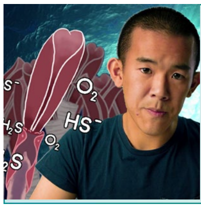

How Giant Tube Worms Survive at Hydrothermal Vents

[Ed talks to camera in front of graffiti wall. Montage of 1970s disco dancers, moving R2-D2 replica at contemporary Star Wars convention, 1980s Macintosh computer with animated talking head, zoom in on a picture of a boom box, animation of Voyager 1 in space. Ed talks to camera while holding model of Alvin and drops it.]

Ed Yong: 1977. A big year. Saturday Night Fever. Star Wars. Apple becomes a company.

The first boomboxes take to the street. Voyager 1 launches on an expedition into the outer solar system. And a small submersible named Alvin begins a dive to the bottom of the Pacific Ocean.

[Archival footage of Alvin prepping for diving and in the ocean in a circular insert that's surrounded by a view of the surface of water while underwater.]

Ed Yong: February 1977. 250 miles north of the Galapagos islands. A place where two continental plates are pulling away from each other on the ocean floor. Three men in a miniature sub set off on an expedition that would completely change our view of how extreme life on earth can be. They were on the hunt for deep-sea hydrothermal vents caused by the rift between those continental plates.

[Archival footage of Alvin's view of the ocean floor. Plumes of vents on ocean floor. Archival footage of life on the ocean floor.]

Ed Yong: Their existence had been predicted for decades, but no one had ever seen them. At a depth of 7,500 feet, their temperature sensors spiked – they had reached volcanically superheated water gushing through the ocean floor. But they also found something that utterly surprised them: life. In extreme abundance. Weird and wonderful. How could this underworld support so much life?

[Archival footage of Alvin exterior on ocean floor and ocean life in a circular insert. Ed talks to camera with underwater view behind him. Archival footage of ocean life.]

Ed Yong: There is zero sunlight here. Skull-crushing pressures, and yet the Alvin crew have discovered a hidden ecosystem. This was NOT what they had expected. They were the first to ever set human eyes on this environment: rich and full of life, like an underwater rain forest. And then they found …

[Archival underwater footage of tube worms. An ocean shadow of a 6-foot-tall human silhouette shines on the worms.]

Ed Yong: … the worms. These bizarre creatures are tube worms. They are giants that can grow over six feet long. Their bodies are encased in white tubes anchored to the rocks. At their upper end is a spectacular crimson plume. It looks like a tube of lipstick that's been pushed out too far. Or like maybe Mick Jagger's lips?

[Ed talks to camera in front of animated pic of tube worms.]

Ed Yong: The Alvin team knew that they had come upon a wonderful zoological oddity. What they didn't know was that the worms would reveal an undiscovered ecosystem that we didn't even think was possible.

["Meredith Jones, Smithsonian Institution" appears next to picture. Pic of Meredith Jones appears next to Ed. Worms in a jar in a lab with the Riftia label.]

Ed Yong: The Alvin crew collects one of the worms and gives it to this man. This is Meredith Jones, the Smithsonian Institution's curator of worms, and as befits his role as chief worm guy, he gives the thing a name: *Riftia pachyptila*.

[Worm artwork; "DO NOT ENTER" and "NO EXIT" signs. Worms in a jar in a lab.]

<u>Ed Yong</u>: Jones dissects the worm. And he encounters something that to us, as nonworm people, is really weird: *Riftia* has no mouth, no gut, no anus. This thing has no way in, no way out. How does it survive if it can't eat, digest, poop? Well, Jones, as a curator of worms, had seen this kind of thing before: gutless worms. Instead of a gut, these worms have an organ called a trophosome. It's brown and spongy and makes up half the creature's length.

[Meredith Jones archival picture holding worm. Worm artwork with the word "TROPHOSOME."]

<u>Ed Yong</u>: A trophosome isn't technically a gut, but it does deal with nutrition.

[Meredith Jones archival picture holding worm. Worm artwork with "SULFUR" text.]

<u>Ed Yong</u>: But this trophosome was different, because there was nothing remotely like food in it. Instead, it was packed with crystals of pure sulfur. Something was going on inside this worm that Jones had never seen before. And that's when Colleen Cavanaugh enters the picture.

[Graffiti with archival '70s disco footage appears in background of archival photos. Colleen Cavanaugh text.]

<u>Colleen Cavanaugh</u>: I was a first-year graduate student at Harvard taking a course called Nature and Regulation of Marine Ecosystems. And the professors organized so that there were four talks on the vents.

[Archival photo of Meredith Jones holding a worm.]

<u>Ed Yong</u>: Jones came in to give a talk about his worms. It was a long talk.

<u>Colleen Cavanaugh</u>: Amazingly, I was still awake when he mentioned that in this trophosome tissue it had sulfur crystals in it.

[Worm artwork with sulfur crystals. "Hydrogen Sulfide HS- H2S" text. Worm artwork. Archival footage of vents on ocean floor.]

<u>Ed Yong</u>: What Jones knew that the water spewing from the hydrothermal vents had a high concentration of hydrogen sulfide, a potent toxin to most lifeforms. So maybe the trophosome wasn't an organ to help feed the worm; maybe it was a filter – something to help get rid of all the poisonous hydrogen sulfide.

[Ed & Colleen intercutting their conversation.]

<u>Ed Yong</u>: And when she heard that …

<u>Colleen Cavanaugh</u>: I immediately jumped up and said, "It-it's clear! They must have symbiotic sulfur-oxidizing bacteria inside of their tissues that are feeding the worm."

<u>Ed Yong</u>: Bacteria?

<u>Colleen Cavanaugh</u>: Bacteria!

AUDIO CLIP (Speaker: Angelic Chorus): BACTERIAAA!!!

[Bacteria choir.]

[Split screen of Ed & Colleen's conversation in circle inserts.]

<u>Ed Yong</u>: And how did Jones react?

<u>Colleen Cavanaugh</u>: He was a little bit dismissive. It was a little bit like, you know, "Sit down, kid." Ultimately, I was able to get some tissue.

Ed Yong: Of the trophosome?

Colleen Cavanaugh: Of the trophosome. So it looks like little pieces of brown tissue.

[Archival footage of lab work, microscope, test tubes, etc. Text on screen: "Chemical analyses, DNA stains, Scanning Electron Microscopy, Transmission Electron Microscopy".]

Colleen Cavanaugh: It took a lot of detective work, chemical analyses, DNA stains, scanning electron microscopy, transmission electron microscopy …

Ed Yong: Ultimately?

Colleen Cavanaugh: I *was* right.

AUDIO CLIP (Speaker: Angelic Chorus): BACTERIA!!!

Ed Yong: So Colleen discovered that trillions of bacteria are living in the trophosome, using the hydrogen sulfide from the vents as an energy source …

[Archival: Vents billowing. Footage of burning red sun with flares. Ed talks to camera while holding potted plant.]

Ed Yong: …in a process called chemosynthesis.

Colleen Cavanaugh: Chemosynthesis is a process using chemicals such as hydrogen sulfide as energy sources.

Ed Yong: As opposed to photosynthesis, which uses sunlight. Plants do photosynthesis. They need wat-eh-hem, um. They need water and carbon dioxide, which they transform into sugars using the energy in …

[Archival footage of forest with sun. Archival footage of exterior of Alvin on ocean floor.]

Ed Yong: sunlight. But the worms can't do that.

Colleen Cavanaugh: It's dark. We're two and a half kilometers down up to, I mean to even deeper. That's, you know, over a mile and a half deep. So it's complete darkness in the deep sea.

Ed Yong: So instead of sunlight, the bacteria ingest and process the sulfides from the vents. In doing so, they excrete sulfur, but they also release energy, which they use to make food for themselves and for the worms.

[Bacteria eating, burping, and farting.]

And that's what chemosynthesis is. Making food not with solar power but with chemical power.

[Artwork of bacteria in worms. Split screen of circle inserts with Colleen talking to camera and an insert of tube worms.]

Colleen Cavanaugh: So it's apparent from a mouthless and gutless point of view that the worm is benefiting from getting its food from the bacteria. When you're a bacterium inside of the animal and you've somehow convinced the host to provide you with the sulfide and the oxygen then you're, you have easy street.

Ed Yong: So it's good for everyone?

Colleen Cavanaugh: That's right …

Ed Yong: Ok so one thing's not quite tracking with me here. So, if *Riftia* has no mouth, how do the bacteria get into it in the first place?

[Circle inserts of archival footage of tube worms and Colleen talking to cameras, intercut with Ed talking to camera.]

Colleen Cavanaugh: So we found out that the bacteria were actually getting in *through* the skin, *through* the body wall into the, the worm.

Ed Yong: Wow! Ok so how do the sulfides get in?

Colleen Cavanaugh: So the hydrogen sulfide goes in via the plume.

Ed Yong: (Pause) So they do have a mouth?

Colleen Cavanaugh: It's more, it's more like a lung.

Ed Yong: But a lung is for breathing …

Colleen Cavanaugh: That's right. It's breathing oxygen just like you and I. But it's also effectively breathing hydrogen sulfide because that's what the bacteria need to produce organic compounds via chemosynthesis.

[Dissolve to archival footage of tube worms.]

Ed Yong: And that deep red of the plume, I mean it almost looks like blood.

Colleen Cavanaugh: It is blood.

[Archival footage of tube worms. Blood Diagram.]

Colleen Cavanaugh: They have a blood supply all the way through it. And the blood is carrying the hydrogen sulfide, the oxygen into the trophosome to the bacteria.

Ed Yong: Huh. And this type of chemosynthesis, is it just a worm thing?

Colleen Cavanaugh: Not at all. It's ubiquitous or it's, it's widespread in nature. Wherever sulfide and oxygen exist, we can look for it and it's found in many of those places.

[Archival footage of vents and life on ocean floor. Ed talks to camera in front of footage of underwater view of surface and ocean floor.]

Ed Yong: Chemosynthesis had been discovered a hundred years ago, but after Colleen's discovery, it was established as the basis of this entire new ecosystem, 7,500 feet below the surface. And in fact, chemosynthesis might have been the way the earliest lifeforms on the planet found a way to survive.

[Archival footage of ocean floor life and vents.]

Colleen Cavanaugh: It took kind of getting away from sunlit environments to see that it's really possible and that the whole ecosystem is dependent on the chemicals in this hot water that's coming up. It's like the fountain of life.

[Crablike creatures on ocean floor. Circle inserts of archival footage of vents as well as Ed and Colleen talking to camera. Circle insert of Ed talking to camera envelops the screen.]

Ed Yong: Very cool, these vent creatures.

Colleen Cavanaugh: It's actually very warm. Well they're in hot vents. [Laughs] Sorry.

Ed Yong: And I think we'll leave it at that.

If you're especially curious about the story behind this episode, check out the link below for an article that dives even deeper into these amazing microbes. And don't forget to follow us on Facebook and subscribe to our channel for more weekly videos. Thanks for watching.

END OF EPISODE