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Bombyx and Bugs in Meiji Japan: Toward a Multispecies History?

by Lisa A. Onaga

Folded just so, the parachute never failed. Always, it floated back to you—silkily, beautifully—to start over and float back again. Even if you abused it, whacked it really hard—gracefully, lightly, it floated back to you.
—John McPhee[1]

Introduction

American writer John McPhee once described with great nostalgia a toy silk parachute that his mother gave him in the 1940s. It represents one of the most soft and simple of combat toys, and, for the writer, it perhaps reminded him of more innocent days. Made of little more than light, strong cloth and string, the tug of an actual World War II soldier's parachute ripcord would allow the fabric to billow out and bring him to a soft landing—ideally to a place of safety. That sign of a life possibly saved, that half sphere of air enclosed by silk, drifted into the center of a US boycott against Japan between 1937 and 1940.

The path of the parachute began much earlier, in fact, before the threat of war loomed in the Pacific. In Japan in the late 1800s, a category of student emerged to partake in "egg examinations" that aimed to prevent the spread of disease in the domesticated silkworm species *Bombyx mori*. These pupils would form a line of defense, standing watch against contagion. Seated at desks placed uniformly next to glass-paned windows, young women or men looked into their microscopes, careful not to cast any shadow that could obstruct their fields of view, illuminated by sunlight. The slides displayed tissue samples from mother moths that had just laid fertilized eggs. These moths, represented in the form of abstract smears, carried potential signs of disease that could decimate entire stocks. The new technicians subjected to this scientific training at relatively new Japanese sericulture experiment stations and institutes were examined for their performance just as much as the moths themselves were. As Americans accepted raw silk fibers with increasing enthusiasm from Europe, China, and Japan, the relationships among humans, moths (including their juvenile forms), and microbes gradually changed and facilitated the mass production of raw silk that Japan would export to the United States by the early 1900s.

The development of scientific interests in the hygiene of *Bombyx mori* shows how investments in human skills connected to the cultivation of the moth species were tied to the production of unease about the growing presence of Japanese fibers in the US textiles market. Thinking historically through Bombyx allows for the investigation of multiple issues, from the craft of silkworm husbandry and the production of scientific knowledge, to matters of safety, national security, and consumer culture. This approach brings into wider view understudied angles that help enrich previous understandings of the US-Japan tensions that ensnarled the history of the industrialization of silk production and trade. The work of examining eggs to prevent the spread of disease is one important aspect of sericulture in modern Japan. Lessons from this highly specific case present a world in itself, but those should resonate broadly among analysts, and not only those of historical inclination. A historical look at egg examinations helps underscore the need for continued empirical attention to the material interactions among nonhumans and humans in a way that complements studies of totemism and the growth of scholarship to consider the material moments of "when species meet."[2] The design of this essay follows one thread of a growing fabric of research involving the "multispecies." A number of scholars have recently opened up a vibrant discussion about multispecies ethnography, which continues to attract attention, not only among scholars committed to anthropological methodologies or to experimental art, but also among those who conduct empirical archival studies in the writing of histories.[3] In the lively, experimental spirit of multispecies research, I explore how a broader view of the domesticated silkworm species, which includes the "bugs" that afflicted it, forces us to re-envision familiar histories of sericulture that centered upon the means and end of "silk making." In this case, a "multispecies" history draws our attention to the materiality of the biotic world that humans and nonhumans cohabit in order to produce a more holistic view of what "make silk."

This essay answers the question of what exactly constituted the stuff of silk neckties, parachutes, dresses, hosiery, and even shower curtains, in the years leading to World War II. The focus of analysis bears upon understanding the formation of threads that preceded the casting of *American* threads that were used by factory workers to make garments or military paraphernelia. The essay looks beneath the shine and sheen of silk in order to consider different issues that stoked or promoted the production of raw silk as well as motivated the reach (or blockade) of this commodity to a predominantly North American market in the first half of the twentieth century. This requires a deliberation of the activities that went into making raw silk in Japan, especially a deeper recognition of the insect employed for this purpose, the domesticated silkworm, *Bombyx mori*, and its parasites. This closer, organism-centric look at textiles thus makes clear the critical value of asking *why* silk could be marshaled overseas on the scale that it did by the 1910s and 1920s. Only then can it make sense to understand why the domesticated silkworm found its species intertwined with the historical formation of an American view that saw silk as a threatening entity, tied metaphorically to the production of international tensions with Japan. The consumer, nation, scientist, technician, and silkworm come together in a way that demands a consideration of the interactions between humans and nonhumans. A number of different organisms can enter a silk narrative depending on the ecological relations paramount to a story. In this particular case of "egg examinations," it is not just the species itself, but a gendered moment in its life cycle that particularly concerned the historical actors at the time.

Microbial Threats

Humans have long had a vested interest in maintaining the health of their silkworm stocks, for robust larvae are necessary for a fruitful harvest of raw silk. Collected at first in the form of cocoons, these curious objects spun by silkworm larvae are then placed in boiling-hot water in order to loosen a single fiber. This fiber constitutes one of many that are twisted together at a filature factory to produce raw silk suitable for commercial use. What is lost in silkworm life is gained in capital. Yet, to perpetuate a stock of silkworms, silkworm breeders must also select some cocoons in order to permit the larvae inside to pupate into a chrysalis and complete its metamorphosis into either an adult female or male moth. The human-chaperoned meeting and mating of moths initiates the moment of egg-laying, which begins the lifecycle of *Bombyx mori*. Multiple species, beyond the domesticated silk moth and the humans, are associated with an understanding of sericulture; there is also the mulberry, the leaves of which are consumed almost exclusively. Then, there are the other bugs.

Historically, a number of diseases have worried the humans who have worked in the business of egg production, but perhaps none have vexed them more than *pébrine*. It was dreaded because it efficiently decimated complete cohorts of silkworm larvae, was highly infectious, and ensured great economic loss. The oft-used French term for this disease suggests a peppery affiliation; in the infected silkworms, the larvae are riddled with unsightly dark spots, and most usually die before any hope of spinning a cocoon. As described by early-twentieth-century silk buyer Leo Duran, "The origin of this is not known, it is hereditary, and a few leaves spoiled with the excretions of sick worms are sufficient to poison a whole roomful of healthy worms."[4] The disease itself had been known previously, but when a *pébrine* blight erupted across France in the late 1850s, it wreaked havoc in southern Europe and posed such a danger to the lucrative income source of silk that imports of Chinese and Japanese silkworm eggs began. Meanwhile, the French Minister of Agriculture assigned Louis Pasteur (1822–1895) the task of determining the cause. By culturing and studying sick silkworms, Pasteur used microscopy to examine the transmission of this disease. After analyzing female moths that had finished laying fertilized eggs and tracking the health of the juveniles that hatched, Pasteur found that it could be possible to confirm whether a specific cohort of eggs was infected. In other words, this microsporidian parasite associated with *pébrine*, which in 1866 remained without a species name, seemed to pass from one generation to the next through the body of the mother moth. Diseased female moths gave way to diseased eggs and offspring.[5] Obversely, healthy females produced healthy eggs and offspring.

The story of the identification of *Nosema bombycis* has received scant attention from historians to date, and scientists today still express uncertainty about its nomenclature. Around the world, experts regard the unicellular *Nosema bombycis* as the first-described Microsporidia, a phylum in the kingdom Fungus. The link between what is now understood as the fungal pathogen *Nosema bombycis*, and botanist Carl Wilhelm von Nägeli, who originally thought it was a yeast, remains a separate subject of analysis; however, its interesting history points to a period when a great deal of new knowledge about disease etiologies was produced, and, with that, contestations of classification.[6] Although Nägeli seemed to have first proposed a name for the disease agent, the role that Pasteur played in understanding the disease transmission has remained unquestioned for its significance in changing human practices of silkworm husbandry.

By the 1870s, Pasteur began to teach skeptical farmers how to identify and manage the disease.[7] The recovery that ensued meant that European interest in Japan as a viable source of fresh silkworm eggs would taper off, bringing an end to this trade. Japan, it could be said, was a loser in the "Pasteurization" of the French silk industry; however, one is hard-pressed not to ignore the importance of Pasteur's work in changing sericultural practice worldwide.[8] There is no need here to fortify a narrative of genius; nor do I aspire to execute the task of following all actors and actants involved with the disciplining of Nosema.[9] Yet, the exchange between the Japanese and the French poses an intriguing set of questions related to the global transmission of new practices and knowledge related to the science of silkworm rearing. Venturing to examine how knowledge of identifying diseased mother moths and their offspring particularly helps to bring into relief a very important counterbalance to the immense importance of German bacteriology and medicine in the history of Meiji period Japan.[10] It also destabilizes assumptions about Japan's indigeneity as an isolated, pure, and therefore hygienic island nation. The movement of live eggs from Japan to France (and Italy and other points in continental Europe) did not indicate a completely disease-free sanctuary for Bombyx; nor did it confirm the transfer of disease to Japan. Facile understandings about Japan's isolated environment or hygienic rearing practices obscure how the Japanese, too, had great concerns about controlling this disease.

Bugs Among Bombyx

The method of verifying the presence of *pébrine* in an unhatched cohort of silkworm eggs was so simple that a woman or child could do it, Pasteur explained to the French Minister of Agriculture.[11] The mindlessness insinuated in the task stood in tension with the precision required to confirm the existence (or nonexistence) of such financially devastating microbes and the seriousness of what was at stake.[12] Pasteur's comment about women and children foreshadowed as much about the important role of the microscope as it did about the growing role of women in science in Japan, especially in relation to silk production. This section dwells on the two creatures that sit on the other end of the eyepiece. This alternative focus does not intend to downplay the significance of how women's roles in the work of enhancing silk yields changed. Rather, the deliberate gaze upon Bombyx and its bugs explicates the scientific process of identification that informed the technical labor that was later required in Meiji Japan.

A light wave of *pébrine* spread in Japan around 1874 and 1875, which attracted the attention of the Japanese Ministry of Agriculture, according to Sasaki Chūjirō (1857-1938), a graduate of the Imperial University of Tokyo and an authority on silkworms and other insects who advised the nation on various aspects of sericulture, especially disease management.[13] Sasaki's memory of the timing of the noticeable outbreak poses interest for the issue of species identification, discussed later in this essay. Those outbreak years *had* followed the International Exposition in Vienna that Sasaki's father, Chōjun (1830-1916), attended as a technical trainee to learn about silk industries in France and Italy. The senior Sasaki had traveled in 1873 with a Japanese delegation, but analysts have not given Sasaki much regard, as he was not a prominent member in standard histories of this event. Yet, as a lower level attaché, he played a critical role in the industrialization of silk production. Tasked to learn French and Italian methods of silk cultivation and reeling, while abroad, he also learned of Pasteur's techniques to inspect *pébrine*. There, he learned of Pasteur's method, which involved the placement of the fertilized mother moth into a bag so that the parent and offspring could be tracked together. Analysis of the adult female conferred the presence or absence of the disease in the offspring.[14]

The work of Chōjun set the stage for a new understanding of silkworm diseases in Japan, and his son would later emerge as a leading expert in the field. After Vienna, Chōjun returned to Japan to work as a clerk in charge of silkworms at the Naito Shinjuku Experiment Station, located within the limits of present-day Tokyo.[15] There, he continued to study the transmission of *biryūshibyō* (微粒子病), the "corpuscular disease," as it was called locally. Although sericulture was not a mainstay concern there, Chōjun could build upon Pasteur's design for disease control by developing a "frame" method of seed-saving. In this method, the mother moth would be placed not inside of a bag, but upon one of 14 or 28 squares drawn in the form of a grid. The silk moths were bounded within each square, in which they would lay their eggs. This method made it easier to locate which silkworm eggs needed to be exterminated.[16] Chōjun's time at the Naito Shinjuku station was limited, however, for it closed down its experiments in 1879.[17]

Further outbreaks of *biryūshibyō* in October 1883 pointed to the necessity of silkworm disease experiments, despite the closing of the Naito station. By 1884, research on *pébrine* could continue in a more official capacity at a new institution, the Sanbyō Shikenjō (Silkworm Disease Research Station). Chōjun eventually handed off most of his work to his prodigous son, who made additional advances in the study of the disease in Japan. It is not beyond reason, however, that the newly developed disease detection methods from France, which permiited the verification of the specific behavior of microbial infection, mediated Chūjirō's interesting recollection of the beginning of the outbreaks in Japan in the years shortly following the return of Sasaki senior to Japan. Even by the 1890s, when the junior Sasaki began his studies of *pébrine* in earnest, it was too difficult to identify the microbe based on symptoms alone. Moreover, the fidelity with which the name of the disease could be matched with the described culprit remained contested in Japan. Following Chōjun's sojourn to France, Chūjiro perhaps developed a clearer idea as to what scientists *ought* to have looked for, which made it possible for him to claim that *biryūshibyō* was first noticed in the 1870s. This also raises the possibility that new analyses and verification techniques helped scientists construe this period as a moment of first outbreak.[18]

Analyses of Sasaki Chūjirō's full work on *pébrine* and the broader Japanese reception of Pasteur's work are out of this essay's scope, but it is worth pointing out that a key product of this moment included the publication of a methodology for the examination of *biryūshibyō* in Japan. In about a decade's time, a year after the silkworm egg inspection bill was passed in 1886, Chūjirō published a monograph, *Biryushibyo nikugan kanteiho: Ichimei seiryo sanshu seizoho*.[19] It suggests that it is possible to expertly judge the presence of the disease with the naked eye. Page by page, life stage by life stage, Chūjirō pointed out all of the possible opportunities for alerting oneself to the presence of *biryūshibyō*, the way that an expert hiker might warn fellow travelers of each treacherous upturned stone and snarling tree root that might cause them to lose balance on a path. Highly manual tactics appear as the mainstay of the text, with illustrations of larvae, belly-up, to show how the tiny spaces between its legs can bear telltale spots. He even showed how the disease could manifest in the chrysalises by cutting open cocoons to tap them out. It mentioned the use of the microscope once, to help make a point about detecting disease in eggs or locating healthy eggs, but the emphasis was clearly on encouraging skills that did not rely on magnification. Indeed, nineteenth-century Western texts on sericulture published outside of Japan suggest that the microscope had been used to help identify the best eggs, from which individuals could be selected in this earliest life stage to later employ in the production of the next

generation.[20] In *Biryūshibyō nikugan kanteihō*, Chūjirō wrote that attention to the female moth alone sufficed as a marker of disease that could be used to ensure a harvest. Considering the aim of promoting the health of the population, in contrast to the survival of a select number of individuals, his book served more as a manual for a "superior" production method, as its Japanese subtitle suggests, which heightened a sense of vigilance for detection, couched in terms of protecting the nation's valuable asset rather than of a preventative method alone. In this sense, careful examination and vigilance, he argued, could also help prevent the presentation of other diseases.[21]
Yet, Chūjirō struggled to develop the most accurate way to describe the disease agent, which was associated with soil, as well as the fecal excretions of silkworms and larval corpses that had succumbed to *biryūshibyō*. In 1896, Chūjirō called the *biryūshibyō* poison "amoeba-like," in an effort to describe the disease agent's actual appearance.[22] This outbreak on Japanese soil illuminates a period of great uncertainty and confusion about the natural history of the invisible, its possible or likely presence during the past, and its very prominent connection with European blight. The convincing means of tracing and predicting disease transmission from mother moth to offspring according to the French description and methods made the late 1800s seem to reflect a time when scientists like the Sasakis were prompted into action on their own terms, even if informed by the discourse of Pasteurian medicine. The scientific moment of disease outbreak, of course, was far from definitive, although the scientists also sought to articulate this. Indeed, it was not Nosema that wrote of its encounters with Bombyx in Japan, but scientists.

Meeting at the Microsope

The Meiji period in Japan had seen tumultuous shifts in various sectors as the government identified strategies to support and encourage industrial growth. New institutions seemed to come into existence as quickly as those they replaced. The ebb and flow of places committed to experimenting in and educating about sericulture in Japan went hand in hand with the growing importance of raw silk exports. Among the new institutions included the Sangyō Shikenjō (Sericulture Experiment Station) in 1886. This experiment station could issue certificates of learning to students who took short-term courses. Their training aimed, by 1887, to produce students who could serve as inspectors of silkworm eggs in accordance with the new egg inspection policy to protect the silk industry mentioned previously.[23] These measures continued to grow, and from 1897, the government began to require the examination of all silkworm eggs nationwide. The experiment station expanded its educational capacity in 1899, when the government restructured it as an institute so that it could more fully support sericulture training. A sister institute in Kyoto, established in June that year, also played an important role in sharing new practices of *biryūshibyō* detection and control.[24]

Stress upon the examination of eggs that drove this push for sericulture education worked as a shorthand for the protocol of policing the seemingly nameless Nosema. A closer look at the actual practice of inspection, at the level of interactions between humans, Bombyx, and their pests, suggests that the focus on egg viability stood for the slightly more violent process of determining which mother moths were positive vertical vectors for the transfer of spores to eggs. Support for the training institutes in Tokyo and Kyoto reflect ongoing change and developments in the relationship between education and agriculture that began before the Meiji period. The government had begun to make four years of elementary education compulsory for boys and girls as of 1872, and, as historian Ronald Dore and others have explained, increasing literacy in Buddhist villages, where samurai taught farmers (and women, boys, and girls) to read and write, facilitated the proliferation of agricultural manuals by farmers.[25] Such manuals helped enhance agricultural production in Japan during the eighteenth century. In the Meiji period, not only did historical actors like the Sasaki pair—scientists—extend upon the culture of publishing pragmatic expert manuals, but the education system embedded itself more clearly within existing sericultural establishments, creating new teachers and new spaces where women and men could be reconfigured as pupils and technicians who would play a crucial role in the enhancement of a growing national industry.[26]

The role of women laborers was not limited to textile factory settings, as historians Patricia Tsurumi and Elyssa Faison have shown, but, if skilled scientific work could extend to this category, the growth of women microscopists could also serve as an indicator of changing labor practices in Meiji silk-making.[27] Of course, the creature that ultimately did the laboring was the silkworm. This egg examination work served as a site where the two sometimes came together. After a female silkworm’s usefulness expired upon depositing her last egg, technicians pulverized the body and placed a sample of its residue onto a slide. Depending on the practices and policies in place at a given experiment station or private egg manufactory, a sample of moths would be examined. For example, depending on the discretion of the overseer, one out of a hundred (or more or less) could be monitored.[28] Through this screening method, it was possible to make the elusive Nosema usefully avail itself. If that mother moth showed a trace of disease, the square containing her eggs would have been manually sliced out of the entire paper and incinerated (along with her remains), in order to leave the healthy ones behind for humans to rear. Undetected Nosema in a mother moth would otherwise grant license to an outbreak that would decimate her offspring with great speed and possibly spread the contagion elsewhere. The implication of the persistence of Nosema, manifest in the hatched larvae, loomed large as an occupational worry of these examiners. There was great value in speedy monitoring, but with it came the stress of possible imperfection.[29]

The Breeding of Silk Politics

Today, the practice of Nosema monitoring is conducted in nearly the same manner as that of the late Meiji period, except with more sophisticated microscopes and computer screens. Male and female silkworms are still separated from each other at a juvenile stage, and fertilized females are still made to lay their eggs one to a square. These developments during the Meiji period show how the lives of this domesticated insect were scientized in a way that has made it possible to fully monitor them from egg to expiration. This was partly enabled as a result of growing interests among scientists in silkworm anatomy. For example, the scientists Toyama Kametaro and Ishiwatari Shitegane published a book on the dissection of the silkworm in 1896.[30] Following this, Ishiwatari described a method for differentiating silkworm sexes in 1904. The history of silkworm sex differentiation is the subject of another project, but it must be mentioned here because it formed the foundation for a new kind of skilled women's work, silkworm sexing.[31] Indeed, scholarship on sericulture and weaving in premodern China shows that the notion of gendered silk work is hardly novel.[32] Scholarly work on Tokugawa Japan has also shown how the work of silk-making has undergone a compartmentalization that divvied up expertise in ways that continued well through the Meiji period.[33] However, this new seasonal female labor had developed especially to help separate male and female juvenile silkworms before they disappeared into the cocoons they spun around their bodies.

Information about this skilled migrant labor remains elusive, considering how so much of the memory of this women's work in the homes of farmers has gone unwritten, only to be passed down orally and re-recorded. This is in contrast to other work of an institutional kind that entered official or scientific records and publications. For instance, the present-day Kōgensha silkworm egg company in Gunma Prefecture notes on their website that the work of sexing silkworms grew around 1912, and that the majority of silkworm egg producers practiced the separation of males and females. The months of May and June were sometimes called the "blooming of parasols," referring to the young women workers who traveled from village to village. Kōgensha reports that around 3000 women had once engaged in this seasonal work, at its peak, and that an advanced silkworm sexer could scan 15,000 heads of silkworms in a day.[34]

Sex differentiation techniques had also rested greatly upon earlier human efforts to monitor their insect wards; the particularities of disease articulated, if not accentuated, the lifecycle of Bombyx in a way that also accommodated detecting the possible presence of Nosema. The awareness of these nonhuman life histories concretized the work of separating male and female silkworm larvae in a way that strengthened ongoing interests in preventing random matings among adults and the waste of good eggs.

The limited success of silkworm husbandry, or sericulture, in the United States, has understandably placed more scholarly attention on the work of distributing and processing imported raw silk and constructing garments, home textiles, or utilitarian products.[35] This is not to say that early American colonial period sericulture, or mulberry culture, has been ignored.[36] However, the study of silk in North America following the industrial revolution has largely dwelled upon the consumption of silks, ranging from areas such as fashion to the plastics industries. These studies have interestingly shown how the moral call to direct the resources of raw silk and nylon to making parachutes and powder bags for the military put a literal run on stockings that comprised about 46 percent of consumed silk products at the time, and contributed to the gradual acceptance of bareleggedness and shorter hemlines in the country.[37] Silk utility textiles used by the US army eventually gained the attention of the American public, as consumers, mainly women, took to department stores in reaction against the Japanese invasion of China as the Pacific War erupted. In 1938, the League of Women Shoppers organized a fashion show in Washington, D.C. entitled, "Life Without Silk: From Morning to Midnight in Cotton and Rayon," to make a point that life could go on without Japanese silk. This well-attended event, which attracted about 600 audience members, elicited a counterprotest by women hosiery and textile workers, whose livelihoods depended on the production of fashion goods.[38] The combination of aesthetics and ethics in this embattled tension between female consumers and factory workers has received scrutiny from historian Lawrence Glickman, who explains that this period of boycott overlapped with an austerity movement—the 1938 development of nylon (also called *artificial silk*) by DuPont notwithstanding—and a total embargo on Japanese products.[39] The 1940 *Science News-Letter* (the predecessor of today's *Science News*) may have put it best (next to an article on the rare flying lemur): the "World's Silk Situation Snarled as if Kitten Had Ball."[40] This news analysis followed the pell-mell chain reaction of events following the US push to direct textiles from domestic use to the military, despite its contradictory dependence on silk from Japan, and, to a lesser extent, Italy. It also conveyed to its American readers how the Japanese government ordered domestic Japanese textile factories to contain at least 20 percent silk in their cotton, wool, and rayon to resolve their silk surplus. Japan's desperate measure to consume silk domestically pointed to another contradiction, for silk was a fabric that common folk did not routinely wear.

Conclusion

The dilemma generated by the prioritization of the production of utilitarian goods in the United States and the embargo on silk and other textiles from Japan in the years preceding the United States' engagement with war illustrates how the raw silk shortage resulted from a confluence of political, ethical, social, economic, and technological issues that seemed to have little to do with the actual harvest success of silk cocoons themselves. On the other side of the Pacific, the increasing yearly tonnage of cocoons produced by newly trained young men and especially women underscores how critical raw silk had become to Japan's potential to express international superiority. Instead of studying silk consumption in and of itself, this study has taken into consideration the materiality of silk, in particular, the organisms involved in producing silk, and various facets of biological management and production associated with Bombyx and its "bugs." This case has opened up a path for exploring a larger terrain of a global history of the multispecies, which requires an angle of analysis that recognize women as key players in the practical arts and science of sericulture. By tracing the silk thread to its biological construction as an excretion of the juvenile Bombyx, we have explored instead the constant tensions between human, insect, and its microbial bugs that fashioned the mass production of eggs in the modern period. Connected to these tensions included a struggle to identify and lay claim to the description of the pests in Europe and Japan that enjoined the creation of solutions and highly practical needs to reduce the prevalence of *pébrine*/*biryūshibyō*. While men, women, and children have long been important caretakers of the domesticated silkworm since at least, if not before, the premodern period, new skills and professions, both temporary and permanent, rallied around the multiple species to preserve or overcome. New scientific knowledge, policies, and institutions accommodated an awareness that epidemic outbreaks could be repetitive. With that, so, too, did space grow to verify and experiment with the microbes described earlier in France and Italy.

In the work of maintaining hygiene and health in silk work, it had become very scientifically clear how susceptible the domesticated silkworm was as a swarm insect. As something highly ephemeral and cared for in Japan, Bombyx could barely be categorized as a bug, in the sense of the unwanted pest. To abate the problems of *pébrine* and other problems, Meiji agricultural officials demanded a greater workforce that would use new skills to implement the scientific inspection of mother moths across Japan. In an answer to this call, a growing base of literate men and, in particular, women, stood ready to learn the work of microscopy, among other tasks connected to silkworm health. The formal and informal work of exterminating Nosema from the larger population of *Bombyx mori* in Japan signals to us a historical transformation of labor in the Meiji period, from the seasonal work of rearing silkworms in home nurseries to the work associated with the production of capital for more distant houses, or raw silk farms. This historical analysis of the multispecies, the pursuit of identifying Nosema, has helped bring to light reasons why the separation of male and female silkworms had particular importance for infectious disease control. This provides a new scenario for understanding how a science and labor force was designed around sexing the silkworm. While disease control and pedigree breeding were distinct activities, their scientization also foreshadows the development of a later silkworm nomenclature system that would be peppered with a grammar of racial thought.[41]
While woven wares may provide us with the most prominent images of mechanized silk production, this study has grounded the airiness of silk in greater "conversation" with nonhumans. Deconstructing the fibers of commercial silk products visible in the United States has shown a path that threads back to silkmoth eggs. This analysis has illuminated how the historical processes of defining not just the moth depended on defining at least one other

unruly nonhuman organism in the early-twentieth century, while spurring new kinds of work. In short, scientists' efforts to detect, describe, and prevent infectious diseases in silkworms and moths produced new material engagements among humans across three continents, Bombyx, and Nosema (and other pests). Continued analysis of the gaze placed upon the mother moth by male scientists policing the entry of Nosema in nurseries should allow for a deeper understanding of the role of science in the manipulation of sex and gender in sericulture, whether in relation to working women or silkworms.

Footnotes

1. John McPhee, "Silk Parachute," *New Yorker* (1997): 108.
2. Claude Lévi-Strauss, *Totemism*, trans. Rodney Needham (Boston: Beacon Press, 1963); Donna Jeanne Haraway, *When Species Meet*, (Minneapolis: U of Minnesota P, 2008).
3. S. Eben Kirksey and Stefan Helmreich, "The Emergence of Multispecies Ethnography," *Cultural Anthropology* 25.4 (2010): 545–576; Celia Lowe, "VIRAL CLOUDS: Becoming H5N1 in Indonesia," *Cultural Anthropology* 25.4 (2010): 625–649; Hoon Song, *Pigeon Trouble: Bestiary Biopolitics in a Deindustrialized America*, (Philadelphia: U of Pennsylvania P, 2011); Anna Lowenhaupt Tsing, "Unruly Edges: Mushrooms as Companion Species," *Environmental Humanities 1* (2012): 141-151; Natalie Porter, "Bird Flu Biopower: Strategies for Multispecies Coexistence in Việt Nam," *American Ethnologist* 40.1 (2013): 132-148.
4. Leo Duran, *Raw silk; a practical hand-book for the buyer*, (New York, Silk Publishing Company, 1921): 25.
5. Gerald L. Geison, *The Private Science of Louis Pasteur*, (Princeton, NJ: Princeton UP, 1995); Rene J. Dubos, *Louis Pasteur: Free Lance of Science*, (New York: Da Capo Press, 1960).
6. C. Nägeli, "Über die neue Krankheit der Seidenraupe und verwandte Organismen," *Beilage zur Botanischen Zeitung* 15 (1857): 760-761; C. Franzen "Microsporidia: a review of 150 years of research," *Open Parasitology Journal* 2 (2008): 1-34. Uncertainty about classificatory nomenclature "arises as Microsporidium Balbiani 1884 appears to be a later synonym of Nosema Naegeli 1857," according to newer efforts to classify the kingdom *Fungi* using molecular phylogenetic data. See David S Hibbett, et al., "A Higher-level Phylogenetic Classification of the Fungi," *Mycological Research* 111.5 (2007): 509–547. For additional information, see J. O. Corliss and N. D. Levine, "Establishment of the Microsporidia as a new class in the protozoan subphylum Cnidospora," *Journal of Protozoology* 10 (Suppl.) (1963): 26–27.
7. Details of the half-decade of work that Pasteur spent identifying the pattern of infection have been discussed in Geison 1995 and Dubos 1960.
8. Louis Pasteur, *Etudes sur la maladie des vers à soie, moyen pratique assuré de la combattre et d'en prévenir le retour*, (Paris: Gauthier-Villars, successeur de Mallet-Bachelier, 1870).
9. For discussion of the "Pasteurian world," see Bruno Latour, *The Pasteurization of France*, (Cambridge: Harvard University Press, 1988): 12.
10. James R. Bartholomew, *The Formation of Science in Japan: Building a Research Tradition*, (New Haven: Yale UP, 1993); Pierre-Yves Donzé, "Studies Abroad by Japanese Doctors: A Prosopographic Analysis of the Nameless Practitioners, 1862–1912," *Social History of Medicine* 23 (2010): 244–260.
11. Pasteur 1870: 49–206; Dubos 1960: 217–219.
12. George S. Davis, *An Address on Evolution and the Pathological Importance of Lower Forms of Life*, (Detroit, 1886): 17.
13. Chūjirō Sasaki, "Biryūshibyō ni tsuite," *Sangyō Shimpō*, 2.29 (1896): 39-47.
14. K. Tomoda, "Secretarial bureaucrats of agricultural policy ministry and agricultural policy during the period of the Naimusho (Home Ministry)," *Journal of Rural Community Studies* 106 (2008): 1-12.

15. Kanji Watanabe, *Yosangaku* (Tokyo: Azumi Shobo, 1948); Tadao Yokoyama, "The History of Sericultural Science in Relation to Industry," *History of Entomology*, ed. Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith. (Palo Alto: Annual Reviews, 1973): 267–284.
16. See *A General Report of Sericultural Investigations*, (Tokyo: Imperial Sericultural Institute, 1910): 11.
17. Sasaki 1896; Watanabe 1948.
18. While the disease at hand is not a direct medical problem for humans, discussion of the use of scientific instruments, including in biomedicine, to observe and define phenomena still bears pertinence. For example, see Michael Lynch, "The Externalized Retina: Selection and Mathematization in the Visual Documentation of Objects in the Life Sciences." *Human Studies 11*, no. 2–3 (1988): 201–234; Nancy Anderson and Michael R. Dietrich, "Photography and Medical Observation." *The Educated Eye: Visual Culture and Pedagogy in the Life Sciences*, (Hanover: NH: Dartmouth College P, 2012): 68–93.
19. Chūjirō Sasaki, *Biryūshibyō nikugan kanteihō: Ichimei seiryō sanshu seizōhō*, (Tokyo: Maruzen, 1887).
20. For example, Alexander Martelli wrote in 1863, "A sound and perfect egg is distinguished under the microscope by its spotted shell, its opacity, and its shape, which should exhibit two very trifling concavities opposite to one another on the globular surface." See *The Silkworm and its Food: An essay towards Introduction of sericulture into the australian colonies, with special reference to raising of cocoons for exportation*, (Melbourne: Clarson, Shallard, & Co, 1863).
21. Sasaki 1887.
22. Sasaki 1896.
23. Kitamura Chikayoshi and Nozaki Minoru, *Nōrin Suisanshō Ni Okeru Sanshi Shiken Kenkyū No Rekishi*, (Tsukuba: Nōgyō Seibutsu Shigen Kenkyūjo, 2004).
24. See Watanabe 1948 for broader discussion of these institutions.
25. Ronald Dore, *Education in Tokugawa Japan*, (Berkeley: U of California P, 1965); Tessa Morris-Suzuki, "Sericulture and the Origins of Japanese Industrialization," *Technology and Culture* 33.1 (1992): 101–121; Andrew Gordon, *A Modern History of Japan: From Tokugawa Times to the Present*, (New York: Oxford UP, 2003).
26. The history of women in science and the production of modern Japanese nationhood remains an area of great potential for future study, which would complement discussion of scholarship mentioned elsewhere in this essay and scholarship on compulsory education in the Meiji period, including sex education—see Sabine Frühstück, *Colonizing Sex: Sexology and Social Control in Modern Japan*, (Berkeley: U of California P, 2003), and the history of women's agency in Japan more generally—see Sharon L. Sievers, *Flowers in Salt: The Beginnings of Feminist Consciousness in Modern Japan*, (Palo Alto: Stanford UP, 1983); Marnie S. Anderson, "Women's Agency and the Historical Record: Reflections on Female Activists in Nineteenth-Century Japan," *Journal of Women's History* 23.1 (2011): 38–55.
27. Elyssa Faison, *Managing Women: Disciplining Labor in Modern Japan*, (Berkeley: U of California P, 2007); E. Patricia Tsurumi, *Factory Girls*, (Princeton UP, 1992).
28. Duran 1921, 25.
29. Chūjirō Sasaki, *Kaiko no sogai*, (Tokyo: Sasaki Chūjirō, 1895); Kibun Fukuda, *Wagakuni no sanshigyō wo sasaeta omona sanshikagaku to gijutsu*, (Tokyo: Nihon Sanshi Shimbunsha, 1990): 14.
30. Kametaro Toyama and Shigetane Ishiwatari, *Jikken santai kaibo: Fu sanbyo narabini kenbikyo shiyoho*, (Tokyo: Fuzanbo, 1896). See also Shigetane Ishiwatari, *Santai kaibo*, (Fujioka-machi Gunma-ken: Mimata Aisaku, 1899); Lisa Onaga, "Toyama Kametaro and Vernon Kellogg: Silkworm Inheritance Experiments in Japan, Siam, and the United States, 1900–1912," *Journal of the History of Biology* 43.2 (2010):

215–264.

31. Shigetane Ishiwatari, "Sanji shiyū no hanbetsuhō," *Dainippon Sanshikaihō* 145 (1904): 17-18; Shigetane Ishiwatari, "Sanji no shiyū kanbestu," *Sangyō Shimpō*, 134 (1904): 456-457. This essay is the first step in outlining a project on silkworm sex differentiation.

32. Francesca Bray, *Technology and Gender: Fabrics of Power in Late Imperial China*, (Berkeley: U of California P, 1997).

33. Tessa Morris-Suzuki, *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century*, (Cambridge; New York: Cambridge UP, 1994).

34. K. Miyazawa, Personal communication. 30 Sept. 2008; see also http://www.kougensha.com/sericulture/history/technology/technology.html. This history of the biology of silkworm sexing is the subject of a separate project.

35. Jacqueline Field, Marjorie Senechal, and Madelyn Shaw, *American Silk, 1830-1930: Entrepreneurs and Artifacts*, (Lubbock: Texas Tech UP, 2007).

36. For example, Emily Pawley, "Coining Foliage into Gold: Speculation, Value, and the Mulberry Bubble, 1826-1839," Paper presentation at Plants, Animals, and Ownership: Innovation and Intellectual Property Protection in Living Organisms Since the 18th Century workshop, Yale University, June 3-5, 2011.

37. See W. R. Wadsworth, "The Future of Silk in the Hosiery Industry," *Journal of the Textile Institute Proceedings* 43.1 (1952): 94–9; William W. Lockwood, "Economics of a Silk Boycott," *Far Eastern Survey* 6.22 (1937): 247–251; Lauren Olds, "World War II and Fashion: The Birth of the New Look," *Constructing the Past* 2.1 (2001): 47–64. The issue of bare legs also drew great attention in East Asia. See also Dorothy Ko, *Cinderella's Sisters: A Revisionist History of Footbinding*, (Berkeley: U of California P, 2005); Hsiao-pei Yen, "Body Politics, Modernity and National Salvation: The Modern Girl and the New Life Movement," *Asian Studies Review* 29.2 (2005): 165–186.

38. "Shoppers Plan Fashion Show: 'Life Without Silk' Theme of Women's League Planned Exhibit," *Washington Post* 19 Jan. 1938: 13; Lockwood 1937.

39. Lawrence B. Glickman, "'Make Lisle the Style': The Politics of Fashion in the Japanese Silk Boycott, 1937-1940," *Journal of Social History* 38.3 (2005): 573–608. Effectually through the expiration of the 1911 Treaty of Trade and Navigation, as well as the establishment of the Export Control Act of 1940 and its extension in 1942. See also Nathan M. Becker, "The Anti-Japanese Boycott in the United States," *Far Eastern Survey* 8.5 (1939): 49–55.

40. "World's Silk Situation Snarled as If Kitten Had Ball." *Science News-Letter* 38.22 (1940): 340.

41. This is detailed in my book manuscript, *Anatomy of a Hybrid* (working title).