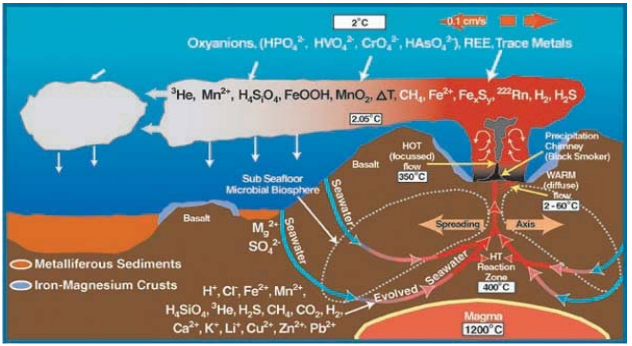
Introduction: Chemosynthesis at Hydrothermal Vents



The fluid that 'vents' out of the hydrothermal vent chimneys is rich in chemicals. As the seawater is heated by magma below the vent field, some chemicals are transferred to the water from the hot crust material. Some of these metals precipitate out of the fluid as it rises, forming the vent chimneys, while other minerals mix with surrounding waters.

Bacteria, or microbes, living on or around the hydrothermal vent use these chemicals for chemosynthesis, the process that makes food from inorganic compounds.

Vent chemicals for chemosynthesis:

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

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

Vent image: *Courtesy of the NOAA Ocean Exploration, 2016 Deepwater Exploration of the Marianas.*
Vent diagram: *Image modified from Massoth et al., 1988; courtesy of Submarine Ring of Fire 2002, NOAA Ocean Exploration.*

Activity Instructions (digital version, *option 1*)

1. Read through the following **organism cards** to learn more about several of the organisms that make up a hydrothermal vent community.
2. Using the information on the cards, **create a food chain** that includes four of the organism cards.
    a. Drag four of the organism cards on slide 17 to form a food chain (move the extra cards off to the side by dragging them out of the way).
        Hint: *You should end up with one organism in each trophic level on slide 19.*
    b. Draw arrows between the organism cards to show the direction that energy is flowing through the food chain.
3. Hydrothermal vent food webs are far more complex than a simple food chain. Now, use all of the organism cards to **complete the food web template** on slide 18.
    a. Type the name of each organism in the empty boxes provided.
    b. Draw arrows to show the direction that energy is flowing through the food web.
        Hint: *Some organisms will eat or be eaten by more than one organism!*

Activity Instructions (digital version, *option 2*)

1. Read through the following **organism cards** to learn more about several of the organisms that make up a hydrothermal vent community.
2. Using the information on the cards, **create a food chain** that includes four of the organism cards on slide 17.
    a. Copy the four organisms you wish to use from slide 17 and paste onto slide 19.
    b. Arrange the organism cards to form a food chain.
        Hint: *You should end up with one organism in each trophic level on slide 19.*
    c. Draw arrows between the organism cards to show the direction that energy is flowing through the food chain.
3. Hydrothermal vent food webs are far more complex than a simple food chain. Now, use all of the organism cards on slide 17 to **create a food web**.
    a. Copy all of the organism cards from slide 17 and paste onto slide 19.
    b. Arrange the organism cards by dragging them into the appropriate trophic levels on slide 19 to form a food web.
    c. Draw arrows between the organism cards to show the direction that energy is flowing through the food chain.
        Hint: *Some organisms will eat or be eaten by more than one other organism!*

Hydrothermal Vent Chemicals

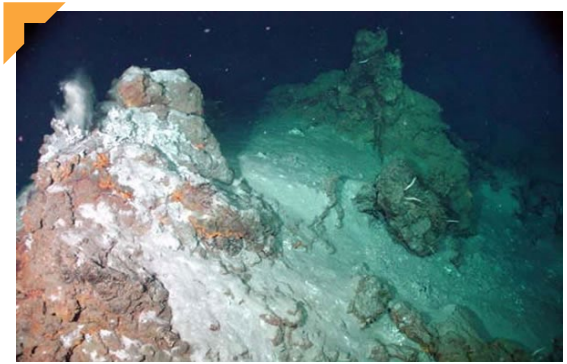
H_2S
Hydrogen Sulfide

O_2
Oxygen

CO_2
Carbon Dioxide

CH_4
Methane

Vent Bacteria, *Arcobacter sulfidicus*

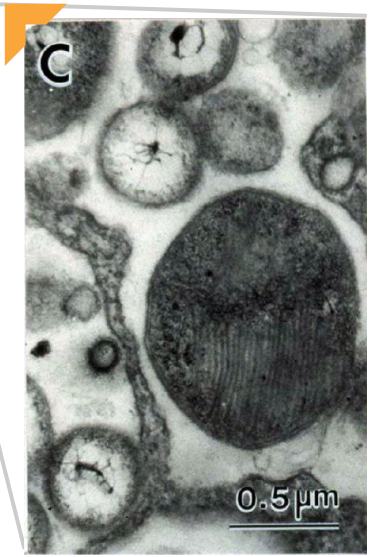


These free-swimming microbes have four long flagella (tails) that help propel them through the water. These bacteria are also able to form bacterial mats that appear stringy or wispy in texture.

The bacteria are chemosynthetic. They oxidize hydrogen sulfide, add carbon dioxide and oxygen to produce sugar (food), sulfur, and water. The food that chemosynthetic bacteria produce serves as the base of the hydrothermal vent food web.

Top: *Image courtesy of Submarine Ring of Fire 2002, NOAA Ocean Exploration.*
Bottom: *Image adapted from "New Vent Site" video. Courtesy of NOAA Ocean Exploration, Galapágos Rift Expedition 2011.*

Symbiotic Bacteria



Symbiotic vent bacteria are found inside the tissues of other vent animals, such as tubeworms or mussels.

The bacteria are chemosynthetic. They **oxidize** hydrogen sulfide, add carbon dioxide and oxygen to produce sugar (food), sulfur, and water. The food that chemosynthetic bacteria produce serves as the base of the hydrothermal vent food web.

The food the bacteria makes is shared with the host organism, and in return the bacteria has a safe home.

The image to the left shows two symbiotic microbes found living inside the tissues of vent mussels.

Mussels: *Image courtesy of Submarine Ring of Fire 2004, NOAA Vents Program.*
Bacteria: *Image courtesy of Fisher et. al, Marine Ecology 1993.*

Vent Zooplankton

Zooplankton are microscopic animals that drift in the ocean. At hydrothermal vents, they usually include the larval forms of several species found near vents, like crabs, shrimp, worms and snails.

These larval forms may drift in the water column for days to months before settling back to the bottom, and are the main means by which new vent sites are colonized.

Here, zooplankton consume bacteria living at the vents.

***Image** courtesy of Submarine Ring of Fire 2014 - Ironman, NOAA/PMEL.*

Vent Shrimp

These small **shrimp** are well adapted for living in the extreme conditions of a hydrothermal vent. They are capable of surviving very high temperatures.

Some species are blind. Instead of eyes, these species have specialized heat sensing organs on their backs that help them “see” the surrounding environment.

Some species of vent shrimp feed directly on the bacterial mats growing on and around vent chimneys for their entire life, while others only feed on the bacteria during early life stages.

***Image** courtesy of Submarine Ring of Fire 2014 - Ironman, NOAA/PMEL.*

Vent Mussel, *Bathymodiolus sp.*

Vent mussels attach to vent chimneys and surrounding rocks using byssal threads, or very sticky filaments produced by the mussels' foot.

The mussels are often found growing in large clusters. The black spots on the shells are former anchor points of mussels who have cut their threads and moved on.

The small gaps between mussels in a cluster are used by other small vent invertebrates like worms or shrimp.

Vent mussels have chemosynthetic bacteria that live inside their gills. The bacteria make food for the mussels by converting inorganic materials into sugars. They are also capable of suspension feeding.

Some species of mussels have more than one type of symbiont in their gills, allowing them to derive energy from different inorganic compounds, such as methane or hydrogen sulfide.

***Image** courtesy of Submarine Ring of Fire 2004, NOAA Vents Program.*

Riftia Tubeworm, *Riftia pachptyla*

Tubeworms do not have a mouth, gut, or anus. They completely lack a digestive system!

Instead of "eating," these animals get their food from special symbiotic bacteria that live within their body in an organ called the trophosome. It is estimated that one tubeworm is host to billions of these chemosynthetic bacteria.

The white tube acts as the outer skeleton for the worm. This can grow over 1 meter (3 feet) in length.

The red plume is bright red in color due to high blood flow. The blood carries important compounds from the water, like oxygen, to the symbionts living inside.

The image to the left appears blurry due to the extremely hot water “venting” out of the vent field, which distorts the image.

***Image** adapted from “New Vent Site” video. Courtesy of NOAA Ocean Exploration, Galapágos Rift Expedition 2011.*

Squat Lobsters (Galatheid Crabs), *Munidopsis alvisca*

Squat lobsters are small crustaceans that roam about the vent ecosystem. They have very long claws. Some species have claws twice as long as their body.

The squat lobsters in this photo appear “hairy” due to the bacteria growing on their shells.

They are scavengers that feed on bacteria mats, small zooplankton, amphipods, and other vent debris.

***Image** courtesy of Submarine Ring of Fire 2014 - Ironman, NSF, NOAA, Jason, copyright WHOI.*

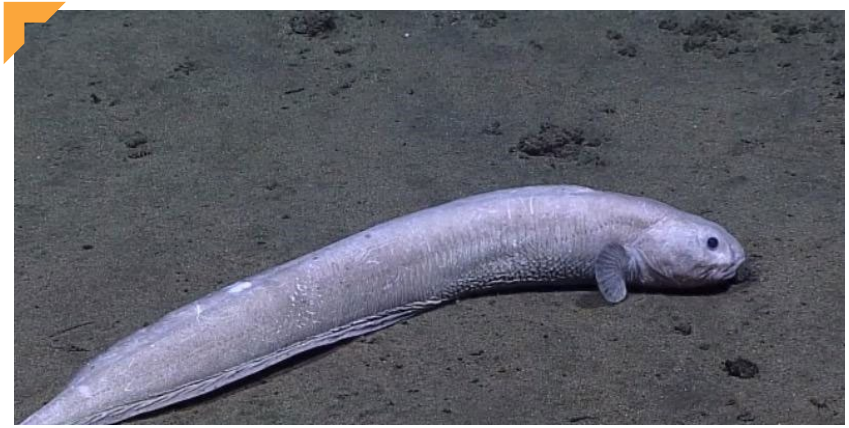
Dandelion Siphonophore

Siphonophores are actually comprised of many individuals that all work together. Some individuals protect the colony, some catch food, and some reproduce. They are a type of cnidarian, closely related to corals, sea anemones, and jellyfish.

Dandelion siphonophores are usually observed anchored to seafloor using their tentacles. This animal was observed at approximately 2,530 meters (8,300 feet) depth, with its feeding tentacles extended around the animal like a spider web. All siphonophores are predatory carnivores believed to feed on copepods, and other small crustaceans like crabs and krill.

***Image** courtesy of the NOAA Ocean Exploration, 2017 Laulima O Ka Moana.*

Eelpout (Zoarcid Fish), *Pachycara gymninium*



These **long, slender white fish** grow up to two feet (61 centimeters) in length. They are quite slow and lethargic. They spend a lot of time floating around clumps of tubeworms and mussels.

Despite their sluggish behavior, they have huge appetites. Eelpouts are predators that feed on everything from tubeworms to shrimp.

***Image** adapted from "New Fish Species" video. Courtesy of NOAA Ocean Exploration, 2016 Deepwater Exploration of the Marianas.*

Vent Ratfish (Chimaera), *Hydrolagus affinis*

Ratfish, also known as a chimaera, have long, tapered tails and short, rounded snouts.

Like sharks, ratfish are cartilaginous, and have no real bones. The prominent lateral line that runs down their side is full of mechanoreceptors that detect pressure waves, similar to human ears.

The vent ratfish is a carnivore and feeds on a variety of animals smaller than itself. It eats crabs, shrimp, smaller fish, and vent mussels.

***Image** adapted from "Chimaera" video. Courtesy of NOAA Ocean Exploration, 2016 Deepwater Exploration of the Marianas.*

Blind Crab

Crabs are scavengers and these blind vent crabs are known to feed on shrimp, mussels, tubeworms as well as each other.

***Image** courtesy of Schmidt Ocean Institute*

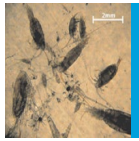
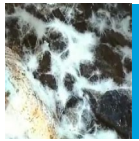
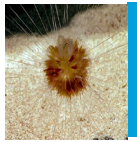
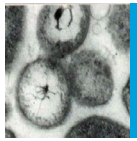
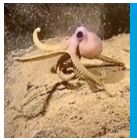
Octopus

Octopods are very active, carnivorous molluscs. They have eight arms lined with suction cups that help them catch prey and they hide in small crevices around the vents.

Certain species of octopods eat many smaller animals in the vent ecosystem such as crabs, shrimp, and mussels.

***Image** adapted from "Octopus" video. Courtesy of NOAA Ocean Exploration, Galapágos Rift Expedition 2011.*

Hydrothermal Vents: Organism Cards

H_2S CO_2 O_2 CH_4	Vent Chemicals
	Zooplankton
	Vent Bacteria
	Dandelion Siphonophore
	Blind Crab
	Symbiotic Bacteria
	Squat Lobster
	Vent Shrimp
	Vent Mussel
	*Riftia* Tubeworm
	Eelpout
	Ratfish
	Octopus

Hydrothermal Vent: Food Web *(Option 1)*

Read through the organism cards above. Fill in the hydrothermal vent food web below by typing in the organism's name where it belongs. Draw arrows between the organisms to show what direction the energy flows through the food web and "who eats who."

Simple Chemicals	Primary Producers	Primary Consumers	First Order Carnivores	Top Order Carnivores
H_2S				
CO_2				
O_2				
CH_4				

Hydrothermal Vent: Food Web *(Option 2)*

Read through the organism cards above. Copy and paste the organism cards on slide 17 below. Create a food web by arranging the organism cards into the categories below. Draw arrows between the organisms to show what direction the energy flows through the food web and "who eats who."

Simple Chemicals	Primary Producers	Primary Consumers	First Order Carnivores	Top Order Carnivores
H_2S				
CO_2				
O_2				
CH_4				

Hydrothermal Vent: Food Web (*Answer Key*)

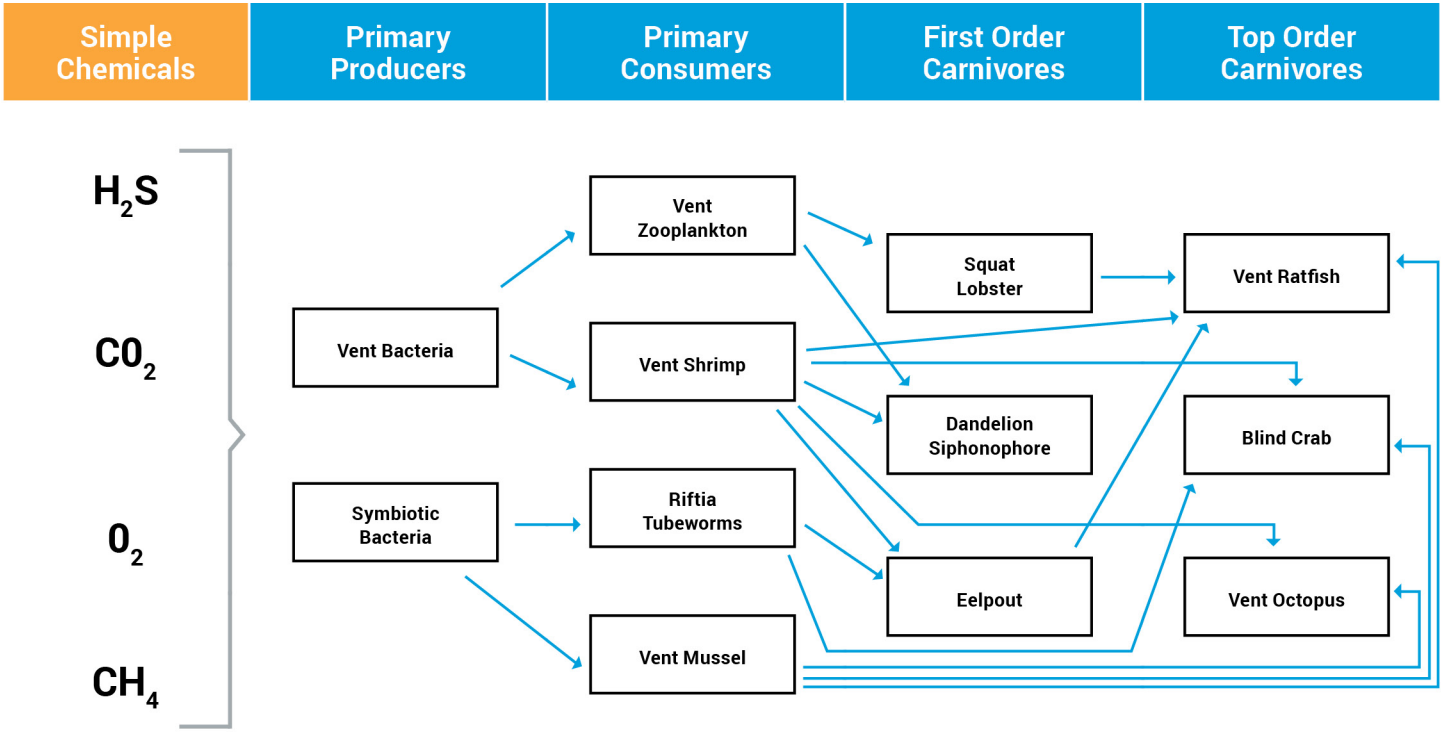


Image Hyperlinks

SLIDE 2
Vent: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1605/dailyupdates/media/may2.html
Diagram: https://oceanexplorer.noaa.gov/explorations/02fire/background/vent_chem/media/chemistry.html

SLIDE 5 (Vent Bacteria)
Top: https://oceanexplorer.noaa.gov/explorations/02fire/logs/jul29/media/anhydrite.html
Bottom: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1103/dailyupdates/media/video/0723-vent-site.html

SLIDE 6 (Symbiotic Bacteria)
Mussels: https://oceanexplorer.noaa.gov/explorations/04fire/logs/april11/media/grazers_600.jpg
Bacteria: https://oceanexplorer.noaa.gov/explorations/06mexico/logs/may20/may20.html

SLIDE 7 (Vent Zooplankton): https://oceanexplorer.noaa.gov/explorations/04fire/logs/april14/april14.html

SLIDE 8 (Vent Shrimp): https://oceanexplorer.noaa.gov/explorations/14fire/background/seamounts/media/eifuku_mussels4_hires.jpg

SLIDE 9 (Vent Mussel): https://oceanexplorer.noaa.gov/explorations/04fire/logs/april11/media/grazers_600.jpg

SLIDE 10 (Riftia Tubeworm): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1103/dailyupdates/media/video/0723-vent-site.html

SLIDE 11 (Squat Lobsters): https://oceanexplorer.noaa.gov/explorations/14fire/logs/december08/media/mussels_lobsters_hires.jpg

SLIDE 12 (Dandelion Siphonophore): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1706/logs/july30/welcome.html

SLIDE 13 (Eelpout): https://oceanexplorer.noaa.gov/okeanos/explorations//ex1605/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1605/dailyupdates/media/video/0707-fish/0707-fish.html

SLIDE 14 (Vent Ratfish): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/dailyupdates/media/video/0504-chimaera/0504-chimaera-1920x1080.mp4

SLIDE 15 (Blind Crab): https://schmidtocean.org/cruise-log-post/animal-life-mariana-back-arc/

SLIDE 16 (Octopus): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1103/dailyupdates/media/video/0721-octopus.html