THE ENDLESS VOYAGE

"Survivors" Episode 121

The deep sea is the largest living space on Earth. It's home to the largest animal communities on Earth, largest in terms of aerial extent, largest in terms of biomass, largest in terms of numbers of individuals.

When we look at the organisms that live on the present land and sea, we're looking at groups that have evolved since that last big extinction.

If you look at something that's advanced in terms of survival abilities, you might look at the insects and say, "Boy they are very advanced." They're very, very, diverse, they're able to handle most of the poisons we throw at them. They eat by some estimates, a third of the food we grow. And we've been battling them for hundreds of years trying to keep them under control.

NARRATOR:
THE OCEAN IS HOME TO A DAZZLING VARIETY OF LIFE. YET THERE WAS A TIME WHEN LIFE STRUGGLED TO SURVIVE. INTENSE ULTRAVIOLET LIGHT…METEORITE BOMBARDMENTS…AN ATMOSPHERE DEVOID OF OXYGEN. THE EVOLUTION OF ADAPTATIONS TO OVERCOME THESE CHALLENGES ENABLED LIFE TO SURVIVE. AS A RESULT OF THESE ADAPTATIONS, THE PLANTS AND ANIMALS WHO INHABIT THE MODERN OCEAN EXHIBIT A REMARKABLE DIVERSITY OF FORM AND FUNCTION…AND SOME DEADLY WEAPONS.

WILLIAM HAMNER, Ph.D., University of California, Los Angeles:
The cubomedusae in Australia, the really big ones that are called sea wasps, are large animals. They're about the size of a three-gallon bucket. They might weigh 20 pounds, a full-grown animal. They're quite large animals. They're great big jellyfish, and they eat great big prey. They swallow big banana prawns in Australia and the banana prawns are strong. And so they've been selected for stronger and stronger nematocysts with more and more toxins associated with them. So when the tentacles hit a banana prawn, it's dead right now. It doesn't ever move again. When they sting people, people often die.

BRUCE ROBISON, Ph.D., Monterey Bay Aquarium Research Institute:
Another neat trick that many deep-sea animals use to protect themselves from predators is what we call the burglar alarm trick. And the best counterpart that we can think about in human behavior is bank robbers. You know that bank robbers often will get away with a sack of money. They open it up and a purple dye package will explode and cover them with purple dye. Down in deep water, a number of animals have evolved a comparable trick, in that they're able to discharge a sticky cloud of bioluminescence that adheres to the predator. And the predator, who was otherwise invisible is suddenly covered with this glowing cloud that it can't scrape off and can't get rid of. And suddenly the predator is vulnerable to the animals that want to eat it, and it can't get rid of the light.

NARRATOR:
SUCH STRIKING ADAPTATIONS HAVE THEIR ROOTS IN THE EARLY HISTORY OF LIFE ON EARTH, WHEN THE CONCENTRATION OF OXYGEN IN THE ATMOSPHERE ROSE DRAMATICALLY. THIS WAS AN EVENT KNOWN AS THE OXYGEN REVOLUTION.

TOM GARRISON, Ph.D., Orange Coast College:
Life evolved from the kind of chemical reactions that started way back then, protein synthesis, DNA. The whole thing got started comparatively early, very early in the history of the Earth. What we did not have was free atmospheric oxygen. And we animals are quite dependent on that. So something drastic had to change, and it took about two billion years for that change to occur. Ultimately, when photosynthetic plants and other photosynthetic organisms began to make oxygen, the oxygen immediately was released into the ocean—there were no land organisms yet—released into the ocean, say four billion, three billion, two and a half billion years ago, and rusted the iron and other kind of oxidizable compounds in the ocean. So the oxygen was immediately used up. Ultimately all the things that could take up that oxygen, took it up, and the plants continued to make oxygen. And it began to build up, 1%, 2%, 5%. Right now the oxygen's about 21% in the atmosphere. That revolution began about two billion years ago. It was complete or almost complete, by about 500 million years ago. But there was enough oxygen in the atmosphere by about one billion, maybe, seven or 800 million years ago, where an entirely new form of life could arise on the planet. We call them animals.

NARRATOR:
THE FIRST ANIMALS WERE IN INVERTEBRATES, ANIMALS WITHOUT BACKBONES. AND THEY DIVERSIFIED RAPIDLY IN THE GEOLOGIC PERIOD KNOWN AS THE CAMBRIAN.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
…Dated about 530 million years ago, at the beginning of what's called the Cambrian Revolution, that is, when all of these various animal phyla just sort of came into being.

DONAL MANAHAN, Ph.D., University of Southern California:
Animal life, the classification of it, is looked at by taxonomists and people interested in evolution and phylogeny, and they divide these animals up into groups called phyla. And there are currently approximately 35 different animal phyla on Earth.

So these are huge groups of organisms, but a cricket isn't all that different, structurally, from a shrimp. They're arthropods that live in different environments and have different kind of appendages but much of their body plan is basically the same. So it's quite a range of organisms. It's an immense diversity. It's really quite fascinating.

NARRATOR:
MANY PRIMITIVE ORGANISMS, THE EARLIEST LIFE-FORMS ON OUR PLANET, DID NOT SURVIVE TO MODERN TIMES. BUT THEIR FOSSILIZED REMAINS PROVIDE IMPORTANT CLUES FOR UNDERSTANDING THE EVOLUTION OF LIFE ON EARTH.

NYBAKKEN:
We have a situation where if you look at some of these fossils forms, particularly the soft-bodied forms—soft-bodied forms don't fossilize well, as you probably know, so there are few good fossil beds of soft-bodied organisms; The Burgess Shale in British Columbia is probably the best. They have organisms in them, we can't place them into a given animal phylum right now. They are so different than anything we have.

DONN GORSLINE, Ph.D., University of Southern California:
Burgess Shale is a very old formation. In geology we call it pre-Cambrian, meaning that it's probably something on the order of 7 or 800 million years old. And it's at a stage in the development of life on Earth when organisms change from predominately soft-bodied to hard-bodied skeletal structures—shells, things of that nature. And so it gives you a view of what organisms looked like several hundred million years ago, but before there were really good hard parts that could be preserved. And as a result of that, it gives us an insight into how various modern groups have developed.

NYBAKKEN:
The soft-bodied ones are the ones that I have the most interest, because many of them we'd never seen before or they hadn't seen in the fossil record before. But there are also something like eight or 10 organisms in there that we can't place. We don't know exactly what group of organisms they belong to. Or maybe they don't belong to anything that's living today. Maybe they're entirely different.

MANAHAN:
Now in the last 10 or 20 years with Molecular Biology coming in, a lot of these traditional views of phyla are again breaking down as people look to the evolution and the commonality of organisms using gene techniques. And so again, it's not by any means all set in stone that these phyla will stay forever. In fact, many taxonomists are pulling phyla off the map because when they look at them they realize they don't hold up the criteria of independence and they're fusing them and changing them and so forth. So it's a very dynamic field.

NARRATOR:
BUT NO MATTER HOW IT'S CLASSIFIED, LIFE ON EARTH CLEARLY HAS ITS WINNERS AND LOSERS.

MANAHAN:
They look at animal life of planet Earth in geological times, there's enormous changes and including too, in the oceans. Many of the fossil records that we see in the oceans are of animals that clearly lived in the ocean that don't exist in the ocean anymore. So some

of the parallels you see about life on land and the big events about extinctions and evolution of life—those things also exist in the oceans as well.

We think in terms of history—the Burgess Shale, for example, hundreds of millions of years old. In that time period there have been several cycles, several periods of very strong change in the fauna and flora both on land and in the sea.

And active field of investigation now, particularly being driven by issues of global warming is this question of biological stability and extinctions. And if we look through the geological records, there's lots of cases of massive extinctions of life-forms. We can see this in the fossil record. Burgess Shale is a very famous example—all these amazingly odd shapes and forms of things that we know are long gone.

NARRATOR:
NEVERTHELESS, SOME PHYLA, INCLUDING SPONGES, JELLYFISH, ARTHROPODS AND MOLLUSKS, HAVE SURVIVED FOR HUNDREDS OF MILLIONS OF YEARS, EVEN IN THE MOST EXTREME ENVIRONMENTS.

NYBAKKEN:
The Antarctic communities, subtidal communities, are dominated by sponges. And most of them are sponges that in other parts of the world are deep-water sponges. So what you have is a community which appears to be pretty stable over long periods of time. And it looks like the organisms are all long-lived.

Jellyfish are a good example of an organism that has very ancient roots. And there are other organisms that are perhaps—I don't want to say less primitive, but sufficiently generalized so that they're able to pass through some of these very extreme events.

HAMNER:
Jellyfish are very simple animals. But they do weird things. They do all sorts of things they shouldn't be able to do because they don't have a brain. They can navigate using sun compass navigation and swim horizontally and maintain compass courses. And they can migrate vertically up and down even though nobody knows how they sense temperature or pressure. They can follow scent trails and navigate according to odor. They have complex reproductive behavior. Males and females are generally separate sexes and they often engage in mass spawning activities. They do all sorts of strange things they shouldn't be able to do and I find that quite fascinating because it's nice to study animals that…apparently get away with more than we think they ought to be able to do.

If you look at a lot of the invertebrate phyla, these are some of the longest lived lines of organisms in the animal kingdom on Earth. We can see them particularly in some areas of the arthropods. They go back deep, deep into geological time and are still around today.

BRUCE ROBISON, Ph.D., Monterey Bay Aquarium Research Institute:
We see one of our favorite animals—vampyroteuthis, which is an archaic cephalopod. It's a modern day species. It lives and is perfectly adapted to live in the here and now. But it represents the cephalopod line—the ancient cephalopod line before it split into eight-armed octopuses and 10—and 10-limbed squid. It has sort of an in between kind of body form. It's a wonderful animal to study because it tells us a great deal about the evolution of the cephalopods and what it was like at an early stage in that process.

NARRATOR:
ANOTHER IMPORTANT GROUP OF SURVIVORS ARE THE INVERTEBRATE CHORDATES. THESE ARE DISTANT RELATIVES OF ALL VERTEBRATES, INCLUDING AN ODD LOOKING ANIMAL CALLED A TUNICATE, OR SEA SQUIRT, WHOSE SIMPLE APPEARANCE BELIES SOME UNUSUAL TRAITS.

DENNIS KELLY, Orange Coast College:
In fact, one sea squirt can fertilize itself, and one animal can create a new population somewhere else. They're filter feeders. They have branchial basket on the inside and they're able to filter plankton and other particles out of the water. But they have probably the finest filter of any living animal on Earth, and they can filter particles that are phenomenally small in size and thus make a living when other animals can't make a living. And they only spend a very short period of their time—their life moving around. It's when the egg of the tunicate develops into a swimming tadpole larvae, which is about a millimeter long. It has a notochord in it and they use that notochord to flick their tale and they swim around until they run into a surface, attach to the surface, and they do a metamorphosis. And for the rest of their life, they're this single filter feeder.

Among the grazers, gelatinous grazers, who feed on the phytoplankton at the base of the food web, are two kinds of pelagic tunicates called salps and doliolids. Essentially, these are animals that have bodies shaped like barrels with circular bands of muscles that they contract in order to force water in one end and out the other. As it goes through the barrel-shaped bodies, filters remove the particles that these animals feed on and the water that's pushed out the back end propels them. Some work that we're involved with there at MBARI is focused on animals called larvaceans or appendicularians. They're pelagic tunicates, and they spin or secrete mucous filtering structures, some of them two meters across in largest dimension. Basically, there are two kinds of meshes—two kinds of nets or filters—a coarse outer mesh that protects the animal and keeps the big particles from going in and clogging the finer mesh inner filter. The animals themselves are sort of tadpole shaped. They beat their tales and pump water through the filtration structure and they feed on the particles that the filters select out.

NARRATOR:
COMPARED TO VERTEBRATES, THESE ANIMALS AND THEIR INVERTEBRATE COUSINS MAY APPEAR MORE PRIMITIVE, BUT THAT DISTINCTION MAY BE MORE PHILOSOPHICAL THAN SCIENTIFIC.

WILLIAM HAMNER, Ph.D., University of California, Los Angeles:
Invertebrates are contrasted often to vertebrates in teaching biology, but it's a silly distinction. There are really 15 or 30 different body plans of animals, depending on who's counting. And things like mollusks are very different from things like echinoderms and very different from jellyfish in their basic body plans. The term vertebrates refers to a group of animals that we belong to because 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.

DONAL MANAHAN, Ph.D., University of Southern California:
Why do we have a backbone? As human beings we have a backbone because we have an internal skeleton. What it basically does is allows us to counter gravity, to be able to stand up in a gravity field. In the ocean, that's less of a driving force for evolution. Because gravity, as everybody knows who swims in the ocean, tends to not be so hard to work against. And so we see a very large amount of diversity of invertebrates in the ocean, which are lacking backbones 'cause they don't need those structural elements to be able to function. They invent other kinds of skeletons.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
It's not always necessary to have more complexity anatomically. You can have an organism that becomes anatomically simpler, but yet is a highly evolved organism. And the best example of that are the parasites, many of which have been evolved from organisms that were more complex.

I think there is a perception out there that if you have a backbone you're smarter. I mean, this is sort of a human-centric point of view. Think of a fish—you know, it doesn't necessarily have—just because it has a backbone, doesn't mean it's smarter than something else in the ocean. So I think we have to be very careful about simplistic definitions of "advanced" and "primitive," because frankly, no organism would survive very long on planet Earth in evolutionary time if it didn't have advanced adaptive mechanisms to survive.

NARRATOR:
PERHAPS NOWHERE ON EARTH IS THE ABILITY TO SURVIVE BETTER DEMONSTRATED THAN AT THAT PART OF THE SHORE ALTERNATELY EXPOSED AND SUBMERGED BY TIDES, A REGION KNOWN AS THE INTERTIDAL ZONE.

STACY KIM, Ph.D., Moss Landing Marine Laboratories, CSU:
The rocky intertidal is a pretty tough habitat to live in. The animals there undergo not only a lot of wave stress from the waves pounding on them, but there's also a desiccation stress. So for the low tide periods of every tidal cycle, they're exposed to the air. And since they're marine organisms that are used to living in water, it's very difficult for them to live under these extremely dry conditions.

GEORGE MATSUMOTO, Ph.D., Monterey Bay Aquarium Research Institute:
When you think about life in the intertidal, where you may have 10 days of extremely hot weather beating down on tide pools, evaporating out water and making that tidal region extremely salty—or you may have extensive rains which are going to dilute that tide pool into almost pure fresh water.

MICHAEL LATZ, Ph.D., Scripps Institution of Oceanography, UCSD:
So this creates special stresses to the organisms living there in that they may be exposed to air and out of the water for a number of hours. They can be exposed to sunlight and the damaging effect of ultraviolet radiation.

NARRATOR:
YET, REMARKABLY MARINE ORGANISMS HAVE EVOLVED A MULTITUDE OF WAYS TO SURVIVE UNDER THESE CONDITIONS.

KIM:
Some of the examples of rocky intertidal organisms include things like barnacles and mussels and both of these animals have to survive out of the water. And they’re able to do this by closing their shells very tightly and retaining a little bit of fluid inside the shell and that allows them to persist during the low tide times when they’re exposed to air and to very high temperatures.

JUDITH McDOWELL, Ph.D., Woods Hold Oceanographic Institution:
Some of the physical stresses that an intertidal organism may have to face is just being dislodged by wave action. And as you look at an intertidal area of some of the more mobile species like crabs and fishes, they’ll restrict themselves to the lower intertidal. They’ll find a crevice to hide away from the waves and protect themselves by just finding a burrow or finding a hiding place within the rocks and the small creeks that form between rocks. But snails, barnacles, mussels, they’ll attach themselves to the rocks. The barnacles will actually cement themselves to the rocks so that they will not be dislodged. The mussels form byssal threads, threads which will actually cement them to the rocks. And the snails have a very strong foot which is very difficult to dislodge them from the rocks. So they all different kinds of adaptive mechanisms to help prevent being washed off the rock and into a lower area of the intertidal zone.

NARRATOR:
AN ORGANISM’S PREFERENCE FOR THE HABITAT TO WHICH IT HAS ADAPTED CREATES A MOSAIC OF SIMILARLY ADAPTED ORGANISMS CLUMPED IN RECOGNIZABLE BANDS ALONG THE SHORE. THIS IS A PHENOMENON KNOWN AS INTERTIDAL ZONATION.

McDOWELL:
On the very high reaches of the intertidal zone—that area in the splash zone that may only be covered in water a couple of times a month—you would find a very restricted group of organisms that would be able to tolerate not being submerged in water for great periods of time. Some snails, some barnacles. As you move down the shoreline in what

is called the mid-littoral zone or the mid-shore zone, the middle part of the intertidal zone, you'll start to find a greater diversity of organisms—organisms such as the mussels that can tolerate aerial exposure for small periods of time. And as you move further and further down into the water to the low intertidal zone you'll start to see even more diversity of species—starfish, sea urchins, crabs, fish.

NARRATOR:
BIOLOGICAL FACTORS SUCH AS COMPETITION AND PREDATION, ALSO PLAY A ROLE IN DETERMINING WHEN AND WHERE AN ORGANISM LIVES.

NYBAKKEN:
What they found out in the Washington's shore was that the mussel, Mytilus Californianus—turns out it is the dominant space competitor. It will outcompete everything else that settles on the intertidal zone and take it over. Well, if this thing is the dominate space competitor, why isn't it just one solid man of mussels? Now the answer has to do with interactions of organisms, and it turns out we have a predator out there, a starfish, pisaster ochraceous, which eats mussels. And if the predator is present, it will keep eating mussels and create spaces so that other organisms can still survive.

Each type of organisms has a preference for a certain set of environmental conditions. This explains why not all organisms are found everywhere in the ocean. So the preference is based on things such as temperature, substrate is very important for animals that live on the bottom. So substrate meaning whether it's muddy bottom, whether it's rocky, whether it's sandy, there are preferences for each type. Also preferences based on temperature, based on the salinity of the water—how salty it is—the amount of nutrients, the seasonal cycles and also biological interactions. So there's a complex suite of conditions that are preferred for each type of organism.

NARRATOR:
MARINE ORGANISMS EXHIBIT A COMPLEXITY OF INTERACTIONS AND A SEEMINGLY INFINITE VARIETY OF MECHANISMS BY WHICH THEY SURVIVE IN THE SEA. YET NEW TECHNOLOGIES AND SOPHISTICATED TOOLS PROMISE TO UNRAVEL SOME OF THE MYSTERIES SURROUNDING THESE ORGANISMS.

BRUCE ROBISON, Ph.D., Monterey Bay Aquarium Research Institute:
If you think about flying over a forest at night in a balloon, with a butterfly net trying to collect enough stuff to tell you what a forest is like and how those animal communities are put together, you get kind of an idea of what the challenge was.

Fortunately, we've had the opportunity now to enter that habitat with human occupied vehicles and with remotely operated vehicles.

NARRATOR:
UNDERSEA VEHICLES HAVE OPENED A NEW FRONTIER FOR OCEAN SCIENTISTS…AND A NEW CHALLENGE FOR HUMANKIND.

ROBISON:
The deep sea, the open ocean, is a marvelously challenging and interesting and fascinating place. It provides a frontier for humankind of the sort that is all too lacking in today's world. We look at space as perhaps the next frontier, and indeed it truly is. But it's probably not going to be…a realistic frontier for most people for another few generations. For humankind to have a focus, to help carry the species further in intellectual and philosophical and cultural development, having a frontier is really handy. And the frontier we have before us now, for the next few generations, is going to be that of the deep sea. And that reason alone I think is enough to respect it and to try to take care of it.

"THE ENDLESS VOYAGE" IS A 26 PART TELEVISION SERIES ABOUT OCEANOGRAPHY. FOR MORE INFORMATION ABOUT THIS PROGRAM AND ACCOMPANYING MATERIALS, CALL: 1-800-576-2988 OR VISIT US ONLINE AT: WWW.INTELECOM.ORG.