30 BRAVE MINUTES - DINOSAURS & FOSSILS TRANSCRIPT

Welcome to 30 Brave Minutes, a podcast of the College of Arts and Sciences at the University of North Carolina Pembroke. In 30 Brave Minutes we'll give you something interesting to think about. Remember you can now subscribe to us on PodBean and iTunes. The topic for today is Dinosaurs and Fossils. Joining Dean Frederick, the Dean of the College of Arts and Sciences, are John Roe and Martin Farley. Get ready for 30 Brave Minutes.

FREDERICK: In the last quarter-century, Hollywood has produced five Jurassic Park movies, all successful commercially, and each building on the 1990 book by popular fiction writer Michael Crichton. The book, deeper and richer in many ways than the original movie-- and isn't that almost always the case? - revolved around some interesting ideas like chaos theory but ultimately is embedded in a line of text loosely phrased as "God created dinosaurs. God destroyed dinosaurs. God created Man. Man destroyed God. Man created dinosaurs." Of course some part of the reason that people flocked to see the films is based on the unspoken reality that the movie will reveal that dinosaurs can also eat Man, at least enough to stitch together a fun plot for five or more films. Oh and selling of boxes and boxes of merchandise fits in there somewhere as well.

Of course these movies are full of bad or at least incomplete science: DNA harvested from an insect encased in amber could happen, but it would not include dinosaur blood as millions of years of time would have caused too much decay- this makes dinosaur cloning beyond science fiction; it's hard to imagine dinosaurs sneezing like they were mammals; T-Rexes likely could see and smell pray reasonably well and they didn't necessarily cause seismic echoes for miles around every time they moved. They probably didn't roar quite so impressively either. Velociraptors seem to have been more the size of big chickens or small turkeys, not the much larger size we see indicated in the films, and, while smarter than some dinosaurs, these velociraptors weren't nearly the rocket scientists seemingly depicted on screen.

Even so, simply put, dinosaurs fascinate us whether it's their size, shape, unusual nature, or the novelty of them. The best guess is maybe 700-800 different dinosaur types of various shapes and sizes existed for a lengthy period of time in the area of 150-200 million years ago. They lived in fairly large numbers long before mankind. They laid a bunch of eggs, and eventually went extinct, probably in response to climate related, geologic, or asteroid-comet events which either effected the food supply very quickly or simply showered enough radiation on them to make survival no longer possible. Plenty of other theories exist.

How do we know anything about any of those creatures? How do we know that some were gigantic and others not so much? How do we know that some had wings, some hunted, others were vegetarians, and still others were loners even as another type might be social enough to travel in herds or packs? The answer starts with fossils.

Fossils are physical remnants which allow scientists to piece together information about prehistoric creatures and their habits. Just this month, fossil remains from a museum in Budapest, Hungary have helped researchers understand a transition species of giant crocodiles that bridged the divide between land-based crocodiles and marine-based forms. The fossil is not a complete specimen; it's a series of fragments, some incredibly small, but yet still sufficient to provide enough information and clues so that we can make important new discoveries or confirm existing ones.

Fossils are often found in proximity to sedimentary rocks so biologists, paleontologists, and geologists end up spending a lot of time together, piecing together the detective work required to make sense of these remains. Case in point, petrified fossils are fossils where the bone and other living material have been replaced by deposited minerals. This process, called permineralization, occurs when groundwater solutions saturate the remains of buried plants or animals. When this groundwater evaporates the minerals are left and they fill in the spaces left as the organism decays over time. Most petrified fossils form from quartz minerals, calcite, iron compounds, or other items.

And sometimes, these fossils and the exploratory research initiatives scientists create from them, help us to draw evolutionary connections between existing animals we can observe in the forest, skies, or aquatic habitat. Physiological and evolutionary adaptation is all around us. By studying fossils and dinosaurs and other beings from the near and distant past, we learn about the interrelationships between habitat and species, something critical not just for understanding the past, but helping us prepare for the future.

My guests for today are geologist Dr. Martin Farley and biologist Dr. John Roe. Let's talk dinosaurs and fossils:

Alright, so what's the most reliable estimate for when dinosaurs walked the earth? How many different types were there really? What were the years like when they inhabited the earth?

FARLEY: Well, the earliest dinosaurs appear in late Triassic period, and continued through the Jurassic, which is famous for giving its name to the books and movies and continued through the Cretaceous period and ended at the end of the Cretaceous period. We can express that geologically in a fairly precise way using the relative Geologic time scale. If we want to attach numbers then those are estimates that have to be attached separately. We can't attach numbers in an exact way because you can't attach numbers directly to any fossils. So, you could say in round numbers they appeared 220 million years ago and went extinct except for the ones with living descendants at the end of the Cretaceous period, roughly 65 million years ago.

ROE: Yeah, and I'll add something to that. Martin alluded to their living descendants and it really depends upon how you define what a dinosaur is. In the traditional sense, yes, they existed in their form of those large reptiles that are popularized in the movies and books for about 165 million years, until they went extinct, but their modern descendants are the birds and we will probably discuss more of the evidence that links those groups together, but there is a lot of misinformation in the popular culture about what actually a dinosaur is or was. Technically speaking as a zoologist, they are a group of diapsid reptiles, meaning they had two holes in their skulls in the temporal region of each side, and there are also archosaurs which included the living birds and crocodilians and also the extinct dinosaurs, pterosaurs, and other groups. One of the traits that makes an archosaur an archosaur is an additional hole called the antorbital fenestra, and that is a hole between the nasus on each side of the head and the eye orbital. Dinosaurs and archosaurs are unique in that they had upright positioning of their limbs for terrestrial locomotion. Indeed all dinosaurs were land-dwelling animals.

FREDERICK: So they could all walk, they could all move at various speeds and rates and for various reasons...

ROE: But they were not in the marine environment, which excludes things like ichthyosaurs and plesiosaurs which are often included in the popularization of dinosaurs. There are a few other traits but we really have to define what we mean by dinosaur specifically to put a bracket on the age within which they exist.

FREDERICK: You have described some of the holes in and around their head. What were the purposes of those and how do they fit in here?

ROE: Well, it is hard to put a functional role into those. It is more of a diagnostic feature that you can ascribe to a fossil or any living creatures that we can assess their skeletons. It is hard to say what the function was.

FREDERICK: So before we continue the conversation deeper, let's talk a little bit about what earth would have been like at the time when the dinosaurs were around. What would have been similar or different about the plants? What would the climate have been like? Take us back in time to the best that you can of when these dinosaurs were on the earth. What is everything else like?

FARLEY: Well, generally speaking the earth was warmer than it is at present. There was variation over this quite lengthy period of time, but generally it was warmer. That means during much of the period sea level was higher than it is at present because of areas that are now ice - polar ice caps that we have today - were melted and in fact, in Cretaceous, the last period of the dinosaur existence we had the highest sea levels of the last 600 million years. Probably at their maximum 250 meters higher than at present, and in North America, as an example, there is a sea way that ran basically through the center of North America, north to south, so that if you were in a ship, roughly at Houston, you could have sailed directly northward all the way to what I will call the Artic, although North America was farther south than it is today. So, the climate was warmer. The vegetation was considerably different. Until the Cretaceous there were no flowering plants and even the flowering plants that existed in the Cretaceous were rather different. There were no grasses, so one of the things that has to make our understanding of the plant-eating dinosaurs different is that they weren't grazing on the grasslands we think of as normal for herbivorous animals today, like the bison here in North America before the Europeans arrived, or the zebras, wildebeests, or similar animals in Africa. That changes how we can interpret what herds of herbivorous dinosaurs were eating in the age of the dinosaurs.

FREDERICK: So they are munching on trees and other wild pieces of vegetation that is popping up in response to this warm climate?

FARLEY: Well, certainly the vegetation was dominated by gymnosperms and ferns and there are living relatives of some of these gymnosperms around today and some that are not. One feature of these gymnosperms today is that they are pretty slow-growing plants. This puts limitations on how numerous these herds could be, because one of the things that everybody is aware of now is that when the grasses grow and in a week you have to go out and mow again. From the point of view of herbivorous animals, this an ever growing buffet.

FREDERICK: Dinosaurs had a little bit of an eating problem?

FARLEY: There is other evidence from the dinosaurs themselves about the nature of their teeth that suggests that they weren't as adept at chewing up the vegetation as the mammalian herbivores that live today, but in addition, things weren't growing as fast so they couldn't have been eating as much or they would have been eating themselves out of house and home. So that makes some differences. The caloric value of some of the material probably wasn't as good either. So it was a different looking landscape which is another problem which you alluded to in the Hollywood reconstruction is that if we plop these animals down in a new landscape and they may not be able to adapt quite so well. It would have looked quite a bit different just from a plant architectural point of view.

FREDERICK: What about the rest of the life forms that were around then?

ROE: There were a lot of major animal groups that we have today. For instance, there were both cartilaginous and boney fishes which evolved about 500 million years ago. Amphibians were present which came on the scene about 400 million years ago. There were many other reptiles as well. Reptiles evolved. The first evidence of reptilian body types was around 320 million years ago and during the age of the dinosaurs there were turtles. At some point snakes and lizards entered the scene. Crocodilians of various types and mammals and birds were indeed there, too. Probably smaller and a little less abundant and diverse than they are now but there was certainly a very complex ecosystem with respect to both plants and animals that would have allowed for interactions of predator and prey, competition, mutualism, and other things that we know of that exist today in shaping ecological communities.

FREDERICK: So when geologists and biologists are out doing fieldwork and you discover a fossil. Beyond the excitement that, as an historian, I can say I find when I am in the archives and I find something interesting, what do you do next? How do you start using those fossils to piece together some of the mysteries?

ROE: I'll start on that one. We can infer a lot from what the fossil has in terms of the context of where it was deposited. For instance, Martin talked a lot about the teeth. We can infer a lot of what their diet must have been consisting of by looking at the shape and size of their teeth. The large grinding molar-like teeth that are present in a lot of the herbivores today were not really the dominant type of tooth. They had more of peg-like raking teeth that would allow to string vegetation off of branches perhaps as those big bactrosaurus when they are eating leaves off of a tree. We can also tell a lot about their diet from what we find in their fossilized feces, called a coprolite. We can examine, if we get lucky, the gut contents of a fossil that was a predator that had just recently eaten something that was unlucky enough to have died just at the wrong time, just after eating it. There is even some examples of fossilized remains of predators consuming prey or tearing them apart in that process. We can also study their footprints to infer things about their behavior. There are some really classic footprint finds of large sauropod dinosaurs like a bactrosaurus, formally known as brontosaurus, moving around in supposedly herds and being pursued by theropod dinosaurs, like the velociraptor or tyrannosaurus rex. They know that they were being followed because the therapod footprints were made on top of the sauropod footprints and there were many individuals, making it likely that they were probably hunting in groups such as packs. We can infer things that we get wrong every now and then, but one example of that is the oviraptosaur which is technically called the egg thief. They were assumed to be predators on eggs that were laid in nests because of the number of individuals that were found basically lying on top of the eggs, but it turns out that the more accurate, correct explanation was that this was actually evidence of incubation behavior. They likely constructed nests, laid eggs, and then sat on top of them and exhibited parental care and were maybe even endothermic and able to incubate their eggs a lot like modern-day birds do. So, there are a lot of interesting things that we can infer from the fossil finds that we get.

FREDERICK: So every time you get a new fossil, you add to the record, sometimes changing the outcomes of what previously had been confirmed.

ROE: That's right. There is constant revision in the scientific process of what the new evidence suggests.

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FREDERICK: What about the dating process? How do we date fossils of various types? How have those dating processes changed and how accurate are they?

FARLEY: Well, the primary approach has been in its own way unchanged for 150 years. As I mentioned a little earlier it is based on relative dating. It starts with a principle that is even older than that called superposition which, if you are shoveling dirt into a bathtub the dirt you shovel in first is on the bottom and it becomes successively newer. The dirt you shovel in last is on top and that gives you a relative order of the layers of dirt or sediment. That gives a relative sequence and any particular location and what people discovered about 1800 is that different layers have characteristic assemblages of fossils in them and you can then go from place to place and see the same characteristic assemblages and that way you can hook up layers that are separating. This is what allowed construction of the relative geologic time scale and attachment of these terms like Jurassic or the older term for the age of dinosaurs, Triassic. Names come particular places. The Jurassic comes from the Swiss Alps, which are actually marine and there are no dinosaurs in them. It is a function of the history of science because chalk as a rock first appears in great abundance in the cretaceous worldwide because of the evolution of phytoplankton that produced chalk at that time. The relative geologic time scale was constructed and allows you to put fossils of all kinds, including dinosaurs into a context. This was all developed before there was any way to attach numerical ages, which basically was developed about 1900 when radioactive decay was discovered and you can use that as a clock, but you can't date fossils directly except for the very youngest fossils that have organic matter, which are much younger than dinosaurs where you can use carbon 14. In the age of the dinosaurs, you cannot date the fossils directly, so you have to date igneous events like volcanic ash falls because the ash produces crystals of minerals that start the clock running and those ash falls occur in the sedimentary layers. You can think of Kilauea erupting right now; it is producing volcanic ash and that ash is falling in various places in our bathtub, filling up with sediment and therefore those ash layers are being incorporated within layers where fossils are occurring. So you can find an ash layer that is lower in the stack of sediments than a fossil or some geologic event you are interested in and one that is higher and you can date both of them and then interpolate between them to the age of the event you are interested in.

FREDERICK: So if I find a fossil out doing field work, I don't stop when I find a fossil. I keep looking to see what is underneath it and what is around it, because all of these various contextual factors really explain the rest of the story.

FARLEY: Well, that's right. What you typically do is you start from some spot which you record and you measure a section. So you have a standard spot and you measure up to where you start collecting fossils. You are basically recording so that other people can come later and reproduce the work and your recording and can therefore find, for example, a datable event like a volcanic ash fall or some other event in that zone. Or, when you are finding new fossils, like dinosaurs or anything else, you may not have a particular age connotation associated with the new material, but you're trying to find fossils that are of a known age. You are trying to get a context so in the vertical section you are going through, you are trying to find material that is already known so that you can put your new material into a known context.

FREDERICK: John, talk a little bit about how we understand that the evolutionary process works. You can talk about dinosaurs or, for that matter, any other species. How do we look over time at changes and see how animals are adapting or, in the case of some fossils, not adapting?

ROE: Right. Well, you are correct that the evolutionary process is something that all living things go through and I'll walk you through the general process first. Then, we might apply it to an example of dinosaurs at some point. Think of a population of organisms. A population is a number of individuals of the same species occurring at the same time and place. In that population you are going to have an enormous amount of phenotypic variation or trait variation. So, it could be morphological variations and body size or color, or the strength of the bones and muscles. It could be physiological hidden variations such as heart rate or metabolic rate. Or, even in the ability to digest sugars or to fight off disease. These traits could be behavioral. There could be differences in personality, running speed, or habitat selection, et cetera. Owing in part to the individual's unique blend of traits, certain individuals in this population are going to have traits better suited to cope with the challenges of the current environment, as well as to exploit the opportunities in it. As a consequence they are going to have a higher probability of surviving to reproduce and thus leave more offspring compared to others that don't have those traits. These traits we would call adaptive and these adaptive traits, if they are heritable, meaning that they are coded into the genetic material of the genes and passed on from parent to offspring, then the traits that gave those parents in those environments success will also be expressed and presumably give the offspring a greater chance of success. These favorable genes and associated phenotypes will then become more frequent in the population over time and by contrast, the less favorable genes and those associated phenotypes that are not as well suited will become less frequent in the population.

FREDERICK: Let me jump in for a quick minute. Some of these are nature-based traits that are passed down from one generation to the next and some of these traits start off as nurture-based ideas. I learned something that helps me to become more successful in living and I might pass that down to my offspring and then eventually it becomes genetically coded?

ROE: The only thing that is passed down from parent to offspring are those things that are coded genetically into the DNA and the things that you learn over the course of a lifetime, you might have a proclivity to learn certain things that are due to the DNA that you have. They could be passed to your offspring, but learned behaviors typically are not going to be passed on, or things that you accumulate during your lifetime. Does that make sense?

FREDERICK: Yeah.

ROE: So, the things that are coded into the DNA, meaning that there is a program that works to build your body from the embryonic through all stages of development. That is what your phenotype is going to emerge as. You really need to think of evolution as occurring, not on the scale of the individual, such as in an individual's lifetime, but as more of a changing in the traits of a population over time through generation after generation of reproductive events following reproductive event, you will see gradual changes in the phenotypic characteristics of the population moving forward.

FREDERICK; So, I know there is this range of scholarship now that is talking about dinosaurs really adapting or evolving at some point from birds. Would they have, at some point in time been covered in feathers? Did this vary by species? What do we think this does in changing the view we have of dinosaurs from film to having a more accurate depiction in our minds?

ROE: A lot of the dinosaurs that we are now discovering with better technology are found to actually have had some form of feather or modification of a scale that resembles a feather. Feathers are hard to preserve in the fossil record because they are a soft structure and generally hard things like bones and teeth are better preserved. But, with better technology and the more fossil finds that we make, we are getting a better record of which animals actually had feathers and there is a whole lot of dinosaurs that we are finding. Several dozen now of species that are known to have had feathers, so we might need to revise how we think the typical dinosaur looked and what their body covering might have been. The first bird-like dinosaur fossil that we found was the archaeopteryx, which was discovered to have lived about 150 million years ago and it is a unique blend of some kind of typical dinosaurian and reptilian traits with some attributes of modern-day birds. So, for instance, the reptilian features that an archaeopteryx had would have been a long, boney tail, as well as a beak, full of teeth, which we know modern-day birds don't have. The last bird fossils that showed evidence of having teeth was about 100 million years ago. So, at some point, this lineage lost the teeth, but the bird features that archaeopteryx has included feathers. Not just feathers, but well-developed, flight-type feathers. They were a flying animal and they had wings and a few other traits that modern-day birds have. They are this transitional form that we look to as an evolutionary biologist to piece together the history of this group as they evolved, or at least some members did, from generation to generation down the line over millions of years, from a reptilian body plan and behavior to what we now recognize as a birdlike lifestyle and body plan.

FREDERICK: Martin, you talked earlier about ways to classify time periods in the past. Talk a little bit more, both of you as scientists, how do we create taxonomies to classify different species, different time periods. How do scientists work through that process?

ROE: Taxonomy is really the study of how we name things; how we ascribe and name a category to help organize the biodiversity that we see. We use the Linnaean system of taxonomy, which is a hierarchical system so you are probably familiar with the terms of kingdom, phylum, class, order, family, genus, and species. So every living thing...

FREDERICK: There is a mnemonic to help you remember that…

FARLEY: There is more than one....

ROE: That's true. So think of these categories like Russian nesting dolls, with the largest of these categories, for instance the kingdom that we started with. Start with the Animal kingdom. Animals are multicellular mobile terra tropes, which means to be in that category, that class, you have to have all of those features to be in the club. That excludes plants, and things that are just single cell. That is the first level of hierarchy and where the dinosaurs, for instance, would fit into. It would include all individuals that have that kind of common set of traits. Then, we go down further. The next category would be phylum. Amongst animals there are about three dozen currently recognized phylum and there would be yet more traits that would be considered to be necessary to be classified in this group to be given that name. Then, we would have a class, order and so on. Classes of modern-day vertebrates would include birds, reptiles, amphibians, and mammals. They would be required to have further yet, more characteristics. Reptiles have epidermal scales, for instance. Birds have feathers. Mammals have hair and mammary glands. So we are getting farther and farther down into a more exclusive group with each of these small dolls that we classify with a name of something. Dinosaurs fit into that of course, as do all living things, and as I mentioned, dinosaurs are reptiles; they are archosaurs, they are diapsids, and so they have some living descendants. They have some extinct relatives as well.

FREDERICK: How do geologists classify things?

FARLEY: Well, in roughly similar ways, but people who deal with fossils have fewer tools than people who deal with living organisms. A big tool now for people who deal with living organisms is to deal with genetic information and with fossils you don't have that. All you have is morphologic information and often, a fairly limited suite of those characters because, as John mentioned, you only have hard part material.

FREDERICK: You know, as a historian, I think of tracing things back in similar and different ways. If we were to take current birds, reptiles, amphibians, and we were to draw millions of years back, would we find direct connections to dinosaur or at least to other specimens who lived while dinosaurs did?

ROE: Well, life is all connected by a branching process of evolution. So, if you go far back enough, we all share a common ancestor. Those connections are there; whether they left a fossil that was convenient enough for us to stumble upon no matter how hard we look, is something that is just a lucky chance event, but the more we look around for them and the more scientists that we train to be doing that and the more methods that we develop to do this better, the greater the chance we are to fill in some of these gaps in the fossil record that could help to elucidate more clearly those transitional forms that do clearly link the dinosaurs leaving modern descendants in greatly modified forms of birds. There are dozens of fossil specimens now, beyond just the archaeopteryx that I mentioned, that are unquestionably high confidence in the connection of these groups.

FREDERICK: All right; final question: from the perspective of both the biologist and the geologist, what is the cumulative effect of dinosaurs and the time that they had on the planet? How should we remember them?

FARLEY: There is no question that, as John mentioned, mammals existed basically as long as dinosaurs did, but dinosaurs played an important role in suppressing, from a competitive point of view, the evolution of mammals. Once dinosaurs went extinct, mammals underwent a big evolutionary radiation, so one of the important effects of dinosaurs was to prevent the broad evolution of mammals for a lengthy period of earth history. That was an important effect of dinosaurs, but, on the other hand, as a paleontologist who works on other kinds of fossils, I can say that all these vertebrates are not a very large part of the biomass and during the age of the dinosaurs a whole bunch of the important phytoplankton that exist today, also diversified and they actually left a big fossil record, too. I mentioned cretaceous is the name for chalk, which is predominately the fossil remains of one particular skeletal material of these phytoplankton and so, from that point of view, it is easy to overstate the importance of dinosaurs.

FREDERICK: So they might just be a small player on a really big stage.

FARLEY: That's right, but they certainly capture people's imagination.

ROE: Yeah, they are just one of many species, or groups of plants and living things that have existed on earth and they happen to have had their time, and at least in the traditional sense they have gone extinct. I agree with Martin's last point in that there is nothing particularly special about their time on earth. They are just another one of these periods of the earth's history that had their day and had the effect of suppressing mammals. They left descendants in the birds, which are really important contributors to ecosystems today. They are really interesting, but I think the biggest effect that dinosaurs have had is kind of the effect that they have had on the scientific process and also inspiring many young scientists by how popular and interesting they are, as large, big reptilian things. There has been a lot of development of methods in science to better make sense of these fossil finds and we can use that to also study the history of the life of other major groups. I know many a scientist who got their start by being fascinated by dinosaurs, and if that is the spark that got them interested in a productive career in any scientific field, I think that is a good legacy to have left for dinosaurs.

FREDERICK: So weep not for the dinosaurs. They came and they left, but they also left some really interesting puzzle pieces that have inspired lots of different scientists to spread out and to branch out into lots of different areas. This has been a really fun discussion. Thank you both for being here and thanks to all of you all for listening to 30 Brave Minutes.

Today's podcast was produced by Richard Gay and transcribed by Janet Gentes. Theme music created by Reilly Morton. Thanks for listening to 30 Brave Minutes and go Braves!