Unit: Oceans of Energy
Lesson 5: Feeding the Deep

Summary: The sun provides the energy for the surface ocean ecosystem, but how does life in the deep ocean survive? This lesson exposes students to the deep ocean environment and the life seen in abyssal plains, whale falls, and hydrothermal vents.

Lesson type:	Discussion
Grade level:	Presented to grade 4; appropriate for grades 2 – 12 with age appropriate modifications
Duration of lesson:	50 min
Developed by:	Jonathan Kellogg (Scientist); Catherine Barber and Carel Wilkin (Teachers)
Developed for:	Sir William Van Horne
School Year:	*2015-2016*
Notes:	• This lesson requires an internet connection or saved publically available videos.

Objectives

- Students should understand that the deep ocean is a vast and diverse environment that is largely unexplored.
- Students should comprehend that very little organic material from the surface sinks all the way to the deep ocean.
- Students should be able to identify two main sources of energy in the deep ocean, whale falls and hydrothermal vent systems.

Materials

- Video: How Deep is the Ocean: https://www.youtube.com/watch?v=Vd69Ot55POg
- Map of global topography/bathymetry (http://topex.ucsd.edu/WWW_html/mar_topo.html or http://topex.ucsd.edu/marine_topo/text/topo.html)
- Video: Deep Ocean Creatures: http://oceantoday.noaa.gov/deepoceancreatures/
- Diagram of marine carbon cycle: http://serc.carleton.edu/eslabs/carbon/6a.html
- Video: Life inside a dead whale: https://www.youtube.com/watch?v=cYbAwulg5zw
- Video: Caged pig forensic experiment in the ocean: https://www.youtube.com/watch?v=xXtSw1FPkhM

- Video: Shy octopus hides inside its own tentacles | Nautilus Live https://www.youtube.com/watch?v=pxuBwfNp2wk
- Hydrothermal vent location map: https://www.interridge.org/irvents/maps
- Video: Gigantic Elaborate Hydrothermal Vents off British Columbia | Nautilus Live: https://www.youtube.com/watch?v=mOtcpa4Ego4
- Video: Giant Tube Worms of the Galapagos | Nautilus Live: https://www.youtube.com/watch?v=QffkyLYB_PA
- Chemosynthetic Food Web: http://oceanexplorer.noaa.gov/edu/learning/5_chemosynthesis/activities/hydrothermal.html#activity

Background Information for the Teacher

Deep ocean communities are very poorly understood, but more is being learned about these fascinating environments every year. With the average depth of the global ocean right around 4000 m, and 1000 m being the maximum depth to which light can penetrate, the vast majority of the ocean is inaccessible to the sun's energy. As a result, animals in the deep ocean have only a few sources of food.

Many younger students lack understanding that the ocean is both deep and has topography. It is useful to remind them that the seafloor is not flat, but rather broken up by mid ocean ridges which form the longest mountain chain on the planet (and can be imagined as though they are seams on a baseball). With most scientific dives to the deep ocean discovering new species, we are learning about this environment all the time.

While energy from the sun is abundant in the surface ocean, bacteria and other scavengers are excellent at utilizing the waste products and decaying matter that is sinking. Therefore, only about 10% of the energy that is made in the surface ocean (0-100 m) sinks all the way to the twilight zone (100-1000 m). Only about 10% of this material, or 1% of the original, makes it from the twilight zone into the deep ocean (1000-4000 m). Last, only about 10% of this sinking material, or 0.1% of the original, makes it to the seafloor. This transfer of carbon through different zones of the ocean is called the biological pump.

One way that energy from the sun can quickly sink to the deep ocean is in the event of a whale fall. A whale carcass has enough mass to quickly sink out of the surface ocean and arrives on the seafloor with large amounts of useful material that are utilized by numerous seafloor organisms. An experiment to investigate how material is consumed by marine life has been conducted by Ocean Networks Canada where they have sunk pig carcasses to the seabed of the Strait of Georgia and then recorded the life that responded to its presence until there was no material remaining. Data from this experiment proved valuable when many shoes washed ashore around the Salish Sea in recent years with feet still in them. Scientists were able to say that this was likely natural disarticulation and was not caused by foul play.

The other major source of energy in the deep ocean are hydrothermal vent systems. These systems occur at mid ocean ridges where the magma, that would eventually become new seafloor, forces fractures in the seafloor. Seawater percolates down through these fractures, is heated by the magma chamber, and because it is hotter than the surroundings, rises up the

seafloor where it meets the ocean between 300-400 °C. Along its journey, the seawater dissolves minerals from the rock so that when it reaches the seafloor it is rich with chemicals, many of which would be toxic to humans, but are vital to sustaining life for chemosynthetic bacteria. Vent systems are thought to exist every few kilometers along the entire mid ocean ridge, however few have been discovered in the southern ocean. However, that is principally a result of not looking for them rather than the lack of presence.

Vent communities are very diverse, but they all start with chemosynthetic bacteria that are either free living or symbiotic in the gut of other organisms. These bacteria are capable of taking the chemicals from the vent fluids and converting it to usable organic matter. From this point, all other life is dependent on the presence of these bacteria. See the references to explore the foodweb organisms in greater depth.

While vent systems are spatially only a small fraction of the seafloor, it is estimated that chemosynthetic organisms at vents and seeps make roughly equal amounts of organic matter compared to that which sinks from the surface.

Vocabulary

- Whale fall – location of a deceased whale that sank from the surface ocean to seafloor
- Euphotic Zone – Zone of the ocean where light penetrates. Typically comprised of both the surface ocean and the twilight zone (~0-1000 m)
- Chemosynthesis – biological process by which inorganic molecules are converted to organic molecules using the oxidation of hydrogen, or hydrogen sulfide, gas instead of sunlight.

Lesson Detail

1. Engage students by asking them what they know about the deep ocean. How deep is it? Is it flat or does it change? Does anything live in the deep ocean?
2. Proceed through videos and narrate videos with additional information that can be found on Nautilus Live, Ocean Networks Canada, or the Okeanos Explorer pages.
3. When describing the marine carbon cycle, or biological pump, an idea to describe it is to ask all students to stand up and form a narrow line at one end of the classroom. They collectively represent all the energy present in the surface ocean. Choose two students to ‘sink’ from the surface ocean into the twilight zone and have them separate from the class. They represent all the energy that has sunk to that depth. Now, have one student sit on a table and kick their legs, where the lower part of their leg below the knee has all the mass that sinks out of the twilight zone into the deep ocean. Have the student sitting on the table take off their shoe and take their shoe to end of the classroom away from the rest of the students. If the mass of all the students together is the energy produced in the surface ocean, then the mass of the one shoe at the far end of the classroom is approximately how much energy would make it all the way to the seafloor.
4. Also, many oceanographic research cruises occur throughout the year and stream live video from the ROV to the internet. The NOAA Okeanos Explorer, Nautilus Live, and the Schmidt Ocean Institute are regularly streaming live video from the seafloor and have scientists commenting and explaining their observations.

5. If you would like to do a craft, it is possible to make your own hydrothermal vent tubeworm using clear plastic straws, red pipe cleaner, red feathers, and glitter glue.
    a. Cut the straws into 2" lengths, pipe cleaners into 4" lengths, and red feathers so they are no more than 1-1.5" long.
    b. Fold pipe cleaner in half and use ends to wrap and attach to feather.
    c. Apply glitter glue in a ribbon along the middle of the pipe cleaners to represent the bacteria in the gut of the tubeworms.
    d. Assemble the tubeworm by sliding the straw over the non-feather end of the pipe cleaner and students can see the "bacteria" inside.
6. Explain that hydrothermal vent tubeworms are fascinating for scientists because they can are large (up to 1.5-2 m long and ~10-15 cm diameter) and they have symbiotic bacteria that live in their gut creating food for their host. Yet, while these animals have been known about for 40 years, scientists still do not know how the bacteria get into the gut since the tubeworm has no mouth and no anus. For more about tubeworm biology, search "Riftia tubeworm biology" online.

Closure Discussion

Examples of questions to help students share their results and observations…

1. Approximately how much energy from the deep ocean is generated locally versus originating from the sun? A: ~50%. Remember that whales originally get their energy from the sun.
2. Remind students that there is still much to learn about deep ocean environments and that expeditions to these locations occur all the time.

References

<http://oceanexplorer.noaa.gov/edu/learning/5_chemosynthesis/activities/hydrothermal.html#activity> Chemosynthetic Food Web. Website hosted by NOAA Ocean Explorer (Accessed 21 April 2016)

<http://oceanexplorer.noaa.gov/explorations/06fire/background/edu/media/ROF06.LivingHeat.pdf> Living with the Heat. Website hosted by NOAA Ocean Explorer (Accessed 21 April 2016)

<http://www.ridge2000.org/SEAS/for_students/cts_mussel_lab1.html> Classroom-to-sea mussel lab. Website hosted by RIDGE2000.org (Accessed 21 April 2016)

<http://www.coexploration.org/C-DEBI/17_4/Hydrothermal_vent_instructor_version.pdf> Hydrothermal Vent Lesson Plan: Educators. Website hosted by College of Exploration (Accessed 21 April 2016)

<http://www.nautiluslive.org/> Nautilus Live (Accessed 21 April 2016)

<http://oceanexplorer.noaa.gov/okeanos/welcome.html>NOAA Okeanos Explorer (Accessed 21 April 2016)

<http://www.oceannetworks.ca/> Ocean Networks Canada (Accessed 21 April 2016)

<http://www.divediscover.whoi.edu/teachers-activities.html> Dive and Discover: Expeditions to the Seafloor Classroom Activities. Website hosted by Woods Hole Oceanographic Institute (Accessed 21 April 2016)