

Challenges of the Deep: Survival at Extreme Depths

George Matsumoto, PhD., Edith Widder PhD., Linda Kuhnz, Erika Raymond, PhD.

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Narration	Visual	Comments/Additional Information
What creatures lurk in the depths of the ocean? How do they survive in a world without sunlight,	Mills' jelly (<i>Crossota millase</i>)	
under crushing pressure, and in bone-chilling cold?	Deep-sea cucumber (Holothurinan, <i>Psychropotes longicaudata</i>)	
Come with us to explore this secret world and discover its hidden wonders.	Caprellid amphipod (Crustacean) on top of yellow sponge	
The ocean is the largest and least-explored habitat on Earth. More than 70 percent of the Earth is covered by water...and that's just the surface. The ocean is deep and holds an enormous living space. In fact, it represents more than 99 percent of the living space on this planet.	Earth, zooming in to the Pacific Ocean	The average depth of the ocean is about 12,000 feet (3,800 m) deep, making this vast fluid environment the largest ecosystem on earth. The majority of the seafloor is covered in deep-sea mud, where dense microscopic animals inhabit the top 4 inches (10 cm); deep-sea mud is the second largest ecosystem on earth. The Pacific Ocean is the largest ocean basin.
Untold billions of organisms live beneath these waves	Seashore, pan out to sea	
Life survives and flourishes—even in a habitat so uninviting that some scientists once believed it could not possibly support life.	Mid-water scene; siphonophores and other gelatinous organisms	Mid-water; the water that is well below the surface but also well above the bottom. Generally defined as open water below 660 feet (200 m), down to a few meters above the seafloor.
But how can life exist without sunlight...at temperatures near freezing...in water containing little or no oxygen...and at pressures so great they could flatten a submarine?	Depauperate seafloor	
And yet these waters teem with life... life that is perfectly adapted for existence in the fluid midwater realm...	Eggyolk Jelly (<i>Phacellophora camtschatica</i>) with hundreds of juvenile octopus	

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and along the vast deep seafloor.	Benthos showing several species of rockfish	<i>Benthos</i> : The collection of organisms living on or in the seafloor (can also be used to describe freshwater habitats).
Almost every known group of animals can be found in the ocean. All of them face the same three basic challenges: finding food, avoiding predators, and finding mates.	Collage of various deep-sea animals (left to right); Dumbo octopus, siphonophore, tomopterid worm, snailfish, urchin, comb jelly, spot prawn	Nearly every animal phylum has representatives living in the deep-sea
Deep-sea animals have overcome these challenges by evolving in strange and amazing ways. Let's explore the unique world they inhabit.	Lithodid crab	
There is little to eat in the deep sea. Bits of food drift slowly down from surface waters, where there is enough sunlight to support photosynthesis and plant growth. These particles, called marine snow, include dead and dying organisms, animal waste, mucus, sediment, and dust.	Marine Snow	
Most, but not all of this marine snow is consumed by microbes and plankton. The rest ends up on the seafloor, creating an organic layer that sustains animals living on the bottom.	Seafloor with detritus	The large particles you see here are "sinkers," which are discarded larvacean houses.
Sunlight is scattered and absorbed by seawater. In clear water it disappears at the rate of 10% for every 75 meters, or 240 feet, of descent.	Sunlight filtering down just beneath the sea surface	
Watch how the colors change. Red, green and yellow are the first colors to disappear. Blue persists to the deepest depths, but it, too, eventually disappears at around 800 meters or the equivalent of eight football fields.	Remotely operated vehicle (ROV) descending; color bars attached to manipulator arm	
Immense pressure is another challenge for animals living in the deep. Water is heavy and as we travel deeper, the increasing pressure pushes in from all sides.	Pressure gauge during decent.	

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<p>As this styrofoam head was carried into the depths by a submarine, the pressure of the seawater compressed it, causing the head, seen on the left, to shrink to a fraction of what it was at the surface, as seen on the right.</p> <p>At 3,000 meters, the pressure is already more than 300 times that at the surface.</p>	<p>Remotely operated vehicle (ROV) descending; styrofoam head attached to manipulator arm with a static picture of the uncompressed head showing on the right.</p>	<p>Pressure compresses the tiny air pockets in the styrofoam, causing it to shrink. Water less compressible, which is why hydrostatic skeletons and a lack of air spaces are common features in deep-sea animals.</p>
<p>As we move deeper, water temperature drops quickly. The average temperature of seawater in the deep ocean is only four degrees Celsius or 39 degrees Fahrenheit, which is just above freezing.</p>	<p>Animation of Monterey Bay, with view descending into the depths. Superimposed temperature graph showing lower temperatures as you move deeper.</p>	<p>The deepest depths of the ocean are an average of 2° C.</p>
<p>At some ocean depths, life-giving oxygen may be in short supply. Oxygen levels are high in shallow water. As marine snow rains down into deeper water, much of it is consumed by bacteria. This feeding activity uses oxygen and creates a region known as the Oxygen Minimum Zone.</p>	<p>Mid-water zone with few organisms. Superimposed oxygen graph showing O₂ levels you move deeper.</p>	
<p>Finding Food</p>		
<p>Even the task of finding food is not simple and has led to a remarkable array of food-finding strategies.</p>	<p>Deep-sea Rattail fish (<i>Coryphanoides acrolepis</i>)</p>	
<p>Active predators such as these large squid roam the ocean looking for slower moving prey.</p>	<p>Humboldt squid (<i>Dosidicus gigas</i>) feeding on small fish</p>	
<p>Other animals conserve energy by waiting for food to come to them.</p>	<p>Predatory tunicate (<i>Megalodicopia hians</i>) catches a small crustacean</p>	<p>This is a sessile animal that lives on hard substrate.</p>
<p>Living drift nets of stinging tentacles can act as traps too. Long chains of animals called siphonophores can reach up to 40 meters, or 130 feet in length and have more than 300 stomachs.</p>	<p>Mid-water siphonophore <i>Praya</i>; head, then long body showing feeding zooids</p>	

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<p>Some animals filter the water for food. This larvacean secretes a net of mucus, then beats its tail to pump water through it. The net filters out very tiny particles, concentrating them into a compact, edible mass. When the net becomes clogged, the larvacean discards it and builds a new one.</p>	<p><i>Bathochordaeus</i></p>	
<p>Filter feeders, such as these corals, passively catch the marine snow that falls from above or drifts by in a current.</p>	<p><i>Paragorgia arborea</i> coral on Davidson Seamount</p>	<p>Their branches house thousands of tiny polyps, each with a row of tentacles. This creates a large surface area for catching nutritious particles as they pass by.</p>
<p>Many animals eat sediment. This sea cucumber uses its tentacles to sweep large quantities of deep-sea mud into its mouth. Its digestive system extracts nutrition and excretes what can't be digested,</p>	<p>The "sea pig" holothurian <i>Scotoplanes globosa</i></p>	
<p>leaving behind characteristic piles of much cleaner sediment.</p>	<p>Holothurian poop (the object to the right is a sea pen)</p>	
<p>Some animals take advantage of rare feeding opportunities. Occasionally a large amount of food falls to the seafloor, providing a concentrated, but short-lived food source. These urchins are eating kelp that was ripped from shallow beds in rough weather, carried out to sea and eventually sank to the deep seafloor.</p>	<p>Hundreds of sea urchins (<i>Allocentrotus fragilis</i>) feeding on drift kelp. There is an octopus visible in the center of the second scene.</p>	
<p>Scavengers, like these hagfish, follow odors released by carcasses. The hagfish defend their feast with a repulsive slime that discourages other scavengers from approaching.</p>	<p>Hagfish (<i>Eptatretus stouti</i>) feeding on a dead fish</p>	<p>Hagfish have chemosensory abilities that allow them to find carcasses from great distances.</p>
<p>When whales and other large mammals die and sink to the seafloor, their huge carcasses provide a large amount food and temporary habitat for many types of animals. When a whale carcass is fresh, mobile animals like sharks and crabs move in to eat meat and fat from the bones.</p>	<p>Whale carcass on the seafloor, mostly stripped of flesh.</p>	

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After the carcass is stripped,	Crab (<i>Chionectes tanneri</i>) feeding on whale carcass	
other animals take over. These newly discovered “bone-eating” worms have no mouth or gut, but have symbiotic bacteria inside their bodies that help break down the fats and oils in whale bones.	<i>Osedax</i> worms	http://www.mbari.org/twenty/osedax.htm
Some animals in the ocean don't depend on food produced in sunlit waters. Instead of using energy harvested from sunlight and photosynthesis, they gain energy from chemicals released near the seafloor.	Hydrothermal vent and “black smoker”.	These deep-sea habitats have only been known since the late 1970's.
Chemical-rich fluids spewing from hot hydrothermal vents are consumed by chemosynthetic bacteria that in turn support animals such as these crabs and amazing giant tube worms.	Giant Tube Worms (<i>Riftia</i>), and hydrothermal vent crabs	<i>Riftia</i> can grow to a meter long.
Another strategy for surviving where there is only sporadic or sparse food is to increase the efficiency of food capture.	Squid (<i>Gonatus</i>), feeding on another squid	
Long, sharp teeth aid predators in catching and holding on to prey.	Viperfish (<i>Chauliodus</i>)	
This black swallower has an expandable stomach that enables it to swallow whatever prey it encounters.	Black Swallower fish (<i>Chiasmodon</i>)	
Living in the Dark: Bioluminescence		
Since no sunlight ever reaches the deep sea, many animals have the ability to create their own light- a chemical process called bioluminescence. For example, this jelly looks red when we shine the submarine lights on it.	Dunce Cap Jelly (<i>Periphylla</i>)	
But when we turn the lights off, we see that the jelly can make light of its own.	Dunce Cap Jelly (<i>Periphylla</i>), bioluminescing	

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<p>At some depths, 80-to-90 percent of the animals are bioluminescent. Deep-sea organisms use bioluminescence to avoid predators and to find food, and mates. Some animals, like this sea pen, bioluminescence for reasons we don't yet understand.</p>	<p>Sea Pen (<i>Umbellula lindalhi</i>) Inset: <i>Umbellula</i> bioluminescing</p>	
<p>Most animals produce light using chemicals they synthesize from the food they eat, but some, such as this deep-sea anglerfish, glow because of bioluminescent bacteria inside their bodies. The anglerfish provides the bacteria with food. In return, the bacteria provide the fish with a glowing lure.</p>	<p>Anglerfish (<i>Oneroides</i>) with bioluminescent lure</p>	
<p>Many deep-sea animals have bioluminescent organs around their eyes that act like headlights, helping them see in the dark.</p>	<p>Fish with blue headlights</p>	
<p>Most animal's headlights are blue, the color that travels farthest through seawater.</p>	<p>Fish bioluminescing blue</p>	
<p>There are interesting exceptions though. This shiny loosejaw fish has red headlights. Although most animals in the ocean can't see red light, the loosejaw can. These fish use their headlights like night-vision goggles to sneak up on unsuspecting, unseeing prey.</p>	<p>Shiny Loosejaw fish (<i>Aristostomias</i>)</p>	
<p>Mating and Reproduction</p>		
<p>Finding food is just one step in the primary goal of all animals...reproduction. How can animals find each other in this vast habitat? Animals of the same species may only rarely come across each other, so deep-sea animals have evolved various mating strategies.</p>	<p>Mid-water scene</p>	

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<p>For example, some squid species mate when they encounter each other. The female stores the sperm but does not develop eggs until environmental conditions are favorable. She fertilizes her eggs when the time is right.</p> <p>Another way to store sperm is to just hang on to its source.</p>	Glass Squid (<i>Galiteuthis</i>)	
<p>Many anglerfish males are tiny compared to the females. They also lack the lures and fangs that females use to capture prey. When a mature male anglerfish encounters a female, he latches on to her body and stays there for the rest of his life. His flesh fuses with hers, her blood stream provides him with nourishment, and, when the time is right, he becomes a ready source of sperm.</p>	Female anglerfish (<i>Ceratidae</i>) with attached male	
<p>Other animals, like these hermit crabs, gather in large groups to mate...perhaps attracted by chemical or other cues.</p>	Hermit crab aggregation	
<p>Hermaphroditic animals such as this comb jelly are able to reproduce on their own...preventing the need for a mate at all. They produce both sperm and eggs.</p>	Comb Jelly (<i>Beroe</i>)	
<p>Longevity</p>		
<p>Many deep-sea animals grow slowly and live very long lives. Deep-sea rockfish can live to be more than 200 years old...</p>	Rockfish (<i>Sebastolobus</i>). There is also a spot prawn in the scene	
<p>and some corals can live to be hundreds, even thousands of years old.</p>	Deep-sea coral (<i>Keratoisis</i>)	
<p>Cold and Pressure</p>		
<p>Other challenges imposed by the deep-sea environment include persistent cold and high pressure. These challenges have been met and overcome with a number of different solutions.</p>	Sea spider (<i>Pycnogonid</i>)	<i>Pycnogonids</i> are not actual spiders, they are crustaceans. They move very, very slowly in the cold and high-pressure environment of the deep sea.

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<p>As an example, the enzyme systems of many deep-living animals are adapted to elevated pressures, and because cold and pressure reduce the fluidity of cell membranes, the structure of their cell walls is unusually constructed.</p>	<p>Holothurian (<i>Pannychia</i>)</p>	
<p>Avoiding Predation</p>		
<p>To avoid predation, some creatures hide out in areas where other animals have a hard time surviving. The vampire squid, for example, lives at depths where the seawater contains very little oxygen.</p> <p>Many animals that live in the oxygen minimum zone have slow metabolic rates and are very good at extracting what little oxygen there is in this region.</p>	<p><i>Vampyroteuthis</i></p>	
<p>Schooling is a common strategy for confusing potential predators...there can be safety in numbers. Imagine how hard it would be for a predator to follow an individual sardine in this school.</p>	<p>Schooling fish</p>	
<p>Growing to a large size is another form of protection. Most predators cannot ingest something as big as this recently discovered jelly which is a meter, or three feet, wide.</p>	<p>Big Red Jelly (<i>Tiburonia granrojo</i>)</p>	
<p>Even without places to hide, animals can camouflage themselves. Because little or no red light reaches the ocean depths, many deep-sea animals are dark red – a color that absorbs rather than reflects available light.</p>	<p>Red jelly (<i>Paraphyllina</i>)</p>	
<p>Black pigment also absorbs the dim blue light filtering down from above and light emitted by bioluminescence. No light reflects back to the eye of the predator, so black animals are also rendered invisible.</p>	<p>Slickhead fish (<i>Alepocephalus</i>)</p>	
<p>Translucent animals are almost invisible in the open ocean. This transparent worm has an advantage because it disappears into the watery background.</p>	<p>Mid-water Worm (<i>Tomopteris</i>)</p>	

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<p>Some animals use a camouflage trick called counterillumination to obliterate their silhouettes. These animals live in the twilight zone between 200 and one thousand meters...or 660-to-33-hundred feet...an area of dim filtered sunlight. The animals' bioluminescent belly lights...called photophores... blur into a light field that matches the color and intensity of the sunlight overhead so that predators looking up from below cannot see their silhouette.</p>	<p>Viperfish (<i>Chauliodus</i>)</p>	
<p>Animals also use light to actively defend themselves from predators. Some animals will release their bioluminescent chemicals into the face of an attacking predator...blinding or distracting their attacker long enough to escape.</p>	<p>Bioluminescing mid-water worm</p>	
<p>This shrimp spews light out of its mouth like a fire-breathing dragon and then back-flips away into the darkness.</p>	<p>Shrimp spewing bioluminescent fluid</p>	
<p>Brilliant displays of bioluminescence may serve as a burglar alarm. When caught in the clutches of a predator, prey may escape by attracting the attention of larger predators that will attack their attacker.</p>	<p>Jelly (<i>Atolla</i>)</p>	
<p>For example, the pinwheel display of some common deep-sea jellies can attract the attention of a predator more than 100 meters, or 330 feet away.</p>	<p><i>Atolla</i> bioluminescing</p>	
<p>The responses of animals to the harsh deep-sea environment are extremely diverse and still poorly understood.</p>	<p>Blob sculpin (<i>Psychrolutes phrictus</i>)</p>	
<p>For as much we have learned about our oceans in the past few decades, there are still many deep-sea animals whose bizarre adaptations are a mystery to us.</p>	<p>Octocoral (<i>Anthomastus ritteri</i>)</p>	
<p>New species, behaviors, and adaptations are constantly being discovered. We have much to learn about these amazing animals and the ecosystems they inhabit.</p>	<p>Barreleye Fish (<i>Macropinna microstoma</i>)</p>	