High School Biology

Unit 9: Energy and matter in ecosystems

Explore how matter and energy flow from one organism to the next! Here, we focus on species-species interactions and at the level of ecosystems, which will scale up to the global level in unit 10. Topics include:

- Species interactions (predation, competition, mutualism, commensalism, and parasitism).
- Food chains, food webs, trophic levels and energy pyramids.
- Carbon and nitrogen cycle.

<table>
<thead>
<tr>
<th>TEKS standards</th>
<th>Example phenomena</th>
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<tr>
<td>SCIENCE.BIO.13.A</td>
<td>How does the decline of wild bee populations impact ecosystems?</td>
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<tr>
<td>Investigate and evaluate how ecological relationships, including predation, parasitism, commensalism, mutualism, and competition, influence ecosystem stability.</td>
<td>Wild bees—crucial pollinators in our ecosystems—are facing alarming declines due to habitat loss, pesticide exposure, and climate change. This decline highlights the importance of relationships among species in an ecosystem, including predation, competition, mutualism, commensalism, and parasitism. The decline of wild bee populations disrupts the flow of matter and energy through trophic levels, leading to broader ecological consequences. This impact extends to the carbon and nitrogen cycles, where bees play a crucial role through pollination. Exploring the challenges wild bees face in agricultural landscapes offers insights into the interconnectedness of species in ecosystems and the importance of maintaining ecosystem dynamics. It is crucial to note that wild bees, not European honey bees, are the ones experiencing decline; despite seeming similar, these species differ significantly. Additional species that can be explored: monarch butterfly (Danaus plexippus), Little Brown Bat (Myotis lucifugus), black-chinned hummingbird (Archilochus alexandri).</td>
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<td>SCIENCE.BIO.13.B</td>
<td>Analyze how ecosystem stability is affected by disruptions to the cycling of matter and flow of energy through trophic levels using models.</td>
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<td>SCIENCE.BIO.13.C</td>
<td>Explain the significance of the carbon and nitrogen cycles to ecosystem stability and analyze the consequences of disrupting these cycles.</td>
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<td>Prompts for students to consider:</td>
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<tr>
<td>- How do shifts in wild bee populations influence species interactions?</td>
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<td>- How does the decline of wild bees affect the flow of matter and energy in ecosystems?</td>
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<td>- How do declining wild bee populations impact ecosystem health?</td>
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<td>- How might the decline of wild bees change the dynamics of biogeochemical cycles, such as the carbon and nitrogen cycle?</td>
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<td>- How does wild bee decline impact plant productivity, ecosystem health, and global ecological balance?</td>
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How do invasive species disrupt species relationships, impact ecosystem health/dynamics, and alter biogeochemical cycles?

Invasive lionfish, voracious predators introduced to the Atlantic Ocean, are wreaking havoc on coral reef ecosystems. This invasion showcases the critical role of species interactions—predation, competition, mutualism, commensalism, and parasitism—and how one change (i.e., the introduction of a non-native species), can have far-ranging consequences. By outcompeting native predators and consuming a wide array of prey, lionfish can alter ecosystem dynamics and disrupt the carbon and nitrogen cycles within marine environments. Their unchecked predation diminishes biodiversity, alters species distribution, and impacts energy flow across trophic levels. Investigating the lionfish invasion in coral reefs sheds light on connections among species in marine ecosystems and underscores the urgent need for strategies to protect ecosystem health.

*This phenomenon can be applied broadly or specifically to species like Burmese python (Florida Everglades), zebra mussels (Great Lakes), cane toad (Australia), kudzu (SE USA), emerald ash borer (North America), water hyacinth (worldwide).*

Prompts for students to consider:

- How do invasive species affect species interactions?
- How does the presence of an invasive predator like lionfish affect the flow of matter and energy through marine ecosystem trophic levels?
- How do invasive lionfish affect marine ecosystem health?
- How might lionfish invasions alter marine biogeochemical cycles, including carbon and nitrogen cycles?
- How does the presence of lionfish influence marine plant productivity, ecosystem health, and global marine ecological balance?

Unit resources

- For the videos in this unit, use the Learning summary video notetaking guide
- For the articles in this unit, use the Article notetaking guide
- For the exercises in this unit, use the Blank workspace template
- Vocabulary and notation notetaker
## Lesson overview

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| **Lesson 1: Interactions in communities**   | Identify and describe the five main types of ecological relationships (predation, competition, mutualism, commensalism, and parasitism) and provide examples of each from various ecosystems. | ● Interactions among species drive the structure and dynamics of ecosystems.  
● Utilize a vocabulary organizer for species interactions with definitions and many examples.  
● Students create a match game from vocab organizer on index cards. No cards? Use cut paper. Mark initials on cards for deck combining & partner play. Use a clip to store for warm-ups and review. |
| **Lesson 2: Flow of energy and matter through ecosystems** | Explain the concepts of energy flow and matter cycling within ecosystems, including the roles of producers, consumers, and decomposers in trophic levels.  
Predict the potential impacts on ecosystem stability when changes occur in ecological relationships due to environmental pressures or human activities. | ● Trophic pyramids illustrate energy and matter flow in ecosystems, linking all trophic levels and highlighting their roles in ecosystem functionality.  
● Assign ecosystems to groups; each member researches and creates a food chain, including decomposers, on sticky notes. Together, design a background and assemble a food web.  
● Groups adjust food webs using "disruption cards," analyze impacts, and conclude with a class discussion. Examples: oil spill, invasive species, habitat loss, removal of apex predator, & drought.  
● Examine events like the Bastrop fire or local examples focusing on ecosystems' resilience, recovery, and changes pre- and post- disturbances. |
| **Lesson 3: Biogeochemical cycles**         | Describe the processes and significance of the carbon and nitrogen cycles in maintaining ecosystem stability. | ● The nitrogen and carbon cycles are key in regulating ecosystems, managing the flow of energy and recycling elements to support life.  
● Before the carbon cycle, emphasize carbon's role in forming essential life molecules.  
● Before the nitrogen cycle, note nitrogen's crucial role in chlorophyll and amino acids.  
● Diagram how fertilizers increase crop yields but negatively impact the nitrogen cycle, leading to eutrophication, dead zones, and biodiversity loss.  
● Discuss the challenges in balancing the need for higher yields with preserving biodiversity. |
Best practices
COMMON MISCONCEPTIONS AND HOW TO ADDRESS THEM

“Organisms create energy from the food they eat.”
Organisms transform food's chemical energy into ATP, not creating but transferring energy.

How to address this misconception
Beginning with the law of conservation of energy to illustrate energy's transformation—not its creation or destruction—sets the stage for delving into processes like photosynthesis and cellular respiration, where food is converted into ATP. Follow with revisiting the conservation of matter, as seen in the cycling of carbon and oxygen between plants and animals through photosynthesis and cellular respiration. This demonstrates that matter, like energy, is neither created nor lost but continuously recycled in ecosystems. Use diagrams to trace energy from the sun through the ecosystem and model the journey of energy in sunlight to show mitochondria's role in energy conversion, highlighting energy's continuous transformation in cells. Diagram energy flow across trophic levels to illustrate food chain structure. Then, introduce matter recycling, emphasizing the role of decomposers with real world examples (e.g., the redheaded centipede (*Scolopendra heros*) breaking down dead plant and animal matter). By recycling matter, decomposers are crucial in linking nutrient cycles to food web dynamics, highlighting the critical role every organism plays in sustaining ecosystem health. Watch ‘Dirty Jobs’ ‘Poo Pot Maker’ to see manure turned into flower pots and also learn about salmon population sampling, available for streaming or on season 2 DVD, with used copies available, which has additional biology-related episodes for extension activities or sub-plans.

“Ecosystems are static entities that remain stable over time.”
Succession showcases the dynamic nature of ecosystems, positively responding and adapting to disturbances of all scales, emphasizing natural resilience and ongoing change.

How to address this misconception
Use the lens of ecological succession to illustrate how ecosystems are inherently dynamic. Mount St. Helens’ recovery illustrates primary succession with life slowly returning, while Yellowstone's rapid regrowth after wildfires shows secondary succession. These examples highlight the inherent variability in how ecosystems respond to disturbances. Incorporate activities like analyzing vegetation and animal population changes through graphs and before-and-after photos of disturbed sites can lead students to explore ecosystem resistance and resilience. This encourages discussions on recovery times across different ecosystems and why they may vary significantly in appearance post-disturbance. Examine fire-dependent ecosystems, like Texas Hill Country’s oak savanna and juniper-oak woodlands, where periodic fires are essential for biodiversity and underbrush control. Highlight that disturbances such as fires and hurricanes foster succession, biodiversity, and nutrient cycling, proving some disturbances are natural and beneficial, showcasing ecosystems’ adaptability and dynamic balance. This exploration reveals ecosystems as ever-changing entities, continuously adapting and transforming in the face of both minor and significant disturbances, highlighting the inherent dynamism and resilience of nature.
CLASSROOM ACTIVITIES

Observing ecological interactions
Explore nature’s web: watch live feeds to see how organisms interact and ecosystems dynamics in real time! In this activity, students will observe and document ecological interactions and build food webs from their observations. This connects to real-life examples of biodiversity and conservation, linking to biology concepts like trophic levels, energy flow, and matter cycling in ecosystems.

Materials: computer(s) & internet access (if internet access is unreliable, screen-record a camera feed to play for the class), student notebooks or data sheets, book “Who Pooped in the Park” (scan in and project to read to class or access via YouTube), paper for group work.

☐ Observation and documentation: use live streams, game cameras, or field trips for students to observe, document, and categorize ecological interactions and trophic levels from producers to decomposers, noting behaviors like predation and mutualism. Check out: Explore.org, Nature Conservatory (nature.org), Alaska Dept of Fish and Game (adfg.alaska.org), Cornell Lab Bird Cam (allaboutbirds.com).

☐ Analysis of food chains and webs: students build food chains and webs from observations, discussing energy flow from the sun to decomposers and energy loss at each trophic level.

☐ Explore the cycling of matter: incorporate how decomposers recycle matter into nutrients for producers. Update their diagrams by adding poop symbols to each organism. Additionally, add in the various organisms that eat dead organic matter (i.e., scavengers, detritivores, decomposers).

☐ Have fun with it: pair this with the book “Who Pooped in the Park?” (garydrobson.com) for a quick lesson on how scat identification can uncover who’s eating whom in ecosystems, for a fun, educational twist.

☐ Connect to conservation and biodiversity: highlight biodiversity’s role in food webs for ecosystem resilience and resistance. Connect this to conservation efforts that safeguard species diversity and ensure the continuity of vital matter cycling and energy flow processes.

☐ “What if” scenarios: have students brainstorm “What if?” scenarios affecting food chains/webs or matter cycling, like removing a keystone species or introducing an invasive species. In groups, they assess how these changes could affect ecosystem dynamics, considering the ripple effects among species interactions and throughout trophic levels.

☐ Presentations and discussions: groups share their “What if?” outcomes with food chain/web and matter cycle diagrams. A class discussion follows on species interactions, , trophic links, and ecosystem health and human well-being.

Extensions: assign students to critique a scientific paper on ecological dynamics, developing their critical reading and evaluation skills by analyzing the study’s methods, data, and conclusions.

Modifications: provide lower-level structured observation sheets during field trips or live streams to guide attention towards key ecological relationships and species roles within food chains/webs.
Trophic level impact analysis

Dive into the wild world of ecosystem dynamics by exploring real-life case studies of trophic level changes! In this activity, students will analyze how events like zebra mussel invasions or Amazon deforestation impact species and energy flow. This connects to biology concepts such as trophic levels, ecosystem interconnectedness, and the ripple effects of environmental changes.

Materials: Student internet or library access, paper and materials for posters.

☐ Case study selection: assign or allow students to select a case study focusing on a significant ecological event that altered trophic levels.
  ☐ Check out: zebra mussel spread in Texas lakes, Blackland Prairie restoration, red imported fire ant invasion, ecological impact of Hurricane Harvey, feral hogs (Sus scrofa), salt cedar (Tamarix spp.) invasion, Amazon Rainforest deforestation, Aral Sea desiccation, Chernobyl, invasive burmese pythons in Florida, California (or Texas) drought and wildfires.

☐ Research phase: (A) background information before the event, (B) details of the event (e.g., species introduction/removal, human activities), (C) immediate impacts, particularly concerning changes in species abundance, trophic links, ecosystem dynamics, and the flow of matter and energy, (D) long-term effects on the ecosystem, biodiversity, and (E) recovery efforts, if applicable, and their effectiveness.

☐ Analysis: create two energy pyramids one prior to disturbance and one following the disturbance and examine how changes in trophic levels affected ecosystem dynamics and matter/energy flow. Reflect on: the interconnectedness of species and ecosystems and the consequences of the change; lessons learned regarding ecosystem management and conservation.

☐ Gallery walk or presentations: have students prepare a comprehensive presentation of their case study either as slides or a poster for a gallery walk.

☐ Class discussion: after presentations or gallery walk, facilitate a class discussion that encourages students to compare and contrast the different case studies, focusing on common themes, unique outcomes, and insights into ecosystem resistance, resilience, recovery, and human impact.

Extensions: implement a peer-review phase where students provide feedback on each other's work before the final presentation, encouraging critical thinking and collaborative learning. Challenge students to compare their case study with another ecosystem that experienced a similar disruption.

Modifications: provide students with a guided template or worksheet that breaks down the research process into manageable steps. Allow students to work in pairs or small groups to share the research workload. Instead of requiring an exhaustive study of all trophic levels, ask students to focus on one particular aspect of the case study, such as the impact on a specific species.

EXPERT INSIGHTS

Utilize local, state, and national forest, park, and wildlife agencies for guest speakers (in-class or video conferencing). The National Park Service has “Chat with a Ranger” programs, where all of the key topics of this unit can be discussed, for almost every national park (nps.gov) e.g., Big Bend National Park, Rocky Mountain National Park and Zion National Park. Tip: If agency websites lack speaker links, use the “Contact Us” section to email directly for arranging class speaker experiences.
GENERAL CLASSROOM IMPLEMENTATION RESOURCES:

- **Weekly Khan Academy Quick Planning Guide**: Use this template to easily plan your week using Khan Academy.

- **Student Learning Templates**: Choose a template for students to record their learning. There are templates for watching videos, reading articles, and doing exercises.

- **Using Khan Academy in the Classroom**: Learn about teaching strategies and structures to support your students in their learning with Khan Academy.

- **Differentiation Strategies for the Classroom**: Read about strategies to support the learning of all students.