[NARRATOR:] Explaining the origins of key traits that distinguish species has long been one of biology's fundamental quests. That's especially true for our own species.

[CARROLL:] If we look at humans as a biologist would any animal, certain features stand out. Our big brains, the way we get around on two legs instead of four, and the way we use our free hands to make tools.

[NARRATOR:] Each of those three traits marks an enormous difference between us and our primate relatives. But when did they evolve? And in what order? The quest to understand our past has revealed much about the evolution of these features, all of them milestones in the great transition from apes to humans. It was many years after Charles Darwin had published his theory of evolution that he finally addressed the question: what about us?

[CARROLL:] He speculated that we are descended from a common ancestor we share with African apes. The hope was that some geologist or paleontologist would one day recover the fossils that would settle the question.

[NARRATOR:] Fossils are essential evidence when putting together an evolutionary history. But in Darwin's day, and for many decades after, few early human fossils had been found anywhere. Anthropologists Louis and Mary Leakey thought Darwin was right about Africa. So, they searched for early human fossils in places like Tanzania's Olduvai Gorge. Here, they found abundant stone tools. But for the longest time, the bones they sought eluded them.

[CARROLL:] For almost three decades, all the Leakeys found were tools, … tools, tools everywhere, but not their makers. But all that finally changed the morning of July 17, 1959.

[NARRATOR:] On a hill Mary had walked by countless times, something caught her eye. Poking through the eroding sediment was a huge upper jaw. Together, she and Louis carefully extracted bones from the skull of an early hominid. Geochemists analyzed the sediment layer it was buried in, and determined this hominid had lived a stunning 1.76 million years ago. Remarkably, the very next year, the Leakeys made another discovery. They designated it Olduvai Hominid number 7. It too was almost 1.8 million years old, but the recovered skull pieces and finger and wrist bones led them to conclude it was a separate species of early hominid. So there were at least two different evolving lineages of humans alive at this time. These discoveries helped swing the focus of human paleontology to Africa. Detailed casts of these, and many other fossil finds, are kept at the Human Evolution Research Center at the University of California at Berkeley. Dr. Tim White, the center's director, has been involved with many of the important hominid discoveries of the past four decades.

[WHITE:] Clearly it was a hominid …

[NARRATOR:] I asked him what the current view is of the Leakeys' first discoveries.

[WHITE:] Well I guess after chasing the tool-maker for so many years, they initially thought, "Oh, we've found the tool-maker." But it turns out this large crest, the huge back teeth of this, show that it's on a side branch of human evolution, probably not the tool-maker. But fortunately, the next discovery was

Olduvai hominid number 7, with a cranium much larger in size and a face much smaller in size, and probably the maker of these very primitive stone tools from the very bottom of Olduvai Gorge.

[NARRATOR:] The early humans found at Olduvai were bipedal tool makers, with brains not as big as ours, but larger than those of modern chimps, our closest primate relatives. So, all of these traits must have evolved between 1.8 million years ago and whenever the human and chimp lines separated. And when did that happen? At that point, no one could say.

[CARROLL:] But then Allan Wilson and colleagues here at Berkeley developed a revolutionary new way to use biomolecules, including DNA, to estimate the time of that split.

[NARRATOR:] Using this approach, researchers have estimated that humans and chimps have been evolving independently for almost seven million years.

[CARROLL:] DNA tells us that our lineage goes back several million years before the Olduvai fossils. What DNA can't tell us is where and when the traits that distinguish us—like bipedality—first emerged. Only fossils, and their ancient environments, can address those questions.

[NARRATOR:] Eastern Africa is a fossil treasure trove because of the geological forces that have created the rift valleys that scar the region. Over the eons, volcanoes associated with this rifting regularly blanketed the region with ash that included radioactive elements, the steady decay of which allows geologists to accurately date sediment layers and the fossils within them. Paleontologist Don Johanson remembers vividly the first time he visited the Hadar region of Ethiopia. A thousand miles north of Olduvai, it has exposed sediments that are over a million years older.

[JOHANSON:] We drove up to the edge of this escarpment, and it just unfolded, and there it was. All of the sediments, getting deeper, and deeper, and deeper. I could not wait to get down there. The driving force was to find something. And then we walked out there …

[NARRATOR:] Johanson recently shared with fellow paleontologist Neil Shubin his memories of the day he discovered the first small bone fragment of one of the most famous fossil skeletons ever found.

[JOHANSON:] You know, my best recollection is that it was right in this area. And I looked at it and almost instantaneously said, "that's a hominid." Just a fragment of elbow, that led to the skeleton.

[NARRATOR:] An international team of scientists helped Johanson recover almost half the bones of an individual who had lived 3.2 million years ago. They called her Lucy.

[JOHANSON:] Finding Lucy was really the first step in this very long process of description, investigation, evaluation, hypothesis testing, trying to figure out where in the world she sat, like we are, on the tree, on the human family tree.

[WHITE:] This is the Lucy skeleton, found by Don Johanson in Ethiopia, she's 3.2 million years old and very representative of *Australopithecus*, the next earlier phase of human evolution, and they are bipeds, … relatively small brains, and no evidence, so far, of any stone tool use.

[CARROLL:] So the stone tool use comes in much later than Lucy and her brethren.

[WHITE:] With early *Homo*.

[CARROLL:] What can we tell about this creature from the fossils?

[WHITE:] When we look down here into the pelvis we see evidence for bipedal walking, a commitment to walking on two legs that is very different from what we see among great apes. So, when we look at a chimpanzee, in the hip, we see the hip bones behind, they're long, they're tall, they're up the creature's back. Whereas in a human, our hip bone is much broader front to back, much shorter, and wrapping around the side, to put these muscles that control pelvic tilt during walking in an advantageous position. Then we can ask the question, is Lucy more like a human or more like a chimp? She has a very short blade on the pelvis, much more like a human. She has muscle attachments, much more like a human. It's a basically biped's architecture, and that's how we know she walked on two legs. But there was a little bit of controversy, even after that, some people said, "Well, how can we really be sure about that?"

[CARROLL:] And how can we be sure?

[WHITE:] Because we found these incredible things in northern Tanzania, older than Lucy, sandwiched between layers of volcanic ash, and it's not what you think, it's not bones. There was a volcanic eruption 3.75 million years ago. The volcanic ash came down on the Serengeti plain, and animals walked across it. … The ash hardened and was buried. In the 1970s, I was lucky enough to be with Mary Leakey out in this area, and we found the trails of hominid individuals, left as they walked across that volcanic ash millions of years ago. It's an amazing, … like a snapshot of time. They went for meters and meters and meters. There are no knuckle marks, no hand prints, just bipedal footprints that look more or less like what you and I would leave on a beach. Human feet, we're all used to them, but they're really strange. Our big toe is in line with our other toes, we don't have a grasping big toe. We have arches, transverse and longitudinal, in our feet. All these features are present at 3.75 million years ago in *Australopithecus*.

[CARROLL:] So *Australopithecus* pushes us all the way back to 3.7 million years or older. She's small-brained, not using tools to our knowledge, but walking upright. So that's telling us that walking upright is yet still an earlier trait. What do we know about that?

[WHITE:] We didn't know very much about it because Lucy and her species only went back to 3.75. So, to take the next step back in time, we had to find older fossils.

[NARRATOR:] Just fifty miles south of where Lucy was found, there are exposed rock layers reaching back six million years. This is where Tim White and a large international team of geologists, paleontologists and archaeologists have focused their combined efforts since the early 1980s.

[WHITE:] What we wanted to do was to plumb the unknown, to figure out what came before the Lucy species.

[NARRATOR:] For a decade, what they'd come for largely eluded them. Until …

[WHITE:] A graduate student at the time, Yohannes Haile-Selassie, found two little pieces from the palm of the hand. Just this bone here. And these little pieces, he picked up and said, "This looks like a hominid."

[NARRATOR:] The excitement of this and other early finds quickly gave way to a disciplined search for more. And there was indeed much more to find.

[WHITE:] Hand, foot, arm, leg, teeth, skull, head to toe, we had coverage of a creature nobody had ever seen before. We nicknamed her Ardi for the genus *Ardipithecus*, the species is *ramidus*, and it's really a skeleton that is representative of the earliest known phase of human evolution.

[CARROLL:] And how old is she?

[WHITE:] She's 4.4 million years old. We know that because these bones were all found sandwiched between volcanic horizons both dated to 4.4 million years ago.

[CARROLL:] So that's more than a million years older than Lucy?

[WHITE:] It was stepping into that black hole beyond Lucy that nobody had been able to step into before.

[NARRATOR:] Removing Ardi from her four-million-year resting place was a real challenge. Her bones were ready to turn to dust.

[WHITE:] That little hill had to be excavated a millimeter at a time. We had to use chemical hardeners on her, extract her in plaster jackets, and then work on each bone under a binocular microscope with a needle to clean the encasing sediment from the soft bone underneath. But what we got as a result of that is a really unrivaled look at the anatomy of a very ancient hominid. We could see the muscle attachments on the finger bones, we could see the scratches on the teeth. It's beautiful anatomy.

[NARRATOR:] With some real surprises, especially below the neck.

[WHITE:] There was an extension in the lower pelvis that showed that she was a climber. In the foot, a large toe that stuck out to the side of the foot, the first time this is ever seen in a hominid, even though all other primates have this. She is this peculiar mosaic of traits capable of bipedality on the ground, but also climbing abilities far superior to those seen in later *Australopithecus*.

[CARROLL:] You couldn't possibly have expected this.

[WHITE:] Nobody could have expected it because you can't predict this from looking at chimps and humans and triangulating. Ardi is neither a chimp nor is she a human. She is a mosaic, 4.4 million years old, a step beyond Australopithecus, a glimpse into that first phase of hominid evolution.

[NARRATOR:] Buried along with Ardi was fossil evidence of the habitat in which she lived and where bipedality evolved. It wasn't what anyone had been expecting. For a long time, scientists predicted that bipedality had evolved in a grassland.

[WHITE:] The savanna has always played a big role in people's speculations. And what we had with Ardi was evidence from her body and indeed her chemistry, as well as evidence from her environment, that showed that she was not adapted to an open grassland savannah existence, even though she had already achieved bipedality.

[NARRATOR:] That evidence included tens of thousands of animal and plant fossils, indicating that she was living in a woodland setting, not an open African savanna. So, bipedality evolved while our ancient ancestors were still spending time in the trees.

[WHITE:] *Ardipithecus* took away any doubt that bipedality was ancient. And it was so ancient that it preceded, by over a million years, the expansion of the brain, the incorporation of stone tool technology.

[NARRATOR:] We now have thousands of hominid fossils from the past six million years. They reveal several phases in the biological evolution of humans.

[WHITE:] You have an early phase, *Ardipithecus*, whose anatomy allows it to climb in the woodlands and walk on two legs. We see *Australopithecus* as the next phase. Lucy a representative of this, a committed biped with a small brain but still big teeth for chewing, big robust faces. Their niche has expanded beyond *Ardipithecus*, they're in more open habitats, they're found throughout the African continent. And then the third phase of human evolution is our own genus, the genus *Homo*, and here we have a creature that really is a technological primate depending more and more on culture.

[NARRATOR:] Stone tools allow early humans to compete first with scavengers and then with predators. They broaden their diets and ultimately their geographic range, leaving Africa. Recently in the Republic of Georgia, hominid fossils were discovered that are as old as the Olduvai fossils. They include the most complete early *Homo* skull ever found.

[WHITE:] That is going to give us insight into the biology of our ancestors, the ancestors of *Homo sapiens* and it's a great illustration of how paleontology is not a dead science, paleontology is the science by which we learn about our past, how we became human.

[NARRATOR:] And what that science shows is that, like all animals, we have a long evolutionary history.

[CARROLL:] Just as four-legged animals evolved from fish ancestors, and birds evolved from dinosaur ancestors over a series of small steps over a long geological time span, we evolved from small-brained, quadrupedal apes over a long time span that is now well documented in the fossil record.