Ask-a-Biologist Vol 017 (Guest Stephen Pratt)

Ant Math -

You think you know a lot about ants? Think again. These tiny animals have a lot of interesting things that they are teaching us. Have you ever thought that ants might be doing math? Learn what biologist Stephen Pratt is finding out about about one very tiny species of ants.

Transcript

Dr. Biology: This is Ask-a-Biologist, a program about the living world, and I am Dr. Biology. You see them almost everywhere you go, even though they're small. At least, as far as animals go, they're small. I'll even bet that some of them visited you the last time you had an outdoor picnic. What am I talking about? Ants. You might think you know a lot about them, but actually, there are many ant species, and they all have interesting stories.

The species of ants we'll be talking about today have colonies so small, that they all live in a single acorn shell. Which, if you've never seen an acorn shell, is about the size of an average grape. But even though they're small, they have some interesting things they can teach us. In fact, you might be surprised what we can learn from these tiny creatures. Like, have you ever thought that ants do math?

Our guest scientist is Stephen Pratt. He's going to let us get into the collective mind of the ants. Dr. Pratt is a professor in the School of Life Sciences at Arizona State University and he uses some very creative and colorful techniques to learn how ants are literally thinking. Welcome to the show, Professor Pratt.

Stephen Pratt: Thanks very much, it's a pleasure to be here.

Dr. Biology: To begin, what is the species of ant you work with?

Stephen: Well, the official scientific name is "Temnothorax." That's a little bit of a mouthful though, so a lot of people call them "Acorn ants," because as you say, that's where they like to live, inside acorns.

Dr. Biology: I can remember that, I think I can do that really easily. Usually, when you think about ants, at least when I think about them, I think there are these ant colonies. You see this pile on the dirt and they have these subterranean homes. Actually, in an earlier show, we had Bert Hölldobler talk about one species of ants that has these huge colonies and they go 10 feet into the ground and they are 90 feet in diameter. Well, your species of ants lives in a single acorn shell. How many individual ants live in a colony?

Stephen: In one of my colonies, if they have 500 ants, that's a really big colony. Most colonies will have maybe 50, 100, 200 ants.

Dr. Biology: But inside the size of a grape, that's pretty impressive.

Stephen: Yeah, the ants themselves are very small. Each one is maybe an eighth of an inch long.

Dr. Biology: Wow!

Stephen: And so the colony can fit quite cozily inside a single acorn.

Dr. Biology: So, did you pick this species of ants for a particular reason?

Stephen: There's a number of reasons, and one of them is the fact that they're so small. Because what I'm really interested in learning about ants is how they solve problems as a group.

What I do all day is I bring a colony of ants into the laboratory. I give them some kind of problem to solve, like, maybe, how to make a decision between where's the best place to eat and where's the best place to live, and then I watch how they solve it.

And so, you can imagine, if I tried to do that with a colony of... You know, army ants has a million members or leafcutter ants who build these huge, underground nests. I mean, for one thing, it'd be too hard just to fit them in the lab. But it'd be very difficult indeed for me to sort of carefully watch what each ant does as the colony tries to solve some problem.

But these guys, they have only a few hundred workers. I can easily track each one of them. On a little bit of shelf space, I can keep 50 or 60 colonies and easily do experiments with them and watch what they do and how they solve problems.

Dr. Biology: You actually mentioned army ants and leafcutter ants and you're working with acorn ants, how many different kinds of species are there?

Stephen: There are something like 10,000 species that have actually been described. You know, given names. But most people who work on ants figure that the real number must be something like twice that, more like 20,000 ants. And so, there's a huge variety of different types of ants as well, you see.

The kind of ants I work on, most people probably wouldn't ever bump into them. They're not the kind of ants you'd see at your picnic. They're not the kind of ants who would make little trails in your kitchen. But there are just thousands of species like that, living in the forest floor and acorns or in twigs or underneath rocks. These guys do a lot of really interesting things.

Dr. Biology: Are there any places in the world that you don't find ants?

Stephen: Well, pretty much the only place where you're not going to find ants is Antarctica.

Dr. Biology: I said that your research actually lets you learn about how these animals think. In a way, it lets you get into the mind of the ants. What have you learned?

Stephen: My real interest in them is not just on how they think, but how they think as a group. You know, you're looking at any one ant, it may not seem like it's that smart, that clever, that able to solve tough problems or anything like this. But if you get a group of them together, they can do really remarkable things.

A lot of times, I try to introduce this by asking people if they've seen this Star Trek television show or movies where you have the "Borg." Where you have this sort of alien race that consists of literally millions of individuals, and you look at any one of those individuals and they're... They seem pretty incompetent, kind of clueless, almost zombie-like.

But if you would ask any one of those individual members, "What's the Borg up to? Who are they going to attack next?" Or whatever it is the Borg needs to know, then they wouldn't be able to tell you anything. But the Borg, as a whole, was able to do these remarkable things. You know, this really sophisticated civilization. Ants are kind of similar. Hopefully a little less dangerous, but they do similar things.

You take a single ant, ask it, say, to... For a colony that's, say, living in an acorn that has broken down a bit. You know, maybe somebody stepped on it. You ask that single ant, "Well, go off and find a new place to live. Go look at all the other acorns that are out there in the forest floor that might be the best place to live." And that single ant isn't really going to be able to do that.

But if you have a group of them, you have 50 or a hundred of them, then they can share that task, they can explore a large area. Each ant maybe can find a different potential new acorn to live in. And then, by sharing information and following various specific rules, the colony as a whole can actually sample all these different places, figure out which is the best place to live and then, move the entire colony to that new home.

Dr. Biology: What makes a good home?

Stephen: The ants tell us what makes a good home, right? So we give them all these different kinds of nests and see what they like. And what they like are a dark nest. They want the inside to be nice and dark, so there's not a lot of light coming in. They like a nest that's pretty spacious for an acorn. Not too small. They like one that has a very small entrance. Because one of the reasons they live in this nest is because they're trying to avoid their enemies. They don't want to be invaded by, say, parasite ants, that will run off with their eggs and young to work as workers in the parasites' colony.

And so, it's easier to defend it when an acorn has a nice, small entrance. They don't want it to be too wet, they don't want it to be too dry. And there's probably a lot of other things that we haven't even begun to explore that they pay attention to, but it's a pretty sophisticated decision they're making. There's lots and lots of different things they are thinking about when they compare these acorns.

Dr. Biology: Do they live anywhere else besides acorns?

Stephen: Well, there's a lot of different species, right? When I say "they," I'm really talking about the species I work with. But there's probably 30 or 40 different species of this genus of ants, and some of them don't live in acorns, some of them will live in rock crevices. So, for example, the ones I've been working with most recently; I just started working with, the ones who live near Phoenix, they live up in the mountains. You'd find them just underneath a little sliver of rock, on top of the bigger rock.

Other ones will live in hollow twigs. There's a few of them who would dig holes in the ground, like you usually think of ants doing. But usually, they find some kind of cavity that they can live in; it's already there. They don't want to have to dig their own cavity, they want to find one already made.

Dr. Biology: How do you set up experiments to learn how the colony thinks?

Stephen: It is very much like a collective intelligence, and in order to figure out what's going on, you have to watch what a colony does. You give the whole colony a problem and see what happens. Like, what nest do they move into if you make them move and choose between different nests.

But the other thing you need is to know what each individual ant is doing as the colony does this problem solving, as the colony thinks. And, the way you do that, is you have to mark each ant individually so you can know which ant is which. You can know, for example, well Martha found an acorn over here and then went off and told Julie about that potential new home.

The only way you can do that is if you can somehow individually identify them. So what we do is we paint them. We put little drops of paint on the ants, and then each ant can now be individually recognized.

Dr. Biology: So you have these ants. They're an eight of an inch in size and you're painting them?

Stephen: Exactly, we're painting them.

Dr. Biology: How are you doing that? I just can't imagine?

Stephen: Well, you have to use of course a very small brush, that's part of it. In fact, we do use a very small brush. We just take a single bristle from an ordinary paint brush. That's not enough though, right? Because these ants are tiny and they like to move, you have to slow them down.

So, we can basically have them fall asleep by putting them in a little bit of carbon dioxide. That will essentially kind of knock them out for a few minutes. But even then they're--if you just come at them with a bristle with paint on it, you're just going to get the ants stuck to the end, and push it around. Its legs get stuck in paint, and it's a terrible mess.

But the other thing you have to do is, take the ant and sort of fasten it in a little harness. The harness is nothing but a sponge, a very soft sponge with a single hair attached to it. Then you just kind of slide the ant under the hair, that keeps her still. Then underneath a microscope you can bring your brush in, and put up to four drops of paint on a single ant.

Dr. Biology: Wow!

Stephen: Yeah.

Dr. Biology: Now did you learn this, or did you come up with this technique?

Stephen: I learned this actually, believe it or not. Yes, I'm not the only one who does this. This is something that people who study ants do quite commonly. I learned it from a fellow named, "Nigel Franks" actually, in whose lab I worked a few years ago.

Dr. Biology: How long did it take you to learn to paint ants less than an eighth of an inch in size?

Stephen: Yeah, it takes a little while. It takes let's say, depends on how much time you can devote to it. Let's put it in numbers of ants you have to mark badly before you can mark them well. Let's say after the first couple of colonies of ants, and where a colony has 15-100 workers, so maybe then 200 ants.

Then you're generally pretty good at it, and so I teach students how to do it now. Some people can pick it up faster than others. I always figure people who have some experience say, building models or painting models, and this kind of thing, or have a leg up on other people.

But I think almost anybody can learn it, after investing a couple of weeks hard work.

Dr. Biology: Is there any indication that... You take this colony of ants, and you basically knock them out for a little bit. You give them all these colorful patterns on them, and then they wake up--is there any indication that the colony looks around, says "Whoa, what happened?" [laughs]

Stephen: "This looks strange." Are they happy, or maybe they think they look better--I don't know. Well, one thing you have to remember about ants is, the world looks really different to them, cause for one thing they don't actually rely on vision that much. If you live inside an acorn, it's dark in there. So, they wouldn't even notice.

They wouldn't be able to detect the presence of these things by seeing, but they can smell them. They have a very, very acute sense of smell. What I find is that I think they actually don't much like the way they smell, if they can detect them. If you mark just a few of them, put them back in the colony, all the other ants will say, "What's this? There's something wrong here."

They'll just sort of go up there, and work as hard as they can for a few hours, and peel the paint right off. But if they're all marked, everybody is marked, then it's almost as if they kind of get used to it. They all recognize, "Well we all--we smell different now. We smell like paint, but we all smell the same."

That's what's important for a colony, to share a common colony odors. They know who belongs with the colony, who doesn't. Then they'll tolerate it, and you can put paint marks on these ants, and they'll still be there a year later.

Dr. Biology: Back to the ant colony. We usually think of, at least for me when I grew up, I was thinking about the queen. The queen gave all the instructions, and ruled the whole colony, and whatever is going to happen came from that central source. The question to you is, "Is that really true?"

Stephen: Well, it's funny. When you hear that name "Queen," and that's what it sounds like, right? It sounds like the ruler. People first started calling these big apparently leading members of the colony "Queens" centuries ago, and that's what they thought. They thought, "This is the ant who's in charge." But in fact, that's not the case.

The queen is very, very important to the colony. The colony would really die without a queen. The queen is the mother of all of the worker ants in the colony, but she's not in any way telling them what to do.

In fact, it's closer to the truth to say the opposite. So for example, when these immigrations I'm talking about, when they find a new home, the queen has no role at all in saying, "Well we're going to move here, instead of there. You guys go and do this, and you other guys go and do that." She doesn't do anything of the sort.

She just basically sits around, and waits for the workers to makeup their minds, and they just pick her up and carry her to wherever it is they want to go. So she's important, but she's not in-charge.

Dr. Biology: Hum- Now someone might say what you've learned, is really great to know. Actually I find it fascinating, at least from a basic knowledge, basic science. But your research extends beyond just knowing how ants think, and problem solve. Can you talk a little about ant algorithms?

Stephen: Yes, "ant algorithms." That's an interesting term, right? In a way what I'm doing when I try to explain what the ants are doing, I'm trying to explain what sort of rules are they using to solve a problem. What rule does each ant follow that will lead the colony as a whole to do the right thing?

What we do when we're trying to work this out is, we're try to come up with a mathematical description of what the ants are doing. This is something you can describe as an "algorithm." It's basically a mathematical recipe for solving a problem.

It turns out that computer scientists who have their own problems to solve, learn something about what people work on ants have discovered about ant behavior. They realize they can actually make use of the same problem solving algorithms to solve human problems.

So, there's a lot of examples of this. A good one, one I like particularly, involves scheduling garbage truck routes. So you imagine you've got a big city, and the city has a fleet of hundreds of garbage trucks. Each one of these trucks has to visit every home and business in the city, and make sure that the garbage gets picked up, but they want to do that in as economical of a way as possible. They want to have each truck take the shortest route, and spend the least amount of time, but they've got to make sure that everybody's garbage gets picked up.

That's a really tough problem to solve, that kind of problem. These computer scientists realize, is they could actually make a sort of artificial, virtual ant colony that would explore solutions to this problem, and come up with the best one.

So, each one of these kind of computer program ants goes around their virtual city, experimenting with different ways to schedule the trucks. If it finds one that looks like it's pretty good, then it will tell the other ant programs to try to maybe explore that a little more.

If it finds one that doesn't work very well, it just says, "Forget about this. Nobody else bother with this any more." That way you can very efficiently have all these little ant-like computer programs, experiments with different solutions, and come up with the best one.

Dr. Biology: Kind of an ant math?

Stephen: Exactly, yeah. It's basically, mathematics based on what ants do.

Dr. Biology: Again, at the beginning of the show we said, "They were small, and sometimes you dismiss them." But here we are, we're dealing with complex problems, and we have solutions coming from what seems to be a small and simple creature.

Well I brought in today--thinking of ants, and color, and painting--the cover of the School Life Sciences magazine, it's called "SOLS." On the cover is this beautiful image. It's your image, and it has all these ants, and they're painted beautifully. They have all these different colors. Almost to me it seems to be an abstract painting, an abstract work. It's something you might even see in a gallery, or a museum.

Do you do a lot of photography, and have you ever thought about a career in art?

Stephen: [laughs] Well, I mean I take a lot of pictures really for a scientific purpose, right? To illustrate an experiment, or something like this. I took that picture basically, because I wanted to make this point about how many ants are in the colony, and the fact that we can identify them all individually.

But sometimes you get lucky, and you have something to photograph that is just really very beautiful, very striking sort of thing to see. That picture, and some other pictures I've taken like that, I think I was kind of lucky in that sense to have something that really looks nice.

One of those pictures I entered in a contest that was actually called, "The Art of Science." The idea was to try to bring these things that people usually think as being very different, together--art and science--to have a look at the kinds of images people create in the course of doing science.

So there were lots of really beautiful interesting images there, that all kinds of different scientists had produced. I was fortunate that they liked that ant picture. They liked that image of painted ants really is a striking one. So, at least I got some recognition for that. I think I got third prize.

Dr. Biology: All right. Actually if I recall, there was an interesting flyer that was sent out to get people to submit their works. Can you tell us about it?

Stephen: That's right. What did it say? It said, "Art is stupid and science is boring. Prove us wrong."

Dr. Biology: I love it, I love it. Break down stereotypes. That's just what you did. I can tell you that I could actually see these again in a gallery. What we have here is a kind of creative collaboration between ant and human.

Stephen: That's exactly right. I like to think of it that way, too.

Dr. Biology: In case somebody would like to see the image we're talking about, they can use a web browser, type in askabiologist.asu.edu/podcast and then go to the content link for volume 17, which is what this episode is, and there we'll have a link to the cover image and the article that talks about your work.

When you go out to collect your ants for your experiments... You now live in Arizona in the desert. Can you find them in the desert?

Stephen: These particular ants, there is some evidence they live there, but people hardly ever see them. It's pretty tough. It's not really their kind of environment. They like it a little cooler. If you go to the mountains outside of Phoenix, that's a great place to find them.

Down here in the desert, there are fantastic ants. Different kinds of ants. Harvester ants who collect seeds. There's all kinds of ants who produce chemical trails they use to forage with. You can see these out on the sidewalk or just out in a field, or any place outside. Sometimes places you don't want to see them. You'll see them in your kitchen.

So there's lots and lots of interesting ants you can see right around here. Right around Phoenix.

Dr. Biology: Is there anything that really surprised you while you've been studying ants? Something you just never even imagined you would see or experience?

Stephen: The thing that most struck me about these is... You know I've been emphasizing it. The colony is a lot smarter than the individual. But still, these individuals can do some things that really impress you. And one of the things these ants is that... I wouldn't go so far as to say that they count, but what they do is they pay attention to how many other ants there are around.

So one of the really crucial rules they use, when they are, for example, picking a new nest, is they repeatedly visit an acorn. They're thinking about moving to it. Some of their other nest mates are also visiting. Other ants are also visiting. And they're kind of keeping track. Each one is keeping track of how many other ants are there, and if there's not too many other ants there, then their enthusiasm about this acorn will be low.

But once the population gets high enough, like lets say it's five or ten ants in there, then they can sense that, and that makes them decide, "OK, this maybe is the place we really should live." And then they kind of switch into high gear about telling their other nest mates about it, and bringing other ants over to see this acorn.

It looks almost like they're counting. They're probably doing something much simpler. Something that involves getting some sense of how often they're bumping into other ants. But still, it's really remarkably impressive, kind of smart thing to be able to do, for an individual ant to be able to respond to, to be able to sense how many of its fellow ants are around.

Dr. Biology: You know, one of the things we didn't talk about is you paint the ants. You paint the ants, which means you can tell one individual from another. How do you watch them all this time, and see them make a decision. What are you using for a tool?

Stephen: Yeah, that's a good point, because after you've got them painted, and if you just sit there and try to watch them... Even with 100 or 200 ants, it's not many for an ant colony, but it's still a lot of ants to try to track. So, what we do is we videotape them. It may take them three or four hours to move, to pick a nest and move into it.

And then we will spend much longer than that going over these videotapes and painstakingly tracing what each ant did at each stage of the invasion. So, videotaping is really, really important. That's probably our major tool.

Dr. Biology: So, how do you record for four hours? A lot of tapes don't go that long.

Stephen: Yeah. Well, what we used to was change the tape. That was like the main thing you had to not forget to do, or otherwise you would be really sorry. Nowadays, we just go straight to a hard drive. You can just basically feed the output from the camera directly into a computer, and as long as you have a big enough hard drive, then you can store hours and hours and hours of recording.

Dr. Biology: So now I can see that we could have a future independent film: "Ants: A True Story."

Stephen: That could be good, yes. Put it on YouTube anyway. I don't know if we can get anybody to pay for it, but we can certainly put it on YouTube.

Dr. Biology: Well, we could speed it up, right? We could do this time lapsed.

Stephen: Oh yeah. That's a good idea, actually. I think a lot can be done there. One of the great things about studying the emigration is that the ants, they're really moving fast. There's a crisis. Their old nest has been destroyed, and they've got to act fast.

But usually, these ants are pretty laid back and they don't like to do anything fast, so if we wanted to study other kinds of behavior that are less about an emergency, then actually, that would be really useful, time lapse. So you can just compress 24 hours of action into 1. That's probably the only way you could practically get good information from them.

Dr. Biology: OK. We don't have the movie on YouTube yet, but is there some place they can see some ant movies?

Stephen: Yes. I put a few of my videos up on my website, so there's some nice ones there, both of lots of ants together, painted ants interacting, and also some videotapes of individual ants recruiting one another when they try to get their fellow ants to visit a site that they like.

Dr. Biology: Well, excellent. I think what we'll do is we'll add a link to your website from this podcast, so people can just go up on our transcript for this podcast and/or the content link, and we'll have a direct link to the movies.

Stephen: OK. That sounds great.

Dr. Biology: I always ask three questions, and it's always fun to this. One of the questions is: when did you first know you wanted to be a biologist?

Stephen: That's a good question. I have to say it was a really long time ago, when I was probably no more than 10 years old, and just playing with ants, watching other kinds of insects, collecting insects.

Really early on, I was really interested in insects and wanted to keep working with them. So as soon as I found out there was such a thing as an entomologist--a person who specializes in studying insects--then I was pretty excited, because I thought, "Well, that's great. That's something I can do when I grow up."

Dr. Biology: Your voice makes you sound like you're a lot older than what you are.

Stephen: [laughs]

Dr. Biology: You're actually a very young researcher here; I just want everybody to know that. So when he says "a really long time ago, " if you're a 10-year old, it probably does seem like a really long time ago, but if you're my age, it seems like it wasn't that long ago.

If you weren't a biologist, I'm going to take any capability for you to do biology or science, and you're going to have to shift into another kind of career, what would you be?

Stephen: Hum, that's a good one. If I could have any ability that I want, ones that I don't have now, then I'd want to be a musician.

Dr. Biology: Is there a particular kind of instrument?

Stephen: I think guitar would be great. Yes, I think it would be really fun to be a guitar player.

Dr. Biology: So do you have a particular kind of music you like, or musicians?

Stephen: Well, classical guitar I find really great, that I really enjoy. Unfortunately though, I have no musical talent at all.

Dr. Biology: Well, I don't either. But that's OK. What advice would you have for a young scientist, or maybe someone who decides that they've always liked ants and they want to switch their careers?

Stephen: Well, the thing about biology is I think you really want to spend as much time as you can with the organism. The great thing about insects is they're everywhere. It's not that hard to find them, to bring them into your home, if allowed to, and sort of look at them and play around with them and see what they do. I think it's that kind of really up-close experience where you're not just reading about things, but you're actually doing things, I think that's what really makes the difference for learning how to do biology, and really enjoying doing it as well.

Dr. Biology: Well, Stephen Pratt, thank you for visiting with us today.

Stephen: It's been my pleasure.

Dr. Biology: You've been listening to Ask-a-Biologist, and my guest has been Professor Stephen Pratt from the ASU School of Life Sciences. The Ask-a-Biologist podcast is produced on the campus of Arizona State University. And even though our program is not broadcast live, you can 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.