MUSIC IN

NEIL SHUBIN VO/OC
From the badlands of Ethiopia to the coasts of Florida… Whoa. Look at that little guy go. In the bones of ancient creatures, and deep inside your own DNA lies an incredible story. The story of your body, and why you're built the way you are. You are a cutie. The shape of your hands, your rich color vision, the way you walk, and even the structure of your brain… I mean, I find that mind-blowing. …Can all be traced back to ancient primates living in an ancient forest.

NEIL SHUBIN VO/OC
My name is Neil Shubin. As an anatomist, I look at human bodies differently from most people. Within us, I see the ghosts of animals past. Distant ancestors who shaped our anatomy in surprising ways. Prepare yourself for a trip back to an ancient world. If you really want to know why you look the way you do, it's time to meet your inner monkey.

MUSIC OUT

MUSIC IN

NEIL SHUBIN VO/OC
If you go down to your local ice rink, you might not expect to find evidence of your ancient evolutionary past. But if you know how to look, there's a story written in the bodies of these skaters, and every one of us. Anyone who's fallen on the ice knows there's one bit of your body you don't want to land on. It's a remnant from a time when our ancestors looked like monkeys, complete with tails. Each of us have a vestige of our tail inside of us, we call that the coccyx. And that sits at the base of our spine. When we fall on that, it really can hurt. And the coccyx is just the beginning. Inside all of us is a record of our ancient primate past, what I like to call an inner monkey. The way we see the world, the way we walk, and even the way we think, can all be traced back to a time when our ancestors lived in the trees.

MUSIC OUT

MUSIC IN

NEI SHUBIN VO
If you have a hard time believing we have an inner monkey, try meeting modern day monkeys face to face. In a sense, these guys, squirrel monkeys, are our distant cousins. That is so cool. Hey, bub. I mean, it's hard not to look at these guys and feel a deep connection, in a way that you don't feel to fish. When you look in their eyes, when you see their hands, you see the little nails and how they grab this little nut, just like I'm holding it here. I mean, it's hard not to feel something powerful connecting you. But the power of that is also scientific, the power of that is in the anatomy, in the bones, and also in the fossils that show us the history we share with them. We're primates, monkeys and apes and people. But we're all part of the same branch of the tree of life, and all primates are different from other mammals…

MUSIC OUT

NEIL SHUBIN VO/OC

…in having certain features that other mammals don't have. We have a certain shape to our skull, our eyes face forward. We have a particular kind of hand that can grasp. We share an evolutionary relationship with them.

MUSIC IN

NEIL SHUBIN VO
To see what I mean, imagine all life that has ever existed on a giant family tree, from the first microscopic life billions of years ago, to all animals alive today. We didn't evolve from modern monkeys. But, if you trace our ancestry back in time, eventually we reach a point where the human line and the lines of all primates meet. This is where our story begins. Our common ancestor. The ancestor of every monkey, ape and human alive today. So what did that common ancestor look like? And how has it shaped our own bodies?

MUSIC OUT

MUSIC IN

NEIL SHUBIN VO
1870. A surgeon from the civil war has returned to his pre-war passion: hunting fossils in the Wild West. In Wyoming territory, he finds a jawbone he thinks might belong to something like a small raccoon. In fact, he's found a creature that lived some 50 million years ago, and occupied a place on our family tree very close to the first primates.

NEIL SHUBIN VO
I've come to meet this creature, called notharctus. And a scientist who knows every inch of its bones, Jonathan Bloch.

JONATHAN BLOCH OC
This is a 50 million-year-old primate skeleton. It gives us a window straight…

MUSIC OUT

JONATHAN BLOCH OC/VO
…into the world of what the earliest primates would have been doing, how they would have been interacting with their environment.

NEIL SHUBIN VO
Wow.

JONATHAN BLOCH OC
That's the real thing.

NEIL SHUBIN VO/OC
This is the real deal.

MUSIC IN

JONATHAN BLOCH OC
Right.

NEIL SHUBIN VO/OC
That is absolutely exquisite.

NEIL SHUBIN VO
Like most modern monkeys, notharctus was a climber, adapted to life in the trees. The evolution of this creature, and others like it, had a huge impact on one of the features that most defines us…

NEIL SHUBIN VO
…our hands.

JONATHAN BLOCH VO
One of the things that's really nice about this hand is that we do have all of the bones preserved.

NEIL SHUBIN VO/OC
So it's like a jigsaw puzzle. You got to put it all together to see how that…

JONATHAN BLOCH VO
It's a three-dimensional jigsaw puzzle.

NEIL SHUBIN VO
To solve the puzzle of notharctus's hands, you have to begin even further back in time. Over 365 million years ago, ancient fish used their fins to crawl out of the sea. Those fins evolved into the feet of reptiles, and later into the paws of mammals, with short fingers that all pointed the same way, and claws. Early primates like notharctus took the mammalian hand to a whole new level, one that seems very familiar to us.

JONATHAN BLOCH VO
When you actually…

MUSIC OUT

JONATHAN BLOCH VO/OC
…articulate all of these bones what you see is that, the thumb is divergent, that is it forms an angle with the index finger. And so that shows you that it could bring its thumb into opposition with the rest of the digits.

MUSIC IN

NEIL SHUBIN VO
Notharctus also has unusually long fingers and nails instead of claws. This is one of the first times in the fossil record that we see a hand that looks like our own, the hand of a primate.

NEIL SHUBIN VO
It's a turning point in the story of the human body, an anatomical change that would eventually let us shape the world around us. So what were early primates doing with these new hands?

JIM VO
Just pull it up like that.

MUSIC OUT

NEIL SHUBIN VO
To find out, I'm going up into the habitat where my ancient ancestors actually lived, up in the trees. Thankfully, I've got ropes, my inner monkey's not what it used to be. Okay, ready?

JIM VO/OC
Yeah. Are you? You got it, natural.

NEIL SHUBIN VO
Whoo-hoo. A little knotty up here.

JIM VO
Just push your hand jammer a bit higher so you can pull the rope through your crawl.

NEIL SHUBIN OC/VO
Whoo-hoo. Thank you, Jim.

MUSIC IN

NEIL SHUBIN OC
This is utterly wild. I mean, I was never a real climber as a kid, and I have to admit I'm a little scared of heights, and uncomfortable in trees. But these creatures are so unbelievably agile all through here, this is their home. They are able to live on small branches, big branches throughout the tree. They can jump branch to branch. You know when you're in the tree, what you see is that the canopy is not one place there are lots of environments, lots of niches up here, and one special one is on the ends of the branches, because it's there where the flowers and the fruits and the insects are. So the rewards are great to be out there. We call it the 'fine branch niche'. And for the earliest primates, being able to get out there would have been really important. And that gives us a clue as to why their hands and feet evolved to be so different from what came before. Creatures with really short fingers and claws, they're really great at crawling these big thick branches, but not so much when you get to the ends of the branches. That's because this sort of hand can't grasp. Lengthening the fingers, and better still adding a divergent thumb, means you can curl your fingers around even the thinnest branches, grasp them tight, and remain stable. We think that's why the hands and feet of early mammals changed. What you end up with are primate hands, wonderfully adapted to moving around the fine branches of trees. Embedded in our bodies is our distant past. The hand I use to write with, to type on the computer, to throw a baseball, that hand has a long evolutionary history, and one important point in that history, was here in the trees on the fine branches, that made a hand with longer fingers and a thumb.

NEIL SHUBIN VO
Life in the trees would lead to another critical change in our ancestors' bodies. A change deep within their eyes, as they began to see the world, in rich color.

MUSIC OUT

NEIL SHUBIN
I first got interested in the evolution of color vision back in 2009. I was watching my two kids Nathaniel and Hannah, playing a game called Hiss where they matched cards of a certain color to make a snake. Nathaniel is about three and a half years older than Hannah, so he should whup her, right? But he consistently lost. And he would lose because he'd make mistakes with one kind of card, which was purple and blue.

NATHANIEL
Aw.

NEIL SHUBIN VO
And then we realized Nathaniel's likely color blind. In a sense, he sees the world like early primates did before they evolved our rich color vision. Nathaniel can only see a limited range of yellows and blues, and can't tell the difference between reds, greens and purples.

MUSIC IN

NEIL SHUBIN VO
This means he's not so great at games like Hiss. But it doesn't affect his life much more than that, and it certainly doesn't affect his ability to find food, or to survive to adulthood. That wasn't…

NEIL SHUBIN VO
…the case for our primate ancestors. For millions of years, they'd been unable to tell the difference between fine shades of red and green. Then, about 23 million years ago, one group of primates evolved the ability to see many more colors. Now they could tell the difference between ripe red fruits, and unripe green fruits and spot the most nutritious leaves. In the evolutionary battle for survival, this would have been a big advantage. So what happened to the eyes of our ancestors? How did our rich color vision evolve?

NEIL SHUBIN VO
To help me answer those questions, I've come to Seattle, to meet one of the world's experts on color vision, Jay Neitz.

NEIL SHUBIN VO
Oh, hey. Neil Shubin here.

JAY NEITZ OC
Hey, great to meet you.

MUSIC OUT

NEIL SHUBIN OC
Good to see you, well, great to be in the color lab.

JAY NEITZ OC
Well, thank you.

NEIL SHUBIN OC
Well, I think we're off to a rocking start with these walls. Oh my, this is the color lab.

JAY NEITZ OC
Yes it is.

NEIL SHUBIN VO
So what's the drill here? Jay's been studying color vision for the last 25 years. He combines cutting edge genetics with studies on humans and other primates.

JAY NEITZ OC
Everything is cool about color.

JAY NEITZ VO

It's a silent language that speaks…

…to our emotions and it's just fascinating.

NEIL SHUBIN VO
This is the place huh?

JAY NEITZ
Yup. This is where we test color vision in the monkeys.

NEIL SHUBIN VO
His work helped scientists figure out that most mammals, including most primates, see a limited range of colors.

JAY NEITZ VO
This is Kramer.

NEIL SHUBIN VO
Hi Kramer.

JAY NEITZ VO/OC
And Kramer's red green color blind, but he has good blue yellow color vision. In order to train them, we use the colors that they can see, so as you can see that here's this yellow blob against a gray background. Kramer, can see that as well as we can. If they get it right, they get a little reward, and they also get a clicking sound.

NEIL SHUBIN VO/OC
Oh he clearly, he was trying to kiss it there. He really did, he went bop.

JAY NEITZ VO
You can see how good he is at it.

NEIL SHUBIN VO/OC
Yeah, he is. Kramer aces this first test. You've done really well there Kramer. But change the colors to red and green, and it's a whole different ball game.

JAY NEITZ VO
If you don't have any color vision, this is completely invisible. If you can't see red or green, this just looks like a totally gray background.

NEIL SHUBIN VO
Most humans can clearly see this red blob, but Kramer can't. Like my son Nathaniel, he can't tell the difference between reds and greens.

JAY NEITZ VO
Okay, Kramer, you were a star.

NEIL SHUBIN VO
So why is this happening? Why doesn't Kramer see the world like we do?

MUSIC IN

NEIL SHUBIN VO
Kramer's eyes, like all eyes, rely on special proteins called opsins to detect color.

NEIL SHUBIN VO
They're held in thousands of special cells in the retina in the back of the eye. Kramer's got two types of opsin, each tuned to specific wavelengths of light. Signals from these opsins are then interpreted by the brain which allows us to perceive color. But to see color like we do, Kramer would need a third opsin, tuned to different wavelengths of light.

NEIL SHUBIN VO
We think our early primate ancestors were like Kramer, they had just two opsins as well. So how did they evolve a third opsin? The answer is in our DNA.

NEIL SHUBIN VO
Each opsin is encoded by a single gene. And when scientists compared these genes, they found that the gene for the newer opsin sits right next to one of the old ones, and significantly, they are incredibly similar. Both facts are telltale clues as to how the extra gene evolved. The old opsin gene must have been duplicated, and one of these copies then acquired a small number of mutations that allowed it to detect different wavelengths of light. But there's one more question. Could our rich color vision result from just duplicating a gene, or would there have to be changes…

NEIL SHUBIN VO
…to the brain as well? To find out, Jay has tried to replicate what happened in nature in his lab.

JAY NEITZ VO/OC
It's actually a great evolutionary question, how did color vision evolve? How can something so complicated evolve?

NEIL SHUBIN VO
Jay implanted a third opsin gene from a human directly into the retinas of a color-blind squirrel monkey called Sam.

JAY NEITZ OC
What we did is really a test to see what's the minimal thing you can do in order to give an animal color vision.

NEIL SHUBIN VO
The results were incredible. Like Kramer, Sam used to fail this test, now he can easily tell the difference between reds and greens. Jay has recreated evolutionary history, and given Sam human-like color vision.

JAY NEITZ VO/OC
You might think, oh it would take him a long time to learn this new pattern in the brain, but as soon as the gene was turned on, the animal began to make these discriminations that they couldn't make before. The brain was already ready somehow. And so in one, you know, very short evolutionary step it goes to this totally different world. You go from…

JAY NEITZ VO
…just having strictly, let's say, five colors, gray, black, white, blue and yellow, to hundreds of different colors, that are all of the blues and greens and purples and oranges.

NEIL SHUBIN
One simple shift opens a whole universe of color.

JAY NEITZ VO
Yeah, that's the amazing thing, it's like there's something almost magical. It's a multiplicative effect.

NEIL SHUBIN VO
For the early primates that evolved this ability…

MUSIC OUT

NEIL SHUBIN VO
…it was a huge advantage one that would eventually be passed on to us.

NEIL SHUBIN VO
And color still plays a huge part in our lives today.

MUSIC IN

NEIL SHUBIN VO
Color helps us communicate, attract attention, and even express emotions. We often take it for granted, but it massively enriches our experience of the world.

NEIL SHUBIN VO
Good boy.

NEIL SHUBIN VO/OC
But our focus on vision has come with some tradeoffs, namely, our poor sense of smell. Like most humans I'm experiencing this wonderful vista here with my eyes. But the dog's experiencing this in a very different way. His is a world of smells. We think that a dog's sense of smell is anywhere from a thousand to a million times better than ours. Like many mammals it's his main way of understanding the world around him. This fundamental difference in our sense of smell is also reflected in our DNA. A dog has about a thousand genes that are devoted to detecting odors. We have roughly the same number, but about 600 of them don't work anymore, they're relics. It's a similar story in other primates with color vision. These broken genes reveal another legacy of our primate past. As our distant ancestors gained this wonderfully rich sense of color vision. What happened was our sense of smell became less important and in the evolutionary world it's use it or lose it. And that's exactly what happened to our sense of smell. It diminished over time.

NEIL SHUBIN VO
So while we can thank our inner monkey for our wonderful color vision we can also blame it for our lousy sense of smell.

NEIL SHUBIN VO/OC
Of course, we humans have also made some radical changes to the ancient primate body plan. Unlike monkeys, we stand up on our own two feet. You know animals have been walking on this planet for over 365 million years, and for the most part, that walking has been on four legs. Walking on two legs is a fundamentally strange way to get around. No other primate, and very few other mammals, move this way. It's a change that had profound effects on the human body. Which begs the question, how on earth did it happen?

NEIL SHUBIN VO

The best place in the world to answer this question is in Africa. A site where the great rift valley…

NEIL SHUBIN VO
…cuts deep into ancient rocks, exposing fossils from our distant past. These are the remote badlands of northern Ethiopia. Look at those rocks. Boom, boom, boom, boom, boom, just totally stretched out. As a paleontologist, that is what I dream about. This is truly in the middle of nowhere.

DON JOHANSON VO/OC
Now you see that volcanic ash cropping out? That's 3.4 million years old.

NEIL SHUBIN VO
That is incredible. My guide is Don Johanson, one of the first people to hunt for fossils here back in the early '70s, and a childhood hero of mine.

DON JOHANSON VO
There's the camp.

NEIL SHUBIN VO
There on the far side of the river right there.

DON JOHANSON VO
Fabulous.

NEIL SHUBIN VO
Two of the most important fossils for understanding the origins of bipedalism have been found in this small region of Ethiopia. Don's taking me to see where the first iconic fossil was found. A 3.2 million-year-old human ancestor known as Lucy.

DON JOHANSON VO/OC
It was a Sunday morning back in 1974. So I came up here looked at this had no idea what was waiting. I was right in this area, right here. What I saw was a fragment of bone, and I looked at it, and almost instantaneously said, "That's a hominid."

NEIL SHUBIN VO
Wow. Lucy made headlines around the world, because although she looked like an ape, she walked on two legs. She was a biped, at that stage the most ancient anyone had found.

DON JOHANSON VO/OC
Once we broke that three million year barrier it was a whole new picture of what our earliest ancestors looked like. One of the most exciting moments of my entire career.

NEIL SHUBIN VO
Since Don first came here in the '70s, scientists have organized expeditions here most years. They've found over 400 individual fossils from Lucy's species. But it's Lucy I most want to meet. Her bones are some of the best evidence we have for what early bipeds looked like.

DON JOHANSON VO/OC
Now of course if this were all articulated properly, you know, the vertebrae…

MUSIC OUT

DON JOHANSON OC
…on top of one another…

NEIL SHUBIN VO
You'd see it.

DON JOHANSON OC/VO
…she'd be about three and a half feet tall. You don't see that.

NEIL SHUBIN
Yeah, you don't get that.

DON JOHANSON OC
Here's the femur.

NEIL SHUBIN OC
That's the left.

DON JOHANSON OC
Top end of the thighbone.

NEIL SHUBIN VO/OC
And this one also when you put it all together, now you have, you know, this is telling bipedal, this is giving a hint of bipedal.

DON JOHANSON OC/VO
Right. This certainly tells it was bipedal. That cants in like that, which is very characteristic. Our knees are close together and they come up to the side, chimps come straight up.

MUSIC IN

NEIL SHUBIN VO
Having the upper and lower leg in a straight line is no good for a biped, it makes for an awkward, waddling gait. Lucy's legs formed an angle, her knees were closer together, just like our own knees this positions the feet directly underneath the body, making walking easier, and more efficient.

DON JOHANSON VO
There we are.

NEIL SHUBIN VO/OC
There we go. So Lucy walked much like us. But she wasn't human. She had many primitive features, too. Now this is a real mix, you know.

MUSIC OUT

DON JOHANSON OC
This is a real mix.

NEIL SHUBIN
Yeah it's amazing.

DON JOHANSON OC
Yeah.

NEIL SHUBIN OC
This is very primitive, right?

DON JOHANSON OC
Ape.

NEIL SHUBIN OC
Apelike, apelike.

DON JOHANSON OC
Very small brain. And very apelike proportions.

NEIL SHUBIN
Apelike. But bipedal.

DON JOHANSON OC
But bipedal.

NEIL SHUBIN OC
Cool.

DON JOHANSON OC
And these hands would have stretched down to about here.

NEIL SHUBIN OC
So down. Yeah, it's the knee almost.

NEIL SHUBIN VO
It is just so utterly fabulous.

DON JOHANSON VO/OC
Isn't it interesting to have the pile of bones, you put her here, and all of a sudden you can see that it was a living person.

NEIL SHUBIN VO
She's beautiful.

DON JOHANSON OC
Yep. Thank you.

MUSIC OUT

GROUP VO
<Singing >.

DON JOHANSON VO
We named her after the people and the land. We named her Australopithecus afarensis, from the Afar region.

GROUP VO
<Singing>.

NEIL SHUBIN VO
So imagine if Lucy was here with us right now, what would she look like?

DON JOHANSON OC/VO
Well she'd be short. She was only about three and a half feet tall. And the one thing that would be familiar to us, she would be walking upright. With those long arms, reaching almost down to her knees, she'd probably have a very odd gait. And as she got closer we'd see that she had a very ape like face. I don't think you would see much of a glimmer of philosophical thought in her eyes. I think in many ways she'd look like the ape that stood up.

NEIL SHUBIN OC
Yeah.

DON JOHANSON OC
You know?

NEIL SHUBIN VO
Yeah, that's amazing.

GROUP VO
<Singing>.

NEIL SHUBIN VO
Lucy tells us that by 3.2 million years ago, our ancestors had fully committed to walking on two legs. What she can't tell us, is how our ancestors first started walking upright.

MUSIC IN

NEIL SHUBIN VO
To answer that question, we need to meet a second iconic fossil, found just 50 miles from the Lucy site. This fossil, called Ardipithecus, has turned our ideas about how we became bipedal on their head.

NEIL SHUBIN VO
I've come to Berkeley, California, to meet the guy who led the team that discovered Ardi, an old colleague of mine, Tim White.

NEIL SHUBIN VO
Tim's out in the field in Ethiopia most years and he documents his work meticulously with a video camera. These rarely seen field-tapes date from the early '90s.

TIM WHITE VO
What we wanted to do was to plumb the unknown.

TIM WHITE OC

To figure out what came before the Lucy species.

TIM WHITE VO
We just literally didn't know what we would find.

MUSIC IN

NEIL SHUBIN VO
Since 1992, the team has run annual expeditions to a remote site called the Middle Awash. Some of the rocks here were millions of years older than the nearby Lucy site.

TIM WHITE VO
You see the two resistant bands, up there on the hill…

NEIL SHUBIN VO
Right.

TIM WHITE VO
…they're digging into the lower band, both of these are dated to 4.4 million.

NEIL SHUBIN OC
This was really…

TIM WHITE OC/VO
We nailed it, so anything between that is 4.4 million years.

NEIL SHUBIN VO
This band of ancient rock yielded some tantalizing fragments. So they scoured this layer for months on end. The breakthrough finally came in 1994. An Ethiopian graduate student, Yohannes Haile-Selassie, found a fragment of hand bone in that same layer.

TIM WHITE VO
He picked up…

TIM WHITE OC
…and said this looks like a hominid,

TIM WHITE VO/OC
…so we scraped and brushed that surface and we found some of these hominid hand and foot bones in place. And so we focused on that little hill. And we turned the video camera on and dug.

NEIL SHUBIN
Oh wow.

TIM WHITE VO
This is the way we took it off virtually a millimeter at a time. You got to be really careful. You know, you scratch that you put your signature on it forever. Here comes the mandible, canines off on the left hand side right there, here are the teeth coming out.

NEIL SHUBIN OC/VO

You know, so as a paleontologist, you're the first people in the entire planet to see that.

TIM WHITE OC
That's been buried for 4.4 million years.

NEIL SHUBIN OC/VO
This was a hugely significant find, a new species of hominid at a critical moment in human evolution. A time when our ancestors were just beginning to walk on two legs. So while they were still in the field,

MUSIC OUT

NEIL SHUBIN VO
…Tim wanted to collect as much information as he could about Ardi's world.

MUSIC IN

TIM WHITE VO
What we're out…

TIM WHITE OC
…to do is to understand everything we can about that time slice, and at 4.4 million years, anything we learn is new.

TIM WHITE VO
And so that means bringing in sedimentologists who understand what kind of a setting, was it a river, was it a flood plain. Bringing in paleontologists expert in the plants, in the birds, in the shrews.

NEIL SHUBIN VO
Wherever they found Ardi's species, they found woodland creatures – parrots, monkeys, and peacocks, as well as woodland plants.

TIM WHITE VO/OC
It was a woodland, not an open savannah setting.

NEIL SHUBIN OC/VO
Now that's a surprise.

TIM WHITE
These were woodland animals.

NEIL SHUBIN VO/OC
That runs counter to so much of what people expected.

TIM WHITE VO/OC
It runs counter all the way back to the 1800s.

NEIL SHUBIN VO
For over a hundred years there's been one main theory of how our ancestors started to walk on two legs. The theory goes like this: we started out as apes that lived in the trees. We looked like chimpanzees, and walked on all fours using the knuckles of our hands. But the climate changed, and only after forest had turned to savannah, did we start

walking on two legs instead of four. Ardi tells a very different story. She was already walking upright while living in the woodlands.

NEIL SHUBIN VO
Ardi's skeleton ran counter to the old theory too. It was unlike anything anyone had seen before. It took a team of experts 15 years to fully piece her together. So how do we know she was bipedal? The man in charge of figuring out how Ardi might have moved was anatomist Owen Lovejoy.

MUSIC OUT

C. OWEN LOVEJOY VO/OC
The critical thing in bipedality is the structure of the pelvis. And at first when you look at this bone you might think that there's not much information here, but actually there's an enormous amount of information that tells you a great deal about what the original bone looked like.

NEIL SHUBIN VO
Using information from this deformed bone, the team was able to reconstruct Ardi's entire pelvis.

C. OWEN LOVEJOY VO
This is a plastic structure that's produced by a three dimensional printer.

MUSIC IN

NEIL SHUBIN VO
The top part of Ardi's pelvis looks more human. The hip-bone is short and broad, a key indicator of bipedalism. But the lower half is much longer than a human pelvis, more useful for climbing.

TIM WHITE VO
When you…

TIM WHITE OC
…got to that detail, you realized it was a mosaic of anatomy that had never been encountered before.

NEIL SHUBIN VO
It suggests that Ardi could walk on two legs, but not as well as later hominids like Lucy. And the rest of her anatomy held surprises too.

TIM WHITE VO/OC
Neither Lucy nor humans have the ability to grasp with their big toe, but this thing had full grasping ability.

NEIL SHUBIN OC
So she has a grasping foot that can walk.

C. OWEN LOVEJOY OC
Yes.

MUSIC OUT

NEIL SHUBIN VO

Even the hands were a mosaic, incredibly long fingers, good for climbing, but a shorter, humanlike palm. And the bones show none of the telltale signs that she walked on her knuckles like a chimpanzee.

MUSIC IN

NEIL SHUBIN VO
So we now have a detailed picture of the crucial time when our ancestors had just started walking on two legs.

NEIL SHUBIN VO
Ardi was small, around four feet tall; a good climber, she moved on all fours when in the trees, but she walked upright when on the ground. She blows the old theory of how we became bipedal out of the water. Not only did our ancestors start walking on two legs when still living in the woods, they never looked or moved like our closest living relative, the chimpanzee. Some scientists don't accept this interpretation. They think Ardi isn't a human ancestor at all, but the relic of an extinct ape.

NEIL SHUBIN VO
But Tim's spent years studying many specimens of Ardipithecus.

MUSIC OUT

NEIL SHUBIN VO
And he thinks the evidence is clear.

TIM WHITE VO
When we looked at the Ardi cranium we saw very small canines. No other ape, living or fossil, has such reduced canines.

TIM WHITE OC
That's a good indicator she's come in our direction a bit. Go to the pelvis.

MUSIC IN

TIM WHITE VO
Same thing. A unique adaptation shared by humans and Lucy.

NEIL SHUBIN VO
We're still not sure exactly why a woodland climber needed to walk on two legs. But thanks to Ardi we now have a snapshot of one of the most dramatic transformations in the history of our species; the transition from walking on four legs, to walking on two. This major change to our ancestral body plan has serious consequences for us today.

MUSIC OUT

MUSIC IN

NEIL SHUBIN VO
These consequences can be seen within our own bodies, and they're not all good. This vault in the bowels of the Cleveland Museum Of Natural History is the place to go if you want to find out what can go wrong with the human skeleton. Dr. Bruce Latimer is an anthropologist and anatomist who was a curator here for many years.

BRUCE LATIMER VO/OC

Well, this is the Hamann-Todd Collection, which is the largest collection of its type in the world. There are over 3,000 skeletons in this room. In each one of these drawers is a complete human skeleton.

NEIL SHUBIN VO
They come from unclaimed bodies at a Cleveland morgue, dating from the early 1900s. If you study these skeletons, one thing becomes clear pretty quickly. The human back goes wrong. A lot.

BRUCE LATIMER VO
There's an enormous amount of back problems. The pain must have been phenomenal, and you just see that all over this collection.

NEIL SHUBIN VO
Turns out, our bad backs are an unwelcome inheritance from our inner monkey.

MUSIC OUT

BRUCE LATIMER VO/OC
We took a skeleton like this that was essentially horizontal, we stood it upright, we've had to change essentially every bone to allow us to do that, and we've forced it into this new position. We have a problem going from this kind of animal into that kind of animal…

MUSIC IN

BRUCE LATIMER OC/VO
…and our main problem is balance.

NEIL SHUBIN VO
On all fours, the weight of our body hangs down from our spine. But turn this body upright, and the weight is all out front, it puts us out of whack. Totally out of balance.

BRUCE LATIMER OC/VO
In order to balance we had to create this curve in your back, and then your head would be back here wouldn't it, so we had to create…

MUSIC OUT

BRUCE LATIMER OC/VO
…another curve here in the middle of your chest, and then your head would be sticking out of the front so we had to create another curve in your neck. And so we have this S-shaped curve in our spine, and we expect that to hold us up. That is an engineering nightmare.

MUSIC IN

NEIL SHUBIN VO
Our S-shaped spine is unique among mammals, and it causes all sorts of problems. The vertebrae that make up the bones of your back, and the discs between them, are put under a lot of pressure, particularly the ones at the very apex of the biggest curve, the thoracic vertebra.

BRUCE LATIMER VO/OC

If you take those thoracic vertebrae and you push on them from the ends too hard, what happens is this, you end up with what's called a wedge fracture. That curve has crunched it. No other animal has anything even remotely like this. It's a consequence of how we walk.

NEIL SHUBIN VO
And it's not just fractured vertebrae, from slipped discs to sciatica our spines go wrong in all kinds of ways. 80 percent of all Americans will complain of back problems at some point in their lives. Our inner monkey has a lot to answer for.

NEIL SHUBIN VO
But I don't want you to get the wrong idea. Standing up on two legs wasn't all bad, or it never would have happened in the first place. It freed our hands, an anatomical change that, combined with our amazing brains, would eventually allow us to make tools and reshape the world around us. This key moment in our evolutionary history is once again visible in the rocks of northern Ethiopia. So geologically one of the things that's special about this is it has lots of layers. Lucy's from one part of it and we're going to another, right?

BILL KIMBEL VO/OC
That's right. We have just jumped about six or 700,000 years in time.

NEIL SHUBIN VO
And that is kind of mind-blowing.

BILL KIMBEL VO
Yeah.

NEIL SHUBIN VO
Paleontologist Bill Kimbel has brought me to a site where you can find stone tools that are over two million years old, if you know what you're looking for. So what do I look for?

BILL KIMBEL OC
Well, you look for flakes on the ground.

NEIL SHUBIN VO
Wow, is that bone?

BILL KIMBEL VO/OC
That is a piece of fossil bone and here is another one.

NEIL SHUBIN OC
See I can't find tool, but I can find bone.

BILL KIMBEL OC
Yeah.

NEIL SHUBIN OC/VO
Right. The important thing about tools is it's the hand and the brain right, it's both together.

BILL KIMBEL OC
Absolutely.

NEIL SHUBIN VO
You got one?

BILL KIMBEL VO
Oh, yeah. You got a nice one.

DON JOHANSON
Well, this is very typically,

NEIL SHUBIN OC
That's a nice one? I don't get this at all.

DON JOHANSON OC
Yeah, I know, it looks like something from your driveway.

NEIL SHUBIN OC/VO
Right. The tool Don's found was made by human ancestors called Homo habilis, who lived a million years later than Lucy.

DON JOHANSON OC/VO
Clearly some early human took a stone, a hammer stone and struck it right there, and got this.

NEIL SHUBIN VO
Oh yeah. That striation, yeah.

DON JOHANSON VO/OC
And you see it has this. Feel that edge. You could use it to strip off meat or whatever.

NEIL SHUBIN OC/VO
So from this rock you can tell where they hit it, how they hit it. It's almost like a time machine you have.

BILL KIMBEL VO/OC
It is. It's a time machine that takes us back to a period when the faintest glimmers of what it means to be human are beginning to emerge, the use of the hand, the cognition, the repeated behavior to produce a stylized tool.

DON JOHANSON OC
It's mind-blowing.

NEIL SHUBIN VO/OC
Wow. Can we look for tools? I want to find a tool. No, that's natural.

BILL KIMBEL OC/VO
No, this is one. You've found one.

NEIL SHUBIN VO
Making tools takes excellent vision, fine motor skills, and a brain that can integrate the two. We humans only have this sort of brain because it's been shaped by our ancient primate past.

NEIL SHUBIN VO

Monkey, ape or human, our brains share a basic architecture that's different from most other mammals. We all have a special region involved with hand-eye coordination. And a greatly expanded visual system, with as much as 40 percent of the brain involved in seeing.

NEIL SHUBIN VO
Our inner monkey hasn't just shaped our bodies, it's shaped our brains as well.

NEIL SHUBIN VO
But if you look at the modern world around us, and everything humans have been able to build, from satellites to skyscrapers, there's no doubt we're more intelligent than monkeys. So what changed? What made our brains so different from those of other primates?

MUSIC OUT

NEIL SHUBIN VO
Hi, Neil Shubin.

TOM BURBACHER OC
Hi Neil, it's Tom Burbacher, welcome to the Infant Primate Lab.

NEIL SHUBIN OC
Good to see you. So this is the monkey place, huh?

TOM BURBACHER OC
This is the monkey place.

MUSIC IN

NEIL SHUBIN VO
Tom Burbacher studies monkeys in order to answer questions about our own brains. He's going to show me an experiment that demonstrates an important difference between our brains, and the brains of a monkey. But the differences aren't what you might expect, especially when we're young. Monkey on the set.

KIM VO/OC
Monkey on the set. Neil, this is "C.I." she's a three-month-old pig-tailed macaque.

NEIL SHUBIN VO
This experiment tests something called object permanence. In other words, whether this monkey knows an object still exists when she can't see it. It's a developmental milestone for both monkeys and humans.

MUSIC OUT

KIM VO/OC
You're going to put a piece of fruit on the toy itself. You'll place it in the well.

NEIL SHUBIN VO

She's looking at it. There.

KIM VO
And you'll move that to completely hide that toy.

NEIL SHUBIN VO
Okay. Oh wow.

TOM BURBACHER VO
There you go. There you go.

NEIL SHUBIN VO
Wow. That is impressive.

TOM BURBACHER OC
Object permanence.

NEIL SHUBIN OC
Just boom, boom.

MUSIC IN

NEIL SHUBIN VO/OC
Three months old, and already "C.I." understands object permanence. "C.I." you are good.

NEIL SHUBIN VO
Hi Geneva, how are you? You are a cutie. Geneva is the same age as the baby monkey. I'm going to do the exact same test on her, under the expert eye of child development specialist, Professor Susan Spieker.

SUSAN SPIEKER VO
She needs to reach for them, show that she's interested.

NEIL SHUBIN VO
Oh I think we've got interest.

SUSAN SPIEKER VO
Oh she's got a good reach.

NEIL SHUBIN VO/OC
You do. Look at you. Oh Geneva, you like those. Hello.

SUSAN SPIEKER VO
Now, Neil, can you get them away?

NEIL SHUBIN VO/OC
Oh, I'm an expert at this. Can I take that for a second? Sorry, it'll be temporary. You are so good that way. I'll pop it in.

SUSAN SPIEKER VO
Make sure she's watching.

NEIL SHUBIN OC/VO
She's watching. Now we'll cover it up, watch this.

SUSAN SPIEKER VO
And she wonders, "What did you do, Neil?"

NEIL SHUBIN VO
What toys?

SUSAN SPIEKER VO
I don't know where they went.

NEIL SHUBIN VO/OC
Wow. That is amazing.

SUSAN SPIEKER VO
Where did they go?

NEIL SHUBIN OC
It is incredible. If it's not there it doesn't exist.

SUSAN SPIEKER OC
Right. Right.

NEIL SHUBIN OC
That is amazing.

MUSIC IN

NEIL SHUBIN VO/OC
So how come a baby monkey beats a baby human in this test? These tests are showing us how rapidly a particular region of our brain is wiring up in development. And it's showing us comparatively that we wire up much slower in this part of the brain than do monkeys.

NEIL SHUBIN VO
Compared to other primates, we humans have an unusually long childhood, even if you take the different life spans into account. This should be an evolutionary disadvantage. But in fact, it's one of our greatest strengths. During childhood, our brains are being shaped by our environment, and by our experience. Extending this phase gives us longer to learn, and pick up new skills. Some think that this is a key part of what makes us so smart.

NEIL SHUBIN VO
But there are other factors too. The brain is made up of vast networks of nerve cells, called neurons, that carry, process and store information. The part of the human brain responsible for higher thought, the cortex, contains more neurons than that of any other animal on the planet, an astonishing 16 billion. These neurons are organized in a uniquely powerful way, they're unusually interconnected. This means we can do things that other primates can't, build complex tools, compose symphonies, and even investigate how our own brains work.

NEIL SHUBIN VO/OC

But before we get too carried away with our own cleverness, I want to inject a bit of humility. That means leaving monkeys behind, and going back to where this series began, my anatomy lab in Chicago, and my favorite subject, fish. The brain of a fish and the brain of a human have more in common than you might think. This is a trip to the beginning, this is as basic as it gets, we're going human, fish, represented by a cartilaginous fish, a shark on the right. And what you have is you see the muscles and nerves and organs inside the shark head. But importantly, you see this yellow tissue, this is the front end of the spinal cord, it's the brain, it doesn't look like much, but it's the shark brain. This is the human brain. This is where it all happens for us, where our memories reside, where you know our fears, our loves, our hates it's all in here. The human brain, really at the surface level…

MUSIC OUT

NEIL SHUBIN OC/VO
…looks nothing like what's sitting inside the shark head. Yet, when you know how to look, you find a very profound similarity and that similarity lies in the overall architecture of the brain itself. In the human we have a forebrain and that forebrain consists of this folded tissue here, where much of our conscious thought happens.   And then there's a midbrain, this walnut sized are in the middle. And then a hindbrain. That's a fundamental division, we see that in development and we see that based on where the nerves exit the brain. Well, if you follow the similar nerves in a shark what you see is sharks too have that same structure – a forebrain, a midbrain and a hindbrain. There's a fundamental architectural similarity among all brains – the brains of people, the brains of dogs, the brains of cats, the brains of monkeys, lizards, frogs, salamanders, trout, bass, even sharks and fish are similar. Each one of them has a forebrain, and a midbrain and a hindbrain, despite the fact that those brains are often very different in function and form.

MUSIC IN

NEIL SHUBIN VO
But that's not the end of the story. The fundamental architecture of our own brains can be traced back even further than fish to a surprisingly primitive animal that doesn't even really have a brain. But I've got to find these tiny creatures first.

PETER HOLLAND OC
Right, okay. Well, we can start trying around here.

NEIL SHUBIN OC
X marks the spot.

PETER HOLLAND OC
X marks the spot. Let's give it a go.

NEIL SHUBIN OC/VO
This is Peter Holland, a world-renowned geneticist, and Head of Zoology at Oxford University in England. Okay, so what do I do?

PETER HOLLAND VO
Just shake it.

NEIL SHUBIN OC
Shake and bake, huh? I'll make it look so easy. Like that? No?

PETER HOLLAND OC/VO

No. They'll be pretty obvious because they'll start, they'll really swim around. The water makes the digging slightly harder.

NEIL SHUBIN VO
It does.

PETER HOLLAND VO/OC
You got one. There's an amphioxus.

NEIL SHUBIN VO
We got an. Whoa. Look at that little guy go. Hey.

PETER HOLLAND VO
Just dip it in the water again, and you'll see it'll flick around.

NEIL SHUBIN VO
Boy, they really flick.

PETER HOLLAND VO
There, you see? There he is.

NEIL SHUBIN OC/VO
Hey, that's beautiful. Look at that. Which is the front? It doesn't look like much, but this tiny creature, called amphioxus, has much to tell us about our own brains. That is cool. Okay, that ranks as cool.

PETER HOLLAND VO
Okay, so let's take a look at a couple of these.

MUSIC OUT

NEIL SHUBIN VO/OC
So I've brought this from the anatomy lab in Chicago, this is a human brain. And when I look at this I don't find any obvious similarities to that.

MUSIC IN

PETER HOLLAND VO/OC
Deep in the genes of this animal, in the development of this animal, and deep in the genes of us and the development of us there are the similarities. They're pretty, they're pretty active.

NEIL SHUBIN OC/VO
Holy cow! Oh that is beautiful. God, they're so clear, too. You can see right through them, you know, it's amazing.

PETER HOLLAND VO
Yeah, yeah, yeah.

NEIL SHUBIN VO
Amphioxus lives in the sand of the ocean floor, filtering algae out of the water. It's from an incredibly ancient group of animals. We've found fossils that look a lot like this in rocks that are over 500 million years old. They are a window

into what came before the first fish. And crucially they don't have anything like what we'd call a brain. The simple nerve chord that runs the length of their body, ends with just a tiny swelling invisible to the naked eye.

PETER HOLLAND VO/OC
If you look at the front end of this animal you don't see it all expanded into a large skull or brain region. It's just pointed.

NEIL SHUBIN VO
But if you look at the genetic makeup of these ancient creatures, you find something truly remarkable.

NEIL SHUBIN VO
To make the forebrain, midbrain and hindbrain that we saw in our lab, you need a series of control genes to tell the cells within the developing brain where they are, they're like a zip code. Those same control genes that make our own brains, are active in amphioxus, but here they're simply building the primitive nerve chord, and the tiny swelling at its front. This means that the genetic…

NEIL SHUBIN VO
…roots of our complex primate brains existed in much simpler creatures that first arose over 500 million years ago.

PETER HOLLAND VO/OC
I think it gives us a glimpse into where our brains came from into the basic organization of the brain of our ancestors.

NEIL SHUBIN OC
I mean, I find that mind-blowing.

PETER HOLLAND OC
It's just an exciting animal.

MUSIC OUT

NEIL SHUBIN VO
He knows you're talking about him. See? He's going.

PETER HOLLAND OC
That's right. He's going. You can see the muscle block's really working there.

NEIL SHUBIN VO
Exactly.

PETER HOLLAND OC
You know, and I think to an evolutionary. Whoa. He's jumped off.

NEIL SHUBIN VO
Oh, he hopped.

PETER HOLLAND OC
Sorry.

NEIL SHUBIN VO/OC
He's going Tiktaalik on us. He's going land-living. He's gone around.

PETER HOLLAND VO
He's gone for the next transition.

NEIL SHUBIN OC
Exactly. He's in the Devonian now.

MUSIC IN

NEIL SHUBIN VO/OC
The search for our inner fish has taken me from high in the arctic… Here was the snout of exactly the creature we were looking for. …to the plains of Africa… Yeah, I just want to run down here and start collecting fossils.

DON JOHANSON OC
Let's go.

NEIL SHUBIN VO/OC
…as well as deep inside our own DNA. And today we saw a little tiny worm living in the mud here in the bay that contains genes that we have that sculpt our own brains, the organ that gives us many of our unique properties. We've seen how our distant relatives, from worms to fish, from reptiles to early primates have defined our bodies. At each new stage of our journey along the tree of life, our ancient animal ancestors have reconfigured what's gone before. And that's how we ended up as the intelligent, creatures with all our quirky flaws, that dominate the planet today. There's something incredibly profound, and I think beautiful in the idea that inside every organ, cell and gene of our body lie deep connections to the rest of life on our planet.

MUSIC OUT

MUSIC IN

MUSIC OUT