

Plants Unit Overview

The Driving Question and Research Base

The *Plants Unit* starts by asking students to express their ideas about the driving question about an anchoring phenomenon: *How does a radish plant grow, move, and function?*

Carbon is the key! In the unit, students learn to tell the story of how matter and energy are transformed as they move through plant systems. A particularly powerful strategy for explaining how plant systems transform matter and energy involves *tracing carbon atoms*. For more information about the *Next Generation Science Standards* **disciplinary core ideas** included in this unit see the sections on the Matter Movement, Matter Change, and Energy Change Questions below and the [Unit Goals](#).

Research base. This unit is based on [learning progression research](#) that describes the resources that students bring to learning about plants and the barriers to understanding that they must overcome. It is organized around an [instructional model](#) that engages students in three-dimensional practices.

Students' Roles and Science Practices

As students learn to answer the driving question by explaining how animal systems transform matter and energy, they play three different roles that encompass all of the *Next Generation Science Standards* **science and engineering practices**. (For more details on science and engineering practices, see the [Unit Goals](#).)

- Questioners: Students explore the driving question, clarify, and generate more detailed questions
- Investigators: Students conduct matter-tracing investigations of radish plants growing; and develop evidence-based arguments about key observations and patterns
- Explainers: Students construct model-based explanations of how a potato plant grows and functions.

Investigation: Plants growing & gas exchange in light and dark



Key observations and patterns

- When plants grow, they gain more dry mass than the soil loses
- Plants absorb CO₂ in the light
- Plants emit CO₂ in the dark

The roles that students play are embedded in the *Carbon TIME Instructional Model* and [Discourse Routine](#). The Discourse Routine guides how classroom discourse aimed first at divergent thinking and then at convergent thinking should be sequenced through the unit.

Good Explanations Answer the Three Questions

Students figure out how to answer the driving question by tracing carbon-containing molecules through a series of movements and chemical changes inside plants. At each stage in these processes they answer [Three Questions](#) about what is happening: the *Matter Movement Question*, the *Matter Change Question*, and the *Energy Change Question*. Below, we use the anchoring phenomenon of plant growth as an example of how students learn to answer the Three Questions for different plants

Note that, in *Carbon TIME*, NGSS **crosscutting concepts** serve as the “rules of grammar” for producing a scientific performance. With respect to plants growing, high quality explanations should attend to the following rules that are implied by crosscutting concepts. Explanations should attend to...

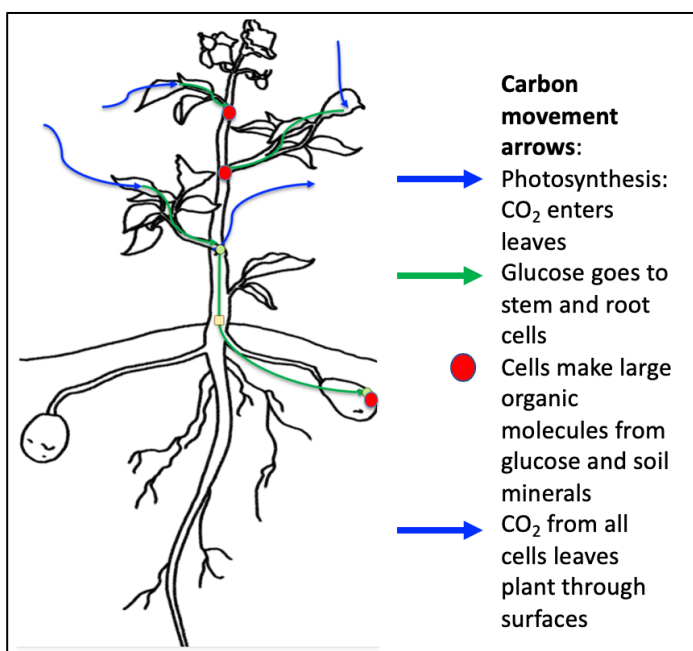
- *Scale* by explaining events and phenomena at the appropriate scale (see more in the structure and function bullets below).
- *Systems and system models and energy and matter* by following rules for tracing matter and energy through systems and system models. For example, neither energy nor matter should be created or destroyed as it moves into, through, or out of a system.
- *Structure and function* by linking structures and functions in explanations at each scale.
 - Macroscopic scale (tracing matter and energy through processes occurring in plants and plants systems)
 - Cellular scale (tracing matter and energy into and out of cells as cellular functions are carried out)
 - Atomic-molecular scale (tracing matter and energy through chemical processes—cellular respiration and biosynthesis—involving molecules with different structures and properties)

The Matter Movement

Question: Tracing Molecules Through Plants

Students learn to tell the following story of how carbon-containing molecules move through plants.

- Carbon atoms enter plants in CO_2 molecules that are absorbed through the leaves, where they become part of glucose (sugar) molecules.
- The sugar molecules travel through the stems and roots to all of the plant's cells.¹
- Some of the carbon atoms stay in the cells, as they are incorporated into the large organic molecules that make up cell structures through biosynthesis.
- Some of the sugar molecules are oxidized in the process of cellular respiration. They leave the plant in CO_2 that diffuses through plant surfaces.



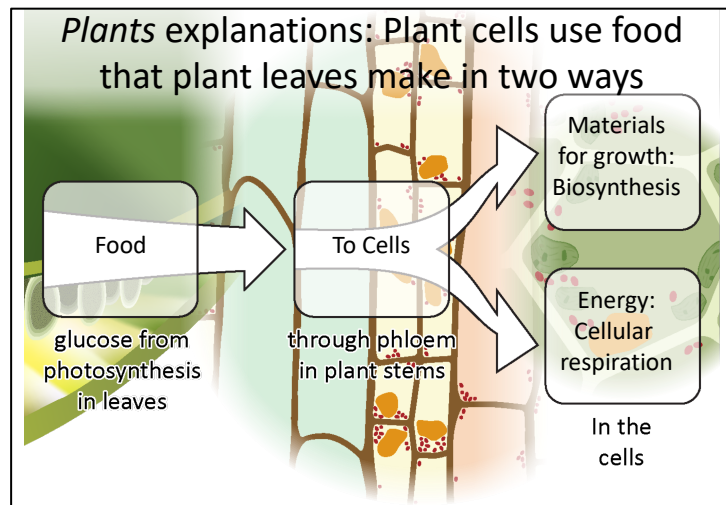
The Matter Change and Energy Change Questions: Explaining How Plants Use Organic Molecules to Grow, Move, and Function

Matter movement is an essential part of the story, but not the whole story. To answer the driving question, students learn to explain chemical changes that occur inside plants:

- *Photosynthesis.* Plants' leaf cells absorb CO_2 and water. They use energy from sunlight to rearrange the atoms into new molecules: glucose and oxygen. Glucose has chemical energy stored in their C-C and C-H bonds.

¹ Sugar molecules travel through the phloem as the disaccharide sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) rather than the monosaccharide glucose ($\text{C}_6\text{H}_{12}\text{O}_6$). We do not feel that this distinction is important for basic life science courses.

- *Biosynthesis and growth.* Plants grow when their cells grow and divide through the process of biosynthesis. Plant cells combine glucose with soil minerals to make other small organic molecules. Then they combine small organic molecules to make the large organic molecules needed for cells' structure and function.
- *Cellular respiration—energy to move and function.* Plant cells get the energy they need to move and function by combining sugars and other small organic molecules with oxygen, releasing energy when high-energy C-C and C-H bonds are replaced by lower-energy bonds in carbon dioxide and water.



How Much Detail?

There are more complicated and more scientifically accurate ways of talking about chemical bonds and about changes in energy; we discuss some of those in detail in our educator resource: [Carbon TIME Content Simplifications](#). But our [learning progression research](#) has shown that there is an important tradeoff here—many students get lost in the details and never learn a basic coherent story that answers the driving question. The *Next Generation Science Standards* take a clear position on this tradeoff; a coherent story based on principles such as matter and energy conservation is more important than the details. Consult the [Unit Sequence](#) tab and the sections on Extending the Learning at the end of each Activity page to decide how much detail is appropriate for your students.