Geologic Time

[MUSIC PLAYING]

PHOEBE COHEN: Hi, I'm Phoebe Cohen, a paleontologist and educator at MIT.

FRANCIS MACDONALD: And I'm Francis MacDonald, I'm a geologist at Harvard University.

PHOEBE COHEN: We're here standing in MIT's Infinite Corridor on the third floor of Building Seven at MIT. The Infinite Corridor isn't actually infinite; it's 251 meters long or about 825 feet long. Twice a year, the sun shines through the windows at the front of the corridor and shines all the way down the entire corridor, an event called MIThenge because of its similarity to the ancient ruins in Britain called Stonehenge, which align with the sun twice a year.

FRANCIS MACDONALD: So although we're here to talk about rocks, we're not here to talk about Stonehenge. We're here to talk about the vast history of our planet Earth. Our Earth is 4.567 billion years old. Now you can remember that: 4.567 billion years old.

PHOEBE COHEN: Francis, how do we know how old the Earth is?

FRANCIS MACDONALD: Well we know that because elements decay with radioactivity and we date these elements in rocks. Now when I mean date elements, I don't mean take these rocks out to a movie. I mean actually we measure the abundances of elements that decay to another element. So rocks become a little bit different. So we measure, for instance, the abundance of uranium and the abundance of lead. And we know the rate at which these elements decay, and that gives us an age of the rock. Now, interestingly, all meteorites have the same age of 4.567 billion years old.

PHOEBE COHEN: If the entire length of the Infinite Corridor represents the 4.567 billion years of Earth history, where should Francis stand if we want him to stand in the exact place where dinosaurs went extinct? Here at position A, here at position B, or here at position C? We're going to take a short break now so that you can discuss with your class and with your teacher where Francis should be standing-- position A, B, or C-- on our Infinite Corridor time line if he wants to stand in the exact place where dinosaurs went extinct.

[THE VIDEO DISPLAYS THE CORRECT ANSWER.]

Wow, Francis, you're really close. Maybe should have a mint. The dinosaurs went extinct 65 million years ago. That may seem like a really long time to many of you, but in the context of the 4.567 billion years of Earth history, it's just a really short time, actually. Today we're going to explore Earth history and learn about all of the events that occurred during Earth's 4.567-billion-year past. Then we're going to learn about how all of that time helps to explain processes that we see happen on Earth, like the build-up of mountains and the evolution of species.

FRANCIS MACDONALD: So you're going to measure out a time line in your classroom or your hallway and measure it out for 4.567 billion years old and separate it in 500-million-year intervals. Your teacher will help you do this.

PHOEBE COHEN: Now we're going to use the time lines that you just created in your classroom or your hallway to place important events in Earth and life history, but we're not going to tell you exactly where those events are. It'll be your job to work with your classmates in groups of two to four to place those events on your time line. Your teacher will have cards with important events on them, such as the opening of the Atlantic Ocean and the evolution of mammals. Work with your class to place your events on your classroom's time line. The events are-- in no particular order-- the rise of the Himalayan Mountains, the building of the Egyptian pyramids, the first evidence of oceans of water, the opening of the Atlantic Ocean, the first dinosaur, the first complex cell or eukaryote, the first land plant, the first mammal, the extinction of the dinosaurs, the first evidence of life, the first humans, the extinction of woolly mammoths, and the first animal.

FRANCIS MACDONALD: Now we're going to show you where each of these events belongs on our Infinite Corridor time line.

PHOEBE COHEN: Francis, why don't you show them? The first event on our time line is the formation of the world's oceans, about 4.2 billion years ago. The next event is the appearance of single-celled bacterial life in the oceans, about 3.9 billion years ago. Then we have the evolution of more complex cells called eukaryotes at 1.5 billion years ago. Next up is the evolution of animals at 600 million years ago. Then in the first plants move onto land about 450 million years ago. The dinosaurs evolved about 230 million years ago. Mammals evolved a little bit later: 180 million years ago. Then the Atlantic Ocean began forming about 140 million years ago. The Himalayan Mountains began forming 35 million years ago. Our genus, Homo, evolved about 6 million years ago. The woolly mammoths went extinct about 12,000 years ago. And the Egyptian pyramids were bill about 2,500 years ago. So as you can see from our Infinite Corridor time line here, even though we think of the Egyptian pyramids as being really, really old, in the context of all of Earth's history, they're really just babies.

Now it's your turn to go back to the time line that you created in your classroom and re-order your events: put them in the correct places and in the correct order. Then take a minute to discuss with your classmates and your teacher any events that really surprised you.

FRANCIS MACDONALD: Now we're going to do some calculations to construct a virtual time line. We're going to use the 24 hours of a day to represent the 4.567 billion years of Earth history. This will help you conceptualize how mind-boggingly long Earth history is.

So with your teacher's help, what you are going to do is you're going to calculate how many virtual seconds it has been since the dinosaurs went extinct. Remember, that's about 65 million years ago. What you'll also do is figure out how many virtual seconds that Homo sapiens came about. That is about 200,000 years ago.

PHOEBE COHEN: Hopefully the 24-hour-day geologic time exercise you just did in your class gave you a better sense of how long Earth history really is. And also gave you a sense that events that, in the context of a human life time we think of as being really old, in the context of the lifetime of the Earth are actually relatively young. So the dinosaurs that went extinct 65 million years ago on our 24-hour clock only went extinct 20 minutes ago. And our genus Homo sapiens, which evolved 200,000 years ago, has only been around for 3.7 seconds, which is a blink of an eye in the context of all of Earth history.

FRANCIS MACDONALD: We've left MIT's Infinite Corridor and are now in the Harvard University Natural History Museum. We've come to this amazing place to see how small changes over vast amounts of time can lead to huge differences.

PHOEBE COHEN: Before scientists knew how old the Earth was, they had a really difficult time trying to figure out certain processes that happen on the Earth. For example, it was really difficult to figure out how huge mountain ranges could form. It was also really confusing to figure out how life could go from simple single-celled forms to the huge array of diversity we see today. For example, just in the animals we have organisms as diverse as humans, antelopes, and beetles. The answer is, as you may have guessed, is all about time. The 4.567 billion years of Earth history help us to explain these important changes.

FRANCIS MACDONALD: So we're going to lead you through two examples and two simple calculations. One on how the Himalayas rose and second, on the rates of evolution in lizards from the Caribbean.

Phoebe Cohen 6/22/11 1:19 PM
Comment: Is this supposed to be and 'secondly' or 'the other'? Not sure what Francis actually said but reads funny

PHOEBE COHEN: Now we'll look at a biological example of the importance of time. We're going to look at a group of lizards, like this one here in this jar, called the Anolis lizards. These lizards live in the Caribbean Islands. We're going to be looking at some research that was done by Dr. Jonathan Losos, who's a professor here at Harvard University. He studies the evolution of these lizard groups in the Caribbean. He noted a group of lizards on one island in the Caribbean whose rear legs, their hind legs, were 2.21 millimeters long. Not a lot-- these are really tiny lizards. Then he and his researchers picked up some of those lizards and put them on other islands that didn't have any lizards on them. And they left them alone.

From 1977 to 1991, those lizards lived on their new islands on their own. Then in 1991, Dr. Losos and his researchers came back to the island and measured the hind leg length of both the original lizards from the original island and then these new lizards on their new islands. They discovered that on the new islands, the hind limbs of the lizards had changed. They had grown from an average of 2.21 millimeters to a range of 2.24 millimeters to 2.26 millimeters. Now that may seem like a really, really tiny difference-- a difference so small, it almost seems impossible that you could even measure it. But again we'll see, using the power of geologic time, that those smallest changes can still accumulate to make huge differences.

[CLASS EXERCISE]

The lizard leg lengths that you just calculated in your classroom might seem a little bit ridiculous. But then think about how big dinosaurs became. They evolved from lizard-like reptile ancestors that were much, much smaller. Over millions and millions of years of evolution, small changes just like the ones you calculated led some dinosaurs to become huge. Also think about the fact that small changes can lead to one species becoming two. You calculated two rates, a slow rate and a fast rate, in your classroom. The difference between the leg lengths of those two lizards would be huge. Do you think that those lizards would still be the same species? Probably not. Small changes accumulating over tens of millions of years lead to one species becoming two, two becoming four, and so on and so forth. That's the process by which all of the diversity of life that we see today has been created.

Here we are in the Harvard Museum of Natural History's mineralogical collection to talk about the Himalayan Mountains.

FRANCIS MACDONALD: The Himalayas are rising as we speak. As the Indian plate drifts northward and collides into Asia, the Himalayas rise at about 10 centimeters per year.

PHOEBE COHEN: I wonder how long they're going to keep rising for. I mean, how much higher are they going to be in 10,000 years or a million years? I guess to figure that out, we need to know how high they are now. Do you know?

FRANCIS MACDONALD: No, I'm not sure. I should go check.

PHOEBE COHEN: Francis, we can figure that out with a satellite. OK, while Francis goes and measures how high the Himalayan Mountains are, we'll take a break and you can do some simple calculations in your classroom with your teacher. First, I want you to estimate how much higher the Himalayan Mountains will be in 10,000 years and a million years. Then your teacher will give you a rate that's been calculated and you can see how the actual rates compare with your estimates.

FRANCIS MACDONALD: So I checked. The Himalayas are about 29,028 feet high. That's 8,848 meters tall. Whew! So if we add that on to what you just calculated, in about a million years, the Himalayas would be about twice as tall as they are now.

PHOEBE COHEN: Is that really going to happen?

FRANCIS MACDONALD: Well, no, actually. There's another force at work here, and that's erosion. At about the same rate that the mountains rise up, wind and snow break down the rock, erode it, and flush it out to the Indian Ocean.

PHOEBE COHEN: We hope that today's BLOSSOMS lesson has given you a greater appreciation for geologic time and enabled you to learn about some of the processes-- like evolution, mountain building, and erosion-- that make a lot more sense when you have an understanding and appreciation for deep time.

FRANCIS MACDONALD: So should we rappel down?

PHOEBE COHEN: Guess so.

FRANCIS MACDONALD: Woo!

PHOEBE COHEN: The Earth is 4.567 billion years old. That's a really long time and a really big number. And so it's hard for anyone and for students to conceptualize that number and really understand what it means. This BLOSSOMS lessons will help students conceptualize that number and understand the processes that occur over geologic time scales. Understanding geologic time is really important for understanding processes like plate tectonics, erosion, mountain building, and evolution.

The supplies that you need in this lesson consist mainly of a 5-meter-long rope or string that you'll use to create a time line in your own classroom. You'll also need event cards that are downloadable from the BLOSSOMS website. Students will probably need calculators to do the calculations as well. Students should have a basic background in biology. A background in geology is very helpful but definitely not necessary. And students should also be comfortable with doing simple arithmetic.

In the first activity, Francis will be standing in MIT's Infinite Corridor hallway in three different positions. The students need to decide which one of those positions is the correct position for where the dinosaurs went extinct 65 million years ago. Sixty-five million years ago seems like a long time, but on the time scale of 4.567 billion years, it's actually a really short period time; therefore, the correct position is the position where Francis is standing the closest to me and to the camera.

In the second activity, students will build their own time line in class. Students should measure out 4.6 meters with a yard stick along their piece of string or rope or tape in their classroom or hallway. Students should then mark off starting at the present backwards every 500 million years, which is every half meter. So every meter is equal to 1 billion years. So there will be a mark at 0, a mark at 500 million years ago, and so on and so forth until the end. There will be a mark at 4.5 billion years and then one mark right next to it at 4.6 billion years, which we'll use as the date for the origin of the Earth, a little bit off from the actual data 4.567 billion years.

Then students will get cards, which are downloadable from the BLOSSOMS website, that have events on them, major events that have occurred in Earth and life history through time like the origin of oceans, the evolution of animals, and the extinction of dinosaurs. You should break your classroom into groups and give each group a subset of those cards. Then students have to guess where along the time line all of their events sit. This is important. Instead of just giving them the answer, they need to try to figure it out on their own first.

Then we'll cut back to Francis and I in the MIT Infinite Corridor time line and we'll show you where and when those events actually occurred, the correct order and the time. Then, in your classroom, the students will rearrange their cards along their time line in the correct order. And, if you have time, you can briefly discuss if there any particular events that really stood out to you as being a lot older or a lot younger than the students or the teachers thought they were.

In the next event, we'll use the 24 hours in a day as an analog for the 4.567 billion years of Earth history and calculate how many seconds or minutes ago from noon on a day the dinosaurs went extinct and our species, Homo sapiens, evolved. So in order to do that, you're going to need to figure out how many millions of years are represented by one minute. On the teacher handout are the exact calculations on how to do that. And when you do those calculations, it turns out that the dinosaurs which went extinct 65 million years ago on our 24-hour clock went extinct about 20 minutes ago. And our species, which evolved about

200,000 years ago, evolved only 3.7 seconds ago on our 24-hour clock analog. So this is just another way to help students conceptualize geologic time.

The next activity involves estimating the height of the Himalayan Mountains. The students will have to guess how much higher the Himalayan Mountains will be in 10,000 years and a million years. Then you'll give them the rate of 10 millimeters per year, and then they will calculate how much higher the mountains actually will be using this rate. Again, it's important for them to guess first before they are given the answer. Then Francis will tell us exactly how high the Himalayan Mountains are and we can see the huge amount of height that is gained by uplift. But we'll also learn that erosion takes away a lot of that height, so the Himalayan Mountains really aren't going to end up being twice as big as they are today, even though that's what the calculation will look like when you do it with your class.

The last activity involves the rate of hind limb length change in a group of lizards called Anolis lizards that live in the Caribbean. These are lizards that are studied by Dr. Jonathan Losos, who's a professor at Harvard University. He studied a population of lizards over a period from 1977 to 1991 and saw that the hind limb length in those lizards changed from 2.21 millimeters to either 2.24 millimeters or 2.26 millimeters. Those are really, really, really tiny changes, but what your students will calculate in class is how those tiny changes over long time scales can lead to really big changes.

For the Anolis lizard activity, students will calculate how much longer the leg length will be in 1,000 years and a million years using both the slow rate and the fast rate of change. On the teacher handout, the calculations are all done out for you so that you can see the vast changes that happen. For the slow rate lizards, after 1,000 years, their legs would be about two millimeters longer. Not that big of a difference. After a million years, they would be 2,000 millimeters longer, or two meters longer, which is really, really big. That's as big as some of the largest dinosaur bones that we've ever seen.

For the fast rate of change lizards, those numbers are going to be even bigger. So it's a little bit of a silly comparison because those specific lizards aren't going to get legs that are two meters long, but the point is to show that small changes accumulating over long time scales can lead to huge changes. And we see that change that happened in the dinosaurs, which evolved from lizard-like reptile ancestors that were much, much smaller than the largest dinosaurs became.

Thank you for using this BLOSSOMS lesson. I hope that this lesson has helped you and your students gain a greater appreciation for how long the Earth has been around for, for some of the amazing events that have occurred during Earth history, and how understanding geologic time can help us understand important processes that occur on the Earth around us every day, like mountain building, erosion, and evolution.

[MUSIC PLAYING]