Tracey: Hello, and welcome to NC State's Audio Abstract. I'm your host, Tracey Peake. A beehive is only as strong as its queen and her ability to produce viable offspring is vital. We're speaking today with Alison McAfee, a postdoctoral research scholar here at NC State about the environmental factors that affect a queen bee’s ability to produce and sustain a healthy hive. Welcome, Alison.

Alison: Hi, thanks for having me.

Tracey: I'm glad you could be here. So let's start out with basic hive structure for folks who may not be super familiar with how these beehives are run. How does a queen bee coronation happen? And what are their lives like once they're in charge of a hive?

Alison: Yeah, really interesting questions. It's actually much more complicated than you might think. So what determines who gets to be queen is it actually happens in two steps. In the first step, it starts way back when the queen is just a larva of one or two days old. And the workers actually choose who gets to be queen by feeding the larvae that they select a different diet compared to a worker larva. And it's super interesting because queens and workers are actually more or less genetically the same. It's totally just this diet that determines what they develop into later. So that's the first step. But workers they'll choose maybe 10 or so different larvae to become queens, and then in the second step, the first queen that emerges, she'll go around and kill all the other ones as they're still developing in their little wax cells. And if two emerge at the same time, then they'll have a duel and fight to the death. So the one that ends up surviving is who gets to be queen.

Tracey: Tell me a little bit about the diet. How can a diet make that much difference? What is the queen eating that the worker bees don't get?

Alison: Yeah. So the queen eats a diet purely of royal jelly, which is this secretion that the workers produce from some glands in their heads. And the worker larvae eat some royal jelly but there's also some pollen and some honey mixed in there later on. So I'm not super up on the really current research because there are still parts of this that we don't understand. But as far as I understand, there's something in the pollen that the workers get that keeps them on the worker trajectory. And it's that lack of this substance that's within the pollen that actually causes the queens to become queens. And there's a whole field devoted to this idea that environmental differences can change development and change gene expression called epigenetics. So the components in their diet modifies what genes are expressed, whether they're queenly genes or worker genes.

Tracey: Okay. And what exactly, I mean, not to go into queen biology 101 or anything, but what is the key difference physically between a queen bee and a worker bee. I know they're a little bit larger, but what else makes them special?

Alison: There are many differences. So you're right the size is the most obvious one. The queens are somewhere around twice the size of workers. But the queens are the only reproductive... Well, the queen is the only reproductive female in a colony normally. So all the workers are females, but they're sterile. They don't normally lay eggs and they never mate. So the queen has these really big ovaries, which is a major contributor to why she's so much bigger than the workers. The ovaries take up around a third of her body mass.

So she's got these huge ovaries and she also has a very well-developed organ in her abdomen called a spermatheca, which is where she stores all the sperm that she will ever need to fertilize the eggs for her entire life. So they mate once in... Well, they mate during one period early in life and they'll mate with maybe 10 or 15 drones and they'll keep the sperm that they acquire from those drones in this spermatheca for years. So that's another difference, is that queens live in the order of years, whereas in the summer workers live around six or eight weeks, in the winter they can live up to... Well, through the winter they can live up to eight months as one end of the extreme, but never more than that.

Tracey: So bringing us back to kind of the original question after the queen bee has emerged and either murdered everybody in their sleep or have fought a duel to the death, then I take it she goes on a mating flight. Does she have to leave the hive that she's born into or is she only born after the existing queen is gone? How does that work out?

Alison: There're many ways that this can happen. Sometimes a queen can be killed accidentally and then the workers go into emergency queen rearing mode. So in that case, the queen would begin to be reared by the workers after the previous queen has died. But sometimes also an old queen will fail over time or slowly stop laying as many eggs or run out of sperm or have something happen to her that makes her less desirable to the workers. Sometimes it may just be old age. And then in that case, the workers could begin rearing a new queen while the old queen is still there and still trying to lay eggs. In very rare cases, you can have colonies with two queens where there's one very old queen and then one young queen that is sort of taking over. But in a normal circumstance, there's only one.

Tracey: So then I guess mating flight happens and the queen comes back and starts laying eggs?

Alison: That's right. Yeah, the queen will fly out of her colony and she'll do a bit of an orientation flight to just figure out how to come back home, but she'll follow a scent trail to something called the drone congregation area, and this is where all the boys go to wait for a sexy young queen to come. And they mate in mid air and the drones will sort of chase after a queen and compete for who gets access to her. Once they've been successful, then they all actually die. So the drone's life is fairly short, but you could think of them kind of living on through the sperm that they donate to the queen that she'll keep safe for years to come.

Tracey: That's a much happier way of thinking about it than.

Alison: Yeah.

Tracey: Mate and die.

Alison: Yeah. But then she'll fly back to her colony and after a few days, maybe up to a week, she'll start laying eggs, and then she'll lay somewhere around a 1,000 to 2,000 eggs per day. The estimates on that vary, but it's somewhere around her body weight in eggs each day. So being a queen is actually quite hard work. They don't have an easy life, I would say. All their time is occupied with laying eggs as much as they can. And the workers will feed her, they'll groom her, they'll even take away her poop when she poops. So really that enables her to devote just all the resources that she can into laying eggs.

Tracey: So obviously the health of the hive or a colony is dependent upon this queens ability to produce offspring and not just offspring but good, viable, strong offspring. And you've done some research lately that focuses on problems with sperm as leading to queen failure, which is one pretty significant cause of colony failure, hive failure generally. So what are these factors? What's going on here?

Alison: Yeah. So there are quite a few ways that the sperm inside a queen can become harmed. Once the males have mated with the queen then she's the keeper of the sperm. She needs to be able to keep them happy and healthy for a long time. That becomes her job.

So when a queen becomes stressed by things like becoming too hot or becoming too cold or being exposed to pesticides, all those things can begin to kill those sperm that she's keeping. And once that happens, that's really bad news because she only has that one mating period early in life. And if her sperms start to die from whatever reason, she can't just go and mate again. So her sperm dying is like a permanent change to her ability to fertilize eggs. And that's a really big problem for beekeepers. Queen failure is something that we hear a lot from beekeepers as being a really significant issue in their operations. But there's not a whole lot known about why this is happening.

Tracey: We know temperature is a factor, are we seeing more queen failures in places where it's becoming warmer or cool? Is there a relationship there? Have you looked into that?

Alison: We don't actually know. It's very poorly documented. And that's because beekeeping is, if you're a beekeeper, you're trying to make money, you're trying to run your business. If your queen starts to fail, you just want to re-queen that colony as fast as you can so that you don't have this big lag time where there are no eggs being laid and your colony becomes smaller and smaller. So there's no widespread reporting system for how often queen failure is happening, for example. There have been some surveys done in Canada and the US, but that's always sort of after the fact. Like trying to get a sense of how pervasive this problem is but not tracking for example how many queen failure events there are over time. So we certainly don't have data on like regional data for how queen failure is increasing or decreasing over time and if that's related to the climate.

But I suspect in the future that we should probably expect failures to increase in regions that are hotter, because climate scientists are predicting that as the climate changes we're going to get more and more heat waves happening in those regions. And not only more of them will happen, they're predicting, but also the duration of them will be longer and the intensity will likely be higher. So I'm a little bit worried for bees that are in the south. Interesting though, even as far north as where I am. I'm sitting here in Vancouver, Canada right now, but in British Columbia, our province, there's actually not too far from here a region where it can routinely get to about 40 degrees Celsius. Unfortunately, I don't have the Fahrenheit translation for that, but it's very hot. It's upwards. Body temperature is 37 degrees which is 98 Fahrenheit. Right?

Tracey: Right.

Alison: So 40 degrees Celsius is somewhere north of a 100, we'll say like 106 or something like that.

Tracey: That is hot, yes.

Alison: So I'd expect that the risk to becoming heat stress will increase in the future as climate change occurs and we probably will get more of these heat waves happening.

Tracey: Are you planning on any sort of additional research into maybe the effect of pesticides or temperature on the sperm that the queens have to further elucidate this problem?

Alison: Yeah. Those are the two stressors that I've really been focusing on so far. I should add also that pesticides stress we again don't have much information on how that has changed over time in relation to the queen's health, but there have been some pretty good studies showing that pesticide residue accumulation in the colony is significantly correlated to queen failure events. So it's definitely a problem there.

Tracey: Okay. So that brings me to my next question, which is what can we do just normal people to keep your backyards bee friendly or maybe try to cut down on... Do what little bit we the public can to kind of help with the queen's health?

Alison: Well, interestingly, I think that temperature is actually the factor that we maybe have the most control over because, well, we can't obviously control the temperature ourselves. That would be great if we could just reverse climate change.

Tracey: Just hit a button on the thermostat for the world.

Alison: Yeah, just kind of dial down.

Alison: What we can do is change essentially the housing for the queens. There are two main ways that a queen can become temperature stressed. The one that... Where she's at the most risk of being temperature stressed is when she's being shipped. So earlier I described how the workers choose who gets to become queen and yada, yada. Well, humans have figured out how to exploit that and kind of trick a colony into producing many more queens than they actually would. And there are some beekeeping operations that produce in the order of tens of thousands of queens per year, and then distribute them both within the country and internationally to beekeepers who are buying them.

So there's a global queen distribution system. In Canada we import around 250,000 queens every year from places like Australia and New Zealand, and a lot of them come from California and Hawaii as well. So when queens are shipped, they're in these tiny little cages that have just a few workers and they don't have much capacity to thermoregulate in there. So they're just vulnerable to whatever the ambient temperature is in the plane or in the van or in the warehouse where they're being stored.

The second way that they can become stressed is something we know much less about, but which I'm worried about, and that is in their actual colony. So we usually think of honeybee colonies as being very thermal regulated, stable environment with the workers keeping everything pretty much around 33 to 35 degrees in there. But we've actually put temperature loggers in colonies and then tracked what happens during an extreme heat wave, and we find that it can get surprisingly hot inside there. So something that we could do to try to prevent that from happening is for example, using hive equipment that has thicker walls.

You might not want to do that as a beekeeper because it's worse for your back when you're having to lift these things around, but that would provide some more installation to both keep heat in in the winter and keep heat out during the summer. Or styrofoam, people don't really like the idea of styrofoam because it's difficult to recycle and can accumulate where you don't want it like the oceans, but it is lightweight and is very insulating. So that would help protect against heat stress and cold stress in the winter as well. So I think we actually have the most control over stress due to temperature spikes.

Pesticide stress is much harder for us to really do much about individually. So if you're a beekeeper, pretty much the only thing that you can do right now is control where you put your hives. So whether you're near or far from an agricultural area. But a lot of beekeepers make a good portion of their income by doing pollination contracts, which by definition means you're putting your colonies right in the thick of an agricultural landscape where there's a fairly high risk. A lot of cities have banned some kinds of pesticides because for just aesthetic reasons, it's not a good enough reason to apply them. So that's a good thing, but I think there's much less we have control over for pesticides.

Tracey: So what is your future research? What direction is that going to take?

Alison: Something that I would really like to do and which is kind of one of my driving forces in this research is to try to come up with a tool for beekeepers to use, to try to figure out why their queens are failing. So failed queens look the same no matter what the reason of failure is most of the time. So it would be really useful for a beekeeper to be able to, say, send a failed queen to the lab, have me run a series of diagnostic tests on her and then be able to tell them like, okay, this queen probably failed because of pesticide stress or she probably failed because she became too hot or something like that.

So I think of this as like doing a molecular autopsy on the queen to try to figure out the cause of failure. And then the beekeeper can make more evidence based decisions for the future in terms of the management of their operation and where they get their queens from and that type of thing. So I actually have another research article that came out this summer on our very first steps to try to develop such a test.

Tracey: That would be great. I'm sure a lot of beekeepers would like to know, not just that their queens are failing but why. That would probably be extremely helpful.

Tracey: I did want to ask you one final question, which is what is the coolest thing that you know about bees? Your favorite bee fact.

Alison: This is the hardest question. I've been asked this before, and I never know what to say because it seems like everything about their lives and what they do is so fascinating.

Tracey: You can pick a top three if one is too hard.

Alison: Maybe. I mean, I think their dance language is really amazing and that's what made bees famous in the beginning, was Karl Von Frisch winning the Nobel Prize I think in mathematics for decoding their dance language. And so if you're not familiar, the way that a worker communicates to other workers where there's a really lucrative source of something to forage, whether it's nectar or mainly pollen or whatever, there's a good patch somewhere. They have to communicate where this is and sometimes over huge distances like miles.

So they'll do a little dance that looks like a figure eight and that the angle at which they do this wiggle run in relation to gravity, tells the workers which direction to fly in relation to the sun. That absolutely blows my mind, that they can translate all of this. First that they can even tell how far away something is, like they fly there, but how do they communicate how far that is? Just the fact that they can perceive that and then convey that information to other individuals is absolutely amazing... it's a tough competition for what's the coolest thing, but I think that might be it.

Tracey: That is cool. Like a little bee odometer and they just clock it in their head and then they come back and being able to be specific as to the position of the sun at the time and the... Yeah, that is amazing.

Alison: Yeah. And to go down this rabbit hole even further.

Tracey: Yes.

Alison: This bee odometer that they have, it's something to do with how fast objects pass through their vision. Like they can tell how fast things are going by and that's how they encode distance. So you can trick bees into thinking they've flown farther than they actually have by forcing them to fly through a tube that has different patterns painted on the inside so that it feels like they're going faster because all these objects are like whipping by, but they actually haven't. You've just tricked them into thinking that they've gone farther than they actually have.

Tracey: Wow. There's a whole area of bee tricking studies. I like that. That's amazing. That really is amazing. Well, Alison, thank you so much for being here. This has been fascinating.

Alison: Yeah. Thank you very much for having me.

Tracey: We've been speaking today with Alison McAfee, a postdoctoral research scholar here at NC State. This has been Audio Abstract, I'm your host, Tracey Peake. Thank you so much for listening.