The Apian Pharmacopeia

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Abstract: This article describes the pharmaceuticalization of honeybee health, a process that has accelerated alongside growing beekeeper concerns about unexplained colony losses over the past nearly two decades. Despite their uncertainty about the causes of colony loss and the role of pesticide exposures in rendering bees vulnerable, many entomologists agree that controlling populations of parasitic mites in bee colonies is the key to bees' survival, making mite infestations a primary target for medical interventions. The pharmaceuticalization of honeybee health means that beekeepers need to track drug administration to prevent toxic interactions, avoid overuse, and reduce resistance. This means not only managing those chemicals intentionally applied, but also those ferried in from outside the colony, notably pesticides and fungicides. Medicalizing a range of husbandry practices like supplemental feeding and mite treatment has become a way to regulate beekeepers' use of medicine as well as encourage it, making medicalization, paradoxically, a means of encouraging restraint.

Keywords: beekeeping, health, husbandry, medicalization, pharmaceuticalization

At a beekeeping symposium in 2017, an entomological specialist described her own progress "toward treatment-free" beekeeping—the "toward" signifying that this is, for many beekeepers, an ideal rather than a practical reality. Her title suggested her appreciation of many beekeepers' preferences, as well as her conviction that eschewing treatment altogether is not currently a viable practice. Few hobbyist beekeepers are enthusiastic about applying chemical treatments to their colonies, but this may also be part of the reason why their colonies die off at higher rates than those of large, commercial beekeeping operations. The specialist opened her talk by explaining that she had begun beekeeping as a child alongside her father in northern Wisconsin, when "it was easy, the bees all lived, and I hadn't even heard about the *Varroa* mite," a parasite associated with colony losses.[1] Contemporary beekeeping lacked that calm ease. Fall colony inspections were often "horrible," with "dying, dwindling colonies." She "got the sense that bees were profoundly ill," suffering from parasitic mite infestations, and

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"death by *Varroa*" mites, she reminded her listeners, is a "terrible way to die." I'm paraphrasing her comments here from my hastily typed notes:

> We just know that they are sick; we don't have to be a scientist to know. Bees in *Varroa*-infested colonies are profoundly unhealthy, profoundly ill animals. That is not the way I want to practice my craft or care for my animals. You are no longer being a good beekeeper if you allow that to persist. These are my animals, they are under my care, and I am going to take care of them from an animal welfare standpoint. The whole point of *you* in that equation is to make it better for *them*.

Making it better for bees often requires treating their diseases. As the first edition of a 2021 textbook on honeybee veterinary medicine observes: "While the list of registered medicines for bees is still small, targets for diagnostics and management decisions have tripled since 2006 and, for the first time, national surveys are funded to document parasites and pathogens across multiple years" (Evans and Chen 2021: 233). Although chemical-free beekeeping practices do exist and are used by many beekeepers, agricultural extension workers cite studies demonstrating the necessity of managing honeybee parasites and pathogens when they encourage beekeepers to adhere to Integrated Pest Management (IPM) practices when caring for their colonies. These involve monitoring and then, only if necessary, treating their bees for a variety of conditions, including mite infestations, intestinal parasites, and bacterial brood diseases like American Foulbrood. These treatments employ a range of nonchemical management practices as well as pharmaceuticals, including acaricides (miticides), antibiotics, and antifungals. As Meghan Milbrath (2016) wrote in a talk similar to the one she gave in 2017 that is referenced above: "We all want to move to a place where we don't have to treat our bees, but we want to make sure it is because our bees don't need treatment, not because we are withholding care."

Not all beekeepers use IPM, however, and many avoid chemicals. Some may treat prophylactically as a preventative measure rather than in response to observed increases in viral or parasitic loads. A 2019 study found, not surprisingly, that owners of larger commercial beekeeping operations, which account for the majority of hives in the United States, were more likely to use chemical methods of mite control, while smaller sideliner and hobbyist operations were likelier to opt for more labor-intensive control methods like removing comb containing drone brood, on which mites gestate (Underwood et al. 2019). Agrochemical companies also encourage the use of treatments, and some showcase their efforts to preserve honeybee health. These shows of investment in bee welfare, pathologies, and treatments may in the case of agrochemical companies serve to divert attention away from the other agricultural chemicals they manufacture for use on crops, some of which may pose threats to bees (Kleinman and Suryanarayanan 2016).

This article describes one outcome of this increase in honeybee diseases and the corresponding escalation in treatment by examining in particular the discourse of entomologists and agricultural extension specialists in the United States doing research oriented toward a range of beekeepers, including large commercial operations and hobbyists. Entomologists' accounts of bee health, which have primarily focused on identifying and managing specific pathogens and parasites against a baseline of overall flourishing, now also concentrate on maintaining bee health through a range of interventions that include the pharmaceutical management of bee colonies. While bee health was once the unremarkable background against which disease might manifest for unlucky colonies, it is now itself a potential site of attention and maintenance. However, as this article outlines, this is not a straightforward task, because identifying the characteristics of healthy or normal colonies when so many colonies are now being treated presents unexpected challenges. As Stephan Lorenz (2021) and Sainath Suryanarayanan (2013) have both observed, understanding how human activities have altered the terms under which honeybee health and illness are produced requires drawing on the perspectives of both the natural and social sciences and on the viewpoints of multiple participants in the care of bees.

Social scientists studying contemporary beekeeping have described how beekeepers respond to honeybees' ill health, sometimes by eschewing not just pharmaceutical treatments but all modern beekeeping practices, sometimes by embracing treatments and more often by selectively incorporating both chemical and nonchemical forms of management (Andrews 2019: 894; Green and Ginn 2014). They have also described the challenges to incorporating beekeepers' firsthand knowledge about the causes and manifestations of poor honeybee health in expert and regulatory frameworks for addressing recent colony losses. Standard forms of regulatory science, or the methods used to assess risks to organisms for the purposes of informing policy, are limited by their tendency to focus on single variables and on acute injuries rather than on sublethal effects (Kleinman and Suryanarayanan 2013), though coalitions of beekeepers and scientists have at times succeeded in broadening the scope of these risk assessments, leading to restrictions or bans on categories of pesticides, in Europe at least

(Demortain 2021). Regulatory knowledge is further hampered by researchers' difficulty replicating true field conditions, a topic this article also addresses (Kleinman and Suryanarayanan 2013; Moore and Kosut 2016; Suryanarayanan 2013).

Although beekeepers' knowledge of bee health may be more sensitive and nuanced, social scientists have also highlighted the importance of considering how human management of bees may render them uniquely susceptible to additional insults from pesticides, parasites, and introduced viruses by making bees dependent on treatments rather than by encouraging them to develop adaptive responses to these threats (Kosek 2010). As Laurent Cilia (2020) argues, the "techno-optimism" of many beekeepers, manifested as a focus on treatments and the manipulation of honeybee genetics, may serve as a form of denial for beekeepers who feel powerless to address the broader social and ecological context of bees' failing health. Lorenz, in contrast, observes how, among European beekeepers, most point to the practices of other beekeepers as the source of bees' illnesses either because of insufficient treatment or excess treatment, depending on each beekeeper's own commitments. In either case, the focus on humans as a source of bees' maladies risks reproducing the myth that bees, despite their long history of cohabitation with humans, represent a "nature" somehow outside human influence (Lorenz 2016; Lorenz and Stark 2016).

This article emerges from a larger project about how hard it has become to define a healthy honeybee, how entomologists, agricultural extension specialists, and beekeepers in the United States have redefined the contours of honeybee health over the past few decades, and how that might relate to experts' changing views of optimal health for other organisms, including humans. That project included 17 open-ended interviews with entomologists studying honeybees, graduate students, technicians, and agricultural extension researchers during 2012–2014, as well as participant observations in research apiaries and informal conversations at conferences, symposia, workshops, and meetings during 2012–2022, and analyses of published articles in beekeeping and academic journals.

In reading interview transcripts, I paid particular attention to participants' definitions of health and disease, their accounts of treatment practices, their descriptions of change over time in apiculture in the United States, and their explanations of risks to bee health. As a historian with a focus on forms of expertise and knowledge production in relation to new and emerging illness categories, I was interested in the views of those entomologists who work on honeybee health, and how the knowledge produced by those entomologists has been taken up by agricultural extension workers and beekeepers. In other words, this was not a study focused primarily on beekeepers' perspectives, though they are certainly present in the analysis because many experts who work with bees are also beekeepers themselves. As Suryanarayanan has observed, entomology in the United States arose in schools of agriculture where entomologists distinguished themselves as experts in pest management, and this focus may encourage even contemporary entomologists to be "control-oriented" in their accounts and less attuned to complex causal pathways for disease (Suryanarayanan 2013).

This project began as a study of how the ailments of a nonhuman organism were medicalized (e.g. Conrad 2007) as entomologists, beekeepers, and agricultural extension workers confronted the emerging diagnosis of Colony Collapse Disorder (CCD) beginning in the first decade of the twenty-first century. I was interested in whether the "expansion of medical jurisdiction" in the domain of honeybee health (Conrad 2007: 4) paralleled processes in other complex, multifactorial illnesses, including conditions in humans. Over time, the focus shifted from exclusively CCD to the broader category of "unexplained colony losses," including CCD, as a target of concern and advocacy. I began asking questions more specifically about how entomologists and other experts on bees struggled to establish the characteristics of healthy individual bees and colonies, as opposed to those susceptible to or on the verge of collapse (Silverman 2013). CCD is characterized by a specific set of symptoms, including the "complete absence of adult bees in colonies with few or no dead bees," the presence of capped brood (bee eggs and larvae), and unlike in typical cases of colony death, stored food that has not been robbed from the empty hive by other, stronger, colonies, suggesting that a toxin or pathogen in the hive may be dissuading potential thieves (Ellis et al. 2010).

In the decade since I began this project in 2012, entomologists have not established a definitive cause for CCD. It seems likely that the condition involves interactions among multiple agents, such as fungicides and pesticides, operating in conjunction with infections that together produce the precipitous decline characteristic of CCD (Evans and Chen 2021). In contrast to the relatively specific diagnosis of CCD, the broader category of unexplained colony losses can and does take many forms (Neumann and Carreck 2010). In both the specific case of CCD and the broader case of ongoing unexplained losses, understanding what characterizes healthy honeybees and honeybee colonies is important for investigating the causes of collapse. This article addresses one part of the background to these conversations among experts and beekeepers, specifically how experts navigate the pharmaceuticalization of honeybee health. It is not an empirical study of pharmaceuticalization in honeybee health but is instead a briefer reflection on how the normalization of pharmaceutical care affects entomologists' ability to know about bee health. More generally, as stated above, it's about the challenges of establishing a health baseline for organisms living in hazardous environments. Although the interviews referenced in this piece took place during 2012–2014, the participants' statements remain indicative of continuing discussions in bee veterinary medicine, agricultural extension work, and entomology, as more recently published articles and textbooks demonstrate.

Medical sociologists use the terms "medicalization," "biomedicalization" (Clarke et al 2003), and "pharmaceuticalization" to highlight distinct processes of capture by medical authority and technologies, and in particular how medical practices penetrate domains previously handled by other experts. In their analysis of biomedicalization, Clarke and colleagues emphasize physicians' tendency to treat the maintenance of health as an ongoing project: "In the biomedicalization era, the focus is no longer on illness, disability, and disease as matters of fate, but on health as a matter [of] ongoing moral self-transformation" (2003: 172). We could call one aspect of the process of cultivating healthy colonies, following Susan Bell and Anne Figert (2012), the "pharmaceuticalization of honeybee health." If medicalization involves using medical language to define problems or medical intervention to treat them (Peter Conrad, quoted in Bell and Figert 2012), pharmaceuticalization represents the process by which pharmaceuticals are proposed as an intervention of choice for "social, behavioral or bodily conditions." That honeybee colonies are often medicated should be unsurprising, given the observation that livestock health as a whole has been pharmaceuticalized, as farmers use breeding and medication to "align" animal bodies with the requirements of intensive farming (Twine 2013: 509). Despite continued uncertainty about the causes of unexplained colony losses and the role of pesticide exposures in rendering colonies prone to collapse, many entomologists agree that controlling pathogens and pests in bee colonies is the key to their survival, and that doing so requires at least some degree of pharmaceutical management. In particular, this involves controlling levels of the parasitic *Varroa destructor* mite, which was introduced to US bees around the late 1980s, and other pathogens, some transmitted by *Varroa*, some existing prior to *Varroa*, and some unrelated to it.

It is worth asking how analyses of both biomedicalization and pharmaceuticalization in humans relate to animal husbandry and veterinary medicine. Recent scholarship has pointed to the hazards and limitations of anthropocentric approaches to the history of medicine and current public health practices. Angela Cassidy and colleagues (2017: 2) have argued that nonhuman animals have too frequently been studied by historians as mere components of the history of human medicine, in terms of their service as model organisms or disease vectors in stories where humans remain the agents and the central concern. In making animals subsidiary to humans in studies of medical knowledge and its transformations, historians neglect those instances where animals have, through their differences from humans as much as their similarities, served as "agents of historical change" by altering medical knowledge (Cassidy et al. 2017: 3). They also remind us that standard narratives within histories of medicine maintain an arbitrary separation between medicine and veterinary science, generating a "narrowly anthropocentric framing of 'medicine' that separates it artificially from other domains concerned with the history of animal health (2017: 3). It should follow that studying processes of biomedicalization in veterinary science, with animals at the center, might yield stories different from, but no less significant than, those found in human health. In the case of honeybees, the pharmaceuticalization of bee health parallels processes in human health. It also suggests complications, like the difficulty of identifying healthy baselines, that are also coming to characterize human health.

Within medicine and public health, "One Health" or "One Medicine" initiatives are intended to unite the fields of veterinary science and medicine and by doing so remedy this disconnect between those treating humans and those tending to other animals (Zinsstag et al. 2011). However, as Steven Hinchliffe (2015) has emphasized, these initiatives often focus narrowly on the importance of epidemic surveillance in nonhuman animal populations as being key to public health campaigns because of the threat of zoonotic disease, keeping human populations and priorities central. By emphasizing the management and elimination of contagions at the expense of understanding the social arrangements and interspecies relations that render bodies of multiple species vulnerable and disease transmission likely, these initiatives may inadvertently create new health risks. One Health projects aim to track, manage, and eradicate contagions. However, health may not be the opposite of disease presence but instead "something of an achievement, a patching together or re-configuring of good husbandry practices, promoting immune responses, vaccinations, sourcing and matching stock and so on" (Hinchliffe 2015: 34). Hinchliffe is here referring to the production of livestock for human consumption, but that same cobbling together of practices increasingly characterizes beekeeping in the United States as well. In both the case of an anthropocentric focus on human medicine as a central site of innovation in healthcare, and in One Health practices that frame developments in veterinary medicine primarily in terms of what they can foretell about the risk of zoonotic disease, we miss opportunities to place animal health narratives at the center of our storytelling. Doing so can offer insights into emerging ways of characterizing health and illness that matter for both animals and humans.

Medicating bees has several distinguishing features, detailed in the remainder of this article. First, entomologists worry about beekeepers' tendency to understand in-hive treatments as something other than medical, because they are framed as being applied to parasites and not to the bees themselves. Experts worry that beekeepers seem not to recognize that their bees' treatments are veterinary interventions and that by administering them they become in essence "medical professionals" for their bees (Johnson 2011). When beekeepers don't perceive their bees as patients, they may ignore possible drug interactions or act without concern for treatment resistance or drug toxicity. Second, beekeepers need to manage resistance, both the growing resistance of parasitic mites to the treatments themselves, and, increasingly, the threat of human antibiotic resistance from antibiotic overuse. For both of these first two reasons, bees themselves have come within the purview of veterinary practice. Third, entomologists are finding that they must develop measures of honeybee health that account for the fact that most commercial colonies are at risk of infestation and under regular treatment. The best way to illustrate these processes is through specific examples of medicating bees.

Reframing Husbandry

The first example draws on the themes from the above-mentioned presentation by the entomological specialist on treating honeybees showing signs of parasitic *Varroa* mite infestation. *Varroa* mites attach themselves to both bee larvae and mature bees, feeding on their fatty tissues (Ramsey et al. 2019). Beekeepers can visually observe them attached to bees' backs and can more precisely measure levels of infestation by soaking a cup of bees in a container of alcohol and counting the mites that fall to the bottom of the jar (this assay can also be done with powdered sugar, a technique that spares the bees). Entomologists have demonstrated that *Varroa* mites are dangerous to colonies, and that untreated *Varroa* infestations have the potential to cause colony collapse, primarily by infecting colonies with viruses carried by the mites while simultaneously depressing bees' immune response and thus ability to resist infection (Di Prisco et al. 2016; Francis et al. 2013; Martin 2001). Colonies with Parasitic Mite Syndrome often collapse as a result of the viruses vectored by mites rather than from the depleting effects of parasitism alone.

But if mites are dangerous, so are the treatments for them, making judicious use a necessity. Beekeepers appear to be using miticides more often. According to the annual National Management Survey conducted by the Bee Informed Partnership (n.d.), a nonprofit that collects bee health data from beekeepers in the United States, nearly all commercial beekeepers surveyed used some form of *Varroa* treatment in 2018–2019. Backyard and sideline beekeepers increased their use of treatments over the past decade as well, increasingly using a combination of chemical and nonchemical treatments and less frequently resorting to entirely nonchemical modes of control (Haber et al. 2019). Some of these changes may reflect responses to changing rates of *Varroa* infestation, but they also suggest that beekeepers are relying more heavily on *Varroa* treatments to control infestations. Their changing practices may, in turn, be in response to the educational efforts of agricultural extension scientists and groups like the Bee Informed Partnership, though these campaigns typically emphasize a range of techniques for mite control. The authors of one survey of beekeepers' mite control measures noted that "varroacides may be a necessary component of management in many beekeeping operations," meaning a part of routine beekeeping rather than an emergency measure (Haber et al. 2019: 1524).

In using these treatments, beekeepers may dose too heavily, use unapproved treatments, or leave treated strips of miticides in their colonies long after the treatment period has ended, increasing the bees' exposure. One entomologist recounted her first observations of colonies experiencing CCD in the mid-2000s, noting that "the other thing that we saw in these migratory colonies that concerned us a lot was the remains of various miticide treatments, not legal miticide treatments" (HW).[2] Beekeepers may formulate their own treatments at levels higher than those approved for use or import miticides not approved by the U.S. Environmental Protection Agency (EPA). Bees are also exposed to both those treatments intentionally applied to colonies and those ferried in from outside the hive, like the pesticides and fungicides applied to crops, which, though a routine part of agriculture, may have long-term effects on colony health (Fisher et al. 2017; Wade et al. 2019). All these interacting factors can make it hard for entomologists to determine what exactly bees are exposed to when they assess treatment hazards. Indeed, by far the most common chemical residues found in comb and foundation wax have been those used to treat Varroa infestations (Mullin et al. 2010). As one entomologist (NZ) complained, exaggerating for effect: “The biggest pest of bees are beekeepers.”

Entomologists thus encourage beekeepers to understand mites as a medical problem of bees and miticides as an active medical treatment administered to the bees as veterinary patients as much as to the mites. As one told me:

> You want to make your bees healthy, think about them as a whole organism. Don’t address one problem and not think about all the other things that are going along too with the organism. So, you know, immediately when the mite came in, we told beekeepers, the researchers told the beekeepers, use their miticides, not paying attention to what those miticides might do, that there are going to be side effects. You know, in the same ways as when we give ourselves a drug, there will be side effects. They may be tolerable, versus the other issue [for which one is receiving treatment], but you want to balance it. (HW)

Beekeepers may overuse miticides because they imagine them to be specific treatments geared toward a single ailment of bees. In actuality, entomologists do not have a complete understanding of the mechanisms through which bees tolerate most miticides. Bees share many metabolic pathways with other insects, and it is not obvious why miticides are less toxic to bees than they are to mites. Indeed, they are likely to be toxic to bees but at higher doses than those that are lethal for mites. As another entomologist (GY) explained of one popular miticide, amitraz: “We have no idea how the bees tolerate it.” It was not that they lacked general models for understanding detoxification pathways and dose responses, but that for this particular treatment entomologists didn’t know how the pesticide functioned without disrupting hormone signaling in ways that ought to have been harmful to bees. Miticides may also impair bees’ behavioral response to mites by limiting the bees’ instinctive grooming behaviors, with one research group noting that while many studies concerned miticides’ toxicity to bees or the risk of contaminating honey or wax with treatments, another notable side effect of miticides was their inhibition of bees’ “natural defense” against *Varroa* (De Mattos 2017: 489). Because of these varied concerns, entomologists are anxious to reframe miticide treatments as medical interventions rather than routine husbandry. This is particularly important given mites' tendency to evolve miticide resistance. Miticides used in the late 1990s were already becoming less effective by the first years of this century; one of the most effective current miticides, amitraz (sold for bees in the United States as Apivar®), has worked well but shows evidence of declining effectiveness, which is possibly related to beekeepers' increased reliance on it as the efficacy of other miticides declines (Rinkevich 2020).

In addition to the miticides' side effects, meaning their likely toxicity to bees rather than mites, bees may be vulnerable to synergistic effects from interacting combinations of miticides, which beekeepers are instructed to rotate yearly to keep mites from developing resistance to the treatments (Johnson et al. 2010; Vandervalk et al. 2014). Exposing bees to multiple chemicals in combination may simply overload the bees' capacity to metabolize the drugs. And modern bees are steeped in miticides. A bee breeder I spoke with pointed out that even starting a colony from scratch with new frames and wax is no guarantee that the bees are not medicated: "Even if you buy a brand-new foundation, there's pesticide residues in there from former use of miticides" (CI). As an article written for a beekeeper audience explained:

> Drug interactions are a major concern for doctors and pharmacists, which is why medical professionals are always asking 'What drugs are you taking?' As a beekeeper, and your bees' medical professional, you also need to watch out for drug interactions and need to be asking your bees, 'What drugs are you taking?' In most cases, you already know the answer to that question since you, the beekeeper, are the one that administers drugs to control *Varroa*, American Foulbrood or *Nosema*. (Johnson 2011: n.p.).

Several things are worth noting here. The first is that entomologists are experimenting with different ways of framing and reframing the act of parasitic mite control from an occasional intervention done to manage a troublesome bee parasite to a potent but routine measure taken to treat a fatal disease. Miticide application is an element of animal husbandry of the type usually associated with domesticated animals but not with managed, as opposed to domesticated, insects like bees. Farmers understand that livestock must be monitored and treated for signs of disease. In this formulation, the needs of honeybees are becoming those typical of other livestock, where becoming a colony's "medical professional" by both diagnosing and treating ailments is a requirement of keeping healthy bees.

Second, entomologists, in conducting research that can inform beekeepers' management practices, provide support for both extension specialists and those beekeepers who argue that beekeepers as a whole must retrain their sensibilities about their bees. Honeybees are no longer self-sufficient organisms, and beekeepers who do not treat are seen as guilty of neglect, carelessness, allowing their bees to suffer, and potentially infecting neighboring bee yards if their colonies collapse, untreated (Andrews 2019: 896; Conrad 2018; Owen 2017). The entomological specialist I quoted above invoked the responsibilities owed animals under the care of humans, saying that she would never allow her dogs to suffer with an untreated illness. Why, she asked, would she do that to her bees?

Antibiotic Management

Many US state apiary inspection programs originated in response to the threat of American Foulbrood (AFB), a bacterial infection of bee larvae. AFB infections are highly contagious and can rapidly eliminate bee colonies. Before antibiotics became available, the only way to manage AFB was to identify and kill symptomatic colonies and burn contaminated equipment. State apiary inspectors visit the colonies of registered beekeepers to survey hives and test for the infection. Burning works best because Foulbrood spores are so persistent, but some states permit the use of antibiotics for Foulbrood (Snyder 2013). For large commercial beekeepers, using the antibiotic oxytetracycline (Terramycin) has been routine, if not universal, because burning hives and equipment is costly. Antibiotics, however, do not cure AFB. They suppress it, and it is likely to return if treatments are withdrawn, so treatment with antibiotics becomes a necessity for this set of beekeepers (and hence, the majority of honeybees in the United States, which are kept in large commercial operations).

Terramycin used for AFB is not the only way for bees to be exposed to antimicrobial chemicals. As one entomologist explained, the supplemental nutrition patties that beekeepers offer to bees as a way for them to build up colonies in the spring when pollen protein sources are scarce present another potential exposure route. These artificial pollen patties contain proprietary formulas that may include antimicrobial preservatives, so beekeepers may not be aware that they are exposing their bees to these substances, even when the beekeepers in question are entomologists conducting research (note that the entomologist here is referring to antimicrobial preservatives and not antibiotic medications):

> That's why a lot of studies with insects, when you use artificial diets you've just purchased from different companies so you get a [brand name] diet and they put antibiotics into these diets and then all of a sudden you realize that the critter you're working with has changed in regards to its ability to deal with its own chemistry or with chemistry that it's exposed to in the course of life. (ML)

As such, bees are entering an era with which humans are familiar, one in which the symbiotic organisms inhabiting their bodies have been modified in significant, as yet uncertain, and possibly irreversible fashion. In the case of bees, chronic antibiotic treatment may modify the symbiotic bacterial communities in their "social stomach," the ecosystem of microorganisms that are shared among members of a colony via pollen preserved as "bee bread." This can in turn affect bees' social immunity, the mechanisms through which the superorganism represented by a bee colony preserves its health (Raymann et al. 2017).

Beekeepers' use of antibiotics has run up against regulators' concerns about antibiotic resistance in humans. In particular, the beekeeping industry is now subject to restrictions originally aimed at preventing the agricultural feed industry from using antibiotics as livestock growth promoters. Regulators' concerns appear to be justified, given that studies point to the emergence of tetracycline-resistant strains of bacteria in honeybee guts. Specifically, beekeepers' longstanding use of oxytetracycline has encouraged the nonpathogenic commensal microbes in bee guts, bacterial communities that insulate against disease and help metabolize nutrients, to develop resistance genes. These genes can in turn be passed on to infectious species (Levy and Marshall 2013; Saraiva et al. 2015; Tian et al. 2012).

Federal regulations that took effect in 2015 specify that a veterinarian must inspect livestock and certify that they are ill before writing a prescription for antibiotics. The regulation requires that what is called a veterinarian-client-patient relationship be in effect. These are defined by states, but most states require that the treated animals have been seen recently by the veterinarian, sometimes within a defined period of time. As the Michigan Pollinator Initiative (n.d.) put it following a 2017 Food and Drug Administration rule, now "bees need vets." Simply bringing an infected frame in for inspection would be insufficient. In order to comply with the law, in most states the veterinarian must make a house call and a diagnosis on site, leading the same initiative to implore beekeepers to "be patient with your vet" and "do your best to educate them on what you know about honeybee diseases" as bees come to be regarded as "animals, and will be under veterinary care."[3]

Entomologists had been urging beekeepers for some time to think of bees as patients, but the regulatory requirement that bees receive veterinary consultation more definitively rendered the bee an animal under medical care. Less than a year after the new guidance, the Honeybee Veterinary Consortium took shape, hosting annual conferences and networks of veterinarians available to prescribe for bees.[4] A presenter at one beekeeping workshop mused that this might at least get more veterinarians interested in beekeeping.

Pharmaceutical Backgrounds

Despite entomologists' and regulators' concerns about the overuse of miticides and antibiotics, they also recognize that treatment is unavoidable, because the conditions that require treatment, *Nosema*, AFB, and *Varroa* mites, are nearly impossible to escape. A 2019 survey by the Bee Informed Partnership indicated that among both large-scale commercial operations and small-scale beekeepers the use of chemical controls for *Varroa* has increased over time, presumably as both hobbyists and professional beekeepers recognized that their colonies stood little chance of overwintering successfully without help through the fall season. This is when mite levels tend to increase, creating the risk of collapse over the winter period when bees are enclosed in their hives. Though the beekeepers surveyed used a range of different chemical and non-chemical control methods, the most effective treatment was amitraz, a synthetic insecticide (Haber et al. 2019: 1512–1513).

A few studies published in the decade following CCD's emergence as a serious concern can illustrate a transition in entomologists' understanding of colony losses and honeybee health prompted by both the ubiquity of *Varroa* and the yearly persistence of CCD. *Varroa* infestation had initially appeared to be a problem unrelated to colony collapse (VanEnglesdorp et al. 2009), according to the results of a study conducted in early 2007, the year after CCD was first reported. However, in a study conducted later that same year, starting in the summer of 2007, researchers in Switzerland tried to predict the onset of CCD by measuring *Varroa* infestation, Deformed Wing Virus (DWV), the intestinal microsporidian *Nosema ceranae*, and low levels of a particular protein (vitellogenin) in colonies. In contrast to the previous study, this study concluded that all were predictors of collapse, but that *Varroa* appeared to be a "key player for winter colony losses," meaning that it was established fairly quickly as a target of control efforts (Dainat et al. 2012). By 2016, in a study citing the 2012 publication, researchers had reframed two of those indicators, the presence of viruses and low protein levels, as themselves signs of *Varroa* infestation rather than independent concerns (Smart et al. 2016). The study design recognized that *Varroa* transmitted viruses to bees and lowered their immunity, and low protein levels were seen as a consequence of parasitism as well. Given the connections among these factors, and the ubiquity and lethality of Parasitic Mite Syndrome, answering whether the two remaining factors, *Varroa* and *Nosema*, could cause unexplained colony loss was no longer interesting: these were known causes of colony loss.

If in 2007 researchers investigated a range of possible underlying causes of colony collapse (or at least significant predictors of it) against a background of otherwise healthy bees, only three years later, in the study conducted from 2010 to 2013, the researchers operated differently. They first treated all of their colonies for *Varroa* and *Nosema*, and then gave them new queens and supplemental nutrition (Smart et al. 2016). This second set of researchers, reasoning that they were operating within a reality in which *Varroa* is pervasive and treatment effectively mandatory for commercial beekeepers, wanted to find other potential individual bee and colony variables that could help predict a colony's survival. Because the presence of uncontrolled *Varroa* infestations and related viruses rendered a colony so likely to fail, these had to be controlled first if researchers were to seek other causes of colony collapse. *Varroa* was no longer a subject of study but a confounding variable that obscured other underlying causes of collapse. As such, *Varroa* was an underlying characteristic of most colonies, as was the presence of medications to control *Varroa*. What was interesting to the researchers was no longer that untreated colonies developed viruses and expired, but rather that adequately treated colonies continued to show signs of ill health and collapsed, especially if they were situated near cultivated land rather than a diversity of foraging resources, pointing to challenges related to nutrition or pesticide exposure. Put another way, researchers recognized fairly quickly that the untreated honeybee was not a useful model for the average commercial colony, either in terms of the effects of treatments on the bee or the effects of an absence of treatments on parasite and disease levels within the colony.

In 2015, scientists at a USDA-ARS (Agricultural Research Service) lab tried to compare different treatment methods for *Varroa*, testing IPM practices against colonies treated with the miticide amitraz and controls (Rinkevich et al. 2017). The group was forced to conclude their experiment two months earlier than planned because the two sets of colonies left unmedicated or undermedicated, the control groups and IPM groups, were so burdened with virus symptoms presumably from *Varroa* infestations that the researchers concluded they would be unable to perform the planned assessments (Rinkevich et al. 2017: 9). It would be impossible to reliably check already dead and dying bees for their sensitivity to the miticide amitraz, one of the factors the study was meant to measure. In order to conduct research, especially studies relevant to commercial beekeepers, researchers needed to learn to mimic the conditions of constant infestation and regular treatment.

As the entomologist (ML) that I quoted earlier on antimicrobials in supplemental nutrition pointed out, background exposure to antibiotics presents similar problems for determining baseline health, or health in relation to toxic exposures. In field experiments where colonies are exposed to solutions containing pesticides, researchers might use artificial nutrition to get bees to "feed efficiently on certain things on a colony level" (ML)—that is, in a field study rather than a laboratory experiment. Researchers might also provide supplemental nutrition after colonies are exposed to potential toxins in order to help the colonies recover from the initial stress of exposure and to allow themselves to measure the longer-term effects of pesticides on colonies. But according to the entomologist, these commercial artificial diets can include antimicrobial preservatives. These "recovery diets" may thus alter the commensal microbes in bee guts, and thus their immune responses, potentially affecting the outcome of the study. Indeed, studies on the efficacy of pollen substitutes have found that they are of uncertain utility in ensuring healthy colonies, though they are widely used (Mortensen et al. 2019). In these instances, the pharmaceutical backgrounds of supplemental nutrition, endemic *Varroa* and miticide exposure, and pesticides in agricultural field sites pose design challenges for researchers who want to find out what baseline bee health looks like in the present and how to preserve it.

Medicated Bees

These three examples—managing mite treatment, antibiotic exposure, and the difficulty of establishing baseline health measures in the context of chronic *Varroa* infestations—show some of the ways that honeybee health depends on pharmaceutical interventions, at least for large commercial beekeepers in the United States. As Bell and Figert (2012) urge us to acknowledge, pharmaceuticalization is not a uniform process.

In humans, it is often bottom-up, driven by practitioners or patients in search of new options, rather than exclusively by manufacturers. It is also inconsistent, and it affects disciplinary and governmental structures unevenly. Certainly, these US-based examples might not hold up in Europe or Asia. They apply most reliably to only a particular category of honeybees, though they constitute the bulk of US bees in numbers—those rented out for pollination services, not those of backyard or sideline beekeepers. Despite the many parallels, the pharmaceuticalization of honeybees also proceeds in ways different from human medicine, because bees' sociability and biology are unlike that of the individualized and autonomous human that often serves as a model for human health interventions, whether or not that model is in fact an accurate representation of humans themselves.

Despite those caveats, these examples illustrate two important, emerging aspects of honeybee health. First, if honeybees are dependent on medical interventions for their survival, it would be easy to assume that beekeepers have been trained to seek what Joe Dumit (2012) calls "surplus health" for their honeybees, understanding preemptive medical intervention to maintain a healthy state as the appropriate response to disease risk, as has happened in much of human medicine. But as I have suggested elsewhere (Silverman 2013), it has proven immensely difficult for entomologists to define baselines for honeybee health because even apparently healthy bees are multiply exposed to pesticides and fungicides and because it is hard to know whether they have always tolerated the many pathogens they now test positive for or whether they are more vulnerable to infection now, and so on. Bell and Figert (2012) point to João Biehl's work on the pharmaceuticalization of public health in Brazil as an example of one important direction for studies of this type. They suggest that we should examine cases in which "the right to health became equated with the right to treatment with pharmaceuticals" (Bell and Figert 2012: 7). This might be especially the case where disease risk is a certainty and markers of positive health are elusive, as with managed honeybees.

But importantly, this configuring of honeybees as vulnerable to infestation and therefore in need of beekeepers to be responsible for managing their health via treatment should also be familiar to those tracking contemporary management practices for other "diseases of risk" in human patients (Vrecko 2016). Scott Vrecko (2016) has described how, when medical professionals understood addiction as a disorder defined by physical dependence and symptoms of withdrawal, they devoted themselves to mitigating acute withdrawal symptoms and aiding patients' detoxification. When in the late twentieth century addiction became for researchers a problem of craving and relapse, "the therapeutic question for biological psychiatrists has become: how do we deal with the risky cravings, the pathological desires, brought about by drug use?", a problem best treated via ongoing pharmaceutical management following an addiction diagnosis (Vrecko 2016: 63–64). Bee health is increasingly equated with the use of veterinary pharmaceuticals, both as a way of protecting against mortality and as a way of forestalling future risk.

The entomological specialist whose presentation I opened this article with urged beekeepers to shift perspectives, addressing in particular the smaller operations and hobbyists who comprise the majority of beekeepers in the United States, though, importantly, not the majority of colonies, which are kept by large commercial operations. Another study using survey data from the Bee Informed Partnership (n.d.) suggests the stakes in the transformation she advocated, that is, toward viewing bees as livestock in need of routine medical care. The authors analyzed US beekeepers' responses to a question about the advantages and disadvantages of *Varroa* treatments, which here are chemical treatments rather than other management practices. In order to understand the different ways that beekeepers conceive of stewardship, the authors analyzed the two extreme responses, namely, that treatment has either "no advantages" or "no disadvantages," which are responses given by the groups they referred to as "treatment skeptics" and "treatment adherents" (Thoms et al. 2019). Importantly, both camps understood their care as aligned with an ideal of stewardship, although the two groups defined stewardship differently. Treatment skeptics wanted to "let bees be bees" by allowing them to fight mite infestations without intervention. Treatment adherents, like the extension specialist, understood good stewardship of the animals in their care to include regular monitoring and treatment for parasites, even if they had concerns about the effects of pharmaceutical management. Good stewardship meant "keeping bees healthy" and keeping bees healthy meant regular medication (Thoms et al. 2019). Commercial beekeepers are not, generally, treatment skeptics (there were none represented in the sample above), suggesting that the norm for the majority of colonies in the United States is to receive treatment.

So, first, honeybees are vulnerable and beekeepers respond to their vulnerability with pharmaceutical treatments that are increasingly part of standard beekeeping practices. Second, and in line with this first point, it is important to ask, along with sociologists studying other forms of chronic illness, how treatments function to transform experiences of disease but also experience in general as treated organisms become standard. In their work on how students purposefully regulate their use of stimulant medications for ADHD and in so doing craft a "medicated self," Meika Loe and Leigh Cuttino described how "strategic pharmaceutical use becomes a way to occupy a middle ground between medical optimization and authenticity" (2008: 319), and they state that students often negotiate this by understanding their use of stimulants as restricted to their temporally bounded academic lives. Discussions about what the contours of healthy but treated colonies look like are worth noting because when good husbandry is equated with treatment, beekeepers and entomologists require new ways of describing health.

Medical researchers and practitioners treating humans may encounter parallel problems in the domain of nutrition and gut microbiomes, where characterizing a "healthy" or "normal" human microbiome is complicated by the reality of nutrition-related conditions like obesity and the prevalence of antibiotic resistance in gut microbes (Shanahan et al. 2023). Hannah Landecker, observing how antibiotic use has shaped human biologies, argues for attending to a "biology of history" that understands "how human historical events and processes have materialized as biological events and processes, and ecologies" (2016: 21). That prophylactic antibiotic use in livestock promotes antibiotic resistance is not a new realization but rather an expected result of routine practice. Richard Twine (2013: 510, 513) cautions against seeing recent regulatory changes in agricultural antibiotic use such as those regarding bees and Terramycin as evidence that experts only now appreciate the entanglements between human and animal health. Instead, observers should understand the lack of action until recently as evidence of the aligned interests of the livestock and pharmaceutical industries, where many of the largest pharmaceutical corporations such as Pfizer, Merck & Co., and Novartis contain animal health divisions. When entomologists recognize that infestation and treatment are existing conditions for colonies being studied, they are effectively eschewing "pure science" (Epstein 1995: 420–422) for a more accurate representation of the population. They are also learning ways to minister to bees as they actually exist when in the care of commercial beekeepers in the United States.

But, third, in encouraging beekeepers to test before treating, or to avoid overtreatment in order to avoid building tolerance in mites, entomologists also encourage an ethic of what Atul Gawande (2017) has called "incremental care" with reference to these practices in human medicine. These practices are lower cost but are the hugely effective opposite of "heroic interventions." Incremental care is, according to Gawande, longitudinal and preventative, meaning that it takes place over time, involves close attentiveness to individual patients, and yields results that are often invisible, the outcomes of disasters averted, not dramatic "rescue work." Importantly, it does not eschew pharmaceutical interventions but recognizes that exercising restraint is crucial to delaying drug toxicity. In the case of bees, this means a chance to use their innate behavioral mechanisms for managing disease. IPM practices, which are essentially monitoring and using nonchemical modes of pest management before resorting to treatment, are, of course, decades old. Unlike humans, bees' short span between generations permits entomologists to hope that bees may evolve innate defenses in ways that make less sense in human terms. That said, when entomologists urge restraint, their admonitions echo discussions about restraint in human medicine that are newly urgent in areas like pain management, where medication overuse has led to drug dependence and addiction. In the emerging field of honeybee veterinary medicine, such an ethic of practice has the potential to become a recognized standard rather than cautiousness learned as result of widely harmful practices.

Conclusion: Cultivating Restraint

We can learn about human health systems by observing how entomologists struggle to characterize the present crisis in honeybee health: it is not only their struggle that matters, but also the particular terms of their struggle. This article described the role that veterinary pharmaceuticals play in their uncertainty. Entomologists have begun to argue that medicating bees is an element of responsible apiculture, that it is not an occasional necessity but a routine form of husbandry. At the same time, they attempt to impress on beekeepers the potency and lack of specificity of pharmaceuticals and the potential for risky drug interactions and cumulative effects. By framing routine chemicals including pesticides, antibiotics, and miticides as medical treatment, entomologists are encouraging a form of care that is also potentially capacious, seeing as it does agricultural plant species, bees, and their commensal gut bacteria as organisms under physician (or veterinarian) care and not as crops and livestock to be merely controlled and managed. Overmedication is a real risk for bees and increasingly for the interwoven ecosystems in which bees live, ones that include humans that depend on the same antibiotics.

Pharmaceuticalization in honeybees is not simply an extension of pharmaceuticalization in humans. Bees' distinctive biology and status as a managed species foreground processes that are as yet only emerging in human medicine. Among these are the imperative to medicate as a form of responsible care, the existence of pharmaceutical backgrounds as a treatment baseline, and, consequent to these first two, entomologists' rejection of a binary between treatment and abstention in favor of an ethics of treatment practice. Entomologists' efforts to educate beekeepers reveal the new form of health they are constructing for honeybees, one characterized not only by husbandry, medical care, and risk, but also by restraint.

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Notes

1. The symposium talk in 2017 covered material that is also available online in a slightly different form (from an earlier presentation in 2016): Meghan Milbrath, "Your Bees Don't Have to Die: How Can We Become Treatment Free Without Killing Our Colonies?," *Sandhillbees.com*. https://static1.squarespace.com/static/56818659c21b86470317d96e/t/5900c8b5bf629a68d138598f/1493223607505/TreatmentFree_Oct2016.pdf (accessed October 3, 2022)

2. I have used randomly generated two-letter identifiers for interview participants for anonymity purposes.

3. Michigan Pollinator Initiative, "Bees Need Vets: Changes in Antibiotic Access for Beekeepers." https://pollinators.msu.edu/programs/bees-need-vets/ (accessed August 3, 2018).

4. The Consortium website reads: "Veterinarians, meet beekeepers; Beekeepers, meet veterinarians!" See https://www.hbvc.org/content.aspx?page_id=0&club_id=213546 (accessed 5 October 2022).

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