Beyond Sunlight:
An Aquatic Chemosynthetic World

- **Abstract**

Chemosynthetic communities in the deep-sea can be found at hydrothermal vents, cold seeps, whale falls and wood falls. While these communities have been suggested to exist in isolation from solar energy, much of the life associated with them relies either directly or indirectly on photosynthesis in the surface waters of the oceans. The sun indirectly provides oxygen, a byproduct of photosynthesis, which aerobic chemosynthetic microorganisms require to synthesize organic carbon from CO2 . Planktonic life stages of many vent and cold seep invertebrates also directly feed on photosynthetically produced organic matter as they disperse to new vent and seep systems. While a large portion of the life at deep-sea chemosynthetic habitats can be linked to the sun and so could not survive without it, a small portion of anaerobically chemosynthetic microorganisms can persist in its absence. These small and exotic organisms have developed a way of life in the deep-sea which involves the use of resources originating in their entirety from terrestrial sources.

1 Introduction

- The Earth’s surface is dominated by organisms which depend on energy captured from the sun through the process of photosynthesis, either as primary producers or heterotrophic consumers. Until the discovery of chemosynthesis in 1887 by Winogradsky, alternatives to light energy for the production of organic carbon remained unknown to science.

Surprisingly, even after the process of chemosynthesis was observed, it was widely thought to be relatively insignificant as a mechanism of primary production (Van Dover, 2000). With the discovery of deep-sea hydrothermal vent systems in 1977 (Corliss et al., 1979), it became clear that chemosynthetic microorganisms were not only present in the deep sea where light energy from the sun is absent, but that they supported large communities and assemblages of higher organisms. Hydrothermal vent, whale fall, wood fall, and cold seep communities are able to make use of the chemical energy found in elements such as sulphide and methane.

- Much of the energy provided by photosynthetic primary production in the surface waters, on which most other deep-water organisms depend, is exploited before it can make its way into the depths, leaving only about 1–20 % to sink past a depth of 1000 m where the last of the sun's light rays can still be detected.

- In a paper on the geomicrobiology of deep sea hydrothermal vents, Jannasch and Mottl (1985) suggest that it was this "dependence of entire ecosystems on geothermal (terrestrial) rather than solar energy" that made the discovery of the vent systems and other chemosynthetic communities in the deep sea so groundbreaking, prompting new theories into the origins of life (Wachtersh ¨ auser, 1988) and on the prospects of life on other planets in ¨ our own solar system (Van Dover, 2000). But is it true? Do chemosynthetic communities thousands of meters below the last rays of sunlight really exist in complete isolation from the influence of the sun? Could such communities persist if the sun were to be removed from the equation altogether? In answering these questions we must first examine the chemical processes involved in chemosynthesis as well as the structure of the organisms and communities which rely on it.

2. Discussions

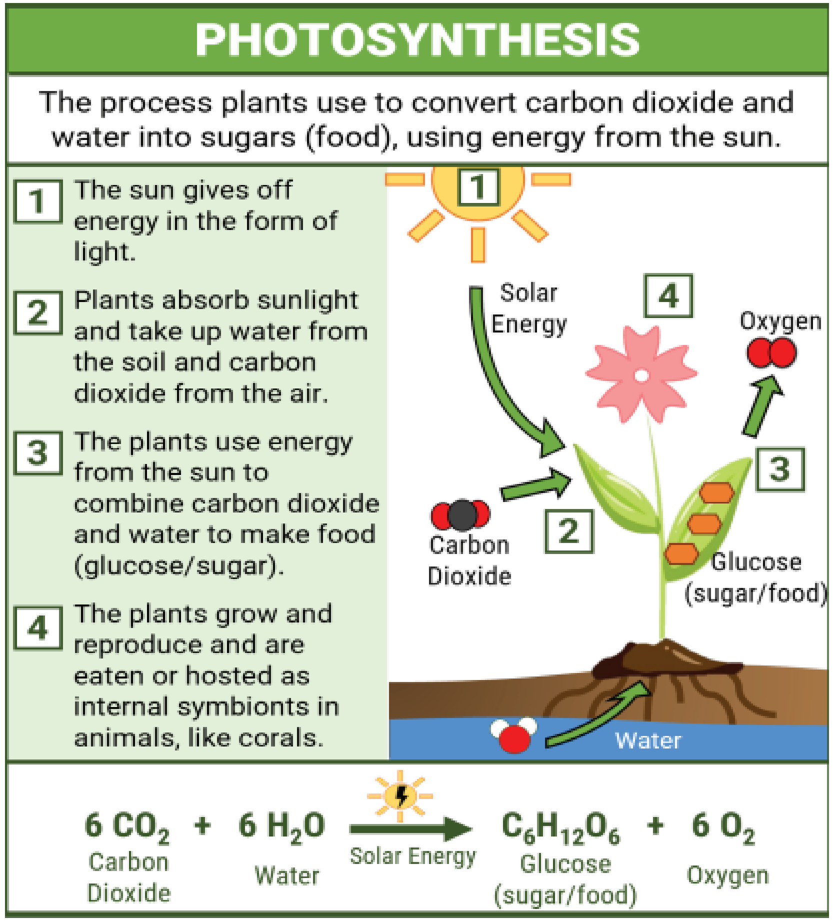
First observed in the deep sea in the 1970s, chemosynthesis is the process by which microorganisms are able to use chemical energy to generate organic carbon from inorganic sources. Basic biochemistry tells us that all metabolic processes, including chemosynthesis and photosynthesis, are comprised of three fundamental elements: an energy source, an electron donor, and a carbon source (Van Dover, 2000). In the case of photosynthesis, light provides the energy while CO2 and H2O provide the source of carbon and electrons respectively.

Like photosynthetic metabolism, chemosynthesis involves the conversion of inorganic CO2 into organic carbon compounds; the significant difference between the two is that in chemosynthesis, the reduction reactions are fueled by the potential energy found between different electron donors and acceptors. While a wide range of electron 5 donors are suitable for use by chemosynthetic microorganisms (see Fig. 2), the most significant for deep-sea communities are sulphide and methane (Jannasch and Mottl, 1985).

>> Alternative Energy for Deep-Sea Ecosystems

Chemosynthesis was first observed as the basis of a food web in 1977 during an ocean research expedition near the Galápagos Islands. There, explorers observed hydrothermal vents on the ocean floor spewing a chemical soup of hot fluid along with thriving communities of giant tubeworms.

Surrounding these hydrothermal vents was a community of several new animal species—thriving despite living in total darkness with no access to sunlight! These incredible communities have since been found at hydrothermal vent fields and at cold seep sites around the globe. Chemosynthetic microbes, like bacteria and archaea, form the base of food webs at hydrothermal vents and cold seeps. Instead of photosynthesis, these organisms use chemosynthesis, the process of creating sugars (food) using energy released from chemical reactions. Unlike photosynthesis, there is not one chemical pathway that defines chemosynthesis



Note: Algae and photosynthetic bacteria not pictured.

Unlike photosynthesis, there is not one chemical pathway that defines chemosynthesis. Different chemosynthetic microbe species live at hydrothermal vent and cold seep communities, each using different pathways to harness energy from the chemical-rich waters emerging from these seafloor features.

- **Why is Chemosynthesis Important?**

In a world without access to the Sun's energy, chemosynthesis provides the basis for the development of rich, diverse communities. Chemosynthetic deep-sea bacteria form the base of a food web that includes a significant variety of marine life including shrimp, tubeworms, clams, crabs, fish, and octopods, just to name a few.

A dense colony of chemosynthetic mussels growing next to methane hydrate at a seep site in the Gulf of Mexico.
Image courtesy of NOAA Ocean Exploration.