Episode 2: The Matrix of Life

GRADE 11-12 TEACHER'S GUIDE

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INTRODUCTION

The Sacred Balance is a four-part video series in which David Suzuki explores our place in nature. In the second video of the series entitled **The Matrix of Life**, David Suzuki explores the relationship between water, air and all life on Earth. The video consists of eight sub-themes, each of which contains resources on The Sacred Balance website www.sacredbalance.com that complement the video. This guide provides teachers with suggestions on how to use the video and website resources in the science classroom.

Themes	Bio	Articles	Games/Animations
1. Human Impact on the Ganges River	Veer Bhadra Mishra	The Quest to Save a Holy River	
2. Discovering Properties of Water	Richard J. Saykally	Richard Saykally on Unravelling the Mystery of Water	H_2O
3. Subterranean Life Forms.	Tullis Onstott	Life Deep in the Earth	
4. How Ancient Life Affected the Atmosphere	Malcolm Walter	How Ancient Life Created the Air We Breathe	The Building Blocks of Life
5. The Amazon's Role in the Water Cycle	Michael Keller	How the Amazon Pumps Water into the Atmosphere	Photosynthesis
6. Monitoring the Weather of the Rainforest		Red Balloons over the Rainforest	
7. The Origin of Glacier Pollutants	David W. Schindler	The Snowdome Glacier: Remote, Serene... Polluted	Postcards from Argon
8. Science and Spirituality		Balancing Science and Spirituality	Looking Up

Correlation to Pan-Canadian Science Protocol

LEVEL	SUBJECT	TOPIC
Senior Science	Grade 11-12	Matter and Energy for Life Evolution Change, And Diversity

PRECIS

Water and air move endlessly together in a shifting dance of shape and place, atoms linking and de-linking to form ocean and atmosphere, transported across the face of the planet by winds. Water and air: these elements are the prerequisites of life -- life is made from them, and life helped create and still maintains them.

In The Matrix of Life, Episode 2 of The Sacred Balance, David Suzuki travels around the world, exploring our intimate relationship with water and air. His journey begins on the banks of the sacred Ganges River in India, a river that supports the lives of 400 million people. With the guidance of Dr. Veer Bhadra Mishra, a Hindu priest and hydrological engineer, David is introduced to the Hindu world view -- a view that sees water, air and all life on Earth as part of a matrix.

With the guidance of some of the world's leading scientists, David explores this matrix. In Las Vegas, David discovers the fantasy city in the desert built on water. In South Africa, he descends three kilometres into the deepest goldmine on Earth to examine the mysterious microbes extracted from water in the rock. It's true: the Earth is alive, and life may have originated in the heat and water in its rocks.

David also visits Shark Bay, on Australia's west coast, to see living examples of the bacteria that billions of years ago created the conditions for life on land through photosynthesis, changing the chemistry of Earth. Life made an atmosphere for itself out of air and water and then spread itself across the planet.

Just as life emerged from the water into air, every human being takes the same journey at birth. Air and water are the matrix that joins all life together. To investigate just how air, water and life combine, David travels to Brazil's Amazon Basin where the tropical rainforest acts as a huge heat engine for the atmosphere. Gargantuan quantities of moisture rain upward into the atmosphere and are transported by winds around the world. But as David discovers in the last stop on this journey, Canada's Jasper National Park, actions in one part of the world have direct consequences on other parts. Scientists there are discovering just how complex the matrix is, as pollutants carried by winds condense when they come into contact with cold, contaminating pristine regions and entering the food chain.

Whether sweeping invisibly through the air as vapour, flowing across the surface of the planet, or percolating through soil, water cycles through the atmosphere, defying human boundaries and human ownership and affecting every living thing. Wherever we are, air and water move through us. What we do to them, anywhere on the planet, we eventually end up doing to ourselves.

TEACHER PREPARATION

- Preview the five-minute highlight video on the Sacred Balance website to familiarize yourself with the content of the video. Alternatively, read the script found at the end of this guide

- Explore The Sacred Balance resources on the website.

- Select appropriate biographies, webcasts, articles or games for students to explore before watching the video or to extend their knowledge after watching the video.

- Select appropriate before, during and after viewing exercises from this guide or adapt and design your own based on the resources here.

- Provide students with the opportunity to learn vocabulary from the enclosed glossary for sections of the video you would like them to see. The glossary consists of two parts: defined words to support the learning of science vocabulary and undefined general words that ESL/ELD students may not be familiar with.

- Photocopy critical sections of the enclosed script for students to read prior to watching the video. Alternatively, provide the sections to students after previewing the video, to free students from the need to take notes during the video.

BEFORE VIEWING

Matching: Properties of Water

Match the words in the first column to the best available answer in the second column.

A._____	liquid water	1) the weak electrostatic attraction between hydrogen and electronegative atoms among molecules
B._____	polar covalent bond	2) the percentage of water found in most living organisms
C._____	two	3) the type of bond between oxygen and hydrogen in a water molecule
D._____	eighty	4) the number of water molecules that one water molecule can link up to due to its polar nature
E._____	tetrahedral	5) the number of electrons oxygen needs to add in its outer shell to be stable
F._____	hydrogen bond	6) the medium of life
G._____	four	7) the state in which water forms a stable crystalline structure
H._____	solid water	8) the shape of a water molecule

Answer Key:

1F 2D 3B 4B 5C 6A 7H 8E

DURING VIEWING

During Viewing

In the video Matrix of Life, some of the people that David Suzuki interviews are: a hydrologist named Veer Bhadra Mishra, a chemist named Richard Saykally, and a geomicrobiologist named Tullis Onstott.

Read the quotations, and highlight two to three key words or phrases that will help you remember the quote as you watch the video. Jot down some notes to help you remember the scene for classroom discussion after the video.

Quotes from the Matrix of Life:

Quote	Scientist	What is happening during this scene?	Comments
Ganga is that which goes, flows forever. That is the literal meaning of Ganga. And that is what life is for us. Life should have flow. It should be flowing all the time. In Sanskrit, we say that water is life.	Veer Bhadra Mishra		
Each water molecule, liquid or solid, is interacting with four other water molecules, and interacting rather strongly. So this creates networks of hydrogen bonds. And it s that particular quirk, four strong bonds, that give rise to the properties of water.	Richard Saykally		
In the search for life we always are looking for liquid water. Water does appear to be the key.	Tullis Onstott		

AFTER VIEWING

1. Read the article: Richard Saykally on Unravelling the Mystery of Water as well as his biography Richard J. Saykally, available on the website www.sacredbalance.com.
Construct a concept map using the water terms that you listed before and during the video. Share your concept map with a partner and make additions where appropriate.

Answer: Student responses will vary.

Enter the phrase water concept map in Google s image search. Study the concept maps. List at least three things that you have learned about water from these maps and incorporate them into your own map.

Answer: Student responses will vary.

2. *My mother still can t understand why I want to spend my life studying water while other people are curing cancer and discovering new drugs and inventing new kinds of computers, and her son is studying water. And I think that just reflects the idea that water is so familiar to everybody that they just can t believe there is something we don t know about it. This is what my mother asks me all the time: what can we possibly not know about water? But from the point of view of a physicist the answer is: a whole lot.*

a) What is it that we don t know about water according to Richard Saykally? Express your answer as a list of questions that Saykally would like to answer.

Answer:
How does water interact with biological systems?
How does water interact with biological systems and the geology of the Earth?
How does water interact with biological systems and the atmosphere?
How does water influences the nature of life on Earth?

b) If he were able to answer all of his questions this year, what impact do you think the knowledge would have on science, technology, society and the environment

(1) in five years?

Answer: Student responses will vary.

(2) in 20 years?
Answer: Student responses will vary.

3. Read the article: Life Deep in the Earth to familiarize yourself with Tullis Onstott.

a) What are the four research questions Tullis is pursuing?

Answer: 1) How does large-scale migration of bacteria occur?
2) Do sub-surface micro-organisms evolve by adaptation or selection?
3) Could life have originated in the sub-surface?
4) What methods can be adapted to test for life in the Martian sub-surface?

b) Based on what you have seen on the video, formulate new questions that might emerge from his research.

Answer: Students responses will vary.

4. Tullis Onstott states in the article: Life Deep in the Earth *I think there are still a lot of risks in this business, simply because there s still so much that we don t know, and it s so easy to draw conclusions, which in the end may turn out to be erroneous. There are still profound questions to be answered....* What can you infer from his statement?

Answer: Tullis Onstott is aware that part of being a scientist is being able to compare and contrast varying hypothesis using specified criteria.

5. Onstott makes mention of two hypotheses on the origin of life on Earth. What are the hypotheses?

Answer: Students should see that in both hypotheses water plays an important role. This confirms that water is the matrix of life. However, in hypothesis one life begins in the ocean floor and in hypothesis two it begins within rocks.

GLOSSARY

alkaline	Alkaline is one way to describe a substance with a pH greater than seven.
anaerobic	Anaerobic is a condition that means the lack of molecular oxygen.
atmosphere	The atmosphere is the gas mass that surrounds the Earth.
bacteria	Bacteria are microscopic organisms consisting of single prokaryotic cells.
concentration	Concentration is the amount of a substance measured in a unit amount of another substance.
condensation	Condensation is a process by which matter changes from the gas state to a liquid state.
crustaceans	Crustaceans are aquatic arthropods, such as lobsters, crabs, shrimps, and barnacles.
cyanobacteria	Cyanobacteria are photosynthetic bacteria.
deposition	Deposition is the laying down of matter by a natural process.
energy cycle	Energy cycling involves the transformation of energy through the environment.
fecal coliform	Fecal coliform are bacteria that live in the intestines of humans.
fissure	A fissure is a long, narrow opening.
geology	Geology is the scientific study of the origin, history, and structure of the Earth.
geomicrobiologist	A geomicrobiologist is a scientist who studies microbes found deep in the crevices of the Earth.
glaciologist	A glaciologist is one who studies glaciers and their effects on the landscape
global positioning system (GPS)	A global positioning system is a system that can determine the latitude and longitude of a receiver on Earth with satellites, computers, and receivers.
hydrogen bonds	Hydrogen bonds are strong intermolecular forces where the hydrogen in one molecule is attracted to fluorine, oxygen, or nitrogen in another molecule.
hydrology	Hydrology is the scientific study of the properties, distribution, and effects of water on the Earth's surface, in the soil and underlying rocks, and in the atmosphere.
hyperthermophiles	Hyperthermophiles are microscopic organisms (prokaryotes) that live deep underground and require extremely high temperatures for growth.
hypothesis	A hypothesis is a plausible explanation for a scientific problem that can be tested by conducting an investigation.
lipids	Lipids are chemicals such as fats, oils, and steroids that do not dissolve in water.
meteorologist	A meteorologist is one who studies the atmosphere, especially weather conditions.
molecules	Molecules are pure substances made of two or more atoms held together by chemical forces.
organic pollutants	Organic pollutants are carbon-based substances, which pollute air, soil, and/or water.
PCBs	PCBs (polychlorinated biphenyls) are environmental organic pollutants that accumulate in animal tissue.
pesticides	Pesticides are chemicals used to kill pests, especially insects.
pH	pH is a measure of how acidic or basic a solution is. The pH scale ranges from 0 to 14.
photosynthesis	Photosynthesis is the process green plants and some other organisms use to make carbohydrates by reacting carbon dioxide with water in the presence of light energy.
phylogenetic	Phylogenetic is the evolutionary development and history of a species or higher taxonomic

	grouping of organisms.
radioactive isotopes	Radioactive isotopes are unstable isotopes of an element that emits radiation.
saline	Saline is one way to describe a substance as salty.
satellite	A satellite is an object launched to orbit Earth or another planet.
sterile	Sterile describes the condition of being free from live bacteria or other micro-organisms.
stomata	Stomata are small pores in the epidermis of a leaf or stem through which gases and water vapour pass.
strata	Strata are regions of the atmosphere, such as the troposphere, that occur as layers.
stromatolites	Stromatolites are sedimentary structures produced over geologic areas by the trapping, binding, or precipitating of sediment by groups of cyanobacteria.
temperature	Temperature is a measure of the average kinetic energy of the particles in a sample of matter.
toxins	Toxins are poisonous substances capable of causing disease when introduced into the body tissues.
Ultraviolet rays	Ultraviolet rays are radiation that lie in the ultraviolet range, wave lengths shorter than light but longer than X-rays.
volatility	Volatility describes how readily a substance evaporates at normal temperatures and pressures.
volcanic vents	Volcanic vents are slits in volcanoes that rise to the surface.
water cycle	The water cycle is the evaporation and condensation of the Earth's water as it evaporates from bodies of water, condenses, precipitates, and returns to those bodies of water.

The following non-science words may be new for students. Provide time for students to study and learn these words prior to watching this episode.

abundant	deposition	matrix	sheer
alleviate	entity	mecca	successive
aloft	fissure	moisture	sweltering
autonomous	fractured	persistent	tenacious
canopy	implication	pilgrims	thrusting
caverns	indigenous	pristine	transformation
contaminants	industrial	properties	triumph
contaminate	interaction	relevant	volatile
contradiction	kin	renowned	

SCRIPT EPISODE 2

David V/O: Life today moves so fast it's hard to make sense of it all. The world seems fractured, full of contradictions. We need to know what holds our world together, rediscover the sacred elements our life depends on. I started my search with water, looking for guidance on the banks of the River Ganges. The people here believe this water is a gift from the gods. Temples line the banks of the Ganges in Varanasi -- India's holiest city. I came here to meet the head of one of the city's largest temples. His name is Veer Bhadra Mishra. He's a renowned spiritual leader, and I was a bit nervous.

David: So glad to meet you.

David V/O: But he quickly made me welcome. He's a man who spans two worlds.

Mishra: Sweets from the temple

David: Thank you.

Mishra: They can last for 15 days.

David: Oh, great.

David V/O: As well as a holy man, he's a doctor of hydrology.

David: This is my first time to see the Ganges River.

David V/O: For Hindus around the world, he told me, the River Ganga, as they call it, is a god.

Mishra V/O: Ganga is the river which has been brought from heavens. We consider her as infinite, the divine. Ganga is one goddess, the mother. She supports the life of 400 million people living in her valley. I don't think there is any other river system in the world which has such a big responsibility. Four Hundred million lives -- no wonder it's considered divine.

Mishra: Ganga is that which goes, flows forever. That is the literal meaning of Ganga. And that is what life is for us. Life should have flow. It should be flowing all the time. In Sanskrit, we say that water is life.

David V/O: Water is life. You can see it right here. Millions of pilgrims come to Varanasi every year to celebrate the power of water. The relationship between people and their world is never simple. Sheer numbers mean that the people who worship the Ganges also contaminate it.

Every year, the festival of Nagnathaiya Lila dramatizes the conflict, re-enacting a story from the Hindu sacred scriptures. The festival is organized by Dr Mishra's temple. As the story tells it, the god Lord Krishna has discovered that the river has been poisoned. He jumps into the water. Krishna discovers the serpent god Kalia hidden under a water lily. He wrestles with Kalia and wins. Then he rides the snake home in triumph. As Dr. Mishra told me, gods and humans alike know that water is sacred. When we honour water we honour ourselves and the rest of life. The world he sees is a single entity.

Mishra: Mountains, rivers, plants, human beings, other forms of life, hey are elements of one matrix. They are not separate; they have interrelationship.

David V/O: We're all elements of one matrix. And water is at the heart of it. Without water, the world's a desert -- and so are we. That's the Hoover Dam, on the Colorado River, and its reservoir Lake Mead -- a water system that supports 18 million people. Out of this piece of engineering came another -- Las Vegas. An entire city exists in a desert because of Lake Mead. It makes you realize the whole world is built on water.

David: So what do you think, is this kind of exciting for you?

Tamo: Yeah.

David V/O: I brought my grandson Tamo along to help me see the water at the heart of this technological fantasyland.

David: That looks just like the Eiffel Tower, except, of course, it's a miniature. There's the Desert Passage; that's as close to reality as you can get there; we're in the desert. Look, look, it looks like it's bubbling; is something going to happen? There it goes!

David V/O: The fountain was a good preparation for the show. We went to see a performance by the Cirque du Soleil. It's a kind of water ballet, celebrating the element and our relationship with it. It reminded me a little of the festival on the Ganges -- strange images that somehow evoke the beauty and mystery of water. What is this substance we depend on every day of our lives? That's what we came to Las Vegas to learn -- the science behind the magic of water. Next morning, Tamo and I went out on Lake Mead with Richard Saykally, a chemist from the University of California at Berkeley who's studying water.

He talked to us about how much we take the stuff for granted.

Saykally: My mother still can't understand why I want to spend my life studying water while other people are curing cancer, discovering new drugs, and inventing new kinds of computers, and her son is studying water. And I think that just reflects this idea that water is so familiar to everybody they can't believe there's something about it we don't know.

David V/O: The truth is, he told us, we don't know the basics. Here we are, looking at about 45 trillion litres of something that's crucial to life on Earth. Yet it's still pretty much a mystery to us.

Saykally: How does water, which covers 70 per cent of our planet, interact with biological systems, the geology of the Earth, the atmosphere? How water influences the nature of life on Earth, that's the big picture, in my opinion, which we are not able to understand completely because we don't understand the pure substance. And that's what we're focusing on.

David V/O: Richard Saykally is studying the basic structure of water -- trying to understand its strange power.

Saykally: I think the greatest mystery of water is the nature of the substance itself. It has 15 different forms of solid; there may be two different types of liquid water. This is amazing behaviour that no other substance known exhibits.

David V/O: The water molecule shapes the world we know. H_2O, two small atoms of hydrogen attached to one large atom of oxygen. It's like a tiny powerful magnet, attracting and holding other water molecules in a powerful grip called the hydrogen bond.

Saykally: Each water molecule, liquid or solid, is interacting with four other water molecules and interacting rather strongly. So this creates networks of hydrogen bonds. And it's that particular quirk, four strong bonds, that give rise to the properties of water. All the properties of water that make it so unusual follow directly from this strong hydrogen bonding. Quite interesting.

David V/O: The bond is strong but unbelievably fleeting. A molecule changes partners many billion times a second. This is what holds the world together. It means the planet's water stays liquid on its surface, absorbing heat, moderating global temperatures. The dance of the water molecule keeps the planet in one piece.

Saykally: Understanding nature is the ultimate goal of science, and water is a very big part of nature. And if we can understand all of its properties and all of its interactions, we'll have done something very beautiful.

David V/O: Water is life, Dr Mishra told me. Richard Saykally agrees. This is how Genesis tells the story: "In the beginning God created the Heavens and the Earth. The Earth was without form and void, and darkness was upon the face of the deep; and the Spirit of God was moving over the face of the waters And God said: Let the waters bring forth swarms of living creatures. Myth and science converge: water is the womb of life. A place like this may have been life's nursery four billion years ago -- volcanic vents on the ocean floor, tapped into Earth's inner fire. Colonies of extraordinary life forms surround the hydrothermal vents. There are bacteria here that thrive in boiling water. Some scientists believe life developed in this crucial mix of water and heat, protected in the deep ocean from the deadly rays of the sun. I went to South Africa to explore another hypothesis with Tullis Onstott, a Princeton geomicrobiologist who's doing remarkable work. He's looking for the origins of life at the bottom of a gold mine. East Dreifontein is one of the deepest mines in the world. Ten thousand miners descend to the depths every day. I joined Tullis and his research team at Shaft No. 5, which is three kilometres deep. When the cage goes down full at shift time, they're absolutely jammed in, like sardines, and it's two miles down. I was terrified, really, because I didn't know about myself. I didn't know myself well enough.

David: I can certainly feel the heat coming up now. What will it be at the bottom of the shaft?

Tullis: They try and keep it at 32, let's put it that way.

David: And what is the rock's temperature at?

Tullis: Ah, that's a different story -- it's about 50 degrees centigrade

David V/O: I was scared of being confined in a tiny space. It's three kilometres down, and it's a journey back in time. Tullis hopes to find bacteria like the ones that first appeared on Earth, billions of years ago. I get to the bottom, and I'm astounded at the size of the caverns down there. I mean, it's a very impressive place in terms of the scale and the sheer technology. You realize the noise coming in is the noise of the fans that have to exchange a huge amount of air to keep everyone down there alive. We're here because the drilling team at the rock face has run into water.

Tullis: In the search for life, we always are looking for liquid water. Water does appear to be the key.

Tullis: They penetrate with a drill bit; we move in as quickly as we can and obtain samples which are free of drilling contamination.

David: So when did you find out about this place, Tullis?

Tullis: We were called by the mining company when they drilled and hit this intersection.

David: Oh boy, it looks hot. It feels hot.

Tullis: Temperatures are 100 degrees centigrade, and it may in fact be populated by hyperthermophiles that are able to maintain their integrity; they're tenacious enough to do that, with growth rates that are phenomenally slower than anything that's encountered in deep-sea environments.

David V/O: Some of these organisms, Tullis told me, grow so slowly they may only reproduce once in a thousand years.

David: What's this going to tell me?

Assistant: It's going to give you a pH

Tullis: There's 913.

David: Oh, wow, so it's alkaline.

Tullis: Yeah, that's exactly right. Most of these waters down here are alkaline. So the water here is not quite as saline as seawater.

David: So, what's Duane doing here, Tullis?

Tullis: Duane is filtering this fissure water in a sterile anaerobic canister. And when we return to the surface, we will filter those water samples so that any bacteria that contain DNA and lipids get preserved on the filter. We then freeze that down, and that information will tell us the phylogenetic relationships of these organisms to their sisters or cousins that exist on the surface of the planet.

David V/O: Tullis told me almost nothing is known about these mysterious microbes from the deep.

Tullis: When you have microbial communities at such enormous depths, are they essentially autonomous down there? They're indigenous to that strata, and they can exist for millions and millions of years. The ice ages come; the ice ages go; the meteorites impact and kill dinosaurs, you know. The mammals take

over, but these guys never see any of that action at all. They're just happily doing their business down there very, very slowly, hardly evolving at all.

David V/O: Microbiologist Duane Moser prepares the samples in the field lab for shipping back to the States. He may be handling organisms that are many thousands of years old, close kin to some of Earth's earliest inhabitants.

Tullis: Some of these organisms resemble the type of organisms that had been found on the surface of the planet. Some of these organisms actually resemble deep-sea hydrothermal vent organisms.

David V/O: And most of them are totally new to science. It's a whole new world, but Tullis explained it comes from the distant past.

Tullis: There are a larger number of DNA signatures that we find that don't closely correlate with anything that's ever been found on the surface. So here we're standing essentially with new branches to the tree of life, some of them that are quite distinct from anything that's ever been discovered before.

David V/O: Tullis calculates there is more biomass below ground than as there is on the surface. It's amazing. Where on Earth does life end?

When life climbed out of the ocean, water was still the crucial element. I went to Australia to learn this part of the story. Shark Bay, on Australia's west coast, is one of the strangest places I've ever visited. These rocks were actually built by the bacteria that made life on land possible. I met Malcolm Walter here. He directs the Australian Centre for Astrobiology at Mcquarie University, in New South Wales.

David V/O: Shark Bay is special because it's a sort of bacterial heaven. It's a mecca, for many sorts of scientists, particularly for geologists and microbiologists because we can come here and really visualize the way the Earth used to work. This is a real window in the world as it used to be three or four billion years ago. Four billion years ago, Malcolm Walter told me, this wasn't the blue planet; it was brown. The atmosphere was pink with carbon; the water brown with iron. Sunlight was lethal, flooding the Earth with deadly ultraviolet rays. Then bacteria evolved that could capture sunlight and use it as a source of energy. They started photosynthesis. They're called cyanobacteria, and they transformed the Earth.

Malcolm: The cyanobacteria were the first photosynthetic bacteria that released oxygen from water. So they took their energy from sunlight, and in doing so, they started a process that broke the water molecules, releasing the oxygen. And that was a process that fundamentally changed the chemistry of the Earth.

David V/O: The world went from being what we call an anaerobic world, or an oxygen-free world, into one that was saturated with oxygen, like our present world. Building up over the millennia, oxygen turned the sky blue and rusted the iron in the water, so it fell to the bottom. Oxygen formed an ozone layer that

blocked the sun's ultraviolet rays, so life could move safely on to land. As part of the process, cyanobacteria built these boulders, Malcolm Walter explained. They're called stromatolites.

Malcolm: Stromatolite is the geological word for this sort of rock. It just means layered rock in Latin.

David: So they're successive layers growing on top of each other, then?

Malcolm: They are. And the reason for that is that the sand gets squashed on top of the microbes. And they need light to live -- they're photosynthetic -- sand blocks the light. So they have to move up, or grow up through the sand, and in doing that, they have to make a new layer. More sand comes on, more microbes; layer-by-layer, they build up these structures, and they get higher and higher.

David: So they're reaching up to the sun, basically.

Malcolm: They are reaching up to the sun, yes. That's what they need, for their source of energy, for growth.

David V/O: For a few billion years cyanobacteria have been building boulders and making mats, layered communities of many different bacteria. They were right there beneath our feet.

Malcolm: Most life on Earth looked like this for two or three billion years.

David: For most of the time, life existed on the planet.

Malcolm: Exactly, exactly. If you'd swum in an ocean two billion years ago, this is exactly what you'd have seen. They're still very abundant. They're particularly abundant here in Shark Bay. But these sorts of microbes occur around the world. This is life.

David V/O: And this is what life did. It made an atmosphere for itself out of sunlight and water. Then it spread across the planet. Each of us has made the same journey -- born out of water into air. Like all other living things, we're mostly water. We carry our own ocean within us all life long. The baby takes his first breath. He enters his new element as it enters him. From now on, he is air as well as water. He's sharing air -- with his family and with the world beyond. The atmosphere that passes through him connects him to every breathing thing that has lived on Earth, since life first made the air we breathe. Moving round the Earth, air and water keep the planet fit for life. And life, I discovered, keeps the cycle going.

Flying into the Amazon basin you see air, water, and forest mix and mingle, it's hard to tell where one ends and the next begins. Add tropical heat, and you get one of the most dynamic places on Earth. I came here to learn more about that vital relationship -- how air, water and life are interlinked. An enormous international research effort is underway in the Amazon rainforest. The Large-Scale Biosphere Atmosphere Project is led by Brazil, with participation from NASA and other international partners. The place is teeming with scientists studying the complex interplay between the forest and the sky. Michael Keller, from the University of New Hampshire, is a leading scientist in the project. He began my education by giving me an overview.

David: Boy, we're really above the canopy here, Michael.

Michael: Above all of it.

David: How high are we?

Michael: About 45 metres, or that's about as tall as a 13-storey building.

David: Oh man, that's high! Why is there such an American interest in the Amazon? What's special about the Amazon?

Michael: The Amazon's the largest extent of tropical forest on Earth, and as a result, it's an important heat engine for the atmosphere. There's huge amounts of water cycling through this forest, and we want to understand how the atmosphere works, I think, just like everybody else on our planet does.

David: Now are the implications of what goes on here relevant to say people in Canada or Europe?

Michael: They're relevant to people everywhere. The more we study our world, the more we understand that it's all interrelated. And we can't understand the weather in Canada and in Europe without understanding the cycling of energy and water right here in the Amazon forest.

David V/O: Each morning, Michael Keller explained, as the sun rises over the rainforest, a transformation begins that keeps the planet alive.

Michael: Trees have leaves; leaves have little stomata in them. The stomata are basically little holes that the carbon dioxide that forms all of us and other organic matter is soaked up through and then turned into sugars and more complex compounds. When that happens, water's leaking out. So here this interface is where that big atmospheric heat engine is happening.

David V/O: The energy of the sun is being used essentially to boil water and evaporate it out of the leaves, and then it's going up into the atmosphere in vapour and being condensed into clouds. It's an amazing idea. The forest is actually raining upwards, thrusting water into the air in incredible quantities.

Michael: A tree this size could probably pump up to seven hundred tonnes of water over the course of a year, bring it out from the soil out into the canopy.

David V/O: Raining up from the canopy, the water flows west in rivers across the sky. It falls and rises many times before hitting the high barrier of the Andes. Air, water and life, I learned more about their vital interaction on a sweltering beach beside the Amazon River.

I was there with one of Brazil's foremost meteorologists, Maria Assuncao Silva Dias. She sends instruments aloft to study clouds.

David: So what is this balloon going to show?

Maria: It's a larger balloon. It will carry a radiosonde. And the radiosonde will transmit to our receiver, by radio, data on temperature, moisture, pressure and wind.

This sonde has a GPS receiver so it gets its position from the satellites and gives us the position of the sonde, and from that position, even if the sonde gets inside the cloud, even if it gets very far away you always know where it is. And from the position you get the winds.

David: Whoa, that's fast! The birds must be wondering what's going on.

David V/O: Tracking clouds over the rainforest, Maria has discovered they're more like clouds over the ocean. They're volatile, building fast, raining out, building again. The forest, she says, is like a green ocean. When the water here heats up, it affects the whole world.

Maria: During the summer, the wet season, when you have all the clouds and rainfall, basically what you are doing is heating the atmosphere. And this heat is like when you throw a stone in the water, and you get all these waves that go far away. The tropical heat source with all this rain, it's like throwing a stone in the atmosphere. And it sends waves that go around the globe. So this is something that impacts not only the region but larger, much larger domain.

David V/O: Clouds have no respect for human boundaries -- not to mention attempts at regulation. What I send off here in the Amazon could end up anywhere on Earth.

Jasper National Park -- a beautiful wilderness along the spine of the Canadian Rockies. I flew in to meet ecologist David Schindler, from the University of Alberta. He's studying what the atmosphere has brought here over the past half century.

David: So how could you find that out?

David Schindler: We chose to go to the highest point -- Snowdome -- just behind this ridge, where we would get the best record at the least melt. And then to go back, chiselling back in annual layers back to about 1940.

The work began when fish in a pristine mountain lake were found to have high levels of industrial toxins. David Schindler and scientists from Environment Canada wanted to find out how the contamination got there.

Mountain lakes are fed by glaciers.

Over several years, researchers have climbed the glaciers to sample the ice. David Schindler told me they've found pesticides, industrial poisons, even radioactive isotopes. They're studying how they were deposited.

David Schindler: From a scientific standpoint, it's just a nice mystery story to try and solve. There are so many different elements that affect the deposition of these things: their volatility, the air temperature, whether it's precipitating or not, whether there are glaciers involved. Altogether, it's just a nice puzzle to try to unravel.

David V/O: The equipment is set up at the top of a glacier or above a crevasse. The researchers descend the face to sample layers of ice laid down year after year.

David Schindler: So we have a glaciologist who works with the group, who goes down the face first and marks the individual years. And our sampling group just goes down and takes a sample of the ice for each stratum. They chisel away the face because that's in contact with the atmosphere and could be contaminated by today's atmosphere. So they go in several tens of centimetres and then take samples of up to 40 litres of ice, which was deposited in that particular year.

Scientist 1: This is tiring up here.

Scientist 2: It sure is. Were at almost three thousand metres. OK guys, haul it up; you might need two people.

David Schindler: When we study the chemistry of the snow and of the ice in the glaciers, we find a real soup of contaminants in concentrations that at high elevations are surprisingly high. Most of these pesticides or PCBs, other persistent organic pollutants, originate in more southerly regions.

David V/O: They're carried here in air masses moving round the globe. The scientists believe they condense when they meet a colder atmosphere or a glacier. It's a process they call cold condensation. As the glaciers melt, the contaminants flow out into the watershed. And there, they move into the food chain. That's how the fish in these clear cold waters absorbed high levels of industrial toxins.

David: So why does it end up in such high concentrations in the fish?

David Schindler: Well once it's in the lake, it goes into small crustaceans, and they're eaten by small trout, and the small trout by big lake trout, and at each step it's magnified by at least ten times. So there's a pretty good burden in the big lake trout by the time it gets there.

David: What does that tell us? What do your studies show us?

David Schindler: I think it should tell all of us that actions in one part of the planet via this interconnection with the atmosphere is likely to have consequences for other regions. So I think we all have to act together to control the contamination of this mutual atmosphere that we share.

David V/O: The atmosphere is a single entity, moving around the world and through every living thing on Earth.

In Varanasi, I saw people acknowledge water's supreme creative power. For devout Hindus, a holy dip in the river is the gateway to Heaven. Dr. Mishra and his music teacher sang me hymns in praise of Mother Ganga's gifts to life. Out on the river I saw the other side of the story. Alongside the temples stand the sewage treatment systems.

Mishra: That pump, this stonemasonry, this is one of the main sewage pumps. There are only five such sewage pumps. There are 30 outlets.

David V/O: Too few, and much of the time not working, he told me. Every day, about two hundred million litres of raw sewage are dumped into the Ganges in Varanasi alone. The divine river is very dirty indeed. As spiritual leader and as scientist, Dr. Mishra is deeply disturbed by the state of Mother Ganga.

Mishra V/O: I pray that I should be able to be intimately connected with my mother for my whole life. And that means that I should be able to go to her, touch her, take holy dip in her waters, offer my prayers. This is what Gangaji is for me. But at the same time, I am a trained scientist; I know what is happening to the river water. And at times, both the things just appear before me. Raw sewage floating on the river, sometimes it breaks my heart.

My respectful, loving heart and my scientifically trained mind, they are both within me. And the interaction between them is a kind of pain, suffering, which I carry all the time. This is just the reality of the world in which I live. It's the world in which we all live -- so what should we do?

Mishra: As brave person, as good person, we should fight, we should struggle to see that this situation improves.

David V/O: Dr. Mishra is fighting hard. The river water is sampled regularly by technicians from the Sankat Mochan Foundation. It was set up by Dr. Mishra to try to alleviate the pollution of the Ganges. In some places, they've found a fecal coliform count that's 300,000 times the acceptable level. Scientists at the Foundation have big plans for cleaning up the Ganges, proposing a natural sewage treatment system using algae in ponds. While they continue to push for government commitment, they've been campaigning to solve the problems at their source -- to reconnect the worlds of faith and action.

Mishra: If I go to a very traditional gathering and start saying that, well, Gangaji is dirty, Gangaji is filthy and polluted, people will say "Please, Mangi, you stop this. We are not able to hear these words." But if I take the same people to one of the sewer outfalls and show them that the whole sewage is being thrown on the body of our mother and say that this is what we are doing collectively in this city, the response is entirely different. Everybody says that, "No, this must not happen. We have to stop it."

David V/O: The Foundation is taking practical steps to improve the lives of communities along the river. We went to Saray Mohana, a town a few kilometres downstream of Varanasi and its sewage outfalls. New wells built by the Foundation bring safe drinking water to the townspeople. The struggle goes on, the conflict we all are caught in -- the gap between what we do and what we know. How do we find a way to reconcile with the sources of life on Earth?

Mishra: There has to be a balance. We have to find how to live in this modern world. The science, technology, religion, faith, all have to work together. And for me this example, that science and technology, one bank of the river, and religion, tradition and faith, the other bank of the river, both the banks need to be firm, and then only the river can maintain the flow.

David V/O: Science and faith agree -- we're part of the matrix that creates and maintains the living world. Wherever we are, air and water move through us, like a river of life. What we do to it, we do to ourselves. Next time, on The Sacred Balance we explore the fire of creation, the endless cycle of energy that creates, destroys and recreates all life on Earth.