Blossoms_-_Meet_the_Family_

PROFESSOR PETERSON: Hi. My name is Jennifer Peterson. I want to welcome you to the Harvard Museum of Natural History.

The Museum was founded about 150 years ago on the campus of Harvard University. It is filled with amazing specimens from all over the world. Some are huge. Others are small. Some are ancient. And some are just surprising.

In order to understand animals better, we can organize them into groups. We can group them geographically like these African animals. Or by ecosystem, like the specimens shown here in our New England forest gallery. Today we're going to think about how we can group animals based on evolutionary relationships, that is, by how closely or distantly related they are to each other.

More specifically we will think about where we, homo sapiens, fit on the great tree of life. What animals are we closely related to? Who is our closest living relative? And how do we know?

Before we think about our human relatives, let's explore some of the ideas and concepts we will be using by looking at a different animal family. Felidae, the cats, a group that's found over most of the world. Let's take a look at some of the cats in our galleries. In our Indo-Asia gallery, we have a tiger, jaguar, snow leopard, cheetah, and this little fishing cat. In Africa we have the lion, serval, leopard, and African wildcat. In South America, we see an ocelot, a jaguar, and Geoffroy's cat.

In your small groups, think about what characteristics you can see in all of these animals that help you identify them as cats, rather than some other animal group. Make a list of four to five characteristics. I will see you in a minute.

Welcome back. You can see a lot of similarities in all of these cat species. They all have a similar body form. They are lithe and muscular. They have large canine teeth, paws with pads, and protractable claws. You probably thought about these similarities when you made your list of cat species. You can see these same physical characteristics in your house cat, as well as extinct cats like this ice age Smilodon, the saber-toothed cat.

The reason we see these similarities is they are connected through evolution. What does that mean? Remember that great tree of life? That tree includes everything alive today, from bacteria to plants to mushrooms, bears, and fish. Like a tree in nature it has a main trunk, and many connected branches. More scientifically, it is called a phylogenetic tree, a tool scientists use to map evolutionary relationships.

It shows that everything alive today is somehow related to everything else. And in fact, we can add an extinct species like the Smilodon, showing that all of these organisms are related to everything that has ever been alive on the Earth. Things that are placed more closely together on the tree-- like plants, animals, and fungi-- are more closely related to each other than things that are placed farther away, like bacteria.

It's a very big, complex tree. We can take a closer look and zoom in at this area, eukaryotes. Those are organisms that have cells with a nucleus and other structures that are contained within membranes. That's still a huge group, including all the plants, animals, and fungi. We can look within the eukaryotes here at animals, still an unwieldy bunch. Within animals, we find mammals, and finally, within this mammal group, we see our group--Felidae, the cats.

Now let's take a look at just a few cat species that we have here in the Museum, and think more specifically about how they're related to each other. Look at the pictures of the tiger, lion, leopard, and jaguar, and place these species on the phylogeny provided. Remember that the species most closely related to each other, will be closest on the tree here. You might want to fill these in first and then build out from there. You can refer to the images provided by your teacher. I'll see you in a few minutes.

Welcome back. You probably came up with at least a couple of different trees, depending on which physical characteristics you considered. You might also consider geography, where you would find these species, and environment, the types of habitats they live in. This tree shows how cats are related to each other based on recent scientific data.

Here are the species you considered. This shows the leopard and the lion as most closely related. The jaguar is equally distant from the lion and the leopard. Farther out we see the tiger. At the base here, this group shared what we call a common ancestor. That means some kind of cat was the ancestor of this entire group. For some reason, the groups split and evolved along these branches to become the cats we can see today.

If we trace farther, we see that this group also shares a common ancestor with all the other cats, but is farther back, closer to the base of the tree. We can see the house cat here, and the saber-toothed cat here-- related, but sharing a much earlier common ancestor with the rest of the group. You can see why we'd group all these cats together on this tree, but how do scientists know, for instance, that the lion and the leopard are more closely related to each other than the lion and the tiger? That surprised me.

The scientists who created this tree used a variety of data types. They did what you just did-- they compared the morphology-that is the physical form and structure of the cats -considered. They also looked at fossils, as evidence for relatedness among the different species. Finally, they compared DNA sequences.

Remember that DNA is how all the characteristics we talked about-- claws, body form, teeth, et cetera-- get passed from generation to generation over time. The more closely their DNA matches, the more closely they're related to each other. Because all of these cats share this common ancestor, they share a lot of the same DNA., and therefore, a similar body form. But we can see differences, too, like size and coat color. These differences show that evolution has taken place; things have changed along these branches over time.

Now let's get back to our Homo sapiens group. In your classroom, I want you to consider these questions and jot down your answers. To whom are we closely related? Jot down five or six probable close living relatives. These should be relatives that are not Homo sapiens, not your siblings, parents, or cousins. These should only be living relatives, not extinct ancestors such as Australopithecus or Homo erectus.

What criteria did you consider when making your list? When making the list, you can think about the shared characteristics we saw on the cats that helped us group them as a family-- body form, protractable claws, et cetera. When you are done, you can share your answers with the class. I'll see you in a few minutes.

Did everyone make the same list of probable human relatives? Did everyone use the same criteria when making their list? Probably not. Your list of relatives most likely included big apes, such as gorillas, chimpanzees and orangutans. You might also have included other primates, like gibbons, bonobos, lemurs, or monkeys. Most likely, you did not include spiders, birds, or snakes.

When choosing probable close relatives, you considered similarities in the way species look.the shared physical characteristics, or morphology, of primates, including forward-facing eyes, relatively short snouts, and grasping hands with mobile thumbs. You might also consider the similar social behaviors you see across a primate group. The reason that all these primates share all these features is that they are related through evolution. Just like the cats, they share a relatively recent common ancestor.

Let's look closely at some other primates in our Mammal Hall, and think more specifically about how they might be related to us, Homo sapiens, and to each other. The primates we will be considering are the chimpanzee, gorilla, gibbon, orangutan, the macaque-- here we have two species of macaque-- and the lemur. Here are two specimens of lemurs in our Africa Hall.

With your group members, look carefully at the pictures of these primates and use your observations to answer these questions. Which two species appear to be the most similar? And why? Which two species appear to be the least similar? And why? Which primate appears to be the most like the human? Why? Does the chimpanzee look more like the gorilla or more like the human? And finally, which species appears to be the most like the lemur?

You might find it useful to make an observation chart, or use a chart provided by your teacher. Keep in mind that you should base your answers only on your observations, not on any previous knowledge you might have. I hope you have a lively debate. I'll see you in a few minutes.

Welcome back. Although it's pretty easy to see similarities in all these primates, you probably noticed that it's hard to discern evolutionary relationships just based on physical characteristics. Let's consider some of the questions posed in the exercise.

Which species appeared to be the most and least similar to each other? Based on size, you might have chosen the human and the gorilla as being the most similar. Then again, the human is really different in locomotion. We're the only obligate bipeds, meaning that we walk on two feet. We are pretty hairless, also different from all the other species. So maybe the gorilla is more like the chimp or the orangutan. Only two species have tails-- the lemur and the macaque. Maybe they are most similar. Your answer really depends on which features you considered and which ones you think are the most important to us in discerning evolutionary relationships.

Did one primate appear the most like the human? There are some notable differences between the human and all of the other species. We already mentioned the fact that we are the only primate that walks on two feet, and the only one with very little body hair. We have extremely large brains, and we are the only primates without grasping feet. We're pretty weird animals. Maybe all the other primates are much more closely related to each other than we are to them.

Based on physical characteristics, the relationships among these primates are unclear. And until recently, scientists debated where to put these primates on an evolutionary tree. When we gained the ability to analyze DNA, things became clearer. That's what we're going to do now. We're going to take a peek at the genetics of these seven primate species. We won't compare the entire genome, which is huge, just the sequences that code for the production of hemoglobin-- an important molecule that's found in the blood of almost all vertebrates.

Hemoglobin is an iron-containing molecule in the blood of almost all vertebrates that transports oxygen in the blood from the respiratory organs-- in our case, from the lungs-- to the rest of the body. Each hemoglobin molecule comprises an iron-containing subunit, two alpha subunits, and two beta subunits. We will be looking at the sequence that codes for the beta subunit, or hemoglobin B, HBB.

We will compare it indirectly by looking at amino acid sequences, rather than DNA. Remember that DNA, through RNA, determines amino acid sequences. So by looking at the amino acids, we can infer the underlying DNA sequences, and therefore, the relationships among these primates. In the next exercise, you're going to compare the amino acid sequences of the primates we discussed.

Your teacher will either give you a paper with the full 146 amino acids for HBB, or just a chart that shows the places where there are differences. Using that, you're going to count the differences and construct a data table, or use the data table provided by your teacher. After you've done that, you're going to use your data to answer these questions. These are the same questions you considered in the previous exercise but this time you're going to be using the amino acid information rather than physical characteristics to answer the questions.

Which two species appear to be the most similar? How many differences are in the HBB amino acid sequence between these two species? Which two species appear to be the least similar? How many differences are there in the HBB amino acid sequence between these two species? Is the chimpanzee's HBB more similar to the gorilla's or to the humans? Which species' HBB is the most similar to the lemurs?

After you've answered these questions, compare them to your answers to the questions in the previous activity. That is the one where you considered primary relationships based on morphology. Were your conclusions the same or different? What surprised you the most about the table? I'll see you in a few minutes.

Welcome back. By counting the differences between the species, we can make a table something like this. Here we see that although we are the only bipedal naked ape in the group, our amino acid sequence matches the chimp's. The only two species with tails-- the lemur and the macaque-- have much dissimilarity in their HBB amino acid sequences.

How can we explain these seeming contradictions? By building a phylogeny, a family tree, the answer should be clearer. Using the amino acid table, create a phylogeny that shows the relatedness of these primate species. You can create one in your group, or use the tree provided by your teacher and fill in the blanks. You'll find it easiest to start with the two closest species, then add the next closest, and so on. Once you've created your tree in your small group, you can share it with the entire class. I will see you when you're done tree-building.

Welcome back. Based on the HBB amino acid sequence, your tree might have looked like this. Or this, with the chimpanzee and human flipped. This still shows the same map of relatedness, with the chimpanzee and human most closely related. Or it can be flipped around on its head.

The orangutan and the gibbon each have two amino acids that are different than the chimp's and the human's. How did you decide where to put these two species? A few things to consider. You might have looked again at the species morphology and used that to make your decision. Or you might have considered geography. Where do you find these species today?

The HBB sequence is just one little part of the entire genome. It doesn't tell the entire tale of evolutionary relatedness. If we look at more sequences from the primates' genomes, the orangutan shares more of the same DNA with the chimp and the human than the gibbon does. And in fact, the chimpanzee and the human share about 98 to 99% of the same DNA.

Now I want you to take a look at your primate tree, and use it to answer these questions. Remember that the more changes you see in this sequence, the longer ago these species diverged from each other, and the longer ago they shared a common ancestor. That's because there's been more time for changes to happen in the DNA. Which two species share the most recent common ancestor? Is the macaque more closely related to the lemur or to the gibbon? Why does the lemur have so many amino acid differences from all the other species? You can answer these in your groups. I will see you in a few minutes.

Welcome back. So far we've used our tree just to show relative degrees of relatedness. Now we're going to add in a timeline, so we can see where these common ancestors were and when these species diverged from each other.

But how do scientists figure that out? They use what's called a molecular clock. They know they can expect a relatively constant rate of changes-- that's mutations in the DNA over time. And using a mathematical calculation, they can pinpoint these divergence times. They also use fossil evidence to check their calculations. Here you can see that the chimp and the human share the most recent common ancestor, shown here at this node. When we add a time scale, we can see that the chimp and human diverged from a common ancestor about six million years ago.

The other species we considered shared common ancestors, as well, but they are farther in the past. We have to go back farther to about 10 million years ago, to find out where the gorilla, human, and chimpanzee shared a common ancestor,then here, to include the orangutan, and here, the gibbon. Were you surprised to see that the macaque was more closely related to the gibbon than the lemur?

Although the lemur and the macaques both have tails, the amino acid sequence shows us the lemur HBB amino acid differs from all the other species, 22 to 25 differences, considered. This is reflected in the timeline. The lemurs shared a common ancestor with the other species way back here, over 50 million years ago. There's been a lot of time for changes to take place in the DNA, whereas the macaque diverged more recently, about 30 million years ago.

In this exercise, we saw the difficulties of discerning evolutionary relationships based just on physical characteristics. There are so many things to consider, and it's hard to know what's important. When we added in the HBB amino acid sequences, we were able to take a more objective look and build our primate tree. So why consider morphology at all? Well, for one thing it allows us to kind of narrow down and decide which species we're considering. It also helps us understand what common ancestors of the modern animals might have looked like.

We saw that all the cats shared certain features that we might guess would also have been seen in the common ancestor. Likewise, we might intuit that our ancestors shared most of the shared characteristics-- grasping hands, forward-facing eyes, and relatively short snouts-- that we see today within our primate group.

In addition, we can use fossils to take a look back in time, and get a better idea of what organisms looked like in the past-- where they lived, and how they changed over time. Fossils also allow us to check our estimates of when species lived, and when they diverged from a common ancestor.

Let's go back to our original questions. Where do we fit on the tree of life? Who is our closest living relative? As we discovered, we are part of the primate group, more specifically, part of the subgroup, the great apes. We are more closely related to chimpanzees, gorillas, and orangutans than to monkeys or lemurs. And we're most closely related to chimpanzees. As primates, we fit within the larger mammal group, which in turn, fits here within the animals. As animals, we are part of this big eukaryote group.

Thank you for joining me for my primate lesson. If you're in Cambridge, Massachusetts, come visit the Harvard Museum of Natural History. You can see all the animals we saw today, and many other natural specimens from all over the world.

Thank you for your interest in my lesson-- Meet the Family: Exploring Relationships in the Primate Group. My overall goal for the program is for students to see the different types of evidence we can use to understand evolutionary relationships among organisms. They will first use shared physical characteristics to predict relationships and then use an amino acid sequence to build a phylogenetic tree. By the end of the program, your students should understand that everything alive today and in the past is related through evolution.

They will see that humans are part of a larger related group of animals-- the primates-- just as all organisms are part of other larger groups. They'll see that these groups are based on evolutionary relationships, and they'll see that multiple lines of evidence can be used to establish these relationships. I chose to set the video in the Museum Galleries because museums are great places for learning. I hope some of you will be inspired to visit a natural history museum near you. Nothing is better than seeing the things in real life.

Before starting the lesson, your students should understand the basics of genetic material, and understand that DNA is made of nucleotide bases. They should know that triplets code for amino acids, and that amino acids are the building blocks of proteins. Some familiarity with phylogenetics is useful, and also the concepts of common ancestors and molecular clocks., although it's not required. We do cover them in the lesson.

If you want some good background lessons in evolution or phylogenetics, you should take a look at the UCMP website, that's the University of California, Museum of Paleontology, that's listed in the resources. The supplies you'll need for the program are really simple. You'll need some paper and writing utensils. If you want your students to share their phylogenies with each other, you might want some really big pieces of paper, or you could have them write on a white board. You might also want to have graph paper for drawing phylogenies.

Everything else you can download from the website. There are images of animals that are open source, so you're free to use them as you wish. And there are a lot of skeletal images, which we use by permission from Bone Clones. So if you want to use them outside your classroom, you should get permission from them.

Now I'm just going to go briefly through the lesson outline. The lesson's designed to be interactive and activity-based. You're encouraged to invite discussion and debate among your students. Before the lesson you might ask your students, “How do scientists determine relatedness among species?” Their answers might include molecular data, fossils, comparisons of modern species, or development. Then you can ask, “Which of these approaches do you think is the most useful?” There's no right or wrong answer there. Each is useful, and all of them together provide the most data.

In segments one and two, your students will practice using some of the ideas and concepts they will use later in the lesson. After segment one, using their previous knowledge, video images in the lesson and printed images of the cats, they'll consider what morphological characteristics they see in all the cat species and share this with their group. You might also ask them, “Which characteristics do you see that are not shared by all group members? “to have them understand that both similarities and differences can be explained by evolution.

After segment two, your students will place four cats on a phylogeny provided and share their trees for the groups. You could facilitate a discussion asking why they placed the cats the way they did.

After segment three, the students will work in small groups to come up with a list of species they think are related to humans, and then share their answers with the groups. The teachers should facilitate discussion, asking how students chose their answers, that is what criteria they used.

After segment four, your students will compare the physical characteristics of primates, and answer the questions posed in their small groups about the similarities and differences they see. They should be encouraged to use observations of the specimens shown in the picture, rather than their prior knowledge to inform their answers.

After segment five, the activity has several versions. Students can use amino acid sequences or a table provided, showing just amino acid differences of hemoglobin B to create a data table. Or you could provide them with a data table to fill out.

After segment six, they will use their data tables to create a phylogeny or fill in the tree provided. This exercise is probably the most difficult part of the lesson. The data does not dictate one correct tree because some of the data is ambiguous. Students can draw their phylogenies on large pieces of paper, or on a white board so that the entire class can see them. This is a good place for discussion or debate, especially among more advanced students. Here if you wish, you can discuss what we call the degeneracy of the genetic code, that is the fact that more than one sequence can specify the same amino acid. Therefore, working backwards from amino acids, you can't know the precise DNA sequence.

After segment seven, students will look at a primate phylogeny, and consider the questions posed concerning relatedness among species. The last question asks about why the lemur has so many amino acid differences from all the other species. If you would like to extend this lesson, see the additional resources provided, and look for the UCMP lesson on Madagascar.

In segment eight, students look at the primate phylogeny, but this time with the timeline below to see when the seven primates diverged from each other.

Thanks again for joining me for my primate lesson. I also want to thank the Harvard Museum of Natural History for letting us film in the galleries, and my colleagues, Arielle and Amy, for giving me useful feedback on my lesson.