

The Science Of Pathogens

It Has To Do With Density, Virulence and Transmission

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Honey bee research at times can be a challenge. What am I saying? It's more than a challenge; it's actually very difficult. Take our latest project as an example. It has been by far the most trying project that I have yet to be involved with. But, at the same time, it has been extremely rewarding because of the folks we've had the opportunity to work with.

Several years ago, Dr. Berry Brosi and Dr. Jaap de Roode, both of Emory University, approached our lab about collaborating on a United States Department of Agriculture (USDA) grant. We agreed without hesitation. And, our joint venture has since moved on to an additional National Institutes of Health (NIH) grant, which will fund the lab for the next five years. In a future article, I'll go into more detail about the study and the Emory team, but, for now, I'd like to give some essential background information about the study.

In a nutshell, the question posed by this study is, "Have we, the beekeepers, created a more virulent mite?" Now, this question stems from research conducted by Dr. Thomas Seeley. Back in 2002-2005, he discovered feral colonies in the Arnot Forest of New York thriving with *Varroa destructor* (Seeley, 2007). This situation raised the question; had bees developed resistance to the mites and/or had the virulence of the mites changed. So, he designed a study to investigate just that. The results of his study did not support the theory that the bees had evolved mechanisms of resistance to mites. However, it did call to question the virulence of the mites living with those bees. Something was going on. Otherwise, why were the bees still alive? Before we go any further, let's back up a bit.

As you are reading this, there could potentially be pathogens all around you. They may be on the chair you are resting in, the desk you have your legs propped on, or the couch you are sunk into. You may find pathogens hanging around on your kitchen table or countertops, on the oven, in the fridge, and in the microwave. When you step outside, pathogens can be hiding anywhere: lurking under stones, slithering in the grass, and lying in wait just to get a taste of you . . .

So, what is a pathogen? The true definition is something that causes a disease such as a virus, bacterium, or other microorganisms. Some parasites are also considered pathogens. All pathogens are parasites, but not all parasites are pathogens; if a parasite doesn't cause a disease, it's not a pathogen. Now, when discussing

pathogens, there are two terms that go along with it: pathogenicity and virulence. Pathogenicity by definition is the ability to cause a disease, which is absolute and qualitative. It either does or doesn't cause a disease. To be a pathogen, it must cause a disease. Otherwise, it's just benign – like the bacterium floating around in that soda you're drinking. Yummy!

On the other hand, virulence is a bit more complicated. Virulence is variable and quantitative. By definition again, it is the measurable capability or ability of a pathogen (micro or macro) to cause disease. It is positively correlated to the pathogen's reproduction rate within the host and negatively correlated with the host's fitness. Let's explore this further.

Say you're heading out of town and about to board an airplane. As you are standing there waiting for your zone to be announced over the intercom, the superficially charming lady behind the podium states that this flight is full and calls for volunteers to check their baggage or take a later flight. You have a meeting in Chicago this evening; so, volunteering is out. You look down at your boarding pass and realize you are in zone 4, which, of course, is the last section to board. Your group finally gets called, and you join the automaton, conga line shuffling toward the plane.

Once inside, you wait patiently for the people arranging carry-ons in the overhead compartments, adjusting wardrobes, and moving into their seats from the aisle ahead of you. You try not to bang your own bag into anyone's knee or elbow as you weave your way down the alleyway. And, finally, you arrive at row 32 – deep in the bowels of the great, aluminum beast. You stow the overstuffed bag and offer apologies several times to the person in seat C as you climb over their legs and squeeze yourself into the center seat (your favorite!). Very

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quickly, you notice the person in the widow seat to your right who looks like he hasn't slept in days; he has dark circles under his eyes, pale and clammy skin, and then, here it comes, the tell-tale gurgling cough. Oh great! I'm sitting next to the sick guy. Well, technically, everyone on the plane is sitting next to the sick guy. You feel bad for him, but, at the same time, you wish that you had gotten that flu shot!

In the case of the flu, each time your travel partner coughs, small water droplets encasing viral particles are released into the air of the passenger cabin. And, as you're sitting there, trapped in your seat, you breathe in these small viral pill bombs. As they make their way through your sinuses and into respiratory system, voila, you become infected. You might not begin to feel the symptoms for days, but the war in your body has begun.

Viruses are nothing more than genes (RNA or DNA) wrapped in a protein coat. This outer coat is covered with spikes, which are like keys. The outer membrane of your cell contains receptors or locks. If the key fits the lock the virus basically fools the cell into allowing access through the membrane. Once inside the cell it races through the cytoplasm until it reaches the nucleus. Just outside the nucleus, the virus breaks up releasing the genes along with chemicals called polymerases, which help to copy these viral genes inside the nucleus. After thousands of these genes have been replicated, they move out of the nucleus and into the cytoplasm where they form new viral particles. Thousands of these new particles force their way out of the cell with only one mission: to find other healthy cells to infect so replication can start all over again. Within days of your exposure, millions of flu viruses have infected millions of your cells. Then, your immune system kicks in, your temperature rises, and you begin to feel like crap.

So, where does virulence come into play? As you know, all living organisms (or, at least most of them) want to reproduce and pass on their genes; thus, life continues on this planet. In the case of a pathogen, however, reproduction is in the immediate sense, as with the flu virus replicating inside your cell, but transmission is equally important in the greater scope of survival. In other words, pathogens need to migrate to other hosts where reproduction can continue. Reproduction and transmission are both very important to any pathogen.

Virulence describes the rate or intensity of reproduction within a host. And, usually, reproduction

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within the host causes harm. So, if the reproduction (and, therefore, harm to the host) is at a high rate, this could effectively decrease the likelihood of successful transmission to the next host.

Think about it. If the host becomes immobile or dies too soon, then transmission may not occur to the next host (the means of transmission and proximity of host candidates are factors that we will discuss in a minute). On the flip side, if too little reproduction occurs within a host, and the pathogen is too easily overcome by the host's immune system, this, of course, may also defeat transmission. So, one would think that natural selection would favor pathogens that find a workable balance between the costs and benefits of harming the host. In other words, there needs to be a correspondence between reproduction and transmission, which translates into a functional relationship between the pathogen and the host. As examples, let's compare two viruses that infect humans: the Ebola and the common flu.

Since December of 2013, several West African countries (Liberia, Sierra Leone, and Guinea) have seen the deadliest outbreak of Ebola ever recorded. Over 500 people have died so far and there are still new cases being reported. While this is scary news, these are not huge numbers however, Ebola is considered an extremely virulent virus because most people infected with Ebola usually die. To become infected, you must come into direct contact with the infected blood or other bodily fluids from an existing host, including certain tropical monkeys and fruit bats, or contaminated medical equipment. This direct fluid contact is the means of transmission, and it is not one of casual encounters - thank goodness! Yes, the Ebola virus replicates so quickly and effectively within the host, it usually knocks down its host too quickly for transmission to another host to take place. And, if

transmission fails, that particular stem of infection ends upon the host's death.

Luckily for us, so far, the disease has remained in the isolated regions experiencing the outbreaks. Plus, according to the World Health Organization, Ebola is *not* one of the hemorrhagic fevers transferred by a vector (ticks/mosquitoes). This is a good thing since vectors can easily increase the transmission of disease.

When we loosely compare Ebola to the common flu virus, there's a difference. Reproduction occurs in both, yes, but not to the same degree of injury to the host. Sure, the sick guy on the plane was suffering, but not so much that he had to cancel his travel plans (and ruin the transmission opportunities for the virus!).

In theory, host density will also affect virulence. If there are plenty of hosts available then the pathogen doesn't necessarily have to keep the host alive. So, reproduction can increase, which decreases the host fitness, but, who cares, there's one right next door? On the other hand, low host density will favor lower virulence since there's little to no opportunity to transmit.

Now, let's get back to the world of the honey bee and how host density comes into play. Century old records from Russia reported there were 0.4 honey bee colonies/km² in the Northwestern forests. Research conducted in Ithaca, New York by Dr. Thomas Seeley discovered feral colonies occurred at a density of approximately 1 col/km² (Seeley, 2006). A km² equates to 247 acres. Do we beekeepers keep one colony per 247 acres in our apiaries?

Each year, roughly 1.6 million honey bee colonies head to the almond orchards of California in order to pollinate hundreds of thousands of acres of blooms. So,

bees and mites from all over the U.S. are unnaturally convened into one area. Plus, prior to moving into the almond orchards, thousands of colonies can be packed into temporary staging yards for weeks. Hence, the mixing of bees and mites begins. Does this sound familiar – i.e., the airplane ride story? With this one move, we have facilitated the transmission of mites (pathogens) and created conditions (high host densities) conducive to increased virulence.

Even when those girls return home from California, they are typically kept in apiaries with 10, 20, 30 or many more colonies. Because of this one management strategy (high colony density), are we, the beekeepers, creating conditions that foster *Varroa* mites, and the viruses they vector, to become more virulent? And, what about other management techniques that may aid in pathogen transmission, such as: mite treatment applications, resource equalizing efforts, performing splits, and swarm control measures? Are they amplifying virulence not only in *Varroa* but in honey bee diseases as well? Lots to consider here.

Ok, long story long, but I wanted to give some background information before I went any further. When we first started working on the concept of this study, it took me awhile to get my head wrapped around the idea of virulence and all that comes into play. Next's month I'll go into more detail about what we've had to do in order to achieve the goals of this study and why it has been so difficult. See Ya! **BC**

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