LIVING ON A CHIMNEY | EDUCATOR

Links to Next Generations Science Standards |

MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Links to Common Core Standards |

CCSS.ELA-LITERACY.RST.1:
Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CCSS.ELA-LITERACY.RST.4:
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.

Theme | Science

Contributing Authors | Lindsay Knippenberg, Science Communication Fellow
Timothy Dwyer, Science Communication Fellow

Pacing | 1-2 class periods

Background Needed | Understanding of basic ecology and food web dynamics

Assessment | STEM Project and Task Rubric provided

Materials/Resources |

- Hydrothermal vent Creature Cards (http://nautl.us/2dQskkC)
- To explore more: devices with online access

Overview

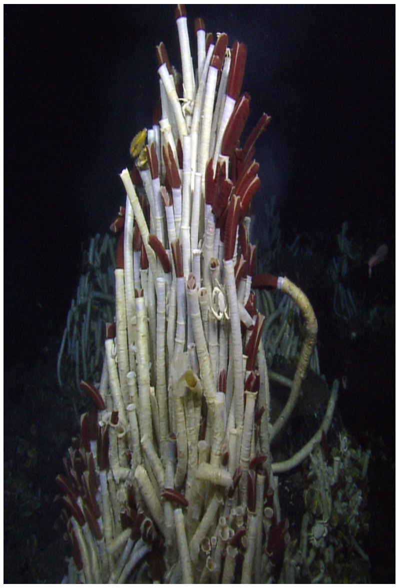
In this module, students will be introduced to various ecological relationships and organisms existing in some of the most extreme habitats on our planet: deep sea hydrothermal vents. Students will use 12 Creature Cards to construct a model food web and to critically assess trophic levels, trophic positions, and ecological niches. Students will use this knowledge to determine the spatial distribution of organisms within a hydrothermal vent community based on provided evidence.

Objectives & Learning Outcomes

- Students will describe the role of chemosynthesis in a hydrothermal vent community.
- Students will create a food web to describe trophic levels within a hydrothermal vent community.
- Students will analyze species distribution and describe the concept of ecological niche based on evidence.

Guiding Questions

- What defines an ecosystem?
  - ✓ **Possible answers:** An ecosystem is the sum of all the interactions between the organisms and the abiotic environment in a given location.
- What are some ways organisms of different species interact?
  - ✓ **Possible answers:** Organisms have predator-prey relationships, cooperative mutualism or commensalism-based relationships. Organisms can compete for space or have parasitic relationships. Species can occupy the same parts of a habitat but not interact with one another.



Set The Stage!

Use these resources (also featured in the student module) to introduce students to this topic and pique their interest in hydrothermal vents:

- 38 Years Later: Return to the Galapagos (http://nautl.us/1swdBBW)
- Exploring Gigantic Hydrothermal Vents (http://nautl.us/1XUbtz1)
- *Alert Diver* Magazine article written by Nautilus Core Team member Megan Cook: http://www.alertdiver.com/At_the_boundary_of_Creation

Additional teacher resource:

- http://journal.frontiersin.org/article/10.3389/fmars.2016.00072/full

Guiding Questions Continued

- Why are hydrothermal vent ecological communities one of the most important discoveries of the 20th century?
  - ✓ **Possible answers:** Until their discovery all complex ecosystems were thought to rely on energy from sun-based photosynthesis. The discovery of vent communities demonstrated life could be based on Earth's internal minerals. Chemosynthetic relationships have brought new study to evolutionary processes on our planet and raised new hypothesis about the types of life that might be found elsewhere in the universe. There are also potential commercial uses for biological properties of the animals and bacteria found in these environments, mineral deposits and chemical compounds found in vent communities.

Define the following terms:

Students will define the following terms and use them accurately to complete this lesson.

Hydrothermal vent

- ✓ A crack or fissure in the Earth's seafloor from which mineral rich geothermal-heated water flows.

Chemosynthesis

- ✓ Production of metabolic energy from the breakdown of inorganic compounds; using chemical reactions to produce food. Vent bacteria utilize hydrogen sulfide and other molecules to make sugar.

Ecological community

- ✓ Populations of two or more different species occupying the same geographical area.

Trophic level

- ✓ The position an organism occupies in a food chain or web. Introduce the sequential terms primary, secondary, tertiary (first, second, third)

Autotroph

- ✓ An organism capable of producing its own energy (sugar) from the sun or chemical energy. Ex: plants and chemosynthetic bacteria.

Endosymbiont

- ✓ Any organism that lives within the body or cells of another organism. i.e. chemosynthetic bacteria within the tube worm's trophosome (an organ that houses bacteria).

Primary Consumer

- ✓ An organism that gets their energy directly from the primary producers by eating or living symbiotically with them (i.e. vent crab or tube worm).

Specialist

- ✓ A species with narrow habitat or food requirement

Generalist

- ✓ A species that regularly includes a variety of prey as part of its diet

Mobile

- ✓ An organism that can move freely around an environment without being attached permanently to the substrate.

Sessile

- ✓ An organism that is attached to the substrate. All hydrothermal vent sessile organisms have mobile larvae to colonize new venting sites.

Species Richness

- ✓ The number of different species represented in an ecological community, trophic level or region. Species richness is a measure of biodiversity and simply a count of species. It does not take into account the abundances of individuals.

Ecological Niche

- ✓ The role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces.

Activity/Tasks

Students will:

- complete guiding questions and vocabulary to get better acquainted with ecological terms and hydrothermal vent concepts;
- arrange the Creature Cards into a food web;
- use the food web to complete tasks one and two;
- complete the conclusion questions.

Educator: Lesson Procedure/Directions

✓ **LESSON SET-UP |** Decide the arrangement of student working groups best suited for your learning environment. Students can also work individually to complete this module. Each student or group will need to have a set of Creature Cards to use for each task.

☐ Helpful tip:

- ✓ Make class sets of laminated cards for added durability and reuse.

Extensions & Adaptations

Introductory |
For younger audiences modify the number of cards and tasks used. Students could use 3-5 cards to build a simple food chain to learn about species and relationships in extreme habitats.

Advanced |
Students can research hydrothermal vents to introduce the concepts of primary and secondary ecological succession.

Students can research and create their own Creature Cards to map out these tasks.

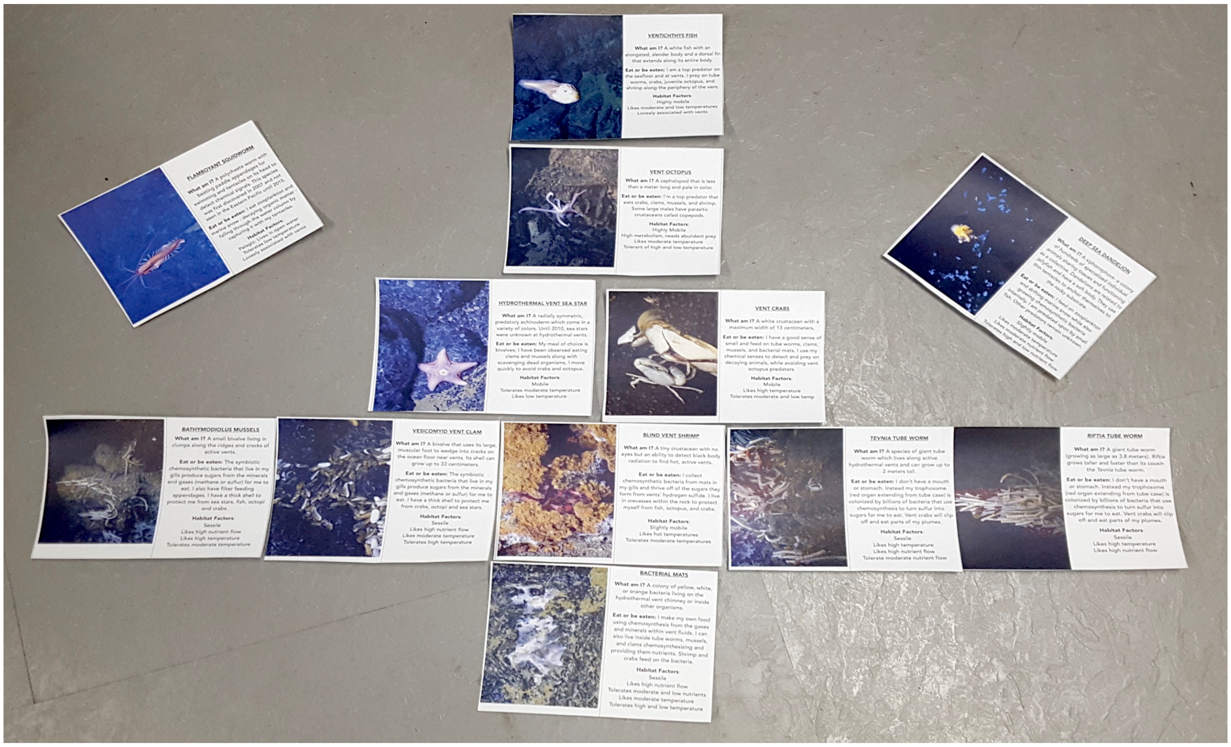
Introduce the concepts of fundamental niche vs realized niche to discuss competitive effects in this habitat

ELL |
Watch this PBS Hydrothermal Vents Spanish language video to introduce this activity: http://nautl.us/1TXWP7j

Task One: Build a model food web to explore trophic relationships

A food web is a graphical representation of who eats whom in an ecological community. Use the information on the Creature Cards to arrange organisms into a food web based on predator/prey/producer relationships. Use this food web to answer the questions below.

EXAMPLE ARRANGEMENT:



Trophic Levels	
How many organisms in this food web are autotrophs?	**1**
How many organisms are primary consumers?	**5**
How many organisms are secondary consumers?	**2**
How many organisms are tertiary consumers?	**1**
How many organisms are quaternary consumers?	**1**
As your Creature Cards are arranged, how many trophic levels are in your food web?	**5**

1. If every animal feeds as low as it can on the food web, what's the minimum number of trophic levels in this ecosystem? Rearrange your Creature Cards to show this scenario.

✓ **Possible answers:** 3 - Autotroph (Bacteria Mat) to Primary Consumer (Clam) to Octopus (Secondary Consumer) OR Autotroph (Bacteria Mat) to Primary Consumer (Tubeworm) to Ventichthys Fish (Secondary Consumer)

2. If every animal feeds as high as it can on the food web, what's the maximum number of trophic levels in this ecosystem? Rearrange your Creature Cards to show this scenario.

✓ **Possible answers:** 5 - Bacterial Mat (Autotroph) to Limpet (Primary Consumer) to Vent Crab (Secondary Consumer) to *Ventichthys* Fish (Tertiary Consumer) to Octopus (Quaternary Consumer)

3. Which organisms occupy more than one trophic level?

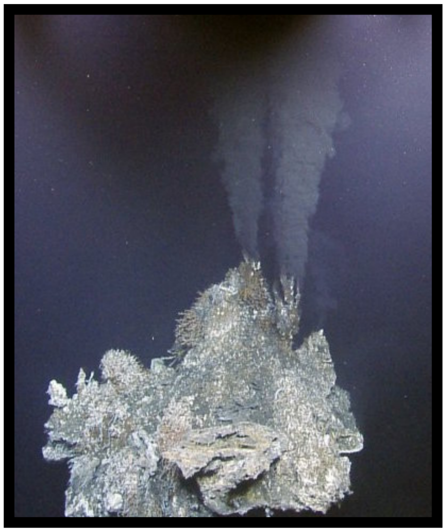
✓ **Possible answers:** Sea Dandelion- Primary Consumer or Secondary Consumer
Crabs - Primary Consumer (of Bacterial mats), Secondary Consumer (of tubeworms)
Octopus- Secondary, Tertiary, or Quaternary Consumer
Ventichthys Fish- Secondary, Tertiary, or Quaternary Consumer

4. For the organisms listed as your answer for question 3, is each organism a specialist or generalist and explain why?

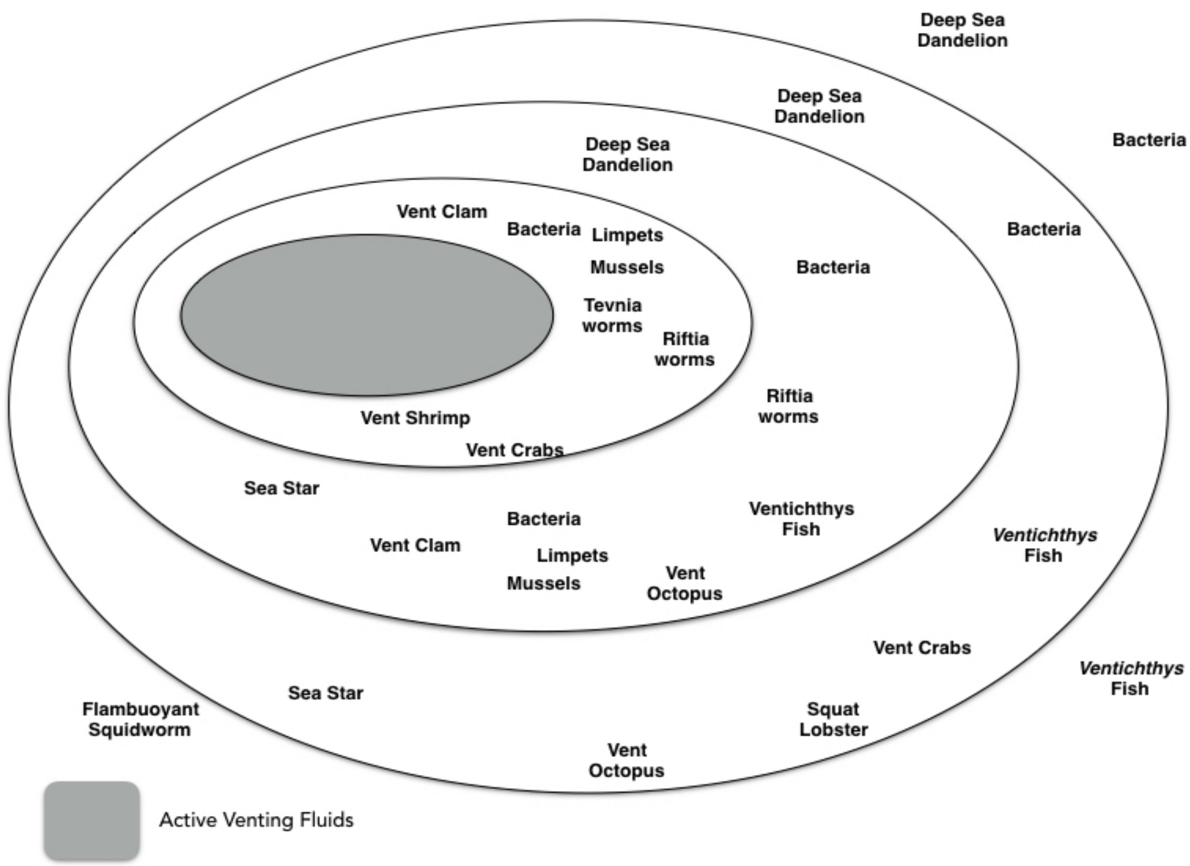
✓ **Possible answers:** All are generalists opportunistically finding food as it becomes available regardless of trophic level.

Task Two: Species Distribution

Species distribution describes the spatial arrangement of various organisms within an ecological community. Creatures' prime habitats in a hydrothermal vent community vary according to their tolerance for temperature and nutrients which decrease with distance from an active vent. Below is an overhead view of a hydrothermal vent. Use the information on the Creature Cards to write the name of each organism into the habitat zone where you think it lives in relation to the active vent. Be prepared to justify your arrangement to a classmate.



Conceptual representation of organisms arrangement based on habitat factors on the Creature Cards. Several configurations are possible. Look to student justifications to discuss habitat distribution options.



Conclusion Questions |

1. Which trophic levels have the greatest species richness? Why are the highest number of species found at these levels?
   - ✓ **Possible answers:** The primary consumers tend to have the highest diversity of species at hydrothermal vent sites. There are many different types of species of shrimp, worms, snails, etc. that rely on bacteria or bacterial mats for energy. Many of these consumers have evolved mutualistic symbiotic relationships with the chemosynthetic bacteria eliminating the need to rely on predation for energy.

2. Which do you think is the primary controller on the size of populations at a hydrothermal vent: the number of predators present or the flow of hydrothermal minerals? What evidence supports your choice?
   - ✓ **Possible answers:** The flow of hydrothermal minerals can control the size of populations at a vent. Rich energetic resources pouring from the hydrothermal vents support a diverse and abundant community of chemosynthetic autotrophs and symbiotic consumers. Compared to other parts of the seafloor, the concentration of energy-availability at a vent (i.e. hydrogen sulfide) is very high. Abundant food resources allow for rapid reproduction of fast growing animals. Biological interactions are also important in controlling population numbers. For example, mussels could prevent more tube worms from moving in, and octopuses may limit the crab population.

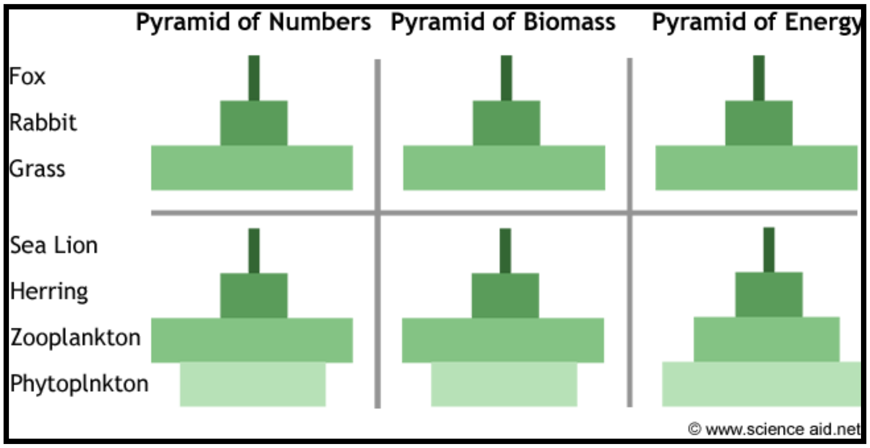
3. If two species have the same preference for a habitat on the vent, what possible interactions will occur if they try to occupy the same space?
   - ✓ **Possible answers:** The organisms will compete for access to vent minerals and space. The species that grows faster or larger, or gets there first, or can hold on tighter, may outcompete the other species and force them to live in less-preferred habitats. The most competitive species will live in its prime habitat.

4. Choose one organism from the Creature Cards and define its ecological niche.
   - ✓ **Possible answers: Vent octopus occupy its ecological niche as a top predator by being highly mobile to move around and find many different types of prey. Because it is tolerant of high and low temperature it can move throughout the vent community searching for sessile and slightly mobile prey.**

For further discussion

Are hydrothermal vent communities more similar to terrestrial energy pyramids or shallow-water marine energy pyramids? What differences are there? Why are these differences present?

Image courtesy of ScienceAid.net.uk



LIVING ON A CHIMNEY | STUDENT

Name: ___________________________________

Learning Goals

- Describe the role of chemosynthesis in a hydrothermal vent community.
- Create a model food web to critically assess the trophic positions within a hydrothermal vent community.
- Describe ecological niches by examining preferred habitats of hydrothermal vent organisms.

Location, Location, Location

- Explore this map to see various dive locations from the Galapagos Expedition: Galapagos Vent Sites.
- Examine this tectonic plates map to answer the question below: http://www.sanandreasfault.org/Plates.jpg Where would you predict to find other hydrothermal vent sites and why?

Introduction |

Have you ever wondered what life and features exist miles down in the sunless, cold, and poorly explored environment of the deep ocean? In 1977, scientists made an astonishing discovery that would forever change our understanding of the organisms, processes and landscapes associated with extreme habitats. This expedition to the Galapagos Rift region off the coast of Ecuador, led by Dr. Robert Ballard, was the first to witness the bewildering landscape and biology of hydrothermal vents.

In June of 2015, E/V *Nautilus* revisited this famous site, the Galapagos Rift, a divergent boundary where the Cocos and Nazca plates slowly move apart. At sites like this cracks develop in the thin oceanic crust and hydrothermal vents are formed. Cold, dense saltwater seeps into the crust penetrating down near the molten rising rock below. The warmed water dissolves minerals from surrounding rock and rises as it expands, less dense than the cold ocean water above. This rising, heated, mineral-rich water shoots out of the crust forming hydrothermal vents, smoke-like clouds and large mineral chimneys.

Since vents are far below the reach of sunlight, organisms living there rely on converting chemicals coming out of the Earth's crust as an energy source rather than sunlight. This process is called chemosynthesis. Chemosynthetic bacteria, which gather energy from Earth's dissolved minerals and gases, form the base of the food chain. The entire ecosystem of clams, mussels, and tube worms rely on this chemical reaction. Hydrothermal vents are studied to help scientists learn more about the origins of life on our planet and how food chains interact in extreme conditions at the boundaries of geologic activity. In this module you will use a set of hydrothermal vent Creature Cards to examine the relationships between different organisms living around hydrothermal vents.

Riftia tubeworms, vent mussels and crabs at the Tempus Fugit hydrothermal vent site rely on symbiotic chemosynthetic bacteria to get their energy.

Guiding Questions |

1. What defines an ecosystem?

2. What are some ways organisms of different species interact?

3. Why are hydrothermal vent ecological communities one of the most important discoveries of the 20th century?

Vocabulary |

Hydrothermal vent:

Chemosynthesis:

DON'T MISS PLAYLIST

Ready to learn more? Check out these video clips and photo albums from Nautilus Live!

- 38 Years Later: Return to the Galapagos (http://nautl.us/1swdBBW)
- Exploring Gigantic Hydrothermal Vents (http://nautl.us/1XUbtz1)
- Gigantic Elaborate Hydrothermal Vents off British Columbia (http://nautl.us/1MceaIA)
- New Discovery: Smoking Chimney and Hydrothermal Vents (http://nautl.us/1UU4p5a)
- Black Smoker Hydrothermal Vent (http://nautl.us/1TbKHzA)
- Measuring Active Hydrothermal Vents in Galapagos (http://nautl.us/1Tmkdve)

Helpful Resources:

- Check out this *Alert Diver* Magazine article written by Nautilus Core Team member Megan Cook: http://www.alertdiver.com/At_the_Boundary_of_Creation
- National Ocean Service vent guide http://oceanservice.noaa.gov/facts/vents.html
- Vent research guide from NOAA PMEL http://www.pmel.noaa.gov/eoi/chemocean.html
- Woods Hole Deeper Discovery page http://www.divediscover.whoi.edu/vents/

Vocabulary Continued |

Ecological community:

Trophic level:

Autotroph:

Endosymbiont:

Primary Consumer:

Specialist:

Generalist:

Mobile:

Sessile:

Species Richness:

Ecological niche:

Task One: Build a model food web to explore trophic relationships

A food web is a graphical representation of who eats whom in an ecological community. Use the information on the Creature Cards to arrange organisms into a food web based on predator/prey/ producer relationships. Use this food web to answer the questions below.

Trophic Levels	
How many organisms in this food web are autotrophs?	
How many organisms are primary consumers?	
How many organisms are secondary consumers?	
How many organisms are tertiary consumers?	
How many organisms are quaternary consumers?	
As your Creature Cards are arranged, how many trophic levels are in your food web?	

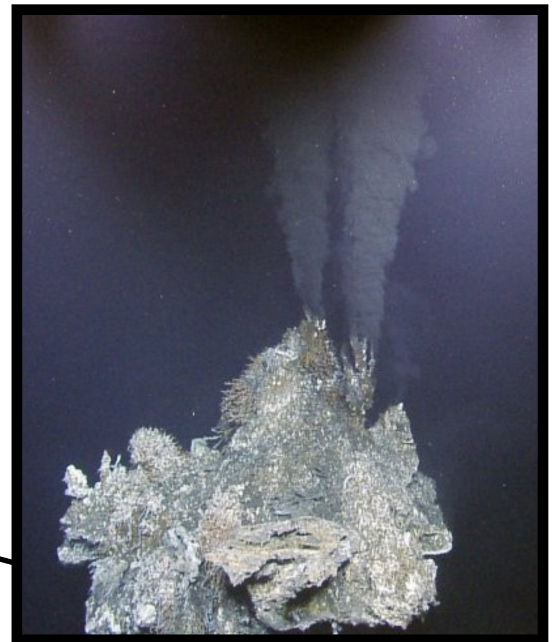
1. If every animal feeds as low as it can on the food web, what's the minimum number of trophic levels in this ecosystem? Rearrange your Creature Cards to show this scenario.

2. If every animal feeds as high as it can on the food web, what's the maximum number of trophic levels in this ecosystem? Rearrange your Creature Cards to show this scenario.

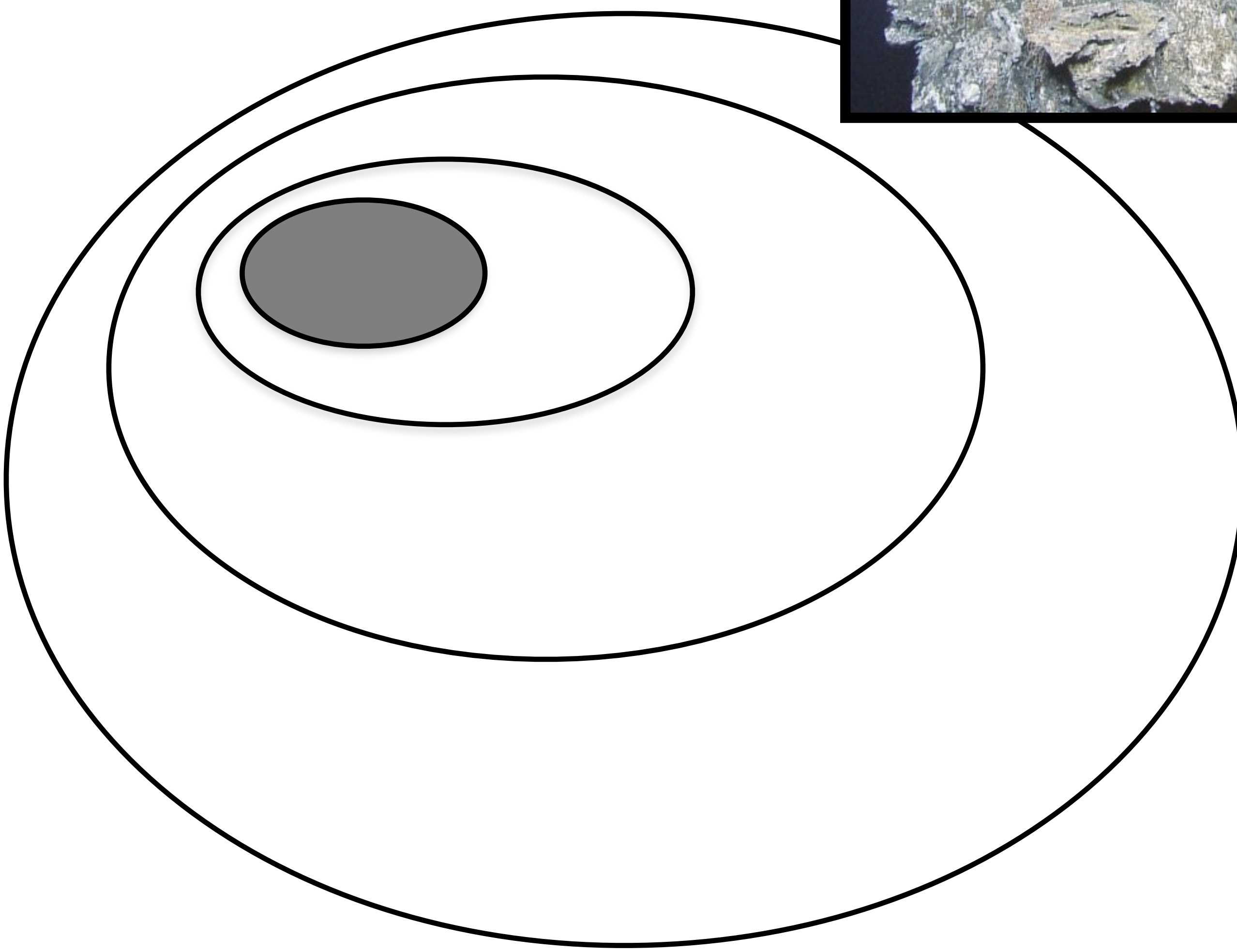
3. Which organisms occupy more than one trophic level?

4. For the organisms listed as your answer for question 3, is each organism a specialist or generalist and explain why?

Task Two: Species Distribution



Species distribution describes the spatial arrangement of various organisms within an ecological community. Creatures' prime habitats in a hydrothermal vent community vary according to their tolerance for temperature and nutrients which decrease with distance from an active vent. Below is an overhead view of a hydrothermal vent. Use the information on the Creature Cards to write the name of each organism into the habitat zone where you think it lives in relation to the active vent. Be prepared to justify your arrangement to a classmate.



Active Venting Fluids

Conclusion Questions |

1. Which trophic levels have the greatest species richness? Why are the highest number of species found at these level?

2. Which do you think is the primary controller on the size of populations at a hydrothermal vent: the number of predators present or the flow of hydrothermal minerals? What evidence supports your choice?

3. If two species have the same preference for a habitat on the vent, what possible interactions will occur if they try to occupy the same space?

4. Choose one organism from the Creature Cards and define its ecological niche.

LIVING ON A CHIMNEY | ASSESSMENT

STEM Project & Task Rubric

OBJECTIVE	CRITERIA			
	4 Exemplary	3 Commended	2 Emerging	1 Developing
Knowledge & Understanding |	Student consistently, correctly and thoroughly answers all questions. Uses an abundance of relevant vocabulary and is able to explain relationships within the content using examples. Can apply the content to other topics or real life.	Student is able to consistently answer most questions correctly. Uses an adequate amount of relevant vocabulary. Can explain relationships within the content and can apply content to other topics or real life.	Student is able to answer some questions correctly. Uses some relevant vocabulary. Student does not elaborate on relationships within the content or make connections between the content and real life.	Student is able to answer a few questions correctly. Inconsistently uses relevant vocabulary. Student does not elaborate on relationships within the content or make connections between the content and real life.
Content Organization, Methodology & Analysis |	Student effectively organizes complex ideas, concepts, and information to make important connections and distinctions. This may include detailed, labeled and thorough procedures, data tables, graphs, diagrams and/or analyses.	Student is able to organize ideas, concepts, and information to make connections and distinctions. This may include mostly detailed, labeled and thorough procedures, data tables, graphs, diagrams and/ or analyses.	Student attempts to organize ideas, concepts and information to make some connections and distinctions. Student is able to provide basic procedures, data tables, graphs, diagrams and/or analyses.	Student has difficulty organizing ideas, concepts and information to make connections and distinctions. Student is unable to provide basic procedures, data tables, graphs, diagrams and/or analyses.
Self-Directed Learner |	Student is actively engaged in the learning process; consistently contributes to class discussions and asks clarifying questions. Seeks out and shares additional resources with the class or teacher. Advocates for his/ her learning needs.	Student is engaged in the learning process. Often contributes to class discussions and asks clarifying questions. Advocates for his/her learning needs.	Student is inconsistently engaged in the learning process. Sometimes contributes to class discussions or asks clarifying questions. Inconsistently advocates for his/her learning needs.	Student is weakly engaged in the learning process. Rarely contributes to class discussions or asks clarifying questions. Rarely advocates for his/ her learning needs.
Technological Tools |	Use of digital resources is always appropriate for the task. Willing to learn and use technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is appropriate for the task. Willing to use technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is sometimes appropriate for the task. Inconsistent use of technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is rarely appropriate for the task. Inconsistent use of technology for inclusion of charts, graphs, pictures, etc. to amplify the message.
Collaboration Skills |	Consistently works effectively and respectfully with a diverse group of learners. Actively checks with others for understanding and how he or she may be of help. Student listens when others speak and incorporates or builds off of the ideas of others.	Works effectively and respectfully with a diverse group of learners. Checks with others for understanding and how he or she may be of help. Student listens when others speak.	Sometimes works effectively and respectfully with a diverse group of learners. Sometimes checks with others for understanding and how he or she may be of help. Student listens when others speak.	Has difficulty working effectively and respectfully with a diverse group of learners. Rarely checks with others for understanding and how he or she may be of help. Student may talk over other students or does not listen when others speak.
Total Score: ____________	**Comments:**			