Investigation: Life on a Hydrothermal Vent

ROV shining light on a chimney.
Image courtesy of the NOAA Ocean Exploration.

Overview

TOPIC: Hydrothermal Vents

FOCUS: Students develop their understanding of chemosynthetic ecosystems and dynamics through sense-making.

GRADE LEVEL: 9th-12th

TIME NEEDED: Two 45 or 50-minute class periods

PHENOMENON (DRIVING QUESTION): How can ecosystems survive without sunlight?

OBJECTIVES/ LEARNING OUTCOMES: Students will:

- **Ask questions to investigate what causes dynamic ecosystems to survive in the absence of light**.
- **Identify patterns in ecosystems to develop a model to explain how components in an ecosystem interact in the absences of light**.

MATERIALS: **Individual Student Materials**

- Hydrothermal Vent Food Web Student Activity Sheet (page 12)
- Hydrothermal Vent Food Web Presentation
  (food web organism cards and instructions for online learning)
- Whiteboards and Dry Erase Markers (or online jamboards)

EQUIPMENT

- Video projection or online sharing capability

NEXT GENERATION SCIENCE STANDARDS (NGSS)

It is important to note that although these are the elements that are identified in the performance expectation (PE), other elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) are incorporated when appropriate. PEs are examples of how the three dimensions could be assessed at the end of instruction and are meant as a guide to build coherent learning progressions.

HS-LS2 Ecosystems:
Interactions, Energy, and Dynamics

Performance Expectations
HS-LS 2-6

Disciplinary Core Ideas
LS2.C

Crosscutting Concepts
Stability and Change

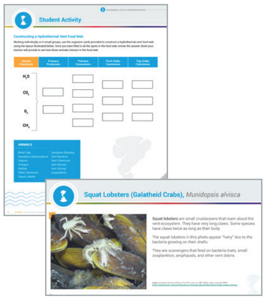
Science & Engineering Practices
Constructing Explanations and Designing Solutions
Developing and Using Models

COMMON CORE CONNECTIONS
ELA/Literacy -
RST.9-10.8
RST.11-12.1
RST.11-12.7
Mathematics – MP.2

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
Principle 1 FC b; Principle 2 FC a; Principle 4 FC b; Principle 5 FCs a, b, d, e, f, g; Principle 7 FC b

Overview cont.

SET-UP INSTRUCTIONS: Cue up images and videos for student viewing (links provided throughout the investigation)



For in-person instruction:

- Copy the Hydrothermal Vent Food Web Student Activity Sheet (one per student)
- Print the Organism Cards
  (slides 4-16 of the Hydrothermal Vent Food Web Presentation) (one per student group)

For online learning:

- Share the Hydrothermal Vent Food Web Presentation with students using an online learning platform *(remove the answer key before sharing)*

Educator Guide

Background

Hydrothermal vents are home to dynamic, diverse ecosystems that exist in the absence of light. Bacteria, not plants, are at the base of the vent food webs (producers), harnessing energy from chemicals in the vent fluids to produce simple sugars through the process of chemosynthesis.

Chemosynthesis occurs under a wide temperature range and utilizes a number of different chemicals depending on the ecosystem. Only a few decades ago, marine scientists were stunned to find complex ecosystems based on chemosynthesis flourishing around deep-sea hydrothermal vents. Because chemosynthetic organisms can function in such harsh and hostile habitats on Earth as deep-sea hydrothermal vents, it seems possible that chemosynthesis may also be occurring under the difficult conditions found on other worlds.

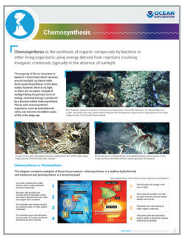
Educator Note

For this activity:

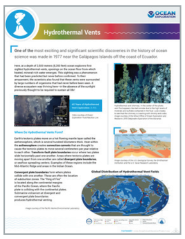
- Students should have a general idea of ecosystem dynamics from middle school, including ideas around the interactions between food chains/webs, energy flow, the cycling of matter and photosynthesis.
- A variety of student interaction techniques are used throughout this investigation to support equitable participation.
- Examples of student questions are provided throughout this activity. Use these questions to engage student in the process of sense-making to move their learning forward.

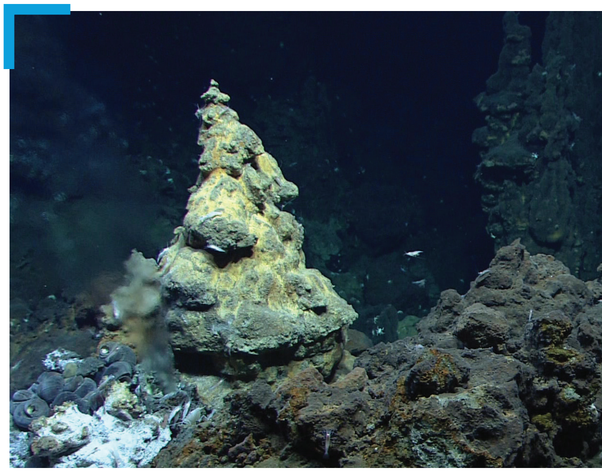
FOR MORE INFORMATION:

- *Chemosynthesis Fact Sheet*



- *Hydrothermal Vents Fact Sheet*





Mata Tolu Chimneys. *Image courtesy of MARUM, University of Bremen and NOAA-Pacific Marine Environmental Laboratory.*

Educator Guide cont.

Introducing the Phenomenon

Engaging in Observation

Begin by asking students to think about and record what they know about ecosystems including food chains/webs and interactions between organisms and their environment. Ask them to share their thinking with a partner and allow students to add to or revise their list. As a full class, ask students to share what they know about ecosystems.

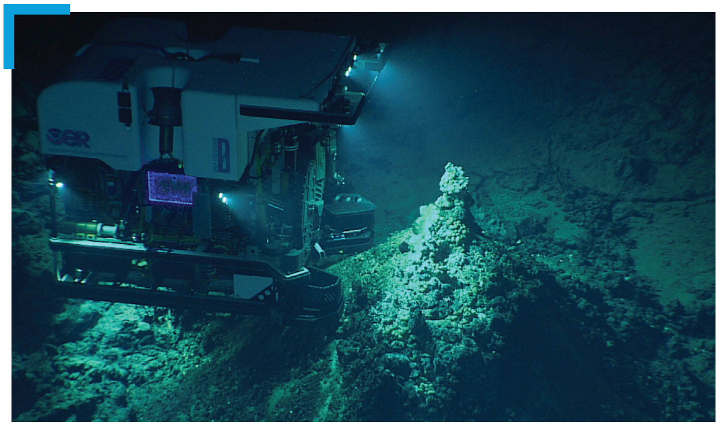
Record student ideas which may include:

- ecosystems contain both living and nonliving things
- ecosystems can change over time
- ecosystems contain food chains and food webs
- food chains/webs contain producers, consumers and decomposers
- plants "make their own food" from the Sun through photosynthesis
- the Sun provides energy for the ecosystem (all living things)

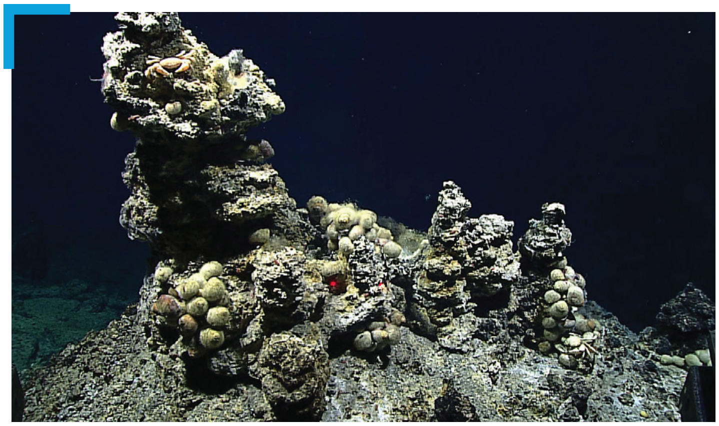
Next, introduce students to the phenomenon by first sharing three or four of these images of a hydrothermal vent ecosystem in the Marianas.

EDUCATOR GUIDANCE

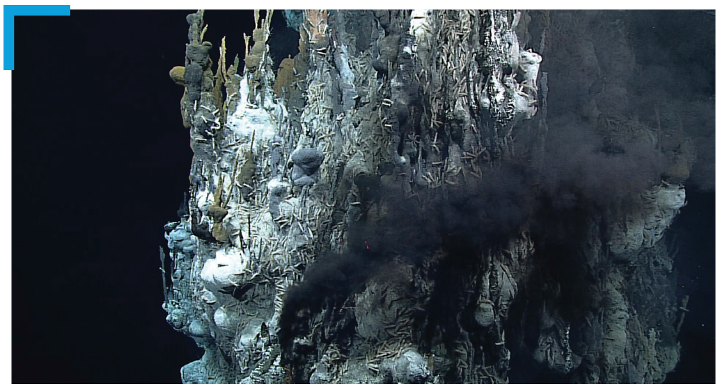
If students don't bring up the Sun and/or photosynthesis, you might ask, "What is the source of energy in an ecosystem? Why do you say so?" and then direct students to turn and talk with a partner. Listen for students to share ideas about plants needing energy from the Sun for photosynthesis; make sure to call on these students first when you bring the class back together.



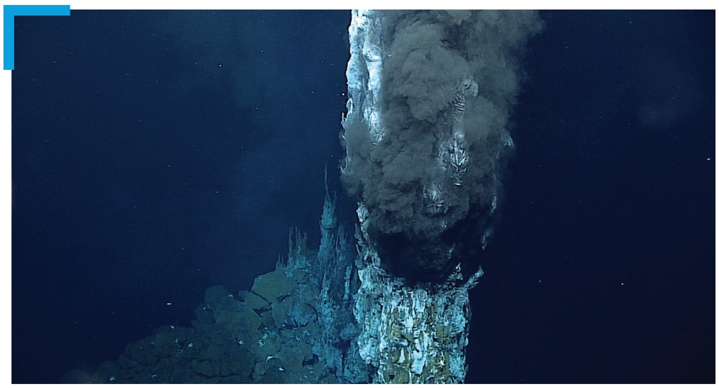
Active venting at a large chimney. *Image courtesy of the NOAA Office of Ocean Exploration and Research.*



Vent covered in hairy snails. *Image courtesy of the NOAA Office of Ocean Exploration and Research.*



Active venting, large chimney cluster covered in animals (blurry due to water temp). *Image courtesy of the NOAA Ocean Exploration.*

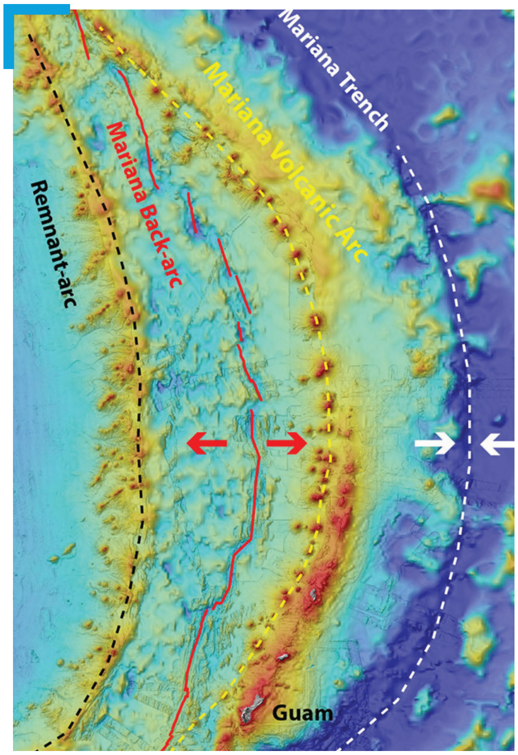


Single black smoker chimney. *Image courtesy of the NOAA Ocean Exploration.*

Educator Guide cont.

Engaging in Observation cont.

Tell students they are looking at **hydrothermal vents** located in the region of the Mariana Trench (a convergent plate boundary). Show the location on the map provided and make sure to point out the hydrothermal vents are located in an area of volcanoes (volcanic arc) associated with the trench and not in the trench itself.



Map showing the locations of the Mariana Trench, Volcanic Arc, and back-arc spreading center and remnant arc. *Image courtesy of NOAA Ocean Exploration, 2016 Deepwater Exploration of the Marianas.*

Give students time individually to record their observations and any questions they may have, then have them share and compare with a partner. Do not invite students to share ideas with the class at this time.

Show students the Hydrothermal Vent video (1:06 minutes) from the NOAA Ocean Exploration 2016 Deepwater Exploration of the Marianas expedition. Again, ask students to make and record observations of the hydrothermal vent ecosystem (this is the same ecosystem they observed in the pictures). Encourage students to capture answers to questions the video provides and to record new questions that arise.

After viewing the video, ask for someone to share the depth of the hydrothermal vents that were observed (3275 meters). Quickly survey students asking "Do you think sunlight reaches that far below the ocean surface?" Then, show students the graphic Distance Sunlight Travels in the Ocean and, if necessary, ask the question again.

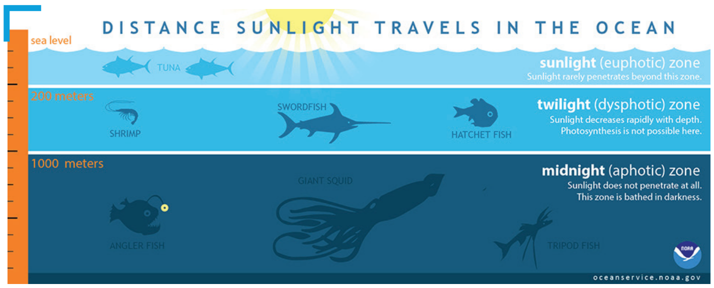
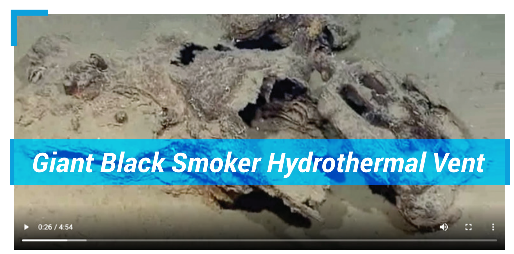


Image courtesy NOAA NOS.

Students should now all agree sunlight does not travel to that depth in the ocean.

Tell students you have another hydrothermal vent ecosystem you would like them to observe and show the location of this ecosystem on a map (maps from NOAA Ocean Exploration, 2011 Galapagos Rift expedition). Point out this hydrothermal vent ecosystem is located in a volcanic area in the Cocos Ridge region (divergent plate boundary) near the Galapagos Islands. Show the Ocean Exploration Trust video Giant Black Smoker Hydrothermal Vent (3:48 minutes). As with the first video, ask students to make and record observations as well as capture answers to questions the video provides (and record any new questions).

Video courtesy NOAA Office of Exploration and Research.



Video courtesy Ocean Exploration Trust - Nautilus Live.

In small groups, have students share their observations. Ask them to identify observations most of the group members have in common and observations only one or two group members noticed. Then, ask students to choose two common observations and one less common observation to share with the class. Record the shared observations.

Educator Guide cont.

Developing Common Questions and Ideas

Again in small groups, ask each group member to write their top three questions on sticky notes (one question per sticky note) and share those questions with their group. Ask each group to choose their top three questions to share with the class, having each group member write their initials on their group's sticky notes. Bring the class back together and invite groups to ask their questions (either record student questions or create a space for students to post them) and share why they elevated these three questions in importance. Examples of student questions may include:

- Are there hydrothermal vents throughout the ocean? Do they all support life?
- What's the black material coming out of the hydrothermal vents?
- Why is the water shimmering?
- How can animals live there when it is so hot (over 300˚ C)?
- Why are so many of the animals white?
- What do the animals eat? Where do the animals get their food?
- What's the white and brown material growing there?
- Are plants/algae growing there without sunlight?
- Does light come from somewhere else since sunlight doesn't go that deep?

Ask students what they think they should figure out first. Many students will want to know more about the organisms living on and around the hydrothermal vents they observed and if other organisms live there. Use their curiosity to navigate to the next part of the investigation.

Figuring It Out

Ask students to return to their small groups and brainstorm ideas about how life can exist and survive at a hydrothermal vent without sunlight. Listen for groups to discuss the following ideas and invite these groups to share with the class when you bring them back together:

- Organism living on and around the vents eat things (like dead plants and algae) that float down from the surface so light isn't necessary. ("Marine snow" does fall to the seafloor and feeds benthic organisms but not enough to sustain the amount life found at vents.)
- Something besides plants/algae must be the producer in the food chain/web (or "be at the beginning" of the food chain/food web).

At this point students have to grapple with big science ideas, some of which seem contradictory to ideas they learned in previous grades. Students have figured out:

- Organisms live deep in the ocean by hydrothermal vents that are really hot - around 300 to 400 degrees Celsius. Hotter than boiling water.
- Hydrothermal vents occur near tectonic plate boundaries (near trenches and spreading centers).
- Sunlight doesn't reach that far beneath the ocean surface, so the hydrothermal vent food webs do not depend on plants and algae.

EDUCATOR GUIDANCE

Some common misconceptions students may share as they experience this phenomenon include:

- algae are plants
- plants and algae can photosynthesize in the dark
- animals in the hydrothermal vent ecosystem survive by only eating dead things that sink to the sea floor
- vent animals are white so they can be seen in the dark

At this point it is important not to try to correct these misconceptions. The lesson is designed to allow students to figure out the important science ideas over time and to change their thinking based on new evidence.

Educator Guide cont.

Figuring It Out cont.

Constructing a Hydrothermal Vent Food Web

Tell students the struggle for food is one of the most important and complex activities to occur in an ecosystem. In small groups, have students explore the Food Web Organism Cards provided. Their task is to build a hydrothermal vent food web using the cards and Student Activity Sheet (page 12) provided. Once they have filled in all the spots in their food web and drawn the connections, show them the complete food web with all connections illustrating how these animals interact.

Next, ask students to share their food web observations with a partner and then with the class. Student observations could include:

- Many more organisms live at hydrothermal vents than we thought.
- The food web seems to start with chemicals.
- Bacteria are the beginning of the food chain/web (primary producers) and not plants.
- There are many different interactions between the organisms just like other food webs we have experienced/observed in the past.

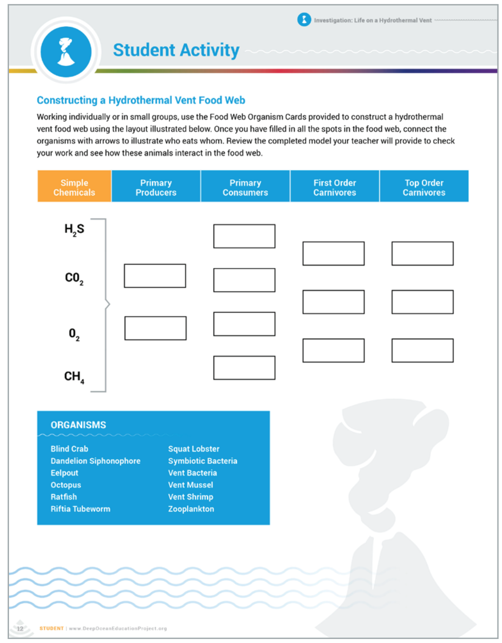
Give students some time to reason through what they have figured out and synthesize this new information. Ask students if they have everything they need to explain how an ecosystem can exist and survive at a hydrothermal vent like we are able to for ecosystems driven by photosynthesis. (Answers here will vary; some students will be confident they can while others think they need more information.)

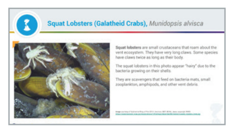
Have students work in their small groups to develop an initial explanation of the interactions between organisms within the hydrothermal vent ecosystem.

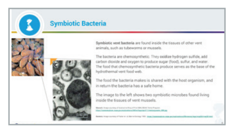
Encourage them to either create and compare lists of components/interactions in ecosystems with sunlight and deep sea vent ecosystems or draw models of the two systems and compare them side-by-side to look for familiar patterns.

As students work on their explanations, tell them to record any new questions they have. New questions may include:

- How do bacteria that live at vents make their own food?
- Plants make their food using CO_2 from the air. Do bacteria (and other vent microbes) need CO_2? Where do they get CO_2?
- If bacteria don't need CO_2 to make their own food, what do they need and where do they get it? From the fluid coming out of the hydrothermal vent?
- What is this process where energy is being created without sunlight?







EDUCATOR GUIDANCE

Tell students that developing an initial explanation at this point is to help them synthesis ideas and organize their thinking; they should not worry about getting the "right" answer.

Educator Guide cont.

Figuring It Out cont.

What is Chemosynthesis? Are Chemosynthesis and Photosynthesis Similar, but Different?

Refer students back to the list of ecosystem components and interactions they created at the beginning of the activity, highlighting the ideas they shared about the Sun, plants and photosynthesis. Ask students, “What are the inputs and outputs of the process of photosynthesis?” Allow students to briefly discuss in their small groups and then take three shares from the class. Students will likely say sunlight and carbon dioxide are inputs and oxygen is an output. Students may or may not include water as an input and sugar as an output.

Next, present the chemical equation for photosynthesis. In the presence of sunlight, carbon dioxide + water + energy from sunlight produces glucose and oxygen.

PHOTOSYNTHESIS →

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Carbon dioxide + Water → Sugar + Oxygen

Ask students to individually record what they notice, share with a partner and then have them share with the class. Observations may include:

- The chemical equation involves carbon (C), hydrogen (H), and oxygen (O)
- Each side of the equation has two compounds (two reactants and two products)
- The compounds on the left side are carbon dioxide and water and the right side is oxygen and sugar (students may or may not know this formula is sugar).
- The total number of elements on each side are the same even though the numbers are in different places.
- Energy from the Sun is needed to start this chemical reaction.

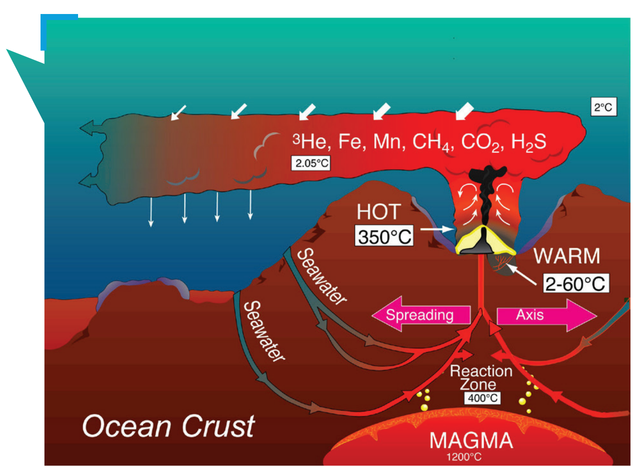
Students will likely come to the conclusion that they need to take a closer look at the chemicals in the water coming out of the hydrothermal vent and the ocean water around the vent. Students may recall seeing “simple chemicals” listed on their food webs. Have them revisit the bacteria card, specifically the ‘what do they eat’ section.

Show students this illustration of vent development. Have them continue their observations and guide them to noticing the chemicals and heavy metals coming out of the vent.

Ask students if it makes sense to compare the chemicals identified in the food web activity to the chemicals in the chemical equation representing photosynthesis.

EDUCATOR GUIDANCE

Students should have prior knowledge gained in middle school about chemical reactions including reactants (inputs), products (outputs), and that matter is conserved. However, if students do not have this prior knowledge it is not necessary that you stop and teach it directly. Instead, have students share what they notice.



Graphic of a vent at a spreading center forming a hydrothermal plume as adapted from Massoth et al., 1988 (not to scale). *Image courtesy of Schmidt Ocean Institute.*

Educator Guide cont.

Figuring It Out cont.

Looking for Patterns

Now that students have used a chemical equation (model) to identify the components (elements and compounds), inputs (reactants) and outputs (products) of photosynthesis, introduce them to the chemical equation for chemosynthesis.

Tell students this equation represents only one of a few different chemical reactions for chemosynthesis (the inputs and outputs for chemosynthesis vary depending on the environment in which it occurs).

CHEMOSYNTHESIS →

$$CO_2 + 4H_2S + O_2 \rightarrow CH_2O + 4S + 3H_2O$$

Carbon dioxide + Hydrogen Suifide + Oxygen → Sugar + Sulfur + Water

In small groups, have students identify the components, inputs and outputs of chemosynthesis. Then ask them to compare the processes of chemosynthesis and photosynthesis. As you move around the room, listen for students to share ideas about the compound consisting of C, H and O. Depending on the class' background knowledge, students may recognize the formula as simple sugar. *Be sure to call on these students first* when you bring the class back together to share their observations.

Students should notice:

- Chemosynthesis involves the same components as photosynthesis, but also, in this instance, involves hydrogen sulfide.
- Carbon dioxide is a reactant in both chemical reactions.
- Both chemical equations involve water, but in photosynthesis water is a reactant and in chemosynthesis water is a product.
- Both chemical equations involve oxygen; in photosynthesis, oxygen is a product and in chemosynthesis oxygen is a reactant.
- Both chemical equations include a compound made of carbon, hydrogen, and oxygen as a product. Some students may also notice the ratio of carbon, hydrogen, and oxygen is 1:2:1 in both chemical equations and that these compounds represent simple sugar.

Revoice student shares about the processes of chemosynthesis and photosynthesis both producing simple sugar. Prompt students to share what they know or think they know about how plants and animals use simple sugar. Students will likely share that plants produce sugar, and both plants and animals use the sugar for energy. Next, prompt students to think about how bacteria use simple sugar. Students will likely say bacteria must use the sugar they produce through chemosynthesis the same way plants use the sugar they produce by photosynthesis.

Share the How Giant Tube Worms Survive at Hydrothermal Vents video (by I Contain Multitudes and PBS) with students to provide additional information about how chemosynthetic bacteria support food webs in hydrothermal vent communities. Reiterate from the video - the bacteria ingest and process hydrogen sulfides from the vents, excrete sulfur and release energy to make food (for themselves and, if applicable, their symbionts).

EDUCATOR GUIDANCE

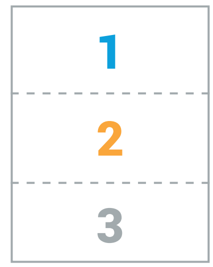
Students who understand energy from the Sun drives photosynthesis in plants may wonder if energy is needed for chemosynthesis to occur and/or where the energy comes from. In this activity, it is adequate to tell students the energy needed for chemosynthesis is stored in the chemical compounds represented on the left side of the equation (reactants) and released when these compounds chemically react. If students have the appropriate chemistry background, you might choose to introduce (and/or review) endothermic and exothermic reactions and bond energy and distinguish between the mechanisms driving photosynthesis and chemosynthesis.

Educator Guide cont.

Synthesizing Our Thoughts

Now that students have figured out more about hydrothermal vent ecosystems, ask them to create a “comic strip” model to explain how ecosystems exist and thrive in the absence of sunlight and predict what would happen if the hydrothermal vent became extinct (stopped ejecting hot, mineral-rich water). Students can create their models individually or in small groups.

Instruct students to divide a sheet of paper into 3 sections. Explain that the sections, or frames, of the comic strip represent the hydrothermal vent ecosystem over time:



FRAME 1: The hydrothermal vent is active and ejecting large amounts of hot, mineral-rich water (present time).

FRAME 2: The hydrothermal vent has just become extinct and is no longer ejecting hot, mineral-rich water (days after extinction).

FRAME 3: The hydrothermal vent has been extinct for a long period of time (years after extinction).

Remind students their models should represent the ecosystem components including organisms, interactions between the components, and explain how the components are interacting (mechanisms). Remind students to use science terms when appropriate and explain their ideas using words, symbols and/or pictures.

As you move around the class, you might ask students the following questions to move their thinking deeper:

- Which components are represented in all of the frames? Which components are unique to each frame?
- How are component A and component B interacting? How might you represent this interaction?
- Where does organism A (B, C, etc.) get its energy? Or where would this organism fall in the food web?
- Where is matter coming from that enters this ecosystem?
- What happens to matter as it moves within the ecosystem?
- Where does matter go that leaves the ecosystem?

Once students have completed their initial models individually, you might have them work in small groups to create a group consensus model.

Engage the class in a gallery walk to observe other individual or group models. As students observe each model, have them use sticky notes to post one thing they like about the model (a component they didn’t include in their own model, the way an interaction between components is represented, etc.) and one question they have about the model. When the gallery walk is complete, allow time for students to reflect on the feedback provided by their peers and add to or change their models.

While students revise their models, identify two or three models that reflect a range of predictions for what will happen when the vents become extinct. Predictions will vary. Some students may think the hydrothermal vent ecosystem will die as soon as the hydrothermal vent becomes extinct because the bacteria won’t have a source of chemicals for chemosynthesis. Others may think “unused” chemicals floating in the water after the vent is extinct will continue to support chemosynthesis. Bring the class back together and ask the groups whose models you’ve identified to share their predictions with the class. As the groups share their predictions, prompt students (both sharers and listeners) to use evidence and/or reasoning (science ideas/principles) to support their claims.

Show students the Ocean Exploration Trust video, Smoking Chimney and Pompeii Worms, of a hydrothermal vent nearing extinction. Then ask them to read the NOAA Ocean Exploration Galapagos Rift Expedition Mission log from 2002, Life Cycles of Vent Communities – So Much to Learn.

Ask students, “Does this new information support or refute your predictions?” Allow students time to review and revise their models based on the information gathered from the video and mission log.

Educator Guide cont.

Putting the Pieces Together

What Did We Figure Out? (Making Sense)

Prompt students to use their models to explain why hydrothermal vent ecosystems change when the vent becomes extinct. Providing sentence starters may also benefit students that need more language support.

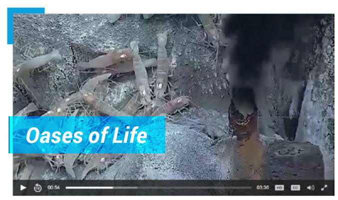
Finally, revisit students' questions and ask them which questions they can now answer. Ask students to discuss their answers with a partner or small group, and then invite them to share their answers (or a partner or group member's answers) with the class. As students share what they've learned, encourage them to think about what they still haven't figured out about these ecosystems and use this discussion to help guide possible further investigations.

SAMPLE STUDENT RESPONSE

When the chemicals stop coming out of the vent the ecosystem will die. The bacteria use chemicals spewed out from the vent to make food by chemosynthesis. Without the chemicals they die. Since bacteria are the primary producers, when they die there is nothing for the primary consumer to eat. When the primary consumers die, the first order carnivores don't have anything to eat and they die. This keeps happening up the food chain until all the living things are gone from the site.

Option

Wrap up this hydrothermal vent investigation with this 3:36 minute video that expands on the activity introductory video, Oases of Life, from NOAA Ocean Exploration, 2016 Deepwater Exploration of the Marianas; and/or the 5:40 minute video 40 Years of Hydrothermal Vent Exploration from Ocean Exploration Trust.

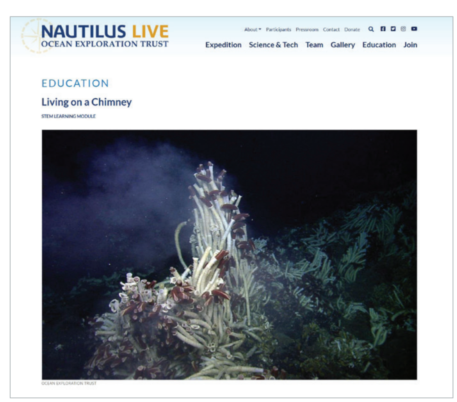


Video courtesy of NOAA Ocean Exploration.

Video courtesy of Ocean Exploration Trust - Nautilus Live.

Extensions

- Many students will want to know if ecosystems like this exist in other places on Earth. Consider providing students opportunities to investigate other extreme environments in which chemosynthesis supports life such as cold seeps, mining waste run-off, and hot springs.
- This investigation can also be used as a starting point to figuring out several big science ideas. In future activities students could:
  - dig deeper into plate tectonics and Earth processes that form hydrothermal vents (HS-ESS1-5 or HS-ESS2-1)
  - explore the chemistry needed to explain the process of chemosynthesis (HS-PS1-1 or HS-PS1-7)
  - make sense of how hydrothermal vent ecosystems maintain equilibrium (with some modification to the following performance expectations: HS-LS2-3, HS-LS2-4, and HS-LS2-5).
- To learn more about vent ecosystems, the organisms that live there and their spacial distribution on a vent, try the Ocean Exploration Trust Activity Living on a Chimney.



Educator Guide cont.

Scientific Terms

As these terms are new to most students, introduce them as they come up throughout the activity after the concept is made clear.

- **Chemosynthesis:** The synthesis of organic compounds by bacteria or other living organisms using energy derived from reactions involving inorganic chemicals, typically in the absence of sunlight.
- **Hydrothermal vent:** Opening on the ocean floor from which heated, mineral-rich water emerges.

Assessment

Opportunities for formative assessment are embedded throughout the activity. The student models that are developed at the end of the activity could be used as an opportunity for summative assessment of learning. For this purpose, you may want to collect models or take pictures of student work.

Suggested model elements to assess include:

Developing and Using Models (SEP)

- Developed, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Stability and Change (CCC)

- Much of science deals with constructing explanations of how things change and how they remain stable.

LS2.C Ecosystem Dynamics, Functioning, and Resilience (DCI)

- Ecosystems are dynamic in nature; their characteristics can vary overtime. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

LOOK FORS IN STUDENT MODELS:

- Chemicals coming from the vent
- Bacteria feeding on the chemicals to produce food for the worms and other organisms
- A food chain/web using the information from that activity
- Models should be labeled (both component and interactions)
- Frame 1 should demonstrate stability
- Frames 2 should demonstrate small changes (vent closing – no chemicals – bacteria dying)
- Frame 3 should demonstrate large change (mostly barren vent system)

Students may also explain what is happening in terms of cause-and-effect relationships.

Adaptations

ONLINE LEARNING

- Image and video links can be provided through a preferred online platform with students divided into small online breakout groups to work through elements of the activity.
- Resources are provided for the food web activity to be executed through a preferred online platform.

DIFFERENT GRADE/ LEARNING LEVELS

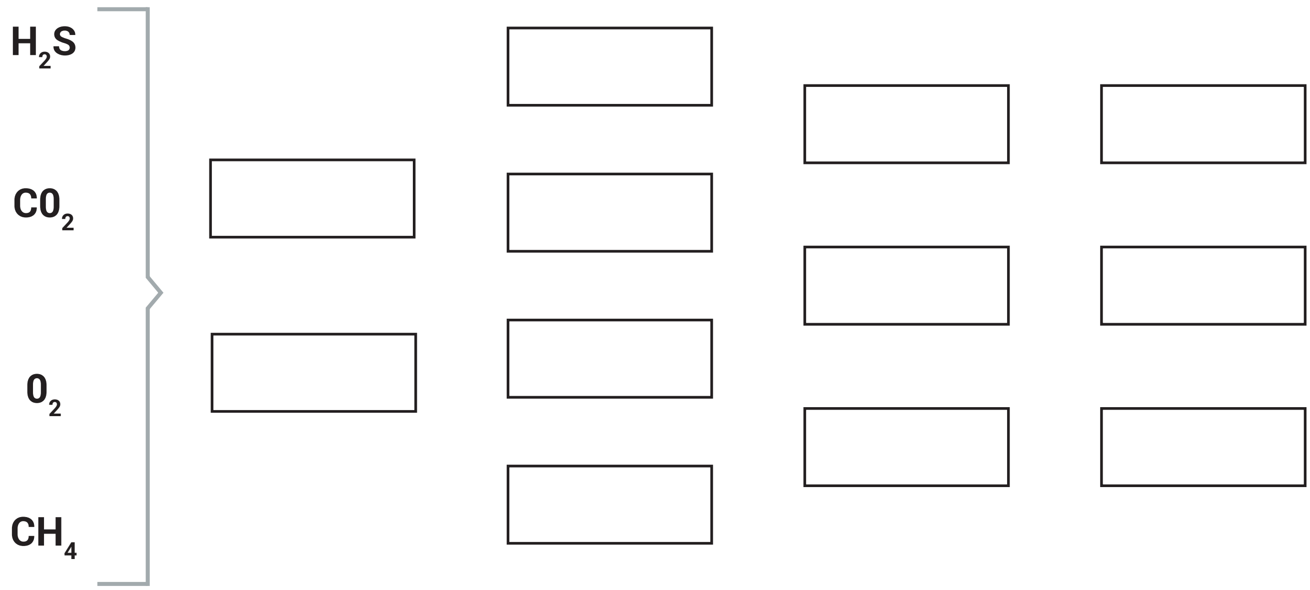
- Guidance based on student background as well as possible extensions are provided within the Educator Guide.
- Some students may benefit from having a transcript of the video to both reference and highlight. The transcript can also be used to remind students of key points to develop questions and ideas for investigation.

Student Activity

Constructing a Hydrothermal Vent Food Web

Working individually or in small groups, use the Food Web Organism Cards provided to construct a hydrothermal vent food web using the layout illustrated below. Once you have filled in all the spots in the food web, connect the organisms with arrows to illustrate who eats whom. Review the completed model your teacher will provide to check your work and see how these animals interact in the food web.

Simple Chemicals	Primary Producers	Primary Consumers	First Order Carnivores	Top Order Carnivores



ORGANISMS

- Blind Crab
- Dandelion Siphonophore
- Eelpout
- Octopus
- Ratfish
- Riftia Tubeworm
- Squat Lobster
- Symbiotic Bacteria
- Vent Bacteria
- Vent Mussel
- Vent Shrimp
- Zooplankton

Investigation: Life on a Hydrothermal Vent Links and Resources

Page 1:
- ROV/chimney (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/dailyupdates/media/june24-hires.jpg
- Hydrothermal Vent Food Web Presentation (editable PowerPoint): https://oceanexplorer.noaa.gov/edu/materials/vent-food-web.ppt
- Hydrothermal Vent Food Web Presentation (pdf): https://oceanexplorer.noaa.gov/edu/materials/vent-food-web.pdf

Page 2:
- Mata Tolu Chimneys (image): https://oceanexplorer.noaa.gov/explorations/12fire/logs/sept23/media/various-chimneys-hires.jpg
- Chemosynthesis Fact Sheet: https://oceanexplorer.noaa.gov/edu/materials/chemosynthesis-fact-sheet.pdf
- Hydrothermal Vents Fact Sheet: https://oceanexplorer.noaa.gov/edu/materials/hydrothermal-vents-fact-sheet.pdf

Page 3:
- ROV/chimney (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/dailyupdates/media/june24-hires.jpg
- Vent/snails (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/jun25/media/1605chimney-hairy-snails-hires.jpg
- Active venting (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/dailyupdates/media/may2-hires.jpg
- Black smoker (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/may11/media/1605vent-hires.jpg

Page 4:
- Convergent plate boundary (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1605/logs/jul3/media/1605mariana-cross-section.html
- Marianas Map (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/jul11/media/1605mariana-trench-map-hires.jpg
- Hydrothermal Vent (video): https://oceanexplorer.noaa.gov/edu/themes/vents-and-volcanoes/multimedia.html#cbpi=media/video/multimedia-hydrothermal.html
- 2016 Marianas expedition (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/welcome.html
- Light in the Ocean (diagram): https://oceanservice.noaa.gov/facts/light_travel.html#:~:text=Sunlight%20entering%20the%20water%20may,200%20meters%20(656%20feet)
- Maps from NOAA Ocean Exploration 2011 Galapagos Rift expedition (webpage): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/leg1/leg1.html
- Divergent plate boundary (webpage): https://oceanexplorer.noaa.gov/facts/plate-boundaries.html
- Giant Black Smoker Hydrothermal Vent (video): youtube.com/watch?v=KtFFmDGIsa4&feature=youtu.be

Page 6:
- Hydrothermal Vent Organism Cards (editable PowerPoint): https://oceanexplorer.noaa.gov/edu/materials/vent-food-web.ppt
- Hydrothermal Vent Organism Cards (pdf): https://oceanexplorer.noaa.gov/edu/materials/vent-food-web.pdf

Page 7:
- Vent development (illustration): https://schmidtocean.org/wp-content/uploads/fk151121-guam-20151123-baker-plume.jpg

Page 8:
- How Giant Tube Worms Survive at Hydrothermal Vents (video): https://www.youtube.com/watch?v=8W_ywzhkR90&feature=youtu.be

Page 9:
- Smoking Chimney and Pompeii Worms (video): https://www.youtube.com/watch?v=9xIUSewbokc&feature=youtu.be
- Life Cycles of Vent Communities – So Much to Learn (webpage): https://oceanexplorer.noaa.gov/explorations/02galapagos/logs/may31/may31.html

Page 10:
- Oases of Life (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/may12/media/video/vents-1280x720.mp4
- 40 Years of Hydrothermal Vent Exploration (video): https://www.youtube.com/watch?v=UVzBjY8oLkk
- Living on a Chimney (activity): https://nautiluslive.org/resource/living-chimney

Partners

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Information and Feedback

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