# THE ENDLESS VOYAGE

"The Water Planet" Episode 101

As far as we know, the Earth holds the solar system records, and maybe even the universe records, but I doubt that, certainly the solar system records, as being the wettest planet around.

Earth is a water world, and so here we have the fundamental requirement for life, and so the question is, "How did the oceans play a role in setting the stage for the early evolution of life?"

If we didn't have water in large quantities on the surface of the Earth, with its moderating temperature capabilities, we wouldn't be able to have life as we know it.

**NARRATOR:**
SOME HAVE CALLED IT THE BLUE PLANET. OTHERS, THE WATER PLANET. STILL OTHERS LIKEN IT TO A GREEN JEWEL. POETS, PHILOSOPHERS, SCIENTISTS AND MATHEMATICIANS ALL HAVE TRIED TO CAPTURE, IN WORDS OR NUMBERS, THE ESSENCE OF THIS PLACE WE CALL EARTH. THE THIRD PLANET OUT FROM THE SUN, IT IS UNIQUE IN OUR SOLAR SYSTEM FOR MANY REASONS. BUT PERHAPS MOST SIGNIFICANT IS THAT SLIGHTLY MORE THAN 70% OF IT IS COVERED IN LIQUID WATER. AND INDEED A CASE CAN REASONABLY BE MADE THAT IT IS WATER, MORE THAN ANYTHING ELSE, THAT TRULY DEFINES AND DISTINGUISHES THE SEEMINGLY MISNAMED PLANET EARTH.

**TOM GARRISON, Ph.D., Orange Coast College:**
This is a very strange place. We have a planet about 7900 miles across, just exactly in the right spot from a fairly stable star. The star is not a multiple system. It's just one star. It doesn't get bigger or smaller. It's not a variable star. And it puts out heat at a particular rate—radiation.

**JEFF BADA, Ph.D., Scripps Institution of Oceanography, UCSD:**
Turns out that the distance from the Earth to the sun is just about in the perfect region for minerals to condense that have associated with them bound water. If you get too close to the sun, that water gets evaporated off. You get too far away from the sun, and it just remains frozen ice. And the Earth is sort of that magical distance where water is bound as minerals.

And, at this particular distance away, we have a liquid water capability, and, as if that weren't interesting enough, this particular planet, for whatever reason, has a tremendous amount of liquid water on it and in it.

**J. WILLIAM SCHOPF, Ph.D., UCLA**
We have the highest waterfalls, we have the largest lakes, the largest oceans, the solar system record for rainfall in Cherrapungi, India in 1891, twenty-six and a half meters of rainfall fell there during the monsoon season that year.

And because water has a tremendous latent heat—because it can absorb tremendous amounts of heat and not go up in temperature very much—the planet can be moderate. Its temperature throughout the course of a year does not vary tremendously. And even more wonderful, ice floats. And when you make solid water—when you make ice—the amount of energy that's given off and reabsorbed as ice forms as melts throughout the course of a calendar year, those things moderate the temperature even further. Another advantage of the ocean is its ability to support materials. It's much more dense than air, a hundred times more dense than air. So you have the ability to float suspended in it without expending huge quantities of energy. Birds have to work very hard, insects, to stay up in the air. Not on the ocean—you can float around. Organisms float around on the ocean with very little need for the expenditure of energy. Also, in the ocean, you have the ability to have transparency. The light can flood through the ocean. It can't flood through dirt. Productivity in dirt is limited to the first, what, two millimeters or something of the dirt. But, in the ocean, you can have photosynthesis down maybe 300 feet or so, maybe 100 meters down there. And so you can have a supportive medium that also is transparent that can have dissolved nutrients in it that has the ability for life to fly around in it or sit there supported platonically in it in great quantities. It's just the ultimate situation for life. And truly all life on Earth is essentially marine.

**NARRATOR:**
TEEMING WITH LIFE, AWASH IN A RICH BROTH OF CHEMICAL NUTRIENTS, PLANET EARTH IS INDEED UNIQUE IN THE SOLAR SYSTEM. BUT AT ONE TIME, THINGS WERE VERY DIFFERENT. THERE WAS NO EARTH, NO SOLAR SYSTEM, NO UNIVERSE. THEN, IN ONE EXPLOSIVE INSTANT…A BEGINNING.

**VIRGINIA ROUNDY, Ph.D., Fullerton College:**
Around 1920 or thereabouts, Hubble told us that the universe was expanding, that the galaxies were getting farther and farther and farther apart. And then people began to think, if it's getting further and further apart as time goes by, if we ran the clock backwards, wouldn't it be getting closer and closer and closer together? And, in fact, since the furthest things are going the fastest, everything would all be in the same place at the same time. And hence was born the idea of a Big Bang, because if it was all at the same place and then it came apart, you have the whole concept of the Big Bang.

**ROGER BLANDFORD, Ph.D., California Institute of Technology:**
Well, the Big Bang is the commonly accepted theory of the origin of the universe, which was at some almost unimaginably small time, the universe was created and then expanded through a variety of stages to give us the universe that we see around us today, which is now being observed as a time about 14 billion years after this initial cataclysmic explosion.

Scientists don't necessarily agree on whether everything was what's called a singularity—meaning that all of the mass and all of the energy was at a point with no physical extent at all, or whether there was some physical extent. So there may have been some physical extent less than the size of one atom, okay? And, at that time, that was the whole universe, 'cause that was everything that is and that's what the universe means—everything, all the material stuff that is. So, and then, that energy exploded outward, and at first, it was very, very condensed, it was very, very hot. Atoms couldn't be formed because it was too hot. Gradually, as space expanded outward, and the universe expanded outward with space, then it got cooler and it got cooler and when we got whole atoms, then the universe became transparent and we could see through it. Before that, light would be absorbed by any free electron that was around. So, now we have a universe that we can see through. That should mean that if we looked to the farthest edges of the universe that we can see, we should be able to see through the universe—as we look further and further away, we're looking back and back and back in time, and as we look back and back and back in time, we should eventually get to that point where it wasn't transparent, because before you had those free electrons absorbing the light. And, in fact, we can get back that far. We can see that far. We see the radiation coming from that.

Probably the biggest evidence that persuaded scientific doubters that this sort of hot Big Bang, is evolutionary cosmology—should be taken seriously and should be developed—was the discovery of the microwave background in 1965. At that time, it was found that the whole sky was bathed in microwave radiation, rather similar to what you might find in a microwave. And it was very quickly hypothesized that this was the sort of left over glow from the Big Bang. And now we know that that is indeed the case.

**NARRATOR:**
IT WOULD BE ANOTHER BILLION YEARS FOLLOWING THE BIG BANG BEFORE THE EARLIEST MATTER CONGEALED INTO THE FIRST STARS AND GALAXIES. EVENTUALLY, AFTER SEVERAL BILLION MORE YEARS HAD PASSED, A CLOUD OF DUST AND GAS BEGINS TO CONDENSE AND ROTATE, TAKING ON A SPHERICAL SHAPE.

**ROUNDY:**
Now in the center of this disc is beginning to form what we call the protosun. Okay, this is—it's gotten hot, it's giving out light, but it's not yet the star because nuclear fusion isn't happening in the center of it.

**NARRATOR:**
DUST GRAINS ORBITING THIS PROTOSUN COLLIDE WITH EACH OTHER, STICK TOGETHER, AND COALESCE INTO LARGER BITS AND PIECES. EVENTUALLY, THE LARGEST OF THESE WOULD BECOME THE PLANETS. MEANWHILE, THE SUN IS HEATING UP.

For rocky planets on the inside of the solar system because we only have things like rock and metal condensing. And on the outer, we get ice and rock, and you have the gases that got shooed out of the middle. And so you get the big gas giant planets out at the edge.

**NARRATOR:**
DURING THIS EARLY PERIOD, EARTH WAS A VERY DIFFERENT PLANET THAN IT IS TODAY. ITS ATMOSPHERE, IN PARTICULAR, BORE LITTLE RESEMBLANCE TO THE ONE THAT WE DEPEND UPON FOR THE AIR WE BREATHE.

**JEFF BADA, Ph.D., Scripps Institution of Oceanography, UCSD:**
The atmosphere of the early Earth, if you followed the reasoning of several authorities in this area, was probably consisted of mainly carbon dioxide and nitrogen gas…perhaps a lot of carbon dioxide compared to today. One of the conspicuous things that's absent is oxygen. Oxygen, people have calculated, was absolutely—would have been undetectable in the early atmosphere of the Earth. Today, we look at the Earth and 21% of the gases in the atmosphere is oxygen. Where did this come from? Well, this is a product of biology.

And, in fact, it took a fair amount of time before biological activity had proceeded far enough along and developed enough to build up a higher level of oxygen.

**TOM GARRISON, Ph.D., Orange Coast College:**
And then, slowly, because of the work of photosynthetic plants and other photosynthetic organisms, the oxygen levels of the atmosphere began to come up.

We look at the rock record, we know that…very early in the history of the earth, some maybe 3.5 billion years ago or so, we have the remnants of what appear to be photosynthetic organisms. Photosynthetic organisms remove CO2 from the atmosphere, convert that CO2 to organic carbon and liberate oxygen. So, early in the history of the planet, we had organisms present that were discharging into the atmosphere a waste product—oxygen—which eventually would begin to accumulate in the atmosphere.

**NARRATOR:**
WITH ITS OXYGEN-STARVED ATMOSPHERE, EARLY EARTH WAS CLEARLY A LESS THAN HOSPITABLE ENVIRONMENT. BUT THE LACK OF OXYGEN WAS HARDLY THE ONLY PROBLEM.

**PAUL JOHNSON, Ph.D., University of Washington:**
The first two or three hundred million years of Earth history was a very unpleasant time to be around. We know this because we see similar craters on the surface of the Moon, and we know if it happened to the Moon, it probably happened to the Earth.

**BADA:**
There was a lot of debris still in the solar system in the form of asteroids, other planets that were orbiting the sun that started interacting with each other. And so the Earth, in its early history, even as it cooled down, was being blasted by asteroids, comets and other

planets.  And so the whole planet was just being peppered with stuff from space.  In fact, about fifty million years after the Earth accreted and had a solid surface, a planet the size of Mars hit the Earth, totally vaporizing that planet and vaporizing part of the Earth.  And that stuff went into orbit around the Earth and formed our moon.

**NARRATOR:**
WHILE THE DEBRIS RAINING DOWN MADE EARLY EARTH A TREACHEROUS BATTLEFIELD, THE BARRAGE OF INTERSTELLAR MATERIALS MAY WELL HAVE CARRIED WITH IT SOMETHING OF ENORMOUS IMPORTANCE—NAMELY, WATER.

Water's made of H2O and the hydrogen was formed probably very close to the origin of the universe, at some time shortly after the Big Bang, probably 14 billion years ago. Hydrogen then, as now, was the most abundant element in the universe.  Oxygen, though, rather heavier, was made in stars.  During the normal life of stars, lighter atoms or elements are converted into heavier ones.  And when stars die, or when they radiate materials and solar winds off their surfaces, those materials then go off and blend with the kinds of things that one finds in space, including the hydrogen.  So oxygen was made stars, and during the process of the lives of those stars and the blowing up of the stars, you get quite a bit of oxygen around, combines with hydrogen and you get water.  And there's lots of water in space.

**NARRATOR:**
THE QUESTION, OF COURSE, IS HOW DID THIS WATER REACH EARTH?

**ROGER BLANDFORD, Ph.D., California Institute of Technology:**
The contemporary view is that a lot of this came from these planetary bodies like asteroids or meteors or perhaps even comets.  And these have a certain amount of water contained in them.  And the buildup of this water produced ultimately the oceans on the surface of the Earth.

There are two schools of where the water came from that covers the Earth.  One school said—says it comes from comets.  It came in from outer space.  Another school said when you accumulate the mass that forms the Earth, then it outgases water.  One theory says it's coming out from the center of the Earth, the other says it's raining down from above.  And the jury's still out.

**NARRATOR:**
HOWEVER IT GOT HERE, WATER WOULD EVENTUALLY COVER MORE THAN TWO-THIRDS OF EARTH'S SURFACE.  THE IMPLICATIONS, NOT ONLY FOR THE PLANET ITSELF, BUT FOR THE LIFE FORMS THAT WOULD ONE DAY INHABIT IT, WERE PROFOUND.

The presence of water is suggestive that you could have life.  It does not necessarily immediately imply that there is life.  My own feeling is that water sets the stage for a cascade of chemical reactions that eventually can lead to living entities. And so, whenever you have water, you certainly have the potential for that chemistry.

We don't know what forms life could take elsewhere, but our life here is water-based, DNA moderated, protein constructed. It requires water in its present state.

**J. WILLIAM SCHOPF, Ph.D., UCLA:**
Why is water important to the origin of life? Two reasons. One, life is made out of CHON—carbon, hydrogen, oxygen, nitrogen. Water is made out of two of those elements—hydrogen and oxygen. So, that's a source of a couple of the elements that are crucial for life. More importantly, is that water was important to protect the little bits of organic matter that were made through non-biologic processes before life got started, so that life could get started.

**GERALD JOYCE, Ph.D., M.D., The Scripps Research Institute:**
There would have to be some organic compounds that could give rise to more complex organic compounds, and so that means some source of carbon containing compounds. Now that could be volcanic activity, that could be syntheses in the atmosphere—from spark discharges, from electrical disturbances in the atmosphere. That could be—and this is sort of a new realization, I'd say in the last five to 10 years—that could be organic compounds that land on the Earth or land on whatever planet, from elsewhere in the solar system.

See, at that time, there was no oxygen in the Earth's atmosphere. If there's no oxygen in the Earth's atmosphere, it means we had no ozone layer to absorb ultraviolet light. But the sun is blasting the Earth with ultraviolet light. And ultraviolet light tears apart organic compounds. So, these organic compounds that were made in the absence of life—before life got started—they might have been made in the atmosphere, they might have been made in deep sea vents, in fumaroles—wherever they were made, once they got into the oceans, the water protected them from being broken down by this intense ultraviolet radiation. And most folks think, therefore, that having an aqueous planet, having a watery planet like Earth, as far as we know, is really a basic requirement to get life started.

**NARRATOR:**
ANY DISCUSSION OF THE ORIGINS OF LIFE SHOULD PRESUMABLY BEGIN WITH A GENERALLY ACCEPTED DEFINITION OF THE TERM LIFE ITSELF. CRAFTING SUCH A DEFINITION TURNS OUT TO BE MORE COMPLICATED THAN MIGHT BE EXPECTED.

The business of trying to define life is a surprisingly difficult sort of thing. It is maybe sort of like…what the Supreme Court says about not very nice pictures. You know, they say when they see it, they can identify it. Well, life is like that.

I would put it this way—and this is not my phrase, this is the working definition that NASA, the civilian space agency, has adopted in their search for life and understanding of life.—and so, the so-called NASA working definition is as follows: "Life is a self-sustained chemical system that is capable of undergoing Darwinian evolution."

Life is made out of organic compounds—that's carbon, hydrogen, oxygen and nitrogen compounds—and has a particular organization, and these things we call organisms—living cells—are separated from their environments and they have the property of being able to evolve over time, and they reproduce. There are only two necessities for life—a source of carbon, hydrogen, oxygen and nitrogen—they have to have a way to bring in these elements so they can build themselves up, and the only other thing life really needs is energy. And there are two ways to do that—you can get energy from eating other things—that's what we humans do—but plants live a different way—plants are able to use the energy of sunlight. So it's those elements—carbon, hydrogen, oxygen and nitrogen—the ability to have an energy source, to reproduce and to evolve. And things that can do that, we call life.

**NARRATOR:**
AS WITH THE QUESTION, WHAT CONSTITUTES LIFE, THE QUESTION OF WHERE ON EARTH IT ORIGINATED IS EQUALLY COMPLEX.

**JOYCE:**
Maybe the surface of the ocean is an interesting place, because it's mixing atmospheric chemistry with what can be maintained in ocean solution. Maybe the interface between the ocean and the land in an interesting place because there's sunlight to drive certain reactions, there's the possibility of concentrating materials in the inter-tidal zone, and so on. All of these have been talked about. There's the warm little pond model. There's the cold little pond model, there's the drying lagoon model.

**TOM GARRISON, Ph.D., Orange Coast College:**
A German patent attorney by the name of Günther Wachtershauser about ten years ago came up with an interesting idea that suggested that life originated not at the surface, but in the deep vents, in the hydrothermal vent areas of the ocean, which probably started up early on because of the physics of the outer layers of the Earth itself.

**PAUL JOHNSON, Ph.D., University of Washington:**
It's a very warm, porous, fluid circulates. There's lot of nutrients in that area and every time a tidal bulge goes by in the surface water, it's pumped. And so this is a warm, stirred incubator, and a lot of people have proposed that perhaps this is a place where life actually started. There are lots of chemical gradients. It's a protected environment. There are lots of chemicals floating around that are the precursors for biological chemicals.

**SEAN CHAMBERLIN, Ph.D., Fullerton College:**
The other sort of exciting result recently has been the discovery of archaebacteria and bacterial populations—archaebacteria are the sort of ancient bacteria that live in very extreme environments—and we have found these types of bacteria at hydrothermal vents. The fact that life can exist at hydrothermal vents at this deep pressure and hot water and

really chemically toxic environment is astounding in a sense and was really a surprise. And it's what leads us to think that perhaps life originated in these types of environments. The discovery of bacteria and archaebacteria living not just on these hydrothermal vents, but beneath the crust of the ocean has been an exciting one in recent years. We actually find organisms now living beneath the surface of our planet—living deep in the crust, in the oceanic crust. And these types of discoveries, while they don't give us proof that these are the conditions under which life originated on our planet, they do provide clues, they do give us a better lead on the types of research that we can perform to try to understand how life might have originated.

**JEFF BADA, Ph.D., Scripps Institution of Oceanography, UCSD:**
I think there's no question that the oceans must have had an intimate relationship with the development of the first living entities on the Earth. The Pre-biotic Soup theory says that the organic constituents that are derived either from direct homegrown synthesis or infall from space would have accumulated in the oceans. And so, you had the raw materials in the oceans. The other thing that we think we know about the early Earth during this period is that there were very few continents. What land masses did exist consisted of nothing more than simple island, arc-type systems. So there were no large land masses on the Earth early in its history, probably at the time when this chemistry that led to the origin of life was taking place.

**NARRATOR:**
FROM ITS LIKELY ROLE IN THE FORMATION OF LIFE TO ITS IMPACT ON GLOBAL CLIMATE, THE WORLD OCEAN HAS SHAPED PLANET EARTH TO AN EXTENT THAT IS ALMOST IMPOSSIBLE TO OVERSTATE. PERHAPS THE BEST WAY TO FULLY GRASP THE ENORMITY OF THE OCEAN'S IMPACT IS TO IMAGINE OUR WORLD WITHOUT IT.

The Earth without an ocean would be drastically different than it is today. The dominant feature of the planet is the ocean. It's about 12,000 feet deep, whereas the land is only about 4000 feet high in average elevation. So this is really the number one feature.

**GERALD SCHUBERT, Ph.D., UCLA:**
Without the oceans, we'd be a very different place, almost certainly. And we have an example of what we might have turned into in one of our neighboring planets, Venus, for example.

But if you could take the ocean out of its basins and put it in space somewhere and just have the Earth everywhere the same as it is now—the same distance from the same sun, the same orbital inclination, everything the same—estimates have shown that the average daytime temperature at mid latitudes in either hemisphere in the summer would be about 125 to 135 Fahrenheit degrees, because we would lack that moderating ability of water to maintain its normal temperature, to ease temperatures when you put heat into it or take heat out. In the winter, at mid latitudes in either hemisphere, the temperatures would be 70 or 80 degrees Fahrenheit below zero—again, because of the tremendous ability that water has to moderate temperatures. So it would be much different place. As far as life is concerned, we wouldn’t have that fluid matrix in which the chemical dance of life could occur. So, if we had life on the planet, it certainly wouldn’t be based the way we see it today.