THE ENDLESS VOYAGE

"Life Goes On" Episode 122

The petrels, the shearwaters, the albatrosses—all these particular severely marine birds can also fly at night, with no moon and no starlight, over the surface of the ocean for hundreds of miles. We don't know how they sense where the ocean is, how they don't fly into it.

I think, possibly, one of the reasons that the dolphins still survive—these bottlenose dolphins—is because they're very, very intelligent. And they've worked out a relationship with us that basically works like this: they just stay out of our way. If we're around, there's too many of us, they leave and they go somewhere else.

You can think of me as a—as an Anglican Vicar in 1890 who only had to give a sermon on Sundays and spent the rest of his life looking at spiders in his backyard. And he knew a lot about spiders at the end of 50 years. Well, that's what I do. I look at the lives of fishes, where they go, how fast they grow, how long they live, what they eat, how they feel about life—that's a hard one because fishes are really dumb.

NARRATOR:
MARINE VERTEBRATES ARE THE WORLD'S LARGEST ANIMALS. VERTEBRATES CAN SWIM FASTER, DIVE DEEPER, FLY FARTHER, GENERATE MORE POWER, AND YIELD GREATER COMMERCIAL VALUE THAN ANY OTHER OCEAN CREATURES. AND THEIR BRAINS ARE LARGE AND ACTIVE. MARINE BIOLOGISTS INFORMALLY CLASSIFY MARINE ANIMALS INTO TWO LARGE GROUPS—INVERTEBRATES AND VERTEBRATES. VERTEBRATES HAVE BACKBONES WHILE INVERTEBRATES DON'T. THERE ARE FAR MORE INVERTEBRATES THAN VERTEBRATES IN THE OCEAN. BUT THE VERTEBRATES, WHICH INCLUDE FISHES, REPTILES, BIRDS AND WHALES, USUALLY GET MOST OF THE ATTENTION.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
This is a classification of convenience. And it also reflects the extreme bias we have as human beings. This is not a scientific classification at all. It's just a classification that says, "Well we are vertebrates because we have a backbone. We have a spinal cord. And so everything that has a spinal cord is a vertebrate. Everything that doesn't is an invertebrate." There are some 34 phyla in the world today—animal phyla in the world. Of those 34, only one has vertebrates in them. And that's the chordates. Now the chordate phylum is defined by having gill slits of some stage in its life history; a notochord, which is a strengthening rod running down the dorsal side of the animal; and a dorsal nerve cord. Those are the three defining features for the phylum chordata. But the phylum chordata contains invertebrates because not all of the chordates have, as adults, a backbone.

WILLIAM HAMNER, Ph.D., University of California, Los Angeles:
The term vertebrates refers to a group of animals that we belong to 'cause we're vertebrates and we have a backbone, but we are also in the same taxonomic category, the same phylum as sea squirts, for example—animals that don't look much like complex chordates at all. We're a small branch taxonomically of a very important phylum of invertebrates, but we're not that different from many of the other members of our phylum. One of the interesting sort of invertebrate chordates are animals like amphioxus. It's this tiny filter feeding, fishlike animal that burrows backwards into the mud and sticks its head out and pumps water across its gills. And the gills secrete mucous and the mucous trap particles and then they swallow the particles with the mucous. Apparently the gill apparatus of a fish—and fish were our ancestors—evolved from this filter feeding cavity that some of these strange little invertebrate chordates exploited very thoroughly.

NARRATOR:
SO THE PHYLUM CHORDATA, THE PHYLUM TO WHICH WE OURSELVES BELONG, HAS BOTH INVERTEBRATE AND VERTEBRATE REPRESENTATIVES. THE MARINE VERTEBRATES ARE DIVIDED INTO FOUR GROUPS: FISHES, REPTILES SUCH AS SEA SNAKES AND TURTLES, BIRDS AND MAMMALS. BY FAR THE MOST SUCCESSFUL OF THE VERTEBRATES, WITH MORE SPECIES THAN ALL THE OTHER VERTEBRATE CATEGORIES COMBINED, ARE THE FISHES.

MILTON LOVE, Ph.D., University of California, Santa Barbara:
I think people who look at evolution don't think in terms of up or down, things are more advanced or less, but on a continuum of sort of advanced characters, then fishes are quite along the way toward some of the most advanced organisms. And the very primitive ones, there are very few left. The fishes without jaws for instance—hagfishes and lampreys. So what we see primarily now are the results of hundreds of millions of years of evolution and fishes have some just exquisite adaptations to the environment they live in. Generally considered the most advanced, the bony fishes—the osteichthyes—which include most of the fishes that we think of as fishes. If you think of a fish, you think of a swordfish or you think of a sunfish or you think of a trout. That group of animals are considered the most advanced.

GREGOR CAILLIET, Ph.D., Moss Landing Marine Laboratories, CSU:
Two features of water, viscosity and density, make life for a fish a bit more difficult than if they were terrestrial or lived in an aerial or atmospheric environment. Fishes, to swim through viscous, dense water—and salt is even more dense that fresh water—have to push themselves through molecules that are very dense and viscous. Therefore there's a lot of friction drag. So fishes that need to move fast have evolved lots of adaptations such as streamlining, length, flexible caudal fins or tailfins, high aspect ratios—which would be similar to a wingspan on a plane but in a vertical way with a fish tail—scales, mucous—various things that make them more adapted to fast swimming. Now the diversity of fishes is extremely high, ranging up to and probably higher than 25,000 species in the world's oceans—including fresh water for that matter. And in those environments the diversity of different locomotory adaptations or anatomies is extremely

broad. So you have trunkfishes that just hover and don't move anywhere. You have sculpins that live on the bottom near rocky intertidal zone and don't move. You have flat fishes that do the same. But then you have tunas and billfishes and sharks and fast swimming things like small anchovies and sardines.

And for some fishes, for instance the great pelagic fishes, the tunas and the billfishes, they have to move all the time. 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. Now some animals stay near the surface just by swimming all the time, but that takes a lot of energy and you have to be a very specific kind of fish to do that. Most fishes when they want to stay above the bottom, they use a swim bladder. Swim bladders—think of them as big balloons inside of your body. Having that little balloon of gas allows you to do is to regulate your buoyancy, and many fishes are very good at that to the point where they will put just the amount of gas into their bodies that will allow them to be neutrally buoyant, so that they neither rise nor sink.

NARRATOR:
SWIMMING AND MAINTAINING LEVEL IN THE WATER COLUMN ALLOW FISHES TO TRAVEL LONG DISTANCES TO LOCATE MATES, TO EAT AND AVOID BEING EATEN. AS A GROUP, MUCH OF THEIR SUCCESS DEPENDS ON THEIR FINELY TUNED SENSES.

GEORGE MATSUMOTO, Ph.D., Monterey Bay Aquarium Research Institute:
There's not light down there yet most of the deep-sea fish have eyes. What are they using their eyes for? Most of the things in the deep sea make their own light. That's called bioluminescence. They have the ability to make their own light. And a lot of these fish are using that light to find food. They're using that light to find each other, to find mates in the deep sea. They're using that light to communicate with each other, to scare each other off, to get rid of predators.

One of the important things to talk about when discussing how fishes survive in the ocean is their sensory mechanisms. Vision comes to mind. Smell or chemoreception comes to mind. But fishes have a fairly unique system called a lateral line system, which is a series of pores and canals along the body and sometimes on the head that allow them to pick up movements of water either from prey or even from just currents.

NARRATOR:
SHARKS GENERALLY HAVE HIGHLY DEVELOPED SENSORY SYSTEMS. THEY ALSO HAVE AN UNDESERVEDLY BAD REPUTATION. MORE THAN 80% OF SHARK SPECIES ARE LESS THAN TWO METERS LONG. AND ONLY A FEW OF THE REMAINING 20% ARE AGGRESSIVE TOWARD HUMANS. THE LARGEST SHARKS ARE AMONG THE LEAST DANGEROUS TO HUMANS, REACHING LENGTHS OF 18 METERS—60 FEET—IMMENSE WARM-WATER WHALE SHARKS CRUISE THE OCEAN SURFACE FEEDING ON PLANKTON AND SMALL FISHES. AS DIVERSE A GROUP AS FISHES ARE, IT'S NOT SURPRISING THEY HAVE EVOLVED AN IMPRESSIVE ARRAY OF DEFENSE STRATEGIES.

Defensive mechanisms in fishes, in marine fishes are highly diverse as well. They range from being large and being predatory—like a white shark. They don't have to worry about—too much about defending themselves. But their prey do. And their prey, in defending themselves, would probably be much better off if they couldn't be seen by the predator, i.e. camouflaged, or if they had some mechanism that made them less palatable to the predator, for example, spines. Rockfish on this coast are not commonly eaten by white sharks for example, because they're spiny.

Certainly camouflage of various sorts are high on the list for almost all fishes, but camouflage can take many, many different forms. As an example, pelagic fishes, fishes that live near the surface of the water in the open ocean are always counter-shaded, that means that their backs are dark and their bellies are silvery. And that's because when you look down in the open ocean, you see the dark water and their dark backs, and they blend in. When you're underneath them and you look at their bellies, you see a silvery belly against a shimmery sky, essentially. Well, this wouldn't be any good at if you lived on a coral reef. If you live on a coral reef, you live in this sort of phantasmagoria of shapes and colors and motion. And you can see that the fishes that live there tend to have what's called—often called clown decoration or clowned camouflage, where you have spots and you have stripes and you have five or six different colors all merging together in what to looks likes to us, is a very striking pattern. But if you put it against a coral reef it blends in very nicely. So those are sort of, in a way, sort of passive ways of avoiding predation. And then there's a whole slug of active ways. At most extreme you have things like flying fish, which will just leap out of the water to escape a tuna or a billfish. And of course flying fish don't fly, they actually gain tremendous speed under the water, they hit the surface and they actually glide.

MATSUMOTO:
Schooling is a very visual defense, where what you're trying to do is you're trying to trick the predator into losing track of you. They can't find you, or they get so distracted by other fish around you. It's a very effective way of protecting theirselves. And you'll find a large variety of different organisms that do that from birds that fly up in the air to swarms of insects, to schools of fish in the deep sea.

NARRATOR:
WHILE FISHES ARE THE MOST SUCCESSFUL AND ABUNDANT MARINE VERTEBRATES, REPTILES ARE THE LEAST SUCCESSFUL. THAT IS, REPTILES REPRESENT THE FEWEST NUMBER OF SPECIES AND INDIVIDUALS. THERE ARE THREE KINDS OF MARINE REPTILES: SEA TURTLES, MARINE CROCODILES AND SEA SNAKES. ALL EIGHT SPECIES OF MARINE TURTLES HAVE STREAMLINED SHELLS AND RANGE OVER GREAT DISTANCES TO FEED ON MARINE PLANTS OR JELLYFISH. THEIR FORELIMBS PROVIDE POWER FOR SWIMMING. WHEN SEXUALLY MATURE, THEY RETURN TO THE BEACHES WHERE THEY WERE HATCHED TO MATE AND TO LAY EGGS. HOMING BEHAVIOR IS A GREAT ADVANTAGE TO AN ANIMAL. IF THE PARENT SURVIVED ITS EARLIEST CHILDHOOD AT THIS LOCATION, IT WILL PROBABLY BE A SUITABLE PLACE TO HATCH THE NEXT GENERATION. TERRIFYING THOUGH THEY ARE, MARINE CROCODILES ARE ALSO ENDANGERED. LIVING IN THE TROPICAL WESTERN PACIFIC AND REACHING A LENGTH OF SEVEN METERS—23 FEET—THESE EXTREMELY AGGRESSIVE FAST-ATTACKING REPTILES HUNT IN PACKS. THEY HAVE HEAT SENSORS IN THEIR MOUTHS, AND SOMETIMES MOVE ASHORE TO CONSUME ANY LARGE WARM-BLOODED ANIMALS THEY CAN FIND. BIRDS PROBABLY EVOLVED FROM REPTILES, AND MARINE BIRDS ARE AMONG THE MOST HIGHLY SPECIALIZED OF ALL VERTEBRATES.

TOM GARRISON, Ph.D., Orange Coast College:
Most people don't have any trouble telling a marine bird from a land bird. A pigeon that lives underneath a pier is not a marine bird. A marine bird, generally speaking, has its feet closer to its back end than a land bird. Think about it—a chicken stands like that with its feet in the middle. A marine bird has to stand up this way. Marine birds—the reason for that, by the way, is because the marine birds have to put their—have to be as streamlined as possible for a long distance, low energy flight. And so their fuselage, so to speak, has to be well faired. Aerodynamics have to be very good. So if your feet are aft a bit, you can kind of nuzzle them up into the feathers and get them out of the slipstream. Marine birds, you'll also find, don't swivel their necks around an awful lot. There's not a lot of neck twisting going on, especially during flight in marine birds. They tend to stay very streamlined, focused on task and there's not a lot of interruption of the airflow. They also have a very high aspect ratio wing. A pheasant, for example, or a chicken, has a wing that's not awfully long relative to its width, its fore-to-aft distance. But a seagull, or especially an albatross, has a superb wing.

NARRATOR:
THE EFFICIENT WING SUPPORTS A LOW MASS BODY. A MARINE BIRD IS EXTREMELY LIGHT, WITH FINE, HOLLOW BONES, AND COVERED BY FEATHERS THAT CAN ACTUALLY WEIGH MORE THAN ITS SKELETON. NOT ALL MARINE BIRDS FLY THROUGH THE AIR. PENGUINS, FOR EXAMPLE, CAN ONLY FLY THROUGH WATER.

GARRISON:
So they can be really gristly, and beefy little guys. And they weigh as much as an equivalent volume of water. They're neutrally buoyant. They have little peg-like feathers that don't look like feathers at all. They're highly modified feathers. And they fly very effectively through the water with scythe-like, very fibrous wings. Their maneuverability is beyond belief. They can do a 90-degree turn—I've seen some videos of them—90 degree turns in nothing. They just turn. They don't seem to have any mass. They're amazing. And they're of course a marine bird, fully a marine bird. Probably the most remarkable group of marine birds are the tubenoses. It's not a very good name for them. It's a boring name, but they're great birds. Things like albatross's fit into this category. They are called tubenoses because they have very obvious tubes in their nose—in their beaks. And the tubes are used for a couple of things. First, to allow them to smell, in some cases, 100 kilometers downwind, the oils—volatile oils of squid, and they can track by dynamic soaring upwind to where those squid are and dip the squid at the surface of the ocean without landing on the ocean. They can land in some cases, but they can actually fly along the surface and just pick the squid out of the surface of the ocean and eat them while they're still flying. These animals don't need any water. They can extract fresh water from their food or from dipping seawater out of the ocean. It's just astonishing, plus they can stay aloft, and some of the albatrosses, like the great wandering albatrosses, can stay aloft for at least a month. We know that because the batteries in the transmitters that have been strapped to their backs last about that long satellite linked. But they don't have to land. They can land, but they choose not to most of the time. Because if you have a 13-foot wingspan, taking off from the surface of the ocean is really dicey, and they tend to just dip the food out of the surface unless it's extremely calm and then they will land for brief rest periods. They prefer to fly.

NARRATOR:
THE MOST HIGHLY SPECIALIZED MARINE VERTEBRATES ARE THE MOST UNLIKELY—THE MARINE MAMMALS. EACH GROUP OF MARINE MAMMALS EVOLVED FROM LAND ANCESTORS BEGINNING ONLY ABOUT 50 MILLION YEARS AGO. ADAPTATION TO LIFE IN THE OCEAN NECESSITATED DRAMATIC CHANGES IN APPEARANCE AND FUNCTION—THE REMARKABLE STORY OF WARM BLOOD IN THE COLD OCEAN.

DENNIS KELLY, Orange Coast College:
Mammals are large, warm-blooded animals that have hair or fur on their body at least in sometime in their life. They all give birth to live, usually precocious young. The young—and this is why they're called mammals—are nursed by the females from mammary glands. Aquatic mammals, mammals that live in fresh water or salt water, are different from land animals because they have to have special adaptations that land mammals don't need. For instance, water conducts heat a lot better than air. So marine mammals have to have ways to hold on to their internal heat that land mammals don't. So many marine mammals, for instance, have big, thick layers of blubber to keep the heat from going out. Also, because water is much denser than air, it's difficult to move through water fast. And so they have to have all kinds of special adaptations to allow them to overcome the friction of water. In the case of the dolphins, they've gone the

furthest of all. They've completely lost their rear limbs and the rear part of their body is this huge fish-like tail, although their tail is horizontal whereas most fish have a vertical tale.

JIM HARVEY, Ph.D., Moss Landing Marine Laboratories, CSU:
The three orders of marine mammals are sort of arbitrarily chosen because we sort of view marine mammals as being all the mammals that use the ocean in some way or another. And those three orders end up including the order cetacean, which includes the large whales, dolphins, porpoises and those types of animals; the order sirenia, which includes the manatees and dugongs; and the order of carnivore, which includes three different groups of animals that use the marine environment. One includes the bears, which has a polar bear as a marine mammal. One is the mustelid family that has the sea otter as the marine animal. And the third one is the suborder pinnipedia, which includes the seals, sea lions and walruses.

The only marine mammal that lives both on land and the sea is the polar bear. And the polar bear is adapted to swim in icy cold waters. In fact, they've tracked polar bears swimming 30 miles at a time through, you know, ice-filled waters. But they also are well adapted to live on either floating ice or fast ice—fast to the land—or on land itself. But they primarily eat marine mammals. They primarily eat seals. And polar bears have thick blubber. They also have very thick fur. They have huge paws which allows them to swim really well and also walk on shifting ice. And they're just a miraculous animal. Their scientific name is Usus Maritimus, which means, bear of the sea. And they're the only one. There's really no other marine mammals that live on land

NARRATOR:
SEA OTTERS ARE ALSO MARINE MEMBERS OF ORDER CARNIVORA. THESE SMALLEST OF MARINE MAMMALS HAVE THE DENSEST AND WARMEST FUR OF ANY ANIMAL. DESPITE THEIR EXCELLENT INSULATION, THEY MUST EAT THE EQUIVALENT OF ABOUT 20% OF THEIR BODY MASS EACH DAY. THE MOST SUCCESSFUL AND ABUNDANT MARINE CARNIVORES ARE THE SEALS, SEA LIONS AND WALRUSES. TRUE SEALS HAVE A SMOOTH HEAD WITH NO EXTERNAL EARFLAPS. THEY LOOK A BIT LIKE FURRY WATERMELONS. THEIR REAR APPENDAGES ARE OF LITTLE USE ON LAND. WALRUSES ARE AMONG THE LARGEST OF THE PINNIPEDS. SOME GROW TO NEARLY TWO TONS. CONFINED TO PRODUCTIVE POLAR SEAS, WALRUSES DIG CLAMS AND CRUSH THEM WITH MASSIVE PEG-LIKE TEETH. THEIR TUSKS ARE HELPFUL FOR HAULING THEIR HEAVY BODIES ONTO ICE FLOES. THE LARGEST AND MOST IMPRESSIVE OF ALL OCEAN ANIMALS, HOWEVER, BELONG TO THE ORDER CETACEA—THE WHALES.

And they're categorized into to two subgroups, the baleen whales are the mysticeti, and the toothed whales are the odontoceti. And the mysticeti, the baleen whales, include the largest whales of all, the blue whale, the fin whale, the sei whale—animals that can be up to 100 feet in length. The odontoceti, the toothed whales, include the largest toothed whale, which is the sperm whale, all the way down to orca, or killer whale, bottlenose

dolphin—which are about 13 feet long—down to the smallest cetaceans of all which are the porpoises, the harbor porpoises being the smallest.

PETER WORCESTER, Ph.D., Scripps Institution of Oceanography, UCSD:
So you have the toothed whales, the ordontocetis, that send out very high frequency pings that reflect off prey or other objects—come back to them so they can track their prey just the way a destroyer would track a submarine or a bat would use it's sonar in air to track objects. The great whales, the mysticetis, also vocalize, typically at much lower frequencies. And I think it's fair to say that we're not entirely sure what some of those vocalizations are for, but the assumption would be that they're used for many of the same things that animals on land would use sound—to locate one another, to keep track of other animals in their pod, for example, to make contact with mates. I guess one of the key examples of the use of sound would be by humpback whales off Hawaii, where the males sing the famous songs that have been recorded and played back, and these are basically displays to attract females to show their dominance.

NARRATOR:
BALEEN WHALES ARE THE LARGEST ANIMALS EVER TO HAVE LIVED ON EARTH. BLUE WHALES, THE LARGEST OF THE LARGE, EAT THUMB-SIZED CRUSTACEANS CALLED KRILL. ABOUT THREE METRIC TONS OF KRILL IS CONSUMED EACH DAY DURING THE FEEDING SEASON, PROVIDING MORE THAN A MILLION CALORIES A DAY. THE HEART OF A BLUE WHALE IS THE SIZE OF A SMALL CAR. THESE ARE THE ULTIMATE MARINE VERTEBRATES, CAPABLE OF INSPIRING AWE AND REFLECTION.

KELLY:
And so every time we study marine mammals intently, we discover new stuff about mammals and ways they can live their life that we didn't realize was possible for a mammal. Some of the deepest diving of all the whales is to thousands of feet down—as much as maybe 10,000 feet down—and they can stay down for over two hours without a breath, and that shouldn't be possible because we can't dive without scuba gear for more than just a few minutes. And by studying these mammals we've found miraculous internal adaptations—enzyme systems that we didn't even realize were there—that allow them to overcome this problem and utilize all the depths of the ocean. So, I'm for spending more time marine mammals, 'cause it tells us more about ourselves.