THE ENDLESS VOYAGE

"Water World" Episode 119

I have a quote here from a textbook by Karl Lagler in 1962 which I love to repeat, and I'd like to read it as best I can. The quote is "Water is highway, byway, communications, medium, nursery, playground, school, room, bed, board, drink, toilet and grave for a fish."

Water is a very different medium than air. Water is—just think of it as really thick. It takes a lot of energy to get a body through water.

I think what makes the oceanic environment so different than the terrestrial environment is that everything's in motion. If you imagine living a life where you were floating, and where everything around you was kind of moving and floating around, it would be a little disconcerting for us, I think. But that's the way it is in the ocean.

NARRATOR:
SINCE THE EARLIEST OF TIMES, THE OCEAN HAS HAD A SPECIAL ALLURE FOR PEOPLE EVERYWHERE. AS A WATERWAY THAT FACILITATES TRAVEL AND COMMERCE, A SOURCE OF FOOD, A PLACE TO ESCAPE SEARING TEMPERATURES, BUT ABOVE ALL ELSE, THE WORLD OCEAN PROVIDES A HOME TO COUNTLESS MARINE PLANTS AND ANIMALS—A HOME THAT PRESENTS AN EXTRAORDINARY MIXTURE OF CHALLENGES AND OPPORTUNITIES, QUITE DISTINCT FROM ANYTHING ON LAND.

STACY KIM, Ph.D., Moss Landing Marine Laboratories, CSU:
One of the big differences between the marine environment and terrestrial environments is that when you're in the ocean, you're surrounded by water, and that's very different being surrounded by a fluid than being surrounded by air.

SEAN CHAMBERLIN, Ph.D., Fullerton College:
It's a very three-dimensional type of environment, the ocean is. Whereas we kind of stay in a sort of horizontal plane in our terrestrial existence, we really don't get to move up and down in much of the three-dimensional sense. In terms of physical factors—of course there's extremes in temperature—they tend not to be as extreme in the oceanic environment as in terrestrial environments.

GREGOR CAILLIET, Ph.D., Moss Landing Marine Laboratories, CSU:
Temperature is probably not as big a factor as most people would think. Most fish are poikilotherms or cold-blooded organisms. That is, their body temperature is virtually the same as the water around them. Now there are exceptions to that. Tunas, bill fishes and some sharks actually have heat retention mechanisms built into their circulatory and muscular systems that prevent warm blood from the muscles going to the gills to get cooled. But most fishes are the same temperature. So the way I presume this works is

that the enzymes that these fishes use for their metabolism are adapted to the temperatures in which they live.

NARRATOR:
NOWHERE IS THE CAPACITY TO ADAPT MORE IMPORTANT THAN NEAR DEEP-SEA HYDROTHERMAL VENTS, WHERE TEMPERATURE EXTREMES ARE COMMON.

GEORGE MATSUMOTO, Ph.D., Monterey Bay Aquarium Research Institute:
The water's not incredibly hot down there. It's not the 400 degrees that some of the invertebrates are living in, but the surrounding waters are much, much warmer than the four degrees centigrade that you might get in the rest of the deep sea. But these fish have adapted to living in these hot waters. You've also got fish that are well adapted for living in extremely cold environments. For instance, there are fish that live in the Antarctic, and in the Artic waters, and they've adapted for their cold environments, and the way they do that is they actually put a form of ethylene glycol into their blood—anti-freeze, the same as we put into our cars, they've got in their bloodstreams—and that keeps their blood from freezing up in these extremely cold environments.

NARRATOR:
WHILE MANY FISHES HAVE THE CAPACITY TO ADAPT TO THE TEMPERATURE IN WHICH THEY FIND THEMSELVES, OTHERS APPARENTLY DETERMINE THAT IT'S SIMPLY EASIER TO MOVE AS TEMPERATURE CHANGES OCCUR.

CHAMBERLIN:
Most fishermen know that fish tend to follow certain temperatures of water, and during periods of El Niño, we find billfish and barracuda even as north as Puget Sound, up in the Seattle area, places where we would normally not see those types of animals at all.

NARRATOR:
IT IS ALSO BELIEVED THAT TEMPERATURE PLAYS A KEY ROLE IN DETERMINING THE DEPTH AT WHICH MARINE ORGANISMS CHOOSE TO LIVE.

CHAMBERLIN:
As you go deeper in the ocean, it gets very cold. The very deepest waters—the bottom waters—on average are about two degrees centigrade, perhaps even lower in Polar Regions, and so there's a whole different set of adaptations for organisms to survive in those types of environments.

CAILLIET:
It's known that young stages tend to be surface dwellers, and therefore live in warmer water, and as they get older, they move deeper and deeper. If they're a water column species or a bottom species, there are species-specific patterns of depth utilization by these animals. We don't know if they choose them or if they're just more comfortable

there, or if they go someplace where it's too warm or too cold, they tend to metabolize too much or too little. But there are definitely depth-specific patterns by species of fishes in the ocean.

NARRATOR:
OCEAN DEPTH IS IMPORTANT NOT ONLY BECAUSE OF ITS IMPACT ON TEMPERATURE, BUT ALSO BECAUSE AS DEPTH INCREASES, SO TOO DOES PRESSURE.

One atmosphere of pressure is equivalent to 33 feet of water in the ocean. So every 33 feet, we're adding another atmosphere pressure.

The organisms down in the deep sea have adapted to this. They do extremely well at this.

BRUCE ROBISON, Ph.D., Monterey Bay Aquarium Research Institute:
At one level we can say that deep-sea animals are adapted to their habitat because they have evolved enzyme systems that function well under high pressure that wouldn't function well under low pressure. Another way that animals living in the deep sea are uniquely adapted to their habitat involves their ability to respire—to take up oxygen from the habitat.

CAILLIET:
Oxygen is required for aerobic metabolism, and fishes have a very tough job of extracting oxygen that's dissolved in seawater, and having it go by their gills in a very efficient way whereby there's a counter-current exchange mechanism, and the gasses in the water are diffused into the blood in the gills. It's a very tough job and they pump a lot of water over their gills to do so.

ROBISON:
Seawater contains only about three percent of the oxygen that air contains. So extracting oxygen from seawater is a big challenge to begin with. And if you go deep in the water column, the oxygen content drops off considerably.

NARRATOR:
AREAS IN WHICH OXYGEN FALLS BELOW ABOUT ONE-HALF MILLIMETER PER LITER OF WATER ARE KNOWN AS OXYGEN MINIMUM ZONES.

LISA A. LEVIN, Scripps Institution of Oceanography, UCSD:
Oxygen minimum zones occur beneath areas of very high surface productivity, but this alone is not sufficient to create oxygen minimum zones. One needs a combination of high phytoplankton production, sluggish circulation and oxygen-poor source waters all come together. We tend to find these along much of the Eastern Pacific Margin, and through much of the Arabian Sea and Bengal Sea in the Northern Indian Ocean. There's also a small well-developed oxygen minimum zone off Namibia.

NARRATOR:
WHILE OXYGEN MINIMUM ZONES DO PRESENT SERIOUS CHALLENGES, FISHES THAT LIVE IN THE DEEP SEA HAVE FOUND WAYS TO MEET THOSE CHALLENGES AND SURVIVE.

LEVIN:
Animals faced with life at very low oxygen levels have evolved some unusual morphologies. Very often there's a proliferation of surface area, and we'll find animals with all sorts of elaborate tentacles and branchae developed to increase the surface exposed to the limited oxygen. Some animals will develop hemoglobin in their blood, which facilitates the oxygen uptake. Often we'll see clams, which normally are not red in other places, full of hemoglobin in low oxygen zones.

And they can scavenge oxygen—they can pull oxygen from the water even when the oxygen content is extremely low. Again, these are adaptations that wouldn't work very well in shallow water, because of the animal's blood and the cells would become over-saturated with oxygen, and under certain circumstances, that could be just as bad as not having enough oxygen. So we see adaptations—physiological adaptations and cellular adaptations—that are critical to survival.

NARRATOR:
JUST AS OXYGEN AVAILABILITY TENDS TO VARY ACCORDING TO DEPTH, SO TOO DOES THE AMOUNT OF LIGHT THAT'S PRESENT.

MATSUMOTO:
It only penetrates in the oceans down to maybe 200 meters if you have clear water. And in more turbid waters, it doesn't even get down that far. Fishes require light for—to see their food, to avoid predators, for finding mates, communication. We know a fish can survive without light, because there are plenty of fish in the deep sea, but they've evolved whole separate ways of communicating and dealing with the fact that there isn't as much light down there. We're learning new things constantly about light, and how fishes see. For instance, in the past 10 years, researchers have finally figured out that fish in the ocean can see in the ultraviolet. Ultraviolet is something that only penetrates maybe 12 inches, 24inches in the oceans, and doesn't get down into the deeper waters. But the shallow water estuary fish and shallow water ocean fish are certainly using that ultraviolet light.

CAILLIET:
As you get down in the water column maybe only 100, 200 meters—at that depth these fishes will have to have pigments in their eyes, in their retinas, that allow them to pick up lights that are totally different than what and I as human beings would see. So vision is one of the very obvious adaptations that marine fishes have had to modify in terms of light reception.

NARRATOR:
ALONG WITH TEMPERATURE, THE AVAILABILITY OF LIGHT APPEARS TO PLAY A KEY ROLE IN WHERE FISHES CHOOSE TO LIVE IN THE WATER COLUMN.

CAILLIET:
You have epipelagic, or surface-dwelling fishes, like tunas or billfish that live near the surface most of the time and have visual pigments that can pick up the wave lengths that come closer to what the sun produces. And then as you go deeper and deeper in the water column, whether it's along the shore or in kelp forests, or in rocky intertidal habitats, or to the deep sea, you tend to have differences that occur in these fishes. They evolve bigger eyes. They have different visual pigments. And those that live at those depths tend to stay at those depths and don't vertically migrate.

NARRATOR:
STILL ANOTHER ASPECT OF THE MARINE ENVIRONMENT THAT HAS A SIGNIFICANT IMPACT ON FISHES IS THE SALINITY OF OCEAN WATER.

If you're born in the ocean, you live in the ocean, you die in the ocean, most organisms can balance that salinity fairly well.

The range in salinities around the world's ocean is not huge. It ranges from probably 31 or 32 parts per 1000 of salt in the water to up to perhaps 35 parts per 1000. So therefore in the ocean, in the marine realm, salinity is probably not a major factor. It doesn't vertically change much. It increases with depth, but not in any radical way. Certainly not as much as you would see for a salmon or a trout that was heading upstream to spawn or leaving a stream after it was a young one to go to the ocean, where it goes from freshwater to salt and back. So in that sequence, you have a tremendous change.

And the amount of physiological changes that they have to undergo in order to adapt to the change in salinity as they go back and forth is extreme.

MILTON LOVE, Ph.D., University of California, Santa Barbara:
Fishes that find themselves in salt water and fishes that find themselves in fresh water face equivalent but opposite issues. Fishes that live in saltwater face the issue of, "How am I going to get rid of all the salt that's pouring into my body?" Fishes that live in fresh water face the issue of, "How am I going to keep the small amount of salt in my body that I really need to function, because I'm surrounded by all this fresh water?" And they handle the problem in opposite ways. Fishes that live in salt water want to get rid of salt like crazy, because water is coming down their throats. Every time they feed, for instance, they take in salt water with their prey and salt water is full of salt. So their kidneys are highly evolved to push salt out as fast as possible.

MATSUMOTO:
And so what they end up with is extremely concentrated urine, and they're dumping out a lot of the salts through their gills and through their urine.

NARRATOR:
THE FLOW OF WATER AND SALT INTO OR OUT OF A FISH'S BODY IS DRIVEN BY A PROCESS KNOWN AS OSMOSIS, WHICH INVOLVES THE DIFFUSION OF LIQUID FROM AN AREA OF HIGH WATER CONCENTRATION TO AN AREA OF LOWER WATER CONCENTRATION THROUGH A SEMI-PERMEABLE MEMBRANE.

SEAN CHAMBERLIN, Fullerton College:
A fish living in freshwater will then be saltier than the water around it, and there will be a tendency for that fresh water to move into the fish, because there's a higher concentration of salts inside the fish than there are outside the fish. That's a problem for a fish. It would tend to make that fish expand and blow up if it didn't have some means for getting rid of that excess freshwater. If you look at the other side of it, a fish in salt water, the fish itself is actually less salty than the saltwater environment in which it lives, and so there will be a tendency for that fish to lose water. So a fish in saltwater is going to have a tendency for water to flow out of its body, which again could be a problem. So they have to take measures and have to adapt certain means, physiological means, keeping that water inside their body.

NARRATOR:
ALONG WITH SALINITY, THE BALANCE BETWEEN ACIDITY AND ALKALINITY OR THE PH IS ANOTHER ASPECT OF SEAWATER CHEMISTRY THAT CAN HAVE AN IMPACT ON FISHES.

KATHERINE BARBEAU, Ph.D., Scripps Institution of Oceanography, UCSD:
The PH tends to be more basic in surface waters. PH is increased by photosynthesis because plants take up CO_2. That increases the PH of seawater. So you see maximum in PH in surface waters. Then as you go down with depth, you get a decrease in PH due to respiration—production of CO_2.

GEORGE MATSUMOTO, Ph.D., Monterey Bay Aquarium Research Institute:
It is a very active area of interest, because with ideas of sequestering carbon dioxide down at the ocean, this has the potential of actually changing the PH over the ocean over the next few dozens of years or so. And while it doesn't seem extreme—we're looking at maybe half a PH change—the PH scale is a logarithmic scale. So we're really looking at a fairly major shift. And some of the things we're finding out, particularly for the deep-sea fish is that even a half a PH change could have dramatic effects on the physiology. One of the effects in particular is an oxygen uptake. And this will be particularly important to fish, but also applies to other invertebrates as well. If you lower the PH by half a PH unit, the ability to bring in oxygen or take up oxygen is cut in half.

NARRATOR:
WHILE THERE ARE ASPECTS OF THE OCEANIC ENVIRONMENT THAT PROVE DIFFICULT FROM TIME TO TIME, ONE OF THE MOST CONSISTENTLY

CHALLENGING AND PERVASIVE IS WHAT SOME DESCRIBE AS THE TEXTURE OF THE WATER.

GREGOR CAILLIET, Ph.D., Moss Landing Marine Laboratories, CSU:
Fishes, to swim through viscous, dense water—and salt is even more dense that freshwater—have to push themselves through molecules that are very dense and viscous. Therefore, there's a lot of friction drag.

CHAMBERLIN:
If you want to think of it as this stickiness of seawater it's really thickness, in a sense. I think the best way to understand viscosity is to think about how much easier it is to run on land than it is to try to run through water.

There's a lot of frictional components there that an animal that lives in air doesn't face. Just try running your hand through your bathtub water and then lift your hand up and run it through the air. It takes more energy to get through the water. And most fishes, they face this problem every single second of their lives. How are they going to through the water, through this very viscous medium?

MATSUMOTO:
For very big things that move very fast, viscosity almost disappears. For very small organisms, viscosity is the dominant force. It is the biggest thing that constrains everything they do. 'Cause when you're living in a bath of molasses or honey, how do you find food? How do you get from one place to another? It becomes very difficult to move. It becomes very difficult to do anything.

NARRATOR:
DIFFICULT, BUT NOT IMPOSSIBLE, THANKS TO A HOST OF ADAPTATIONS THAT ENABLE MARINE ORGANISMS TO FUNCTION IN THIS CHALLENGING ENVIRONMENT.

Fishes, in particular fast fishes, some of which can travel up to 70 miles per hour in the ocean—the very fast tunas and marlins and those types of fishes—they have adaptations really that streamline their bodies and to try reduce viscous forces on their bodies so that they can swim more rapidly through the medium.

LOVE:
So how are they going to do that without expending huge amounts of energy? Because really in evolution, that's the key. How do you do what you want to do expending the least amount of energy? And there's huge selective pressure to do that, to be as efficient as possible. So how do fishes do things most efficiently dealing with this very difficult medium? Well, the first thing is, for those fishes that have to move a lot you can reduce the amount of friction on your body. You can cut down the size of your scales. Scales stick out and produce a lot of friction. There are fishes that have no scales. They've taken it all the way down there. You can have your fins which stick out and produce friction, tuck down into little folds. If you look at a tuna when it's swimming fast, the

fins on its sides, the pectoral fins, fit really neatly into little grooves so that it's smooth along the sides of its body. So you can reduce friction that way. You can produce mucus, most fishes do that, which also reduces viscosity between your body and the water. So that's certainly a way of being able to move through the water in a more efficient way.

NARRATOR:
ANOTHER ELEMENT THAT ADDS ONE MORE CHALLENGE TO THE MIX OF CONDITIONS THAT FISHES MUST FACE IS TURBULENCE.

CHAMBERLIN:
Turbulent environments are the kind that you might encounter in coastal regions, where you have breaking waves. Or if you're living on a rocky shore, with waves breaking—it would be very highly turbulent. This turbulence would tend to want to rip you off the rock if you were an animal living on the shore. And some of these animals living on rocky shores in particular again have adaptations that help dispel those forces and help prevent them from being ripped off the rock, whether it's having a very strong glue like in the case of barnacles that are, you know, literally just one of the strongest glues in the world, that glue them to the rocks, or having sort of, kind of amorphous body that can kind of move with that turbulence as well.

NARRATOR:
ONE OF THE FACTORS THAT IN PART DETERMINES THE AMOUNT OF TURBULENCE AT A GIVEN LOCATION IS DEPTH.

BRUCE ROBISON, Ph.D., Monterey Bay Aquarium Research Institute:
The deeper you go in the oceanic water column, the more the environment becomes calm. Up near the surface it can be very active. Wind-driven circulation and things like that make a very challenging environment for an animal to hold position or to move through. But as you go deeper, things calm down. And in very deep water, below 1000 meters, there is very little water to struggle against.

NARRATOR:
LIGHT, TEMPERATURE, PRESSURE, SALINITY, VISCOSITY, TURBULENCE—EACH OF THESE PLAYS A PART IN DEFINING THE OCEANIC ENVIRONMENT. AND IT IS AGAINST THIS DIVERSE BACKDROP OF CHALLENGING AND DYNAMIC ELEMENTS THAT THE ANIMALS OF THE WORLD'S OCEAN WAGE A DAILY BATTLE FOR SURVIVAL. SCIENTISTS WHO ATTEMPT TO CATEGORIZE OR CLASSIFY THE DIFFERENT AREAS WITHIN THE MARINE ENVIRONMENT FACE A CHALLENGE OF THEIR OWN WHICH, WHILE CERTAINLY NOT A MATTER OF LIFE OR DEATH, IS NONETHELESS CONSIDERABLE.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
Classifying the marine environment; there are multiple ways of doing it. There's never been, at least to my knowledge, a universally acceptable classification of the marine

environment. You could say, "Well you can classify the marine environment into those things that live in the water column, and those things that live on the bottom." That's one way—pelagic and benthic. You could also classify them by depth. Those that live on the surface, those that live in mid-water, those that live in deeper water. It's just going down and going through layers of water. And in fact, that has been done, and people talk about the various depth zones. And someone will say, "Well I worked in the mesopelagic." What does that mean? That means that you work in a mid-water area that's between 700 and 1000 meters deep—let's say something like that. So you could classify them that way.

You could classify the marine environment like you classify the terrestrial environment. They could say, "We could talk about polar marine environments, we could talk about temperate marine environments, we could talk about tropical marine environments." So there's all these different ways of doing it. And each one has a certain validity, depending on what you're trying to get across.

NARRATOR:
AS DIFFICULT AS IT MAY BE TO CATEGORIZE THE VARIOUS REALMS OF THE MARINE ENVIRONMENT, IT IS PERHAPS EVEN MORE DAUNTING TO CLASSIFY THE 25 TO 30,000 SPECIES OF FISHES THAT LIVE IN THAT ENVIRONMENT.

One of the things we really want to do besides trying to find out as much as we can about the ocean environment, is part of that is learning what's in the ocean. And we can't really understand, or even begin to comprehend the ecosystem, unless we know who the players are.

SEAN CHAMBERLIN, Ph.D., Fullerton College:
Life in the ocean is classified really in the same way as we classify all life. We break life into categories that make it easier for us to understand the relationships between organisms. Not only the relationships in terms of whether they get along or don't get along, whether one's eating the other or not, but also sort of their evolutionary relationships.

NARRATOR:
ORGANIZING ANIMAL LIFE BY PHYLA IS PERHAPS THE MOST COMMONLY PRACTICED FORM OF CLASSIFICATION.

DONAL MANAHAN, Ph.D., University of Southern California:
There are currently approximately 35 different animal phyla on earth. I'll give you an example of a phylum. The phylum arthripoda, the arthropods. This would include insects, that would include crabs, lobsters—that's an example of a grouping. Echinoderms, the sea urchins, the sea stars—would be an example of another phyla.

CHAMBERLIN:
The simplest organisms that we find in the ocean are probably the sponges. Very simple organisms, but they seem to be the first ones that arose—the first multi-cellular organisms that arose in the oceans. The most complex, of course, are the whales and the sea lions and the marine mammals. And we have, you know, major groups in between, the Cnidarians being the jellyfish, sea anemones, the mollusks, the bivalves and clams and those types of things—shells. And then some more advanced protochordates—if you want to think of the things just before moving into the vertebrate kingdom—we also find as well in the oceans. So just about every type of organism we find on land we do find some representative in the oceans.

NARRATOR:
WHAT MAKES THE TASK OF CLASSIFYING OCEAN LIFE EVEN MORE COMPLICATED IS THAT SCIENTISTS ARE STILL DISCOVERING NEW SPECIES.

GEORGE MATSUMOTO, Ph.D., Monterey Bay Aquarium Research Institute:
We know all the whales in the world, or so we thought. In the last 20 years, we've now described two new species of whale. Whales—these are air-breathing animals that come up to the surface, usually live close to shore, and we've got two new ones just in the last 20 years. One of those, which lives off the California coast, we've described only from specimens that have washed ashore from bones that were recovered. Nobody's seen it yet. Nobody's seen it alive. And so, that's in the surface waters, where thousands of people are going out to the beach or in boats. Now you take that same problem and you go down into the deep waters, and you'll start to get an idea of the magnitude of the problem. We don't know what's living down there. There are large squids that we've seen just in recent cruises. We've now got 15 new species of large deep sea squid that have been recorded by remotely operative vehicles by cameras and video only. We still have no specimens. And those are just sort of the large animals. When you think about some of the smaller organisms, you know, there are just, who knows how many out there that haven't been described. And as we go down there and we find new species, it just becomes clear to us that the ecosystem is much more complex than anybody had ever imagined.

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