School Garden

Phenomenon/Problem:

Two groups of lettuce can be growing under similar conditions, yet one group shows clear signs of insect damage while the other remains mostly unharmed.

Lettuce growing next to basil seems to experience less insect damage than lettuce growing alone or near other plants. This pattern appears repeatedly enough that it raises an important question: could the presence of one plant actually influence how insects interact with another?

This phenomenon suggests that plant interactions in a garden may be more complex than they first appear. Instead of thinking about plants as isolated individuals, it starts to look like they are part of a connected system, where what grows nearby can influence outcomes like pest damage. Observations like this lead to deeper questions about what is happening and why—and create an opportunity to investigate how living things interact within an ecosystem.

Essential Questions:

- Why do lettuce plants near basil experience less insect damage?
- What can repel insects from plants?
- Why are some plants more insect-resistant than others?
- How can understanding plant interactions help design better gardens or greenhouses?
- How do interactions between organisms shape ecosystems?

Stimuli: How will students experience and/or observe the phenomenon/problem?

Your school has a large garden that helps grow fresh food for the cafeteria, and part of your job is to help take care of it. One day, while checking on the lettuce, you notice many of the leaves have small holes. When you look closer, you spot tiny insects clustered along the stems and undersides of the leaves. It looks like these pests—aphids—are feeding on the plants and causing damage.



Curious, you decide to compare these plants to lettuce grown on the other side of the garden. The lettuce in the second location looks healthier—larger leaves, fewer holes, and no obvious pests. You carefully inspect several plants but don't see the same insect activity you observed before. Why is one group of lettuce struggling while the other is doing so well?



To figure it out, you begin listing the conditions in each location. You think about sunlight, temperature, watering, and soil. Some differences stand out, but in one location, the lettuce is planted right next to basil, while the damaged lettuce is growing next to different plants. This observation makes you wonder if the presence of basil could be connected to the healthier lettuce—and gives you an idea worth investigating.

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Related Phenomena/Problems:

- People plant basil and citronella plants near patios and notice fewer mosquitoes.
- Basil plants experience less pest damage than lettuce.
- When given multiple plant options, insects consistently choose certain plants over others.
- Farmers and gardeners often use companion planting strategies to support crop growth and pest management.
- Crop rotations and diversified planting systems are used on farms to help manage pests over time.

Considerations for Instructional Design:

- Have students make a claim regarding what happens to plant growth and insect damage when planted near basil.
- Have students provide an explanation of why there is different insect damage depending on a plant's proximity to basil.
- Engage students in making a prediction about what happens when plants are moved closer or farther from basil.
- Have students plan and conduct an investigation to test a hypothesis on what happens when plants are planted closer to basil.
- Encourage students to ask questions that can be investigated within the school garden.

Explanation:

Aphids

The observed damage on lettuce plants is caused by aphids. Aphids are phloem-feeding insects that insert needle-like mouthparts (stylets) into plant vascular tissue and remove sap, which contains sugars, amino acids, and nutrients essential for growth. This feeding causes several measurable effects in lettuce:



- Nutrients that would normally support leaf growth are removed by aphids.
- Aphids excrete honeydew, which promotes fungal growth that blocks light from reaching leaves.
- Aphid feeding triggers plant stress responses that alter growth-regulating hormones.

Additionally, aphids reproduce rapidly through parthenogenesis (asexual reproduction), allowing populations to increase exponentially in favorable conditions. Because of this, even a small initial infestation can lead to dense colonies that significantly reduce plant productivity.

Chemical Detection of Plant Signals

Aphids rely on chemical sensing systems to detect specific molecules in the air. Plants release volatile organic compounds (VOCs)—small, carbon-based molecules that diffuse into the environment and act as signals.

Aphids have specialized sensory receptors (in their antennae) that detect these VOCs and allow them to identify plant species, evaluate plant quality, and select feeding and reproduction sites.

Lettuce emits a set of VOCs that aphids recognize as a suitable host signal. When lettuce is grown alone or with few other species, these signals are consistent and easy for aphids to detect.

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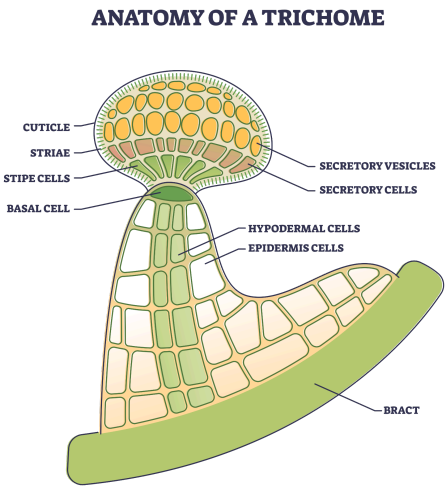
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Basil VOCs

Basil also produces VOC scents. Unlike lettuce, basil produces a large variety of secondary metabolites, including strongly aromatic VOCs such as terpenoids. These molecules differ significantly in chemical structure from the VOCs released by lettuce.

On the surface of basil leaves are tiny structures called glandular trichomes (microscopic "hair-like" glands). These are specialized epidermal cells that:

- Synthesize VOCs (especially essential oils like terpenes and phenylpropanoids)
- Store them in small pockets just under the leaf surface
- Release them into the air when the compounds diffuse outward or when the plant is disturbed



Inside these glands:

- Enzymes build VOC molecules from basic carbon compounds produced during photosynthesis
- These molecules accumulate in a subcuticular space (a small storage chamber)
- Eventually, they move across cell membranes, cell walls, and the leaf cuticle into the surrounding air

These basil VOCs are small, lightweight molecules that can easily evaporate into gas. Therefore, they can diffuse through the air over distances and create a "chemical field" around the plant.

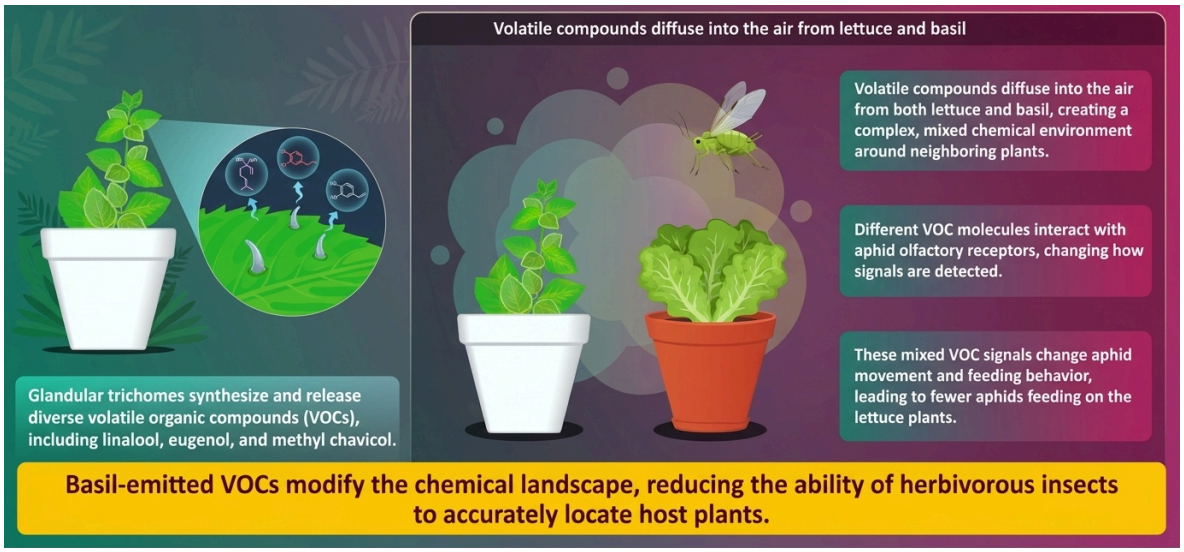
Basil produces VOCs such as linalool, eugenol, and methyl chavicol. When aphids smell these VOCs, it may cause:

- Sensory masking: Aphids normally use lettuce VOCs as host signals to locate the lettuce. Basil VOCs mix into the air, making lettuce harder to detect.
- Sensory interference: Some basil VOCs actively interfere with the insects' olfactory system. They bind to sensory receptors and disrupt how signals are processed in the nervous system. This reduces insects' ability to orient towards food sources.
- Direct repellency: Some basil compounds trigger avoidance behavior, meaning the VOC scent is interpreted as unsafe or unsuitable.

The molecular structure of each VOC determines how it interacts with insect biology. At the same time, the structure of aphid sensory receptors determines what molecules they respond to.

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Biodiversity in Populations

The interaction between basil, lettuce, and aphids illustrates how biodiversity influences ecosystem functioning. In the area where lettuce is grown alone or with limited plant diversity, the chemical environment is relatively simple. Lettuce VOCs dominate, creating a clear and consistent signal that aphids can easily detect. This allows a single pest species to specialize and dominate, leading to high levels of herbivory.

In contrast, the presence of basil increases species diversity and introduces a more complex mixture of VOCs into the environment. Diverse plant communities produce a wider range of chemical signals, which can disrupt host-finding by herbivores.

Plant volatile compounds are known to influence the behavior and performance of many organisms, shaping ecological interactions at multiple levels. In this context, basil functions as a chemical modifier of the ecosystem, changing how energy and matter (in the form of nutrients and biomass) flow through the system by reducing herbivore pressure.

Garden Design

Understanding the interactions between organisms in an ecosystem can influence how a system should be designed. Garden systems can be designed to prevent pest establishment through biological interactions. Example design solutions would be:

- Interplanting basil and lettuce in alternating rows
- Placing basil around the perimeter of lettuce beds
- Increasing overall plant diversity with additional aromatic species

Student and teacher questions about this phenomenon/problem that could be instructionally productive:

- What is the basil emitting that could affect insects at a distance?
- How could we design garden layouts to prevent pests?
- How far do basil plants protect other plants like lettuce?
- Do all types of basil plants protect against lettuce?
- If this works with basil, what characteristics would another plant need to produce a similar effect?
- Does basil protect other plants from aphids, such as bean plants or broccoli?

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Explaining the phenomenon/problem or related phenomena could lead students toward developing the following DCIs:

HS-LS1.A:
- Systems of specialized cells within organisms help them perform the essential functions of life.

HS-LS4.D:
- 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.

HS-ESS3.C:
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

HS-ETS1.B:
- 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.

HS-LS2.A:
- 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-LS4.C:
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

Notes about relevance and authenticity (funds of knowledge, interests, identity)
Why might students be engaged?

- Students may grow and/or eat these plants
- Can be applied to students' local schools, gardens, and communities
- Connects plant biology to food production and management decisions
- Encourages students to think about design solutions to a local and relevant problem

Resources/References

Aphids in Home Gardens. University of Maryland Extension. (n.d.). https://extension.umd.edu/resource/aphids-home-gardens/

Aphididae: The life cycle and control of Aphids. *Biology Insights*. (2025, August 4). https://biologyinsights.com/aphididae-the-life-cycle-and-control-of-aphids/

Carvalho, M.G., Bortolotto, O.C. and Ventura, M.U. (2017). Aromatic plants affect the selection of host tomato plants by *Bemisia tabaci* biotype B. *Entomol Exp Appl*, 162: 86-92. https://doi.org/10.1111/eea.12534

Deletre, E., Schatz, B., Bourguet, D. *et al.* (2016). Prospects for repellent in pest control: current developments and future challenges. *Chemoecology* 26, 127–142. https://doi.org/10.1007/s00049-016-0214-0

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Döring, T.F. (2014). How aphids find their host plants, and how they don't. *Ann Appl Biol*, 165: 3-26. https://doi.org/10.1111/aab.12142

Hatt, S., Thomas F. Döring. (2023). Designing pest suppressive agroecosystems: Principles for an integrative diversification science. *Journal of Cleaner Production*, *Volume 432*, 139701, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2023.139701

Hoidal, N. (2026). Companion planting in home gardens. University of Minnesota Extension. https://extension.umn.edu/gardening-minnesota/companion-planting-home-gardens

Holt, Robert D., Michael Barfield. Direct plant–predator interactions as determinants of food chain dynamics. *Journal of Theoretical Biology*, Volume 339, 2013, Pages 47-57, ISSN 0022-5193, from https://doi.org/10.1016/j.jtbi.2013.04.034

Kumaraswamy, S., & Huang, Y. (2024, November 28). Molecular interactions between plants and aphids: Recent advances and future perspectives. MDPI. https://www.mdpi.com/2075-4450/15/12/935

Séverin Hatt, Thomas F. Döring. (2023). Designing pest suppressive agroecosystems: Principles for an integrative diversification science. *Journal of Cleaner Production*, *Volume 432*, 139701, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2023.139701.

Sun, Y., Guo, H., & Ge, F. (2016, April 13). Plant-aphid interactions under elevated CO2: Some cues from aphid feeding behavior. *Frontiers in Plant Science.* https://pmc.ncbi.nlm.nih.gov/articles/PMC4829579/

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