"In Search of Human Origins Part One"

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ANNOUNCER: Tonight on NOVA, a tiny female collapses into an ancient lake. She emerges three million years later, and a determined anthropologist finds her fossilized bones. Could she be the missing link between ape and us? For Don Johanson, she is the starting point of a tireless quest to understand our past. "In Search of Human Origins."

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DON JOHANSON: In the remote past, more than three million years ago, a tiny female lived by a lake on the edge of the lush forests of Africa. She was part ape, part human. She lived a brief life, but her story continues to unfold. By an extraordinary set of circumstances, she left tantalizing clues to her life and our origins. Who was she and what can we discover about this earliest of our most ancient ancestors? We know she existed because we found these, her fossilized bones, in the very spot where she died all those years ago. Fossils like these are so rare, that they're even harder to find than diamonds, but they're the key to understanding our origins, knowing who our ancestors were, and how they lived. The human story begins in one of the most geologically fascinating places on the planet, the Great Rift Valley of Africa. It's an enormous split torn in the Earth's crust that runs from the forests of Tanzania to the deserts of Ethiopia. In some places, the rift is thousands of feet deep and exposes the last fifteen million years of the Earth's history. I'm Don Johanson and over the last twenty years, I've been leading fossil hunting expeditions in this remote part of Africa on the trail of our earliest ancestors. The journey takes me and my team right down to the floor of the Great Rift. It takes two days driving dawn to dusk, if our vehicles don't break down. But it's only in places like this where the fossils we're looking for can be found. People often ask why we look in Africa for remains of our earliest ancestors. Well, Charles Darwin had a pretty good answer to that question over a century ago. When he observed the close similarities between humans and modern African apes, he correctly concluded that we must have shared a common ancestor. Starting with the modern human skull, we can trace our ancestry back millions of years. And as we travel back in time, our ancestors look less and less like us. They begin to resemble our closest relatives, the African apes with their small brains. Fossil skulls like these help us unlock the mystery of our past. And it is in Africa that the earliest human fossils are found. Our team always camps here, at a place called

Hadar, in Ethiopia, on the banks of the Awash River. The river is our lifeline in this otherwise waterless place. After two days of bumping along dusty roads, there's a welcome peacefulness about the camp. The days quickly settle into the rhythm of expedition life. The local people are nomadic tribesman called the Afar. We've known them twenty years. This is their land and they allow us to come here and help us in our search. Ever since I first came to Hadar, they've taken it up themselves to guard us personally, because this is also bandit country. It's not the most comfortable place to work, but if you're a fossil hunter like myself, it's a dream come true. When I first came to Hadar, I realized that this was exactly the place I was looking for. It's potential is absolutely staggering. When I began to walk these gullies and valleys, I saw tons of fossils eroding out of these ancient geological strata. There's almost no vegetation, so the seasonal rains do most of the work for us, scouring the surface, uncovering buried fossils. There are bones of every imaginable creature, perfectly preserved in stone. But even here, human remains are incredibly rare. That's because the journey from a living creature to a fossilized bone only happens under the most unusual conditions. I can make a good guess about how our earliest ancestor might have been preserved millions of years ago. She wasn't killed by a predator, she died a natural death. Undiscovered by scavengers, her body simply sank into the soft sediments of the lake. There, lying undisturbed, her flesh slowly rotted away. Sand and gravel washed in by heavy rains gradually covered the bones. Over the millennia, hundreds of feet of sediments built up, burying the bones deeper and deeper. Minerals from the sediments gradually replaced the calcium of her bones, almost molecule by molecule, turning them to stone. Over the next few million years, she remained buried, but the movement of the Earth's crust, continuing to enlarge the Great Rift, brought her ancient grave closer to the surface. There she lay until rains cut down through the Earth, and one heavy storm brought her to light again. Spotting such rare human fossils doesn't happen often. But we can discover a great deal about our ancestors' world by looking for the more plentiful remains of the animals that lived with them. As soon as we're settled in, everyone is eager to see what this year's rains have washed out onto the surface. We're a team of Ethiopian and American scientists, and with us, some of the sharpest-eyed fossil-finders of all: the local Afar people. There's really no other way to find fossils, except to walk these exposures day-in, day-out, hoping to find something interesting. Here, for example, there's just a canine of a hippo, and a very beautifully preserved molar of a giraffe. It's interesting that virtually every animal has its own diagnostic anatomy, it's own diagnostic features, so even from a single tooth like this, we can tell what kind of a creature it was, a good specimen that we'll catalogue and bring back to camp. But how could hippos and giraffes live in this harsh desert? It must have been a very different place three million years ago. All told, we've collected more than ten thousand specimens from over a hundred species, everything from rodents to elephants. The clues to their lost world lies scattered all over the ground. Although it's a seemingly uninteresting piece of bone, if you look at details, you begin to see a number of clues. For example, the shape of the tooth indicates that it was probably from a pig, part of a lower jaw. But even more intriguing is a series of indentations on the inside of the jaw. And if we look at them with a hand lens like this, it's obvious that that bone was pushed in when it was fresh, and it's very likely that this pig, three million years ago, had wandered down to, say the edge of a river, and became dinner for some lucky crocodile. A picture of our ancestors' world vanished world is beginning to emerge. Here's more of this elephant tusk that's eroded out down this slope, and here are both tusks of the elephant. And here are the upper molars. By keeping track of every fossil we find, we can map out a world totally different from Hadar today. The geologists can help us, too. They sample ancient layers of the Earth that have been exposed in the Great Rift Valley. Geologist, Tesfaye Yemani, has discovered that Hadar was wet and forested millions of years ago.

TESFAYE YEMANI: This is a landsat image of the Hadar area, and then as you can see, there are several dry river coming from the western mountain of Ethiopia, flowing to Awash River. The same thing was happening during the time of between four and three million years ago, except this, the river were flowing through very thick forests and not a desert like today.

DON JOHANSON: At the time of our earliest ancestors, this place was lush and green. Back then, there were rivers and lakes with communities of animals living in and beside the water. Here were the pigs and the elephants whose fossils we found. Deep in the forest lived the apes from which we and chimpanzees are descended. The lives of today's chimpanzees hint at our close kinship with the apes. Even though they have smaller brains than we do, chimpanzees have many human characteristics. They're highly social, they have a sort of language, and they use tools. In the distant past, we shared a common ancestor with these chimps, so our earliest ancestor must have been part ape, part human. For well over a century, people have been fascinated by the search to find the missing link, a creature that would bridge the gap between ourselves and the primitive apes. It was always thought that the key feature that separates us from the apes is intelligence. It was logical to think, then, that the earliest ancestors would have large brains. The argument goes like this: the chimpanzee skull holds a brain three times smaller than modern man. If increase in brain size set us on the path from ape to human, it was thought that the missing link should have first developed a big human-like brain. Back in the heat of Hadar, following the trail of the missing link is grueling work. The sun pushes the temperature to over a hundred degrees. But there's always an air of anticipation, because you never know what might be in the next ravine. This is a fossil-finder's dream: a perfectly complete skull partly concealed beneath a covering a sandstone. But it's not one of our ancestors, it's a baboon, a kind of monkey. In a century of fossil hunting, skulls have always been the prize. After all, if our earliest ancestor were a large brained ape, a skull would be the perfect proof. But the story is like a detective thriller, full of false trails, never straightforward, and it can all change unexpectedly, because from time to time a fossil is found that is so different that it entirely turns the story of our origins upside-down. The trail began not with the skull, but with something totally unexpected. I was surveying late one afternoon when we were out collecting some elephant teeth, and I looked down on the ground and found in a couple of pieces this knee joint. At first, I thought it was just from a monkey, maybe a baboon, but it went together in a way that didn't look like any monkey. If it wasn't a monkey's knee what was it? It looked vaguely human, but how could that be? I needed an expert opinion. Owen Lovejoy is an anatomist, part-time forensic scientist and an expert on animal locomotion. If anyone could tell me what sort of creature that knee belonged to, he could.

OWEN LOVEJOY: When Don brought the Hadar knee back from Ethiopia, he brought it over to my house and laid it out on the living room carpet, and I knew instantly, that was a human knee.

DON JOHANSON: My suspicions were confirmed. As Lovejoy pointed out, the joint had all the hallmarks of a creature that moved around on two legs, not on all fours. Walking upright is something that only humans can do. And it needs a special kind of knee joint, one that can be locked straight. A chimp gets around on all fours. If it tries to walk upright, it's knee joint doesn't lock. It's forced to walk with a bent leg and that's tiring. This mysterious fossil really perplexed us. What was a modern-looking human knee doing among fossils that were millions of years old. We had to find out how old that knee really was. The hills at Hadar contain distinct layers of light colored volcanic ash. We can't date fossils directly, but we can date the ash. And once we know how old the ash is, we know that any fossil found beneath it is at least that old. With the eye of a connoisseur, the geologists select the best ash samples for analysis back in the lab. Dating techniques are so precise that we only need small samples, as little as one single crystal or grain. The purest crystals are blasted by an Argon laser we've nicknamed Flash Gordon. As it melts, the crystal releases Argon gas. The amount of gas given off gives us a direct estimate of the age of the volcanic ash, and once we know that, we could work out the age of any fossil we found nearby. The results were exactly what we had hoped for. The knee was over three million years old, one of the oldest human fossils ever found. I felt sure we were onto something completely new, yet the knee posed troubling questions. What sort of ancient creature would have a modern knee? I kept turning it over and over in my mind. What did it mean? We needed more fossils and luckily the knee generated such scientific interest that we had no trouble mounting another expedition. And the next year we were back once more at Hadar. On every expedition, breakfast is the time we spend planning the day's work. One morning, two of us decided to go back to a gully that we hadn't finished working on the day before. Fossil hunters sometimes rely on hunches, and that morning, I had a hunch that this would be my lucky day. I was headed back to my land rover, it was about noon time, and I was going to drive back to camp. And I just happened to look over my right shoulder, and I noticed a small piece of bone resting on the surface of the ground, and as I began to look around and scanned the slope, I could see not only bits of a leg, but bits of a skull, a little piece of a jaw, and I realized right there in that noon day sun that what I had literally stumbled across was most of an entire skeleton. In ancient times a creature died. Now after three million years, her bones had come to light. A skeleton as old as this had never been found before. As more and more of these precious fragments came back from the field, a buzz of excitement ran through the camp. Everyone knew instinctively this was something big.

TESFAYE YEMANI: To find such a fossil was wonderful for me, you know. It was a night I'll never forget. And it was wonderful for Ethiopia, too. After this, everybody wanted to come here to look at our Lucy.

DON JOHANSON: The shape of the lower jaw and tiny details of the teeth alerted us to an intriguing mixture of ape and human-like features, something we'd never seen before. Some of the fragments were tiny, hundreds of them were collected, carefully cleaned and laid out on the table. The whole camp was absorbed with the mystery of what this creature looked like. The pelvis was in fragments. It took hours to piece it together.

TESFAYE YEMANI: In Ethiopia, you know, we called her Dinkanesh. It means "thing of wonder."

DON JOHANSON: The hours passed. No one thought of sleep, we had so much to do. Then we looked at the knee. It was modern, human-like, just like the one I'd found the previous year. As we put the bones together, we saw they came from one tiny adult female, standing only three and a half feet tall. This was the creature we'd been looking for. The celebration began. One song was placed over and over, and we named our new find Lucy. Lucy became an almost instant celebrity in anthropological circles. She didn't look like anything we had ever found before. She was something very different. And because of that, she opened up for us an entire new chapter on human origins. Lucy turned old predictions upside-down. It was thought the missing link would be a smart ape that walked on all fours. Here was the skeleton of a creature that looked like it could walk like us but with many ape-like features. The ape that stood up, it was a revolutionary idea. We needed Owen Lovejoy's expertise again, because the evidence wasn't quite adding up. The knee looked human, but the shape of her hip didn't. Superficially, her hip resembled a chimpanzee's, which meant that Lucy couldn't possibly have walked like a modern human. But Lovejoy noticed something odd about the way the bones had been fossilized.

OWEN LOVEJOY: When I put the two parts of the pelvis together that we had, this part of the pelvis has pressed so hard and so completely into this one, that it caused it to be broken into a series of individual pieces, which were then fused together in later fossilization.

DON JOHANSON: After Lucy died, some of her bones lying in the mud must have been crushed or broken, perhaps by animals browsing at the lake shore.

OWEN LOVEJOY: This has caused the two bones in fact to fit together so well that they're in an anatomically impossible position.

DON JOHANSON: The perfect fit was an allusion that made Lucy's hip bones seems to flair out like a chimps. But all was not lost. Lovejoy decided he could restore the pelvis to its natural shape. He didn't want to tamper with the original, so he made a copy in plaster. He cut the damaged pieces out and put them back together the way they were before Lucy died. It was a tricky job, but after taking the kink out of the pelvis, it all fit together perfectly, like a three-dimensional jigsaw puzzle. As a result, the angle of the hip looks nothing like a chimps, but a lot like ours. Anatomically at least, Lucy could stand like a human. The case for our earliest ancestor walking upright was growing stronger, and Lucy wasn't the only evidence. Around the same time, another remarkable fossil was found by a team working in Tanzania led by Mary Leakey. It was a mysterious footprint. Three and a half million years ago, a volcano erupted a thousand miles from Hadar near a place called Laetoli in Tanzania. Over the weeks, it threw tons of ash into the air that repeatedly blanketed the landscape. By a stroke of good fortune, the eruption took place at the beginning of the rainy season. As the rain set in, the ash became muddy and covered with animal prints. A bird picked its way across the ground, followed by a scurrying African hare. Then as time passed, another creature arrived that left prints we would all recognize. Eventually, all these prints were covered by ash from another eruption and preserved forever as they hardened into rock. Three and a half million years later, Mary Leakey's expedition uncovered this trail. There were footprints from at least two individuals, apparently walking side by side. The unusual chemistry of the volcanic ash was like plaster, preserving the prints as a series of detailed molds and casts in solid rock. Evidence like this would delight a forensic scientist like Owen Lovejoy. The analysis of footprints from a crime scene can be vital in identifying a suspect. How different were those ancient footprints in Laetoli from ones like these?

OWEN LOVEJOY: There's no better evidence than that provided by a footprint. That's what makes the Laetoli prints so exciting, because they give us a direct record of how our ancestors walked almost four million years ago. When we compare the Laetoli print to that of a chimpanzee, the difference is immediately obvious. The chimpanzee, which is a quadruped, but occasionally a biped, still has a free great toe, and that great toe extends out away from the foot and leaves a very distinct mark. On the other hand, when we compare the Laetoli print to that of a crime scene human print, they're virtually indistinguishable. The great toe is in line with the rest of the toes. And what this has done in the human and the Laetoli print is to create an arch. And that's a hallmark of typical modern upright locomotion, because the arch is an energy absorber. And that's the kind of fine tuning that you would expect in a biped that had been that way for a very long period of time.

DON JOHANSON: So a picture of Lucy and her kind begins to emerge. They were strong walkers. Like us, they could keep going all day long, probably in search of food. But how human-like were they in other ways? Had they begun to develop a human-size brain to go with their human walk? Lucy couldn't help us there. Her skull was almost entirely missing. So knowing the exact size of Lucy's brain was the crucial bit of missing evidence. But from the few skull fragments we had, it looked surprisingly small. What we needed was a complete skull. Finding one has always been our goal. On the second day of this expedition, I'd gone out to search a remote part of the valley alone when I found tantalizing fragments of a skeleton. I rushed back to camp and alerted the team. We decided to drop everything, pack our gear and set out on the dusty drive to search for more. I was sure that the bone fragments I'd found, a piece of skull, an arm bone, and some finger bones, belonged to a human ancestor. Fragments found together like this are so rare that we needed everyone's help. We were excited, but tense. Would we find the rest of this ancestor? When we arrived, we mapped out the area where I'd found the small piece of arm bone, and a tiny fragment of skull that were freshly broken. That meant they hadn't been on the surface long. There was a chance that the rest of the arm bone, and maybe even more of the skull, were still buried in the hillside. Because they're so delicate, complete skulls hardly ever survive. The dig had to be conducted with meticulous care. The stakes were high. We hoped we were about to uncover another Lucy, maybe even more complete. The work requires extraordinary concentration. We hardly exchange a word. There's a lot of ground to cover, but we try to make sure nothing escapes our attention. All the spoil is screened with an expert eye to double check for any minuscule fragments, but it's mostly just dirt. After a week of painstaking and exhausting digging, we hadn't found anything. Our initial optimism was flagging. Where were the bones? Because if the skull had eroded out, it goes into so many pieces, and we've not found a single fragment of it. I mean not—nothing. Setbacks and fruitless days are all part and parcel of an excavation. All we can do is return each day and keep searching. After a week, we sent part of the team off to search in another location, but a few of us stayed on. Any fragment raises our hopes because it may be part of the puzzle. Another week passed, and we'd found a few fragments, but no sign of any skull. But on an expedition, you can never be sure what will happen next. I clearly remember that evening. At dusk, I returned to camp. The moment I arrived, I could tell that something was up. The team we'd sent off had returned to camp with a bag of bones. To the expert eye, those fragments were clearly part of a skull. We'd found it at last, the prize fossil, a skull from Lucy's kind. In the afternoon, when it's too hot to dig, Bill Kimbel, a resident anatomist, began to put the pieces together.

BILL KIMBEL: The world has been waiting for a complete skull of Lucy's species for a long, long time. And it's going to take a great deal of work to assemble it, to see what the brain size might be, what the relationships might be between the various components of the skull, but even already, we can see that as we assemble larger pieces from smaller pieces, joining them together, we're beginning to get a fairly impressive picture of a species that has a very ape-like face with big protruding brow ridges, very ape-like.

DON JOHANSON: We think Lucy's skull might have looked something like this, with a receding forehead and a prominent face. And with a brain case no larger than a chimps, this was no smart ape. That skull tells us for certain that our earliest known ancestor was a small-brained creature, capable of walking upright, much like modern humans. It tells us that our ancestors first stood up, and only got smart later. But why was walking so important in our evolution? In order to understand that, we have to learn more about how Lucy and her kind made a living three million years ago. Even before Lucy's time, the climate of tropical Africa was changing. There were alternating seasons, wet and dry and less rainfall overall. The dense forests were beginning to shrink. East of the Great Rift, the forests were replaced by open grasslands with scattered clumps of trees. Under these new conditions, some species died out entirely, and others took their place. New species of antelope were colonizing the forest edges. High in the trees, the ancestors of today's monkeys were on the increase. The monkeys' strategy is to produce a lot of young quickly. Their populations expanded rapidly at the expense of the apes, who reproduced much more slowly. Before long, the apes were in retreat, pushed out by the monkeys. The number of apes declined along with the shrinking forests. Except, that is, for one: Lucy, the ape that stood up. How did her upright stance, her ability to walk on two legs help Lucy and her kind compete in a new and changing world? Lucy probably became a walker while still very much dependant on the forest for food. But when the forest became sparse and times got tough, Lucy and her kind could still survive by walking across the grasslands to reach the clumps of trees where her food was found. And her hands were free to collect and carry the valuable food she found. This slight advantage was all she needed. While the other apes declined, Lucy and her kind flourished. But how did this way of life effect the rest of Lucy's day to day existence? Can fossils give us any insight into her behavior? Back at the excavation, weeks of hard work and hundred degree temperatures were finally producing results. We unearthed some pieces that looked like an arm bone, the ulna, the bone between the elbow and wrist. We'd never found a complete one before.

BILL KIMBEL: I think it looks—looks good for finding more of it.

DON JOHANSON: You know, I think there's no questions that this is just an ulna. See this groove here? Look.

BILL KIMBEL: Is the styloid there?

DON JOHANSON: I think the styloid process is preserved.

BILL KIMBEL: Terrific. I wonder if we're going to get a fit between this piece here and this piece?

DON JOHANSON: Well, I, you know, this one's broken at sort of an angle, and that's very jagged. Yeah. I don't know. If there is anything missing between here and here, it's got to be just a little bit.

BILL KIMBEL: It can't be very much. I'll tell you the geometry of the break on this fragment looks perfect for fitting on the piece that—

DON JOHANSON: It looks very, very similar to the original one I found. I wonder if we can, is this ready to lift out?

BILL KIMBEL: I think we are OK.

DON JOHANSON: Well, it's got a color match. Yep. There it is. It's perfect.

BILL KIMBEL: So how big do you think it'll be?

DON JOHANSON: You mean lengthwise?

BILL KIMBEL: Mm hm.

DON JOHANSON: I mean lengthwise, all right, if you put those together, put that out there like that, it's going to be the length of my arm.

BILL KIMBEL: It's going to be modern-sized.

DON JOHANSON: The length of that arm bone was a real surprise, because Lucy was only three and a half feet tall. We urgently needed to check that all the pieces really fit together and that meant heading back to our field lab by the side of the river. So what I'm doing is just picking away, sand grain by sand grain, the adhering stones so that we can get a close look at what the original anatomy looked like. It's really amazing to see how much detail is actually preserved on these three million year old bones. Final little pieces of sand out of the marrow chamber. Brush that off. Perfect. Just perfect. The final little piece to the puzzle fits in right there, and fantastic. Complete ulna. Just amazing. You know, not only is it important because it's a three million year old ulna and so beautifully complete, but because for, of what it tells us about Lucy. Comparing it to Lucy, for example, in terms of anatomy, these two bones, both about three million years old, are essentially identical. But it's obvious that the new ulna is nearly twice the size of Lucy's. And such substantial difference in body size really has important implications for behavior. These fossils suggest that some of Lucy's kind were much larger than others, nearly twice the size. Such enormous differences are seen today in mountain gorillas, and it's clearly related to their social life. This is a harem in which a single, large male controls a group of small females. The silver back male is almost twice the size of the females, and this leader of the group, he mates with each female in turn. He can easily control all the females. In this lush environment, they find all the food they need without wandering far. And if any other male tries to invade, the silver back throws in all his weight and attacks with his huge canine teeth. To survive in gorilla society, males have to be much larger than females, and have vicious fighting teeth. Finding an arm bone twice as large as Lucy's raised the possibility that the new bone was from a large male, and that our ancestors fit the gorilla pattern, that they had lived in a harem. But not all the evidence fits. The landscape Lucy lived in was very different from the lush jungle of the gorillas. Lucy had to range widely in her search for food, and that would have made it hard for a single male to dominate a group of females. And there were other clues that didn't match the gorilla model. Over the years, we've found hundreds of teeth from Lucy's kind, male and female. Surprisingly, the males have small canine teeth, just like the females. That could mean that there was no need for males to fight for control over females. Perhaps they weren't living in a harem after all. Some scientists have speculated that the lack of fighting teeth in our ancestors means that males and females were paired off in monogamous couples. For now, the evidence points both ways, but contradictions like this keep us questioning our ideas and looking for more fossils. What we do know is that these creatures were walking like us over three million years ago. And that was a distinct advantage. They could cover long distances, forage for food, and carry it back, perhaps to a faithful mating partner. We believe Lucy's species was the root of the human family tree. She is our earliest ancestor, the missing link between ape and human. And what about Lucy, herself. What did she look like? We know from the teeth, the jaw and now the skull fragments we found, that Lucy had an ape-like face with a brain just a little larger than a chimps. She may have had dark skin and patchy hair to protect her from the sun. Walking upright freed her hands to develop a more precise grip than other apes, more like our own. And even with her small brain, perhaps she was beginning to have a more human like awareness of herself and her surroundings. Lucy and her kind must have been extraordinary creatures. We know that they persisted as a species virtually unchanged for over a million years. That's ten times as long as we ourselves have been around. We know that they led relatively simple lives, because one key feature was missing from their behavior. Yet a few hundred thousand years after Lucy, some of her descendants made a major breakthrough, a breakthrough that would have profound influence on our own evolution. They began to make these: stone tools. Who made these tools and why? They are a clue to the next chapter in the search for human origins.

ANNOUNCER: To respond to this program or to find out more about NOVA, visit NOVA's website at pbs.org. To order NOVA's "In Search of Human Origins" on videocassette, call 1-800-949-8670. This three hour set is $49.95 plus shipping and handling. Individual programs are also available for $19.95 each. Next time on NOVA, to eat or be eaten. On the untamed savanna, skill and cunning are the weapons of choice. Were our tiny forbearers predators or prey? How did they survive? "In Search of Human Origins, Part II."

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