When one is viewing a bottom that has never been seen nor sampled previously, most of the organisms that one is seeing represent a new distribution record. This means that one is documenting and establishing that a given species exists where it was not known to exist before. Distribution records in the scientific literature often state, “Hatteras to Brazil, down to 10 fathoms (fathom: 6 feet)”, for example. Those are fairly broad statements. But when one is viewing benthic communities at 50 meters and below, the vertical distribution range of the species viewed is being enlarged and extended, at least regarding depth.

Needless to say, many of the organisms being viewed below 50 meters may be new to science. New species descriptions will require obtaining one or more biological samples, or at least very precise photographs and images of the organisms, which will take a little time. But we are not boasting when we state that of all the organisms being viewed in this book, we estimate that 25% or more will represent new distribution records, and 10% or more will represent species new to science.

Of the biota being viewed by the very deep submersibles, such as ROV HERCULES and ROV ARGUS, all organisms viewed may represent new distribution records, and many may represent species new to science. Science is an ongoing process, because the evolution of the universe had a beginning, but it never ends.

Máximo Cerame-Vivas
The region of the Earth we are discussing

The benthos, the ocean bottom, has been as far away from scientific observers as the Moon. There have been some fairly thorough benthic species assemblage studies at wading depths, but beyond that depth, observations had been limited to those who were adept at free diving or who could defy frigid temperatures in the higher latitudes. The advent of Self Contained Underwater Breathing Apparatus (SCUBA) and the wet suit freed divers to explore greater depths, yet only the bolder and better trained ones would venture down to 30 meters or beyond. Even these, however, were limited in their observation time by decompression tables and the availability of compressed air.

Deeper benthic sampling had relied on heavy gadgets dropped or towed and dragged over the bottom, often very destructively. During dragging operations, the gear often got hung on the bottom and snagged with great risk to the handlers on board. Cables would snap with whipping force, or rigging
would fail, sometimes trapping or seriously injuring handlers on deck. “Watching the wire” during a dredging operation was often a fearsome task, and some ships had shock absorbing “accumulators” to buffer the yanking pulls of a wire that was towing a device that was dragging over a hard and rough bottom.

Eventually cameras were developed to look over benthic communities, but these were tethered to the mother ship. They had to carry down their own lamps, since there is no natural significant light beyond 200 meters (656 feet), and even this only during some hours of the day, when the sun’s angle may provide a favorable “window” for deeper light penetration. A light beam coming at 30° from the horizon or below will be substantially reflected or scattered from the surface and most of the light will not be able to penetrate the water. Therefore the “cone” of light penetration into water, in reference to the face of a clock, is the angle between 10 o’clock and 2 o’clock.

Below 200 meters there is no light that would allow for photosynthesis. Stroboscopic lights, lamps that emit a very strong beam during a very short flash, were developed in the Nineteen Thirties by Dr. Harold Edgerton, known to oceanographers as “Papa Flash.” “Strobe” lights have been very useful to underwater cameras. The strobe flash is so rapid that fish, for example, are photographed before they can react to the flash and flee from it. There is doubt as to whether they can even see it.

Manned submersibles eventually came into being and allowed observations down to the greatest depths, but these are very expensive vehicles, and bringing them up through the surface and back on board the mother vessel are very delicate and sometimes difficult operations.
A welcome freedom for remote benthic observations finally exists. There are now torpedo-like devices that can be programmed to dive, cruise near the bottom over a given course entirely on their own, and resurface to get retrieved. These robotic Autonomous Underwater Vehicles (AUV’s) represent a quantum leap that will no doubt provide us with observations and information about the benthos not foreseen just a half century ago. Some AUV’s have been rated to dive down to 3,000 meters (9,842 feet). Tethered vehicles controlled robotically by cable, Remotely-Operated Underwater Vehicles (ROV’s) can be guided throughout their dives and are preferred vehicles for some underwater explorations.

Dredge used for sampling the shelf benthos. The leading edge (left) is part of a bulldozer blade. An outer bag of chain mail protects the inner collecting net. The rear strut (right) trails a safety line with floats at the surface end.

From The Distributional Pattern of Benthic Invertebrates of the Continental Shelf Off North Carolina.
(1a) the Petersen grab open, ready to hit the bottom; (1b) the same, closed with the sample inside; (2a) the van Veen grab open, ready to hit the bottom; (2b) the same, closed; (3b) the Knudsen grab ready to plunge; (3a) the same coming up upside down with the sample in the cylinder (the scale above, right refers to Figs. 1, 2 and 3); (4a) (with the scale below, left) "close-up" in longitudinal section of the Enequist bottom sampler; (4b) the same, seen from outside. Note: In the van Veen the cable should be a single loop, through rollers at the ends of the arms, for a stronger bite. Drawn by Poul H. Winther for G. Thorson.

From Hedgpeth
Thermal layering

Deep benthic communities often bore no relationship to the communities near the surface. In fact, some benthic samples often revealed species which were from another biogeographic zone or province. This need not seem unusual. Mountain peaks at the Equator are often covered with ice. Though torrid Equatorial temperatures may prevail at sea level, the temperature often drops as one ascends and many mountain ranges in the tropics feature non-tropical climate regimes at higher elevations, often having year-round ice at their peaks.

The same applies to ocean environments, although inversely. Torrid tropical waters are often less dense and float over colder deeper waters, with an abrupt change in temperature between the warmer surface water and the colder deeper water. The abrupt temperature change as one goes deeper is termed the thermocline. The depth of the thermocline may vary, though it is often noticed or observed at depths of between 25 and 100 meters, and may also vary up or down. Waves may also develop in the thermocline, and it may be deeper or shallower as its waves pass or progress. One may safely assume that waters get colder as one goes deeper. Also, seawater need not freeze at 0° Celsius. Due to its salt content, ocean waters below freezing temperatures may remain unfrozen at greater depths.

We are now entering into the interesting realm of ocean waters transporting their own marine climates, which may be vastly different from the climates of the geographic latitudes into which they enter. In oceanography, geographic latitudes do not dictate marine climates: ocean currents do. Ocean currents carry with them their own temperatures, their own salinity profiles and their own species constituents, mostly in the form of planktonic larval stages or juveniles. A good example of how ocean currents dictate marine climate is seen in the distribution of corals and their assemblage into reefs. Coral reefs have long been thought of as tropical marine phenomena. Though corals exist in colder and deeper waters, there is no reef development in the sense of a community where corals are growing upon corals and among corals.

If we take the tropics as the zone between the Tropic of Cancer, 23.5° North latitude, and the Tropic of Capricorn, 23.5° South latitude, and if we take this as the coral reef building zone because these are tropical latitudes, we will note that the distribution of coral reefs is constricted towards the Equator on the Eastern side of the ocean and expanded North and South on the Western side of the ocean. On the Atlantic, coral reef distribution spans roughly between Senegal to the North and Gabon to the South on the Eastern Atlantic, whereas they extend from Cabo Frío, Brazil, to Florida on the Western Atlantic. On the Pacific, coral reefs extend from Ecuador to Baja California on the
Eastern Pacific, whereas they range between Australia and Japan on the Western Pacific. Clearly, tropical water masses pinching towards the Equator on the Eastern ocean while spreading away from the Equator on the Western ocean account for this distribution, not the latitudinal Tropics of Cancer and Capricorn.

In the Caribbean Sea and the West Indies region, major water masses that often contribute to the ocean-current complexity come from the great South American Rivers: the Amazon and the Orinoco. The fishery of the dolphin fish or Dorado, Coryphaena hippurus, and its relation to the intrusion of South American river water patches into the Caribbean, has reached almost legendary heights.
The “Cocktail” that is the Caribbean

Viewing a calm sea lends the impression that it is a continuous, homogeneous and uniform body of water, and that a sample from the surface, from midwater, or from the bottom would yield three “aliquots:” perfectly equivalent samples in their chemical or physical nature. Not so. The three samples might be quite different and represent three different water masses and three different environments. Yes, the sea can be that compartmentalized.

The Caribbean bordering the Greater and Lesser Antilles entails several water masses, each with its own distinctive features and origins. The surface layer can be designated as the Caribbean Surface Water. It ranges from the surface to the thermocline, or the boundary where its temperature changes abruptly. The thermocline is at its shallowest, 25 meters or so, in September-October, and at its deepest, about 100 meters, between January and March. This water layer or water mass is very susceptible to wind and tidal currents, and components of South American river waters are often present, water from the Orinoco being most prevalent, while water from the Amazon may penetrate further East into the Atlantic. Eddies from each river may be noticed and they can be both either cyclonic (counter-clockwise) or anti-cyclonic (clockwise).

Below the surface water mass lies the Sub-Tropic Underwater, which extends down to 180 meters. Below this lies the Sargasso Sea Water, down to about 325 meters. Bear in mind that the Sargasso Sea is bound by the large gyre in the North Atlantic and is quite deep, with some of its deep layers extending into the Caribbean. The next water mass extends down as far as 700 meters, this being the Tropical Atlantic Central Water. Below this lies the Atlantic Intermediate Water, down to 900 meters, and below this, all the way down to the bottom at around 4,000 meters, is the North Atlantic Deep Water. These are the water masses that make up the Caribbean Cocktail. Their names give away their origins.
Caribbean Surface Water

27°C Thermocline 25 to 100 m

20°C Sub - Tropic Underwater 180 m

18°C Sargasso Sea Water 325 m

7°C Tropical Atlantic Central Water 700 m

5.2°C Atlantic Intermediate Water 900 m

4°C North Atlantic Deep Water 4000 m

2°C Antarctic Intermediate Water
Eddies

Occasionally a parcel of water from a major South American river like the Orinoco will flow into the Atlantic and enter the Caribbean. Under such conditions huge eddies or pools —Mesoscale Eddies— will become very visible and conspicuous in Caribbean waters.

“Mesoscale” eddies are large whirlpools in the ocean with diameters of hundreds of kilometers. Their influence can extend to depths of 1000 m or greater. Oceanographers are only now beginning to document the prevalence, extent, and influence of such features in the world ocean. The availability of third-generation ocean color imagery from the Moderate Resolution Imaging Spectroradiometer-MODIS sensors aboard NASA’s AQUA and TERRA platforms, and support for direct observation at sea, have allowed characterization of such an eddy interacting with the Orinoco River plume (ORP) while traversing the eastern Caribbean basin.

The ORP extends seasonally across the basin from August through November, 3 to 4 months after the peak of the seasonal rains across northeastern South America. At this time, a thin plume of relatively low-salinity water, rich in phytoplankton and bearing significant amounts of colored dissolved organic matter, covers a large swath of the basin, offering a striking contrast to the intensely blue oceanic waters of the adjacent northwest Atlantic Ocean.

Ocean color imagery and sea surface height topography (SSHT) in August 2003 revealed a large circular structure extending 230 km across the eastern Caribbean basin embedded within the Orinoco River Plume. Sea Surface Height Topography indicated that the feature was a cyclonic eddy, rotating counterclockwise about its axis, drifting westward at about 7 cm/s−1.

The deeper Atlantic water, the Atlantic Bottom Water, does not enter the Caribbean, since the ridge between the Lesser Antilles is higher (rises to shallower depths) than the depths where the Atlantic Bottom Water flows.

The depths of the mesophotic coral reefs discussed in this book lie well within the Sub-Tropical Underwater level and above, and the deep coral lie within the Sargasso Sea Water level.
Cyclonic Eddy Entrains Orinoco River Plume in Eastern Caribbean.

By Jorge E. Corredor, Julio M. Morell, José M. López, Jorge E. Capella and Roy Armstrong. 2004
Benthic or bottom species can be separated into three categories. There are those benthic organisms that can move about readily and travel freely. These are considered mobile or motile species. There are those that, capable of moving about, chose to remain in the same general area. These are classified as behaviorally territorial. And then there are those organisms that are physically attached to the bottom, or sessile forms, that must stay put and cannot go anywhere. Sessile forms are more susceptible to being affected by changes in currents that would subject them to a different marine climate when their water mass shifts. In this regard, it is the sessile forms that describe the more or less stable benthic communities, they being the ones that cannot leave when their marine environment shifts. Corals, being firmly attached to the bottom, are, of course, sessile marine organisms. Their presence or absence alone may help describe marine climates.

Another feature of corals is the presence of microscopic algae, Symbiodinium or zooxanthellae, embedded within their tissues. The pigment of the zooxanthellae dictates the apparent color of a given coral. Since zooxanthellae are photosynthetic and require light, only corals within the illuminated depths of the ocean would be able to support the algae. The mutualistic relationship between the coral and the zooxanthellae, however, is not obligatory. Some corals may support them and some may not, but those corals that have zooxanthellae are better off in the sense that these algae contribute food and nutrients to the coral. The fact that coral
reefs are among the most productive of marine communities, while thriving best in the clearest of waters where there is a dearth of planktonic organisms that may become food for the coral, is explained on the basis that zooxanthellae, and not planktonic food, provide nourishment to the coral.

Coral “bleaching,” the loss of its pigment that results in a whitening of the coral, is essentially due to the absence of zooxanthellae in its tissue. If this absence persists for too long, the coral may eventually die off. It would seem then that the coral “needs” the zooxanthellae, since it often benefits from it.

Corals living in mesophotic or twilight conditions would benefit their zooxanthellae by providing a broader surface of its tissues exposed to the dim light. Corals would then benefit from altering their morphotype or life form. Coral species that near the surface in shallower and better illuminated waters might be arborescent (tree-like) or spherical and brainlike, would greatly benefit by spreading their contours and providing broader surfaces to their zooxanthellae for the capture of the dim light in deeper water. Thus, coral species that in shallow water appear round (spherical) or arborescent, in mesophotic conditions appear with surfaces greatly spread, flattened, and with fewer upright branches.

Coral reefs in shallow waters are very complex topologically, offering many groves, nooks and crannies that provide microhabitats and hiding places for small and juvenile organisms. In fact, the term “coral reef” is often meant to describe a community that is structured by corals growing upon corals and among corals, as opposed to solitary corals that grow sparsely. The mesophotic coral communities described here, with their flattened and spread morphotypes, are essentially shingles of coral growing upon and among shingles of other corals. The resulting reef structure at these depths of dim light are much more complex than their shallow water counterparts, offering many more small passages and compartments for juvenile forms to hide and protect themselves from enemies and predators. The next quantum leap in oceanographic instrumentation would be the development of a device that would allow for observations within these passages and compartments, a sort of endoscopic query of these very complex habitats.

Corals growing in “shingles” upon other corals do not always induce peace, comfort and protection. Many of the photographs seen in the transects here illustrated show corals “fighting.” These are no wrestling matches, but the edges of corals touching other corals sometimes reveal tissue damage as corals attack one another and digest away each others’ tissues; fights no less violent than wrestling. As Darwin said, evolution is the fight for existence and the survival of the fittest. “Fitness” here may be as subtle as developing growth patterns that may maintain some distance or isolation between the tissues of neighboring corals.

Sessile bottom organisms such as corals and sponges are not expected to move about in search of favorable habitats exploiting larger areas of bottom, though they seem to be able to spread their distribution nonetheless. That “migration” or exploration and settlement of new habitats is accomplished not by the adults themselves, but by planktonic larval stages. Needless to say, a larva that is planktonic is being carried about passively by drift and ocean currents, though it may have some feeble motion of its own. There may be plankton feeders along the way that may take advantage of that larva as food. If allowed to survive, it may come to a place where it is able to settle and develop, but competition may ensue with other organisms already in place. Many factors may affect that larva unfavorably, and the success of a given species in attaching to the bottom and growing will often depend upon the number of larvae available in the plankton. Species that shed thousands of larvae that eventually result in only one or two surviving are not uncommon in the benthos. To many larvae, success may depend upon its reaching a hard bottom where it can attach and grow.
How these bottom communities come about

There are species assemblage differences — differences in the species groups that make up and predominate— within the bottom communities of, say, East of Vieques, West of Puerto Rico, and South of Paraguera, for example. These assemblages respond to (1) bottom conditions, (2) surrounding environment, and (3) diaspora availability. And, of course, as scientists must often say, “among others,” which is an elegant form of covering one’s behind.

First and foremost, the larvae or diaspora (diaspora; life form for spreading and dispersal, such as seeds, larvae, spores, etc.) will depend upon whether the bottom is favorable to them to be able to settle there. Is the bottom loose sand and/or fine particulate silt? Is the bottom a hard consolidated substrate? Is the bottom pebbly or loose rock? Is the bottom a rock outcropping?

Planktonic larvae will settle and attach to the substrate, but if the bottom is sand or silt they may become buried in the bottom as soon as they attain some size. Or the size of the bottom particle to which they attach may be too small and the developing larva may topple when it grows. Or the bottom may be too densely populated by species which might not tolerate the larval invasion.

The surrounding environment might not be favorable to the diaspora. Perhaps a nearby river outfall represents a source of fresh water that dilutes the salinity over that bottom. Or perhaps that river outfall may carry with it periodic or permanent loads of sediment that blanket the bottom and smother the diaspora. Perhaps temperatures may vary abruptly. Bottoms above thermocline depths may be exposed to the vagaries of the thermocline itself. If the thermocline is well above the bottom, the bottom temperatures are low. If the bottom is within the thermocline depth, the bottom is warm as the thermocline shrouds it, and cool as the thermocline abandons it. Such differences in temperature will favor, of course, those species that tolerate a broad range between warm and cold, but will eliminate those species that have narrow temperature preferences.

Diaspora availability will be the prime and prevailing factor when a bottom becomes cataclysmically available. A benthic region may be subjected to hyposaline conditions by heavy floods and runoff from land and suffer mass mortalities. In a sloping hard and consolidated bottom that has been covered by loose sediments over decades, the bottom may suddenly slough off like in an avalanche — turbidity current — and expose a new barren surface fresh for repopulation. The species that will repopulate those bottoms will be those whose diaspora are available at those times.

That diasporal availability will depend upon the life and reproductive cycles of the neighboring species present. If a given species, let’s say, frees — sheds — its diaspora in spring, coinci-
dental with the turbidity current that made bottom available, then that species will settle over that “new” bottom and be a component of the species assemblage that populates it. If on the other hand, a diasporal shed does not coincide with the bottom availability caused by the freshwater impact, as an example, then those diaspora would have been lost and nothing would have happened except for a planktonic food source. A neighboring bottom, under similar prevalent environmental conditions, but without having undergone a turbidity current phenomenon or a hyposaline shock event, may sport an entirely different species assemblage even if within the same region.

After all, that’s what ecology is all about! Among other things, of course!
Clear deep sea vent at the Von Damm site, Cayman vents, near 2,300 m or 7,545 feet deep. The blurred portions are caused by water of different densities mixing. This blurring phenomenon is known as schlieren. (NOAA Ocean Exploration) (Dr. Cindy Van Dover, Duke University Marine Laboratory)
The Deep Sea and Life in the Universe

Studying the oceans makes us rethink all the sciences way back to creation.

You are probably awed, as most are, by formidable universal truths in nature. One was the dogma that all life on Earth depended upon energy from the Sun. Chlorophyll was the miraculous molecule that allowed life to capture the energy from the Sun and, via some chemical gymnastics, synthetize food in those organisms that hosted chlorophyll, and then spread the food supply to all animals via the food chain or the food web.

It was almost religion to learn that nature had one energy source—the Sun—and one provider of food—plant life—that united all biota in the natural community into one ecosystem. There were admirable relationships established, and there was also much talk about trophic levels, primary producers, primary, secondary and tertiary consumers, and consumers even beyond. There were also decomposers, and recycling of nutrients, and charts and diagrams of energy flow and trophic level efficiencies. We all marveled at how much was wasted in transferring biomass from one trophic level to another. It was poetry at its best and many of us read a magic plan in all of Nature. This plan and wonderful organization still stands.

But why would the gift of life have been bestowed upon Earth, this only one speck in one Solar System; the system itself a mere speck in one galaxy which is itself a mere speck among many other galaxies, super clusters, and perhaps among many other universes. Surely, there must also be life elsewhere. Why just us? Why only here? There must be any number of planets or celestial bodies at the right distance from sources of light—of energy—where there may also be water, nutrients, and other conditions favorable to life.

A search began for those favored circumstellar habitable places or regions labeled as Goldilocks sites or zones. Goldilocks is the girl of Goldilocks and the Three Bears fame. In April 2014 NASA's Kepler Space Telescope, which had been launched March 7, 2009, discovered an Earth-sized planet in a Goldilocks zone orbiting a star. This planet was identified as Kepler 186f. Based on previous Kepler findings, however, it had been estimated that within a thousand light-years of Earth there are thousands of habitable worlds. Kepler 186f lies within the Kepler-186 system, about 500 light-years from Earth, in the constellation Cygnus.

Many searches for extraterrestrial life have been based on the intention of discovering intelligent life, or beings that would somehow be able to communicate with us. But life is life, and, given enough time, life may always evolve into some kind of an intelligent being. After all, this universe arose in the Big Bang of 14 billion years ago, and the Earth arose within this universe 4.5 billion years ago. Unicellular life came upon the Earth only 3.5 billion years ago, multicellular life 450 million years ago, and Homo sapiens, the rookie, sprang only less than a quarter of a million years ago. It took 3.5 billion years for life on Earth to evolve into an “intelligent” being of only a quarter million years’ existence.
- Bing Bang to Earth
- Earth to Unicellular life
- Unicellular life to Pluricellular life
- Pluricellular life to Homo sapiens
- Homo sapiens
The marvel of life is life itself. While we once thought that most of the Earth was uninhabited because of extremely unfavorable conditions to the existence of life, we now know that forms of life exist in hot geysers, in cold ice sheets, in famished deserts, in acid pools, in hot brines, and, yes, now in supercritical hot marine vents, under the crushing pressures of the sea, at frigid depths.

We have always been enamored with the heavens, but have paid precious little attention to our oceans, which are less transparent than our atmosphere. A more modest instrument than the Kepler Space Telescope, a vehicle named ALVIN operated by the Woods Hole Oceanographic Institution since 1964, discovered the first hydrothermal vents on the sea floor off the Galapagos Islands in 1977. Hydro (water) thermal (heat) vents have since been seen at more than 25 sites in the Pacific, the Atlantic, and, the deepest at 5,000 m (16,000 ft; 3.1 mile), in the Caribbean at the Cayman Trough, the world’s deepest undersea volcanic rift. These Cayman Beebe vents, 4,960 m deep, emit water that is up to 485° C. A nearby vent site, the Von Damm, is 2,300 m deep. These vents were discovered in 2009 and 2010. Though water is supposed to boil at 100° C, at these depths and under pressures of over 250 atmospheres, the 485° C water turns supercritical and does not boil. It merely flows into surrounding ambient water temperatures of 2° C to 4° C.

The Caribbean is a choice sea to study hydrothermal phenomena. It has the Cayman Rift to the west, with steady and persistent hydrothermal vents, and Kick-em Jenny, an undersea active volcano, to the southeast. Kick-em Jenny, 8 km to the north of Grenada, is a periodically erupting volcano that has erupted twelve times since its discovery in 1939. It last erupted in December 2001. Some say it may give rise to a new island in the Antillean chain.

There is intrinsic heat within the Earth. The temperature at the center of the Earth is around 6,000°C. That is just below our feet 6,378 Kilometers or 3,963 miles down. A temperature of 6,000°C is also that of the outer layers of the Sun — the photosphere— which emits the light used for photosynthesis.

Hot magma and volcanic lava have been around since long before man, and long before man began burning fossil fuels. Seawater seeps through the Earth’s crust at depths where the crust is thinner, or is carried down by subducted sediments, —bottom material that is being buried inwards at places where two tectonic plates are coming together— and comes in contact with hot magma or volcanic lava. Then this supercritical water spews upward in the hydrothermal vents and we have 485°C water entering a 2°C or 4°C oceanic environment.

One would assume that water 485°C above ambient would kill all organisms that are around and near. Not so. The organisms at and around these vents inhabit there at population densities that are 10,000 to 100,000 times above the densities of the nearby fauna at the surrounding sea-floor communities. The energy source, besides heat, are the chemosynthetic bacteria —chemoautotrophic bacteria; bacteria that sustain themselves on chemical nutrients— that are nurtured by H2S (hydrogen sulfide), a compound that is toxic to other form of life on Earth. The chemoautotrophic bacteria may exist within the tissues of the tubeworms prevalent at these vents at densities of 285 billion bacteria per ounce of tubeworm tissue. Hemoglobin in the tubeworm tissue combines with H2S and transfers the H2S to the bacteria.

Small “smoker” vent, venting a dark plume, at a depth of 2,500 m at 9°50’ N along the East Pacific Rise. (Image provided by Dr. Richard A. Lutz, Rutgers University.)
The check list of organisms at hydrothermal vents are tube-worms (vestimentiferan annelids) some over 10 feet long, amphipods, copepods, shrimp, crabs, snails, octopi, bivalves, fish and eels, among others. Tube worms have no mouth, no anus, and no digestive tube.

Organisms living under extreme conditions are called extremophiles, or affiliated to extremes (high salinities, high acidity, high levels of radiation). A group of scientists have taken interest in the chemo autotrophic bacteria in muds and sediments under extremely hot vents, extreme pressures and in absolute darkness.

We are now in the Deep Hot Marine Biosphere, a realm which was completely unknown to us before the nineteen seventies. At the risk of repetition, we know more about the moon than we know about the Sea. Some feel very strongly that deep-sea thermal vents are where life had its origins: the cradle of life on primitive Earth.

That the species abundance and diversity surrounding marine thermal vents exist at all, in spite of crushing pressures, supercritical temperatures, total absence of sunlight, no chlorophyll, and no photosynthesis, this should be our wake-up call to start looking around for other paradigms of life in the universe. There may be other environments where life abounds.
Lobster over a vent 2,500 m deep at 9°50' N along the East Pacific Rise. Many organisms at these depths are without pigments. Color would be of very little use to them at this absolute darkness. (Image provided by Dr. Richard A. Lutz, Rutgers University.)

Zoarcid eelpout fish and crabs over tube worms at a depth of 2,500 m at 9°50' N along the East Pacific Rise sea vent. (Image provided by Dr. Richard A. Lutz, Rutgers University.)
Environments like Europa, a moon of Jupiter, and Enceladus and Titan, moons of Saturn, are likely candidates for life beyond our Earth. As are the thousands of other options beyond our solar system.

Europa’s surface is water ice. It has a tenuous atmosphere of oxygen. Cracks in the ice of Europa’s surface are caused by the crunching gravitational pulls of Jupiter. Below Europa’s icy surface, a liquid water ocean 100 km (60 mi) deep is subject to tidal flexing of forces from Jupiter’s gravitational pull, and the tides heave in an asymmetry that generates some heat. The volume of this ocean is estimated at more than twice the volume of the Earth’s oceans.

In 2004 the NASA and ESA joint exploration spacecraft Cassini-Huygens reached Saturn. While flying by Saturn’s moon Enceladus, discovered a water-rich plume venting from Enceladus’s south polar region. This geyser-like jet of water vapor emits ice particles, hydrocarbons, and sodium chloride crystals into space. Over 100 such cold volcanoes have been identified. These cryo-volcanoes — volcanoes that are cold instead of hot — suggest that Enceladus is geologically active and has an ocean below its surface, as do other moons of our solar system.

The exploration of Titan, the largest moon of Saturn, by the module Huygens, which landed on its surface, revealed an exotic cold world with an atmosphere, hydrocarbon lakes, ice and varied hydrocarbon compounds on its surface. Extremophiles on Earth warn us that we should not disregard some type of biotic process on Titan.

In November 2014 the ALMA (Atacama Large Millimeter/submillimeter Array) radio telescope observed a young star — only one million years old — and discovered that she has a planetary disk and details of planets beginning to take shape. This star, HL Tau, 450 light/years from Earth, is a developing new solar system. Radio telescopes like the Atacama, which can separate antennas as much as 15 km apart, can “see” behind clouds of dark dust in impressive detail.

We must free ourselves from the mental constraints of believing that there is but one method to Life, subject to merely one set of life supporting conditions. We are learning from our own oceans that marine life may take advantage of life-supporting conditions through methods that man had not yet discovered. Life is too precious and too unique to peak and culminate just once in this universe. Our approach to marveling at the diversity of Life will one day evolve into wonderment at the diversity of methods for Lives: different kinds of Lives. Our oceans are vast enough, and diverse enough, to teach us these wonders. But only if we care to look. We might learn a lot more about Life and Lives among the stars if we just studied our own oceans a little bit better.

ROV hovering over Cayman sea vent, Von Damm site. (NOAA Ocean Exploration) (Dr. Cindy Van Dover, Duke University Marine Laboratory)