SECTION: INTRODUCING HONEY BEE TAXONOMY

So the first thing to think about when one is going to focus on a particular species is, what type of organism is it. So I just wanted to remind you what type of animal is a honey bee. And that's really just a way, because we understand how evolution connects all living things together, of asking, "Who are its particularly close relatives?" And so what I've given you are the typical hierarchical classifications, starting with domain and then coming down to the species we study. And just to remind you that every species has a Latin binomial that designates a specific species. There can be sub-species, or even stocks or family groups within that, but they're all one particular species. As is typically the case, there are multiple common names that designate a particular species. But here we typically just say "honey bee" when we mean honey bee, we don't usually say their names.

The other point I want to make is, though Mr. Stone has told you that the entire order classifications are products of the human imagination or human intellectual activity – that they don't exist in a real way that a species exists at a particular point in time – they are very useful for helping us understand who is more closely related to whom. And that's important in biology, because we can study one thing, and then by studying that one thing as a model, we can learn lots about other similar things. So in the most simple way, we can learn more about other members of the genus – that is, other honey bee species – by studying the European honey bee. We can then learn about other insects that are so closely related that humans have designated them as a family, and so on and so forth. So we can learn things about all animals or all eukaryotes through the study of the honey bee.

One of the really interesting features of the BeeSpace project is that it seeks to use the honey bee as a model animal to address things that are relevant, I think, to every animal that has a nervous system. We'll put maybe the sponges with their sort of more distributed nervous system to one side, and say that what we learn from the study of honey bees will tell us about the nervous system, and because nervous systems run behavior, about the behavior of all animals. And that at a more fundamental level we can learn about the cell biology of all eukaryotes by studying the honey bee. So we'll put this aside, and you'll have a bee-centric week, but everything you learn is in the service of this broader set of questions.

So here's a lovely photograph of the common honey bee, or the European honey bee, taken by a bee researcher, Marla Spivak in Minnesota. And I just show you that to remind you – you know what a honey bee looks like, but I want to show you that – and show you some of the other species. But first, answer a question. This bee is on a flower, collecting pollen to take back to the hive. What's her hive look like? Where is she going to go back to? If you followed her with her load of pollen, where would she go back to?

[Student: Maybe a tree hole?]

A tree? Okay, so if this were a naturally occurring or what we might call a feral population, in a tree. That's where we would find the nest of a honey bee. If this was a honey bee living in a human-managed situation, where would it go?

[Student: To a box.]

Back to a box. So what's a common feature of a tree hole and a box?

[Student: They're dark.]

They're dark. That's exactly right. They're gonna go inside something. One of the very interesting things about this genus is that they don't go inside when they go back to the hive. And so here's a dwarf honey bee, Apis florea, a member of the same genus, photographed in its nest in Thailand. And it's not inside a tree hole, and it's not inside a box. And so there's a big big difference in behavior between two species so closely related that if you looked at it, if we were all able to go to Thailand and go out – this is a good field course for Uni students – and find Apis florea, you would all say, "that's a bee," but look at the big difference in behavior.

It is possible, I believe – not possible at present but possible within the next decade – probably to understand both the evolutionary origin and the direct causes of this difference in behavior. And a project like BeeSpace, that helps us understand the information encoded in the genome and how it plays out in the brain, will help us.

Here is another bee that doesn't go into a dark place. It's a large bee, Apis dorsata, in Nepal. Once again, you could look twice – it's a little larger and a little more fuzzy – but I think you'd still say, "It's a bee." another closely related species that behaves differently in some ways than the honey bee.

So that raises a question of how can we tell different species apart, and when we have very closely related species, how can we give them their correct names? So I have this figure here, this is Apis cerana, the Eastern or Japanese honey bee, I have this figure here to remind me to tell you that, by the end of this week, if I ask you to tell me how to tell some species apart, you can say, "Let's just use some DNA comparisons, or just look it up." I wanted to remind you that it's possible to tell closely related species apart even before we understood the chemical nature of DNA, that it's possible to use morphological markers – or differences in appearance – to identify different species.

And so one of the most helpful set of markers, not just for honey bees but for other closely related insect species, are differences in the pattern of wing veins. So all of you have probably looked at butterfly wings. And today – I show you this because you're all going to look closely at a honey bee wing. What you may not have thought of is that the wing is not like your fingernail – which is dead tissue – but a wing is living tissue and so it needs to have a blood supply. And so the veins of a wing bring the blood to the living tissues of the wing. But they develop in species-specific patterns, which allows us to sort species apart. So that's one of the ways we can tell different species apart.

Now of course there are differences in underlying DNA sequences, and then in the regulation of how genes are expressed – when particular genes are turned on at various stages in development – which account for these tiny differences in European honey bee and Eastern honey bee, and so there are underlying mechanisms for that. So here's the first thing that I want you to look for, when you look through the dissecting scopes later this morning. Look at the patterns of wing formation.

Now we have no trouble, because for the purposes of research we raise our own bees, and because we've only got this single honey bee in North America, so we don't have any problem knowing that we're studying this species. Does anyone know why we've just got this one honey bee in North America?

[Student: Was it introduced to America?]

That's right. So this is this invasive, exotic species that is destroying our native American pollinators. (laughs) This is an introduced species. It was brought here and introduced to the eastern United States at the time of early colonization. It turns out that the honey bee was not able to get through the Rocky Mountains on its own, so it had to go, I guess by ship, around South America, to San Francisco and then to the western United States.

Later in the week you could have a cool philosophical discussion about whether the honey bee is a "model organism." You probably are familiar with other model organisms like the fruit fly and the laboratory mouse, and you might want to think about, what defines a model organism and, then, is the honey bee a model organism?

So just a few bee biology basics. Honey bees are a type of insect that has a life history that's referred to as complete metamorphosis, sometimes referred to as "holometaboly" (writes on board); that's contrasted to "hemimetaboly," to get the proper term there. And I'll simplify and say that this basically means: "has a pupal stage," and "has no pupal stage." So the four stages of honey bee development are, then, the egg – which is shown here in this cross section cut through the comb, but you won't be able to see things as clearly as this, because when you look at comb you'll be looking down into it. But if you've got the right comb, with the sun in the right position as you're out visiting the hives, you should be able to see what look like little grains of rice in the bottom of the cell; those are the eggs. You'll much more easily with your naked eye be able to see larvae, and I have a few photos of those. You will know the pupae are present, but you won't be able to see them, and I'll show you why in a moment. And then the adult is what you get at the end of metamorphosis. So this is embryogenesis, the embryonic stage, and if we studied that early development – which is not typically done – we could learn about how for instance the nervous system is first assembled. Things that happen to the larva and the pupa determine many of the things that the adult will do, and so they're of great interest to bee biologists who are interested in behavior.

So here we see, if one is looking down – and this is I think all you'll be able to do, because I don't think you'll cut a cross-section the way it was shown – but you'll be able with good lighting to see the eggs in the bottom of the cell. Here are the larvae, and the larvae are swimming in the food that has been secreted by glands in the head of worker bees. They are little maggot-type larvae, so think maggot when you see these larvae. They go through several stages – some are small, some are large. Here are more larvae in the bottom of a cell; some are being fed by worker bees that are sticking their head down. And I wanted to show you this: The pupae are hidden by a secretion, or cap, that are made by the worker bees to cover the pupae. So we could with our fingernail – maybe you'll be able to do this when you go out to the bee lab – you could scrape off that cap and you could see the developing pupa underneath. But otherwise you won't see them.

SECTION: BEE BIOLOGY
So the very cool thing about the honey bee colony is that it contains two sexes, males and females – no surprise there. So there's dads and moms. But that there are also two different ways of being a female, which are referred to as castes. And so shown here are a worker bee, who is a female, the drone, who are male, and then the queen, who is also a female. And a great deal of research in the twentieth century established that every female egg that is laid has the potential to become a queen, and that it is enriched feeding of young larvae that allows a bee to select the queen path of development. And it does so through diet, change in a pattern of hormone secretion, and then hormones act on target tissues to reprogram them and make a queen rather than a worker. So in a way, the queen really is what she ate – but she had no choice in it, she ate what she was fed by workers. So there's a whole body of literature that helps us understand when workers choose to make a queen, make one of their sisters into a queen. So the two sexes are female and male, and the two big castes are queen, who is able to mate and reproduce, and then the workers, who are sterile.

What's really interesting is that within the workers, we can also define what are referred to as “behavioral castes” (writes on board). And that's just a sort of biological way of saying not all workers do the same thing. Some workers are specialized to leave the hive and collect pollen and nectar, and we call them “foragers” (writing); some of them are specialized to tend to the larvae, their little sisters, and we call those “nurses.” There are other specialized tasks, like specialists who carry the dead bees out of a colony – those are referred to as “undertakers.” and the interesting thing about the behavioral castes is that, unlike reproductive and sterile female castes, these are very fluid – so that in the course of her life, a worker bee can be all of these.

There is a general tendency for a progression through these tasks to be organized by worker ages, so that younger workers tend to be nurses and older bees tend to be foragers. But the whole thing is amazingly flexible. One of the themes that you'll hear later in the week is this behavioral flexibility. Because it must be matched by flexibility in signaling in the nervous system. It must be matched by flexibility in the underlying patterns of gene expression. So that's the reason the honey bee is such an interesting research subject.

Now the queen here is marked, because – although particularly when she's laying eggs her abdomen is much larger than that of any othe bee in the colony – it's marked to make it easy for the beekeeper to find her. And so what you'll be typically faced with is not a nice display like this, but something a little more like this. So who wants to point to the queen? I'm going to give this pointer to – if no one volunteers, I'm going to give this pointer to ... [hands it to Student] See if you can find the queen there.

Okay, so that's more like the real world, where – and this is actually, Nick and Katy can tell you that a frame can be boiling with bees, have many, many more. [To Student] Do you want to go up closer? Be the teacher? That'll help.

Student (walking to front): Is it marked?

Dr. Fahrbach: Oh that would be way too easy (laughs). Okay, well this is what you'll face.

Mr. Stone: Call for a lifeline.

Dr. Fahrbach: Do warm and cold.

[They discover that a laser pointer won't display on an LCD panel] No, it's like reflecting off in some really weird way. (laughs)

[Student points to a bee in the photo, with her finger]

Dr. Fahrbach: Oh, what made you think that? Oh, in the middle. No, that would make it too easy, but the queen often is surrounded by other workers who are feeding her, because she won't feed on her own. This is really challenging. Gonna try again?
Student: That's okay.

Dr. Fahrbach: (To Student) Alright, come on up.

Student: That one, maybe?

Dr. Fahrbach: Yes. Looking at that really big distended abdomen filled with eggs. Very good! So it's really challenging. Beekeepers who can do this in a second, in a glance at that faster than I can, have a lot of knowledge. So you will be needing all your powers of observation. So pay attention when you're out at the hives tomorrow, because you will need to be really focused. Find a drone? Drones are harder because I haven't given you a clue for that. [Student rises]. A drone's sole function is to mate with the queen. The drone finds the queen visually.

[Student: That one?]

Dr. Fahrbach: Yes, yes. Stubby body, what we call the squared-off butt would be a good clue. Don't quote me on that, but use that. (laughs) And then because the drone finds queens using vision, really enlarged eyes. So in a way you can cue in on just the chunkiness, but if you got in closer ...

Student: It also looks like he doesn't have those characteristic stripes that the worker has on the tail.

Dr. Fahrbach: You know, there'll be variation in that, so there's a lot of – the striping pattern is under genetic control. A queen mates many times, up to 20 times, and she has an organ attached to her reproductive system that she can store the sperm in. And then a particular colony or nest is a group of all different family, each with a different father but the same mother. So some of that variation you see reflects the fact that the family have lots and lots of step-siblings.

So because we're going to look through good stereo microscopes, it's good to refresh our memory of the body structures of an insect. And they're up there, because you all know head, thorax, and abdomen. And so I'm going to point out features that I want you specifically to look at. One thing I want you to notice is that the thorax is where all the cool things are attached to – with one exception, and that's the stinger. So the wings originating here, and for the legs to originate here. If you have an active imagination, think back on that little legless larva. So do you have like a vision of a maggot? That's the magic of metamorphosis, that this little maggot grew these beautiful jointed appendages and these wings. So some of us, in fact the first thing I studied in insects had nothing to do with behavior – I just was fascinated by how something legless could make a leg in a couple day's time.

So, bees make wax. They make it with glands that are in their abdomen. They secrete these scales of wax, and then they chew and mold it and work it and engineer it into the comb and the caps that they use to cap their honey and the caps on the brood. So I want you to, when you have your worker bees, to turn them over. It's unlikely that you'll actually be fortunate enough to see wax being created, but I want to you look at the different body segments and appreciate the apparatus for making wax under there. You make wax too, but in a very limited sense. So what's your wax-secreting organ? [student: Your ears]. Your ears, yes. So it's not very useful, and I wouldn't recommend trying to build a honey comb out of it.

Another feature I'd like you to look for is on the hind leg. So you'd have to look at the front leg, the middle leg, and the hind leg. And on the segment third from the end, so tarsi, basitarsus and tibia, you'll see a specialized abundance of hairs which serve as a pollen basket. So the bee can carry much more pollen back to the hive on these hairs than she could if it were just accidental, if she had to rely on just her general body surface. So this is a specialization of honey bees which I want you to pay attention to.

Then we could spend the whole time under the dissecting microscope looking at the head. It's my favorite part of the honey bee. It's loaded with sense organs. So I want you to see what you're going to see. This is the head of a dead honey bee – because the mouth parts are typically neatly folded up. You don't see the bees flying around with their tongues hanging out – something's wrong if you do. But you can carefully take a probe and spread those out, and appreciate the fine structure of the mouth parts.

It's Monday and you guys still need to get warmed up, so tell me the five senses and then tell me what organ a bee uses to experience those. Each person can give me a sense, and then the way a bee senses that.

Student: Vision. Compound eyes.

Dr. Fahrbach: Good, so vision and compound eyes. The interesting thing about compound eyes is – our eyes are sort of an extension of our brain as it goes back into the visual center; our eyes are really like a little brain in the front of our head. And compound eyes and the nerve cells that get that information about light are directly connected to the brain. So if you could find the compound eyes in the head of a bee – and it's not hard, so I know we can all do it – you can become a bee neuroanatomist, because you know that the brain lies between those two compound eyes. So you have found the brain if you find the compound eyes.

However, bees also have eyes on the top of their head. These simple eyes, which I hope you'll be able to see today, are called the “ocelli” (writes on board). The compound eyes give bees the ability to see colors and the ability to see shapes, and they use those in their ability to move about in the world outside the hive. There is not color vision in these three simple eyes, and there is not form vision. So there is just general sensitivity to light and dark. What do you think bees use that for?

[student voice, off camera]: Navigation.

Dr. Fahrbach: That's a good start, tell me more. [student voice is indistinct] It's more primitive than that. Bees do such cool things that sometimes we sort of assume they're doing more, but you're on the right track.

[another student's voice] Check if they're in shade or in sunlight.

Dr. Fahrbach: Yes, and that's important to navigation. So it's not just “shade and sunlight.” How about “flying upside down versus flying right-side up”? (laughs) Okay. Any other thoughts about that?

Student: It's got to be really confusing when it's cloudy outside.

Dr. Fahrbach: Oh. The bees have ways to work around that.

Student: Finding the entrance to a hive?

Dr. Fahrbach: Well, any transition from light to dark. It would be exactly correct. Now, there's also a neat experiment which was done, in which a bee was otherwise normal, but black paint was put on top of these three simple eyes. There was a very curious result. It turned out that the bees basically flew alright, so it's probably not – they have other senses to detect gravity, so they know when they're right-side up. They were actually able to get back into their nest, so it's probably not “oh it's dark, I must be at home.” it turns out that what these bees could not do, is they didn't realize the sun was going down. So they didn't know it was time to go home. And they had trouble getting out of the hive at the right time in the morning. So all the evidence to date is that this is a specialized system for making sure that the sun is up, or the sun is going down. These are not using information from their compound eyes, even though they're seeing light there, and it goes to different parts of their brain. They are using two separate visual systems, which intersect in the brain.

Student: So do all the bees get up at the same time in the morning?

Dr. Fahrbach: A colony will – it's not as well organized as that, but typically foraging will begin – depending on temperature and things – at sunrise, and bees will be home by sunset. And they use this system on the top of their heads.

Alright, that was one sense. I've got four more we can talk about.

Student: Well they taste. Do they use their tongues for that?

Dr. Fahrbach: Alright, they're definitely able to taste. I think I have a – yes, so bees can definitely taste what they eat, and boy are they good at making fine distinctions among sweet, sweeter and sweetest and preferring the sweetest. And just as we have taste receptors on our tongue, they have them on different parts of their mouth parts. They have them on different parts of their body, too, but they are definitely able to taste what they eat. So that's good! That's two. Go for three?

Student: Touch, using their antenna.

Dr. Fahrbach: Touch using their antenna. That's certainly true. And a lot of us, the first word that we use for antennae was "feelers," and they definitely are able to feel things with their antennae. But I'll expand on that and say that we touch with our fingers, but we also can feel touch all over our body surfaces. And insects – bees are not unique in this – also have touch receptors embedded in their cuticle, so they can feel touch on their surface. They can also feel the movements of many of the hairs and bristles that are on their body, so they have a very exquisite sense of touch. Okay, that's not the only thing they antennae are for. Who hasn't contributed? What's the other – there are two other senses associated with the antennae. Two others. And guess what? The antennae is a good answer for both of them.

Student: Sense of smell?

Dr. Fahrbach: Sense of smell. Okay. So there are odor receptors on parts of the antennae, which are proteins that bind to volatile odorants and send that information to the nervous system. So that't the main chemical sense. We've got one more. What's the sense at least? This is a hard one.

Student: Hearing.

Dr. Fahrbach: Right. You have to really be an entomologist to know this. Many insects, bees included, feel vibrations through a special organ that is in the antennae. It's called the Johnson's organ, and it's located at the first crook in the antennae. And so that is the ability to sense vibration. It is not tuned to what you and I would consider the audible frequency range, or it doesn't cover our whole audible frequency range. But it permits bees to hear things like wings beating, and higher frequencies. Then they use their general sense of touch to hear frequency, or to experience lower-frequency vibrations. Very good. And so the antennae, then, is the correct answer for touch, hearing, and the chemical sense that we call olfaction. Taste receptors primarily associated with the mouth parts, and then two completely separate visual systems. So there's a lot to look at on the head. And with a little magnification you should be able to see all of those features.

One point I want to make is that the antennae will look pretty solid at the lower magnification you can use. But the odor molecules actually have to get in. So there actually are little holes or pores in the cuticle which permit those molecules to go in. There's nothing magical or funny about it.

Alright, that's a good review. So we started with this. Had to show you this really cool picture. Many of us have never seen bees in a natural cavity. It is a rarer and rarer thing – in part because humans in the United States spend less and less time outdoors, although some of you do. And because there are fewer and fewer wild populations of bees. If you look closely here, there's a cavity inside this tree, and you can see guard bees arranged at the entrance. You will see bees at the entrance of managed hives you see at the University of Illinois bee lab tomorrow. But that is exactly – the bees are doing in that human-provided habitat exactly what they would be doing in a natural situation. I want to show you this figure. It was sent to me – I belong to this consortium of honey bee researchers – and a guy serving at Fort Bragg in the military in North Carolina found this tree and photographed it, and actually managed to have it protected. So at least there's one wild bee colony down at Fort Bragg. So he sent me that photo – he actually sent me a very cool video.

[end of Part 1 recording]

SECTION: BEEKEEPING

But in general, the bees that you will see are not living in tree cavities. And you should consider yourself fortunate if you are able to see that remarkable natural sight. In general, the bees are all living in removable frame hives, sometimes called Langstroth hives after the person who developed this concept of hive building. So it's worthwhile to say it was wood and wax when the bees were living in trees, and it's still wood and it's still wax – sometimes with a little plastic thrown in – when bees live in human-provided boxes. Because I know that you're going to see this, and because I know this is such a high-end course that you're not going to learn beekeeping – you're going to learn bee biology – I want to give you a brief overview of what you're going to see.

So let's work from the bottom all the way up to the top. It's wet and damp out there in the grass, so it's usually on a stand. I don't know how they are here at Illinois. I get my hives in North Carolina up on cinder blocks – the ground is nasty. You wouldn't want to spend your life or raise your children on a damp patch of ground. There's a bottom board, and this is probably not representative of modern bottom boards because all bees now typically are infested with some form of parasitic mite. And one of the simplest ways to control mites is not to install a wood bottom board, but to have a mesh or screen bottom board. And it turns out that mites are – they can do a lot of things, but if they fall down to the ground, they find it hard to crawl back up. So you see the mites on a bee's body, sometimes they let go, they fall down, and if you have a mesh screen here, they can't get back.

This is the heart of the hive, this deeper box here that we call the brood chamber, the nest. It's filled with wood frames with comb on them, each frame individually removable. You will be encouraged to look at frames tomorrow, and you will think quite naturally of frames as two-dimensional – just as in the photo where I asked you for the queen and the drone. That's a good percept. I want you then to think of the nest as three-dimensional, built of those individual two-dimensional frames. If you think of it that way, you should see that the valuable things, like the larvae, should be towards the center of that three-dimensional space. And on the edges you'll find the pollen, the nectar and some honey for feeding it. So that switch, between the two-dimensional frame and the three-dimensional space. You know, come to North Carolina, keep bees with me, because you'd be a natural for that.

Brood nests may be multi-level. It's just shown as one level here. It's typically separated from frames in which bees are storing honey, by a net called a queen excluder. And that's because humans are kind of fussy about not having bee parts, body parts, in their honey – it sort of decreases the marketability of it. So we use a queen excluder to keep all the reproductive activity down low, and to keep the honey nice and clean and easy to extract. Honey can be in round frames, some beekeepers produce round honey-in-the-comb, and encourage bees to do that by giving them round shapes. And then a top board, and then a top to keep the rain out. Those are the basic components.

Student: Yeah, I was just going to ask what happens when it rains, because the wood's gonna rot.

Dr. Fahrbach: Okay. So, a good beekeeper – you know, bees are pretty inactive in winter in most of North America, so a good beekeeper is spending the winter repairing the woodware, painting the woodware, and preparing to replace a certain proportion of his or her woodware each year. So beekeeping is actually a pretty cheap hobby. For a county beekeeping presentation, I estimated that for about $225, one could set up a hive of bees in his or her backyard. But it does rot, you're exactly right.

We often see white hives, but that's just tradition, and in many other countries white is not the preferred color. So you'll see all these things. Is everybody going to be wearing a veil? And gloves? Okay, so that means with a veil and gloves, you will be able to get your noses up close and see all these things. And if you don't see some of these things, ask why not, and maybe that will be a research colony or a colony that's being managed for some really interesting project – that by the absence of something you'll find out.

SECTION: POLLINATION
Okay, so I'm not going to talk at length about pollination, but just to remind you that pollen is one of the things that you find in the bee colony. The point of pollination – and here you'll see that I'm a zoologist, not a plant biologist – is to get the pollen from the stamen to the stigma, and the details of plant reproduction always seem very sordid to me. So we'll move on (laughs).

But that's the big deal. Bees are collecting pollen not because they like plants so much, but because they need a protein source in their diet. Nectar may contain trace amino acids but almost no protein, and you need protein to build cells and tissues in the next generation. So bees are avid collectors of pollen, and it sticks all over their body and into those specialized pollen baskets on their hind leg. And if you're lucky enough to do some entrance observations before you open a colony tomorrow, you should be able to see pollen foragers. You'll see more or fewer depending on what's blooming. But when there are pollen foragers it's easy to tell. We have abundant wildflowers in North Carolina – it's a different type of agricultural area; we grow tobacco and grapes for wine, not corn and beans. So in the spring, this would be a representative pollen frame – it is, from one of my colonies in North Carolina. And the different colors here represent different kinds of pollen. And that is all going to be turned into baby bees – that's the source of protein for tissue development.

Student: What are the black spots?

Dr. Fahrbach: Black spots would be holes, maybe a little bit of nectar. This would be a pollen frame, but there's always differences of opinion putting nectar around there. Bees will also store water – they need to drink water and they use it for cooling the hive. Or, it could be empty.

SECTION: PATHOGENS AND COLONY COLLAPSE DISORDER
Alright. So, I'll take a little more time, and one of the most important areas of modern bee research – in addition to brain and behavior, which I think is the leading area of honey

bee research – is to support bees as pollinators. So we have this species which has been introduced to the United States. And they've made their way, but the natural or feral colonies of bees are not sufficient to pollinate all the food crops. So there's a massive bee industry in which bees are reared in the southern United States, they're loaded on trucks and they're trucked all over the United States for purposes of pollination. Much more important than the honey producing and wax producing industry. I never thought about wax production at all until I moved to North Carolina – and North Carolina, particularly Winston-Salem, is the home of Moravians. Is anyone familiar with the Moravian tradition? This came from Europe, part of Germany, came originally to Bethlehem, Pennsylvania, and then before the Revolutionary War came to North Carolina. And these are the people who invented the use of candles at Christmas Eve services. I never realized that. And they absolutely require beeswax candles. So there's a huge beeswax industry in North Carolina, to supply the needs for all those Christmas Eve services. So there's a lot of interest in supporting bees, making it possible to rear bees in large numbers.

And sort of the enemy of beeswax producers are bee diseases. So it's worth reviewing what makes honey bees sick. And basically it's the same things that would make you sick. Animals are subject to viral infections. A very famous Nobel laureate, Josh Lederberg, once remarked that he didn't think it was pre-ordained that the viruses weren't going to be the only thing left on the planet – that there was no reason to think animals and plants should win in the competition between viruses and multi-cellular organisms. So there are many viral infections of honey bees, and I think you'll probably talk about them later in the week. There are also bacterial infections of honey bees. So just as you can get a virus or a bacteria – if you have a bacterial infection, you can treat it with an antibiotic, and the same is true for bee infections.

Also parasitic infections, and although those of us who live in temperate parts of the United States don't normally think of ourselves as filled with parasites, the life of a human most places on the planet is to have a lot of parasites associated with different parts of the body, particularly the gut. So in this way bees are not different from other animals. But in North America they've had their populations particularly reduced by parasitic infections. And the problem with parasitic infections is, if the parasites are animals they are then close relatives in that grand sense of biology like my first slide, of what they're infecting. And so the drugs or treatments that will kill the parasite will also likely kill the host. So it's tricky to get rid of parasitic infections. There are also fungual infections of honey bees, or the bee equivalent of athlete's foot. And then a mysterious syndrome called Colony Collapse Disorder. Which is actually a phenomenon that describes how, in the past couple of years, beekeepers in North America have been much less successful in getting colonies through the winter than in the past, and the causes for this are not known. And so it's something to think about later in the week.

I thought I'd show you a bacterial infection and then some parasitic infections. American foulbrood is the most economically important infection of bees in North America. You won't see this at the well-managed University of Illinois Bee Research Facility, but if you were to see a frame with sort of bad-looking caps on the brood, you might suspect something was wrong. If you did take your fingernail and flick that cap off, instead of a beautiful pupa developing underneath, you'd find a mess of goo, and that would be a sign of bacterial infection. And this is never going to become an adult bee. In fact, that goo is part of a diagnostic test – if you put your wood probe in an it comes out as a lump of goo, that's a pretty good clue that you've got American foulbrood. And although one can treat with drugs, the bacteria have a life cycle that involves a very resistant spore form, and so burning the infected hives is the method of control. [to UI researchers] Do you have any foulbrood here? [Reed and Katy answer no]. We don't either. I've only seen it in courses, yet it is – beekeepers' faces turn ashy-white if they've ever seen it.

Nicholas Naeger: I saw one colony in Ohio, and you could smell it the second you opened up the lid. It's bacteria and it's gooey, and yep, we burned the hive.

Dr. Fahrbach: Yep. You won't face that, but even in the best-managed research facility on the planet, you have a good chance of seeing some of these guys. These are varroa mites. In this case they're on a drone pupa which has been pulled out of a cell, so they are not hard to miss and they are feeding on the internal body fluids of that bee. The bee may be complete development, although if the infestation is very severe it's unlikely to be able to do so. If it does so, though, it's going to show signs of its early parasitic infection. Damaged or abnormal wings are one of the tipoffs. Even if you don't see the mite here, you can tell the signs of infection. And of course, I don't know about you, but if my wings looked like that I would probably fly shorter distances if I could fly at all, and there's no replacement wing shop for bees. So it's a very very serious thing. We'll kill bees, we'll kill colonies, if the infestation is severe enough. Just another example of a mite on an adult worker. Mites have a complex reproductive cycle, which you can look up or may be discussed with you later in the week. It involves their transfer into the cells and their reproduction there. So the mites enjoy the urban living that characterizes the honey bee colony, because there are no end of hosts there.

Alright, the final – actually I have seen something really disgusting in a honey bee colony, and the first sign was this. Any idea what caused this?

Student: A fungus.

Dr. Fahrbach: A fungus? That would be a really good guess, and in fact that's what I first thought. But it's not a fungus. This is silk.

Student: Spiders?

Dr. Fahrbach: Not spiders, but very close. What else makes silk? I heard it – silkworm? Yes, caterpillars spin silk in cocoons. Even when they're not doing it with the same elan as a silk moth, all caterpillars will spin silk in order to attach themselves. This is silk, it's produced by the wax moth, and this is wax moth damage. This is the pupa of a wax moth. This is a wax moth, that has a special adaptation that allows it to digest wax. If you had – if we could genetically engineer you guys so that you could eat wax and get the carbon out of it, where would you like to live? You might throw away the honey and chow down on the wax.

Nicholas Naeger: It's a very common fishing bait, wax worms.

Mr. Stone: Pet stores also sell them as a food source. No exoskeleton, as they're worms.

Dr. Fahrbach: Okay. So, wax moth at the U of I sometimes?

Nicholas Naeger: Yeah, but it's more of a problem if – when the bees are healthy they'll kick them out of the hive, they'll sting them. It's more of a problem when we take the honey off the comb. They'll get into the comb where there are no bees, and make their little tunnels. So what we'll do is we'll take the wax moth and the comb, we throw the whole box into the freezer overnight, and that takes care of that. (laughs)

Dr. Fahrbach: Right. I mean, mothballs would work, but (laughs)

Nicholas Naeger: Mothballs would get into the wax.

Dr. Fahrbach: The wax, so again, that's the problem – if you have an insect that attacks another insect, you are really limited because what you do to the prey will damage the host.

SECTION: VENOM

So a final favorite topic. Who here has been stung by a bee? Raise your hand. (most hands in the room go up) That's amazing! Many people are much more cautious. Those of you who didn't raise your hand are probably wondering what all the fuss is about. And so, this is a little bit of an insight into what the fuss is about. The stinger is found on the worker bee. It is the structure that develops from what would have been the ovipositor, or the egg tube, in the female. So the stinger is said to be a modified ovipositor. You'll see in a moment, it's attached to exocrine glands that produce secretions, some of which are venomous, in the worker bee. If you're lucky and if you're not allergic and if you get stung, this is what the sting site will look like 24 hours later. A researcher at Michigan State allowed himself to be stung, or stung himself, and then documented the subsequent appearance of the sting site. So probably some of you could tell me about this – a little bit of scar tissue forming at the actual site of the sting, and then amazingly, sometimes amazingly large area of redness, representing some damage to the small blood vessels underlying the skin.

Student: Oh yes.

Dr. Fahrbach: Describe it. (laughs) Painful? But, anyone want to elaborate on that pain? Itching is what a lot of people would say, and that is caused by your body's defensive reactions to presence of a foreign protein. So what should you do when you get stung by a bee? What would be a good way to treat it?

Student: Hot water?

Dr. Fahrbach: Hot water? I'm not sure. That would bring more blood to that area, more white blood cells, so I probably wouldn't do that.

Student: Pull out the stinger?

Dr. Fahrbach: Pulling out the stinger, and I'll show you why in a moment. That just reduces the amount of venom that goes in. What you're seeing here is basically your body's acute allergic reaction. So you want to take something that you would take for allergies, like Benadryl or the generic equivalent, or Benadryl spray. That's assuming that you're not having a whole-body reaction. You'll probably hear about sting safety. But the fact is, I really liked what Jack said – if you're not allergic, this is not life-threatening. And if you were a vertebrate bear, or something who really wanted that honey, it would be annoying but it wouldn't deter you. That is sort of the whole history of humans and honey bees. Yeah, it's annoying to get a sting, but it doesn't really deter us. So a lot of people in bee research like to pretend that they're really tough because they can work on a stinging insect. But the fact is, that's sort of a myth.

So the poison gland here is dissected, and you may be able, with chilled or frozen material, to pull out the stinger and maybe get some of these attached structures. The reason you want to get that stinger out, and that's very good advice from an audience member here, is that the worker bee who was stung as it moves away there are little barbs on the stinger so it remains in the sting, parts of the poison gland plus parts of her digestive tract will be pulled out as she moves away. So she's a goner, but if you can pull that out, that's less venom in your arm and less of an allergic reaction.

SECTION: AFRICANIZED “KILLER” BEES

alright, so one final topic if we have a little bit more time. I wanted to say that knowing biology demystifies the world. And I feel Mr. Stone must have told you, you'll be afraid of far fewer things if you understand biology, because they won't seem mysterious to you. And that's understanding both disease processes, how your own body works, and it's also things that appear in the mass media, like “killer bees.” so I want to tell you that you already understand enough biology not to be afraid.

“Killer” bees are what bee biologists refer to as Africanized honey bees. And Africanized honey bees are the same species as the European honey bee, Apis mellifera, but they represent a cross between representatives of our North American/European population and bees that have been happily evolving and living for a very long time in Africa. If we had an Africanized bee and a European bee, you'd be very hard pressed to tell them apart just by inspection. Now, you could do DNA sequence comparison, and that would sort things out for you, just the way that we could look at different populations of people from northern Europe and humans from Ethiopia, we could sort them out on the basis of slight differences in DNA comparison. But their behavior is different. So there are differences which would be interesting to bee biologists to explain. But they're not different in that “these bees are not killers,” and “these bees are killers.” What Africanized honey bees are is, they are more defensive around their hives than European bees. So they are shorter-latency, shorter time to stinging. More bees will come out and sting. And so if you disturb the hive of an Africanized bee, you'll get more stings. But out at flowers, or in a swarm, practically no difference. So, a little difference in behavior. This is the type of thing that, by the end of the week, you'll see that the BeeSpace project might be able to tell us what difference between these two populations within the same species accounts for the difference. The only reason you should be afraid of Africanized bees is if you are tied up. So domestic animals who can't run away because they're tied up or confined are at risk. Any human whose mobility is impaired - so very young humans or very old humans – are at risk. And then anyone who foolishly without sufficient protective gear opens up a hive of Africanized bees is going to be. But that doesn't describe me. I don't think any of those things describe any of us in this room, and don't describe the majority of the American population. So it really tells us it's a subject for a media psychology or a cultural anthropology course about how this (points to words "Africanized bee" on slide) Turned into this (points to words "killer bee"), because it's really not the underlying biology for that thing.

The cross between, or the meeting of, the European honey bees and the African honey bees occurred in Brazil, and there were very good reasons – or people believed there were good reasons – to bring the African bees to Brazil, because the climate conditions were more similar there to African than they are to Europe. Since that time decades ago, the Africanized type of honey bee has spread by swarm and by natural migration, and humans have moved them around. But because of their African origins they have subtle differences in the way they build up their colonies and build up their populations, that makes it difficult for them to take a harsh winter. So I'm pretty sure Illinois is not in their future.

Student: I've also heard that these Africanized bees follow their attacker for a longer period of time.

Dr. Fahrbach: You know, I've heard that, but that's still in the realm of anecdote. That doesn't mean it's not true.

Nicholas Naeger: At the same time, bees are very strong fliers because they can carry a lot of pollen and nectar, but they're not very fast.

Dr. Fahrbach: Right. If you walked quickly – unless you're that confined domestic animal, a young human someone with movement impairment. But that is anecdotal. And that's a really good point to make. We are looking at populations that are not genetically uniform, so the European population is a mongrel population of a mix of European stocks – some people use the term "race," but I think "stock" has replaced that – different populations of bees, of some particular versions or alleles of genes over-represented. So a mongrel population of European bees. There's an equally gentically diverse population of African bees – cross them together, and there is no such thing as "the" Africanized bee. There are some Africanized bees where we would have to go to the DNA sequence comparisons, because we can't tell them apart on the basis of their behavior. And I have to tell you – there are some European honey bees that were not Africanized, which are so mean that you just have to kill the colony, because you can't work them. There's a lack of genetic uniformity – or to flip it the other way a lot of genetic diversity – that shows up in these behavioral traits.

However, there are plenty of Africanized bees here in the southern United States. That's economically important because that's where people are making the pollinator bees all winter. Folks need to take careful measures to ensure that they are raising gentler European bees. And there's actually no good reason at all why we don't have Africanized bees in North Carolina – and they once appeared at the port of Wilmington but were denied entry. (laughs) But the climate is good, and we're near places where there are Africanized bees, so it's one of the mysteries of biology that we don't fully understand the movement of different populations. And so there's a lot of good biology projects in the making there.

And then were they able to establish, they could definitely take our very mild North Carolina winters. Which is the final reason why, you know, you should consider coming to Wake Forest. (laughs) It's those short, mild winters. And I think you could probably walk or bike almost every day of the year in Winston-Salem.

[recording ends]