

**Bones, Stones, and Genes: The Origin of Modern Humans**  
**Lecture 1 - Human Evolution and the Nature of Science**  
**Tim D. White, Ph.D.**

**1. Start of Lecture 1 (0:00)**

[ Music ]

**ANNOUNCER:** From the Howard Hughes Medical Institute... The 2011 Holiday Lectures on Science. This year's lectures, "Bones, Stones, and Genes: The Origin of Modern Humans," will be given by Dr. John Shea, Professor of Anthropology at Stony Brook University; Dr. Sarah Tishkoff, Professor of Genetics and Biology at the University of Pennsylvania; and Dr. Tim White, Professor of Integrative Biology at the University of California, Berkeley. The first lecture is titled "Human Evolution and the Nature of Science." And now, a brief video to introduce our lecturer, Dr. Tim White.

**2. Profile of Dr. Tim White (1:12)**

[ Music ]

**DR. WHITE:** Anthropology provides not only a cross-cultural understanding in where we came from, but anthropological science provides a way to really find out the truth about where we came from. If one imagines that humans were created at the same time as dinosaurs, that's a prediction. One can go to the fossil record and ask, Have there ever been humans found with dinosaurs? And the answer is no. Stone tools: When we date the earliest stone tools, we find out they came in 2.6 million years ago. Did humans make those stone tools? We can go to the fossil record and we can find fossil evidence. Are there any humans then? And what we find is that there aren't. There aren't humans. But the things we find have some human characteristics. These are creatures that aren't here anymore. You can only extract them from the fossil record. And so, human evolutionary studies show that humans got here like all of the rest of the biological world: we evolved. And the only way to figure out how that happened is by going to the real data. And when we do that as scientists, the one thing that keeps coming back, no matter how many times we've tested it and gone back to the fossil record, or the genetics lab or something else. We evolved.

**3. Civilization's Attention Span (2:52)**

[ applause ]

**DR. WHITE:** I'm a paleontologist but I'm going to start with the present, and then I'm going to say a few words about the future. But most of the time, I'll be talking about the past. This lecture is about human evolution and the nature of science. Before we get started, I'd like to thank the Howard Hughes for having us all here, hosting us together for this great opportunity of the Holiday Lectures. Start with this quote: "Civilization is revving itself into a pathologically short attention span. The trend might be coming from the acceleration of technology." We all know about that. "The short-horizon perspective of market-driven economics." We hear about that every day. "The next-election perspective of democracies." Every day. "The distractions of personal multitasking." Every day, all of us suffer from all of these things that shorten our attention span, that make us focus on the day. Who said this anyway? Turns out to be the guy, Stuart Brand, who started the Whole Earth catalog in the 1960s, and he now runs a foundation called the Long Now Foundation. And they put a zero in front of the date. Why? Their mission is to foster long-term thinking and responsibility in the framework of the next 10,000 years. That's quite a mission. That's about the future. We'll come back to that at the very end of the last lecture I give here.

#### **4. Overview of Lecture (4:34)**

Let's start with this man. Since we're at a lecture, it might be good to think about what this man... Does anybody know who this is? This is Charles Darwin as an old man. And when he was reflecting upon his days as a student, Charles Darwin said this about lectures: "The instruction at Edinburgh was altogether by lectures, and these were intolerably dull." [laughter] Now, these are not going to be dull lectures, this Holiday Lecture series, and I want to preview my little piece of this for this morning. We're going to talk about what science is. We're going to talk about why modern medicine needs to be evolution minded. We're going to talk about human evolutionary studies. I'm going to ask, How do we begin to appreciate our place in nature and in deep time? These are pretty challenging topics.

#### **5. Where do we come from? (5:27)**

In fact, it is a most profound question, this question about, Where do we come from? Every culture, it turns out, has its own answer. Now, you can find a pretty good summary of this... good starting place is this website called BigMyth.com. And you can go there and they have a map, and you can choose which culture you want to look at: Australian Aboriginal, South American Indian. Each culture has its own answer for where we come from. But not all of these answers are correct. In fact, we now know enough to say that none of them, not one of them is correct. Now, Darwin asked this very same question. Even as a young man on the *Beagle* in the 1830s, as he set off around the world, and Darwin came from a world in which the answer was basically this. We all recognize the iconography here. Species were separately created, in their present form, around 4,000 B.C., around 6,000 years ago, and that's Earth history. Darwin started that voyage basically thinking that, but by the time he reached middle age, by 1857, he had figured out not just that things had evolved, but he had figured out why: natural selection. But it turns out another man named Wallace, making independent observations in a different part of the world, had come up with the same explanation. And so, they began a correspondence. And Darwin was asked by Wallace, Oh, what are you going to do in your forthcoming book about human evolution? And Darwin answered this way: "You ask whether I shall discuss Man; I think I shall avoid the whole subject, although I fully admit that it is a highest and most interesting problem for the naturalist." And indeed, Darwin stayed good to his word. Two years later, he published in 1859 a book called "On the Origin of Species." Not the origin of the species, not the origin of the human species; on the origin of species in general: species of snails, insects, starfish, and so forth. He only said this about human evolution in that book, that "much light will be thrown on the origin of Man and his history." Darwin waited 12 years before he addressed this question: How did this happen? "This" meaning *Homo sapiens*? And he addressed it in this book called "The Descent of Man," where he says, "We are not here concerned with hopes or fears, only with the truth as far as our reason allows us to discover it. I have given the evidence to the best of my ability." And for Darwin the scientist, indeed for the Howard Hughes Medical investigators, for all of us as scientists, it is all about reason and all about evidence.

#### **6. Ancient Humans in the Western Hemisphere (8:42)**

Now, the University of California, Berkeley, on the West Coast of the United States where I work, is located right here, just on the East Bay. If you were to sail through the Golden Gate coming eastward, about 100 years ago, you would have seen this: a very large edifice, a mound. It's called the Emeryville Shellmound, and it was being exploited for commercial purposes. But the earliest archaeologists at my university were out there at the Emeryville Shellmound and they were excavating. They were digging into this mound, and they found the remains of people. They found archaeological evidence as they

excavated into this mound, and as they reached the bottom of that mound, 18 meters down, they didn't know how old these remains were. There was no really good way to tell. It wasn't until much later that radiocarbon dating was developed, and applied to the carbon material at the bottom of this mound, and it turns out the bottom of that mound is around 3,000 years old. And that's about as far back as you can go in my local area in California. That seems like a long time when we only live 100 years, but it's not very much in geological terms. To find some older things, we have to go to a sister campus; that's the University of California, San Diego. And we go down there and you recognize it from the Google Earth view here by the pier down at the bottom of the frame. And if you see that light post in the upper view where that nice surf is coming in to the pier, and you go up above on that bluff, that's a place called La Jolla. It's one of the richest, ritziest areas in the United States. The Chancellor of the University has a mansion up there. They call it The Residence. Actually, it's not being used right now, but the Chancellor wants to expand the residence. But an interesting thing happened, because in the 1970s when they were excavating on that property, they found these two human burials, end to end, buried. And when they did the C-14 dating, it turns out these things are nearly 10,000 years old. These are some of the earliest skeletal remains in the Western Hemisphere. Remarkable. And they bear on this question: Who were the first human occupants of the Western Hemisphere? It's a question that scientists have been interested for a very long time. And we can use bones and stones and genes to ask that question. Now, here's an article from this summer, I'll read you the headline; it's from "Wired Science." "Scientists Fight University of California to Study Rare Ancient Skeletons." Why would scientists have to fight their own university to study bone, stones, and genes? And what kind of scientists would there be out there in the world that would fight their own university? [laughter] Guilty as charged. Now, here's the background. It turns out that there is a local Indian tribe known as the Kumeyaay, and the Kumeyaay have demanded that the university rebury these remains. Why? Because the Kumeyaay think, they believe, that they were created in the San Diego area at the beginning of time as Kumeyaay, and they stayed the same way ever since. So anything there must be theirs, must be repatriated, and must be reburied. But as this journalist points out, at nearly 10,000 years old, the exceptionally preserved bones could potentially produce the oldest complete human genome from the continent. And as Sarah Tishkoff will be explaining during the Holiday Lectures, we can now use ancient DNA to understand ancient people, including ancient *Homo sapiens* like these, some of the first in the Western Hemisphere.

## **7. What is science? (12:27)**

Now, this brings us to the question of what science is. And after Darwin published his work, Darwin wasn't much of a public personality, public speaker; he didn't like it much. But this man did, Thomas Henry Huxley, known as Darwin's Bulldog. He got out and strongly supported Darwin's ideas, and he had a great definition for science. He said, "Science is nothing but trained and organized common sense," and I hope that you bring that just to these lectures and think about science in that way. If you're interested about what science is, you can go to a great website called Understanding Science, and it'll tell you the details. But to pull the kernel out of this, science is a body of knowledge, on the one hand, and the process for building that knowledge, on the other hand. And it has two components that are critical. In fact, they're crucial. And for those of you who go on in science, you're going to find yourself applying these things all the time. All good scientists do. You have to have a creative component and a critical component, and we want you to employ those during these lectures, during the interactives, and so forth. A little more detailed explanation of what science is was offered by the evolutionary biologist John Moore, who wrote a book called "Science as a Way of Knowing". It's a way of knowing by accumulating data from observations and experiments, seeking relationships of the data with other natural phenomena, and excluding supernatural explanations and personal wishes. That's what science is. And science is never complete. Each new discovery produces new questions. So there

are plenty of questions out there in the world that haven't been answered yet, and we are hoping that you here will tackle some of those and go on to careers in science.

## **8. Relationship between medical science and evolution (14:19)**

But what about medicine? Where does that stand? Well, prehistorically, most medicine was actually faith based. Even historically, if you look at the 1800s, a lot of medicine was basically faith based. We didn't have the imaging technologies, the diagnostic technologies that we have today. Today, take a look around you. You are at the Howard Hughes Medical Institute. This is the premier institution, one of the world's most important establishments for the conduct of medical science. Why would this institute dedicate its Holiday Lectures to this topic, evolution? Well, we can look to the roots of the answer, not with Charles Darwin, but two generations back. Erasmus Darwin, his grandfather... turns out he was a physician; he was a doctor. And in 1809, the very year that Charles Darwin was born, Erasmus Darwin published this book called "Zoonomia," and he said this: "A theory founded upon nature that should bind together the scattered facts of medical knowledge would thus on many accounts contribute to the interest of society and would teach mankind, in some important situations, the knowledge of themselves." Thinking about, what would that theory be, that theory founded upon nature? Well, it turned out to be evolutionary biology. And it turns out that the acorn didn't fall very far from the tree because his grandson was the one who figured out why the evolution happened: via natural selection.

## **9. Biomedical implications of human evolution (16:02)**

I'm going to give an example of this. We're talking about medicine; we're talking about biology and evolution. Medical specialties arising from our peculiar two-legged mode of locomotion today include: orthopedics; podiatry, walking on two feet, entire weight of the body. Obstetrics? What does obstetrics have to do with human evolution? Well, turns out a lot. Human beings are primate bipeds with big brains. Let me introduce a couple of my partners in this lecture. This is the chimpanzee, common chimpanzee. This is a modern human. If we were to take their heads, and take and saw them in half, and put them up on a screen, you'd see pretty much that. And what that is a big, big space inside the human cranium for the human brain. That has some biomedical implications. There's a very high maternal mortality at child birth, very high compared to other mammals, even under Western medical conditions, very high, very strong selective force, opposed to the selective forces leading to walking on two legs. It's a compromise, it turns out, between brain size and bipedality. Today, we have C-section rates that are climbing, not just in this country, all over the world. It's one way around the problem that wasn't available to our ancestors. Our young are born altricially. They're like fetal for quite a while; they're very helpless. And feeding cow's milk to our babies and adults has health consequences. It's like we can't do anything in medical science without coming to the conclusion that, because of evolution, we have to be evolution minded. Humans recently invented agriculture and became sedentary. Some biomedical effects of this: epidemiology of diseases in large populations that are now linked together by transcontinental jet aircraft; epidemics today, we hear this often; obesity; cancer; heart disease. These are fundamental biological things that have to do with evolution. So modern medicine has to be evolution minded.

## **10. Basic classification of great apes and human origins (18:25)**

And human evolutionary studies sort of sit at an intersection and integrate a lot of different sciences: the biological sciences, the earth sciences, and the social sciences. And we'll talk about all those things today in the Holiday Lectures. This integrative science of human evolutionary studies, we can start with something really quite simple, and that is classification. We've taken our closest living relatives, shaved them, stood them up on two feet for comparative purposes. What's the one on the left?

**STUDENT:** Orangutan.

**DR. WHITE:** Orangutan. Genus name: *Pongo*. One on the right? That's pretty easy. The big one's pretty easy, too. And this one here?

**STUDENT:** Chimpanzee.

**DR. WHITE:** Chimpanzee. Now, we can put, and what are these names? What do they indicate? These are the genus names; they have species names. We're *Homo sapiens*. That's *Pan troglodytes*. They're placed by zoologists in families. And you're all familiar with the zoological hierarchy. Families. Traditionally speaking, all of the apes were placed into the Pongidae, and all of humans and direct human ancestors and close relatives are placed into the family Hominidae. And that's the sense that I'll use this term in today. But when we think about these primates, the great apes on the left and the lone surviving hominid, *Homo sapiens*, on the right, from the 1800s onwards, after Darwin published these ideas, people began to think about the fossil evidence more and more strongly, and there was virtually none of it in those days. There was quite a bit of anatomical evidence. By then, chimpanzees had been discovered, dissected, analyzed. People like Huxley studied them and saw that they were close relatives but it took a long time for the anatomists to work this out. And in the meantime, something happened by the 1960s. A completely independent line of evidence opened up, became available, and we began to be able to explore the relationships among these living primates using biomolecules. And it turns out that we are more closely related to chimpanzees, now we have their whole genome; gorillas; little more distantly, orangutans; little more distantly, gibbons; and then monkeys, and lemurs, and your cat, and a fish, and so forth. And that's basically the tree of life as we understand it today. Now, you're going to hear this family referred to a couple different ways. I'll use the term hominid; other people use hominin. They're effectively synonymous, means exactly the same thing. It means everything on our side of this split point, the last fork in our little twig of the family tree. But we're not the only ones there. We're going to meet in these lectures a creature known as *Australopithecus*. It's a funny creature. It's all gone, or maybe not, because its genes in altered form are in you and in me. That's a fantastic thing that we'll get to with the fossil record. That fossil record is really an amazing thing. It's pretty good the younger you get; like at the Emeryville Shellmound, the last 3,000 years, we can do pretty good. But as we go back in time, the record gets poorer and poorer because we basically lose paleobiological evidence. So when we think about this tree, the human evolution tree of life, this is the poster that was created for the Holiday Lectures, and we focus in not just on the primates, but we're focusing in on this strange creature, human beings, very bizarre. Think about it: this species is naked, bipedal, brainy, tiny faces and canines, has culture, has no estrus that we see in other mammals, has a very wide geographic range, eats all kinds of things. What a bizarre organism. Where does it come from? That's the question that we ask, and we have to ask it on a six-million-year time scale,

### 11. Difficulty of conceptualizing millions of years (22:54)

the last six million years of evolution, and this is hard to think about. It's hard to think about millions. And the reason for that is it's easy, we have evolved as primates, who think about time in ontogenetic and personal terms. Ontogenetic terms, minus three days. This is what you looked like three days before you were born, and then, three days after you were born, you looked pretty much like this. And then, six months later, this amazing thing happens: your brain has expanded dramatically. [laughter] Now, that's not a fake picture; that's the same sock monkey for scale, so this is a scaled scientific photograph showing what happens in that six-month period. That is extended fetal growth of the brain. That's a remarkable thing in a mammal. And it's easy to think about intergenerational time. We think

about our own line: our great-grandparents, our grandparents, our parents. We are their children and we will have children. And as these children come into the world, they will pass their DNA to the next generation, and so on and so forth. But that's about the future. When we talk about the past in historical time, we have to think about our lifetimes on the longer sweep of history, and we put numbers on this, dates, and I haven't put a zero in front of these. We're going back in time, back from your lifetime, that little bit at the end to the Trojan War, the Pyramids of Giza, a little before that, the origin of writing; that's where history ends and prehistory begins. We're going back prehistorically; there are those burials at La Jolla. Nearly 10,000 years ago, the origins of agriculture, but that's not much. Historical time is fleeting compared to geological time, which takes place on a scale of millions of years and is difficult to comprehend. And so, what we've done is to take some representative fossils, and there are literally thousands of hominid fossils that have been found since Darwin, and these thousands of fossils can be seen; you'll see some of them here in these lectures. I've chosen just a select few; we'll have some tomorrow.

## **12. Visualizing six million years (25:04)**

But before we get to those fossils-- who were once living individuals-- before we get there, I want you to try to relate to this great time depth somehow, and one convenient way to do it is to let a pixel on your laptop stand for a year. It would take six laptops, six million pixels to equal six million years. Now, what about your lifetime on that scale of six million pixels? Well, let's say that the Howard Hughes Medical Institute really does its job fantastically well during your lifetimes, and you all live to be 100 years old. That's optimistic. But why not be optimists? Especially about that. 100 pixels, your 100-year lifetime. Samuel Clemens, a.k.a. Mark Twain, the great American author, "Innocents Abroad," "Roughing It," fantastic literature. His take on humankind was quite interesting because he was an avid reader, Mark Twain, and he read Darwin's books. In fact, at Berkeley in our Bancroft Library, we have Mark Twain's copies of Charles Darwin's books, and they were contemporaries, and Twain would write in the margins of Darwin's book, so he had an appreciation of what Darwin was saying. And Twain said about humans: "If the Eiffel Tower were now representing the world's age, the skin of paint on the pinnacle-knob at its summit would represent man's share of that age." And he went on, of course, in another place to say: "Man was made at the end of the week's work when God was tired." [laughter] The great American humorist, Mark Twain. The great American evolutionary biologist Stephen J. Gould, put it in these terms: "Geology's most frightening fact: human existence occupied but the last geological micro- millisecond of this history. If humanity arose just yesterday as a small twig on one branch of a flourishing tree, then life may not, in any genuine sense, exist for us or because of us." That's pretty profound.

## **13. Phases of human evolution (27:17)**

Let's place this in the context of that tree and our relationships. Here we have the hominids, this clade; we're going to be studying this in some detail in these two days. We're going to learn about the genus *Homo*, not just *Homo sapiens* but other ones; *Australopithecus*, another genus deeper in time; and finally, a creature called *Ardipithecus*, takes us closer to that split point than we have ever been in the fossil record. We can think of this in terms of phases of human evolution: *Ardipithecus* representing the earliest phase; *Australopithecus*, and there are different species we'll be talking about; and finally, our own genus, the genus *Homo*. And the way that we understand those phases, the way that we understand where we came from, is with evidence and with reason, just like Darwin said it would be. We're going to then study that evidence, the evidence of bones, the evidence of stones, and the evidence of genes, in order to try to understand [laughter] this very, very strange primate, *Homo sapiens*. [ Music ]