Bees in Crisis: Colony Collapse, Honey Laundering, and Other Problems Bee-Setting American Apiculture[1]

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There is no better evidence of the way the practice of apiculture has changed than a comparison of the recommended housing schemes provided for bees across the centuries. Victorian-era beekeeping is illustrated in a figure in H. D. Richardson's *The Hive and the Honey-Bee* (1847). Emphasizing humane treatment of honey bees, the breeding box is not merely housing for bees; it is rather a "pavilion of nature" equipped with glass jars so that the beekeeper can commune with his charges and observe them busy at work (Figure 1). This image starkly contrasts with that of twenty-first-century honey bees housed in the "bee hive carrier" designed by Robert and James Blake (1977 US Patent 4,033,620, 5 July 1977). According to the patent application:

> . . . it is an object of the invention to provide a common frame for a great plurality of bee hives whereon rows of hives are supported on moveable supports and these supports are moveable apart relative to each other on the frame so as to provide spacing for the bees to work between the rows of hives and for manual servicing thereof. Another object of the invention is to provide for convenience of transporting large numbers of bee hives on a common carrier so that they may be readily transported at a moment's notice. Another object of the invention is to provide a variety of mechanism for spaceably disposing rows of hives apart on a frame or vehicle chasis and for retracting the hives into close proximity to each other for storage or transport. Another object of the invention is to provide a van boxlike enclosure for a plurality of superimposed rows 60 of bee hives which may afford winter storage as well as air conditioning for bees to condition them

1 Read 28 April 2011.

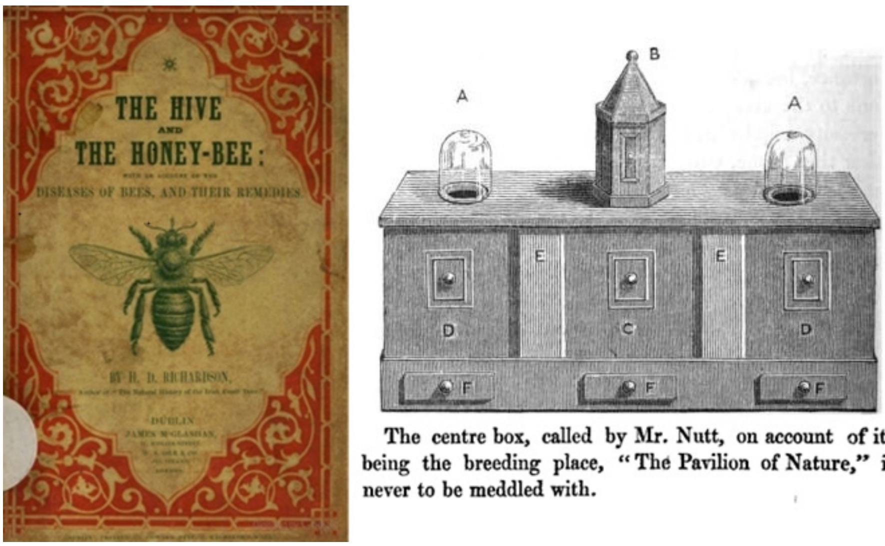

FIGURE 1. The bee hive as a "pavilion in nature," depicted in H. D. Richardson's 1847 text *The Hive and the Honey Bee*, 46.

> early so as to build up the force before pollen is ready thereby attaining maximum production of honey at the earliest possible season of the year.

Inventions such as the bee carrier designed by the Blake brothers (Figure 2) were inspired by the demands of contemporary migratory beekeeping. Every year, honey bees are unceremoniously loaded up in wooden box hives by the hundreds onto flatbed trucks and driven 2,000 miles or more across the country to provide pollination services to 800,000 acres of almond trees in California's Central Valley for a concentrated 2-week period, after which they are then trucked to other locations for other jobs. How this transformation, from pavilion of nature to assembly-line factory, came about is an exceptionally appropriate topic to discuss in Philadelphia, as the seeds of that transformation were actually planted in this city and involve the remarkable contributions of the Reverend Lorenzo Lorraine Langstroth, a Congregational minister who while living here in 1851, invented what is arguably the most transformative technological innovation in apiculture in more than 1,000 years. In some ways, Langstroth's "promotion of useful knowledge" proved to be as useful to honey bees as it was to people; in other contexts, however, Langstroth's contribution created new challenges to bees that he could never have envisioned.

FIGURE 2. (top) Figure from "Bee Hive Carrier and Transport Means," U.S. patent filed by R. L. Blake and J. D. Blake (1977 US Patent 4,033,620, 5 July 1977). (bottom) Hives of honey bees in California's Central Valley ready for spring almond pollination (photo by Dennis vanEngelsdorp).

In his early days, Langstroth was fascinated by insects but was discouraged by his parents from pursuing that interest professionally; instead, he received a classical education at Yale and became a Congregational minister (Naile 1942). He never did abandon his interest in insects, however. He became enthralled with bees and, having had a classical education, was familiar with the writings of Greeks and Romans about apiculture in ancient days. That background led him to bemoan the lack of humanity that characterized beekeeping of his era, mentioning that:

> . . . killing bees for their honey was, unquestionably, the invention of the dark ages, when the human family had lost—in apiarian pursuits, as well as in other things—the skill of former ages. In the times of Aristotle, Varro, Columella, and Pliny, such a barbarous practice did not exist. The old cultivators took only what their bees could spare, killing no colonies, except such as were feeble or diseased.
>
> The modern methods have again done away with these customs among enlightened men, and the time has come when the following epitaph, taken from a German work, might properly be placed over every pit of brimstoned bees:
>
> here rests,
> Cut off from useful labor,
> A Colony of
> Industrious bees
> basely murdered
> by its
> ungrateful and ignorant
> Owner. (Morley 1899)

Langstroth's careful observation and amazing insight are what led to a technological improvement that revolutionized the world of beekeeping. His most groundbreaking innovation, recorded in the collection of his papers in the American Philosophical Society Library, is embodied in a sketch for his patent for what he called a *movable frame hive* (Figure 3). His insight was that honey bees, when they construct a hive, leave corridors or walkways of about 1/4 to 3/8 of an inch in width so they can maneuver around the inside of their cavity nest. If the span is greater than that distance, they fill it with wax comb. If the gap is smaller, it is perceived as a crack or breach, and the bees seal it with *propolis*, a resinous, glue-like material made with plant exudates. Langstroth reasoned that he could put a wooden frame inside a box with 3/8-of-an-inch clearance around its perimeter; by doing so, he could provide a surface for the honey bees to use to build their comb, and the clearance around the perimeter would permit him to lift

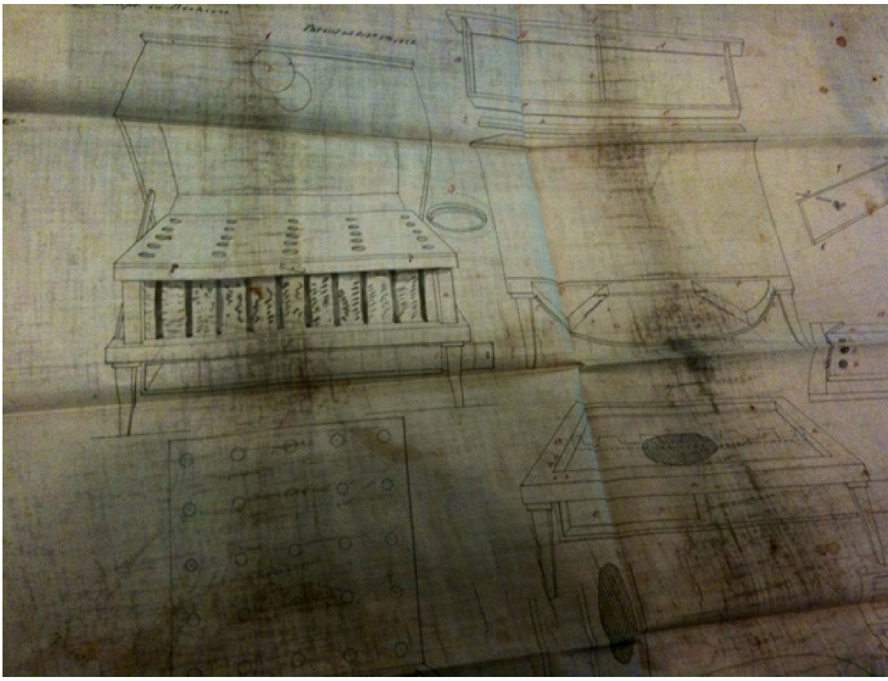

FIGURE 3. Sketch by the Reverend Lorenzo L. Langstroth of the design for a movable frame hive (from the Langstroth collection at the American Philosophical Society Library).

up and remove the frame from the box without destroying the wax. The ability to remove honey-filled wax comb, extract the honey, and then return the empty wax cells to the hive is an important consideration because wax is a secretion made by abdominal glands, and bees must consume 10 pounds of honey to make one pound of wax. Reusing the wax, rather than destroying it, thus represented a significant improvement in the economy of the hive by reducing the wastage of honey.

In 1853, Langstroth applied for a patent, showcasing the benefits of his innovative design:

> The chief peculiarity in my hives, as now constructed, was the facility with which these bars could be removed without enraging the bees, and their combination with my new mode of obtaining the surplus honey . . . . The cutting of the combs from their attachments to the sides of the hive, in order to remove them, was attended with much loss of time to myself and to the bees, and in order to facilitate this operation, the construction of my hive was necessarily complicated.

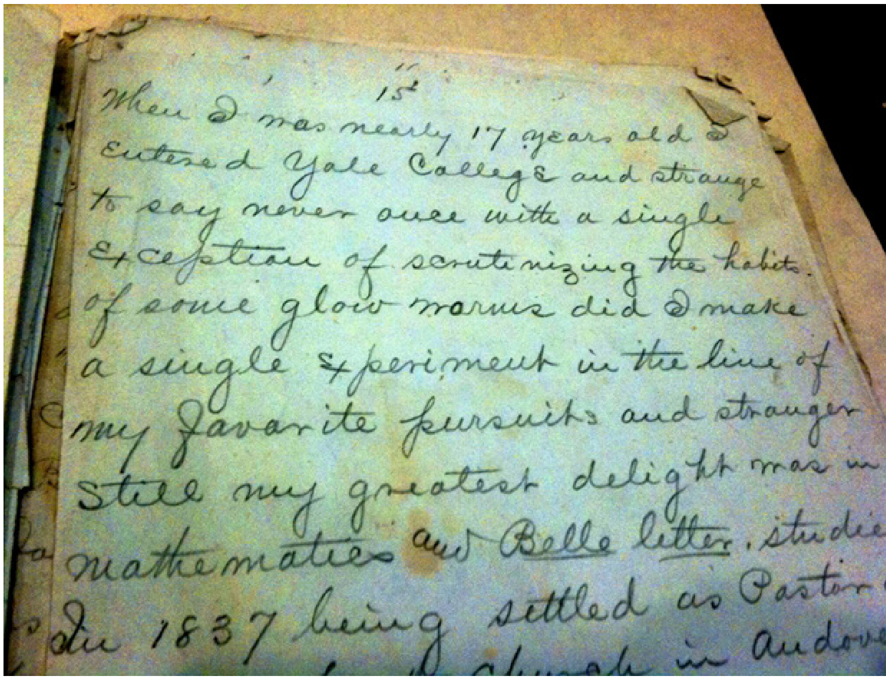
When I was nearly 17 years old I
Entered Yale College and strange
to say never once with a single
exception of scrutinizing the habits
of some glow worms did I make
a single experiment in the line of
my favorite pursuits and stranger
still my greatest delight was in
mathematics and Belle letter studie
In 1837 being settled as Pastor o
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FIGURE 4. Page of the unpublished autobiography by the Reverend Lorenzo L. Langstroth (from the Langstroth collection at the American Philosophical Society Library).

> This led me to invent a method by which the combs were attached to MOVABLE FRAMES, and suspended in the hives, so as to touch neither the top, bottom, nor sides. By this device, I was able to remove the combs at pleasure, and if desired, could speedily transfer them, bees and all, without any cutting, to another hive.
>
> Honey may be taken from my hives in the frames, and the covers of the cells sliced off with a sharp knife; the honey can then be drained out, and the empty combs returned to be filled again. A strong stock of bees, in the height of the honey harvest, will fill empty combs with wonderful rapidity. I lay it down, as one of my first principles in bee culture, that no good comb should ever be melted; it should all be carefully preserved and given to the bees . . . . Bees seem to fancy a good start in life, about as well as their more intelligent owners. (Langstroth 1857)

Another advantage of what became known as the *Langstroth hive* was that the boxes could be stacked, with boxes at the bottom of the stack for rearing brood and boxes added on top of the stack to accommodate growing honey stores. Thus, the frames emptied of honey could

be replaced in the hive; in addition, the stackable box design meant that honey yields could be greatly enhanced.

The rapid and widespread adoption of the Langstroth hive created a demand for all kinds of innovations and led to a wave of technological advances in beekeeping (Horn 2005). The ability to remove frames and leave the comb intact led to a need for new methods to extract honey from wax cells in ways that minimized damage to the wax. The first centrifugal extractor was patented in 1865 by Franz von Hruschka. With this modified centrifuge, the now-removable frame filled with honey could be lifted out of the hive, the wax caps sealing the cells sliced off, and the frame placed in a centrifugal extractor to be spun at high speed; the honey is flung out of the cells to collect on the walls of the drum and drain out through a spout. Efficiently emptied of honey, the frame, wax cells intact, could be replaced in the hive and refilled with honey by the bees. This new method of extraction, in turn, created a market for a mass-produced foundation, the surface on which wax cells could be built. Accordingly, Ohio beekeeper and entrepreneur Amos Ives Root introduced the first mass-produced foundation in 1876.

Unfortunately, other technological innovations were having an impact on agriculture in this era as well—most notably, the introduction of inorganic pesticides to control plant-feeding insects and other agricultural pests. The discovery of the insecticidal properties of Paris Green, or copper acetoarsenite, a blue-green pigment used in painting, in 1879 led to the development of a wide variety of inorganic pesticides based on heavy metals, with hydrogen cyanide introduced as a fumigant in 1886 and lead arsenate in 1889. In addition, new devices were invented to distribute these compounds throughout the environment cheaply and efficiently. The backpack sprayer was invented in 1874; the cyclone spray nozzle was patented in 1887; the first dusting machine for pesticide applications was introduced in 1893; and the first steam-powered sprayer appeared a year later (Lodeman 1913). Although the inorganic insecticides were, as desired, highly toxic to insect pests, they were not very selective; their ubiquitous use and broadcast application techniques for crop protection meant that foraging honey bees entered the line of fire with frequent and fatal results.

That beneficial insects, such as bees, could be caught in the crossfire of the chemical warfare against agricultural pests was not an idea that was immediately embraced by the scientific community. Renowned entomologist J. A. Lintner was dubious: at a North American Beekeepers Association meeting in Albany, New York, in 1891, he cautioned against jumping to conclusions and argued that "experiments were

necessary to *prove* that bees were ever killed by the spraying of fruit trees" (Larrabee 1891; Lintner 1891). In response to this call, a committee of three chaired by F. M. Webster of the Ohio Agricultural Experiment Station set out to provide that evidence. By 1895, the toxicity to bees of insecticide sprays on flowering fruit trees had been definitively demonstrated. Langstroth, who died in 1895, had lived long enough to glimpse the collateral damage inflicted on bees as a consequence of agricultural insect pest control by pesticides.

Thus, less than 20 years after the first use of inorganic pesticides to control insects, the first scientific evidence was obtained that sprays on fruit trees to kill pest insects do, in fact, as a non-target effect, kill bees. U.S beekeeping through the twentieth century and continuing into the twenty-first was characterized by lawsuits filed by beekeepers for accidental or sometimes just careless exposure of their bees to chemical pesticides that resulted in massive losses. Each new generation of pesticides took its toll on bees (Atkins 1992). With the mid-twentieth-century discovery of the insecticidal properties of the chlorinated hydrocarbon DDT, inorganic insecticides were largely replaced by synthetic organic insecticides, including not only the chlorinated hydrocarbons but also the organophosphates. Although these compounds were substantially more selective, with considerably lower vertebrate toxicity, they proved to be toxic to bees. By the 1970s, synthetic pyrethroids were added to the pest control armamentarium; particularly in encapsulated form, these proved to be highly toxic to honey bees (Atkins 1992). The pattern continued into the twenty-first century with the widespread adoption of neonicotinoids, to which bees turned out to be highly sensitive (Johnson et al. 2010).

Another twentieth-century innovation that had an impact not only on all of agriculture but also on apiculture in a most particular way was the improvement in intercontinental travel and transportation. The resulting globalization of trade brought into the United States an unprecedented number of non-native species, many of which became quickly established and seriously destructive. Right around the turn of the twentieth century, the number of invasive exotic pests, particularly insects and mites, skyrocketed (Aukema et al. 2010). Bee deaths were unfortunately the collateral damage to this particular innovation in agriculture as well. Although U.S. borders were closed to imported bees by the passage of the Honey Bee Act of 1922, aimed specifically at protecting American bees from parasites and pathogens afflicting bees elsewhere in the world, the law alone could not keep out intruders. Starting in the mid-'80s, there were two disastrous accidental introductions (Sammataro et al. 2000). The tracheal mite, a parasitic

blood-sucking mite that lives in the respiratory structures, or tracheae, of honey bees, first made an appearance in the early 1980s; by the mid-1980s, an even more devastating parasite, the varroa mite, had arrived. *Varroa destructor* is a blood-sucking ectoparasite that preferentially attacks the honey bee while it is pupating. When larvae are about to pupate, the cells in which they have developed are sealed shut by adult workers in the hive; thus ensconced, the larvae spin a silken cocoon, shed their larval exoskeleton, and begin the metamorphic transformation to adulthood. During this reorganization of cells and tissues, the pupa remains relatively incapable of movement; thus, parasitized pupae are unable to rid themselves of mites and, sealed in their wax cells, they are inaccessible to adult workers who might otherwise groom them to remove the mites. A varroa mite infestation can actually cause entire colonies to collapse. To add insult to injury, varroa mites can also serve as vectors, or carriers, of pathogenic viruses (Bowen-Walker et al. 1999; Chen et al. 2004; DiPrisco et al. 2010). In the 1990s, American bees acquired yet another introduced pest, the small hive beetle *Aethina tumida*. A member of the family Nitidulidae, the small hive beetle is not a parasite in the technical sense. Rather, the adults are attracted to sweet substances and lay their eggs near the honey stores in a hive; hatching larvae foul the honey as they consume it and, in doing so, change its properties so that it ferments and becomes unsuitable for the bees (Lounsberry et al. 2010; Neumann and Hoffman 2007).

Desperate to protect their bees from mites in particular, beekeepers resorted to the use of pesticides in the hive itself. In 1991, two pesticides were approved for varroa control—tau-fluvalinate, a synthetic pyrethroid, and coumaphos, an organophosphate. Despite the rapid evolution of resistance to these two pesticides in varroa mite populations (Elzen et al. 1998, 2000), beekeepers continued to use these compounds hoping to rid their bees of these devastating parasites.

In view of these developments, it was not entirely surprising that the last 25 years of the twentieth century saw an alarming decline in the number of beekeepers; the estimated number of U.S. beekeepers dropped from 212,000 in 1976 to 135,000 in 2006 (National Academy of Sciences [NAS] 2007). It soon became apparent that a decline in the number of beekeepers means a decline in the number of bees. In fact, by 1996, all around the world people were noticing that pollinators of all stripes, as it were, were experiencing apparent declines in abundance (Buchmann and Nabhan 1996)—so much so that in 2005, the NAS convened a study committee to examine the status of pollinators in North America to determine whether, in fact, the United States had

sufficient pollinator resources to meet the needs of its natural and managed ecosystems.

I was very much honored to serve as the chair of that committee. We worked for 18 months and released a report in October 2006 (NAS 2007). One of the inescapable conclusions we reached was that, in fact, the long-term population trend for the honey bee in the United States was demonstrably downward. As for the causes of the decline, it was abundantly apparent that introduced pathogens and parasites were contributing to this decline, as were habitat degradation and loss. Beyond the expropriation of land for urbanization and agricultural expansion, new technology had also changed the landscape, concomitantly resulting in an unintentional reduction in resources for pollinators. Expansion of monoculture agriculture in the United States with the incorporation of genetically modified crops designed to resist herbicides meant that farmed acreage was largely free of pestiferous weeds that are actually important sources of pollen and nectar for many pollinators. In terms of consequences, the committee concluded that the greatest impact of the decline in managed bee colonies was not so much on honey production as on pollination services. In the twenty-first century, the estimated value of honey bee pollination to U.S. agriculture was estimated to exceed $15 billion dollars, vastly dwarfing the value of the honey crop. Due to their eusocial behavior, the large size of their colonies and their ability to pollinate a large number of plant species, honey bees became essential to the production of more than 90 U.S. crops. Declines in honey bee supplies in the absence of viable alternative species for pollination on demand were exacerbated by expanding acreages of fruits, nuts, and vegetables with concomitant increasing demands for pollination services, thus creating shortages and raising pollination costs. Growers who pay beekeepers to rent colonies for almond pollination saw costs per hive rise from just over $30 in 1995 to more than $70 in 2005 (NAS 2007).

October 2006 was also exactly the moment when the first reports of the mysterious phenomenon called *colony collapse disorder* (CCD) appeared. A typical honey bee colony has between 20,000 and 30,000 sterile adult females, called *workers*, who carry out all tasks in the colony associated with rearing larvae, defending the hive, obtaining nectar and pollen, and processing the nectar and pollen into honey and beebread. It is the oldest and most experienced workers who leave the hive to forage for nectar and pollen to provide the fuel and food for the colony. Beginning in fall 2006, beekeepers reported massive declines in the numbers of adults, particularly foragers, who were departing the hive and not returning. Left behind were larvae, a small cadre of nurse bees to care for the larvae, the queen, and stores of beebread and honey.

This type of behavior is highly aberrant for honey bees and antithetical to the survival of a colony. As the disappearances expanded to more than 20 states by February 2007, when one-half of America's bees are needed in almond fields, CCD became a national concern (Barrionuevo 2007). The attendant publicity in national news media led to a proliferation of theories spanning the gamut from sublime to ridiculous; among the latter were suggestions that bee decline was the result of secret aerial chemical spray programs by the U.S. military, Russian mind control experiments involving electromagnetic radiation, and Middle Eastern terrorism, among others.

To make a long story short, an unprecedented amount of scientific attention was suddenly focused on figuring out what was causing the problems in a $15 billion industry that had been allowed to suffer through a century of benign neglect. About the only technological improvement in beekeeping in the 150 years since Langstroth's patent was the development of artificial insemination techniques in the 1930s. Fortunately, after that century of neglect, in October 2006 new, more refined scientific tools became possible with the publication of the complete sequence of the honey bee genome by a consortium of more than 60 scientists, with funding provided by U.S. federal funding agencies and the apiculture industry (Honeybee Genome Consortium 2006). Along with the genome sequence itself, the honey bee genome project provided an array of genome-enabled tools to use to explore bee biology.

Among the first studies of CCD to be published was one by Diana Cox-Foster and colleagues at Penn State and Columbia, who used a technique called metagenomics to identify new pathogens and parasites (Cox-Foster et al. 2007). Basically, *metagenomics* is the use of genomic methods to examine entire communities of microbes associated with a particular environment; in the case of Cox-Foster et al. (2007), the environment under study was the body of a honey bee. These investigators found a panoply of pathogens, including one Israeli acute paralysis virus (IAPV) that had never been reported in the United States. These authors identified a strong correlation between the presence of this virus and a diagnosis of CCD. That it was not strictly the causative agent of CCD was suggested by a study published one month later by Chen and Evans (2007), documenting the presence of IAPV in U.S. bees collected in the years before CCD appeared. Nevertheless, pathogens, old and new, encompassing bacteria, fungi, microsporidia, trypanosomes, gregarine protists, amoebae, and almost 20 different viruses, continued to be implicated in CCD specifically and bee decline in general (Evans and Schwarz 2011). In 2009, vanEngelsdorp et al. (2009a) showed that bees with CCD are associated with a heavier

pathogen load, and Bromenshenk et al. (2010) reported the presence of a microsporidian and an iridovirus new to science disproportionately in declining hives. Johnson et al. (2009) also demonstrated, using microarray analysis, that bees with CCD have more picorna-like viruses, and as a result of the way the microarray was produced, these authors also documented greater ribosome damage in the form of fragmented ribosomal RNA in bees with CCD.

The *microarray* is a genomic tool used to examine patterns in gene expression in an organism in contrasting conditions—in this case, healthy bees versus those diagnosed with CCD. Picorna-like viruses are vectored, or carried, by varroa mites, and they all act by attacking the ribosome, or the protein-synthesizing component of cells. Like other viruses, picorna-like viruses reproduce by hijacking the cellular machinery of the host and reprogramming it to produce viral, rather than bee, proteins. The microarray revealed fragments of broken ribosomes. This finding is consistent with a scenario whereby viral overload overwhelms the ribosome, leading to degradation and consequent loss of function. A deficiency of functional ribosomes may compromise the ability of a bee to produce proteins that it uses to cope with a wide array of stresses, including pathogen and parasite attack or, significantly, chemical contamination.

New, more sophisticated analytical chemical techniques also revealed staggering amounts of chemical contamination within managed hives. A preliminary study by Frazier et al. (2008) determined that 100% of the samples taken from hives across the country were contaminated with high levels of the two acaricides that beekeepers were using in desperate attempts to control varroa mites. Even more alarming, however, were the trace amounts of every other kind of pesticide. Fungicides and herbicides were present, along with multiple classes of both old and new insecticides. A more complete study of pesticide residues involving almost 900 hundred samples of pollen, beebread, wax, foundation, brood, and adult bees from apiaries in Florida, California, and Pennsylvania (Mullin et al. 2010) revealed remarkably high levels of pesticide residues not just in wax but also in pollen, beebread, and the bees themselves. More than 121 different pesticides and metabolites were detected, with an average of six pesticide detections per sample and at levels up to 214 parts per million in pollen.

Ironically, that these contamination levels are so high is, in part, one of the unintended consequences of Langstroth's great nineteenth-century innovation. The movable frame hive facilitated recycling of the wax comb by beekeepers. In 1851, when the movable frame hive was introduced, this recycling was a desirable goal, reducing or even

eliminating the need for bees to produce large quantities of new wax after honey was harvested by the beekeepers. The use of in-hive pesticides, however, was nonexistent in 1891; with incursions of arthropod pests, such as the varroa mite in the twentieth century, highly lipophilic and hence wax-soluble pesticides began to be used with regularity. Beekeepers have recycled their foundation ever since the movable frame hive became popular, but, in the altered chemical environment of the twentieth century in particular, this practice contributes to the accumulation of in-hive pesticides applied by beekeepers, as well as agrochemical pesticides brought in by foraging bees with nectar and pollen. At high concentrations and in potentially synergistic mixtures, these residues can compromise the immune system, delay development, reduce longevity, and otherwise negatively affect bee health (Boncristiani et al. 2011; Wu et al. 2011, 2012).

Yet another cost-cutting twentieth-century beekeeping practice that seemed to be entirely reasonable in the early 1970s proved to be otherwise in the twenty-first century. To maximize honey yields and reduce costs, beekeepers sought alternatives to honey for sustaining colonies through the winter; both sucrose syrups and high fructose corn syrup were found to be suitable substitutes in terms of acceptability and survival value (Barker and Lehner 1978). These assays, however, were conducted before the introduction of varroa mites and the widespread use of in-hive pesticides and concomitant accumulation of pesticides in wax and other hive products. Recent studies have confirmed that certain plant-derived constituents of honey, notably p-coumaric acid, function as nutraceuticals that, on ingestion, upregulate genes encoding enzymes that detoxify xenobiotics, including phytochemicals and pesticides (Mao et al. 2013). High fructose corn syrup, by contrast, does not upregulate detoxification genes (Johnson et al. 2012). Upregulation is functionally important; adding p-coumaric acid to a diet of sucrose increases detoxification by honey bees of the in-hive acaricide coumaphos by approximately 60%. Beekeepers' opting to feed their bees high fructose corn syrup instead of honey may thus be compromising the ability of the bees to detoxify agricultural and in-hive pesticides. Moreover, p-coumaric acid, a universal component of pollen and honey, also upregulates genes encoding antibacterial peptides on ingestion; beekeepers who switch their bees to high-fructose corn syrup through the winter may also compromise the ability of bees to fend off diseases.

Bees did not evolve in a world of high fructose corn syrup and refined sugar, so it is not altogether surprising that their detoxification system is highly attuned to the food they manufacture themselves. Ironically, in recent years, high fructose corn syrup has found its way into

honey consumed by humans, as well as by bees. Unscrupulous honey sellers around the world have taken to adulterating honey with cheaper high fructose corn syrup. Such adulteration is difficult to detect by any means other than sensitive chemical analytical techniques, including liquid chromatography coupled to isotope ratio mass spectrometry (Cabanero et al. 2006). As it turns out, adulteration with things far worse than high fructose corn syrup is also going on worldwide and, along with honey laundering, is an enormous problem and a challenge to today's beekeeping industry. *Honey laundering* is the term used to refer to the trans-shipping and relabeling of honey originating in China for importation into the United States (Strayer et al. 2014). Costs of honey production are substantially lower in China than in the United States, and in the early 1990s, stiff tariffs and duties were imposed on honey imported from China to prevent honey dumping. To get around these tariffs and duties, unscrupulous dealers began sending honey to the United States via a third country, where the Chinese honey is repackaged and relabeled as originating in the third country. In 2009, more than 40% of imported honey was trans-shipped and/or misrepresented to circumvent tariffs. In one honey-laundering conspiracy alone, federal prosecutors indicted 11 individuals and six companies for illegally importing "a total of 606 shipments of Chinese-origin honey . . . between March 2002 and April 2008, though declarations incorrectly stated that the honey originated in Russia, India, Indonesia, Malaysia, Mongolia, Philippines, South Korea, Taiwan, and Thailand . . . . The defendants allegedly conspired to illegally import more than $40 million worth of Chinese-origin honey to avoid antidumping duties totaling nearly $80 million" (Strayer et al. 2014). Moreover, some of the trans-shipped honey is contaminated with pharmaceutical antibiotics, pesticides, and other contaminants.

Despite declarations in the popular press in 2007 that, with CCD, the "Apis-pocalypse" had arrived, American apiculture appears to have survived the short-term crisis. In the wake of the appearance of CCD, the Apiary Inspectors of America have been surveying America's bees, and the numbers in 2010 indicated that bee numbers were increasing—about 2 million colonies (140 billion bees) were rented for pollination services. Hive rental fees are up as well, averaging $150 per hive, up from $35 in 2000 (access http://home.ezezine.com/1636/1636-2011.02.26.13.37.archive.html). According to the results of the April 2012 Bee Informed Partnership Winter Colony Loss Survey, overwintering 2011–12 losses, estimated at 22.5%, were significantly lower than the 29.9% recorded the previous winter (Spleen et al. 2012). Honey producers, too, may have benefited from the increased focus on

honey bees. According to the U.S. Department of Agriculture's Agriculture Research Service (USDA-ARS) annual honey industry survey:

- At 175.9 million pounds, honey production was up 20% compared with 2009's record low (since 1949).
- There were 166,000 more honey-producing colonies than in 2009, the first time in 3 years that colony numbers did not decline. (access http://www.abfnet.org/displaycommon.cfm?an=1&subarticlenbr=132)

However, other numbers were cause for concern:

- 252 million pounds of honey were imported in 2010, an increase of more than 40 million compared with 2009.
- Exports, at 30.4 million pounds, were up by only 1.4 million pounds.
- Per capita consumption in the U.S. averages out to 20.4 ounces per person; only 9.4 ounces of that consumption on average comes from U.S. bees. (access http://www.abfnet.org/displaycommon.cfm?an=1&subarticlenbr=132)

By comparison, Americans eat 140 pounds of sucrose and/or high fructose corn syrup every year (Berenbaum 2010). Although CCD has indisputably hurt apiculture, the industry is also hurt by this negative trade imbalance and the relative lack of interest in honey on the part of U.S. food processors and consumers.

Although honey may not be essential to the welfare of U.S. agriculture, a healthy workforce of managed pollinators is, and the crisis in 2007 led to extraordinary bipartisan cooperation in taking steps to ensure the continued viability of American apiculture. Passage of the 2008 Farm Bill marked the first time in the history of farm bill legislation that pollinators in general and honey bees in particular were even mentioned. Language was incorporated into the bill providing $10 million per year for grants to support research into honey bee and solutions for CCD; $7.25 million per year to build research capacity within the USDA-ARS to study CCD and other threats to bees; and $2.75 million per year for honey bee inspections and surveillance. In addition, the Federal Crop Insurance Act and the 1974 Trade Act were amended to provide disaster insurance access for beekeepers.

The 2008 Farm Bill was precedent-setting by all measures in terms of recognizing the significance of honey bees as managed pollinators. The challenge, however, is to keep bees in political bonnets in the absence of a crisis. Disturbing signs of political short-term memory loss appeared less than 6 months after passage of the 2008 Farm Bill. In February 2009, for example, Senator John McCain tweeted a message

identifying "the 10 porkiest projects" in the pending Omnibus Spending Bill; number 10 on this list was $1.79 million for a "honey bee factory" in Weslaco, Texas. That honey bee factory was the USDA-ARS bee research facility that was authorized for support by the 2008 Farm Bill, for which he voted earlier (Berenbaum 2011). Of the more than $60 million authorized, ultimately only $3 million was eventually allocated. In 2009, in another positive action for bees, honey bees were added to the Emergency Livestock Assistance Program; just like disaster insurance for cattle owners, chicken owners, and owners of other kinds of livestock, beekeepers became eligible to recover damages from the federal government when disaster strikes. However, Senator Mitch McConnell, along with Louisiana Senator David Vitter, pointedly criticized what they called "honeybee insurance," apparently not recognizing that the "$150 million" in the legislation was for all kinds of livestock operations, not just beekeeping operations. Vitter actually stood on the floor of the Senate and specifically asked "any member to come and explain what that provision was" (access http://www.washingtonmonthly.com/archives/individual/2009_02/016767.php), despite having personally voted for exactly the same legislation twice: first in early 2008 to authorize it and again later that year to override President Bush's veto.

It's not that Congress is entirely obstructionist; bees do have allies in high places. A new Congressional Pollinator Protection Caucus, CP2C, was founded by Tim Johnson (Illinois) and Alcee Hastings (Florida) in 2010. This is encouraging at first glance, but is less so in the broader context; there are, in fact, 276 congressional caucuses, 20 of which were founded between December 2009 and March 2010, the time period during which CP2C was formed. As one news report recounted, "The new caucus is similar to dozens of other congressional 20 that cover topics from wine and shellfish to minor league baseball and multiple sclerosis" (access http://www.mcclatchydc.com/2010/06/25/96578/new-congressional-caucus-focuses.html#storylink=cpy).

People often ask me how they can help the bees. Buying local honey is a great way to both support local beekeepers and ensure the quality and purity of the product. For the long term, however, to guarantee that a viable, functional fleet of managed pollinators will continue to provide adequate pollination services to the vast, diverse enterprise that is contemporary U.S. agriculture, perhaps the best strategy is to continue to explain "the birds and the bees" to politicians so that sufficient funds are available to support research that improves our understanding and management of the amazing and irreplaceable *Apis mellifera* into the next century.

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