Ask A Biologist Vol 082 (Guest Bruce Archibald)

Time Traveling Paleoentomologist

If you could travel back in time what would you find 50 million years ago? What was the climate like and what plants and animals were crawling, walking, and flying around? Paleoentomologist **Bruce Archibald** takes Dr. Biology back in time to explore the planet during the Eocene Epoch where things were a bit different than today – including a giant flying ant that would make anyone look twice.

Transcript

Dr. Biology: This is "Ask a Biologist," a program about the living world, and I'm Dr. Biology. Today we have the opportunity to do some time traveling. In this case we're traveling back in time, and not just for a short trip. We're going to be going back as far as 50 million years.

What's the occasion for the journey? Well, my guest has been exploring the world around 50 million years ago. He's been learning about insects living at that time. Oh, and by the way, scientists call that period of time the Eocene Epoch.

While he's been back there, what's he been doing? He's been studying tiny insects. Some of which are smaller than the nail on your little finger. He also has an interesting story about a giant insect. Well, giant by our standards. You might be asking how large? Well, how about an ant that's five centimeters long, which is about two inches, or using our hand analogy the size of an adult thumb. Along with his work with insects, he's been studying the climate these animals lived in and their diversity. In other words, how many different kinds of species of insects lived during the Eocene Epic?

My guest today is Bruce Archibald. He's a paleoentomologist in the Department of Biological Sciences at Simon Fraser University. In case paleoentomology is new to you, paleo means old or ancient and entomology is the study of insects. So Bruce spends his time studying ancient insects and the world they lived in.

Today we learn how this paleoentomologist travels back in time and what he's discovered. Welcome to "Ask A Biologist" Bruce Archibald and thank you for taking the time to visit with me.

Bruce Archibald: Thank you Dr. Biology.

Dr. Biology: Let's get started with just a couple words just so that we have some of our vocabulary down. First is biodiversity and the reason I bring it up is you hear it a lot. But I think it's good to know a little bit more of what we're saying. So what is biodiversity and why do biologists talk so much about it?

Bruce: Wow, well there's a lot of different ways of defining it. I'm looking at it in terms of species richness in a community and that is how many species are you packing together. But there's a lot of different ways that people define biodiversity depending on the kinds of questions they're asking. Species richness in a community is sort of the thumbnail sketch of how I'm looking at it.

Dr. Biology: Right, so it's not just the number of species but the number of different kinds of species.

Bruce: Mm-hmm.

Dr. Biology: Comes up because if we talk about the tropics, it's not uncommon for them to say it's a very rich environment. It's very biodiverse. Then if you move further north you end up with less biodiversity.

Bruce: Absolutely, yup.

Dr. Biology: That's part of the reason that that term gets used. I agree that that's not necessarily the only reason. The other thing is I talked about us traveling back in time, but I want to be really more accurate. Do you have a time machine?

Bruce: Well, I've got the fossil record.

Dr. Biology: Exactly. You do get to go back in time by studying those fossils.

Bruce: You bet. Yeah.

Dr. Biology: That's the next best thing to a time machine.

Bruce: Absolutely.

Dr. Biology: And in some cases, maybe even easier because they don't run away, right?

Bruce: That's right. [laughs] They don't.

Dr. Biology: Let's talk a little bit about what is a fossil and how are they made.

Bruce: Fossils, the way I define them and look at them, are the remains of animals and plants or fungi. Anything that was living, or their works that are found from a long time ago.

Now, their works might mean their track ways or the nest of a bee that might be found as a fossil. Or if you find a fossil leaf and it's all torn up from chewing marks, that might tell you a lot about the insects that were feeding there at that time . The fossil's not only the leaf but the fossil is the trace of the behavior left behind by those insects, as well.

The word fossil can cover a wide range of things which tell you about life in the past.

Dr. Biology: And how they're made. How do fossils get made?

Bruce: There are a lot of different ways in which fossils are made. For example, a lot of the fossils that I look at, they were in a forest surrounding a lake. The leaves and the insects maybe blew out or flew out and landed on the surface. Then floated for a short while on the surface tension. Then sank down through the water column to the mud below.

Each year a little bit more of this dust-like mud would settle over them. And eventually the lake basin fills up with sediment. Then that gets compressed and that mud squished and turned into stone. That's one way that fossils are made.

Fossils can also be made in other environments, in a marine and oceanic setting or in amber for example, which is the resin of trees. They get stuck in there like a sticky trap and covered over by the resin. Then that winds up in maybe a coal swamp where the trees get turned into coal.

There's a lot of different ways in which life can be preserved from the past. Like I say track ways, for example. Walking along the muddy river bank. That muddy river bank is filled in with sediment and then exposed millions of years later.

Dr. Biology: What makes a good fossil?

Bruce: Well, once again, it depends on the questions you want to ask. A good fossil leaf for a paleobotonist might be very complete and whole. A good fossil leaf for someone who studies insect behavior might be one that's all eaten up. That would be a good one for that person.

For me, I look at insects body fossils, that is the actual body insects themselves. What I want to see is something that's clearly preserved so that I can see the minute details is as complete as possible. Lot of fossils are mushed up, to use the scientific term, or incomplete because of the way the rocks split or whatever.

You often need to see a lot of the structures, defined structures to understand what that insect was. So, a good fossil for me has got enough for me to really tell who it was and what it's related to today.

Dr. Biology: That's brings me to a really great point. That's how much detail can be captured in a fossil. Let's go back to basically something that's stone. We won't do the amber. What kind of resolution can you get compared to film or a really good digital camera?

Bruce: You can get amazingly good fossil insects. In fact, modern entomologists are often shocked when I show them some of the fossils of insects because they can't understand how good these can be. I can get tiny wasps that are maybe four to five millimeters long in which I can look down to the wings and see the tiny hairs on the wing membranes.

Dr. Biology: Would it rival film?

Bruce: Yeah, some of the insects that I'm looking at is really limited by the lenses in the microscopes. There's more detail there than I can see with the gear that I've got to look at them.

Dr. Biology: So optically, we can even get to the level of resolution that fossils have?

Bruce: You bet, and gear will get better and better, and we will be able to know more and more. That's why we put these things away in drawers and maybe in a hundred years time someone has some super space age equipment and to be able to do a lot more than I could do with them today.

Dr. Biology: Ah, the future paleobotanist or...

[laughter]

Dr. Biology: ...the paleoentomologist.

Bruce: That's right.

Dr. Biology: This is actually a fun topic because a lot of people have seen fossils. They've seen amber on, for example Jurassic Park as a classic where they see the amber.

Bruce: Yes, absolutely.

Dr. Biology: Then stone, it's not unusual to go out to a trade shows and other places where people actually sell them as pieces of art. There are actually beautiful pieces out there. The other place you see them, as you mentioned in the drawers, tucked away in the natural history museums.

A lot of times you don't even get to see them because maybe they're not the pristine beautiful piece the whole specimen that you get to see, but they have a lot of information in them. What I'm curious about is, why are museum fossil collection so important?

Bruce: Oh, wow! Well, they're super important. For example, there's not that many people who look at fossil insects like myself. Some of these fossils sites their a lot more paleobotanists if you look at the fossil plants. Paleobotanists will go to a site and collect these leaves and other plant material. And then they'll see, "Oh, there's much insects here. Well, I'll just taken them aside in the box."

Those going on a museum collection, they might sit there for 50 years or 80 years or a hundred years until the right pair of eyes come along and sees them. As long as the're safely and carefully stored in the museum with the right database, somebody will come along one of these days and say, "Ah, I know what that is." I'm able to work on that.

Dr. Biology: I find that really interesting, because I think some of your work, you've even gone back to some early collections that they gather just much information at that time, and then you've revisited it.

Bruce: Absolutely.

Dr. Biology: It reiterates the fact that it's not always that we're changing the answers or what we know. We're just getting better tools to understand better what we have in front of us.

Bruce: That's right. Sometime we do change the answers because we have better equipment to ask the questions more finely. Of course, in science, everything is the best knowledge we've got at that time. Best answers we have available. Sometimes, we can get better answers either by theoretical of answers., people understood things better, or sometimes just the equipment. It gets better.

Back in Galileo's time, he could see a certain amount with his telescopes but now we've got the Hubble, and our answers are more precise. We could do more stuff.

Dr. Biology: We were just talking about microscopes as well. Robert Hook and Anton Van Leeuwenhuek. It was interesting because because that's a fun story in itself. You could see then, you could see cells, but you couldn't see inside cells. Now, we've got new, you can get into the organelles. Within the organelles, you can get into the DNA, and it goes on and on. All with better instruments.

Bruce: I should just interject this here for a second. We were talking about mosquitoes, and amber, and the whole "Jurassic Park" thing. That actually happened in a certain sense. But now, I'm talking about a shale fossil, fossil in rock.

That was a friend of mine. Dale Greenwalt, who works at the Smithsonian, was looking at shales about the same age as I'm looking at in British Columbia, a little bit younger. In Montana, he found mosquitoes there. Those shales are, I believe, about 47 million years old.

He is a geochemist, so he was able to look at these fossil mosquitoes and do some analysis and find the iron compound in this mosquito's gut was a blood meal. He was able to do that and get to that level to see this ancient mosquito's last meal.

Dr. Biology: Wow. Let's go back to our museums.

Bruce: Yes.

Dr. Biology: Turns out that not uncommon that you go and visit other museums and look at their collections.

Bruce: Sure.

Dr. Biology: We're going to talk about one of your finds, and that is by today's standards, a giant ant.

Bruce: [laughs] Yeah. You bet it was giant.

Dr. Biology: It's not like, there's a 1954 movie called "Them," where it's these giants ants. I mean, they're...

Bruce: The size of a tank or something.

Dr. Biology: Yeah, size of a tank. These aren't like that, but it's still an amazing find. There's really is an interesting story with these ants. Can we talk a little bit about them?

Bruce: As you mentioned, I found this specimen in a museum drawer. I was visiting Denver Museum on Nature and Science. I don't know it's formal name, Culture, Nature and Science or something.

The paleobotanist there, Kirk Johnson at that time. He said, "Yeah, we got this great, big fossil insect. We want you to take a look at it," and I, "That sounds pretty good." I went down and I looked at it. I immediately knew, "Oh, I know what this is." It was one of these giant ants.

I knew it because they had been found in Germany. They were pretty famous from Germany. There had been a wing of a ant related to that found from North America, but it was a smaller one. It was a small relative, but none of these giant ones before. The wings are also known from Britain, I believe, from the UK.

Anyway, I saw this and I thought, "Oh my God. OK. Here are these ants have come over from Germany at some point, or which way we don't know. From here to Germany, or from Germany to here." I recognized this ant right off the bat.

Dr. Biology: Yet, tell me a little bit about what the ant would look like today...

Bruce: Sure.

Dr. Biology: ...if you got to see it.

Bruce: In fact, if you took a little bird, and you plucked its feathers, and set it next to this ant, this ant would be size of that little wren or maybe a little chubbier. The queen ants have wings. They're flying ants. Flying along, they would have been very impressive.

I named this ant "Titanomyrma lubei." The name lubei was named after Mr. Lube, finder of the fossil. But, Titanomyrma was a fun name. "Myrma" just means ant, and "Titano" means titan of the ants.

I found out recently that it was actually used in a video game. But in that game, they show the ant as being the size of a dog, which it's fun.

Dr. Biology: We're talking 50 million years ago. If we think about today, how does an ant get from Germany to North America today? It's different than what could've happened back 50...

Bruce: You bet. I should just mention also that I found it in a drawer of a Denver museum, but it was unearthed in Wyoming. That was where the fossil was found. Once again, it was roughly 50 million or so years ago. That turned out to be a very interesting story about how the distribution changes of animals and plants.

At that time, that's called the Eocene Epoch, is the name of that time, the early part of the Eocene Epoch, the North America and Europe was connected by land. I'm sure your listeners may be aware that continents move by tectonic forces, there's continental drift. The Atlantic Ocean has been opening up. Europe and North America are moving away from each other.

That's a good fun fact. If you take your thumbs and put them so that the pointy ends of your thumbs are apart from each other, the two thumbnails are growing away from each other at about the same rate that Europe and North America are separating from each other. Ain't that a good fun fact?

Dr. Biology: Yeah.

Bruce: [laughs] Anyway, back then, 50 million years ago, Europe and North America were still connected. But, they were connected through Greenland. You could walk from here in Arizona all the way to Spain, or whatever, through forest all without getting your feet wet.

There was this also a time when there was low sea level around the world for a bunch of other geologic reasons. You had low sea level. The continents closer together formed these land bridges.

Actually, that didn't last long, geologically speaking. It was an interval of time when we had this connection available both through the closest of the continents and the lowered sea level.

Dr. Biology: But we have a tendency, when we think of time these days, we think seconds, minutes, years. In this case, it's how long for this land bridge?

Bruce: Oh boy, honest, it could have been 10 million years of so. An instant in time. [laughs]

Dr. Biology: Geologic time.

Bruce: That's right, paleontologically speaking. Like I say, forest across of the Arctic, and probably forest right up to the Arctic Ocean at that time. There was no ice sheets or harsh winters at that time.

There was all of these plants and animals able to extend their ranges across the pole and make a common range between Europe and North America at that time. A lot of things that we see today, kinds of trees or those sorts of things, which are uncommon between the continents may have at that time expanded their ranges in that way.

It was still temperate. Things that lived in hotter climates would have found it difficult to cross that northern land bridge, because the climate may have been similar to that of say, I don't know, Portland, Oregon today or so. If you like to live in a tropical climate like Brazil, you might find it hard to migrate through an area that has the climate like Portland.

This big ant tells a pretty interesting story about how plants and animals are arranged between the continents today. The different kinds with different climate tolerances may be arranged between the continents.

Dr. Biology: All right. Let's switch gears just a bit. You have another project. It's also with fossils. It's again around the same period of time, about 50 million years ago. It has to deal with seasons, temperatures, and biodiversity. Can you tell me a little bit about what you've learned?

Bruce: What I looked at in the project that I did is I looked at climate and how climate might affect biodiversity as it changes from the topics into the temperate zone into higher latitudes.

As you mentioned, there's two climatic factors that really differ. One is the amount of sunlight and heat. There is greater in the tropics. The other is that it has very low temperature difference between summer and winter.

If you're down in Costa Rica for example, the average yearly temperature is maybe about 26 degrees, 25, 26 degrees. That's really hot. It's hot there all year round.

Dr. Biology: In Fahrenheit, that's around 78 degrees.

Bruce: All right. Your coldest month average temperature is only about a degree below that. Your warmest month, a degree above that. Your fluctuation from the coldest to your warmest month is only a couple of degrees.

Dr. Biology: Even in Fahrenheit, that's what, 75 to 79 or something like that.

Bruce: It's not a whole lot.

Dr. Biology: No.

Bruce: But, you get up into the temperate zone here, you're going to have these wild fluctuations. Maybe 28, 30 degrees or so centigrade.

Dr. Biology: Forty-eight degrees, I can tell you right now when you do that.

Bruce: [laughs]

Dr. Biology: If you do 20 degrees, you're going to be around 68 degrees Fahrenheit. Then, how cold maybe?

Bruce: It depends on where you are in the Northern hemisphere, but you might get the coldest month mean temperature about minus seven or so.

Dr. Biology: Right, that's 19 degrees Fahrenheit.

Bruce: OK. You need a coat, you definitely do. By mean temperature in that coldest month, the average temperature each day can be colder or hotter. You can have drop down to pretty cold days within that cold month.

Dr. Biology: Certainly below freezing.

Bruce: You bet. The point is this that we have this wild fluctuation between summer and winter. It gets stronger and stronger as you move from the equator away into the north or to the south.

Both of these things change. As you mentioned, the variables. The heat and light coming in is one variable. How does that affect biodiversity? Or, as temperature seasonality increases as your biodiversity drops. Is that the cause?

Now, there's various explanations. For example, the heat and light hypothesis, idea might be that you have this luxuriant growth, so you have big populations. You can have big populations of things that would be rare. That allows for lots of different species to live together. There's one explanation.

Or, the seasonality explanation might be that when you get into northern areas, you have this wide range between summer and winter. You want more generalists. You want fewer kinds of things, but those things that are there can live in lots of different types of environment.

That means less species, even if you've got lots of individuals less species together. Those are the types of explanations people have. It's really hard to separate. It's really hard to figure out which might be the case.

We go to the ancient world where we may be able to find an answers and break this logjam and find a way of examining this. That's what I did for this project. I sampled insects in Costa Rica, in a lowland tropical jungle today. I sample insects is Massachusetts, in a temperate zone forest by a lake, and these are modern insects.

Then I sampled fossil insect community in British Columbia, Canada. This fossil community lived at a time in a upland, in this cool upland, where the average yearly temperature is about the same as Seattle today, or Portland, or Vancouver.

But the seasonality was extremely low. Very, very mild winters. You maybe didn't need a sweater. Of course that doesn't mean much sitting here in Arizona to say you didn't need a sweater, but if you have average temperature like Vancouver to say, "You didn't need a sweater in the winter," that's saying something.

What I wanted to know is, was the biodiversity of these insects like it is today in the temperate zone? The common factor would be the coolness of the fossil site and the modern temperate zone. Or, was the biodiversity high like it is in the modern tropics? Then the common factor would be the low seasonality. The fact that the summer and the winter are pretty different.

It was by having this third sample site that I could try and understand which of these two variables is associated with change and biodiversity.

Dr. Biology: The answer?

Bruce: To make a long story short, this is a big, long project.

Dr. Biology: How many years did you spend on this?

Bruce: That was about seven years, I think.

Dr. Biology: I just want people to realize that you just didn't go out. It was something over night.

Bruce: I had to collect massive amounts of insects in all of these places. I'd assigned them all to species level and work them up. It was a very fun project, but it was also a long time. That's science. [laughs]

What you're getting at the answer here is that the biodiversity in this temperate, coolish upland of ancient British Columbia was similar to that of a modern lowland tropical rain forest.

Dr. Biology: There were a lot of different kinds of species.

Bruce: It was tremendous numbers of species packed into these communities. This indicates this change in biodiversity we see across the globe today maybe associated more with stability, temperature seasonality, than with the heat and light of the tropics.

Dr. Biology: The wider the swing between hot and cold in a particular location is going to have an impact on the number of species that you'll be able to have in that location.

Bruce: That's right. How it is that living things respond to this forcing factor, this triggering mechanism? We don't yet know why it might be that seasonality could affect diversity in that way. That's another project for one of your listeners to go to grad school and figure out. Seriously, there's a lot of interesting projects out there still undone. That's one of them.

Also, I love to do everything twice. By that, I mean we want to do something then confirm it with another angle. Not only did I take the insect samples and specimens, but also leaf samples.

Working with a paleobotanist, Dr. David Greenwood out of Brandon, Manitoba. For part of this project, we looked at the broad-leaf tree diversity and found that that actually was more similar to the tropical parts of Queensland, Australia than it is to Massachusetts. This was the second confirming aspect of this study. We looked at plants as well.

Dr. Biology: I love the fact that you left something for the future paleobotanist or paleoentomologist to do.

Bruce: [laughs] Yes.

Dr. Biology: That leads me into a part of the show that I love doing with all my scientists. We have three questions.

Bruce: OK. You have not prepped me on this.

Dr. Biology: I never prep my scientists.

Bruce: [laughs]

Dr. Biology: I want you to think on your feet. The first one is, when did you first know you wanted to be a biologist, or if you all ready knew you're going to be an entomologist or paleoentomologist. What was the "aha" moment?

Bruce: I certainly liked these things when I was little. I was very interested in insects, animals and plants, but in a general way. I didn't have this particular liking for one over the other. I was very fortunate in having parents who read books to me when I was really little about nature and the natural world. That was a really good thing.

When I was a little kid, I liked to watch nature shows, and that kind of stuff. I liked to get out in the woods. But, I put that in the background until I was older, until I was grown up. Then I started to become more and more interested by reading books on fossils. I decided to go out looking for fossils near where I lived in Vancouver.

Sure enough, I found a variety of fossil insects. I thought,"These are really great." I thought, "Maybe there's got to be a lot of things you could tell from these." I took them around to local universities.

I was very much encouraged by the people there. They said, "Well, maybe this is something you should follow up on." It was very nice to get that encouragement, because I didn't believe I could do it.

Part of it was realizing that there was very little known about these fossil insects, and that there was big opportunity there to do the work and to figure out new things. That was one of the things that surprised me getting into science all together.

I thought pretty well everything was known, or a lot more was known. The more I got into it, the more I realized that we're still in the golden age of discovery. That there is a lot of great fundamental questions out there to approach and to try and work on. That is not going to go away anytime soon.

Dr. Biology: How old were you when you went out on your first fossil digs or hunt?

Bruce: Well, I was grown-up. Let's see. I might have been like 40 years old.

Dr. Biology: You came back to it definitely later on.

Bruce: I came back to it as a grown-up, absolutely. I spent many years away from it. There were a lot of people saying, "Oh, you can't do that." But, they were wrong.

[laughter]

Dr. Biology: I'm glad you decided to come back and do it. But now, I'm going to take it all away.

Bruce: OK.

Dr. Biology: You can't be a biologist, and so all the forms of being a biologist. Most of my biologists love to teach, so I'm going to take the teaching away just so you can't slide into that. This is where you get to stretch. If you could do anything, what would you be? What would you do?

Bruce: Wow, I'd love to be a cook. I don't know that I would be that good at it, but you could always try. I think to me, cooking is about the most creative thing that you can do and has this immediacy because you eat it up and it's gone.

People who are really good cooks amaze me, because they can go into a fridge and just see what's there. They turn out something wonderful, because they've got that ability to put it together in that creative mind. I admire that.

Dr. Biology: It's an important point. I think scientists that are creative are also the most successful.

Bruce: It shares the aspect that what you really need, I think, to be a good scientist is the same. That is the ability to see the connection between things that other people might think are unrelated.

You see one thing over here, and one thing over there, and you think, "Ah. What if we combine them," or, "Oh. What if we use that technique?" It's the ability to make those connections.

Dr. Biology: The last question. This is a perfect one for you.

Bruce: [laughs] All right.

Dr. Biology: The reason why is you came to your current career later in life, right?

Bruce: Mm-hmm, yeah.

Dr. Biology: I always ask, what advice would you have for our future biologists, or paleontologists, or entomologists. In your case, someone maybe who's been doing it as a hobby. They did it when they are younger. Now they think, "I'd like to do that for my..."

Bruce: Full-time.

Dr. Biology: Yeah.

Bruce: What advice would I give? The advice that I would give is do the thing that excites you the most. The reason I say that is because going to university is a lot of hard work. If you enjoy it, if you like it, if you're excited by your goal, you won't mind that.

You'll find that hard work also pretty fun, because you're flexing your muscles. It's like going to the gym, but you've got to put in that effort. If you're not really excited, it's not going to work. You're not going to have that gasoline within you to make you go. My advice would be to pick what really excites you, what really makes you excited to do.

Dr. Biology: Bruce Archibald, thank you very much for visiting with me today.

Bruce: Thank you, Dr. Biology. It's been a pleasure.

Dr. Biology: You've been listening to Ask a Biologist. My guest has been Bruce Archibald, paleoentomologist in the Department of Biological Sciences at Simon Fraser University. Bruce has been here visiting ASU to give a talk at our new natural history collections facility.

If you want to learn more about giant insects, journey on over to our story on prehistoric insects called "Big, Big Bugs." This is where you'll get to learn about insects that lived over 300 million years ago. The address to the story is pretty long, so here's the easy way to do it. Just do a search on "prehistoric insects," then type "ask a biologist" with it. We'll be a number one hit.

The Ask a Biologist podcast is produced on the campus of Arizona State University, and is recorded in the Grass Roots Studio, housed in the School of Life Science, which is an academic unit of the College of Liberal Arts and Sciences.

Remember, even though our program is not broadcast live, you could still send us your questions about biology using our companion website. The address is askabiologist.asu.edu, or you can just google the words "Ask a Biologist." I'm Dr. Biology.

Transcription by CastingWords