Life and the Physical Ocean – Tutorial Script

Marine life in the oceans includes organisms of all sizes, shapes, and character – from the smallest bacteria and protists – single-celled heterotrophs and autotrophs visible through only the highest power microscopes – to the largest organism on planet Earth – 30 meters or 100 feet long – the Blue Whale. Each of these organisms interacts with and is affected by the oceans in different ways.

As you may remember from a previous lecture on seawater, the **viscosity** of water changes as characteristics like temperature and salinity change. Viscosity – a fluid's resistance to flow – plays a major role in how marine organisms of different sizes move through the oceans.

These glass vials are filled with different viscosities of engine oil. There is a gas bubble currently at the top of each. When we flip over the vials, we can watch the gas bubble rise through each one of these vials at different speeds. The higher the viscosity, the greater a fluid's resistance to flow, the longer it takes gas to move through the oil. The least viscous oil shows rapid movement of the air bubble. How does water's viscosity compare with these oils? Water is much less viscous than any of these oils, and to most of us it seems very fluid indeed. The same is true for most large marine animals – to them, the viscosity of the water seems quite low. To move even more quickly through water marine organisms have developed a number of special characteristics, including streamlined bodies, scales to minimize surface drag, oil to coat surfaces and minimize drag, retractable fins, powerful oxygen-rich muscles to provide propulsion, and aerodynamically shaped caudal or tail fins. The goal for all nekton – organisms that swim freely through the oceans – is to be able to overpower water's viscosity and minimize drag to increase speed.

[Video segment: This shape is not streamlined. As the liquid strikes the front or leading edge, pressure builds up, which causes resistance. Then as it rolls off the rear, it is thrown into spins or eddies, which create s suction behind the body. Regardless of shape some resistance is unavoidable. As the liquid goes by the shape, its direction of flow is changed, and this change of direction wastes power. By rounding off the corners, this change of direction is made more gradual so the amount of effort is decreased and resistance is cut down. Making the shape longer and thinner tends to cut down on resistance. This decreases the violence of the eddies and reduces the suction in the rear. With an even thinner shape, the liquid flows more easily and there are fewer eddies at the rear. A streamlined shape with blunt nose and tapering rear eases a hole with the least resistance and brings the liquid together at the rear with the least disturbance. The ideal streamline follows a strict geometric design which engineers call a parabola. The length should be just about three times the greatest width. Such streamlining makes it easier for an object to get through the air by reducing wind resistance. The higher the speed the more it helps.]

A lot of the same characteristics that allow marine organisms to swim quickly and minimize drag are the same things that world champion swimmers use. New swimsuits are designed to mimic scales. The fastest fish in the world's oceans is the tuna, and the scales of the tuna fish are similar to the texture on these new swim suits.

But what about microscopic organisms and floating seaweeds? These organisms have very different relationships with ocean viscosity. As this video shows, for a microscopic organism, the viscosity of seawater can feel quite strong, like what it would feel like for us to swim through honey. Small organisms can create so much drag when moving through the water that they can cause the other small organisms around them to be pulled along or spun around. Most planktonic organisms are not actually trying to move through water – they are simply trying to stay near the surface where they can get enough sunlight to perform photosynthesis – or where they can feed on each other. Plankton, because they cannot move faster than currents, want to maximize their drag to keep them afloat. They do so through a variety of techniques including emitting and floating in a drop of oil, having gas containers inside their bodies, or increasing their overall surface areas to maximize drag. They increase surface area by having many appendages, spines, hairs, holes, crevices, and long flat bodies. However, the best way to maximize drag is to just get smaller and smaller. This image shows us that as a spherical body gets larger, its surface area decreases relative to its overall volume. To get highest surface area per volume or weight, you want to be the smallest possible.

What adaptations have organisms made to increase **buoyancy**? There are a number of methods that nekton and plankton use to keep themselves afloat. Cartilaginous fish reduce their density with oil-rich low-density organs and low-density cartilaginous skeletons. Most bony fish balance their denser bony skeletons with an internal gas-filled organ known as a **swim bladder**. This organ is flexible and cigar shaped. It is filled with gas or emptied as needed to achieve neutral buoyancy at any depth. It's kind of like having a balloon inside your body that you can slowly fill and empty as needed. The only real drawback to this organ is that descents and ascents have to happen slowly to give the fish time to re-equilibrate pressures in their bladders to match those outside. If they ascend too quickly, such as when caught on a fishing line, their internal bladders will end up at much higher pressure than the outside environment, and the bladder will push outward and upward through the mouth, killing the fish. If fish with swim bladders descend too quickly, the pressure outside will exceed the pressure in their bladders, and the fish will be squeezed inward. Fish with swim bladders simply make sure they rise and fall slowly.

Another method of buoyancy is used by animals with hard shells. These shells can contain chambers called gas containers which fill with gas to keep the animal afloat. These organisms can rise and fall quickly through the oceans with no harmful effects unless they descend too deep. At high pressures the gas containers, because they are rigid, will be crushed, causing death to the animal. Organisms with gas containers include foraminifera and the chambered nautilus.

Pause now.

Marine organisms that live at depth have to be able to handle the increase of 1 atmosphere for every 10 m of depth. That means that at 1 km below the surface, the pressure is 100 atmospheres or 100 times surface pressures. How do these high pressures affect marine organisms? In addition to the potential crushing of rigid gas containers, any other rigid internal cavities can be crushed, if they are filled with only air. That includes ear drums, nasal cavities, and lungs. Scuba divers and other diving mammals such as seals and whales will remove as much air as possible from these cavities before diving. Whales have collapsible rib cases. After a depth of just under 100 meters, the rib cage will have completely collapsed and the lungs with them. There will be no more air remaining in these areas. Instead all the oxygen the organism needs is stored in hemoglobin in the blood and myoglobin in the muscles. This oxygen is not a gas and can be used as needed. Upon ascent, scuba divers have to worry about a problem known as the bends. The gas these divers have been breathing have been entering the blood stream and dissolving under pressures equivalent to the surrounding water pressures. When they ascend, these gases will exsolve out, forming bubbles in the blood. This process is similar to what happens when you open a soda can – the lower pressure makes the gas immediately bubble out. That can kill a human if it happens quickly like with the soda can. To prevent this from happening, scuba divers must ascend slowly, stopping periodically to allow the gases in their blood to exsolve out slowly and re-equilibrate. Note: this is not a problem for free divers, because they are not breathing oxygen when they descend. They use up all the available gaseous oxygen in their blood stream as well as most of that held in their hemoglobin. When they return to the surface, they have no gaseous oxygen to exsolve out. Marine mammals breathe air and have lungs, yet due to their unique abilities to store oxygen and collapse their rib cages, they can hold their breaths for long periods of time and have been known to dive to depths exceeding 2 km!

How does **changing light color and intensity** affect marine organisms? We know that the color and intensity of light change as we descend into the oceans.

Pause now.

Blue light is the light that remains the longest and descends the deepest before being completely absorbed. Red light is absorbed first. What that means, among other things, is that objects with red pigment will have no red light to reflect and will absorb all available light, looking black. That's a strategy used by some marine organisms that live in the lowest areas of the photic zone – by having red pigment, they appear black and thus fade into the surrounding darkness. It also has an important effect in the coastal waters, where green is the color that descends deepest. Since all photosynthesizing organisms have green as their primary pigment, what happens if this is their ONLY pigment and they are in a region where only green light is available? The green light will not be absorbed, and there will be no light available for photosynthesis. Organisms in these environments must have other pigments, known as accessory pigments, so that they have a way to absorb the green light. Seaweeds that live in these regions have either red or brown accessory pigments.

Pause now.

Another important effect of light availability is that photosynthesizing organisms can live only in areas of the ocean with at least 1% of surface light availability. We call this depth the base of the photic zone and the compensation depth for photosynthesis. Though there is still some minimal light available below this depth and thus photosynthesis can still technically occur, it is not enough light to make enough sugar to meet the photosynthesizing organisms own daily energy needs. Thus, no photosynthesizing autotrophs can exist below this depth. Large numbers of heterotrophs will rise above the compensation depth at night and feed on these photosynthesizers and on each other in the protection of darkness. During the day they descend back below the photic zone, just under the pycnocline, fleeing the light, where they hide and wait for the next night's feast. We call this large daily migration, the **deep scattering layer**, because it is such a large mass of organisms it can be detected by sonar. One of the major consequences of this behavior is the lowest oxygen levels in the world's oceans occur at the depth where these organisms hide during the day. Why? Because as they respire, they use up oxygen. There is no photosynthesis to replenish it. And because they are beneath the pycnocline, mixing is slow, so these levels get low and stay low.

There are some organisms in the oceans that can produce their own light. We call this light **bioluminescence**. It is usually produced by chemical reactions either performed by the organism itself or by bacteria living in an organ inside the organism. Light-producing cells are called photophores. This fish has a number of photophores lining its belly. Why? Countershading. When fish in the ocean look up, they see a small amount of surface light coming downwards. These photophores allow this fish to blend in with that light for any predator below it that is gazing upwards. Meanwhile, predators above it looking down see its dark top, which helps it blend in with the darkness below. Other uses of bioluminescence include luring prey, sighting prey (by producing light in an area that has none), luring or communicating with mates, distracting predators, making predators more visible to their own predators, and luring hosts (for the organisms that are looking to find their way into the intestines of other organisms). Please watch the video links on the website to see some of these examples in action.

How does **changing temperature** affect marine organisms?

We call organisms **ectothermic** if they have no internal temperature regulation, but instead have to use the external environment to regulate their temperature. You've probably also heard this called cold blooded – not a great term for most ectotherms, which have no blood, or might actually have very warm internal temperatures (think of a black marine iguana in the sun on a black rock). Ectothermic organisms include most fish, reptiles, and invertebrates.

We call organisms **endothermic** if they have internal processes that can be used to regular temperature. They have also been referred to as warm blooded. Endothermic organisms include mostly marine mammal and birds.

Ectothermic organisms in the ocean handle only very narrow temperature ranges. If temperatures get too hot or too cold, these organisms will migrate to a new location. If they can't they die. Too cold and metabolism shuts down, or even worse, fluids and cells freeze. Too warm and metabolism speeds up so much that organisms burn out and die. Endothermic organisms can handle all temperatures. These organisms can travel through and experience all the different temperatures in the ocean without detriment to their health. Since they maintain their own internal body temperatures, the outside temperature doesn't affect them. However, they do have to expend a lot of energy maintaining their internal furnace.

Ectothermic and endothermic are end-member descriptions of heat regulation. As you can imagine, in the natural world, there are organisms that sit somewhere between the two. For example, though in general, fish are considered ectothermic, tuna and the great white shark are considered endothermic because they use internal metabolic processes to raise their internal temperature higher than their surrounding environment. However, their internal temperature is also affected by their environment and fluctuates as they move through varying ocean temperatures.

Increasing temperatures can trigger more than just migration or death for those who can't migrate. Heat makes almost all chemical reactions happen faster. It increases the toxicity of pollutants in the water. It can also signal spawning.

Increasing temperature will decrease gas solubility, so there is less oxygen in the water for necessary respiration. It also decreases viscosity as discussed earlier. That means plankton will have a harder time staying afloat and need to find new ways to increase their surface area, like growing new appendages or spines or hairs or forming chains together.

What about ocean currents? How do these affect marine organisms? In the shallower areas of the world's oceans, where currents are strong, organisms like seaweeds, that can grow holdfasts onto the rocks, can benefit from a continually recharged zone of nutrients and oxygen transported by these currents. Larval organisms use currents to find new locations in which to grow new populations. Organisms that are fragile, though, and cannot survive the high energy of currents and waves, will have to find safer places to live so they aren't torn off rocks or pushed against them.

Pause now.
For more information and more detail, continue on to the next video in this series.

[end credits]

Living Ocean Video Series:
Part 1: Life and the Ocean's Physical Environment
Part 2: Life and the Ocean's Chemical Environment
Part 3: Marine Life Symbiosis

Life and the Ocean's Physical Environment
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