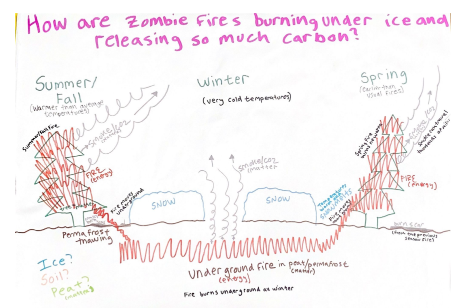
UNIT STORYLINE

Unit Question: What causes fires in ecosystems to burn and how should we manage them?

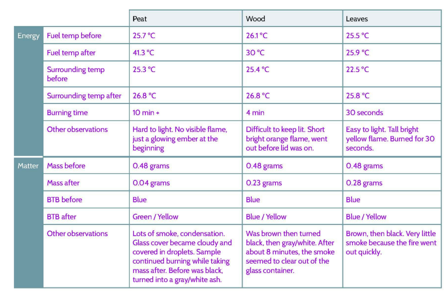
How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES | VIDEOS OR IMAGES | DATA SETS | READINGS | COMPUTER INTERACTIVES

Lesson Set 1: What causes zombie fires to burn under the ice and what are the consequences?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 Lesson Set 1 3 days **How can fires burn under ice and release so much energy and matter?** Anchoring Phenomenon	 *Fires in the Arctic are burning under ice.*	We do a visual inquiry to investigate zombie fires. We share our experiences and ideas about how our lives are connected to fires. We develop initial models to explain the interactions in the zombie fire system and how they release so much carbon. We develop a DQB and decide to investigate how zombie fires could be burning under the ice. We figure out: • Zombie fires burn under ice throughout the winter. • In zombie fires, peat is burning in the thawing permafrost. • Lots of carbon is put into the air when these zombie fires burn. • Zombie fires are not very common but are becoming more common.	

⇓ **Navigation to Next Lesson:** We figured out zombie fires burn under ice and release carbon. We wonder what is happening with the matter and energy in the peat/permafrost that allows fires to burn under ice.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 Lesson Set 1 2 days **What is peat and why does it burn so much?** Investigation	 *Burning peat and other fuels releases carbon dioxide and energy.*	We decide to investigate what is burning in zombie fires. We observe and burn peat and other fuels for fire. We read about the relationships between permafrost and peat and notice and wonder about why peat formed. We figure out: • We can explain puzzling observations using energy and matter concepts. • Peat, made from ancient plants, is widespread and used as fuel. • Peat is carbon-based and releases CO_2 when burned. • Peat burns slowly, emitting much CO_2 and energy. • Permafrost is ground that stays frozen for years, even centuries. • Arctic permafrost thaw reveals peat.	

		Peat	Wood	Leaves
Energy	Fuel temp before	25.7 °C	26.1 °C	25.5 °C
	Fuel temp after	41.3 °C	30 °C	25.9 °C
	Surrounding temp before	25.3 °C	25.4 °C	22.5 °C
	Surrounding temp after	26.8 °C	26.8 °C	25.8 °C
	Burning time	10 min +	4 min	30 seconds
	Other observations	Hard to light. No visible flame, just a glowing ember at the beginning	Difficult to keep lit. Short bright orange flame, went out before lid was on.	Easy to light. Tall bright yellow flame. Burned for 30 seconds.
Matter	Mass before	0.48 grams	0.48 grams	0.48 grams
	Mass after	0.04 grams	0.23 grams	0.28 grams
	BTB before	Blue	Blue	Blue
	BTB after	Green / Yellow	Blue / Yellow	Blue / Yellow
	Other observations	Lots of smoke, condensation. Glass cover became cloudy and covered in droplets. Sample continued burning while taking mass after. Before was black, turned into a gray/white ash.	Was brown then turned black, then gray/white. After about 8 minutes, the smoke seemed to clear out of the glass container.	Brown, then black. Very little smoke because the fire went out quickly.

⇓ **Navigation to Next Lesson:** We figured out peat is made of layers of dead plants and releases CO2 when it burns. We wonder why those plants did not break down and what happens when peat forms.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 3

Lesson Set 1

4 days

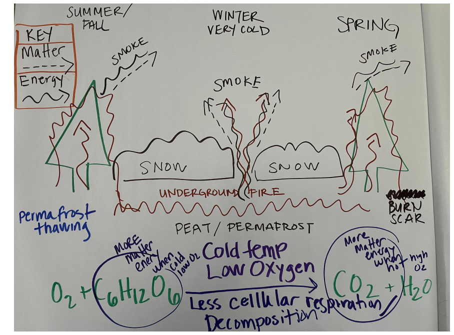
Why is there so much peat that has not decomposed in the permafrost?

Investigation

Peat does not decompose very much in permafrost.

We look at images, develop models, and investigate how temperature affects decomposition rate. We plan and carry out an investigation, using yeast to generate evidence for an explanation about why there is so much peat. We figure out:

- Energy and matter from plants are typically returned to the atmosphere by decomposers.
- Conditions such as temperature and oxygen levels affect the rate of decomposition.
- The mechanism of decomposition is cellular respiration.
- Energy from sugar is transferred to yeast and other decomposers during cellular respiration.
- Matter from sugar is transformed during cellular respiration to grow more yeast and produce carbon dioxide and water.
- In the permafrost/peat system, cold temperatures and low oxygen levels slow the rate of decomposition and cellular respiration.
- When rates of decomposition are low, the matter and energy do not flow out of the permafrost/peat system, making a carbon sink.



⇓ **Navigation to Next Lesson:** We figured out that carbon and energy are trapped in permafrost/peat due to slow decomposition/respiration. We wonder why there were so many plants in the Arctic that made peat if it is so cold.

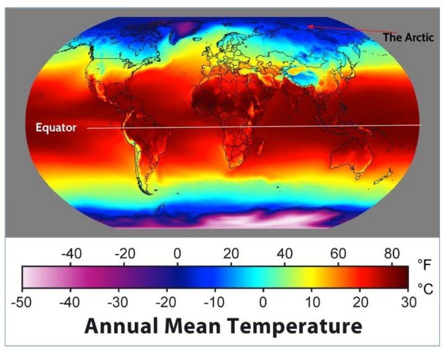
LESSON 4

Lesson Set 1

1 day

How did so much plant energy and matter get into the peat in the zombie fire system?

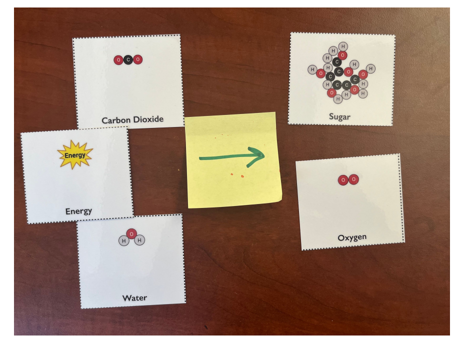
Problematizing, Investigation



Solar energy in the Arctic provides energy for photosynthesis.

We investigate how so much plant matter was stored as peat under the permafrost. We read about Earth's conditions thousands of years ago that allowed for the formation of all of that peat. We figure out:

- Increased solar radiation in the Arctic increased the potential for plants to capture and store chemical energy in carbon-based compounds through photosynthesis.
- As solar radiation in the Arctic decreased, many plants died, and peat and permafrost were formed.



⇓ **Navigation to Next Lesson:** Now that we see that there is a relationship between solar radiation and photosynthesis, we need to investigate this. We need data!

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

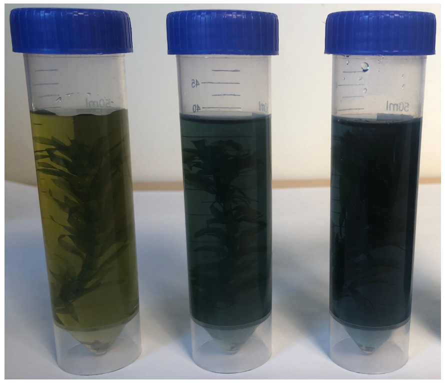
LESSON 5

Lesson Set 1

3 days

Could changes in the Earth's tilt cause more energy and matter to be stored in plants?

Investigation



Plants make different amounts of starch when the light angle changes.

We plan and carry out an investigation to determine how differences in available solar energy impact how much carbon dioxide is captured and stored as chemical energy in plants. We figure out:

- Increased solar radiation in the Arctic increased the potential for plants to capture and store chemical energy in carbon-based compounds.
- As solar radiation in the Arctic decreased, plants died, and peat and permafrost were formed.
- Through photosynthesis, plants convert carbon dioxide and water into sugar and release oxygen.
- More solar energy means more carbon dioxide is captured and stored by plants as sugar and oxygen.
- Plants convert excess sugar into larger carbon-based molecules, such as starch.

	Uncovered		Covered	
	Before	After	Before	After
Indirect Light	Yellow	Green/ Blue	Yellow	Yellow
Direct Light	Yellow	Dark Blue	Yellow	Yellow

⇓ **Navigation to Next Lesson:** We figured out that changes in solar energy based on differences in the Earth's tilt are responsible for the matter and energy stored in peat under the permafrost. We think we have figured out enough to try to explain how zombie fires can burn under ice and release so much carbon.

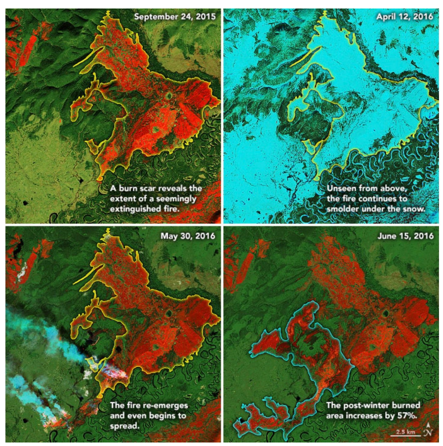
LESSON 6

Lesson Set 1

2 days

How do zombie fires disrupt the flow of energy and cycle of matter in Arctic ecosystems?

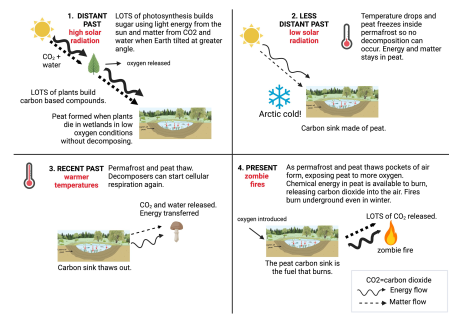
Putting Pieces Together



An infrared image shows the heat energy of a zombie fire burning underground.

We develop our class consensus model based on evidence we collected to construct an explanation for zombie fires. We return to our DQB to update our questions and revise our Driving Question: What causes fires in ecosystems to burn? We figure out:

- Photosynthesis captures energy from sunlight and converts to chemical energy in carbon-based glucose fuel, taking carbon out of the air and into the plants. Plants with extra energy and matter, assemble glucose into larger molecules.
- Plants in the Arctic die and get submerged where it is too cold for decomposition to happen quickly. Generations of plants die on top of one another resulting in more and more matter and energy remaining underwater/ice.
- Peat is layers of partially decomposed plants. When permafrost thaws, peat is exposed. Peat can now decompose and burn.
- Zombie fires burn carbon sinks in the peat/permafrost system releasing tons of CO_2.
- In the recent past, peat was frozen in permafrost, keeping matter and energy, but if in the future more permafrost thaws, then more matter and energy will be available.



⇓ **Navigation to Next Lesson:** We figured out how zombie fires are burning in the Arctic, but we wonder if there are other ecosystems with carbon sinks burning and what makes them vulnerable to burn.

Lesson Set 2: How is global carbon cycling affected by fires?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 7
Lesson Set 2

2 days

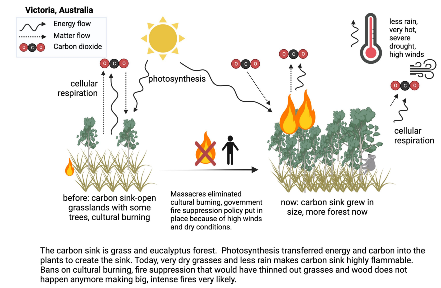
What is happening to carbon sinks in other ecosystems?

Investigation

Fires are burning in carbon sinks around the world.

We use case studies to investigate places, lands, and waters where global carbon sinks are burning with more frequency. We analyze how energy and matter are moving through each system and discuss the historical events and decisions that contributed to the current conditions that make each carbon sink more likely to burn. We develop small-group models to help us come to consensus on the conditions that make carbon sinks more likely to burn. We wonder what the consequences and large-scale impacts are of fires from all of these ecosystems. We also wonder about ways to manage fires into the future. We figure out:

- Many different ecosystems have carbon sinks created from the flow of energy and matter into plants by photosynthesis.
- There are common climate-related and human-caused factors in ecosystems that make the energy and matter in carbon sinks more likely to burn.
- Fire increases the flow of matter and energy from the biosphere to the atmosphere.



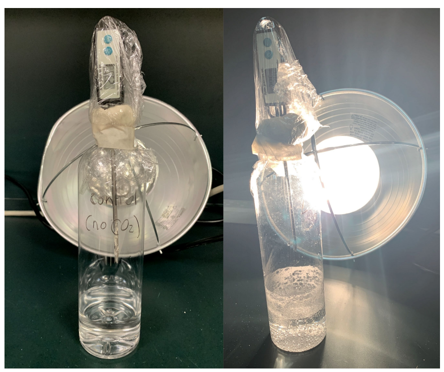
⇓ **Navigation to Next Lesson:** We figured out carbon sinks are burning due to drought, rising temperatures, land use changes, and fire suppression. We wonder about the larger consequences for all of these fires.

LESSON 8
Lesson Set 2

2 days

Why should we be concerned that carbon sinks around the world are burning?

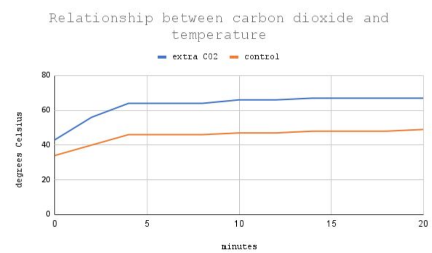
Investigation



Carbon dioxide from fires in the atmosphere is causing the temperature to increase.

We investigate the effect of increased carbon dioxide on temperature, develop directional hypotheses, and collect evidence to support our hypotheses. We revise our hypotheses to explain the relationship between atmospheric carbon dioxide and temperature at the global scale and investigate data collected by scientists. We figure out:

- Increased carbon dioxide in the air causes increased air temperature.
- A directional hypothesis explains the effect of carbon dioxide concentration on temperature in a simulated system.
- Global data indicates the relationship we figured out in our investigation system is similar to the relationship at the global scale.

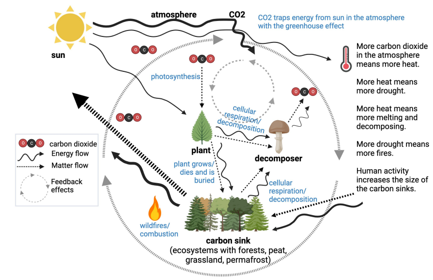


⇓ **Navigation to Next Lesson:** We figured out that increasing atmospheric carbon dioxide increases temperature and wonder how the relationship between carbon dioxide and temperature affects other systems.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 Lesson Set 2 2 days **What are the global effects of increased carbon dioxide from fires?** Investigation, Putting Pieces Together	Atmosphere *Fire influences how carbon and energy cycle through Earth's systems differently than in the past.*	We use a quantitative model to simulate how carbon and energy flow through Earth's systems. We develop a model to determine if carbon dioxide levels and temperature will continue to grow as more carbon sinks burn. We figure out: • Human actions caused the burning of carbon sinks, which shifted the balance of carbon (matter) and energy in the Earth system, releasing energy and matter from plant-based carbon sinks from the biosphere into the atmosphere. • A (positive) feedback effect is created as increased carbon dioxide causes increased temperature and increased temperature causes more drought, which leads to more wildfires that release additional carbon dioxide into the atmosphere.	

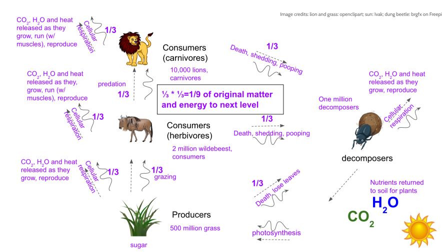
Atmosphere

Dice roll	What happens?	Where to next?
1 - 2 - 3	You remain in the atmosphere as a molecule of carbon dioxide, CO_2 (matter). **Energy remains in the same arrangement of atoms.** Record this action and roll again.	Atmosphere
4	You enter the ocean as carbon dioxide, CO_2, and are dissolved in the water (matter). **Energy flows to a new system in the same arrangement of atoms.**	Ocean
5 - 6	You are taken in by a producer as carbon dioxide, CO_2. The producer uses energy from sunlight and water to rearrange you into molecules used to build biomass (matter) of the producer. **Energy flows to a new system AND the atoms are rearranged.**	Producers



⇓ **Navigation to Next Lesson:** We figured out burning carbon sinks creates a positive feedback effect between carbon dioxide and temperature and wonder if we can reduce this by managing carbon sinks better.

Lesson Set 3: How do we design solutions to manage the impacts of fires?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 Lesson Set 3 3 days **How can we help manage the matter and energy in fire systems?** Investigation	 *Successful management of carbon sinks to prevent large wildfires uses a variety of methods that affect the flow of carbon and energy in ecosystems.*	We investigate four case studies of successful fire management. We read about how prescribed burning, cultural burning, restoring grazer populations, and replanting forests help manage the amount of available carbon and energy that burn in wildfires. We use a mathematical representation to explain how these techniques could help fire management in ecosystems. We investigate fire risk in our own community and ways to reduce that risk. We figure out: • Managing the amount of fuel available to burn in carbon sinks through prescribed burns, cultural burns, and grazing helps reduce an overabundance of built-up energy and matter. • Planting trees can remove carbon dioxide from the atmosphere and has the potential to reduce atmospheric temperature. • Energy and matter flow through each level of a food web through producers, consumers and decomposers.. • Fire management decisions have short- and long-term consequences for both social and ecological structures and systems.	

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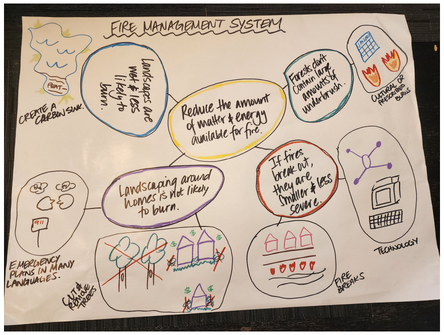
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td colspan="4">⇓ Navigation to Next Lesson: We figured out successful fire management includes a balance of plants and animals. We wonder how we can protect the places, lands, and waters we care about.</td></tr>
<tr><td>LESSON 11
Lesson Set 3

3 days

What decisions can we make to help manage fire in communities we care about?

Putting Pieces Together</td><td>
Fire management systems must meet criteria, constraints, and community needs.</td><td>We create fire, matter, and energy management systems for reducing carbon emissions for places, lands, and waters we care about. We acknowledge species, kinds, and behaviors at different scales of the ecosystem we want to protect. We break down fire management criteria into simpler criteria. We share and seek knowledge from our community members. We share and revise fire matter and energy management systems, putting pieces together from the unit connected to five dimensions of complex socio-ecological systems. We figure out:
• Criteria need to be broken down into simpler ones to manage fire to see who will be impacted (human and nonhuman) by our decisions.
• Making decisions involves and impacts people at many levels in the systems we care about.
• The places, lands, and waters we care about are complex, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
• We can answer many questions on our DQB.</td><td>
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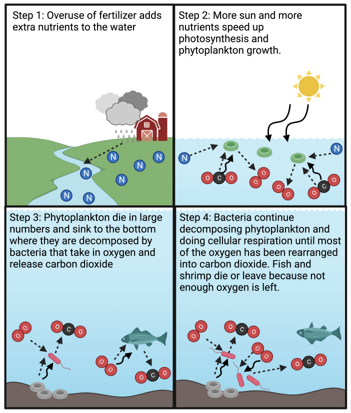
<tr><td colspan="4">⇓ Navigation to Next Lesson: We figured out it is helpful to break down criteria when designing fire management systems. We wonder if we can apply what we figured out to a new phenomenon.</td></tr>
<tr><td>LESSON 12
Lesson Set 3

1 day

Can we use everything we have figured out about fires to explain a new phenomenon?

Putting Pieces Together</td><td>
Massive fish kills happen in the Gulf of Mexico.</td><td>We complete a Transfer Task about eutrophication in marine ecosystems to demonstrate how what we figured out throughout the unit about the flow of energy and matter applies to other systems. We figure out:
• Carbon and oxygen cycle in systems such as the Gulf of Mexico, including the hydrosphere, atmosphere, and biosphere.
• Factors such as temperature and nutrient availability affect components of the system and can be observed through inputs and outputs of photosynthesis and carbon dioxide.</td><td>
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<tr><td colspan="4">⇓ Navigation to Next Lesson: This is the last lesson in the unit.</td></tr>
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LESSONS 1-12

28 days total