instructor asks how carbon from the animal becomes biomass in nearby plants. While students initially misidentify uptake of carbon via roots, an experiment in decomposition allows students to link decomposer respiration to release of carbon dioxide, which can be taken up by plants and fixed via photosynthesis

Novice ideas and IVV Learning Goals

Novice Ideas

- Plants only need water and sunlight to grow.
- Plants absorb / soak up carbon through their roots, along with other nutrients from the soil
- Decomposition happens when organisms liquify and fall apart because they don't have energy anymore.

- Decomposition is due to spontaneous oxidation by molecular oxygen
- Decomposition is a separate process from respiration
- Decomposers release carbon into the soil
- Respiration is limited to the animal kingdom

Ideas addressed in the IVV

- Plants take in CO_2 (from the air) that is a product of other organisms' respiration
- Carbon cycling between plants and animals is a complex process requiring both respiration and photosynthesis.
- Decomposition occurs when microorganisms metabolize dead organisms for nutrients
- The waste products from respiration (CO_2 and H_2O) are used by plants for photosynthesis to make sugar.
- Plants and microorganisms also respire, just like we do.

Recommended In-class Curricular Material

Please see the MINT FAQ (https://ivv.rit.edu/FAQ.php) for general information on the use of MINTs and IVVs with your class. The following curricular materials are provided as examples of resources that may be used in class to further student learning towards IVV and MINT learning objectives.

- Maskiewicz AC, Griscom HP, Welch NT. Using targeted active-learning exercises and diagnostic question clusters to improve students' understanding of carbon cycling in ecosystems. CBE Life Sci Educ. 2012;11(1):58-67.
- Smith MK, Toth ES, Borges K, Dastoor F, et al. Using Place-Based Economically Relevant Organisms to Improve Student Understanding of the Roles of Carbon Dioxide, Sunlight, and Nutrients in Photosynthetic Organisms. *CourseSource*. 2018. https://doi.org/10.24918/cs.2018.1
- Allen M, Kuhmlann ML. Search for the Missing Sea Otters: an Ecological Detective Story. National Center for Case Study Teaching. http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=167&id=167

Assessment Question Information:

The research team has developed multiple select questions for assessing IVV effectiveness. Please contact the research team (https://ivv.rit.edu/about.php) if you are interested in assessing IVV use in your course.

Acknowledgement

This material is based in part upon work supported by National Science Foundation (NSF) grants 1432286 and 1432303. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.