

BLOSSOMS - Using DNA to Identify People

[MUSIC] Hi. My name's Megan Rokop and I work here on MIT campus at the Broad Institute of MIT and Harvard, which is the biomedical research institute. Today, we're going to do a lesson talking about using DNA to identify people.

As you can see on this slide, I'm showing you a picture of DNA. This is what DNA looks like. It's a molecule made up of atoms. There's a lot of carbons and hydrogens and nitrogens and oxygens. It forms a three-dimensional structure shown here as a double helix. Now the backbone of the structure, which is the two spirals you can see, are always the same along the DNA molecule. But the rungs in the middle can be different and there's actually four different kinds of rungs. We abbreviate them A, T, G, and C.

While this is what DNA actually looks like, a three-dimensional molecule, on this slide you can see how we represent DNA. We represent DNA by writing out the sequence as a series of A's, T's G's, and C's. This slide shows about 2,000 letters and your first instinct may be that this looks like a lot of DNA, but actually each cell in the human body contains 3 billion of DNA letters that you get from your mom, and 3 billion DNA letters that you get from your dad. This is only 2,000 letters. Imagine the amount of DNA in one of yourselves.

I want to ask you a question about this slide now. Let's say that these 2,000 letters of DNA were the sequence of DNA at one particular region of a chromosome in me, and these are the series of letters in the sequence and the order that you would find them at some position in my DNA. If we looked at the same position in the DNA in anyone else on Earth, how many of these 2,000 letters do you think would be different between me and anyone else on Earth? I'm going to give you a minute to discuss that and will answer the question when you get back.

Welcome back. Let's say this screen is 2,000 letters of DNA in some position in my DNA. The question was, how many of these letters of DNA would be different between me and anyone else on Earth? The answer is, maybe one or two.

Let me show you an example on this slide. We've got our 2,000 letters and maybe in me, this whole thing is the order of the letters that you would find in the order and the sequence. Maybe in someone else in the world this T right here might be a C. Maybe down here this A might be a G. All the other letters would be the same sequence in the same order. And that's because all humans on Earth are at least 99.9% genetically identical to every other person on Earth. So we're really similar.

Everyone on Earth has a different DNA sequence from everyone else on Earth, except for one exception. I can say that I have different DNA than anyone on Earth, but the one exception would be if I had an identical twin. Two identical twins have the identical sequence of all 3 billion letters that they get from their mom, and all 3 billion letters that they get from their dad. Everyone other than identical twins have different sequences from each other. And so, we can use DNA sequence to tell people apart.

This is a technique called DNA fingerprinting or genotyping. On my next slide I'm going to show you those two words. This is what our lesson is going to be dealing with today. It's one technique. It just has two different names. It's a technique to use DNA to identify people. The reason it's called DNA fingerprinting is that, that's an analogy to actual fingerprinting, where every person has a different pattern of bands on their fingertips. Every person also has a different DNA sequence. We can basically fingerprint people by using their DNA.

The other term is genotyping, and this is because this technique allows us to see what type of genes people have. I told you that different people have different DNA sequences. And let me show you what I mean by that on my next slide. Before I show you two different people differing from each other, first I just want to

show you the DNA sequence from one person. I'm showing it to you in this format so that you can see how exactly we write out a representation of a three-dimensional structure.

Here's the sequence of DNA from a person. The double helix that you see is a three-dimensional structure of DNA. But I can write out one strand and then write out the other strand next to each other using a series of letters. And that's what I've done on the right-hand side of the slide. These letters are A's, T's, G's, and C's, and anytime you see an A on one strand, you see a T on the other strand. Anytime you see a G on one strand, you see a C on the other strand. A's bond with T's, and G's bond with C's. This is how we write a DNA sequence.

Normally, actually, we don't write it vertically, so I'm going to turn it for you on my next slide so that it's horizontal. Here's an example of a DNA sequence from a person. I'm going to call him human number one. When I say that people have differences in DNA sequence, what I mean is, shown on this slide, where now I'm showing human number two. There's a position where human number one has a G on the top strand and human number two at that same position, has an A on the top strand. All the other letters are the same. You actually have to look through over a thousand letters of DNA to find this difference but when you do find them, this is what they look like.

We use DNA fingerprinting to look at differences in DNA like this to tell people apart. What I'd like to ask you to do now is to brainstorm uses of this technique. So in what situations do you think it would be useful to use the DNA of people to identify them? I'll give you a moment to brainstorm and I'll see you when you're done.

Welcome back. The question was, what uses would you have for a technique where you could use the DNA of people to identify them? Remember, DNA fingerprinting, or genotyping, allows us to identify people, based on their DNA. What would we actually use this technique for? Hopefully, you've had a chance to brainstorm and on my next slide I'll show you some of the possibilities that I came up with.

One situation is paternity testing, or trying to determine the parents of a child. Another situation is forensics. Let's say there's a crime scene and a hair or a piece of skin is found at the scene of the crime. You could isolate DNA from that sample and figure out who the person was that left the sample there.

My last example is one that actually we do here at the Broad Institute all the time. What we do is look at the patterns of DNA between people and compare them routinely. The reason that we do this is to try to figure out which portions of the DNA are associated with specific diseases.

We take thousands of people who have a disease, let's say heart disease, and thousands of people who don't. We look at the differences in their DNA sequences. We look for the differences that always look one way in the people with a disease and always look a different way in people who don't have disease. That's how we find regions of the genome that are associated with different diseases.

Today in our lesson, we're going to focus on the first two uses, paternity testing and forensics.

When you're looking at genes that are associated with diseases, you often use the kinds of sequence differences that I showed you before. On this slide I'm reminding you that humans can differ by sequence, for instance, human number one having a G and human number two having an A. Although these are the differences we use for mapping genetic diseases, these are not usually the differences that we use when we're doing paternity testing or forensics. Let me show you what those look like.

On my next slide I'm showing you a different way that people can differ in their DNA. Before I was showing you a difference in sequence, where a letter was different. Here the sequence of these two people is the same. Both people have a repeat in their DNA that says G, T, G, T, G, T, over and over again. The difference is that human number one has three repeats. Their DNA says G, T, three times in a row, where human number two has five repeats, G, T, five times in a row. These two people don't differ in sequence, they differ in length.

On my next slide, I'll show you that if you count up the letters of DNA in the top strand of each person's DNA, human number one's DNA would be 18 letters long and human number two's DNA would be 22 letters long. So, if we have a technique that separates DNA by size, we can actually tell these people apart.

We do have a technique that does this and I'll show you that on my next slide. This technique is called gel electrophoresis. There's three things that I'd like you to remember about gel electrophoresis.

The first is the main point, which is that it's a technique that separates DNA by size. The second is how it works. You actually put the DNA of people into a slab of gel that feels a lot like Jell-O or gelatin. This gel is a matrix. What I mean by that is, I could turn this room into a matrix. If I took a whole bunch of pieces of string and I taped one into that wall, and then I stretched each piece of string across in a different pattern and taped the other end to that wall. So imagine the room that you're sitting in now, full of string. That would be a matrix.

Let's say I want to race a very large molecule and a very small molecule. They would move through the matrix with different speeds. This is what we do with DNA and the reason we can get DNA to race through the matrix is that DNA is negatively charged.

What would you do to the other end of the room, if I were a piece of DNA, to make me want to go to the other end of the room? I'm going to give you a moment to think about two things. First of all, what would you do to the other end of the room to make me want to move there? And secondly, if there were two pieces of DNA here, one very large and one very small, how might they behave differently as they raced towards the other end of the room? I'll give you a few minutes to brainstorm and I'll see you when you're done.

Welcome back. If DNA moved through the matrix, first of all, why would it want to move in the first place? If I'm DNA and I'm negatively charged, and if you make the other side of the room positive then I'll be attracted to the other side of the room and I'll want to move there.

Now, what if there were two molecules of DNA and they both had to move through the matrix? One was very large and one was very small. The small one can move quickly through the matrix because it's small enough to fit in between the holes, in between the pieces of string. Whereas the large molecule would try to move but it would be very large and it would get tangled up, and thus move slower. That's how gel electrophoresis works.

I'd like to show you how this technique works in my lab but first I just want to introduce you to the principles. Then we'll go into lab and take a look at the technique.

Let's say that you had DNA samples from people and you wanted to separate them by size using a gel. What would you do? On my next slide, I'm going to show you the first step that you would do.

What you would do is take all the DNA in the sample which, remember, every human cell has 3 billion letters from its mom and 3 billion letters from its dad. We're only usually analyzing a very small amount of that DNA. What we do is use a technique called PCR, where we pick a left and right boundary of the DNA and we copy only the segment in between those boundaries. On my next slide I'll show you what that looks like.

You pick the left and right boundaries and then you make many, many copies of just that region of DNA. Here I'm showing only a few copies but in the lab we make millions and billions of copies. Now we have a bunch of copies of just the region we want to look at.

Basically, here's how the technique works. You isolate the DNA from the person. You make many copies of just the region that you want to study and then you're going to run the DNA through the gel. I'd like to

show you what this actually looks like in lab. Why don't you come with me and we'll go do this technique together in my lab.

Hi. Welcome to my lab here at the Broad Institute. I'm going to be showing you how this process works here in lab. And here you can see the equipment that I'll be using to show you how to use gel electrophoresis to identify people based on their DNA.

Typically, we store our DNA samples like this in these tubes and I got these tubes out of the freezer. Typically we store DNA at minus 20 degrees Celsius, which is the temperature of a standard freezer. The first thing that I'm going to do is take a little sample of those samples of DNA and I'm going to put them into these smaller tubes, which we'll use to copy the segment of the DNA that we're interested in.

I'll be using my Pipetman to transfer, for each sample, a small amount of the liquid into the small tube.

The next thing I'm going to do is add the reagents or chemicals that I'll be needing for each copying reaction to each one of the tubes. This includes all of the necessary chemicals that take you from having a small amount of DNA, to copying it into a large amount of DNA.

Each time I pipette a different sample, I use a different pipette tip so that none of the samples are contaminated with each other. Now I have all my samples in the tubes, at this step I'll be adding the mixture of all the chemicals necessary to do the reaction. I have that here on ice in this tube. The reason I have everything on ice is because this reaction is sensitive to temperature and so I want to keep all the reactions on ice until I'm ready to start the reaction.

Again, I'm changing pipette tips each time so that none of my samples contaminate one another. Now that I have all of my DNA samples mixed with the necessary chemicals, I'll be putting these smaller tubes into what we call a PCR machine. Remember, PCR is the name of the technique to copy a segment of the DNA to make many copies of it.

This is my PCR machine right here. In these small tubes, I'll just give them a little mix there and they fit right into these holes inside the machine. When I've put all four of my tubes into the machine, I just close the lid, lock it down, and then I hit start and the program's going to start running.

What the program is actually going to do is that this machine, although it's called a PCR machine, it really is a heating block. This machine is a heat block that changes temperature really rapidly. It's going to change temperatures and each step of the copying reaction happens at a different ideal temperature. So as it changes the temperatures, the steps of the copying reaction can occur in the order in which you want them to.

Now remember what this machine is doing. This machine is doing the copying reaction that I'm showing on this slide, where we make many, many copies of just one piece of the DNA. I want to give you a moment to think about why is it this copying reaction is necessary? Why could we not just take all the DNA from a person and directly analyze it on a gel? I'm going to give you a moment to think about why the copying step is necessary. You can talk amongst your classmates and then I'll tell you the answer when we get back.

Welcome back. The reason we need to copy the DNA is two-fold. The first reason is just an amount issue. The amount of DNA we can typically isolate from a person simply isn't enough to see it directly on a gel. Instead, we need to copy it so that we have more DNA, such that we are able to see it on the gel.

The second reason is that we only want to look at one segment of the DNA. You don't want to look at all the DNA from the person. Therefore, the copying reaction allows us to just select one piece of the DNA from that person, make many copies of it, and then visualize just that segment on the gel.

This process actually take a few hours and so I set up PCR reactions before we started filming and I have them in this ice bucket here. The next thing I'm going to do when the PCR reactions are done and I have my

segment copied, I'm going to transfer again a small amount of that into these tubes right here. In these tubes I'm going to mix the DNA with an orange dye. This dye is going to allow me to see the DNA and then I'll be loading it onto this gel here.

The first thing I'll do is transfer a small amount of orange dye into each of the tubes that I'll be placing the DNA samples into. You can see this orange dye in my pipette tip. It's just a colored substance that we can see with our eyes. DNA is transparent so we can't see it with our eyes.

Now I'm going to be transferring a small amount of each sample into those tubes. Here's my PCR reaction. I place it in a tube to mix with the orange so that now we can see it. Now that we have all of our DNA samples to load onto the gel, I'm going to load them onto the gel.

The way that works is that this is your slab of gel right here. If you can see from the side, the gel is actually coated in two pieces of plastic but the opaque substance in the middle is the gel matrix. This gel right now has a plastic comb in it that's protecting 12 holes in the gel. We can load each DNA sample into one of these holes.

I'm going to put the gel down on to the lab bench and for each one of my DNA samples, I'm going to load them into one hole in the gel. I'm loading my DNA samples of the different people individually into each hole in the gel. And the orange dye helps me to see that I've actually successfully gotten the DNA into the hole. Once I've loaded all the DNA samples, I'm actually going to load one other special sample. First I'm going to add a little orange dye to it.

The special sample is not the DNA of a person but rather it's a mixture of samples of DNA that we buy from a company. The different pieces of DNA in this mixture are pieces of DNA of sizes we know. So we use it like a ruler or a standard to be able to tell the lengths of the pieces of DNA that we don't know in the samples from the people. This will be our ruler or standard and we call it ladder.

Now what I'm going to do is hit this button and that starts the current running through the gel. Now the DNA samples are going to move from the holes where we loaded them all the way down to the end of the gel right here. So you'll see the orange dye progressing. The orange dye, remember, is not actually the DNA. The DNA is transparent and you can't see it at this step but the orange dye allows us to see that the samples are travelling. Once the orange dye reaches the end of the gel, we'll expose this gel to certain wavelength of light and that will allow us to see the DNA.

This takes about half an hour. I actually started another gel for you before we started filming this segment. You can see that the orange dye is almost at the end of the gel here. So this gel is almost done running. When it's done running it'll beep to tell me it's done, and then we're going to take it into the dark room so that you can see the results.

So here we are at the dark room. This is where we're going to visualize the gel. I've got my gel here and we're going to go in and shine a certain wavelength of light on it so we can see the DNA.

Here we are in the dark room and I've got my gel. I put my gel into this light box right here and then I simply turn on the light and all of the bands of DNA appear.

Here you can see the results of the gel. Lane five is not a sample from a person. Remember, that's ladder that we bought from a company. You see a series of bands of DNA. Each one is a different size and we know the sizes of those DNA so that's our standard. Lanes six, seven, eight, and nine contain the DNA from four different samples.

For instance, in lane nine you can see that there's a single band. Whereas in lane seven, there are multiple bands. What I'd like you to do now is take a moment to discuss why you think it is that some people show one band, whereas other people show multiple bands. I'd like you to write down for each person how many bands you see, whether those bands are longer or shorter, and then also explain why some people show

multiple bands and some people show one band. We'll discuss the answers to these questions when we come back.

So when we were in lab, you saw a picture of a gel that looks a lot like this slide here. As you can see in this slide, some people show one band of DNA. Other people show two bands of DNA.

Why is that? The reason is that people who only show one band of DNA actually have double that amount of DNA, as you can see in the difference in the intensity of the band. Remember, everyone gets their DNA from their parents. Everyone gets half their DNA from their mom, and half their DNA from their dad. If a person shows only one band in this gel that means that the DNA they got from their mom was the same length as the DNA they got from their dad. There's two times as much DNA in that band, which is why it's darker.

The person who shows two bands, however, must have gotten the different lengths of DNA at that section from their parents. So you see two different lengths of DNA in their lengths.

So that's how you interpret a gel like this. In this gel, for instance, as you can see from the ladder markings on the left-- remember the ladder is like a ruler for us-- person number three has about 22 letters long, whereas person number one and person number two have DNA that's both 22 letters long and 18 letters long.

I just want to show you a quick pictorial view on this next slide to remind you that when you're looking at these gels, you're looking at the DNA that comes from the parents. Here's a picture of the DNA actually sitting in a human cell. The round part is the nucleus and as you can see there are chromosomes in the nucleus. In my picture here I'm only showing three chromosomes, a very long one, a medium one, and a short one. In actual human cells there are 23 different chromosome. You would get 23 chromosomes from your mom and 23 chromosomes from your dad.

Here on this slide I've labeled a section of DNA in the same position of the long chromosome from the father, and the long chromosome from the mother. As you can see, one section has three repeats of C, C, T, while the other section only has one region of C, C, T. Thus this region from the two parents of this person contains different sizes, so this person would show two bands at this position.

Let's go back and look at the gel I was just showing you. I've now labeled the lanes a little bit differently. I've labeled one person as me, another person as the person I refer to as Mom, and another person as the person I refer to as Dad.

I have two questions for you. Using the data in this gel, can these people be my parents? And my second question is, are these people my parents? I want you to discuss as a group whether you think these people can be my parents based on this gel, and whether this gel shows you that these people are my parents. We'll discuss the answers when you come back.

Welcome back. Let's answer the questions that we were just discussing. Does this gel show these people are my parents? Can these people be my parents? Well the answer to, can these people be my parents, is yes. The reason that's true is that as you can see, the person I refer to as Dad only has one length of DNA, the 22 letter long version. If this were my dad, he would have to give me the 22 letter long version and I have that version.

I also have a version that's 18 letters long and so does my mother. I could have gotten the 18 letter long version from my mother. Therefore this gel is consistent with these people being my parents, i.e., these two people each giving me half of their DNA.

Are these people my parents? This gel does not prove that these people are my parents although the gel is consistent with them being my parents. The reason the gel doesn't prove they're my parents is that, if every person only has one of three possible patterns that they can show on this gel, either only 22 letters long,

only 18 letters long, or both 18 and 22 letters long, then given that there's 7 billion people on Earth, you could pick any two people at random and they might be consistent with me in this gel.

However, this is actually how we do paternity testing in forensics. How do we use this technique for paternity testing and forensics if this gel doesn't prove that these people are my parents? The answer is that you have to remember that we are just looking here at a very small number of letters from a total number of letters of DNA that's 3 billion letters from my mom, and 3 billion letters from my dad.

If we ran another gel and we looked at another segment and these people were consistent with me, you would be more convinced that they were my parents. If we ran an infinite number of gels looking at many, many different parts of the DNA and they always matched me, you would be very convinced these people were my parents.

You can actually ask a statistician, how many regions of the genome do you have to look at and have these people match me, so that you can say that they most likely are my parents, given there are 7 billion people on Earth? And statisticians can answer that question and tell us that we have to look at about 20 different sites on the DNA. That's how this technique works.

Now I'd like to do an example with you. First we're going to do an example with paternity testing and then we're going to do an example with forensics, of how to use this technique. On my next slide, I'm going to show you the introduction to this exercise. The first example is that there's been a mix-up in a maternity ward. And there's three babies A, B, and C, and three sets of parents, one, two, and three. We're going to match which sets of parents go with which baby.

On your worksheet you'll see a similar picture to the one I'm showing on my next slide. Here's a region of chromosome 15. This region has a repeat of T, T, A, G, G, A, T in the middle. This region can be repeated n number of times, a different number of times in different people. We're going to analyze this region of chromosome 15 in the babies and in the parents to see if it can tell us which babies go with which parents.

On your worksheet you'll also see the following picture. This is the result of the DNA analysis of chromosome 15. You can see the ladder markings on the left and you can see the patterns that are given by all of the parents and all the babies. What I'd like you to do is answer the questions on your worksheet and those questions are shown here.

First, given the data so far, which of the three babies can you conclusively connect to a set of parents? Second, how did you conclude this? Third, why can you not determine, at this point, all of the babies and all of their parents? And finally, how do you think you would go about conclusively determining all the matches of the parents to the babies, using DNA fingerprinting analysis? I'd like you to answer those questions on your worksheet and we'll talk about the answers when you're done.

Welcome back. Let's go through the answers to the questions on your worksheet. First, the baby you can conclusively connect with a set of parents is baby A, who goes with parents set three. The way you can conclude this is the 25 length repeat.

If you look at your ladder, you find n equals 25. You see that band and that band is only present in dad number three and in baby A. Baby A had to have gotten the 25 repeat length from someone and the only person he could have gotten it from was dad number three. That's how you can conclude that dad number three, and therefore also mom number three, goes with baby A.

The other two parents, one and two, actually cannot be matched at this point with babies B and C. That's because if you look at the types of genes, the genotype, of parents number one and parents number two, and you think about all the different possible genotypes of children that they could have, they could actually each have either baby B or C.

How would we actually go about concluding whether parents one and two go with babies B and C? Remember, this is just a small segment of chromosome number 15. These are maybe hundreds or thousands of letters of DNA but we have 3 billion letters of DNA from our mom and 3 billion letters of DNA from our dad. We can go look at another region of another chromosome and see if that one answers our question.

Now if you look at your worksheet, you'll see a picture like this. This is a region of chromosome four. In this region, the sequence C, A, G is repeated a certain number of times in the middle of the sequence. I'm going to show you another gel, also shown on your worksheet, that shows the results of analyzing the same people at a different region, a region of chromosome four.

What I'd like you to do now is analyze this gel and answer the questions you see on your worksheet. Those questions are shown here. Given all the data in this problem, I want you to match the three sets of parents with the three babies. I also want you to explain how this site on chromosome four allowed you to match parents one and two with babies B and C. You can work on these questions on your worksheet, and I'll see you when you've got those answers.

Welcome back. Let's go over the answers to those questions. The first question is to conclusively connect all three sets of parents with all three babies. We already know from chromosome 15 that baby A goes with parents three. What we can find from this gel is that baby B goes with parents one and that baby C goes with parents two.

How do we find that? If you look at this gel here, baby B has two copies of the 80 repeat length. If you look at parents one and parents two, both dad number one and mom number one have that 80 repeat length. Thus, they could've each given the 80 repeats to baby B. However, neither dad number two nor mom number two have that 80 repeat length. So, parents number two could not be the parents of baby B.

If you look at baby C, baby C has the repeat length of 70 and the repeat length of 40. If you look at mom number two, mom number two is the only parent who has the repeat length of 40, and thus she could've given this 40 repeat to baby C. Baby C's other repeat is 70 long and dad number two has the 70 repeat length, so he could have given it to baby C.

Thus, in conclusion, parents three go with baby A. Parents one go with baby B and parents two go with baby C. That's how you match the babies to the sets of parents.

This technique of DNA fingerprinting, as we've discussed in this example, can be used to identify people for paternity testing. But the same technique can also be used in forensics analysis. I'd like to show you an example of that now.

Do you remember the gel that we were looking at earlier in the lesson in lab? I'd like to show you that gel again. In this gel, you can see that lane five contains the ladder, and lanes six, seven, and eight contain the DNA of three suspects. We'll call them D, E, and F. Lane nine contains DNA found at the crime scene. What I'd like you to do is analyze this gel and answer the following question. Which suspect, D, E, or F, has DNA that matches the DNA from the crime scene? Discuss the answer to that question and I'll see you when you're done.

Welcome back. In the gel you just look that, suspects D, E, and F had the following DNA patterns. Suspect D had one band that was higher up in the gel. E had two bands, one that was higher and one that was lower. And F had one band that was lower. When you looked at the DNA from the crime scene, there was one band that was lower and it was the same length as person F. Thus, suspect F's DNA matched the DNA found at the crime scene. That's how DNA fingerprinting analysis can be used in forensics.

During the filming of this lesson I had the opportunity to visit the Identification Unit at the Cambridge Police Department. This is the lab where the Cambridge Police Department can investigate items found in a crime scene for things like fingerprints or for DNA.

For instance, here you can see that I'm getting my cheeks swabbed. This is how the technicians at the Identification Unit isolated DNA from someone who's potentially a suspect. They can also isolate DNA from items found at a crime scene, such as a water bottle or a weapon. You can watch a full video tour of the Identification Unit in the video that's found after this lesson.

I hope that you've enjoyed the lesson today as we learned about DNA fingerprinting analysis, how it can be used to identify people based on their DNA, and how it works as you saw in my lab. Thanks for joining me and I hope you enjoyed learning about paternity testing, forensics analysis, and DNA fingerprinting.

Thanks for your interest in my BLOSSOMS lesson on using DNA fingerprinting in paternity testing and forensics analysis. The main objectives of this lesson are for students to learn how DNA fingerprinting works, to see it actually work as a technique in lab, and to be able to analyze the data that is generated by DNA fingerprinting, and use it in situations such as paternity testing and forensics analysis.

There's no background information necessary for this lesson although it's helpful if students already know that DNA is a genetic material and is made up of A's, T's, G's, and C's. It's also helpful if they know that genetic material of any one person comes from their parents, and that 50% of that material comes from the mom and 50% comes from the dad.

There's no necessary materials for the lesson other than the worksheets that are provided and ability to project or print out the slides. There's nine segments to this lesson and I'll go through each one and what happens in each segment and between segments now.

In segment number one, I introduce the concept of how you look at a DNA sequence, a series of A's, T's, G's, and C's. I asked the students that if you're looking at 2,000 letters of DNA, how many of those letters might be different between any two people on Earth? I give the students time to brainstorm this number and usually students guess a lot higher than what it actually is, which is one or two letters.

When I come back in segment two, I reveal that only one or two letters out of 2,000 would be different if you compared any two humans because any two humans are 99.9% identical. Then I talk about how the differences in DNA, those less than 0.01% of letters, can be used to tell people apart. I ask the students to brainstorm uses for a technique where you would be able to tell people apart based on their DNA.

After segment two, most likely the students may come up with either paternity testing or forensics. In segment three, I come back and go over those uses, but I also talk about how at the Broad Institute where I work we use this technique all the time to find genes that are associated with disease.

Then in segment three, I introduce how DNA fingerprinting can work to look at the differences in length of DNA between people, for instance, a length of a repeated sequence between two people, as opposed to differences in the actual sequence or what the letters are. These are the differences that are usually used in paternity and forensics analysis.

I talk about how you can separate a piece of DNA by size in gel electrophoresis. And I posed two questions to the students about how they would get DNA to move through a matrix, given that DNA is negative, and also what they think would happen to the speed of DNA if you raced a big piece of DNA versus a small piece of DNA through a matrix.

When I come back in segment four, we talk about how you can get DNA through a matrix by making the other end of the matrix positive so the DNA is attracted to it, and how large pieces of DNA move slowly through the matrix and small pieces move quickly. Then I introduce the concept of what this technique would actually look like.

In segment four, we actually go into the lab. I do a DNA fingerprinting experiment and I show the results of a gel at the end where there are three different DNA samples. One has a large piece of DNA, one has a

small piece of DNA, and one has two different pieces of DNA, a large and a small. Some people show one band in the gel and other people show two bands.

I ask the students to write notes about how many bands they saw in each lane, whether the bands were longer or shorter in each lane, and also why it is that some people show one band and other people show two bands. We answer this question in segment number five and the answer is because every person gets half their DNA from their mom and half their DNA from their dad, and if the mother's and father's DNA are of different lengths, then the person will show two bands. If the person inherits the same length from both parents, the person will show one band.

This is usually a very difficult concept for the students to grasp, so I go on to show this concept as a picture, where I show the nucleus of a human cell. I show the maternal and paternal versions of three different chromosomes and label one section so that they can see that the little section might be slightly different lengths because the maternal version and the paternal version had a different number of repeats.

Then I show the students a sample gel with the DNA from three people, the person I label as me, a person I label as the person I refer to as Mom, and then the person I refer to as Dad. I ask the students if the gel shows whether or not these people can be my parents, and whether or not these people are my parents.

In segment six, I explain that the two people can be my parents because the gel is consistent with my DNA, but that it doesn't prove it. So I talk about how we use many regions of the DNA to actually show whether we think that someone is a parent of a child, or we think that someone's DNA has been found at a crime scene.

Then we start the main exercise of the lesson, where I give the students a gel showing three babies and three parents and asking them to use the DNA in this gel to figure out which set of parents, one, two, or three, goes with which baby, A, B, or C.

When we come back in segment seven, we discover that you can tell that baby A goes with parents three, but you actually cannot tell which of the other two sets of parents go with the other two babies. Then we go on to examine another site on a different chromosome that actually will tell us which parents, one or two, go with which baby, B or C.

The students analyze that gel from that other region of a different chromosome between segments seven and eight. Then in eight, we go over the final answers, which are that baby A goes with parents three, baby B goes with parents one, and baby C goes with parents two.

Finally, I show the students an example of a gel from forensic analysis, which is actually the gel I ran in lab. In this gel there were three suspects D, E, and F. D had the one band that was higher in the gel. E had two bands, one higher and one lower. F had one band that was lower.

There's a final lane of the gel, which is the DNA from the crime scene and that lane has one band that's lower. It matches the DNA from suspect F. This shows that DNA found at the scene of the crime matches the DNA of suspect F.

In segment nine, I have asked the students to determine which suspect's DNA matches the DNA from the crime scene. They figure out that it's suspect F and the lesson ends with a summary of the lesson being about using DNA fingerprinting to tell people apart, and how that's used in both paternity testing and forensics analysis.

I hope that you enjoy using this lesson and thanks so much for being a part of BLOSSOMS. [MUSIC]