The King of Dinosaurs or a Chicken Dinner? One Paleontologist's Quest to Activate Atavistic Genes and Create a Dinosaur.

[MUSIC PLAYING]

Hi. I'm Justin Lessek.

And I'm Diana Aljets.

And we're biology teachers at Columbia Heights Education campus in Washington, DC.

And today, we're brainstorming ideas to help our students make connections between genes, proteins, and evolution.

Right now, our students understand DNA structure and they know the steps to protein synthesis.

He's done it. Jack's done it. He's made a dinosaur.

Wait, you think some guy has made a dinosaur?

Well, not exactly made a dinosaur. But this famous paleontologist, Jack Horner, believes that there's dinosaurs among us, right now. What do you guys think?

Take a look at these pictures of modern animals. Which one do you think is most closely related to dinosaurs like Tyranosaurus rex?

Once you've decided and answered the questions on both sides of the handout, discuss with a partner which animal you chose and why. Write the name of your number one animal on a piece of paper and turn it into your teacher. Later during the lesson, your teacher will announce the results.

So how did you guys do? While you were answering questions, we were asking those same questions to people we met on the streets.

Most closely related to a T. rex, I would say the salamander, because when I think of T. rex I think of dinosaurs and then that makes you think of reptiles.

The chicken seems more similar because its posture is similar to what a T. rex's posture is usually portrayed as.

I choose the dog for the main reason because the body weight proportional, because when I think of a Tyrannosaurus rex, I think of big head, small hands, and big legs.

So here we are in the paleontology gallery of the Harvard Museum of Natural History. It's an amazing spot and a perfect place to talk more about dinosaurs.

And now that you've had a chance to choose who you think is T. rex's closest living relative, we're going to move on, so that later in the lesson you get to use biochemical evidence to find out who truly is T. rex's closest living relative.

So Diana, earlier in the lesson you mentioned a paleontologist named Jack Horner. Warner Maybe we can use Jack to help us. Can you tell us more about him?

Definitely. But maybe it will be easier to let Jack explain about his research during his TED talk he gave in 2011.

When I was growing up in Montana, I had two dreams. I wanted to be a paleontologist, a dinosaur paleontologist, and I wanted to have a pet dinosaur. And so that's what I've been striving for all of my life.

I was very fortunate early in my career, I was fortunate in finding things. I wasn't very good at reading things. In fact, I don't read much of anything. I am extremely dyslexic and so reading is the hardest thing I do.

But instead, I go out and I find things. And I just pick things up. I basically practice for finding money on the street. And I wander about the hills. And I have found a few things.

And I have been fortunate enough to find things like the first eggs in the Western hemisphere, and the first baby dinosaurs in nests, and the first dinosaur embryos, and massive accumulations of bones. And it happened to be at a time when people were just starting to begin to realize that dinosaurs weren't the big, stupid, green reptiles that people had thought for so many years. And people were starting to get an idea that dinosaurs were special.

And so at that time, I was able to make some interesting hypotheses. Along with my colleagues, we were able to actually say that dinosaurs, based on the evidence we had, that dinosaurs built nests and lived in colonies and cared for their young, brought food to their babies, and traveled in gigantic herds. So it was pretty interesting stuff.

I have gone on to find more things and discover that dinosaurs really were very social. We have found a lot of evidence that dinosaurs changed from when they were juveniles to when they were adults. The appearance of them would have been different, which it is an all social animals.

In social groups of animals, the juveniles always look different than the adults. The adults can recognize the juveniles. The juveniles to recognize the adults. And so we're making a better picture can what a dinosaur looked like. And they didn't just all chase jeeps around.

So now we know that dinosaurs were social animals. But we still don't know who they're most closely related to. Is there a dinosaur DNA out there? If so we could take our dino DNA sequences and then compare them to the DNA sequences of our other seven animals.

No, there's no dinosaur DNA. But we could use dinosaur protein from Jack Horner's dig. Could that work?

Protein will definitely work. For those of you watching in class, how and why do you think we can use protein, and not just DNA sequences, to figure out how closely related two different species are? We'll give you a few minutes to think about this and discuss as a class.

Welcome back. I hope you had a good time discussing the question. Now, we're going to talk about why you can use protein to figure out how related two species are.

Most of you know that DNA molecules are just long sequences of nucleotides, each containing one of four letters, A, G, C, or T. The nucleotide the repeated over and over, thousands of times, to make chains reading things like T, A, C, G, G, C, T, A, G, and on and on. During transcription, one of the two DNA strands is transcribed into a single strand of mRNA. During translation, the mRNA strand is translated into amino acids.

Every three letters of mRNA codes for a specific amino acid. For example, in the diagram you can see that G, U, U codes for the amino acid valine, which is represented by a V-A-L in the diagram. When translation is finished, you have a sequence of amino acids.

Right. Proteins are just made up of long chains of amino acids. And if you know the amino acid sequence, then you know the protein. Therefore, you also kind of know the DNA sequence, almost.

This slide shows the first 10 amino acids in human, chimp, and tuna hemoglobin proteins. Take a few minutes to look at the sequences. Based on your observations, make a hypothesis on which two organisms are most genetically similar. We'll keep the slide off while you guys talk amongst yourselves and we'll be back in about two minutes.

If you said human and chimpanzee, you're correct. Scientists agree. And it's well known that humans and chimpanzees are more closely related to one another than fish.

So based on what we know now, we could compare our protein sequences in dinosaurs to those from our other seven animals from the beginning of our lesson.

OK, let's check back with Jack on that subject. Jack was actually a technical consultant for the movie Jurassic Park. And he's going to first discuss why those techniques weren't exactly accurate.

If you want to make a dinosaur, you go out, you find yourself a piece of petrified tree sap, otherwise known as amber, that has some blood-sucking insects in it, good ones. And you get your insect and drill into it, and you suck out some DNA, because obviously all insects that sucked blood in those days, sucked dinosaur DNA out.

And you take your DNA back to the laboratory and you clone it. And I guess you inject it into, maybe an ostrich egg or something like that. And then you wait. And lo and behold, out pops a little baby dinosaur. And everybody's happy about that.

And they're happy over and over again. They keep doing it. They just keep making these things. And then they-- then, then, and then. Then the dinosaurs being social, act out their socialness and they get together and they conspire. And of course that's what makes Steven Spielberg's movie, conspiring dinosaurs, chasing people around.

Now, I assume everybody knows that if you actually had a piece of amber and it had an insect in it and you drilled into it and you got something out of that insect and you cloned it, and you did it over and over and over again, you'd have a room full of mosquitoes, right?-- and probably a whole bunch of trees, as well.

Well, if you want dinosaur DNA, I say go to the dinosaur. So that's what we've done. Back in 1993, when the movie came out, we actually had a grant from the National Science Foundation to attempt to extract DNA from a dinosaur. And we chose the dinosaur on the left, a Tyrannosaurus rex, which was a very nice specimen.

And one of my former doctoral students, Dr. Mary Schweitzer, actually had the background to do this sort of thing. And so she looked into the bone of this T. rex, one of the thigh bones. And she actually found some very interesting structures in there.

They found these red, circular looking objects. And they looked, for all the world, like red blood cells. And they're in what appear to be the blood channels that go through the bone.

And so she thought well, what the heck. So she sampled some material out of it. Now, it wasn't DNA. She didn't find DNA. But she did find heme, which is the biological foundation of hemoglobin.

And that was really cool. And that interesting. Here we have 65-million-year-old heme. Well, we tried and tried. And we couldn't really get anything else out it.

So now you've seen the clip, we have a couple of questions for you to discuss with your classmates.

First off, consider digestion. Why is it unlikely that we'll ever be able to get dinosaur DNA from a petrified mosquito?

Second, heme is part of a protein found in red blood cells. Why do you think we were able to recover intact pieces of heme, but not DNA? And think about whether or not red blood cells have DNA?

We'll see you after the break.

Welcome back. From Jack's talk, it sounds like paleontologists have discovered part of a protein in dinosaurs that we could compare to our other animals. It's called heme. And it's part of a protein called hemoglobin.

And besides heme, we can also use a protein called collagen, which paleontologists have been able to extract from the bones of T. rex.

Collagen would be an even better protein to look at than heme. Collagen is in the connective tissue of animals. So it's in our skin. It's in our tendons.

It's what gives our skin sort of elasticity properties. It's why you can pull your skin and it bounces back into shape. In fact, collagen is the most abundant protein in the human body.

Now using that information, we're going to go to the National Center for Biotechnology Information or NCBI. There, we're going to use what's called a protein BLAST.

Let's move to a classroom to do this part.

So this is where we're going to do our protein BLAST. BLAST stands for Basic Local Alignment Search Tool. So in a protein BLAST, we enter a protein sequence. And then the BLAST will compare our sequence to the amino acid sequence of all the other animal proteins in the database.

So a BLAST is kind of like a Google search, except it's for DNA, or specifically for genes. In this case, we'll be entering this protein name. And then it's going to give us a readout of hits. The first hit is going to be the most relevant.

So now, we're going to use that collagen protein sequence that we talked about earlier in the lesson. Except now, we're going to put it into the protein BLAST and it's going to then generate and compare all the protein sequences from those seven animals that we talked about earlier. And we'll find out who is the closest living relative to T. rex.

Some of you might be in a classroom that has computers and so you can do this activity on your own, following the directions that your teacher is going give you. If you don't have computers in the classroom, you can follow along, and we'll demonstrate on video.

This section of the lesson is primarily for students who do not have computers with internet connections to run the BLAST on their own. If you are running the BLAST yourself, you can skip to the next segment.

First, we'll open our internet browser and type www.sciencebuddies.org into the URL. Next, we'll type "T Rex" into the Science Buddies search bar on the top right of the page, underneath the color tabs.

The most relevant hit is for "BLAST into the Past to identify T. Rex." That's the link we want to use, so we'll click on it. The introduction to this new page explains what you've already learned, that paleontologists have discovered a partially intact collagen protein from a fossilized T. rex.

If we scroll down the page, we'll come to the "Experimental Procedure" section. This is what we want to use.

In step one, we are given the actual amino acid sequence for T. rex collagen. You'll notice that there are a lot of hyphens. These are actually parts of the protein that could not be recovered. The letters each represent a different amino acid. You can see that there are five distinct stretches of amino acids that were recovered.

In step two, we are told to copy the entire collagen sequence from step one, so that we can paste it into the BLAST. We'll make sure to copy even the first line, which gives the BLAST identification info. Now, we'll open up a new tab in our browser.

We'll copy www.ncbi.nlm.nih.gov into the new tab we've just opened. On the right side of this NCBI site, there's a list of options under "Popular Resources." We want to click on BLAST.

On the BLAST site, we'll scroll down a bit to look at the options under "Basic BLAST." We are looking at protein sequences, so we want to click on "Protein BLAST." Now, we are on the page where we'll actually get to enter the protein sequence.

The first text box under "Enter Query Sequence" is where we'll paste the T. rex sequence that we copied from the Science Buddies page. This is the long sequence full of hyphens and letters that we were looking at earlier.

The next section of the page is labeled "Choose Search Set." Next to the database, choose "UniProtKB/Swiss-Prot." We'll leave the "Organism" box in the same section empty. But underneath that, there's a text box labeled "Entrez Query."

In this box, we'd like to write COL1A1 open bracket GENE close bracket AND 1400:1500 open bracket SLEN close bracket. This code can be found in step seven of the Science Buddies website.

The first part of this code limits the search to the type of collagen sequence found in the T. rex. The second part limits the search to amino acid sequences that are between 1,400 and 1,500 amino acids long. Otherwise, the BLAST might only give us tiny fragments.

Next to "Algorithm," we'll make sure that "plastp (protein-protein BLAST) has been selected. Before we click the BLAST oval on the bottom of the page, we'll make sure we've check the box that says "Show results in a new window." Now, we're ready to click BLAST.

A new page will open to show that the BLAST is working. The top of the page will give the job title and indicate that it's working on the Tyrannosaurus Rex search. Below that, it will say that "No putative conserved domains have been detected." You'll see some search details below this. And towards the bottom, it will say that "This page will be automatically updated in a certain number of seconds."

This means that the BLAST is working, but that it will take some time. Be patient, and eventually the Results page will show. You will see a colorful graphic with green and blue lines underneath "Graphic Summary." Scroll below this to "Descriptions."

This table will give us the information we need. There are seven rows, one for each of the living organisms that we are investigating. The organisms are ordered by their Max scores. The Max score is a value that indicates the relatedness of this specie's sequence to our T. rex sequence.

The most related organism is the first, with a Max score of 78.6. This organism has an E value of 9e negative 21, which is nine times 10 raised to the negative 21st power. This represents the likelihood that the sequences are not related.

If you understand scientific notation, you'll know that this is a very, very small value, and thus an indication that our first species sequence is in fact very closely related. To determine which animal this first species is, we'll click on the link in the left-hand column under "Accession." Now, we'll scroll until we see "Source" on the left-hand side.

This tells us that Gallus gallus, or chicken, is the most closely related to our T. rex. If you were doing this yourself, you would do the same thing we did for chicken, for each of the other rows. When you were finished, your data table would look kind of like this.

Remember at the beginning of the lesson when you made those predictions on who you thought was the most related to T. rex, take those handouts out now. Some people chose based on appearance, some chose based on movement, and others chose based on things that they had read or heard before.

Now, we've use the protein BLAST to answer the question the molecular way, using biochemistry. So we entered the T. rex collagen protein and compared it to the same protein sequence in animals that are alive today.

The chicken is T. rex's closest living relative. Take a minute to look at your teacher's tally from the predictions you made earlier in the lessons. Did you and your classmates guess correctly?

So now we know that chickens, and probably other birds like ostriches, are the direct descendants of dinosaurs, like a Tyranosaurus rex. But so what? Even if they are relatives, a chicken doesn't look like a Tyranosaurus rex.

So now that's where atavistic traits come into play. Atavisms are genes that have been regulated to not express an ancestral characteristic. For example, humans have the capacity to have a tail. However, during development, that gene is turned off, so that we no longer have a tail.

So wait. You and I both have the genes to have a tail?

Exactly. We have the gene to give us a tail. But it's been regulated and shut off, so that we'd no longer expressed that gene.

So all of genes can be turned on and off, just like a light switch.

Exactly. And for chickens, some of those atavisms are the ones that give the chicken teeth, a tail, and claws.

And so we can figure out how to regulate those atavisms in chickens, then we'll have our tiny T. rex?

Yes. So Jack Horner is actually going to tell us a little bit more about that, in greater detail.

An atavism is a ancestral characteristic. You've heard that occasionally children are born with tails. And it's because it's an ancestral characteristic.

And so there are a number of atavisms that can happen. Snakes are occasionally born with legs. And here's an example. This a chicken with teeth.

A fellow by the name of Matthew Harris, at the University of Wisconsin in Madison, actually figured out a way to stimulate the gene for teeth. And so was able to actually turn the tooth gene on and produce teeth in chickens. Now, that's a good characteristic. We can save that one. We know we can use that.

We can make a chicken with teeth. That's getting closer. That's better than a glowing chicken.

A friend of mine, a colleague of mine, Dr. Hans Larsson at McGill University, is actually looking at atavisms. And he's looking at them by looking at the embryogenesis of birds and actually looking at how they develop. And he's interested in how birds actually lost their tail. He's also interested in the transformation of the arm, the hand, to the wing. He's looking for those genes, as well.

And I said well, if you can find those, I can just reverse something and make what I need to make for the sixth graders. And so he agreed. And so that's what we're looking into.

If you look at dinosaur hands, Velociraptor has that cool-looking hand with the claws on it. Archaeopteryx, which is a bird, a primitive bird, still has that very primitive hand. But as you can see, the pigeon, or a chicken, or anything else like a bird, has kind of a weird looking hand, because the hand is a wing.

But the cool thing is that if you look in the embryo as the embryo is developing, the hand actually looks pretty much like the Archaeopteryx hand. It has the three fingers, the three digits. But a gene turns on that actually fuses those together. And so what we're looking for is that gene. We want to stop that gene from turning on, fusing those hands together, so we can get a chicken that hatches out with a three-fingered hand, just like the Archaeopteryx.

And the same goes for the tails. Birds have basically rudimentary tails. And so we know that in embryo, as the animal is developing, it actually has a relatively long tail. But a gene turns on and resorbs the tail, gets rid of it. So that's the other gene we're looking for. We want to stop that tail from resorbing.

So what we're trying to do really is take our chicken, modify it, and make a "Chickenosaurus." It's a cooler looking chicken. But it's just the very basics.

So that really is what we're doing. And people always say well, why do that? Why make this thing? What good is it?

Well, that's a good question. Actually, I think it's a great way to teach kids about evolutionary biology and developmental biology and all sorts of things. And quite frankly, I think if Colonel Sanders was to be careful how he worded it, he could actually advertise an extra piece.

Anyway, when our dino chicken hatches, it will be obviously the poster child, or what you might call the poster chick, for technology, entertainment, and design. Thank you.

Now that we've heard that, let's review a little bit. First off, why does Jack Horner want to make a dinosaur?

Next, what does Horner's team plan on doing to make a dinosaur and how does he actually plan on doing it?

Finally, do you think this is a good idea? What are the possible positive and negative consequences of creating a dinosaur?

So I hope after today's lesson, it's a little bit more clear on how the genes and proteins are related and how exactly Jack Horner plans on making a tiny T. rex.

Scientists has used protein BLASTS, just like the one that we performed, to compare the amino acid sequence in dinosaur proteins to the amino acid sequences in living animals, like salamanders and dogs. With this information, they have determined that chickens are the direct descendants of dinosaurs.

And now, they're working on finding additional atavisms in chickens, you remember those genes that are no longer expressed, that they got from their ancestors.

They believe that if they can regulate these atavistic genes, that they'll be able to create a dinosaur, or at least to have a chicken with teeth.

Did it. There's a dinosaur out there. I know he's made a dinosaur. I feel it.

This is how you started this whole discussion off. What do you mean, he created a dinosaur?

Your coffee. It's rippling.

Oh, the coffee. I think that's just my foot. I've been kicking the table and I think it's shaking the table. I think Jack Horner has a ways to go before there's actually dinosaurs running around on the street.

That may be true. But I still believe there's a chickenosaurus out there somewhere.

So what do you guys think? Is this an unrealistic dream of a few ambitious paleontologists or do you really think that we can make a T. rex from chicken embryos?

For some follow up, consider reading Thomas Hayden's 2011 article from Wired Magazine called "How to Hatch a Dinosaur." You'll learn more about Jack Horner, his team, and their efforts to create a tiny T. rex. We've also attached a reading guide to the lesson, if you're interested.

So I hope you guys have enjoyed this lesson, just about as much as we have. And until then, enjoy.

Thanks for being interested in the lesson. It's one that Diana and I have had a lot of fun putting together. It's one that we've used for a couple of years now with our students. And so it's changed a little bit over time and we've tried to kind of streamline it.

The objectives of the lesson are really kind of broad and two-fold. First of all, we felt like this was a great opportunity to implement the use of a database. And so when the students are able to use the BLAST and access the NIH database, we feel like that's a very valuable thing that they're learning to do. And also just to get more experience with the relationship between DNA and proteins, which brings us to kind of a prerequisite.

I think it would be a very, very confusing lesson if students at this point don't really understand the structure of DNA. We talk a bit about nucleotides and we throw out words or sequences like G, C, A, T, T, C. And if that all sounds very foreign to them, I think they could get lost at a few different points in the lesson. And central dogma and the concept of protein synthesis and this flow from DNA to mRNA to protein, I think is very important that they've seen before this, as well.

We very briefly, I think we do mention transcription and translation. And I think that is going to complicate things for kids, if those are words they've never heard before. But really if you've covered DNA structure, if you've covered protein synthesis, I think this is a pretty accessible lesson to just about all levels of students.

We really developed this with sort of an intro biology student demographic in mind. I think especially the database portion would be a great thing for AP kids to use. I know that's a big part of the AP curriculum now, is being able to use databases.

Which again brings us to this idea that we developed this lesson to be very flexible. And so you certainly do not need to press "Play" at the beginning and watch it straight through or anything. If you find that certain pieces are going to be useful, use those particular pieces. There are stops and pauses and things throughout the lesson.

And for certain classes, maybe your kids will need five minutes instead of two minutes. Some classes, some higher level classes, might need 30 seconds. So it would probably be a good idea to see the lesson all the way through, before you're suddenly showing it in class, because you know your students the best and sort of what they'll need.

So ultimately, there's three parts to the lesson. There is the BLAST, there is the article, and there is the TED Talk given by Jack Horner. The article is also about Jack Horner. So both of those things can kind of be used in tandem or you can use the article for homework, because it's an interesting article and has a lot of really neat things to say and really sort of supports the lesson. We don't really go into the article in this particular lesson. But that's where we originally got the idea from.

And we're attaching a reading guide, which you will be able to find on a link on the BLOSSOMS website. And the reading guide, I think it would be a great opportunity probably to have your students either do a prereading and they could answer the questions from the reading guide for homework. You could use it after they've seen the video.

I think the article would spur a nice, maybe class discussion on bioethics. We've done that in our class. And we've also used this as sort of a way to anchor our protein synthesis unit.

So maybe, like we said, it's important that there is some prerequisite stuff there and that they have a very basic understanding of protein synthesis vocabulary. But once that's been introduced-- I think last year we sort of put this inside of our protein synthesis unit and we used the old dinosaur context of it as just a way to kind of engage our kids. And I think that worked really well for us.

And also just a sidebar, is that before we did this lesson, we did use another BLOSSOMS lesson that dealt with phylogenetic trees, so that the students had a very clear idea of how DNA and the sequences related to kinship. And you can find that on the BLOSSOMS website.

Yeah. And that is a great BLOSSOMS video to watch beforehand, because it focuses on using DNA sequences and finding subtle differences in DNA sequences to create those phylogenetic trees. And that sort of parlays very nicely into using amino acid sequences rather than DNA sequences.

We're going to put both of our email addresses, by the way, on the website as well. So if you have questions, we would love to hear from you and be able to answer those questions as well. But, thanks again. We're really happy that you're using this lesson and we're glad we could help.

So take what you want, use it how you want, and have fun.