Video Transcript - The Evolution of Agriculture in Ants

Maggy Benson: You have probably heard of ant farms. However, have you heard of ant farmers? How have ants evolved to actually grow and harvest their own food? We will find out today when we speak with entomologist Dr. Ted Schultz. I should grab [00:00:30] some lunch while I am out here. Wow!

Maggy Benson: [00:01:00] welcome everyone. We are live from Q?rius to bring you another episode of Smithsonian Science How? With us today is Smithsonian entomologist Dr. Ted Schultz to talk to us about farming and ants. Thank you so much for joining us, Ted.

Ted Schultz: It's really great to be here.

Maggy Benson: So Ted, we're really excited to learn about farming and ants, it's something that I don't know how many people know that ants actually farm. But before we explore that big idea, we really want to know why ants are important in the first [00:01:30] place. I'm sure many of our viewers think that they're just household pests. So let's ask our viewers what they think.

Maggy Benson: Tell us why you think ants are important. Are they important because they have High bio diversity? Live a long time? Are really abundant? Provide ecosystem services?, or Are super independent? Tell us what you think by picking the correct answer in the poll that appears to the right of your video screen.

Maggy Benson: [00:02:00] So Ted, we're both watching the polls come in and we see that 87 percent of our viewers think that they provide ecosystem services. How'd they do?

Ted Schultz: Well that's a really good answer and it's true. There are a lot of species of ants. There's something like 14,000 described, another, we think there's 20,000 altogether. There are key numbers of most ecosystems, [00:02:30] and if you went into a particular ecosystem and you had the magical power to remove all the ants, the ecosystem would fall apart. They have intimate relationships with lots of different plants and animals and insects.

Maggy Benson: And they're a diverse group too. I'm seeing a lot of different types of ants on the screen here.

Ted Schultz: Oh yeah, they're amazingly diverse. Twenty thousand species that do all kinds of different things.

Maggy Benson: So what makes them so successful?

Ted Schultz: Well that's a good question and [00:03:00] I think the key answer is they're social organisms. There are other social organisms. Some bees are social. Some

wasps are social. All termites are social. There's even social naked mole rats. But ants are arguably the most successful social organisms because they have the most species.

Maggy Benson: Is there a special word for the super social behavior?

Ted Schultz: Eusociality, which means true sociality.

Maggy Benson: So what's unique about the social behavior of ants, [00:03:30] especially when you compare them to other nonsocial animals?

Ted Schultz: Well, all social organisms have a division of reproductive labor where you have workers that don't reproduce and you have a queen, or in the case of termites, a queen and a king, that do reproduce, but what makes ants special is that in many lineages of ants, they've taken sociality to the next level.

Maggy Benson: What does that mean?

Ted Schultz: Well, they all go through complete [00:04:00] metamorphosis, but when-

Maggy Benson: As we're seeing right here?

Ted Schultz: As we see in this image. But the queen lays eggs. Some of them can develop into workers and they can develop into workers that all look the same in the primitive ants, or they can develop into workers that are normal sized and soldier workers, and in other cases, they can develop into a lot of different sized workers.

Maggy Benson: Do you have an example that you can show us here?

Ted Schultz: Yeah, I've got a [00:04:30] tray of leaf-cutter ants, all from the same colony.

Maggy Benson: Those are all from the same colony, so those are all really-

Ted Schultz: And this is the range of the sizes of workers from very tiny to big soldiers, and in the middle is the queen and a male.

Maggy Benson: Wow, she's huge!

Ted Schultz: Yeah, the queens are extremely large.

Maggy Benson: So the queen, I mean, is that a queen in this picture too?

Ted Schultz: Yeah, what you're seeing in this picture is a fungus garden that has [00:05:00] lots of worker ants on it, and over on the right, the queen, who is much larger than even the largest soldier ant in the colony.

Maggy Benson: So soldier ants, what's their role in the colony?

Ted Schultz: Well, as you might expect from the name, in a lot of ant species, the soldiers are the defenders. So if I'm down in the tropics and I'm digging up a leaf-cutter nest, for instance, all the soldiers, which have big heads and big mandibles, will converge on that spot like white blood cells in [00:05:30] an organism and attack me.

Maggy Benson: Like this? I wouldn't want to meet him if he was my size.

Ted Schultz: Yeah, that's a very aggressive ant. Other soldiers I mean are wimps and do other jobs. They, in some ants, the soldiers crush seeds and run away when intruders come.

Maggy Benson: So we're seeing, I think ant intruding, what is this, other colonies?

Ted Schultz: So in the cases where soldier are defending, they defend against [00:06:00] me, they defend against ant eaters. But they also defend, as you can see here, they can defend against army ants. The way army ants make their living, in many cases, is (that) they go into nests. They take the babies, the larvae and the pupae, and they take them away and they eat them. Some ants have taken this behavior, this brood robbing behavior to the next level and they take away pupae as you see in this picture, that pupae…

Maggy Benson: That white.

Ted Schultz: That cocoon. And they take them back to the nest, their nest, but they [00:06:30] don't eat them. Instead, they raise them up and they use them as slaves.

Maggy Benson: Oh my goodness. Wow, that's really sophisticated behavior.

Ted Schultz: It's very sophisticated.

Maggy Benson: That's not something I expected from something that I used to think were really just household pests. So, where does farming come in? This is your specialty. Do all ants farm?

Ted Schultz: No.

Maggy Benson: Grow their own food?

Ted Schultz: No, only a small subset of ants farm and those are the ants that I mostly study. All ants are [00:07:00] social, and because they're basically kind of like super organisms; they divide up the work, they can do some very complicated things, like raid other nests or take slaves. But I think the most complicated thing that

ants do, or certainly one of the most complicated, is they grow gardens for food, they are true farmers.

Maggy Benson: So you mentioned leaf-cutter ants. Are leaf-cutter ants part of that fungus-farming group?

Ted Schultz: Yeah, leaf-cutter ants [00:07:30] are some of the most highly evolved of fungus-farming ants. You can see on the screen right now leaf-cutter ants cutting up leaves. But also in the fungus-farming ants, there are primitive fungus farmers that don't cut leaves.

Maggy Benson: You showed me specifically how a leaf-cutter colony operates earlier this week in your ant lab. Let's actually have a look at that and show our viewers.

Maggy Benson: So this is really, really cool. What is it?

Ted Schultz: [00:08:00] Well what you're looking at here is one of my pet leaf-cutter colonies. Each of these plastic boxes is a chamber. Most of the chambers are filled with fungus gardens, but these two chambers up here are foraging chambers.

Maggy Benson: They are really busy.

Ted Schultz: We've just fed them some leaves, so they're actively cutting up the leaves and carrying through these tubes to the different fungus gardens. And when they get those cut up leaves to the fungus garden, they take them in, they cut them up [00:08:30] into tiny, tiny pieces so that ultimately what's left is kind of a leaf mulch. Then they add that leaf mulch to the edge of the growing fungus garden.

Maggy Benson: What do they do with the fungus?

Ted Schultz: Well they eat it. Ants absolutely need the fungus for survival. If they didn't have the fungus, they would die. It's their sole source of food for the adults and the larvae. All fungus-growing ants depend on their garden fungi for food.

Maggy Benson: This is an incredible relationship here between the leaf-cutters and the [00:09:00] fungus. Thanks so much for sharing this, Ted.

Ted Schultz: Sure.

Maggy Benson: Ted, that was really neat to be in your ant lab and see that happening and we're actually seeing it here now on the set of Science How?. These guys are really processing all of those leaves so quickly; I can see them hard at work. How much vegetation can they actually go through?

Ted Schultz: Well, although this may be hard to believe, in South America, leaf-cutter colonies are basically the ecological equivalent of a large herbivorous [00:09:30] mammal.

Maggy Benson: Like a cow?

Ted Schultz: Like a cow. So if you were to, for instance, take out, if you could take out all the ants in that colony and weigh them, they would weigh as much as maybe a cow. If you could measure how much vegetation, fresh vegetation they're harvesting every day, (that) would be as much as a cow eats. They also live a very long time. They can become over 15 years old.

Maggy Benson: All right, let's get to some of our student questions. We have a lot of them coming in. This question [00:10:00] comes in, well they're going so fast, they're going off my screen. So this one comes from Canyon Ridge. What is a leaf-cutter ant? Can you describe one of them?

Ted Schultz: Yeah, it's a fungus-farming ant and not all fungus-farming ants are leaf-cutters, but in particular, it harvests fresh vegetation, in some cases leaves, in other cases grasses, depending on the species and feeds those to its fungus, it grows the fungus [00:10:30] on that fresh plant material.

Maggy Benson: So this question comes in by video, so let's have a look.

Daniel: Hi I'm Daniel and I was wondering how ants are more social than humans?

Ted Schultz: Well that's a really good question. Humans are social. We live together in cooperative social groups just like ants and we can live together in extended family groups and our offspring, our sons and daughters can stick around even to the age of 30 or more and just help us [00:11:00] out with raising maybe their younger brothers and sisters. That's very much like ants. The thing about ants is, the workers do not have the option of leaving and starting their own families, they are incapable of reproducing themselves, so the queen reproduces, the workers help and that's different from humans.

Maggy Benson: Great question, Daniel. This question comes from Gavin from Southeastern Academy. What happens to the worker soldier ants when the queen dies?

Ted Schultz: [00:11:30] Well what happens in most cases, when the queen dies, the colony dies. The queen is essential for the survival of the colony.

Maggy Benson: Great question. This one is coming in from Kyle and Parker. What climate do ants mostly live in?

Ted Schultz: Well the largest number of species is by far in equatorial regions so there's lots and lots and lots of species in Africa, Asia, South America, [00:12:00] Australia,

in the humid tropics, but ants do spread north and south into the temperate zones, so ants are important players in almost all ecosystems.

Maggy Benson: Ted, we're looking right here at some of your study sites. I know you were recently in Brazil and Paraguay. Where else do you do your research and what do you do?

Ted Schultz: So because fungus-farming ants are all in the new world and because they are largely [00:12:30] in the South American tropics and Central American tropics, I spend a lot of time in South America. I've been in many South American countries, particularly Brazil, and I was recently in Paraguay. Surprisingly even in the fungus-farming ants, almost 50% of them are known only from one collection of specimens that are in a museum somewhere. We know nothing of their biology. So I spent a lot of time trying to learn more about the biology of these species.

Maggy Benson: [00:13:00] So you're actually looking for living ants to be able to better understand the biology.

Ted Schultz: I am and I spend a lot of time locating nests. In these primitive small fungus-growing ants, the nests are very small and very hard to find, and then I spent a lot of time digging up the nests and collecting the fungus gardens and the ants.

Maggy Benson: Very interesting. I want to hear more about what you want to learn from this, but I think it's another great opportunity to ask our viewers what they think you can learn from studying living ants. Viewers, [00:13:30] here's another opportunity to tell us what you think. What do living ants show you? Social behavior? Personalities of ants? Pest control options? or Evolutionary patterns? You can respond using the window that appears to the right of your video screen.

Maggy Benson: Ted, it's really fun watching these results come in. It looks like we have a smattering [00:14:00] of answers, but most people think social behavior and evolutionary patterns. What do you find?

Ted Schultz: Well both of those are absolutely true. Good answers, really good answers. When I go out into nature and I study these ants, I ask questions like, how big are the colonies? Are the workers all the same size or do they have regular workers and soldiers or maybe even other sized ants? What's [00:14:30] the nest architecture? How many chambers do they have? What are they bringing in that they're planting their fungus on? And all of those, by studying these modern ants, I can understand evolutionary patterns that have occurred over time.

Maggy Benson: So over time, how long are we talking here? How long have ants been farming?

Ted Schultz: Based on all the evidence, we know they've been farming for about 55 million years.

Maggy Benson: 55 million years?

Ted Schultz: Yeah.

Maggy Benson: [00:15:00] That's a really long time.

Ted Schultz: Yeah, and compared to humans who have been farming for maybe 10,000 to 12,000 years. Here's an example on the screen right now of a fungus garden of a primitive fungus-growing ant. This particular species likes to hang the fungus garden from the ceiling.

Maggy Benson: Oh wow, so that looks a lot different from the garden that we saw in your lab.

Ted Schultz: Yeah, it is different, yeah.

Maggy Benson: So what kind of evidence do you have that actually tells you that they have been farming for 55 million years? [00:15:30] Is there anything in the fossil record?

Ted Schultz: Yeah, I mean, surprisingly, there are a lot of ways that allow us to reconstruct the past. The best thing would be a time machine. Unfortunately, we haven't invented time machines yet. I'm first in line for when they do.

Maggy Benson: I'll be second.

Ted Schultz: But there are fossils, so there are a lot of fossils of ants but for fungus-farming ants, there's only fossils in Dominican amber.

Maggy Benson: [00:16:00] Is that what we're seeing here?

Ted Schultz: Yeah, so this is an example of two pieces of Dominican amber and as you can see, those pieces are very small.

Maggy Benson: So teeny, I mean that's a quarter for (scale) -

Ted Schultz: And even smaller are the ants inside of them. But I can look, that's what one of those ants looks like, I can look back in time by looking into that piece of amber under a microscope.

Maggy Benson: So how old is that amber?

Ted Schultz: Well the amber is unfortunately only about 15 million years old, which sounds like a lot, but the fungus-growing ants are 55 million [00:16:30] years old, so we have to rely on other sources of evidence to understand what happened all that time ago.

Maggy Benson: What evidence is that?

Ted Schultz: Well we spend a lot of time constructing phylogenies. These are evolutionary trees or family trees of insects and ants. This on the screen is a family tree of phylogeny of all insects. In addition, if you look down at the bottom most part, you see that beetles and moths and butterflies [00:17:00] are each other's closest relatives. They are more closely related to each other than they are to ants, bees, and wasps. Therefore, as you move to the left on this tree, you are moving back in time and you are looking at their shared common ancestors, and that shared common ancestor of all three of those groups must have evolved complete metamorphosis. This is metamorphosis where you go through a larva, a pupa, and an adult, which other insects do not [00:17:30] have.

Maggy Benson: So you are really taking the DNA from living species that are on earth today and you are putting them on a family tree to better understand their evolution through time.

Ted Schultz: Yeah, we're using DNA sequences and computer algorithms to construct family trees of species.

Maggy Benson: So what does the family tree for fungus-farming ants look like?

Ted Schultz: It looks like this, so in this ... This is a phylogeny for fungus-farming ants. Moving to the left, you're going back in time. At this [00:18:00] most extreme right, the tips of the branches are living species of fungus growing ants, or more accurately, they're DNA sequences of living species and as we move to the left, species that are closely related coalesce into their common ancestors. Then as we move farther to the left, those common ancestors coalesce into other common ancestors and we can work our way all the way back to 50 to 55 million years ago to the common ancestor of all fungus [00:18:30] farming ants, the ant that first began to practice agriculture.

Maggy Benson: Wow, so these DNA sequences can help you understand the evolutionary pattern all the way back through 55 million years.

Ted Schultz: Yes.

Maggy Benson: I saw the ant heads on that phylogeny, on that family tree too. Are we looking at just fungus farmers here?

Ted Schultz: These are just fungus-farming ants and you can see there's a wide diversity of them. The last few are leaf-cutter ants, the most recently evolved ones.

Maggy Benson: So when you're looking at that tree, does it help you understand anything about [00:19:00] the crop they're growing? I mean, we grow corn and tomatoes. These ants are growing fungus, but is it all the same?

Ted Schultz: It's not all the same and that's the thing I'm most interested in is the associations and the symbiotic evolution between the ants and the fungi that they grow. When I look at that tree, and because I know what fungi they're growing, I can see that the pattern's very non-random. Closely related groups of ants are cultivating closely related groups of fungi. What you're [00:19:30] seeing on the screen right now is the fungus garden of a lower primitive fungus growing ant that is growing, that they are constructed on the bottom of a rotten log in Amazonian Brazil.

Maggy Benson: Wow, that's really cool.

Ted Schultz: Here's another example of a garden chamber that we removed the fungus from and another garden chamber that still has the fungus garden in it.

Maggy Benson: So Ted, not only do these ants grow their own fungus, but you showed me in your ant lab when I visited that they actually tend to it and keep it healthy. [00:20:00] Want to show the visitors?

Ted Schultz: Yeah, I sure do.

Maggy Benson: All right, let's take another look. How do they keep the garden healthy?

Ted Schultz: Well, it's a big job, because there are a lot of microbes, bacteria, and other fungi that are constantly trying to eat the garden fungus, so every square centimeter of this garden is visited by an ant every few seconds.

Maggy Benson: Wow, they're very diligent.

Ted Schultz: They're extremely diligent. What they do is, if they encounter some [00:20:30] bad mold or bacteria, they try to pluck it out. If they can't do that, they apply antibiotics to it to control it, and those antibiotics originate either in glands on the ant's bodies or from bacteria that are growing on the bodies of the ants. In all the highly evolved fungus-growing ants like these leaf-cutters, the fungus is also dependent on the ants. We know that the fungus is not found outside of associating with ants.

Maggy Benson: [00:21:00] So Ted, as you've just described to us the fungus and the ants are living in this symbiosis, but then we have another player, bacteria, which is also another living organism. I mean, how does that live in the presence of the fungus and the ants?

Ted Schultz: The ants have glands that nourish the bacteria to promote their growth on their bodies so that they can use these antibiotics and maybe other things that we don't know about. Oh, for instance, in this picture, underneath the chin of that ant that's looking straight at [00:21:30] you, you can see a patch of this white *Actinomyces* bacterium. *Actinomyces* are a kind of bacterium that humans also

get antibiotics from. Here's an electron micrograph of that ant, and on the left, you can see what that bacterium looks like. It's filamentous.

Maggy Benson: So there's really a very complex and sophisticated practice going on here with the fungus, the ants, and the bacteria all living together to promote healthy ants and a fungus crop.

Ted Schultz: Yeah, [00:22:00] the closer we look at the system, the more and more complicated it gets and the more microorganisms we discover that are part of this symbiosis.

Maggy Benson: In the video segment, you started to mention that some of the fungus actually cannot survive without the ants.

Ted Schultz: Well that's true and that's also very interesting. All fungus-farming ants need their fungi to survive, they can't live without it. In the primitive fungus-growing ants, the fungi that they grow are able to [00:22:30] live without the ants. However, in the more highly evolved fungus-growing ants, including the leaf cutters, something has changed and their fungi cannot live without them; so in that case you have a true mutualistic symbiosis in which both the ants and the fungi depend on each other.

Maggy Benson: This is a really interesting relationship and something I never expected from ants. It sounds like we really have a thing or two to learn about their farming practices, even though I would think that they might want to deviate [00:23:00] from their fungus diet for like a Snickers bar or something like that.

Ted Schultz: I don't know, we offer them things and they never take them, so, they stick with their fungi. But yeah, if you think about it, these ants have been practicing agriculture for 55 million years, and they could just sort of decimate all of the trees in their neighborhoods, but they don't. Somehow they're practicing sustainable agriculture. They've also been using antibiotics for 55 million years. And the microorganisms [00:23:30] that are the target of these antibiotics - it seems like (they) could have evolved resistance, and maybe they even have, but somehow, the ants are able to come up with antibiotics that continue to work in this system.

Ted Schultz: Humans have been practicing agriculture for a much shorter time, and we have trouble with our pesticides. Pests evolve resistance. The same with medicine. We've been using antibiotics for only 75 years and our diseases [00:24:00] evolve resistance. I'd like to believe that humans could learn something about agriculture and maybe even medicine from ants.

Maggy Benson: Thank you so much for sharing that with us. It sounds like we do have a little to learn from them. We have a ton of questions coming in from our viewers. Let's get to some of them. This question comes from the students watching here in

Q?rius, the Tacoma Education Campus, how did ants evolve, where did they come from?

Ted Schultz: Well ants are basically ground dwelling, [00:24:30] wingless, in the case of the workers, wasps. They come from a group of wasps that are called hunting wasps that, as far as we know, it's still kind of a question we're asking, but they're clearly stinging wasps that evolved eusociality in which the workers have no wings.

Maggy Benson: Ellie and Dylan from Canyon Ridge would like to know where queens come from.

Ted Schultz: Well, if you think [00:25:00] about solitary wasps, wasps that are not social, each individual is like a queen. I mean, they're queens, they have wings, they lay eggs, so the real question to ask is where do workers come from? In ants, they invented this new thing called workers.

Maggy Benson: And Peyton and Riley ask a related question. Are there king ants?

Ted Schultz: Well king ants would be the males that I just described that go out and mate. Unfortunately for them, they [00:25:30] don't spend the rest of their lives with the queen, they just die.

Maggy Benson: Great questions coming in. Ted, we have another question coming in by video, so let's have a look.

Gigi: Hi, I'm Gigi and I was wondering if farming ants eat anything other than the fungi they grow.

Ted Schultz: Yeah, actually, I kind of oversimplified in that video. They have to eat their fungus to survive, and that's true for the larvae and the adults. But adults, if they're wandering around and they [00:26:00] discover a piece of fruit or something, they will drink the fruit juice from it, and they'll share it with their nest mates. Like all ants, they have a social stomach and they can store things in that stomach and regurgitate it to their fellow workers.

Maggy Benson: Frank wants to know, and kind of related, how they actually make their gardens.

Ted Schultz: Well it starts out with the queen, she has to carry a bit of her mother's garden with her in her mouth when she starts her new nest. She spits it out [00:26:30] and she takes care of that garden until her first babies turn into workers and start taking care of it, and then it gets slowly built, and then more rapidly built from there. So basically they're bringing in new leaves and things and adding it to the garden and expanding the garden.

Maggy Benson: Ted, how did you get your start as an entomologist? What made you interested to pursue this career?

Ted Schultz: Well when I was a kid, I spent a lot of time outdoors and I loved animals, I loved to collect lizards [00:27:00] and snakes and frogs and toads and I also liked to collect insects, and I really liked to try to keep them alive. I learned more about biology, but then years went by when I was doing other things, and then when I was much older, I decided, I'm going to study biology. And there's been no looking back since then.

Maggy Benson: Ted, if some of our viewers watching today are interested in ants and entomology, where can they learn more?

Ted Schultz: [00:27:30] Well, we have barely scratched the surface of discovery of the natural world. Contrary to what a lot of people think, it's mostly unknown. We only know a very small amount, so anybody going … This generation, your generation, going into biology could make, will make a huge difference in our knowledge base. Go to a museum. [00:28:00] Go to a public library and check out books. Take a biology class, and by all means, go outdoors and look around. Even if you live in the middle of a city, there are thousands of insect species that you could be watching.

Maggy Benson: Ted, thank you so much for sharing all this wonderful information.

Ted Schultz: You're welcome, it was great.

Maggy Benson: Viewers, thank you so much for all of your awesome questions and for being here today on Smithsonian Science How? If you want to learn more about ants, you can visit the Smithsonian's National Museum and Natural [00:28:30] History's website, The Hidden Life of Ants, and you can also visit antweb.org. If you missed part of this program or want to see it again, it will be archived later this evening at qrius.si.edu, and we hope to see you next time on Smithsonian Science How? Thanks so much for being here.