

4th Grade Lesson Plan

Mazes, Maps, and Magnificent Animals in the Deep Sea

Created by Nadia Stoker

Edited by Trish Mace and Dr. Caitlin Plowman

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1. Title & Grade Level

Mazes, Maps, and Magnificent Animals in the Deep Sea (4th Grade)

2. Lesson Summary

The deep sea is home to a wide diversity of marine animals that exhibit forms and behaviors that enable their survival in habitats very different from those on land or in shallow waters. Once thought of as a desolate, barren landscape with little life to study, we now know the deep sea has a high diversity of animals, as well as geochemical processes that allow it to be inhabited. There are deep-ocean ecosystems that are independent of sunlight and photosynthetic organisms for energy. Hydrothermal vents, submarine hot springs, and methane cold seeps rely on chemical energy and chemosynthetic organisms to support life. These habitats are the site of further deep-sea exploration that could continue to reveal to scientists how organisms can survive in the most extreme conditions.

Students will complete a maze that simulates a dive to the bottom of the ocean in the human-occupied vehicle (HOV) ALVIN. Along the way, as the students complete the maze, they will collect data. The data collected will allow students to begin characterizing and describing the deep-sea habitat they are exploring. Based on the data they collect, students will read descriptions of known deep-sea habitats to determine which site they've visited. The descriptions will reveal the site's latitude and longitude but not its name. Students will then plot the locations of their site on a map of known hydrothermal vent sites. Once the students have plotted their sites using the data they collected, they will discover the site's name. With the name, students will read more about their specific site and reflect on what they learned during their deep-sea dive as an ALVIN pilot. Given the coordinates and name of their site, students can plot their sites on different maps that reveal more information, such as the site's depth and its position in relation to tectonic plates. Students will analyze and interpret map information to learn more about the planet's features. Students will learn about the deep-sea animals at each site and how diverse life forms have internal and external structures that support survival, growth, and reproduction in one of the planet's most extreme habitats.

3. Objectives

- a. Students use map-based data to identify the locations of hydrothermal vents, cold seeps, and brine pools.
- b. Students use data to plot the locations of different deep-sea habitats and learn about their depths, locations, and connections to tectonic plates.
- c. Students learn about deep-sea habitats, including the types of animals that inhabit different sites.

4. Estimated Time

- a. 60-90 minutes

5. Alignment with Next Generation Science Standards

4-LS1-1 From Molecules to Organisms: Structures and Processes Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. Performance Expectation Grade: 3-5, 4

4-ESS2-2 Earth's Systems: Analyze and interpret data from maps to describe patterns of Earth's features. Performance Expectation Grade: 3-5, 4

6. Alignment with Ocean Literacy Principles

OLP 1: Earth has one big ocean with many features.

OLFC 1B: Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape, and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys, and flattest plains are all in the ocean.

OLP 5: The ocean supports a great diversity of life and ecosystems.

OLFC 5G: There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

7. **Focus Question:** What animals live on the bottom of the ocean and where can they be found on a world map?

8. Materials

Included:

- a. Information on deep-sea habitats and animals
- b. 6 different mazes leading to 6 different sites in the deep sea with solutions
- c. Map of tectonic plates

Not Included:

- d. Writing utensils
- e. Projector (optional)

9. Preparation

- f. Print mazes
- g. Read background information

10. Lesson Steps

Step one: Introduce hydrothermal vents and methane seeps using the background information provided on pages 1-2 of the work packet.

Step two: There are six printable mazes that lead students to six different deep-sea sites (pages 8-13). Distribute the mazes (one per student) evenly throughout the class to ensure all six sites are explored. Each student also needs a printed work packet (pages 14-23). Read page 3 of the work packet to the class.

Step three: Allow students time to complete their mazes. Then have students collect and record data where their pencil crossed through words or images on the correct, direct route to the end. Note: Students should not record data where they veered off the direct path. Explain that salinity is a measure of how salty ocean water is. Explain that the materials collected are types of minerals that can help scientists to understand how a hydrothermal vent or methane seep works, as well as how deep-sea animals interact with a site.

10. Lesson Steps (continued)

Step four: Once students have completed their maze and filled in their data collection boxes, have them return to the table on page 3 of the work packet. Using their data and the table, the coordinates of their site will be revealed. There is an answer key for instructors on page 5 that reveals which site belongs to each maze. Note: Do not reveal the name of the site yet.

Step five: Students use the coordinates and page 4 to find their site on a global map of hydrothermal vents. By plotting the coordinates on this map, the site's name will be revealed.

Step six: Now that students know the name and coordinates of their site, they will use page 5 to learn about the deep-sea habitat found at that location.

Step seven: Allow students independent time to read pages 6-7 about the deep-sea animal that was collected during their dive.

Step eight: Students will complete page 8 by gathering information about their site from pages 5-7.

Step nine: Have students share their sites, animals, and fun facts in small groups or as a class.

11. Extensions

- a. View the [Deep Sea Equipment](#) video on the Born in the Abyss website to learn more from Alvin pilots and engineers about the technology and equipment that allows for deep-sea exploration. LINK
- b. View the [Diving in Alvin](#) video on the Born in the Abyss website to hear stories from pilots, engineers, scientists, and students about their deep-sea dives.
- c. Print and cut out the deep-sea animals on pages 6-7 of the work packet. Use a classroom map to plot the locations of all six sites together using the different animals as markers. Alternatively, students can use the NOAA bathymetry map (page 10) to plot the locations of all 6 sites and learn more about the features associated with hydrothermal vents and methane seeps.
- d. Students can compare the global distribution of hydrothermal vents from page 4 with the global distribution of methane seeps using the NOAA Methane Seep Map (page 9). Students should note that methane seeps are typically concentrated along continental margins and slopes rather than in deep-ocean basins. Students will observe that vents are found on the seafloor, primarily at mid-ocean ridges.
- e. Visit this [story map](#) to learn more about the deep-sea animals that live near methane seeps and the research conducted by marine biologists.
- f. Visit WHOI's interactive version of the [hydrothermal vent map](#).

[Next Generation Science Standards](https://www.nextgenscience.org/)

<https://www.nextgenscience.org/>

[Ocean Literacy Principles Handbook by NMEA/NOAA](https://www.marine-ed.org/ocean-literacy/overview#ocean-literacy-overview)

<https://www.marine-ed.org/ocean-literacy/overview#ocean-literacy-overview>

[Born in the Abyss Film Website](https://www.stephenlow.com/born-in-the-abyss/#larval-biology-basics)

<https://www.stephenlow.com/born-in-the-abyss/#larval-biology-basics>

[Deep-sea Research Story Map](https://storymaps.arcgis.com/stories/7aeb59bf68df4b8c94dff05c84aa1dd6)

<https://storymaps.arcgis.com/stories/7aeb59bf68df4b8c94dff05c84aa1dd6>

[WHOI Hydrothermal Vent Map](https://www.whoi.edu/ocean-learning-hub/multimedia/vents-around-the-world/)

<https://www.whoi.edu/ocean-learning-hub/multimedia/vents-around-the-world/>

[NOAA Methane Seep Map](https://oceanexplorer.noaa.gov/wp-content/uploads/2024/05/what-are-cold-seeps-fact-sheet.pdf)

<https://oceanexplorer.noaa.gov/wp-content/uploads/2024/05/what-are-cold-seeps-fact-sheet.pdf>

[NOAA Bathymetry Map](https://www.ngdc.noaa.gov/mgg/image/global_topo_large.gif)

https://www.ngdc.noaa.gov/mgg/image/global_topo_large.gif

[Yeti Crabs](https://oceanconservancy.org/blog/2020/12/18/curious-yeti-crab/)

<https://oceanconservancy.org/blog/2020/12/18/curious-yeti-crab/>

[Grenadier](https://www.mbari.org/animal/rattail-fish/)

<https://www.mbari.org/animal/rattail-fish/>

[Pompeii Worms](https://www.mbari.org/animal/pompeii-worm/)

<https://www.mbari.org/animal/pompeii-worm/>

[Scaly-foot Snails](https://www.marinebio.org/species/scaly-foot-snails/chrysomallon-squamiferum/)

<https://www.marinebio.org/species/scaly-foot-snails/chrysomallon-squamiferum/>

[Deep-Sea Brittle Stars](https://www.shapeoflife.org/news/featured-creature/2023/03/27/deep-sea-brittle-star)

<https://www.shapeoflife.org/news/featured-creature/2023/03/27/deep-sea-brittle-star>

[Deep-Sea Brachyuran Crabs](https://oceanexplorer.noaa.gov/multimedia/oceanos-explorations-ex1903-dailyupdate-s-july1-media-crab/)

<https://oceanexplorer.noaa.gov/multimedia/oceanos-explorations-ex1903-dailyupdate-s-july1-media-crab/>

[Tube worms](https://www.boem.gov/newsroom/ocean-science-news/tube-worms)

<https://www.boem.gov/newsroom/ocean-science-news/tube-worms>

[Born in the Abyss Deep Sea Equipment Video](https://youtu.be/BchtWodGDL4)

<https://youtu.be/BchtWodGDL4>

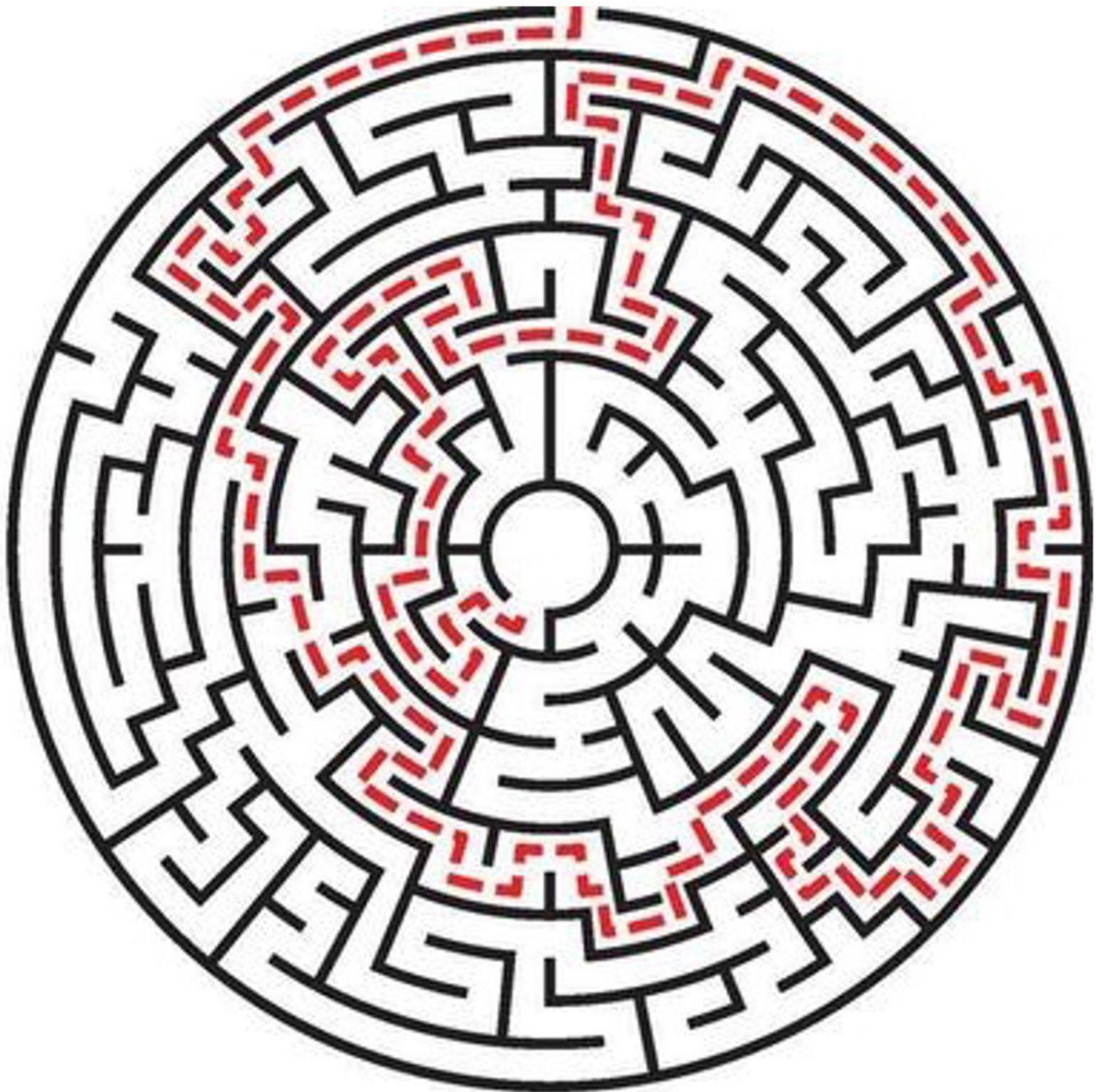
[Diving in Alvin video](https://youtu.be/TMMF3Jc4GoM)

<https://youtu.be/TMMF3Jc4GoM>

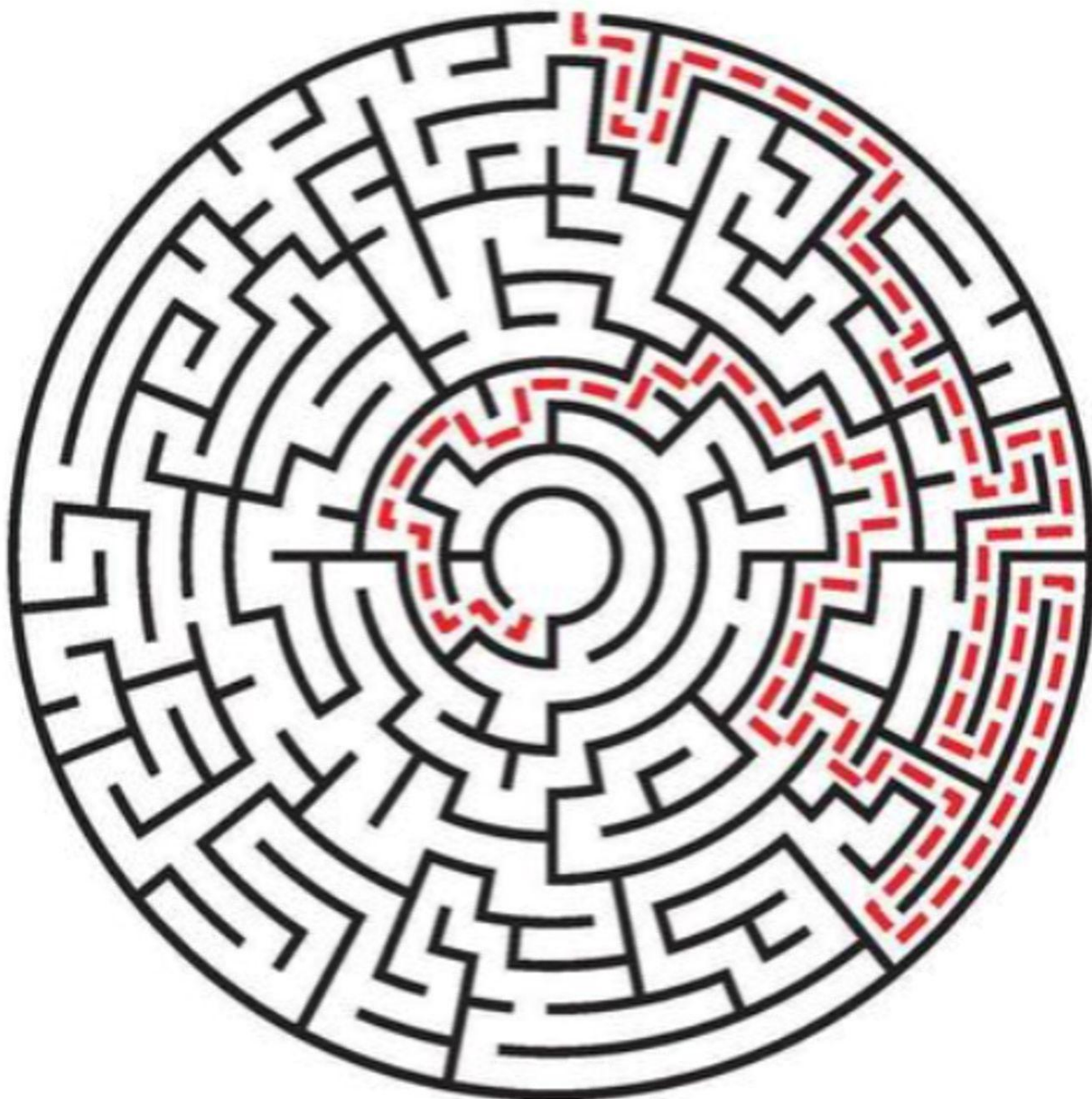
Answer Key for Instructors

Maze #	Temperature	Animal Collected	Materials Detected	Salinity (PSU)	Site Coordinates (longitude, latitude)	Site Name and habitat type
1	300 °C	Pompeii worms	Iron	40	(15° S, 110° W)	East Pacific Rise Hydrothermal Vent
2	21 °C	Tube worms	Methane	120	(28° N, 88° W)	Gulf of Mexico Brine Pool Methane Seep
3	10 °C	Shrimp	Manganese	36	(0°, 90° W)	Galapagos Rift Hydrothermal Vent
4	200 °C	Mussels	Hydrogen sulfide	36	(37° N, 32° W)	Lucky Strike Hydrothermal Vent
5	380 °C	Yeti crab	Iron	38	(60° S, 150° W)	Pacific Antarctic Ridge Hydrothermal Vent
6	90°C	Scaled snails	Methane	35	(25° S, 70° E)	Central Indian Ridge Hydrothermal Vent

**Solution #1
For Mazes
1,3,5**



Solution #2
For Mazes
2,4,6



Data Collection

Temperature:

Salinity (PSU):

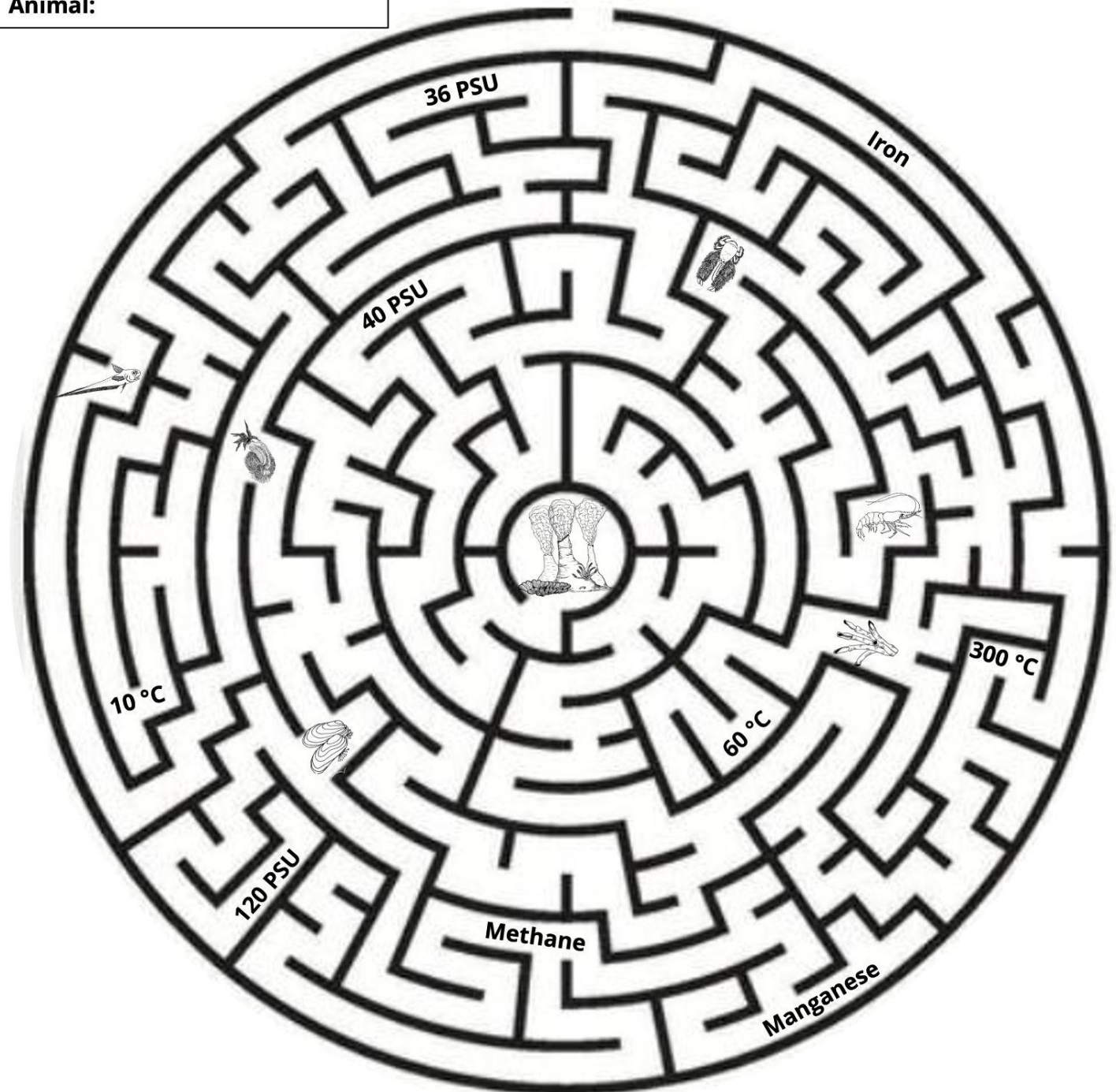
Material:

Animal:



START

Maze #1



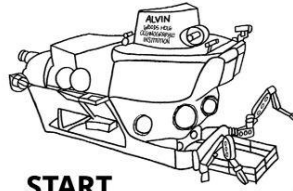
Data Collection

Temperature:

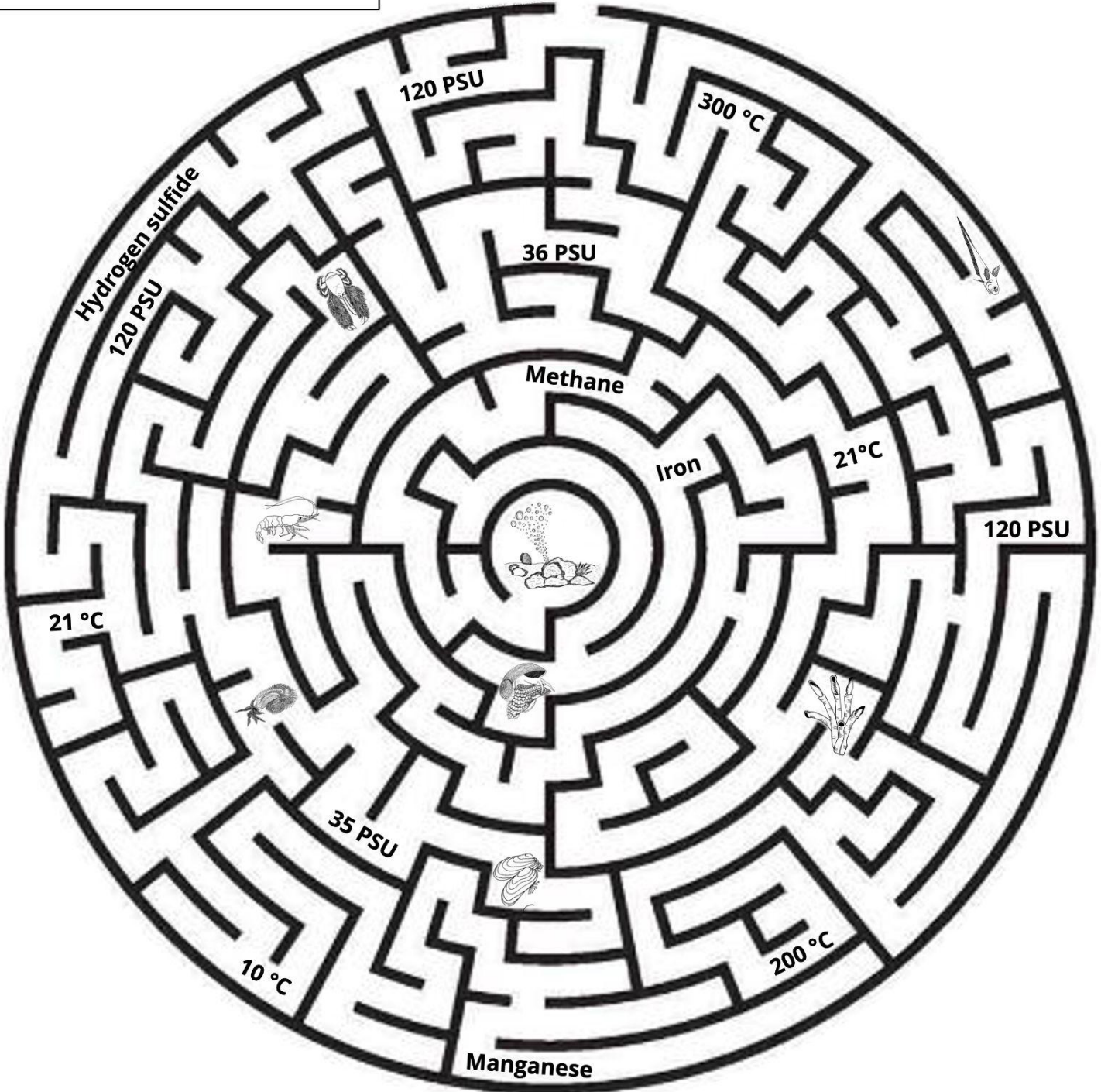
Salinity (PSU):

Material:

Animal:



START



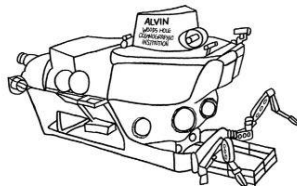
Data Collection

Temperature:

Salinity (PSU):

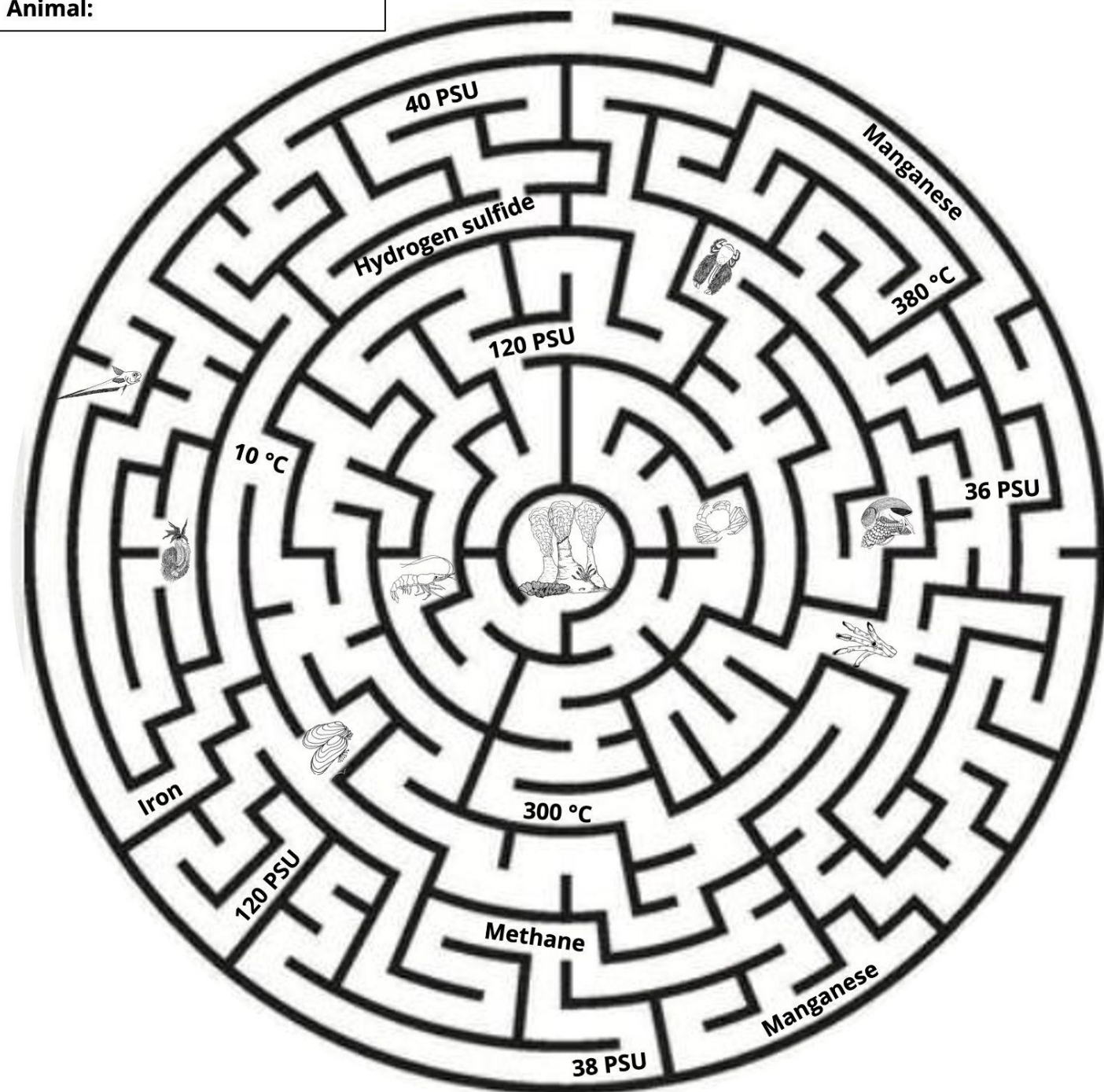
Material:

Animal:



START

Maze #3



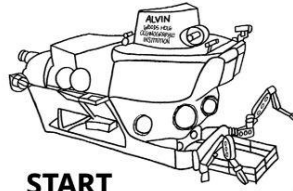
Data Collection

Temperature:

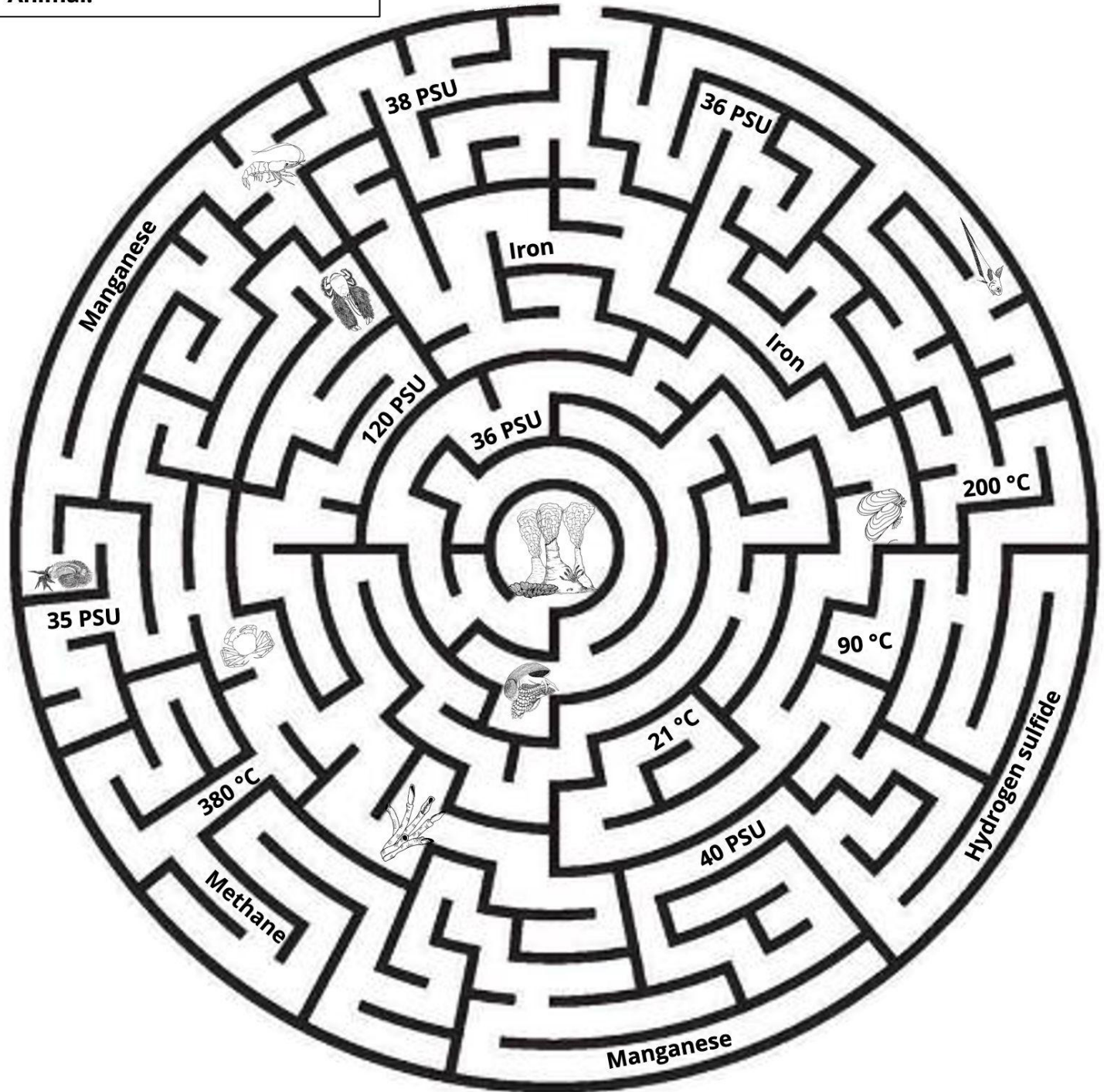
Salinity (PSU):

Material:

Animal:

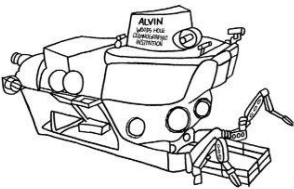


START



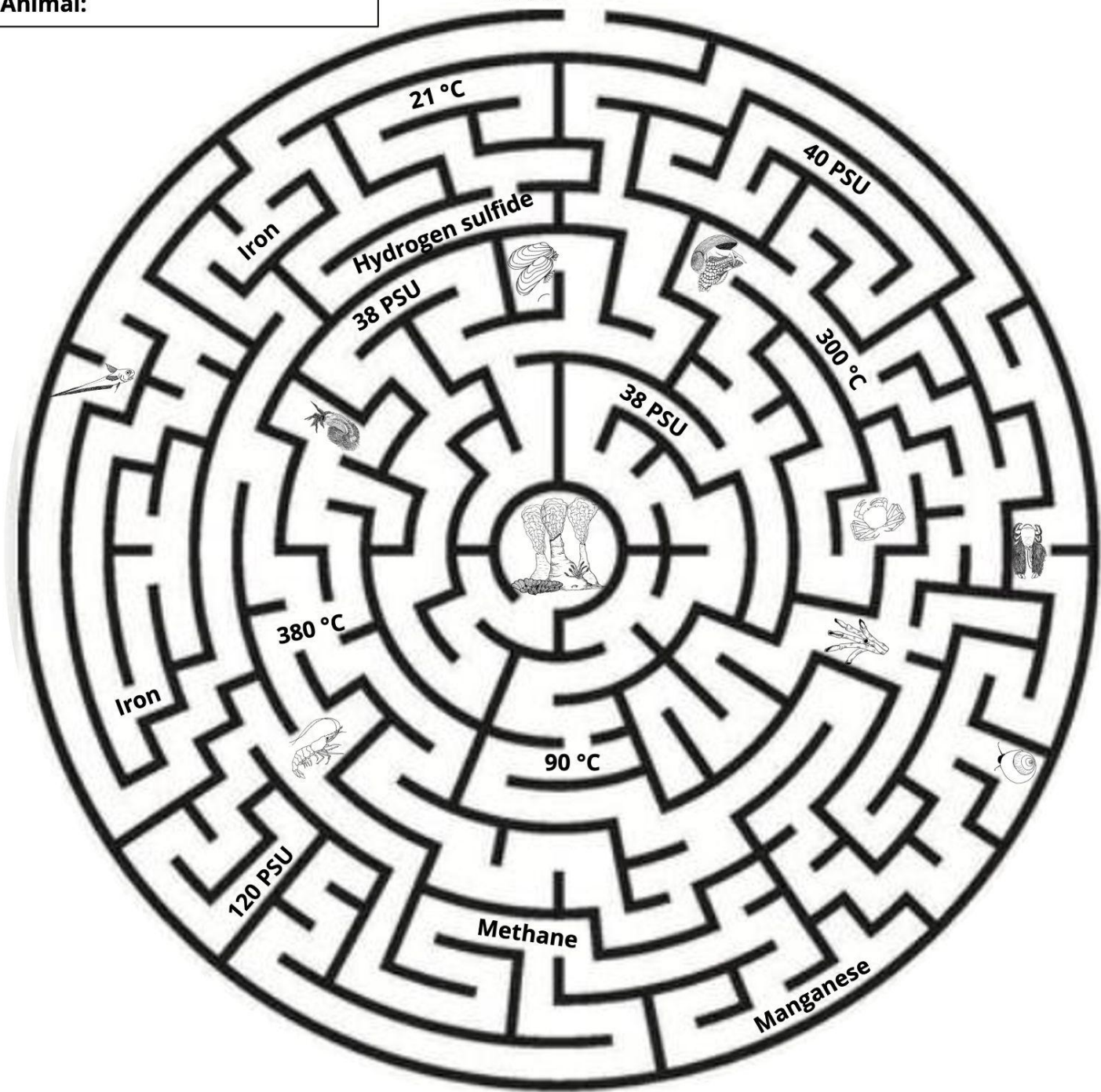
Data Collection

Temperature:
Salinity (PSU):
Material:
Animal:



START

Maze #5



Data Collection

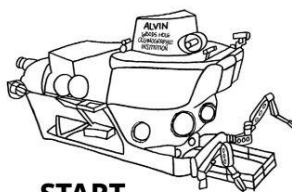
Temperature:

Salinity (PSU):

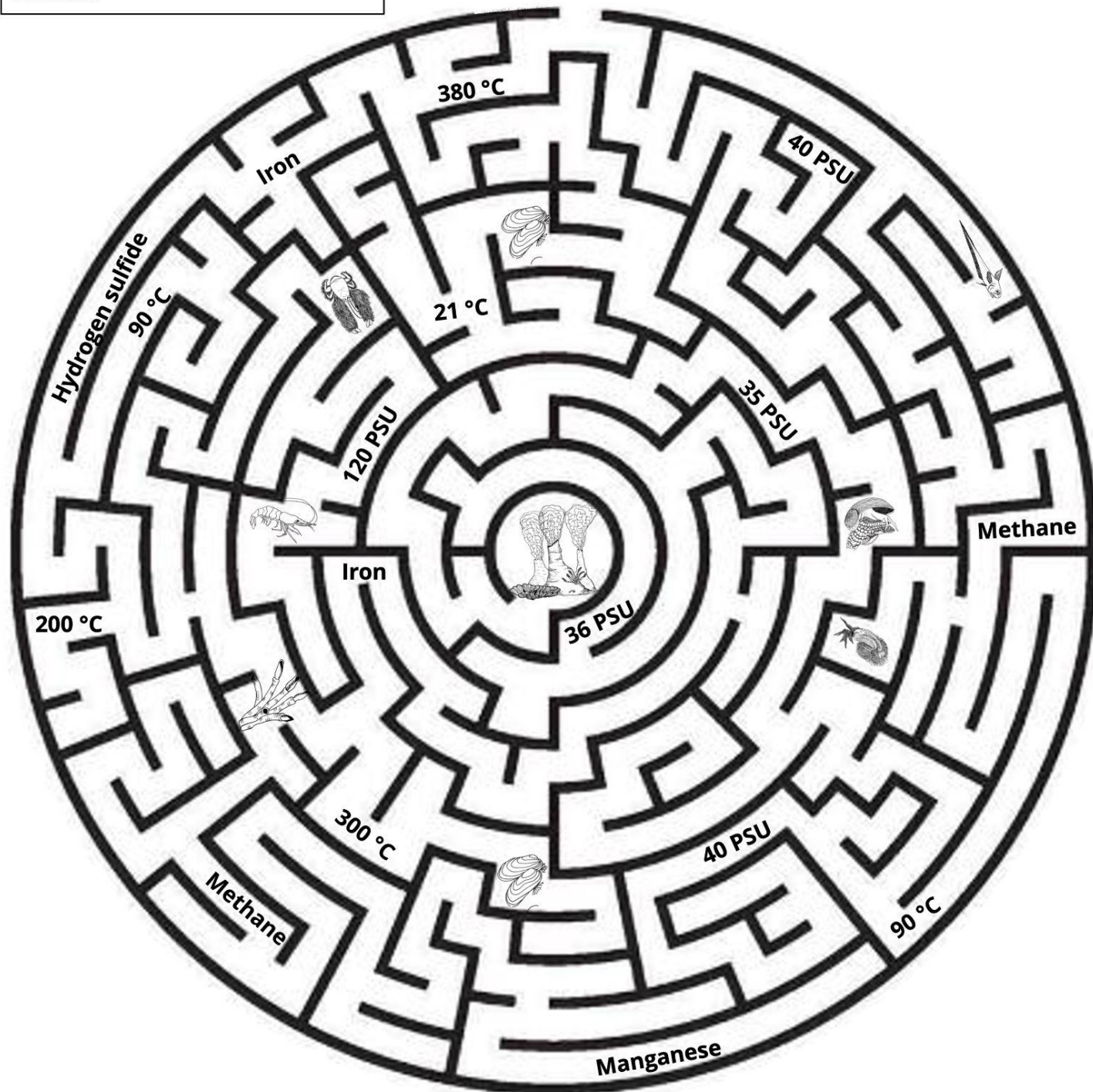
Material:

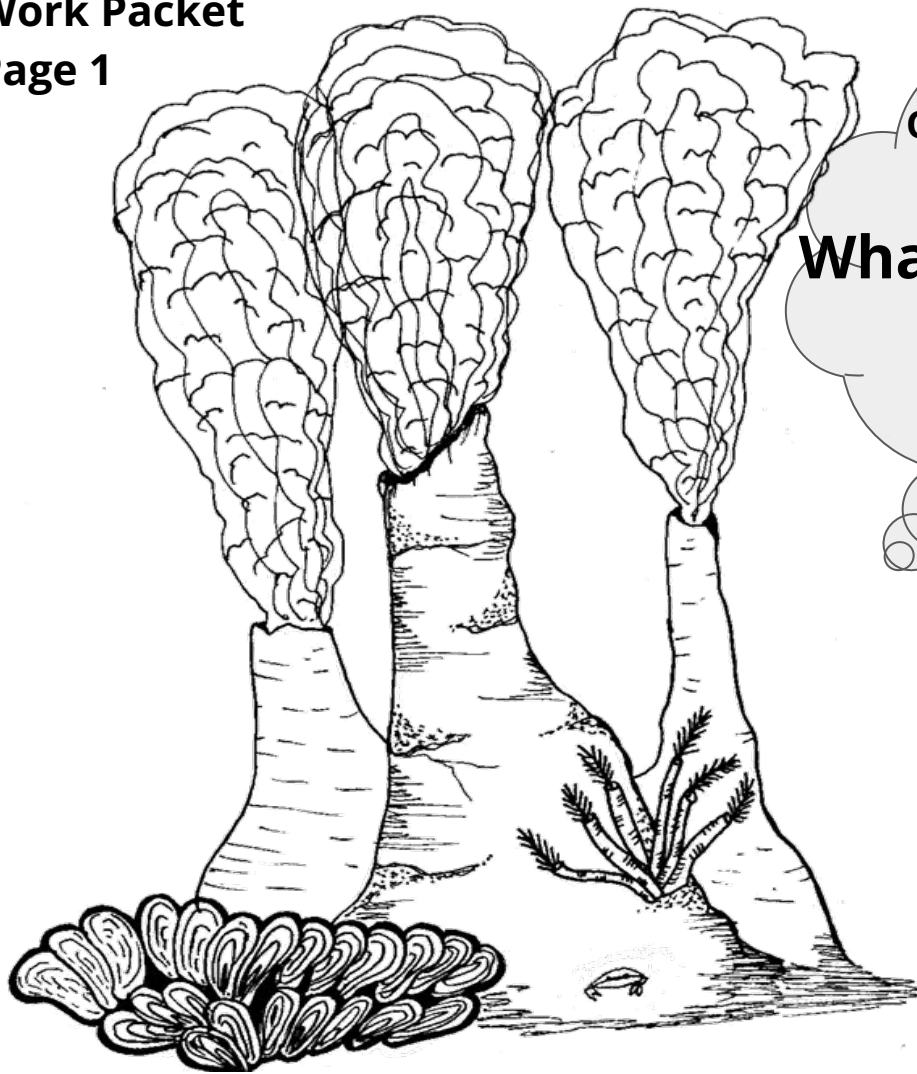
Animal:

Maze #6



START





Question:

What is a hydrothermal vent?

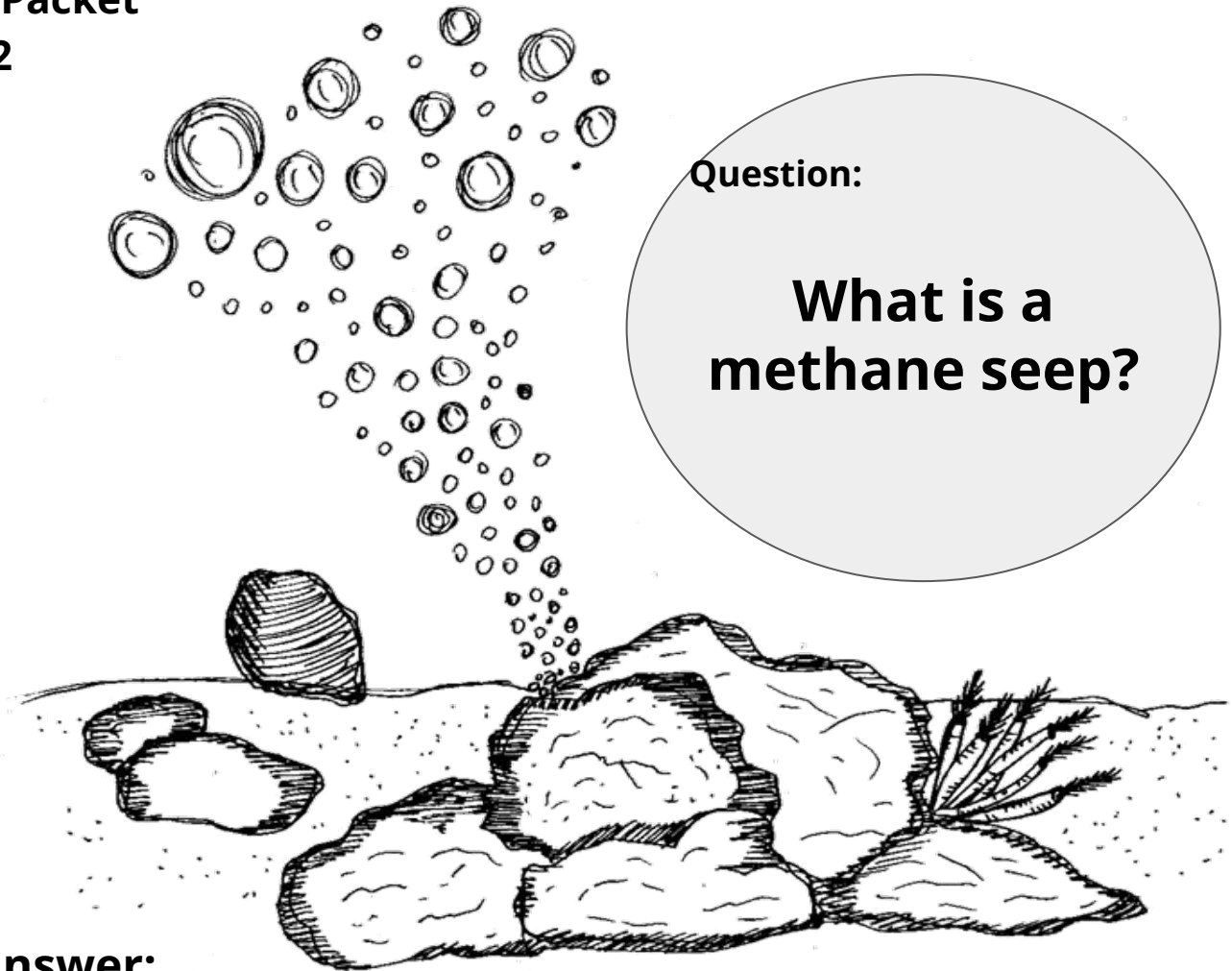
Answer:

Hydrothermal vents are like chimneys on the bottom of the ocean that are formed by volcanic activity and the movement of tectonic plates, resulting in vents that pump out fluids filled with minerals and chemicals.

A hydrothermal vent is formed when cold seawater sinks down through cracks in the ocean crust. These cracks are found near places with volcanic activity like spreading centers or subduction zones which are places on Earth where two tectonic plates move away or towards one another. In these areas, magma wells up to the surface or just below the seafloor. As ocean water moves down through cracks and porous rocks, the super-hot magma causes chemical reactions that remove oxygen, magnesium, sulfates, and other chemicals from the water. In the process, the fluids become hotter and more acidic, causing them to leach metals such as iron, zinc, copper, lead, and cobalt from the surrounding rocks. The heated fluids rise back to the surface through openings in the seafloor, known as hydrothermal vents. The fluid temperatures can reach 400°C (750°F) or more, but they do not boil under the extreme pressure of the deep ocean.

As they pour out of a vent, the fluids encounter cold, oxygenated seawater, causing temperatures to drop rapidly just inches away from the vent. This drop in temperature leads to a rapid series of chemical reactions. Sulfur and other solids precipitate—or come out of solution—to form metal-rich towers and deposits of minerals on the seafloor—some reaching over 30 feet tall! These minerals sometimes are visible in the gushing fluid, which is why some hydrothermal vents are called white or black “smokers.”

The hard structure of the vents and the chemicals in the vent fluid support a unique food web that survives without sunlight. In many hydrothermal vent communities, the ecosystem is based on bacteria that convert hydrogen sulfide and other chemicals in the vent fluids into sugar for energy. These “chemosynthetic” bacteria provide food for larger organisms such as tubeworms, shrimp, and mussels.

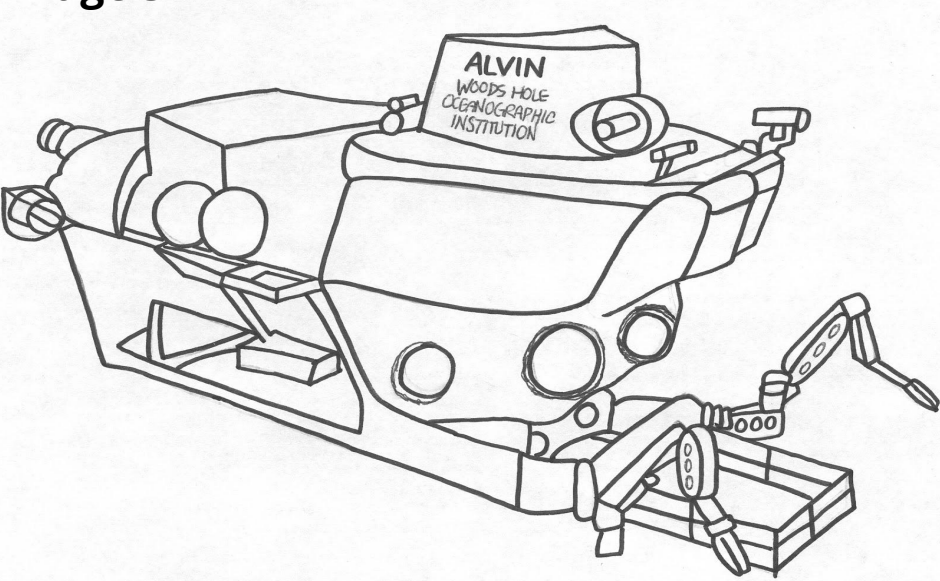
**Answer:**

A methane seep is a natural geological feature where methane gas escapes from the Earth's crust into the surrounding environment. Seeps are caused by the decomposition of organic matter deep within the Earth, which produces methane as a byproduct. Methane seeps appear as columns or streams of gas bubbles streaming upward out of the ocean floor.

In contrast to hydrothermal vents, methane seeps are known for the relatively low temperature of the hydrocarbon-rich fluids (methane, hydrogen sulfide) that ooze from the seabed which match the surrounding deep-sea water, and they are even called "cold seeps". They are termed "seeps" because the materials ooze slowly through cracks, rather than erupting violently. Methane seeps also support specialized communities, including mussels, clams, and tubeworms, that rely on chemosynthetic bacteria that can use methane to make food.

Work Packet

Page 3



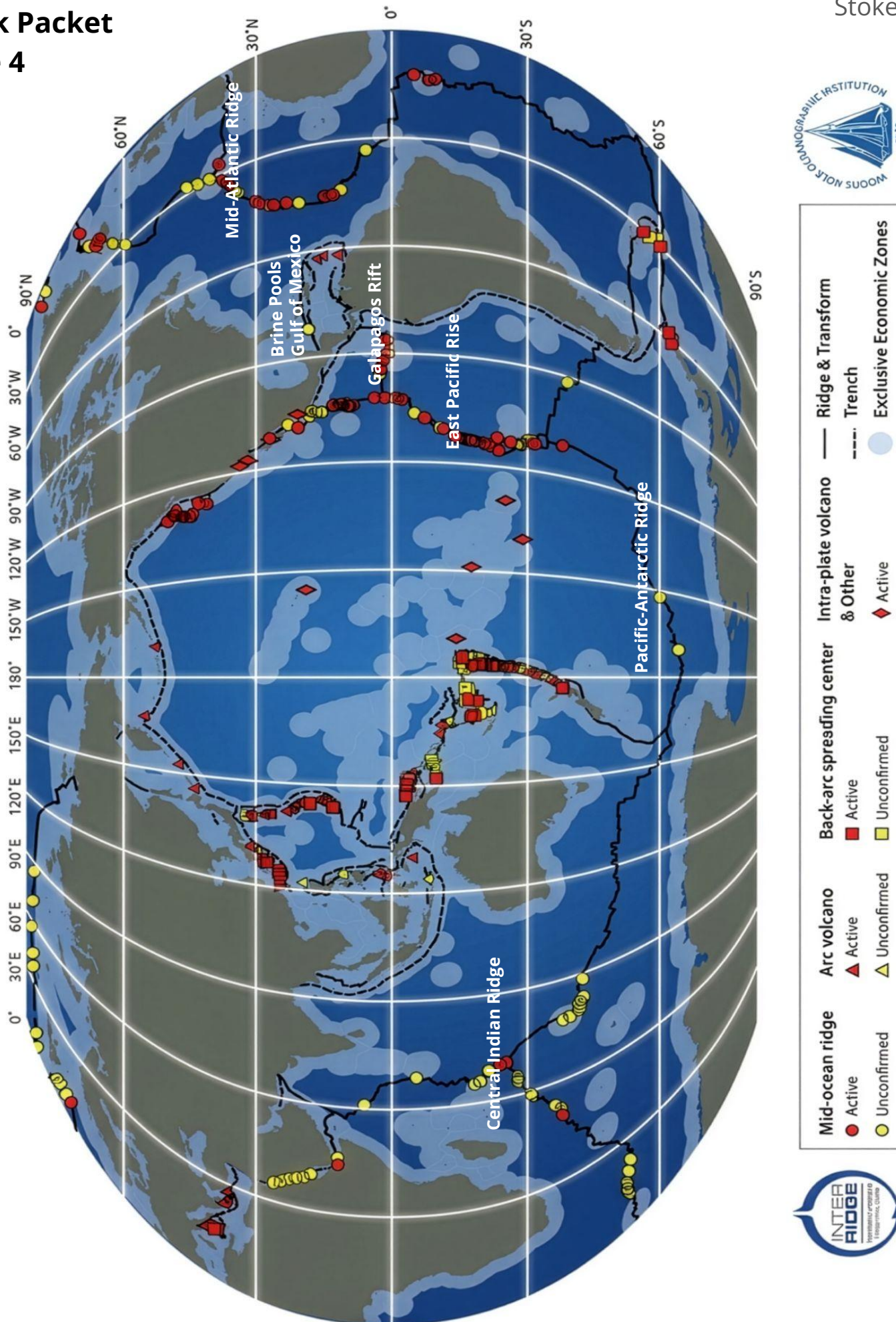
You are now the pilot of the Alvin submersible. As you descend to the bottom of the ocean and explore the seafloor by completing your maze, you will collect data. Be sure to note only the data that your pencil crosses on the correct path to the habitat at the center of the maze.

Once you reach the center of the maze, you’ve reached your site. Use the data table below and the data you collected while working on your dive maze to reveal the exact coordinates for the deep-sea site you’ve discovered while on your Alvin dive.

Temperature	Animal Collected	Materials Detected	Salinity (PSU)	Site Coordinates (longitude, latitude)
300 °C (572°F)	Pompeii worms	Iron	40	(15° S, 110° W)
21 °C (69.8°F)	Tube worms	Methane	120	(28° N, 88° W)
10 °C (50°F)	Shrimp	Manganese	36	(0°, 90° W)
200 °C (392°F)	Mussels	Hydrogen sulfide	36	(37° N, 32° W)
380 °C (716°F)	Yeti crab	Iron	38	(60° S, 150° W)
90°C (194°F)	Scaly-foot snails	Methane	35	(25° S, 70° E)

Use the coordinates from the table to find your site on the map of hydrothermal vents on page 2. Once you’ve found your site on the map, use the coordinates to learn more about your site on page 3.

Global Distribution of Hydrothermal Vent Fields



Mazes, Maps, and Magnificent Animals in the Deep Sea

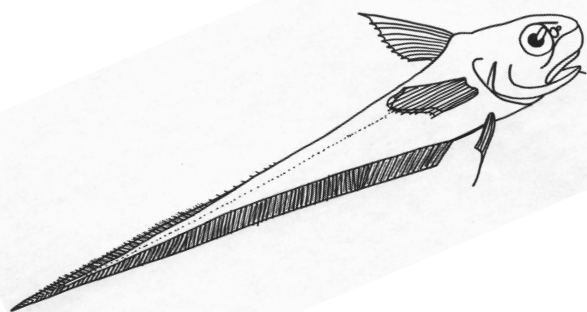
Work Packet Page 5

4th Grade
Stoker

Site	Site Description
Central Indian Ridge	There are multiple hydrothermal vent fields on the Central Indian Ridge. The vents pump out fluids that are rich in hydrogen and methane due to chemical reactions with rocks that have a lot of magnesium and iron. These vent communities support deep-sea shrimp and snails including the unique scaly-foot snail. Some vent chimneys are up to 78 feet tall. The first hydrothermal vent in this region was discovered in 2000.
Lucky Strike (Mid-Atlantic Ridge)	The Lucky Strike hydrothermal vent field is a large, active system made mostly of basalt rock, located on a submarine volcano. The vent communities at Lucky Strike are covered with large mussel beds that support over 79 species. The first active vent at this site was discovered in 1992 by accident with the Alvin submersible during a deep-sea rock sampling mission.
Pacific Antarctic Ridge	The vent communities in this region support mussels, clams, and snails as well as the unique yeti crab. Because it is near the Southern Circumpolar current, this region allows scientists to study connections between Pacific and Atlantic vent communities. The first active vent in this region was discovered in 2010.
Galapagos Rift	The hydrothermal vents found at the Galapagos rift were the first active vents discovered. They were found in 1977, with the deep-sea submersible Alvin. This discovery helped scientists understand chemosynthesis. Vents at this site pump out mineral-enriched water that is up to 752°F (400°C). This site is known for giant tube worms that grow over 6.5 feet tall as well as large mussels and clams.
Brine Pools Gulf of Mexico	A brine pool is a “lake” on the bottom of the ocean filled by water that is 3-8 times saltier and therefore denser (heavier) than the surrounding seawater. The high density creates a distinct surface with shorelines and waves as the brine pool water does not mix with the surrounding ocean, but settles into low spots on the seafloor. These pools form when methane seeps are near ancient salt deposits. There is no oxygen in the brine pools so nothing lives in them, but mussels and tubeworms surround the pools.
East Pacific Rise	The East Pacific Rise hydrothermal vents are along one of the fastest-spreading tectonic plate boundaries on the planet. This spreading leads to volcanic activity on the seafloor. The vents here pump out mineral-rich water at over 752°F (400°C) that looks like black smoke. They were discovered in 1979 by scientists in the Alvin submersible. Communities near hydrothermal vents in this region feature giant tube worms, mussels, and clams.

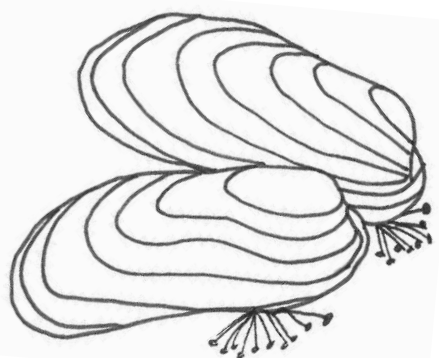
Common Deep-sea Animals

These animals are abundant in the deep sea. While they may resemble animals that are found in shallower water, they each have unique adaptations that allow them to survive in the deep sea where there is high pressure and no sunlight.



Grenadiers

These common deep-sea fish are dominant predators near hydrothermal vent and methane seep communities. They eat octopuses and other fish. Grenadiers travel between vent and seep sites and the surrounding deep ocean floor in search of prey. These slow-growing, long-lived fish live in darkness. They have large eyes to detect bioluminescent prey, sensitive barbels (whiskers) on their chins for tasting/feeling food on the bottom, and a lateral line system to feel vibrations in the water.



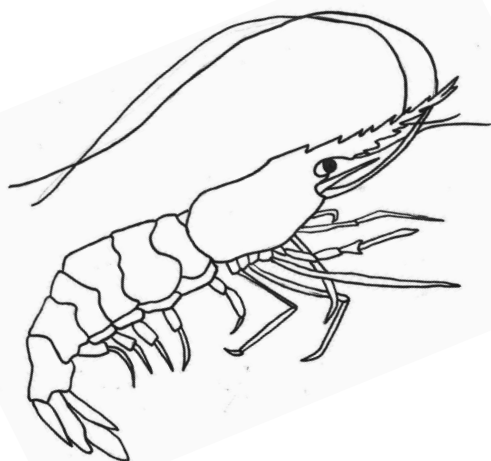
Bathymodiolus mussels

These deep-sea mussels are famous for their relationship with chemosynthetic bacteria that give them the energy and nutrition they need to survive. The bacteria live in the gills of the mussels and turn chemicals from vents and seeps into the energy that keeps the mussels alive. This symbiosis is a very important adaptation in the dark, deep sea where food can be hard to find. Mussels are important because they provide hard surfaces for other animals to live on.



Tube worms

Tube worms are commonly found living in clusters near hydrothermal vents and methane seeps. These animals host symbiotic, chemosynthetic bacteria that live inside the worms. Lacking a mouth and a gut, these worms rely on the bacteria for all of their food. In turn, the worms provide protection for the bacteria. The bacteria turn the chemicals into nutrients, allowing some tubeworms to grow up to six feet tall or live up to 1,000 years.



Shrimp

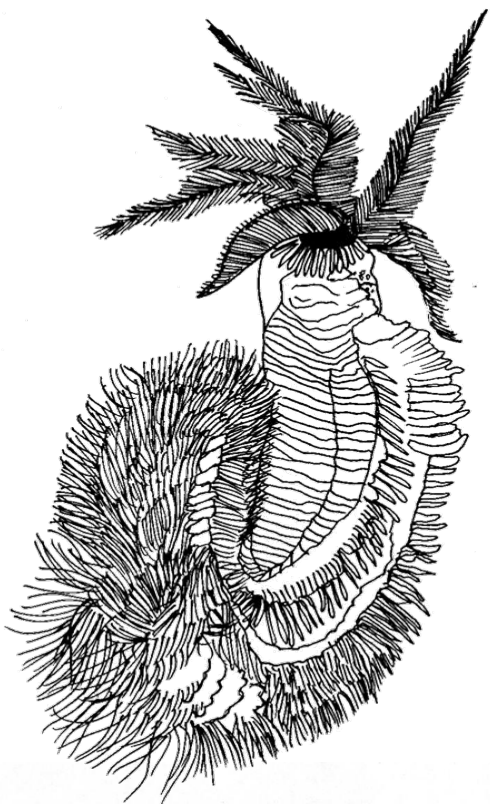
Deep-sea shrimp are abundant at hydrothermal vent ecosystems in the Atlantic and Indian Oceans. In some places, there are over 300 shrimp per square foot. These shrimp host chemosynthetic bacteria in their mouths and gill covers. The shrimp give the bacteria a home while the bacteria provide the nutrients the shrimp need. Many vent shrimp are blind but have a light-sensitive area on the top of their heads that detects the faint glow from hydrothermal vents, which helps them move through the darkness without entering dangerously hot water.

Less Common Deep-sea Animals

While found in the deep sea, these animals are limited to a few locations. They each exhibit unique adaptations that allow them to survive in the deep sea where there is high pressure and no sunlight.

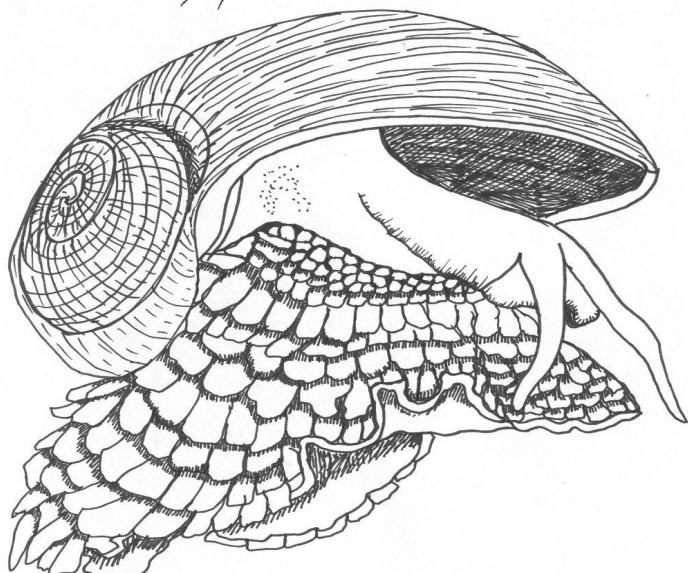
Pompeii worm (*Alvinella pompejana*)

The pompeii worm is one of the most heat-tolerant animals on the planet. These worms live in tubes on hydrothermal vent chimneys in the Pacific ocean, surviving temperatures up to 176°F (80°C). They position their tails in this hot water while their heads stay in cooler water (71°F or 21°C), inches away. They are protected by a layer of bacteria that can be up to 1/2 inch (1cm) thick. The bacteria feed on the mucus secreted by the worm and act as an insulation layer that protects the worm's head from extreme heat. These worms also survive by eating the bacteria that grow on their bodies. These animals were named after the ancient Roman city of Pompeii that was buried in ash from a large volcanic eruption.



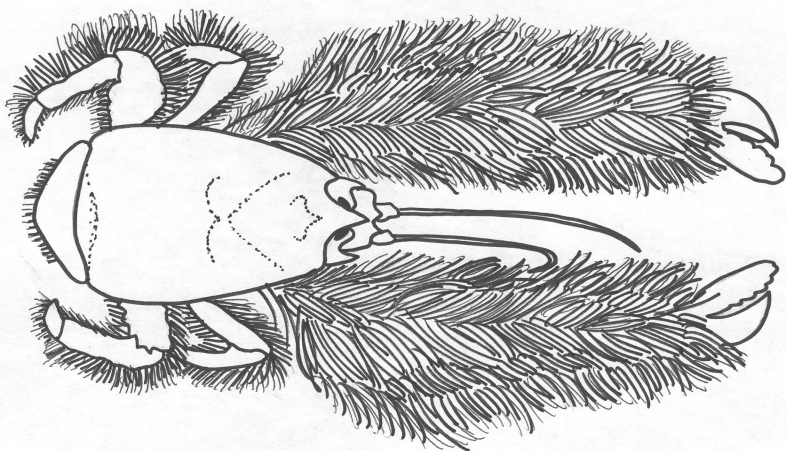
Scaly-foot snail (*Chrysomallon squamiferum*)

The scaly-foot snail is the only known animal to incorporate iron sulfide into hard parts of its body including its shell. It also uses iron sulfide to create a metallic armor of overlapping scales on its foot. These snails do not eat but rely on symbiotic, chemosynthetic bacteria in their esophagus. The snails provide protection and the bacteria provide nutrients for the snails. The snails have one of the largest hearts compared to their body size in the animal kingdom (4% of their body mass) to provide oxygen to their bacteria.



Yeti crab (*Kiwa tyleri*)

Yeti crabs were first discovered in 2005 near hydrothermal vents in the Pacific. These crustaceans are roughly 6 inches long and are known for their "furry" claws that are covered in bacteria-trapping bristles called setae. These setae allow the yeti crabs to "farm" the bacteria, cultivating colonies of bacteria on their own arms to eat later. They have even been noticed by scientists to "dance"—wave their arms to stimulate bacterial growth. These crabs are blind and white. Their white, hairy look gives them their yeti name.



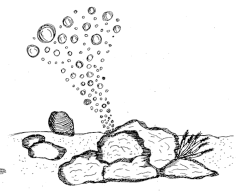
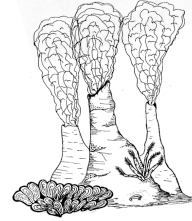
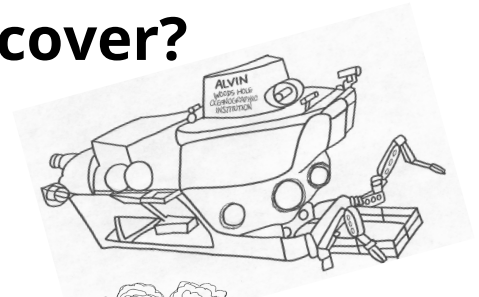
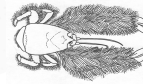
Alvin Dive: What did you discover?

Site Name:

Coordinates:

Site Type:

Animals Found:



Write three facts you learned about the deep-sea habitat you discovered or the animal you encountered on your dive using complete sentences.

1.

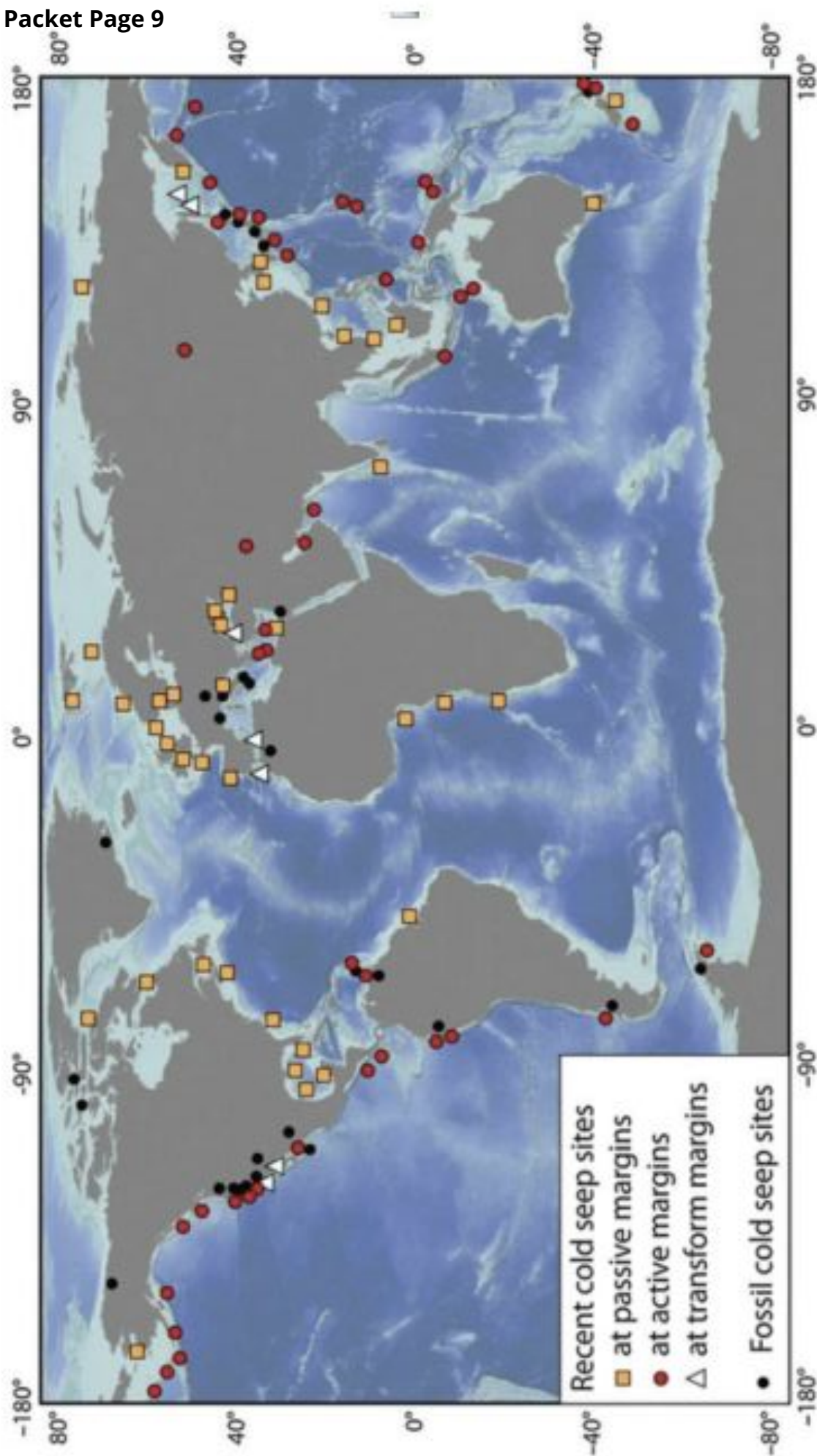
2.

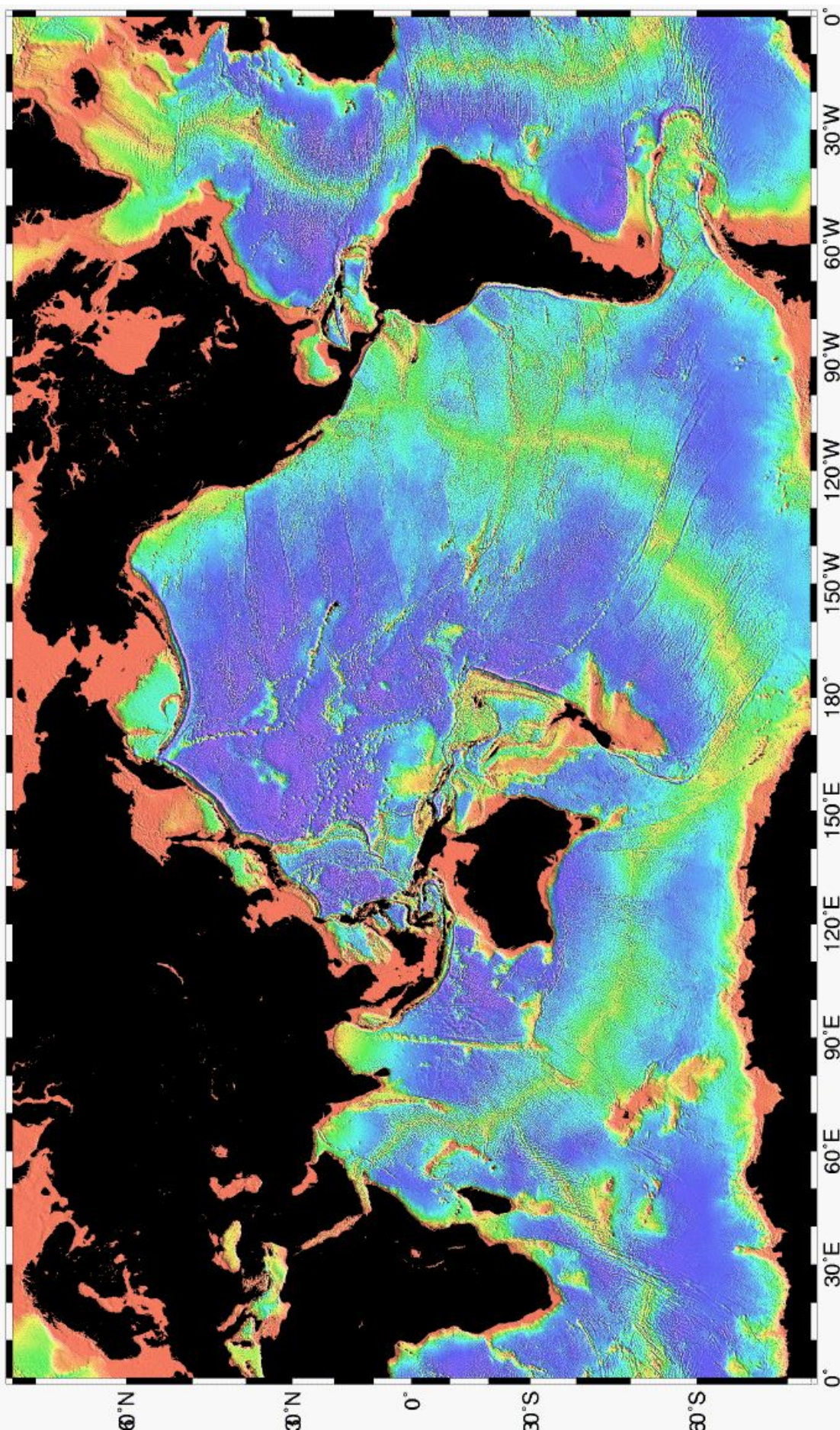
3.

Mazes, Maps, and Magnificent Animals in the Deep Sea

Work Packet Page 9

4th Grade
Stoker





LEGEND:
land = black
continental shelves and oceanic plateaus = red
mid-ocean ridges = yellow-green
abyssal plains = blue to purple