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## What's The Buzz All About? Creating Understanding of Colony Collapse Disorder

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Eastern Kentucky University

What's The Buzz All About? Creating Understanding of Colony Collapse Disorder

Honors Thesis

Submitted

In Partial Fulfillment

of the

Requirements of HON 420

Spring 2016

By

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**Abstract**

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Abstract: Honey bees are perhaps humanity's most important pollinators. Although they influence an incredible number of plants that we consume every day, their contributions to mankind's diet are often overlooked. However, this may soon cease to be the case; if honey bees continue their downward descent and disappear, the foods they pollinate will too, leaving an enormous void in their wake. One of the leading causes of honey bee loss is Colony Collapse Disorder, a mysterious phenomenon in which hives suddenly collapse, seemingly without cause. This thesis asks several questions: What is CCD? What causes it? How can it be prevented? This thesis discusses the research on the first three questions, and explains the process behind writing a novel that seeks to explain both CCD and its potential impact on our lives, and bee roles and behaviors, to better educate the next generation on honey bee issues.

Keywords: Colony Collapse Disorder, creative thesis, honors thesis, honey bee(s), CCD

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Honey bees are a peculiar aspect of modern life. On the one hand, they provide an overwhelming number of the foods we eat. On the other, they are hardly noticed by the average person going about their day, unless they buzz close enough to be perceived as a threat. Most people do not consider the path that their food took to reach their table, least of all how it began – as a single flower, open and waiting for a honey bee’s touch. Honey bees are essential to our modern way of life; despite this, news of their collapse has not reached most Americans. Beekeepers are weathering unsustainable losses every year, losses that put the entire honey bee population – and our comfortable way of life – at risk.

One of the most perplexing factors in honey bee loss is Colony Collapse Disorder, often referred to as CCD. In order to be classified as CCD, a colony’s loss must meet certain criteria, which means CCD does not make up all of honey bee loss; however, it is an important component of the issue, and one that must be studied and understood if we are to turn the tide of honey bee loss before it is too late.

I first became interested in CCD after taking an Honors Science course (SEEing Science in Appalachia) that focused on honey bee loss and its implications. I was surprised by how little we understood about the factors behind CCD, and how most

people were unaware it existed at all, despite its potential impact on their lives. I decided to pursue this topic in my Honors thesis, both in hopes of understanding the problem and spreading awareness of it. To tackle both problems, I had to ask questions that would allow me to explore the topic thoroughly: What is the impact of honey bee pollination on our lives? What is CCD? What causes CCD? How can CCD be prevented? While performing my research, I also became aware of how few people knew about CCD, or even about bees in general; to solve this problem, I decided to put together a creative project that would explore all of these issues.

### **Pollinator Impact**

The impact of pollinators on a global scale can appear initially difficult to determine. The most obvious impact of pollination is on agricultural crops. While pollinators have been shown to benefit 87 of the 115 leading global crops, they only contribute to 35% of the total global crop production volume, versus 60% for non-pollination-dependent crops (Klein et al. 2006). In terms of caloric count alone, wind-pollinated crops, such as corn or wheat, may be sufficient; however, many pollination-dependent crops provide vital macro- and micronutrients essential to a healthy diet (Klein et al. 2006). Pollinator-dependent crops also bring variety and cultural color into the human diet. However, pollinators benefit more than just humans; pollinators also aid 80% of wild plants in setting their fruits and seeds (Potts et al. 2010). The most common cause of reproductive difficulties in uncultured plants is a lack of pollinators (Potts et al. 2010). In this way, pollinators provide several valuable services, both in providing crops



essential to human nutrition and aiding in the growth of natural wild plants essential to their ecosystems.

Of the world's pollinators, honey bees are the most prolific and well-known. Because of their diversity in the crops they frequent, reproductive ability, and ease of handling, they are the only commercial bee species in the United States (Johnson 2010). In the United States, honey bee pollination is estimated to be worth between \$15 and \$20 billion per year (Johnson 2010). Honey bee pollination is essential to roughly one third of the U.S diet; this statistic stems not only from plants entirely dependent upon bee pollination (such as almonds, cherries, carrots, and blueberries), but also those that receive yield boosts from pollination (including soybeans, watermelon, and peanuts), and those that contribute to other aspects of our diet (such as alfalfa and clover, which are used as foraging crops for various livestock) (McGregor 1976). Bee pollination is also helpful for cotton, which is a component of most textiles, as well as livestock feed (McGregor 1976). In addition, bee pollination can provide further benefits to various crops through cross-pollination, which often produces plants displaying traits of hybrid vigor; these plants tend to be healthier and more productive than their parents (McGregor 1976).

The varied benefits of bee pollination thus make them invaluable not only to beekeepers, but to farmers and consumers as well. Without honey bees, pollination-dependent plants, like almonds, could all but disappear, and plants that rely on pollination for large yields, such as soybeans, may become scarce in relation to growing global demand, thus increasing the price for the consumer. The production costs of many commercial goods would also greatly increase. Currently, many small farms can rely on

the free pollination of bees in their area, but larger, commercial farms often ship bees in from across the country in order to meet their pollination demands. Since 1961, the proportion of pollination-dependent crops has increased over 300%, vastly outstripping the growth of the honey bee population (Potts et al. 2010). As the bee population shrinks, the supply of available hives will decrease, leading into an increase in pollination costs. Consequently, even the pollination-dependent crops that remain on the market will increase in price. Overall, the decline of the honey bee population will limit the availability of many fruits and vegetables for the average consumer, and may impact the availability of other products (such as beef, dairy, and cotton products) as well.

### **Colony Collapse Disorder**

With the significance of the pollination services that honey bees provide in mind, the importance of understanding CCD as a key factor in honey bee loss becomes apparent. 2011 marked the fifth year in a row that winter losses of managed honey bee colonies were around 30%, an unsustainable number for most beekeepers (vanEngelsdorp et al. 2012). From fall 2007 to spring 2008, an estimated 35.8% of U.S. honey bee colonies were lost; of these, 60% presented with symptoms of CCD (vanEngelsdorp et al. 2008). From fall 2008 to spring 2009, the percentage of deceased colonies with CCD-like symptoms fell to 36.4% (vanEngelsdorp et al. 2009), but rose again to 42.1% of deceased hives in the fall of 2009 to the winter of 2010 (vanEngelsdorp et al. 2011). Over the winter between 2010 and 2011 alone, 29.9% of U.S. colonies were lost, 26.3% of which presented with CCD-like symptoms (vanEngelsdorp et al. 2012). Beekeepers who suspected their hives had fallen prey to CCD also experienced higher losses than

beekeepers who did not (vanEngelsdorp et al. 2012). Because CCD made up at least a quarter of losses in each of these surveys, and many of the other factors listed are believed to be entwined with CCD (*Varroa* mites, *Nosema*, and pesticides), CCD appears to be a very important component of understanding honey bee loss as a whole.

Understanding and controlling CCD could help quell the unsustainable losses beekeepers are currently experiencing, thus ensuring their pollination services will still be available to farmers and consumers. But how is CCD defined? What causes it? And what solutions exist to halt its spread before it's too late?

### **What is CCD?**

CCD is defined by five criteria: rapid loss of adult worker bees, few or no dead bees found at the hive site, presence of brood, a small cluster of live bees remaining (including the queen), and pollen and honey stores within the hive (Johnson 2010). Each of these criteria reveal something unique about the disorder. The speed at which the worker bees disappear makes it difficult to identify a collapsing colony ahead of time; thus, beekeepers are often caught by surprise, and unable to deal with the issue before it is too late. Compounding the problem is the lack of dead bees left behind; the lack of dead bees makes their cause of death difficult to determine, and obfuscates the cause of CCD even further. Another unique component of the disorder is the combination of brood (baby bees) and the queen remaining within the hive. Oftentimes when many bees seem to disappear at once, it is part of a swarm process, in which the queen abandons the hive and takes approximately half of the worker bees with her in order to begin a new hive (Somerville 1999). However, with CCD, the queen remains behind, and the percentage of workers missing is much higher. The presence of brood means that the queen is still

healthy and performing her reproductive duties, so there is no pressure to create a new queen, which can also lead to swarming behavior. Finally, the presence of pollen and nectar stores within the hive means that the honey bees are not lacking in food, and appear to be foraging normally. All of these factors make the bees' departure from the hive extremely unusual, and suggests a complex cause – or multiple causes – may be behind the bizarre manifestation of the disorder.

### **What Causes CCD?**

While a single answer would be convenient, most research suggests that CCD is in fact caused by multiple synergistic issues, including parasites and pesticides, which may stress the bees and weaken their immune systems, leaving them vulnerable to various pathogens. Exploring the validity of these causes and their possible interactions with each other is essential to understanding CCD.

#### Parasites

The most prolific parasite of honey bees is the Varroa mite, or *Varroa destructor*. Varroa mites are not an original parasite of the European honey bees used for pollination in the U.S.; Varroa mites originated in Asia, but spread to the European honey bee when the two populations interacted (Conte et al. 2010). Because Varroa mites and European honey bees did not evolve together, European honey bees have little defense against the mites; consequently, infected colonies often die between six months to two years after becoming infested (Conte et al. 2010).

Varroa mites feed off of the hemolymph (blood) of bee brood, as well as adult bees (PSU 2015). Mature female mites emerge with their host bee, and go on to lay more eggs within new brood (PSU 2015). The feeding behavior of Varroa mites injures and

weakness their hosts, often leading to deformities, which impact their vitality and lifespan, and may impact the ability of foragers to return to the hive, which could account for the absence of dead bees around the hive in CCD colonies (Conte et al. 2010). Varroa mite infections also may manifest with empty nests that still contain food and brood, similar to CCD's symptoms, but generally have an obvious mite presence that some CCD colonies do not (Conte et al. 2010).

Varroa mites bring with them numerous pathogens. Hives with Varroa mites are almost entirely infected by Deformed Wing Virus (DWV) and Acute Bee Paralysis Virus (ABPV) (Conte et al. 2010). The mites also weaken their hosts' immune systems, leaving them open to attack from other pathogens, including Chronic Bee Paralysis Virus (CBPV), Slow Bee Paralysis Virus (SPV), Black Queen Cell Virus (BQCV), Kashmir Bee Virus (KBV), and Sacbrood Virus (SBV) (Conte et al. 2010). Because female mites also leave their hosts to lay eggs in bee larvae, they can act as vectors for transmission of these viruses from bee to bee (Conte et al. 2010). Varroa mites can also lead to the passage of diseases from nurse bees to brood via feeding, from drones via semen, and from queens via infected eggs (Conte et al. 2010). All of these viruses either kill the bees outright, or sap their strength enough that they cannot contribute to building up the hive and its food stores for winter, thus leading to winter collapses (Conte et al. 2010).

Ultimately, Varroa mites are one of the largest threats honey bees face. Varroa mites kill bees not only through weakening them by drinking their hemolymph, but also directly pass pathogens onto them, and weaken their immune systems, opening them up for further infections. Varroa mites' interactions with pathogens may thus be one of the synergistic factors causing CCD.

Another parasite, the small hive beetle or *Aethina tumida*, has also been blamed for possibly causing CCD by interfering with honey bees' overwintering (Shäfer et al. 2010). Hive beetles scavenge off the food stores of the hive, and may invade the cluster honey bees form during the winter to stay warm, which could weaken them to the point of collapse (Shäfer et al. 2010). However, research suggests that hive beetles in fact have difficulty entering the cluster, and thus have a high mortality rate in the winter, implying that they may not be a factor.

### Pesticides

Another key factor in CCD is the widespread use of pesticides, namely neonicotinoids. Neonicotinoids are systemic, meaning they exist in every tissue of the plant, including nectar and pollen (Henry 2012). Neonicotinoids attack pests' central nervous systems to kill them (Henry 2012). Although originally touted as being more ecosystem-friendly than their predecessors, neonicotinoids may also adversely affect bees. In addition to possibly killing bees through direct exposure, neonicotinoids may also have varying sublethal effects, including neurological damage, which can affect their behavior in a myriad of ways. Neonicotinoids can also affect bees other than foragers, as foragers may bring contaminated nectar and pollen back into the hive (Henry 2012). The neonicotinoids suspected of harming bees include Clothianidin, Thiametoxam, Deltamethrin, and Imidacloprid, which will all be discussed in turn.

Some neonicotinoids may kill bees at levels lower than acceptable field concentrations. Clothianidin has been observed to kill bees at doses as low as .075ppm when ingested, 1,000 times lower than the field concentration (Laurino et al. 2011). Bees indirectly exposed to Clothianidin died until the doses were 20 times lower than the field

concentration (Laurino et al. 2011). Although it is often argued that neonicotinoids are largely used on plants bees do not pollinate, and thus are unlikely to affect them, bees may ingest the nectar or pollen of oilseed rape, which is often treated with Clothianidin (EFSA 2013a). Bees may also be directly affected by the application of the pesticide if it is sprayed, or may come into contact with pesticide-laden dust drifting from treated maize (EFSA 2013a).

In a similar study, Thiametoxam was found to kill bees via ingestion, with doses as small as 200 times less than the field concentration (Laurino et al. 2011). Thiametoxam also killed bees through indirect contact until the doses were lowered to 50 times lower than the field concentration (Laurino et al. 2011). Another study found that Thiametoxam contributed significantly to forager bees dying of homing failure (being unable to find their way back to the hive); after being exposed to the pesticide, between 10.2 and 31.6% of the foragers would fail to return to the hive (Henry 2012). If this loss holds steady within a hive, the hive will have difficulty replacing its foragers quickly enough to meet the demand for food, which can be detrimental to the hive's strength and success (Henry 2012). As with Clothianidin, concerns about bees coming into contact with Thiametoxam through pesticide-laden dust from treated maize, oilseed rape, cereals, and cotton, as well as through guttation fluid (sap from within the plant rising to the leaves) from maize exist (EFSA 2013b).

Finally, Deltamethrin, generally applied to oilseed rape, can also cause mortality to bees at the maximum concentration measured in the field (Decourtye et al. 2004a). Deltamethrin caused neurotoxic symptoms within the bees, such as trembling and paralysis, and ultimately death (Decourtye et al. 2004a).

In the same trial, another neonicotinoid, Imidacloprid, did not kill the bees even at 2-10 times the maximum concentration measured in the field, but did deter the bees from returning to the same food source, which could be detrimental to pollination-dependent plants, and may limit the bees' ability to gather food (Decourtye et al. 2004a). Another study found that Imidacloprid may impair the medium-term retention of bees in regards to finding food sources, which suggests that the pesticide may impair honey bees' abilities to form memories, which could in turn prove detrimental to their foraging habits (Decourtye et al. 2004b). Imidacloprid was also found to increase levels of the fungus *Nosema* in colonies exposed to sublethal doses of the pesticide, which suggests the pesticide may work synergistically with the pathogen, weakening the bees enough to allow the fungus to take root (Pettis et al. 2012; Alaux 2009).

An additional way neonicotinoids may affect bee behavior is by pairing with the stresses of overwintering. A study comparing the overwintering practices of honey bees exposed to common neonicotinoids versus those unaffected found that the majority of bees in neonicotinoid-treated hives disappeared from their hive during the course of winter, a hallmark of CCD (Lu et al. 2014). However, the neonicotinoid-affected colonies also ceased rearing brood, which does not align with the typical CCD pattern (Lu et al. 2014), leaving the connection between neonicotinoids affecting overwintering behavior and CCD somewhat ambiguous.

### Pathogens

Numerous pathogens currently afflict honey bees; many of these are exacerbated by outside influences, including parasites and pesticides. The most widely discussed honey bee pathogen, in relation to CCD, is *Nosema ceranae*; however, many other



diseases exist, and most are not well understood. Any of these could potentially be linked to CCD.

The fungus *Nosema ceranae*, like the Varroa mite, originated in Asia, and spread to the Western world (Paxton et al. 2009). As with Varroa mites, this means the European honey bee has little defense against the fungus (Paxton 2009). *Nosema* has been shown to have a high mortality rate, and to be highly infectious (Higes et al. 2007)

*Nosema* has often been blamed for heavy colony losses, as it puts stress on the bees and weakens them; however, because it generally appears in weakened colonies with other ailments, it is difficult to say whether *Nosema* was the primary agent of their collapse (Paxton 2009). In one study, *Nosema ceranae* was found in 100% of CCD colony samples, but also within 80.9% of non-CCD colony samples (Cox-Foster et. al 2007). While this makes it difficult to determine whether *Nosema* is an agent or mere byproduct of a colony's collapse, it does show how abundant the fungus is in western colonies. Even if *Nosema* is not a direct agent of CCD, it may work in conjunction with other factors, such as pesticides, to hasten a colony's collapse. Fipronil (a phenylpyrazole class insecticide) and Thiacloprid (a neonicotinoid) are pesticides that are not generally fatal to honey bees alone; however, when combined with *Nosema*, honey bee mortality was found to be significantly higher than in bees only exposed to *Nosema*, implying that the pesticides were lowering the bees' ability to fight off the fungus (Vidau et. al 2011). This could explain why *Nosema* is almost always found in collapsed hives, but also found in others that have not yet collapsed; the interaction between pesticides and *Nosema* and other diseases may be a key factor.

Several other diseases have also been implicated in CCD. Tobacco Ring Spot Virus (TBSV), an RNA virus originally found in tobacco plants, can infect bees through the plant's pollen. Foragers then carry infected pollen back to the hive, thus infecting any bees that consume the tainted pollen (Li et al. 2014). Varroa mites have also been shown to carry the virus (Li et al. 2014). Although the bees studied displayed no outward signs of TBSV, it is possible that heavily infected bees could suffer nerve and muscle damage, especially if compounded by other diseases (Li et al. 2014).

Picorna-like viruses, such as Deformed Wing Virus (DWV) and Israeli Acute Paralysis Virus (IAPV) may also be factors in CCD (Johnson et al. 2009). DWV has been found to appear most prominently in weakened colonies on the verge of collapse (Li et al. 2014). DWV causes crippled wings, bloated abdomens, paralysis, and often death in its hosts (Lanzi et al. 2006). DWV, like Acute Bee Paralysis Virus (ABPV) and Kashmir bee virus (KBV), is transmitted by Varroa mites, whose parasitism weakens the host until it can no longer fight off infections (Lanzi et al. 2006). The prevalence of DWV and other diseases in CCD-affected colonies suggests that these diseases, in combination with Varroa mites' debilitating effects, may cause colonies to collapse.

With all these diseases, clear synergistic effects between the disease and either pesticides or pathogens is shown, giving credence to the theory that CCD is caused by multiple factors interacting in complex ways. The fact that none of these have been explicitly linked to CCD highlights the complex, multifaceted nature of the issue. Unfortunately, CCD cannot be boiled down into a single cause or agent, which makes proposing solutions to control it that much more difficult.

### **What Can Be Done to Stop CCD?**

Because of CCD's multifaceted nature, no one solution will deal with all of the possible causes of CCD. Rather, solutions to each individual problem must be combined in order to produce an effective result.

Varroa mites are one of the most important factors in CCD. In addition to directly harming the bees by drinking their hemolymph, Varroa mites also carry numerous diseases that may prove fatal to weakened bees. Varroa mites were once treated with pyrethroids, an older generation of pesticides introduced prior to neonicotinoids, but these have fallen out of favor as the mites have grown more resistant to them (Conte et al. 2010). Oxalic acid, a relatively new miticide, has been shown to control mite populations, and may be a viable alternative for the time being, but runs the risk of mites becoming resistant to it as well (Conte et al. 2010). Strains of entomopathogenic fungi, such as *Metarhizium anisopliae*, *Beauveria bassiana* and *Clonostachys rosea*, have also been shown to kill Varroa mites without harming the mites' hosts (Hamiduzzaman et. al 2012; Ahmed and Abd-Elhady 2013). Although research into these fungi is still ongoing, these could prove to be excellent miticides in the future, which would quell not only the Varroa mite population, but also the various diseases they transmit.

An often-suggested method of controlling CCD is through banning pesticides, namely the controversial neonicotinoids. While it is possible that banning these pesticides may have a positive effect, it is premature to take such drastic action. The methods by which pesticides affect honey bees are still not well understood, nor are the effects themselves. Officials must also weigh the desire to keep a healthy honey bee population with the need to keep pests from devouring crops; while honey bees are vital to the

production of many foods, pesticides also ensure that those same foods – and others – are not destroyed by gluttonous pests. Ultimately, more research on both how bees come into contact with pesticides, and the effects of pesticides – whether lethal or sublethal – on bees must be conducted before a ban can be considered. Even if pesticides are banned, additional control of mites and various pathogens will also be necessary to stop the spread of CCD.

Finally, although not a direct solution, increased education and awareness about CCD would be beneficial. As most people are unaware that CCD exists, or unaware of the importance of pollinators in their lives, increased awareness on both subjects could help push for more research on the subject, and – if necessary – more drastic action from the government, such as banning pesticides. Increased education could also help out in small ways, such as encouraging people to plant bee-friendly flowers in their yards or gardens, or discouraging people from using pesticides on their garden plants or from calling pest control to eliminate swarms. Although these efforts are small, they would still be beneficial to honey bees – and humanity – as a whole. The desire to increase awareness, both of CCD and bees in general, led me to consider a creative aspect to my project.

### **Creatively Understanding CCD & Bees**

While researching my thesis, I was continually surprised by how many people around me seemed to have no understanding of the issue. I myself had not heard much about CCD before my Honors Science class; in the months leading up to the class, I kept my ears pricked for any news of the issue, and was surprised by how often articles

seemed to come up in the news, and then were promptly forgotten. When describing my thesis to friends, family, and even acquaintances, I was generally met with blank stares. Despite the overwhelming impact of pollination on our lives and the world, most people had no understanding of the issue – or, if they had heard of it, they chose to ignore its implications.

Throughout my project, I also became aware of the general lack of awareness people had concerning bees themselves. My knowledge of bees was somewhat limited before taking the class and pursuing my own research; I had little understanding of their inner hierarchy, beyond the obvious separation between the queen and workers, and little knowledge of their other fascinating behaviors. As my research developed, I became more interested in the bees themselves, and wanted to share this knowledge with others, in hopes of dispelling some of the fears associated with bees, and possibly interesting others' in both beekeeping and the bees' plight.

To spread awareness of CCD and knowledge of bees in general, I decided to write a young adult dystopian novel exploring a world in which the honey bee population became unable to support mass agriculture, due to being ravaged by CCD. Later on in the planning process, I decided I also wanted to incorporate elements of honey bee society and behavior into my novel. However, because of the difference in these two goals, I had to take two different approaches in attempting to describe CCD and attempting to convey honey bee behavior and information. When analyzing my audience, I realized that they would have little to no knowledge of CCD. Consequently, I had to be direct when describing CCD's causes, effects, and impacts on our lives if left unchecked, to ensure my message would be understood. However, I did not want to overdo the message, as

young adults tend to dislike feeling as though they are being preached at or forced to learn. This ended up working in my favor; the society I set up is so far removed from the present time that they have almost no knowledge of the disorder, and thus cannot openly discuss it. Rather, a specific character – a beekeeper with access to historical records – explains the problem to the main character, a young girl named Dahlia, in a single chapter. The beekeeper’s explanation serves to show Dahlia – and the audience – how their society reached its present point, by describing both the causes of CCD and the inaction that led to it becoming an unstoppable problem. In this way, I was able to describe CCD in a way my audience would understand, without overdoing it to the point of losing their interest.

Explaining the behavior and hierarchy of bees was another matter. Because bee behavior is so complex, I knew it would be difficult to express through my novel. The most obvious way was to have the beekeeper character take on Dahlia as an apprentice of sorts, and explain various aspects of bee society throughout the book; however, I did not want my audience to feel they were being burdened with unnecessary knowledge. I wanted them to be able to learn about bee society without feeling they were being instructed the entire time. Thus, although there are several scenes in which the beekeeper instructs Dahlia on various aspects of bee society and caretaking, the bulk of our information about bee behavior comes from the society itself, which is based on that of actual bee societies. In this way, I was able to explore the roles and behaviors of bees, as well as the threats they face, ultimately tying in the conflict of the story with CCD itself.

## **The Roles**

In the novel, humankind has been reduced to a number of small, scattered villages, after massive crop failures led to food shortages that eventually led to several wars. The villages are led by Queens, who direct all the actions of the villagers, and – supposedly – care for the bees, which provide the bulk of the villages’ stable food supply. The Queens decide the roles of all the villagers in a ceremony known as “the Casting.” Villager roles include Drones, Attendants, Cleaners, Guards, and Foragers, among others. There are also additional roles necessary for human societies, such as farmers (known as Tenders) and blacksmiths and the like.

Regrettably, I was not able to include the roles of nurse bees in the story; although I toyed with the idea of special Nurses being delegated to raising the children, the central conflict of the story was reliant upon the existence of family units, which Nurses would undermine.

### The Queen

The novel is entitled *Apiarchy*, as a play on words between apiary – a collection of beehives – and monarchy. All of the villages have a central monarch, known as the Queen – this fact is justified in-universe as the upper class controlling the last of the honey bees, and thus the food supply. Because honey bees were equated with food, and therefore life, those in power saw fit to associate themselves with the honey bee as closely as possible, thereby linking themselves with power in the minds of their subjects. Over time, they cultivated the idea that they were the only ones able to take care of the bees, thus giving themselves divine status in the minds of the people. Honey bees also

provided them with a convenient model for building a society in which everyone was subservient to the Queen and her family.

In bees, queens “lead” their hive, in that if they leave it, the majority of the hive will follow. In *Apiarchy*, the Queen is the unquestionable decision-maker of the village. She decides the future roles of every member of her village, in accordance with the needs she foresees. The Queen also sets the laws and punishments for the village, editing her predecessors’ as she sees fit. Because of her divine association with the bees, she is seen as unquestionable by those beneath her, just as how healthy queens are not challenged by their own colony.

Bee queens also have the responsibility of producing all of the eggs in the hive. As it was obviously impossible for a human Queen to do such a thing, I instead decided she would be in charge of the reproduction of the villagers. Because their societies are so small – generally under 1,000 people – the risk of inbreeding is a constant threat. To avert this, the Queen decides who can and can’t marry, using family trees that go back many generations (though she presents this as being some sort of divine knowledge). The Queen also decides when a couple can have children, and how many they are allowed, in accordance with both the village’s needs and the vitality of the family’s bloodline.

### Drone

In honey bees, drones are male bees born for the specific purpose of mating with a virgin queen of another hive, so the new queen has access to as much diverse genetic material as possible. Drones do not contribute to their home hives at all, and instead live off of the hive’s food stores, somewhat like parasites. Come winter, drones are generally killed or driven out of the hive, to preserve the hive’s food supplies.



In the fictional village, Drones fulfill a similar role. Drones are vital to the village system, because the small size of each village means there is a high chance of inbreeding if fresh blood is not constantly introduced into the system. Thus, Drones are selected to leave their home village and head to a designated village, where they pledge themselves to their new Queen and start a family with whoever she chooses. Because the parasitic qualities of real drones are impractical in a human society with limited resources, the Drones take on normal worker roles when they settle into their new village. In return, another village sends a Drone to the first, thus replacing the worker that was lost, and providing the village with new blood.

Because Drones are so important to maintaining the vitality of the village system, every Casting ceremony has at least one male Cast into the Drone roll (barring a year in which no males come of age). Drones are always male because of the physical danger the journey between villages presents. Before leaving their home village, they undergo special training to allow them to cope with the dangers they may face on the road; even so, there is always the risk that a Drone will be lost on the way, making the position quite undesirable.

### Attendant

In bee society, the queen has a number of special bees, known as the queen's attendants, who feed and groom her. In the fictional village society, an equitable position exists, known as an Attendant. Attendants function as both handmaidens – caring for their assigned royal's physical and emotional needs – and advisors, offering council on difficult decisions. Because Attendants come from the worker class, they often have insight into the lives of the workers that the Queen and other members of the royal family

do not. The position is highly coveted because of its proximity to the royal family. To be appointed as an Attendant is considered a great honor. In the novel, the main character, Dahlia, is chosen to be the Queen's heir's Attendant, as part of the Queen's overarching plan for her succession. Because of her background and entrance into the royal manor, Dahlia thus gives us perspectives on both classes of the fictional society.

### Cleaner

Many worker bees focus on cleaning the hive and other bees; they may remove bodies, ruined comb, and waste, and may also clean other bees. In the village, the Cleaner class mostly serves in the Queen's manor, and functions as maids or general caretakers. Like Attendants, it is considered somewhat prestigious despite the degrading work because of its proximity to the royal family.

### Guard

When bees reach a certain age and the venom in their stingers becomes most potent, they may become guard bees. Guard bees stand at the entrance to the hive and examine every bee that enters to make certain they are from the home hive. If the bee is actually an invader, the guard bees will sting it to death. Guard bees also attack other predators, like wasps, that attack the hives. Depending on the object of their ire, guard bees may die when they sting their target, as the barb can become embedded in the target's flesh and rip free of the bee.

Similarly, in the village, Guards serve as protectors of the village. Though they mostly focus on watching the manor and royal family, they also conduct periodic patrols to protect the village's borders and its crops. Guards are completely devoted to their Queen, and are more than willing to die in her service if she deems it necessary.

### Forager

Forager bees tend to be older bees whose loss would impact the colony less than younger bees. Foragers leave the hive in search of pollen and nectar, which they bring back to be stored within the comb. Foraging can often be perilous, as being far from the hive leaves them vulnerable to weather, pesticides, predators, and simply getting lost.

The Foragers in *Apiarchy* are somewhat different from forager bees. While forager bees perform their duties voluntarily, Foragers in the village are compelled to leave via exile. Generally, Foragers are people who have committed some severe crime; however, the Queen will allow them to remain in her service if they bring her back various valuable materials that the village cannot produce itself, such as metal from ruined cities. Foragers are never allowed to reintegrate back into society, but are provided some supplies and occasionally shelter for their services. They are similar to forager bees in that their duty is quite dangerous, as they too must deal with weather, predators, and other threats. They are also similar in that their duty is invaluable to the village, as their searching provides many materials that the village cannot create itself, but must scavenge from the people of the past. In the story, the Queen makes use of Foragers to find large quantities of metal, which she then uses for her own purposes.

### **The Behaviors**

Several bee behaviors are alluded to throughout the story, although most are not explicitly explored, with the exception of swarming. As with bee behaviors, I did not want to overload my readers with too much information and risk losing their attention; rather, I sought to incorporate it through our model society, thus letting the readers experience such behaviors firsthand.

### Swarming and Supersedure

One of the most important behaviors that appears in the story is that of swarming. Swarming is the basic method for hives to reproduce. Generally, swarming occurs when the queen feels the hive has grown too crowded, and lays eggs in queen cups throughout the hive. When the new queen cell is in place, the queen will leave the hive in search of a new hive site, taking roughly half of the workers with her. If multiple virgin queens emerge after the old queen has left, they will generally fight until only one remains; this victor becomes the new queen.

In the novel, similar behavior occurs. The Queen of the main village has decided she wants to expand her borders. Rather than finding a new village site, as in typical swarming behavior, she decides to take over other nearby villages and acquire their surrounding land. However, as with swarms, the Queen cannot leave her home village without a ruler. Consequently, she crafts a plan to use Dahlia as her prospective new heir, while she goes elsewhere, and takes a number of her workers with her, to act as soldiers. Dahlia also has a conflict with another young woman that the Queen is secretly grooming as a possible heir, thus reflecting the conflict of emerging virgin queens. Conflict between virgin queens is also mirrored in the relationship between the Queen and the Queen's older sister; the Queen attempted to kill her sister and failed, and instead drove her into forced isolation so the rest of the village would believe she was dead, and leave the path to succession open for the Queen herself.

The Queen's interactions with Dahlia also imitate another behavior. The Queen initially welcomes Dahlia in as an Attendant, and then claims that Dahlia is actually her daughter who was hidden away after a crisis, thus mimicking the behavior of a queen bee

laying her replacement. However, the Queen's claim is eventually revealed to be a lie; Dahlia's parents are in actuality mere workers, in an allusion to worker bees occasionally laying eggs in queen cups by themselves. Generally, this only happens when the queen has either been lost to swarming, or is growing too old and failing in her duties. Old queens who are no longer effective layers are replaced in a process known as supersedure. Supersedure may be undertaken by either the queen bee herself, or worker bees. When the new queen emerges, she may coexist with the old queen for a short time; however, eventually the old queen will disappear, leaving the new queen in charge. This too is mirrored in the novel; Dahlia is intended as the Queen's successor by the Queen herself, but in actuality comes from the worker class. She and the Queen coexist up to a point, but eventually Dahlia realizes the Queen is no longer fit for her duties as ruler of the village, and overthrows her. Both swarming and supersedure are thus expressed in a way that is not immediately obvious to the reader, thus educating them without making the story's point too explicit or overwhelming.

#### Tying Into CCD

The various behaviors of the village hive can also reflect the effects of CCD. Like a bee colony, the villagers have to contend with both parasites and pathogens, and their inability to do so ultimately leads to the collapse of their society's norms.

The parasites represented in the story have several incarnations. Foragers are directly referred to as parasites by the Queen when she exiles them; one of the novel's first scenes involves the Queen exiling a man for stealing more than his allotted portion of food to feed his family. The Queen claims the village must be "cleansed" of the man's law-breaking ways, to avoid becoming contaminated. The use of "cleansing" and exile

thereby parallels both the cleaning behaviors of bees to rid themselves of parasites, and the self-imposed exile some bees take when they have become heavily infected and seek to avoid infecting the rest of the hive. However, the Queen herself is revealed to be a parasite, as she takes more than her allotted share of food, both to feed herself in excess and secretly trade with other villages in return for goods she needs. The Queen also neglects her supposedly sacred duty of caring for the bees her village depends on, instead delegating that duty to her defeated sister. The Queen's vices thus heavily burden her village, bringing them closer to collapse.

The village also contends with pathogens, both in the form of illness and the symbolic representation of ideology as a disease. The Queen's real daughter was killed by an unknown disease, due to the society's lack of medical care and knowledge. Other characters are mentioned as having perished for the same reason. Ideology also presents itself as a disease; Dahlia's brother, Brier, is exiled for speaking out against the Queen, again in a manner similar to the self-imposed exile of heavily infected bees. However, Brier's ideas infect his sister and others, leading to a revolution from within the village itself. In this way, the village proves itself vulnerable to symbolic pathogens; unable to fend them off, it instead falls prey to them, leading to the dissolution of the traditional order.

Pesticides are alluded to, but briefly; the beekeeper character mentions that pesticides once harmed bees, but that they were also invaluable, as they kept the crops from failing. Without the presence of pesticides, the bees the village depends on are doing well, but the crops that they pollinate are weaker and more vulnerable to failing, thus putting more pressure on the village. Ultimately, the pressures of parasites,

pathogens, and pesticides (or lack thereof) are shown in the village, reflecting the struggles that actual bee hives face today. While the ending to the novel is a happy one, it still explores the dangers of CCD, as well as informing the readers about bee roles and behaviors.

### **Conclusion**

Ultimately, Colony Collapse Disorder is an extremely important issue for today's modern society, but not one that will be easily solved. Despite the incredible importance of pollinators, most people are unaware of their impact on the world and on their diet. CCD is an especially difficult issue, both because of its relative obscurity and its complex nature. CCD cannot be boiled down to one single cause that would be simple to treat; rather, it is a result of the complex interactions of multiple factors, including parasites, pesticides, and pathogens. Although some solutions, such as new miticides, currently exist, more research is needed to fill in the whys and hows of these causes before true solutions can be formulated. I sought to further this formulation by spreading awareness of CCD and bees themselves through my creative project, which explained CCD to its audience and explored the various roles and behaviors bees express via a human surrogate, in the form of a feudal village. In the future, I hope to further spread awareness of CCD, and educate more people about bees and their value to us.

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