"Life's Really Big Questions"
– SHOW 1103

EPISODE OPEN

ALAN ALDA Our ancestors spent a couple of million years bashing rocks like this to make tools. And that may have helped make us human. You want to cut some?

ALAN ALDA (Narration) See how our hands set us free -- and gave us baseball. How an ancient telescope found an alien world.

ALAN ALDA And here we were.

DAVID LATHAM And tonight's the night!

ALAN ALDA (Narration) Meet a baby robot that may grow up not needing us.

ALAN ALDA The computer knows more than I do in this case.

ALAN ALDA (Narration) And learn why Noah's flood may have been caused by a snowball.

ALAN ALDA I'm Alan Alda. Join us as Scientific American Frontiers heads out to explore Life's Really Big Questions.

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NOAH'S SNOWBALL

ALAN ALDA Every now and then on Frontiers we take a look at some of the really big questions scientists are asking -- probably the kind of big questions human beings have been asking ever since we became human. Which is, incidentally, one of the big questions we'll be tackling today -- just when and how did humans set out on our uniquely human path? As we'll see later, Tujo here may be able to help us out with that particular big question. The thing is that big questions don't have easy answers -- that's what makes them big. So we may not always come up with answers to our questions. But asking them can still be a lot of fun.

ALAN ALDA (Narration) Of everything that's happened since the world began, one event was more dramatic than any other -- and perhaps more significant. Astonishingly, we didn't even know about it until a year or two ago, when geologists Paul Hoffman and Dan Schrag came up with the extraordinary idea that the earth was once frozen solid, like a snowball. These rocks, on the New England coast, were formed when the snowball began melting 600 million years ago. In what was then the ocean floor, a stone fell from the melting ice and plopped gently into the mud.

ALAN ALDA Here's a moment, many millions of years ago, where that ice started to melt just enough for that rock to fall out of the ice through the ocean and down into that sediment. And we're looking at a specific moment in time there.

DAN SCHRAG That moment, you can put your finger on it and say, this is the moment of the biggest climate change in Earth's history, where it flipped from being incredibly cold to incredibly warm, and we can now tell the story of that.

ALAN ALDA (Narration) It's a story that's breathtaking enough by itself. But it may also unlock the answer to a really big question: how did life become interesting enough eventually to produce… us. But let's start with the rocks. What we're walking on may be near Boston now, but once -- 600 million years ago -- it was in what later became equatorial Africa.

ALAN ALDA There were glaciers all over Africa at this time, is that what you're saying?

PAUL HOFFMAN That's right. At 600 million years ago, every continent in the world was covered by ice.

ALAN ALDA (Narration) And according to my companions' startling hypothesis, it wasn't just the continents that were ice bound.

DAN SCHRAG We see here sea ice that was formed in the last few weeks. But 600 million years ago, the sea ice was a mile thick.

ALAN ALDA A mile thick, the oceans were…

DAN SCHRAG The oceans were frozen over.

ALAN ALDA And so the whole earth was in fact this giant snowball.

DAN SCHRAG That's why we call it a snowball.

ALAN ALDA It sounds more like an iceball, I mean it was really impenetrable.

DAN SCHRAG It's extraordinary. The idea that this happened makes you rethink everything that you think you know -- about life on this planet, about the chemistry of the earth, about the geology of the earth.

ALAN ALDA (Narration) Here's what Hoffman and Schrag think happened. For reasons they don't fully understand, 600 million years or so ago the earth cooled by a few degrees and the polar ice caps began expanding slowly toward the equator. As more and more of the earth's surface became covered with the highly reflective ice, more and more of the sunlight falling on the earth was radiated away into space.

PAUL HOFFMAN When you get to about half the earth's surface covered, that is the ice line's down to about 30 degrees north and south of the equator, then the effect is unstoppable and the whole thing just freezes over instantly, all the way to the equator.

ALAN ALDA Instantly, meaning… how quickly does it go?

DAN SCHRAG Probably in a few years. And once you have the whole planet white, once the whole planet's surface is white from the snow and ice, the temperature plummets. It goes down to about minus 50 degrees C.

ALAN ALDA (Narration) And there the earth might have remained forever --- a brilliant white cloudless snowball floating in space. What saved it were its volcanoes, poking through the ice and spewing into the atmosphere the gas that today we fear may be leading to global warming -- carbon dioxide. Eventually carbon dioxide built up to levels where the Greenhouse Effect kicked in with a vengeance. Temperatures started to rise, the equatorial ice began to retreat -- and the snowball melted as suddenly as it was formed.

DAN SCHRAG When the snowball ended and you started to melt the ice at the equator, you could say literally all hell broke loose, where in a hundred years you go from a completely frozen planet to the warmest state the earth's ever been in.

ALAN ALDA (Narration) This cataclysmic climate change must have been devastating for life on earth -- or so you'd think. But life today is very different from life 600 million years ago -- when it was quite literally still stuck in the mud -- boiling mud.

ALAN ALDA Is this whole park on a crater, a volcanic crater?

SUE BARNES That's right, that's what Yellowstone is, the remnants of a massive volcano that occurred on the order of 800,000 years ago. Blew ash all over the western United States and this is what is left of it. It is still pretty active.

ALAN ALDA Pretty...This is as active as it is ever going to get now?

SUE BARNES Ever, no.

ALAN ALDA It is going to blow again, you are telling me.

SUE BARNES We are very...there is a very thin crust area. It could well..

ALAN ALDA Are we standing on one of the places that ...

SUE BARNES It is going to come up here first.

ALAN ALDA It's bubbling already.

SUE BARNES That's right.

ALAN ALDA (Narration) Whenever they visit here, biologists Sue Barnes and Norman Pace first measure the water temperatures -- which seem way too high for the sort of life that occupies most of the planet today.

NORMAN PACE So this is going to be all water temps now, Sue.

SUE BARNES O.K. That's fine.

NORMAN PACE O.K. Read them off.

ALAN ALDA 182, 180

SUE BARNES Whoa.

ALAN ALDA I'm sorry.

NORMAN PACE No, it's o.k.

SUE BARNES It's not fatal.

ALAN ALDA Have you lost many microbiologists?

SUE BARNES Nope.

ALAN ALDA I saw a bleached bone up there.

ALAN ALDA (Narration) But in fact there is life here. Even where it's boiling, the mud is teeming with microscopic creatures.

ALAN ALDA All my life I have been taught that if you boil the water you will kill anything nasty in it. And if you boil the medical instruments, you will make them sterile.

NORMAN PACE That is certainly true for the sorts of organisms that would infect us. They would not survive the boiling. But if you evolved, if you were capable of, if you are in fat city if you are in such a hot environment, then it doesn't matter.

ALAN ALDA (Narration) We've brought along a microscope, to take a look at these heat-loving creatures.

SUE BARNES Should be in focus.

ALAN ALDA (Narration) I'm looking at the sort of microbes Sue and Norm believe were once -- and for a very, very long time -- the only life on earth.

ALAN ALDA That was -- that's like looking through a time machine in a way...

NORMAN PACE In a very real way...

ALAN ALDA To the earliest days.

NORMAN PACE In a very real way. I think that, that these organisms, the general properties of these organisms will be not at all too dissimilar from the nature of the earliest organisms.

ALAN ALDA (Narration) Even after two billion years of evolution, this is all life had come up with. At least it was well equipped to survive the snowball, nursed through the deep freeze by the heat of the same volcanoes that eventually re-warmed the earth. But life not only survived the snowball. It was about to be transformed. To see how, we've come to southwestern China. Our journey begins with a train ride on a rainy summer morning. On board the train is biologist Andy Knoll.

ANDY KNOLL We've all heard of the Big Bang through which the universe is thought to have begun. But in biology, there's another kind of big bang--a big bang of animal evolution. Life began at least three and a half billion years ago, but it wasn't until 580 to 570 million years ago that we see any kind of animal life--and then, in just a few million years, we have a tremendous diversification of different types of large and complicated animals. And here in China, we see one of the best available records of that biological big bang.

ALAN ALDA (Narration) It's in the Chun Jiang Hills of Yunan that you can see spectacular fossils of those first animals, in rocks that formed out of mud on the bottom of an ancient ocean, 550 million years ago. In rocks just a little older than these, all fossils are still microscopic -- so this place marks the very beginning of animal life. There's been an excavation here for almost five years, and today Andy is meeting the man behind it, paleontologist Chen Jun Yuan.

ANDY KNOLL It's in there that the event beds that really captured the fauna are found.

CHEN JUN YUAN Yeah, yeah.

ALAN ALDA (Narration) The real fossil hunting here takes place across the road, where 30 local women split the newly excavated rocks into thin slices. They get paid about 50 cents per fossil found -- plus a bonus for unusual discoveries. The rocks are loaded with fossils.

ALAN ALDA (Narration) While the fossils come pouring in, Professor Chen tries to figure out what they were. Andy Knoll ...two valves, and then the animal inside is a little bit shrimp-like.

CHEN JUN YUAN Yes.

ALAN ALDA (Narration) This seems to have been a kind of combined clam and shrimp.

ANDY KNOLL It has almost like a fin on it, which would help it to move through the water.

CHEN JUN YUAN Yes. Andy Knoll Interesting. How about this, these look like big pincers.

ALAN ALDA (Narration) And this fossil has the familiar look of a lobster claw. Chen's never found a whole one, but he's got enough parts to know these animals could get huge.

CHEN JUN YUAN The largest one can be two meters long. Andy Knoll Two meters long, that's...

CHEN JUN YUAN Very large, a large mouth. Andy Knoll And so this could eat everything else in the whole Chun Jiang fauna.

CHEN JUN YUAN Right.

ALAN ALDA (Narration) Many of the fossils don't look like anything alive today. But for the first time, life had broken through the constraints imposed by being simple single-celled creatures, and had begun an explosive exploration of the possibilities of complexity. Animals had arrived. And that brings us right back to our snowball.

PAUL HOFFMAN The question ultimately is, were animals inevitable? Would biology have come up with animals in any case, or did you have to hit biology over the head with a hammer?

DAN SCHRAG Or hit them with a snowball. ALAN ALDA So it sounds like you feel you had to hit it over the head with a hammer.

PAUL HOFFMAN Yeah, because of the coincidence in timing. It's hard to ignore the fact that you had this explosion of multicellular animal life in the immediate aftermath.

DAN SCHRAG For two billion years you had algae and bacteria living and nothing happened. And then all of a sudden, after you've had these repeated glaciations, that's when multicellular life occurred. It's possible that it's a coincidence, but I think it's unlikely.

ALAN ALDA Yeah, it's such a giant event…

DAN SCHRAG Yeah, it's amazing.

ALAN ALDA It's such a clear marker in history.

DAN SCHRAG Exactly. I mean, in some ways it's like Noah's Flood, a catastrophe and then a redemption that actually ends in a much more interesting world than you had before.

ALAN ALDA (Narration) It's a captivating idea: that volcanoes saved both our planet and our ancestors from an icy coffin, in a period of cataclysmic climate change that kick-started animal evolution -- and that eventually led to us. While Paul Hoffman and Dan Schrag are very aware that the snowball earth hypothesis is just that, a hypothesis -- they are still savoring its invention.

ALAN ALDA When all this came together for you, was it a gradual process or was it a volcanic explosion?

PAUL HOFFMAN Well in my case it was like a flash. And all of a sudden my world was transformed. Because not only did I suddenly get this clue but I just knew in my bones almost from the instant not only that it was right but also that it was a big thing, a big deal.

DAN SCHRAG We tend to… Both Paul and I are night owls and we tend to talk late at night about science. And at about one or two in the morning we had a conversation and it was sort of an epiphany for both of us. And as a result for the next two months we were both scurrying back and forth, new ideas flying, and that exciting discovery, being able to go out into the field and know that you've forever changed the way people think about this, that moment of discovery was amazingly exciting.

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HANDMADE HUMANS

ALAN ALDA Billions of years of evolution has produced probably billions of different living things. But of those billions, only one -- so far as we know -- wonders about how and even why it's here. Which poses perhaps the biggest of life's big questions. What happened some four or five million years ago that set us off on our unique journey to becoming Homo sapiens? We know it happened in Africa, when a species of ape left the trees of the forest behind and strode away on two legs, freeing its hands to become… well, that's what our next story is going to explore.

RESEARCHER Make a fist. Point at something.

ALAN ALDA (Narration) I'm returning to the stone age -- equipped with a cyberglove, able to measure every subtle movement of my fingers and hand. It's a great mix: the very latest in high tech being used to study the oldest tech of all -- tools made of stone.

RESEARCHER Close your fist.

ALAN ALDA Ah, there, I got a nice piece there.

STEVE SHAKELY I think we have natural here.

ALAN ALDA Now I have two. Here, you want to cut some? I'll go halves with you on that antelope. Well, how did I do with this? Mary Marzke I think we're quite impressed with how you did with that. Very effective. Removed a lot of flakes.

ALAN ALDA So that must mean it must be innate, right?

ALAN ALDA (Narration) That's the idea we're exploring in this story -- that our hands were designed for making stone tools -- that they were in fact designed by making stone tools.

STEVEN SHAKLEY You've got quite a cutting edge here, so you'd be quite competitive. So you can move up 100,000 years.

ALAN ALDA (Narration) Of course, the hands of our ancestors got a great start. This is Tujo the orang-utan, one of the stars of the Phoenix Zoo. Orangs and humans last shared a common ancestor about 12 million years ago. While we've both been evolving ever since, Tujo's hands give us a glimpse of what ours may have once been -- extremely dexterous, but shaped by a life in the trees.

MARY MARZKE You notice that he's carrying it in his foot.

ALAN ALDA Yeah.

MARY MARZKE When they're moving around, they have two hands that they're moving on the branches with. And the only way to keep the fruit with them is to carry it in the foot. And the feet act very much in coordination with the hands in manipulating foods.

ALAN ALDA (Narration) Tujo uses his feet not just to carry the grapefruit but to help eat it too -- and needs at least both of his hands to help resist the pull of his teeth.

MARY MARZKE Possibly we would do that with a big piece of fruit, but as it gets smaller we would get a good purchase on it with our thumb and fingers which adapt to the shape of the grapefruit.

ALAN ALDA (Narration) To Mary Marzke this is an important clue as to what makes our hands different -- and far more capable. But before our hands could change they had to be free. And that meant standing on our own two feet.

ALAN ALDA Is that Lucy there?

WILLIAM KIMBEL This is Lucy. This actually is a copy of her bones.

ALAN ALDA (Narration) Our most famous ancestor, Lucy lived about 3.2 million years ago in what is now Ethiopia.

ALAN ALDA How do you know she was an adult?

WILLIAM KIMBEL Well, we have her lower jaw. And we can see that her last molar tooth, the so-called wisdom tooth, is erupted and was being used for chewing. (And we can actually see that) because the tips of the little cusps on top of the teeth are polished and worn, (meaning that she was using them to chew.) That's full adulthood. Three and a half feet tall, however, which is you know, when down on the ground is not much bigger that a good sized umbrella you know when you put its tip on the ground. So she's very tiny. Her brain -- although we don't have too much of her skull, unfortunately -- what we do have suggests a brain size not much bigger than that of a chimpanzee. And that really drives home one of the most important points about Lucy. And that is the stark contrast between her anatomy beneath the neck, which is fully consistent with an upright two-legged walking; and the anatomy above the neck with a very primitive ape-like jaw and teeth and a very tiny brain.

ALAN ALDA (Narration) One of the below-the-neck features suggesting Lucy walked upright is her pelvis -- short and wide when compared to the pelvis of a chimp. Then there are the leg-bones themselves.

WILLIAM KIMBEL You can see here's the hip and here's the knee. And there's a very pronounced angle as the thighbone runs from the hip joint to the knee. With the knees being much closer together.

ALAN ALDA Yeah, I can see that over here too.

WILLIAM KIMBEL Very obvious. Very obvious in a human. And in a chimpanzee, when it stands upright, that's not the case. The thighbone is more or less perpendicular to the ground, in contrast to what we see in Lucy and modern humans.

ALAN ALDA (Narration) This combination of a tall pelvis and upright thighs give chimps their characteristic waddle when they walk on two legs -- not an efficient way of getting around -- especially when you're in a hurry. But Lucy was probably quick on two legs, and she had bipedalism's most useful spin-off -- genuine hands rather than modified feet.

ALAN ALDA Is this Lucy's hand or one of her relatives?

MARY MARZKE This is a composite set of hand bones from Lucy's relatives. Beautifully preserved. Very nice joint surfaces. And some of the interesting things are at the base of the index finger where there are three joint surfaces, and these surfaces are oriented in the way that they are in modern humans. And they are all different from the way that they are oriented in chimpanzees. And the different orientation would have allowed a little bit of rotation of the index finger…

ALAN ALDA Rotation meaning what?

MARY MARZKE Rotation toward the thumb. And when you rotate the index finger toward the thumb, this helps you to grasp.

ALAN ALDA (Narration) Lucy's ability to pick up and firmly grasp an object like a round stone opened up a whole new way of earning a living. Chimpanzees throw stones -- but underhand and not very accurately. Lucy's ability to hurl a rock hard and on target brought her into a different league.

ALAN ALDA Would Lucy have been able to pitch?

MARY MARZKE She could have. She had the anatomy to do it. And if she had practiced she would have been able to pitch. She had a hand that could have grasped the ball, and controlled it. And she had a pelvis that allowed the balance of the trunk on the hind limbs. So she could have used her trunk as leverage in pitching. As we watch these pitchers, they're rotating their trunk and then they're putting on the brake with their gluteus maximus muscle so that their arm accelerates in a whip-like way. And she had both of these features both in the hip region and in the hand. So it takes a lot of practice, but she could have done it.

ALAN ALDA (Narration) Of course, Lucy's strikes weren't on batters but small game -- and could have significantly increased her food supply. We're back in the lab again, where Mary has assembled a team of experts to delve more deeply into the link between anatomy and the technological breakthroughs that set our ancestors apart from everything that had lived before.

RONALD LINSCHEID Ouch!

ALAN ALDA (Narration) Dr Ronald Linscheid is a retired hand surgeon. Nick Toth is an archeologist. The needles in Nick's arm and hand are implanting thin wire electrodes into his muscles to measure how vigorously they contract.

RONALD LINSCHEID You're going to feel a little stick right about there. May have felt that hit the bone a little bit.

ALAN ALDA (Narration) Nick will also be wearing the cyberglove I was modeling earlier -- and you'll understand now why my participation in the experiment ended right there.

MARY MARZKE Alright Nick, imagine there's an animal there, and that's your food for the night.

ALAN ALDA (Narration) Mary's purpose in organizing this little party is to closely monitor the hand and its muscles when Nick, then his wife, Kathy Schick, start behaving like stone-agers. Our ancestors from the time of Lucy -- 3.2 million years ago -- may have been hot on the mound… But they would have had problems at the plate. Here's a chimpanzee letting off steam with a stick. He's swinging it with great determination, but his grip is quite different from that used by a baseball batter. Our old friend Tujo the orang-utan uses the same grasp as the chimp, with all four fingers curled into his palm. Neither modern orangs nor chimps -- or even, it turns out, Lucy -- can do what we can do: rotate our little finger across the palm to touch the thumb.

MARY MARZKE The advantage of having this rotation can be seen when you hold something cylindrical, like this bone, where you grasp things in a trough, across the palm with the little finger and the thumb strongly opposed. And this allows you to bring the tool down in line with your arm.

ALAN ALDA That's interesting. I was taught in tennis to squeeze these last two fingers as I hit the ball. And that gives control.

MARY MARZKE Yes.

ALAN ALDA And that's what they were able to do when they shifted over to this kind of a finger.

MARY MARZKE Yes.

ALAN ALDA (Narration) It was a shift that didn't take place for a few hundred thousand years after Lucy's time -- but when it did, our ancestors would certainly have made the most of it. After stunning, say an antelope with a well-aimed stone, the tennis racquet grip would have made finishing it off much easier. Of course, not everything was easy to kill.

ALAN ALDA So what did it take, about a million years for people to find out you couldn't kill a pillow?

ALAN ALDA (Narration) But look at this. As Steve Shakely takes his turn with the glove and the electrodes while making a stone tool, you can see he's relying on the flexibility of his hand to manipulate and grip the stone he's hitting.

ALAN ALDA There's so much attention paid to the opposable thumb. But the opposable pinky turns out to be really valuable. I mean, if I hit this stone without that little finger giving me pressure, this stone would just come right out of my hand, right?

MARY MARZKE Yes.

ALAN ALDA I can really manipulate it and keep it right where I need it with strength.

ALAN ALDA (Narration) So while Lucy could have gripped the hammer stone like a baseball, only her descendents could have cradled the stone being struck firmly enough to have fashioned it into something useful. Mary Marzke plans to use the data she's getting from her volunteer Stone-agers to help her interpret the fossil bones that are all that remain of our ancestors. Kathy Schick meanwhile has re-discovered the one inescapable consequence of making stone tools.

ALAN ALDA So what have you left yourself with here?

KATHY SCHICK Tourniquet! You don't want to see this.

ALAN ALDA Oh God! You know this is heroic what you're doing for science. In all the years we've been doing this show I've never seen people bleed for science like that.

KATHY SCHICK Only a flesh wound!

ALAN ALDA (Narration) From the time our still non-human ancestors started making stone tools two and a half million years ago, until just a few thousand years ago, this is how we fashioned the tools and weapons we used gradually to dominate our planet. With grips we use today to hold a bat and ball, our hands helped make us human.

ALAN ALDA I get the impression talking to both of you that we can do amazing things with our hands now because of what these people did a couple of million years ago with stones. We can work the keys of a computer. But I also get the impression that the very invention of a computer, the way we use our minds to come up with a computer, is in a way an outgrowth of this stone work.

STEVE SHAKELY Very much so.

ALAN ALDA Trace that for me a little bit. You may not be able to document every step along the way, but what's your thinking on that?

STEVE SHAKELY Well, I think a lot of it has to do with, we as human's ability -- and I think that really separates us much from the animal world -- this ability to look into the future. To build something today that will make our lives easier tomorrow. Now some might argue that computers don't necessarily do that, they make our lives more complicated. But I think that in general that's why computers were invented, to make our lives easier in the future, to get through the day. And stone tools were no different. And somebody 2.5 million years ago must have discovered and thought and invented this piece, this flake, to make his or her life easier in the future.

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ROBOT INDEPENDENCE

ALAN ALDA (Narration) Evolution may have created billions of different living things. But it hasn't stopped there. Thanks to our invention of the computer, evolution is now producing a whole new generation of creatures.

KARL SIMS Evolution by itself has led to the creation of incredible complexity. Ourselves, all the organisms in the world. This process happened on its own. At least in my opinion. There was nobody that assembled all of these wonderful things in the world. On computers, we can simulate the same process and we can get these very complicated, very interesting things without having to understand them and assemble them.

ALAN ALDA (Narration) Karl Sims was one of the first researchers in what is now a burgeoning field --- artificial life. He started by giving his computer the instructions for a set of basic parts.

KARL SIMS The bodies of these creatures are fairly simple. They're just made of some number of blocks. The blocks are connected by joints which can bend or twist. The creatures also have a nervous system. They have sensors which can sense the angle of the joints or sense contact. And the nervous system processes the signals from the sensors and tells the muscles when to move, which generates some kind of behavior. I've given it the capabilities to include all these elements but the computer actually decides how they're assembled and used in specific creatures.

ALAN ALDA (Narration) Numbers chosen randomly by the computer -- a synthetic genetic code -- described how the first simple creature would look, and how its nervous system would be wired. Then it was put into a simulated lake and told to swim. It twitched but didn't get anywhere, so now the computer went to work. Using the original numbers as its base, the computer made a few random changes -- the equivalent of mutations. It did this again and again, creating a new generation of 300 different offspring. Then all the offspring got a swimming test, with the best swimmers selected as the basis for the next generation. KARL SIMS When the computer makes mutations in the genes of these creatures, it has no idea what these mutations are going to do. Sometimes the mutations might knock out pieces of the nervous system and perhaps cause the muscles not, not to move any more. But other mutations might actually improve the motion.

ALAN ALDA (Narration) So from the original creature, increasingly better swimmers evolved over generations, all without any human intervention. In the end, this was the best swimmer of all. But when Karl Sims put it on simulated land... it was like a fish out of water. So over subsequent generations, the mutation and selection process had a new goal -- to walk. After 15 generations, this was the champion. Other computer runs have produced even better walkers

KARL SIMS Sometimes these evolving creatures would think of solutions to their goal which were completely different than I expected. In this one example, the creatures got taller and taller and taller, and would simply fall over. Instead of figuring out some clever way of walking, they would fall to generate horizontal velocity. What I was telling them to do was to just move, and falling was a perfectly good solution as far as they were concerned. So this creature specialized in falling for as long as it possibly could, including doing a complete somersault.

ALAN ALDA (Narration) Karl Sims' creatures may have evolved some very clever tricks, but they are confined to the virtual world of the computer screen.

ALAN ALDA All right. What do I do, take a piece and put it next to this?

ALAN ALDA (Narration) But here in Jordan Pollack's lab at Brandeis University, artificially evolved creatures have already taken the first steps into the real world.

ALAN ALDA You know, you should have had a five-year old come and do this. What am I making here?

PABLO FUNES We call it a lamp. We don't really know what it is. It's a structure that the computer evolved or designed through evolution.

ALAN ALDA (Narration) The Brandeis computer is told the basic facts about Lego bricks -- their weight, how firmly they stick together and so on. Then through hundreds of generations the computer uses its virtual Legos to evolve structures selected for how well they perform a certain task -- in this case, to hold a 20 gram weight as high and as far to the left as possible. This is the computer's best current solution. A human -- in this case me -- gets involved only to build it. This design was evolved to reach out as far as possible without breaking. And this crane was evolved in the computer to lift a 100 gram weight. The point of actually building the structures is to see how well a design evolved in the virtual world -- where everything is perfect -- holds up when it meets the real world, where almost nothing is perfect.

JORDAN POLLACK Put it down gently sir.

PABLO FUNES Oh, it broke!

ALAN ALDA Ahh, was that me or was that the computer?

PABLO FUNES I think that was…

JORDAN POLLACK I think that was a gap in the table.

PABLO FUNES I think that the books moved. ALAN ALDA The book moved?

PABLO FUNES Yeah, I think that the books slipped.

ALAN ALDA These books?

PABLO FUNES Yeah.

ALAN ALDA Now there's an example of the real world, right? That thing worked in the computer. Had you ever put that catalogue on top of it?

JORDAN POLLACK No.

PABLO FUNES Yeah.

JORDAN POLLACK Oh, yeah, actually, before…

PABLO FUNES Yeah, we have tried it, yeah.

ALAN ALDA OK, well, there's another example of the real world.

JORDAN POLLACK That's right.

ALAN ALDA Sometimes the real world works one way and sometimes it works the other way.

JORDAN POLLACK Well, why don't we see if we have more success standing up today's new structure. Betsy and Greg have finished it, it's never been tested before.

PABLO FUNES The other ones had been tested before.

ALAN ALDA Lot of help that was.

ALAN ALDA (Narration) Now it might seem odd in a show about life's really big questions to be worrying about whether a computer-designed Lego lamp is going to stand up. But Jordan and Pablo see this as the first step toward something far more ambitious: machines that are not only designed without humans but are built without humans. In other words, robots that don't need us at all.

JORDAN POLLACK So there it is. It stands.

ALAN ALDA (Narration) But first things first.

ALAN ALDA It's holding its own weight.

JORDAN POLLACK It's holding its own weight. And now the question is, sir, you have a real way with robots…

ALAN ALDA I have a touch for this.

PABLO FUNES Oh no, not again.

JORDAN POLLACK So put it between the last two knobs.

ALAN ALDA (Narration) OK, drum roll please.

ALAN ALDA I'm not going to jerk it, I'm just going to let it go… Look at that!

ALAN ALDA (Narration) Mission accomplished. Now about those robots that can do without us. This artificially evolved creature is one of several the Brandeis computer has come up with that are very similar to the ones Karl Sims' computer created. Except that these creatures -- with only minimal human help --are already making the leap into reality

HOD LIPSON The idea is that not only do we want the robots to be autonomous in terms of behavior and in terms of power but we also want them to be autonomous in terms of their own design and manufacture.

ALAN ALDA (Narration) Hod Lipson has written a program that allows the computer's design to be directly printed out in plastic. We've speeded up the time it takes; but the remarkable fact is that between telling the computer what the robot should do and actually taking the robot out of its miniature factory, no human was involved. There are still a few tricky steps that haven't yet been automated -- like plugging a motor into… well, at this point I'm not quite sure what.

ALAN ALDA The computer came up with this loose hanging down piece in the evolution of this thing. What was it told to do, what was it told to make?

HOD LIPSON The only thing the computer was told to do was to make something that moves. And we will see, this flappy thing is very important for its motion.

ALAN ALDA OK, this is great. You know, if you just… I come up to this table and I look at this and you say the computer invented this great thing and it moves and it uses this to move, I'm thinking, I don't think so. The computer knows more than I do in this case. I can't wait to see this move around the table. HOD LIPSON That's the nice thing -- you get creative surprising sometimes solutions.

ALAN ALDA Yeah. There, oh look at that. There's something especially weird and interesting about the fact that the computer thought it up and then it told another computer to make it. And then you just had to help it a little bit….

JORDAN POLLACK Plug in the motors…

ALAN ALDA (Narration) It's possible of course to see these awkward machines as the innocent forerunners of a sinister robot race that evolves beyond our control -- But Jordan Pollack sees them rather as prototypes for cheap, disposable robots for everyday use.

JORDAN POLLACK You might (have a meta-robot in your home and you) say, gee, I want something to clean the front gutter of my house and you generate a robot and out it comes and you throw it up onto the roof and it cleans the gutter of your home, and when it's done you throw it in the recycling bin.

ALAN ALDA Oh I have this robot-making machine…

JORDAN POLLACK A robot-making machine…

ALAN ALDA Depending on what I need that week.

JORDAN POLLACK Exactly.

ALAN ALDA (Narration) But as our little robot gets recycled in the laboratory toaster, it's hard not to wonder if one day robots that can evolve and manufacture themselves will find humans unnecessary.

HOD LIPSON These things might completely do without humans and surpass maybe human engineering capability and reach something that we can't think of today.

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ALIEN WORLDS

ALAN ALDA (Narration) The top of a modest mountain in Massachusetts may seem an unlikely place to be asking our next big question: Are we alone in the universe? The telescope here is almost 70 years old -- and looks it.

ROBERT Stefanik I can operate the telescope from here…

ALAN ALDA (Narration) With only a 61-inch mirror, it's puny by the standards of today's telescopes, located on far more exotic mountaintops. But it's playing a key role in searching for alien worlds.

DAVID LATHAM Come up and take a look at the instrument.

ALAN ALDA It seems hard to believe that with a relatively small telescope you can find something so tiny as a planet.

DAVID LATHAM Well, we don't find the planet. We only see the motion that the planet makes on its parent star. In fact we have a model over here that might help you see how that works a little better. Here we have our model of an extra-solar planet. There's a star like the sun, and then out there swinging around in its orbit is a planet. Of course planets are much fainter than their parent stars because they only shine by reflected light. So it's almost impossible to take a picture of a planet. Instead we look for the motions of the parent star. The star is much more massive than the planet so its motion is much smaller. The planet swings in a wide orbit and the star swings in a small orbit in response to the pull of the planet.

ALAN ALDA Now when you're looking with the telescope, are you seeing the star move from side to side the way it appears to me or are you looking at something that goes away from you and toward you?

DAVID LATHAM Well, right now it's going away from you and that's the motion that we're measuring, back and forth along the line of sight.

ALAN ALDA (Narration) My hosts point the telescope at a favorite star.

ALAN ALDA And what is it you like about this?

DAVID LATHAM Well I like it because it looks a lot like the sun. ALAN ALDA What, has it gone behind a cloud now?

DAVID LATHAM Yeah, the star has gone behind a cloud now.

ALAN ALDA (Narration) The clouds part long enough for the star's spectrum to be recorded. And it's these lines that reveal the star's wobble back and forth.

ROBERT As the star moves, these lines will shift their position, depending on what their velocity is.

ALAN ALDA (Narration) The telescope here is old but it's cheap -- and that's why it's useful. With it, David and Robert can sift through hundreds of stars, looking for just the ones that wobble -- and so are candidates for those much more powerful telescopes on much more imposing mountains. Over 13,000 feet up at the top of Mauna Kea in Hawaii, for instance, is the Keck telescope. The mirror here is almost 400 inches across. Its ability to collect far more light means it can see far more details in the wobbles of stars -- and in the last few years, the Keck and other huge telescopes have produced a cornucopia of likely planets -- over 30 in all. Almost all these other possible worlds are huge and orbiting much too close to their parent stars to support anything like life as we know it. The most dramatic discovery made by analyzing stellar wobbles has been of three planets orbiting a star in the constellation Andromeda. But looking for wobbles has its limitations -- at best it says only that something is tugging on a star.

DAVID LATHAM But there's another way that you might deduce that there's a planet in an orbit around a star, and that's if it happens to go between the observer and the star. You'll see the light of the star blocked a little bit.

ALAN ALDA Right now that planet is not passing across the plane that the camera's looking, I don't think. It wouldn't see anything.

DAVID LATHAM Yep. Too bad. So you have to look at a lot of stars to see the ones that are lined up just right to see a transit.

ALAN ALDA (Narration) And as it turns out, only days before my the patience of the Harvard team had paid off with the first ever observation of a planet passing in front of another star.

ALAN ALDA Oh, there it is. That's the one, huh?

ROBERT That's it.

DAVID LATHAM This is a star that's been in our catalogs because we've been observing it for seven years. So in August we gave this star to one of the graduate students at Harvard and suggested he go look for a transit. And we told him when to look because of course we know the orbit so we know when the planet is going in front of the star, if it goes in front. We had no idea it would go in front. It might go above it or below it and we might never see anything. But he's a graduate student, you know, he has time to do things like that, and damned if he didn't find it, in September, on the 8th of September, the 15th of September. A very exciting way to begin a PhD research program for Mr Charbonneau I can tell you!

ALAN ALDA (Narration) From an observatory in Colorado, the graduate student measured the star's slight dimming exactly when David Latham had predicted it. The amount of light blocked gave the diameter of the planet -- the first time this has ever been possible. The planet turns out to be a little bigger than Jupiter and far lighter than the Earth -- still an unlikely spot for life, but unquestionably a planet.

ALAN ALDA This is big stuff, isn't it? I mean…

DAVID LATHAM This is very exciting. ROBERT Yeah, this is very exciting.

DAVID LATHAM Something this exciting only comes along once or twice in your career. And you caught it!

ALAN ALDA Here we were.

DAVID LATHAM And tonight's the night!

ALAN ALDA And not only that, the clouds parted for us, that's the great thing. What's drawing you on like this? What personally is making you look for those planets?

DAVID LATHAM It's on of the big questions. Is there life elsewhere out there? And if there's life, does it live on a planet? And are there planets where they might live? And we have an opportunity in this age to make a contribution to the answers to those questions.

ALAN ALDA (Narration) Meanwhile, the contribution of this elderly little telescope doesn't stop with simply screening stars for wobbles.

ALAN ALDA This is your box here?

PAUL HOROWITZ This is the apparatus that we built at the Harvard Physics Labs, and you can see it's a sort of parasite, it's screwed on to the side of the spectrograph which as you know is looking for planets around other stars. And we're also looking for planets, but in a slightly different way. We take about a third of their light and we look instead for a different kind of signal. We look for a sudden flash of light from an alien civilization's laser, sent in our direction to establish contact with us, civilization to civilization.

ALAN ALDA (Narration) You heard right: Paul Horowitz is looking for laser beams, sent our way by aliens who've detected our planet and are looking to open a dialogue. And if that isn't amazing enough, he sees what could be a laser flash every couple of nights or so.

PAUL HOROWITZ We've spent extra time observing many of these objects because you know, it's kind of fun, you see a flash in the data in the morning and you'd have to have rocks in your head to say, well, on to the next object.

ALAN ALDA It sounds like it would be a semi-eureka to get a second flash from an object.

PAUL HOROWITZ Well, you know, how about three or four, equally spaced…

ALAN ALDA Well, yeah, that would be a big eureka. But I mean if you got a second flash, wouldn't your hair start to stand up on the back of your neck?

PAUL HOROWITZ Yeah, well, we probably have an object with two flashes, so I'd better be cautious about hair standing on end.

ALAN ALDA You think you have one…

PAUL HOROWITZ Well, we have to look at the data. But I think we've seen objects with a couple of flashes. I should say that the fuzziness in my statements here have to do with the fact that in the summer, when humidity is high, these detectors start to show artefacts, and in summer we definitely have multiple hits on objects. But we don't take it too seriously. We have to hope that aliens will communicate with us wintertime, North America.

ALAN ALDA (Narration) Paul Horowitz is the first to acknowledge that his way of looking for planets is a long shot. But astronomers have growing confidence not only that planets are commonplace in our galaxy, but that methods for detecting them will soon allow us to look for Earth-size planets -- and even for signs of life. Then we'll know where to point our laser beams -- if we decide to say hello.

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I,ROBOT

ALAN ALDA (Narration) To end our show on Life's Really Big questions we've come to a man whose job it is to wonder about such things -- a philosopher. The old stereotype of philosophers of course is that they spend their time counting how many angels can dance on the head of a pin or just contemplating their navels. Dan Dennett isn't that kind of philosopher -- though as a graduate student in philosophy he did once spend some time contemplating his arm.

DAN DENNETT Somebody raised the question of what's going on when your arm falls asleep and you can't move your arm, and it seems this dead appendage, if you try to move your arm, you can't. I thought, well that's a good question, and I don't know the answer. And I was amazed to see that the philosophers present not only didn't know the answer but didn't seem to want to know the answer or thought that maybe they should just think about it. I thought, well, I don't think that's going to work.

ALAN ALDA Must have been a bunch of angels in there.

DAN DENNETT Well, something. But I thought, well you know, I just took the fact that I didn't know the answer to that question, even though it was my arm, that maybe the best route to your own mind is through the mind of others, find some science, see how the parts work.

ALAN ALDA (Narration) Dan Dennett has been trying to see how the parts work ever since. In particular he's fascinated by how simple parts can be put together to make complex things -- like people.

ALAN ALDA I thought it was really interesting that you said in one of your books that we were descended from robots and composed of robots. In what way?

DAN DENNETT If you think of an individual single cell as a sort of little robot, like a bacterium is a robot, we're descended from bacteria. And there's a trillion and counting cells in your body and in mine. Each one of those is clueless, it's not conscious, it's just a little machine doing its job. And it's very myopic. It doesn't know about the outside world, it just knows about its surface, and very little about that: just a few inputs and a few outputs. So you have a trillion myopic robots with different powers, with different jobs, different specialties. You put them all together just right and you get a human being. Or an elephant. Or an oak tree.

ALAN ALDA Yeah. And before you got the human being, at least in the course of the history of our planet, you got a lot of other animals, and we think we're distinguished from them. We keep trying to find ways in which we're distinguished from the other animals. How would you say we are, or are we?

DAN DENNETT I think one of the really fascinating and also frustrating controversies that's been running for centuries concerns, well, are we just animals or are we really different from animals? And the answer is, we are just animals, we're mammals, but we really are different. And primarily what makes us different is human culture. And primarily what makes that possible is language. What language and human culture let happen was just an explosive capacity to know. We have created this vantage point, where we, and we alone can sort of look back and say, "wait a minute, I'm not so sure that the highest good in life is procreating and replicating more of my kind. I think I'd rather be a poet or I think I'd rather join a monastery or be a scientist or who knows what…"

ALAN ALDA (Narration) For Daniel Dennett, nature -- with its mindless little robots exquisitely assembled into trees or birds or people -- is a source of endless wonder. And nothing is more wonderful than the fact that we can wonder -- a human gift denied to even the most appealing of the creatures with whom we otherwise have so much in common.

ALAN ALDA When you see a dog lying in the sun, choosing that one little spot on the living room floor, there's this terrible urge to think the dog has chosen it, the dog is aware of it, or the dog is looking out the car window, seeing sights. Looks like enjoyment.

DAN DENNETT Sure, I think it is.

ALAN ALDA So there's some kind of thought going on.

DAN DENNETT Oh, yeah. Certainly. I think that more complicated, so called higher animals, mammals, birds, do have many of the properties that we have in our minds. They also lack some. In particular, they lack the sort of elbow room to reflect on their own reactions to things, so that they can feel pain and they can anticipate pain to some degree, but they can't sort of dwell on it the way we can. And the same goes for pleasure. I think one of the prices that we pay for being capable of multiplying our suffering through reflection and reliving and anticipation is that we also get to have more joy. We get to think about our lives and our prospects in a way that no animal can.

ALAN ALDA So that implies that we have some kind of freedom of choice. And do you feel we do?

DAN DENNETT Yes. I think that human freedom is as different from the sort of freedom that other species have is human language is from say, birdsong. Yeah, the bird can fly wherever it wants, but it doesn't have very expansive desires. It doesn't have a vision of what life could be that makes freedom like our freedom such a big deal. It's not such a big deal because it doesn't realize what the options are. It doesn't really have any way of grasping even the wonderfulness of what it's doing. But with us it's different. I mean, we could dream of flying for hundreds of years, for thousands of years we could dream of doing what the birds do. Now we can do it.

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