Revised Human Evolution Teaching Kit

* Has there ever been a time when you thought about what it would be like to scurry along tree branches with the squirrels?
* Have you ever wondered what it would be like to try and walk if you were a monkey?
* Do you sometimes think about having a super sensitive nose like a dog?
* Why do you think that the teeth in your mouth are smaller and less pointed than a dog’s?

It turns out scientists who study humans, called anthropologists, have been thinking about these questions for a long time. It might seem strange at first, but at different stages in our evolutionary history, our some of our ancestors experienced firsthand what it was like to run along tree branches, have a super sensitive nose, and to walk like a monkey. Our earliest ancestors, called Plesiadapids, were closely related to rodents and tree shrews and were almost indistinguishable from the squirrels that run and chatter in trees in the present-day United States.

These tree-dwelling dudes didn’t look much like primates on the outside, but a closer look at the fossils from Colorado and Wyoming give them away as lemur and monkey ancestors. Plesiadapids evolved during the Cretaceous period, extending from 144-66 million years ago, when dinosaurs still ruled the earth. These animals are closely related to an early primate, nicknamed Ida discovered in a cave in Germany in the early 2000s. Although Ida probably spent most of her time running along tree branches like a squirrel, she had opposable thumbs, and binocular vision like a monkey. Practice touching your thumb to the palm of your hand. Give yourself a high-five – you belong to primates, one of the only animal groups that can do that. Opposable thumbs give us the ability to pick up, manipulate, and fashion objects. Ida probably didn’t make tools, but she used her thumbs to grab onto tree branches like a modern monkey, and passed that ability all the way down to you and me.

As we’ve mentioned several times before, Ida’s skeleton looks a lot like a squirrel. How, you may wonder, can biologists be sure she’s our ancestor and not just a prehistoric squirrel? The answer, it turns out, is sort of complicated but has a lot to do with a careful analysis of the parts of animals that don’t change.

Before we get started, you’ll need a little bit of an introduction about skulls. The skulls come in two pieces. The top part, where the brain, eyes, and upper teeth go is called the cranium, and the bottom part, which is made of the lower jaw and teeth and is called the mandible. Practice putting the two parts together so that the teeth come together naturally. It might be best to try this first on the human skull because you can compare it to your own skull. The back of each mandible (the side opposite the front teeth) has a pair of thin projections that end in rounded surfaces. These rounded surfaces connect with a pit a little behind the upper teeth on the cranium and allow the animal to chew by rotating against the cranium.

# Phylogenetic Thinking Activity

Pick up and feel the skulls labeled A, B, and C. Compare these skulls, and try to decide which ones go together. Try to group the skulls by the relatedness of the animals they came from – it might be hard to figure out which traits correspond to how the animals are related to each other and which traits correspond to similar lifestyles in the animals. Try to group the skulls in such a way that it reflects the ancestry of the animals, what gave rise to what. Think of it as building a family tree of the animals. There might be a girl at school with a voice that sounds just like your sister, but in this activity you would group your sister with you instead of her sound-alike because siblings are closely related. Try and group the skulls before you go on to the next paragraph.

# Thinking about Phylogeny

What animals do you think the skulls were from? Take some guesses and think about why you guessed those animals before you go on.

Ok, now I’ll tell you what the skulls are from. Skull A is from a housecat, B from a rabbit, and C from a lizard-like animal from New Zealand called a tuatara. If you grouped A and C together (housecat and tuatara), you might have been tricked by some of the superficial similarities between the skulls. Both skulls have a long row of teeth and similar overall shapes. If you put B and C together, you might have considered the large teeth in the front of the skull, the side-facing eye openings, or the relatively small jaw bone.

Some of these traits reflect adaptations to each animal’s way of life, not shared ancestry. The rabbit’s teeth are different from those of the other animals because they are specialized to gnaw on heavy plant material with their front teeth and grind it up with their back teeth. The rabbit also has eyes and nostrils that point way out to the side to help it spot predators all around while it is eating or resting. In order to find out how animals are related evolutionarily, despite their current adaptations, we need to focus on traits that don’t reflect recent adaptive changes.

Now feel the part of the skull where the brain would go in each animal – behind the eye. In the cat and the rabbit there is only one hole – called a temporal fenestra (fenestra means window in Latin, and the window is in the temporal bone), but in the tuatara there are two. The case of having one temporal fenestra instead of two is not likely to be the subject of selection – in almost all cases the pattern of opening in the side of your skull is not important to survival. As a result, this trait will likely be conserved in evolution, telling scientists more about who’s related to whom than what their lifestyle is like. So now we have our answer – the rabbit and the bobcat are more closely related to each other than either us to the tuatara. Did you find this sort of confusing? Don’t worry – a lot of very smart scientists have been arguing about the relationships of living and extinct animals for hundreds of years.

To better understand how scientists group animals, let’s talk about cars. Imagine you encounter four vehicles in a parking lot – two trucks, and two compact cars. You know two of the cars were produced in the United States, and two in the United Kingdom. It might be tempting to suggest that both trucks were produced by the same company, because they do similar things. But you can find trucks and compact cars in both the United States and England, as people want to drive these cars all around the world. If you examined the steering wheel, however, you could immediately tell which car came from where: the English drive on the left side of the road and have steering wheels on the right hand side of the car. In contrast, Americans drive on the right and have steering wheels on the left side. Which side the steering wheel is on really doesn’t matter – both trucks and cars will get you where you want to go, but it does tell you about the car’s origin. Just like how the side of the steering wheel informs you as to the origin of the car, the number of temporal fenestrae and other important traits can tell you about the origin and grouping of animals. Biologists call these kinds of traits **homologies, traits that are present in both organism’s common ancestor,** and depend on them for classification. Can you think of another example of a common homology?

# Thinking About Different Types of Locomotion

Alright, back to early primates. Think about what it would be like to run along tree branches, up and down tree trunks, and hang from the ends of branches like Ida. What sort of chances in your body would make that easier? Would your hands be useful? What about your feet? If you examine the toy squirrel, you’ll notice that its arms and legs are almost the same length – are yours like that? Humans have longer legs than arms causing us to bend our knees awkwardly when we try climb up a tree like a monkey. Our hands are still pretty generalized – they’re not too specialized for any one particular function, but our feet are super flat and inflexible. Why do you think we’re adapted to have such inflexible soles and longer legs?

Modern primates get around in many different ways – let’s try them out!

Many primates get around by terrestrial quadrapedalism, meaning that they walk around on the ground using their hands and feet together. Monkeys use plantigrade locomotion, walking on the flat palms and fingers of their hands, much like a bear. Let’s try it out – try and move around the room while keeping your feet and palms flat on the floor – you may want to remove your shoes first. Pay attention to how efficient this is, and where different parts of your body are oriented as you proceed. (walk). How did that feel? Did you notice that your back was at a funny angle and your arms were constantly trying to catch up to your legs? Why do you think monkeys can get around easily this way and you can’t?

Monkeys that live in trees also walk on all fours, but use their feet and hands to grip branches instead of holding them flat on the ground. If you tried to climb a tree, you’d find your hands to be much more useful than your feet because humans have evolved a highly inflexible foot. It’s terrific for high-efficiency two-legged walking, but it can’t bend to grab tree branches or flex inwards at the ankle to make climbing up a trunk any easier. In addition, the monkeys of South America have a special adaptation that helps them get around the trees even more easily. Can you think of what it is? It turns out these monkeys can use their tail as a fifth limb, wrapping it around branches and even hanging from it, allowing them to get around faster and reach fruits that are sort of out of the way.

Gorillas and chimpanzees get around slightly differently. They also walk on all fours, but their knuckles contact the surface instead of their palms. Try walking on all fours again, but this time bend your hand into a half-first first, so that the backs of your fingers touch the ground, but not the back of your hand. Does this work any better? Why do you think chimpanzees and gorillas knuckle walk like this?

To look for answers, let’s pretend to be primatologists and directly compare the bones in the feet of humans and chimpanzees. Pick up the two feet and try to compare them as best you can. What are the major differences you notice? What can you tell about the length, angle, curvature, and position of the toes? What about the position of bones in the ankle?

The next kind of locomotion, called brachiation, a form of arboreal locomotion in which animals swing from tree to tree using their arms, is totally different from the other two, and is essentially the same as what humans do on the monkey bars on the playground. By swinging from branch to branch with their grip-ready primate hands, these primates can achieve terrific speed high above the ground, up to 34 miles per hour! Don’t try to go this fast on the jungle gym, though – monkeys need specialized shoulder joints and extremely long arms to achieve these speeds.

## Why do you think humans evolved bipedal locomotion instead of using one of the other ways primates get around?

# Thinking about different types of sensory information

After Ida and the Plesiadapids, the next large group of animals closely related to you and me are the lemurs. These animals, also known as strepsirrhines (so named because they have wet noses, like a dog), currently live almost exclusively on the island of Madagascar, off the coast of southeast Africa. All other monkeys and apes alive today belong to the haplorhines (having dry noses).

# Sensory Skull Analysis Activity

In the box you will find a model of a ring-tailed lemur, a lemur from Madagascar, and a model of a Vervet monkey, a haplorhines monkey from mainland Africa. Familiarize yourself with the shapes of these animals, and then pick up the skulls and see what differences and similarities you notice.

First off, feeling around the eye socket of both animals, you’ll notice that the skull walls off the eye socket completely in the monkey, but only forms a thin bar behind the orbit in the lemur. Why do you think this is?

Scientists think that the bony bar or wall, called post-orbital closure because it closes off the eye region behind the eye itself, serve to protect the eye and stabilize it during chewing, and rapid head movement. In mammals without post orbital closure, the eye moves up and down within the skull during chewing and leaping. In addition, as the eyes starting moving forward in the head to support binocular vision, the back of the eyes became more exposed because they were not pointed towards the inside of the skull anymore. Thus, to protect increasingly forward-facing eyes, the evolution of post orbital closure became necessary. What does it mean that monkeys have a higher degree of post orbital closure than lemurs?

The next obvious difference has to do with the shape of the face. Lemurs have a long muzzle, extending straight out of the skull like a dog whereas monkey faces are shorter, with the mouth angled down and compressed into the face. Compared to a dog, the lemur again seems like a handy intermediate between the monkey and other mammals. This is important because the long muzzle of the dog and lemur provide a great deal of room for nasal turbinates, important in the mammalian sense of smell. At the same time, however, the muzzle blocks the field of vision from the eyes, and prevents the use of binocular vision in a large percentage of the field of view. A shift to a shorter face and a higher degree of post orbital closure, then, represents a shift of importance of the senses – monkeys rely much more on their vision and much less on their smell than lemurs. This also ties in with the shape of the nose – lemurs still have wet noses, which work much better than dry noses for smelling.

Compare the general shape of your own skull to the two primate skulls. What trend do you notice?

# Thinking about teeth

Remember that I told you that the ring-tailed lemur is closely related to you – it may even be quite similar to your direct ancestor. Does the lemur skull seem like a human skull? There are obviously a lot of differences, but let’s focus on the teeth for now. Because teeth are the primary way in which animals interact with their food, the shape and type of teeth can tell biologists a lot about what an animal is like. Now we’ll examine the dentition of the lemur, a Chacma baboon, and humans to try and determine which animals are most closely related.

If you feel the lemurs jaw, you’ll notice that they have one big fang-like tooth on each side of the upper and lower mouth. Feel your own mouth and try to find the same tooth – you have one, but it’s smaller and less pointed. These teeth, called canines, are used in many mammals to grab onto prey, like a wolf dragging a deer down by the mouth. In primates, these teeth are instead primarily used for display, and are sexually dimorphic, meaning that the size differs between the sexes. Pick up the baboon skull and feel the canine teeth. What do you notice about them? You should have realized – they’re huge! The canine teeth in these baboons are used in antagonistic displays between males – the females instead have very little canine development and the skulls in general are less robust. In the baboon skull notice also the huge furrows above the jaw that follow the canine teeth up towards the eye. These teeth are so huge that the animal needs robust bracing in the skull to support lever forces acting on the canines. Feel between your nose and your canine teeth and you’ll also notice these furrows, but they’re a lot smaller just as your canine teeth are smaller.

In the front of the mouth, you’ll find flat incisors in every species. In primates, these teeth are used to grasp food and pull it into the mouth, as in when you use your front teeth to bite into an apple. Examine the incisors on the bottom jaw of the lemur. Do you notice something special? The teeth are pointed directly out in front of the animal and make a flat shelf – like a comb. What do you think this is used for?

It turns out that lemurs use this “tooth comb” in self-grooming, like a housecat uses its tongue. Because lemurs eat mostly soft fruit, they don’t need robust incisors to rip flesh off of carcasses or plants, and can afford to have these specialized front teeth. Now feel your incisors, and the incisors of the baboon. What differences and similarities do you notice? In general form, the incisors of both animals are similar, with the baboon’s teeth being much more robust than your own. Why do you think this is? What is it about the diet of a baboon versus a human that requires much bigger and stronger teeth in the monkey? The answer is probably cooking and tool use. Humans likely started using fire for cooking around 125,000 years ago, enabling them to not only extract more energy out of their food, but also to soften the food before chewing. In addition, people also use sharp tools to cut up foods before eating them. Humans therefore need to invest fewer resources in strong teeth to grind up rugged meat and plant foods.

The teeth in the back of your mouth, molars, are also found in all of these animals. Feel the back teeth and try to decide how they are the same and different. What did you notice? Did you decide that again, that the human teeth are the most reduced in both size and complexity? Most anthropologists would agree, also noting that the lemur had quite pointed molars. Molars are flat teeth with multiple cusps used for grinding food – you use the teeth in the back of your mouth to chew vegetables and bread before swallowing. It makes sense that lemurs have pointed molars – their diet of fruit doesn’t include much grinding, and the pointed molars help them to slice fruit into edible pieces. Humans are born with three molars in each part of the mouth, but the outer ones are often removed as “wisdom teeth,” and don’t erupt out of the gum until almost full adulthood. Can you think of a reason for such late development in human molar teeth?

Finally, there are some intermediate teeth in between the canines and the molars. Because they come before the molars, scientists call them premolars and they serve to process food for chewing by the molars. Do you notice anything strange about the lemur’s premolars? First off, you should be able to tell that they are again unusually pointed and adapted to a diet of fruit. Second, the lemur has three of these teeth on each side of its mouth! If you look carefully you’ll note that the baboon only has two, just like yourself.

Next, let’s count the number of teeth on the top in your own mouth, the baboon, and the lemur. If you’re careful you’ll notice 18 teeth in the lemur, 16 in the baboon, and somewhere up to 16 in your own mouth. The difference is because of the premolars – the lemur has 3 in each section of its mouth whereas humans and baboons only two. Summing up all the information we’ve collected about the teeth, can you make a hypothesis about which two of the three primates are the most closely related?

It turns out that baboons and humans are both Anthropoids, more closely related to each other than either are to the lemur, as you can easily tell from the teeth. The lemur is the only species with certain primitive traits including the incisor tooth comb, the presence of a third premolar, highly pointed molars and premolars. Lemurs and baboons both still have large canines, however, as this trait is lost between the evolution of baboons and humans.

# Brain Size and Cognition

Let’s take a look at one more of the features on these skulls. One of the first differences scientists noticed between different species of primates was brain size. Compare the lemur skull with the bobcat skull and the lizard skull. The big rounded protuberances in the back of the lemur and bobcat skulls are the braincases – the bony sphere that encases and protects the brain. Try and find this in the lizard (hint: you may have to feel through the temporal fenestrae).

Did you find it? You might have realized from your search that mammals have much larger brains relative to the whole skull size than reptiles. Now, compare the bobcat with all of the primate skulls (lemur, monkey, baboon, and human). What do you notice?

Maybe you were able to tell that primates, especially monkeys and apes, have relatively larger brains than other mammals. This is taken to the fullest extreme in humans, which have spherical braincases that totally dominate the skull. Brain size is related to intelligence – animals with more brain per total body weight are generally smarter. Why do you think humans, and primates in general have relatively bigger brains than other animals? Can you think of any other unique features of primates that would go along with bigger brains?

# The Path to Modern Humans

Find the skull labeled *Homo erectus*. This is the skull of an animal that lived in Eurasia and Africa from roughly 1.9 million to 150,000 years ago, an early hominid that resembles some of our early ancestors. With what you’ve learned so far, try and determine as much as you can about this animal from its skull. Remember to think about what it may have eaten, and how it would have learned about the environment.

Think about your observations. In which ways is this skull similar to a modern human? In which ways is it similar to other primates, such as the lemur, monkey, or baboon? Scientists can use these observations to determine which features of modern humans evolved first. For example, because the *Homo erectus* skull has a reduced snout, but still a relatively flat braincase, we know that the switch to vision-dominated sensation occurred before the development of modern cognition. In other words, early hominids could probably see and smell like modern humans before they could think like them. Spend a few minutes and try and determine all you can about human evolution from the skulls.

When you’re through thinking about this, pick up the 11x17 textured phylogeny. Take a few minutes to get a sense for what the diagram is like – note the animal names and the shape of the tree. This is a diagram representing how the animals in this kit are related and evolved. Each circle on the tree, called a node, represents a branching point between two groups of animals. For example, the circle between the bobcat and the rabbit represents some animal that was a common ancestor of a rabbit and a bobcat. If this was a family tree of yourself and your sister, the node connecting then would be your parents. With this information, use the phylogeny to learn which animals are most closely related. What species is most related to modern humans, *Homo sapiens*?

After you’ve become comfortable with the phylogeny, use it to review what you’ve learned about skulls and evolution. Try and think of a major step in skull evolution at each step. For example, at the node where the rabbit and bobcat are connected, skulls developed only one postorbital fenestra. Note that all of the skulls above this node on the tree also have this character – it got passed down along the way. Try and do this for each node. How does the phylogeny help you to understand how skulls have changed from lizards all the way to humans?

# Summary

In the following activities we’ve learned a lot about the classification of animals and the similarities and differences amongst primates and humans. First, we learned how tricky it is to find the right characters to use when trying to figure out how animals are related – it’s easy to understand how most times a new fossil animal is discovered there is a long period of arguing before scientists decide where it belongs in the family tree.

Next, we learned about the different kinds of locomotion used by different primates. Can you remember what they are? Why do you think humans are the only primates that walk upright? Then we acted like detectives, using the skulls of primates to deduce things about their lifestyles. Can you remember what the relative length of the snout means about what kind of senses the animal uses? What about the different kinds of teeth? Finally, what can you say about the evolutionary pressures that caused humans to be so different in shape from our common ancestors?