SILKWORMS, SCIENCE, AND NATION: A SERICULTURAL HISTORY OF GENETICS IN MODERN JAPAN

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SILKWORMS, SCIENCE, AND NATION: A SERICULTURAL HISTORY OF GENETICS IN MODERN JAPAN

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This dissertation describes how and why the source of raw silk, the domesticated silkworm (*Bombyx mori*), emerged as an organism that scientists in Japan researched intensively during the late nineteenth and early twentieth centuries. People invested in and exploited the lucrative silkworm in order to produce a delicate fiber, as well as to help impart universal claims and ideas about the governing patterns of inheritance at a time when uncertainties abounded about the principles of what we today call genetics. Silkworm inheritance studies such as those by scientists **Toyama** Kametarō (1867–1918) and **Tanaka** Yoshimarō (1884–1972) contributed to ideas developing among geneticists internationally about the biological commonalities of different living organisms. Silkworm studies also interacted with the registration of silkworm varieties in and beyond East Asia at a time when the rising Imperial agenda intertwined with the silk industry. Different motivations drove silkworm science, apparent in the growth of Japanese understandings of natural order alongside the scientific pursuits of universality. *Tōitsu*, a "unification" movement around 1910, notably involved discussions about improving silk and decisions about the use of particular silkworms to generate export-bound Japanese silk. I show why the reasons for classifying silkworms within Japan had as much to do with the connection between textiles, power, and social order as it did with the turn toward experiment-based biological articulations of inheritance, which together interacted with ideas about Japanese nationhood.

BIOGRAPHICAL SKETCH

Lisa Aiko Onaga was born Lisa Yen-Chen in Brookfield, Connecticut, USA, in 1978. She grew up in Pittsburgh, Pennsylvania, and Kobe, Japan, where she attended the Canadian Academy for three years. She graduated from Brown University in 2000 with a Sc.B. in biology with honors, where she conducted research in marine ecology and evolution and cultivated her interests in science writing. She worked at the American Association for the Advancement of Science in Washington, D.C., for three years as a communications officer for *Science*. She has also been a freelance science writer and worked as a media relations contractor for Burness Communications, representing major international nonprofit organizations.

At Cornell University, Lisa was in the first cohort of recipients of the Cornell Presidential Genomics (now Life Sciences) Fellowship. Since returning from her dissertation fieldwork in Japan, Lisa has resided in the Bay Area, California, and was been a visiting researcher of the Office for History of Science and Technology at the University of California, Berkeley, from 2009 to 2011. While completing her dissertation, Lisa co-founded Teach 3.11, a participant-powered digital resource that helps educators and scholars locate and share information related to the history of science and technology concerning the triple earthquake, tsunami, and nuclear disasters in Japan. After receiving her Ph.D., she will join the Center for Society and Genetics at University of California, Los Angeles, as a lecturer and postdoctoral fellow with support from the D. Kim Foundation for History of Science and Technology in East Asia. She will join Nanyang Technological University in Singapore as an assistant professor in the history division.

To Yoko and Eimei / Xiurong and Yung-Ming

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LIST OF ABBREVIATIONS

[DRO]	Diplomatic Record Office, Archive of Ministry of Foreign Affairs, Japan.
[NA]	National Archives at College Park, MD.
[OS]	Ōkuma Shigenobu Collection [4751], Waseda University Library Collections, Japan.
[SU]	Stanford University Entomological Collection: Records, 1891–1929. Stanford University Special Collections and University Archives.
[TY]	Tazima Yataro Collection. Institute of Sericulture, Dainippon Silk Foundation, Ibaraki, Japan.
[TNA]	Papers of the Japanese Sericulture Experts; Reports of the Ministry of Agriculture, Thailand National Archives, Bangkok, Thailand.

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INTRODUCTION

The mooring made of my silk
fastens Yamato to the deep.

– Sasaki Chōjun, *Kaiko no yume* [Dream of the Silkworm], 1890[1]

Sericulture. Culture of the silkworm. Silk culture. Multiple worlds inhabit this word referring to the cultivation and production of a fiber spun together by insects and humans and the worlds they create. The fibrous end of the sericulture spectrum has attracted the attention of a number of historical works that excavate centuries of silk making, movement, and trade across vast geographies. A number of works, including a recently edited collection of classic and new essays about silk, trace the creation of economic networks before the development of the steam engine as well as during the early industrialization of Pacific economies.[2] Such scholarship has helped push the bounds of a terrestrial Silk Road eastward to the sea, making clear the critical role of the Japanese archipelago.

Silk in Japanese history often features in Meiji-period narratives of industrialization and overseas trade that intertwined with discussions of capital production, often involving transnational entrepreneurial contexts.[3] The iron that scaffolded the interiors of silk factories also helps explain their place in building

[1] Sasaki Chōjun, *Kaiko no Yume* [Dream of the Silkworm] (Tokyo: Sasaki Chōjun, 1890). Yamato, meaning old Japan. All Japanese names appear as written and spoken in Japanese, with last name preceding given name. Macrons are not used for popular place names such as Tokyo or Kyoto.

[2] Debin Ma, ed., *Textiles in the Pacific, 1500–1900* (Aldershot, England: Ashgate/Variorum, 2005); Rudolph Matthee, *The Politics of Trade in Safavid Iran: Silk for Silver, 1600–1730* (Cambridge; New York: Cambridge University Press, 1999); Claudio Zanier, *Where the Roads Met: East and West in the Silk Production Processes (17th to 19th Century)* (Kyoto: Istituto italiano di cultura, Scuola di studi sull'Asia orientale, 1994); Anh Tuấn Hoàng, *Silk for Silver: Dutch–Vietnamese Relations, 1637–1700* (Leiden: Brill, 2007); Kären Wigen, *The Making of a Japanese Periphery, 1750–1920* (Berkeley: University of California Press, 1995).

[3] Haru Matsukata Reischauer, *Samurai and Silk: A Japanese and American Heritage* (Cambridge, MA: Belknap Press of Harvard University Press, 1986); Jacqueline Field, Marjorie Senechal, and Madelyn Shaw, *American Silk, 1830–1930: Entrepreneurs and Artifacts* (Lubbock: Texas Tech University Press, 2007).

Japan's national economy, leading to a familiar narrative of the relationships between technology, scientific advancement, industrialization, and progress.[4] But this dissertation takes a different turn on the road, focusing on the silkworm (*Bombyx mori*). The silkworm has appeared in scholarly analyses pertaining to this era, but this cultural history clarifies further why the culture of this insect – its cultivation and the harvest of its cocoon to become silk, its emergence in the late nineteenth and early twentieth century as an organism studied by scientists, as well as the ways in which it has been embedded in society – has had as much to do with the production of the nation as it did with the production of life scientists and genetics in Japan.

The heterogeneous work of silkworm scientists, which related at times to the rising imperial agenda that informed the state of sericulture, included the collection and registration of silkworm breeds collected within and beyond Japan. The approach of combining histories of science and technology and of modern Japan in this study helps illuminate how the mass production of raw silk depended on a "scientification" of the silkworm in Japan at the turn of the century. During this period, different human actors, including state scientists, breeders, and university researchers, also helped make silkworms within and beyond Japan legible as scientific objects and as objects of state manipulation. These processes occurred simultaneously with the "biologization of inheritance," or the ways in which the mundane terms "heredity" and "inheritance" gained increasing metaphoric use in biological experiments and contexts.[5] That is, silkworm studies in Japan also appear to have joined larger discussions about the location of commonalities in the genetic principles shared among different organisms.

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[4] David Wittner, *Technology and the Culture of Progress in Meiji Japan* (New York: Routledge, 2008); Wittner, "The Mechanization of Japan's Silk Industry and the Quest for Progress and Civilization, 1870–1880," in Morris Low, ed., *Building a Modern Japan: Science, Technology, and Medicine in the Meiji Era and Beyond* (Macmillan, 2005); Mikio Imai, *Tomioka seishijō shoki keiei no shosō : shichishiten kara no apurōchi.* (Tomioka, Gunma Pref.: Imai Mikio, 1996).

[5] Raphael Falk, *Genetic Analysis: A History of Genetic Thinking* (Cambridge: Cambridge University Press, 2009), pp. 14–24.

The turn toward experiment-based articulations of heredity took place in the world of silkworm cultivation, meaning that the science of genetics that emerged from it had connections with textiles, power, and social order. By analyzing the different research activities that surrounded the silkworm, it is possible to understand how people made use of silkworms to propel a sense of natural order and to impart universal claims and ideas about the governing patterns of inheritance at a time when uncertainties abounded about the laws of what we today call genetics.

Various activities of classifying silkworms rendered them tractable for the dual purposes of 1) wealth accumulation through the export of silk and 2) the production of scientific knowledge in the early 1900s. In Europe and the United States, researchers in the natural sciences also increasingly compared different organisms in order to draw together lessons toward a common, general biology. These biological experiments and efforts to locate universal principles overlapped with and contrasted with features common to natural history studies of earlier centuries, such as the collection and description of unique kinds of plants and animals and inquiries of life and nonlife.[6] The history of the science of the silkworm told here is thus one that shows how the early-twentieth-century Japanese silkworm biologists performed their studies in ways that made the insect serve as the object of multiple veins of research in the life sciences in a way that was part of an international conversation about the formation of new biology. I demonstrate that what may have at times seemed like the operation of contradictory scientific motivations in the early 1900s actually constituted a key feature of silkworm science in modern Japan.

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[6] Staffan Müller-Wille, "Hybrids, Pure Cultures, and Pure Lines: from Nineteenth-Century Biology to Twentieth-Century Genetics," *Studies in History and Philosophy of Biological and Biomedical Sciences* 38 (2007): 796–806; S. Müller-Wille and V. Orel, "From Linnaean Species to Mendelian Factors: Elements of Hybridism, 1751–1870," *Annals of Science* 64, no. 2 (2007): 171; Hans-Jörg Rheinberger, *An Epistemology of the Concrete: Twentieth-Century Histories of Life* (Durham [NC]: Duke University Press, 2010), p. 6. "If biology had asked, upon entering the ranks of the sciences around 1800, what distinguished living from nonliving things, it tended to ask, around 1900, what constituted life as such and what pertained to all living beings as compared to each other."

1. Language, History, and *Tōitsu* of the Silkworm

Debates over the improvement and degradation of silk and silkworms in the early twentieth century centered on the organism, technological intervention, and legal regulation; the context was the question of how export products – silkworm eggs and silk – would represent Japan. Actors in the Meiji period also positioned representations of Japan rhetorically in terms of Japan's deep history. For instance, Sasaki Chōjun (1830–1916), a silk technical expert and author of the 1890 *Kaiko no yume* (Dream of the Silkworm), opened his concise text on sericulture from a silkworm's point of view and began with a poetic line about silk, in which the silkworm is shown to be holding "Yamato" (the folkloric term for an originary "old Japan") moored to its place in the ocean.[7] Silk matters were not immune to serving as a vehicle for essentialist articulations of nationhood; silk and silkworm science were part and parcel of the project of nationhood.[8] Exactly how the matters of silk and science factored into a Japanese "mythico-history" in which practitioners of silk wittingly and unwittingly entrenched themselves and their work within essentialized, racialized conceptions of the nation is one of the issues this dissertation raises.[9]

Why did cataloging silkworm varieties warrant the attention of sericulturists and scientists in Japan? Answering this depends partly on recognizing the history of colonial threat and efforts to avoid colonization by Europeans or Americans; the new categories of authorities and experts analyzed in this dissertation appeared as the silk

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[7] Sasaki, *Kaiko no Yume* [Dream of the Silkworm].

[8] Jimbei Kawashima, "Japanese Industries: Weaving and Dyeing," in *Fifty Years of New Japan (Kaikoku gojūnen shi),* ed. Marcus B. Huish, comp. Shigenobu Ōkuma, 550–563 (London: E. P. Dutton, 1909). Artist to the Imperial Household, Jimbei Kawashima traced the origins of weaving in Japan to ancient times and laid out the cultural reasons for the rise of the Meiji weaving industry: national ceremonial, decoration of temples, shrines, and priestly robes, garb used in musical performances, martial attire, tea ceremony, and "manners and customs of the common people" such as marriage ceremonies.

[9] Liisa H. Malkki, *Purity and Exile: Violence, Memory, and National Cosmology among Hutu Refugees in Tanzania* (Chicago: University of Chicago Press, 1995), pp. 102–104. Malkki describes mythico-history as a "subversion in process" by which a group recognizes a truth meaningful to them. Such "truths" have a different role than a merely incorrect fact; rather, they serve to explain the group's present in terms of their parsing of the past.

industry responded to these issues. The exertion of greater control over silkworms and their handlers reflects growing scientific interests in silkworms and how those interests manifested in the promotion of national management of the sericulture industry and the pursuit of research, including the registration of silkworms across the administrative region. Akin to the sort of conversions toward national consciousness that colonial "mapmaking" engendered by helping make subjects visible and their containment believable, similar processes, though arising from within the country in question itself, rendered Japan's multiple silkworms "legible" as a species and as individual objects of study.[10]

Legibility as an analytic category may evoke the conformity that James C. Scott critiques of monocultures that characterized state-planned agricultural projects of high modernism. The ease of reading a land with vast plots of monocultures came with numerous problems.[11] My conceptualization of legibility is one that reflects the shift from local authorship of silkworms to multiple understandings of the silkworm as a research organism and as a species whose variation was an object of interest to investigators, the state, and producers who eventually made it possible to yield fibers that could use hybridization of various silk moths to produce raw silk that could pass as Japanese.[12]

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[10] D. Graham Burnett, *Masters of All They Surveyed: Exploration, Geography, and a British El Dorado* (University of Chicago Press, 2001); Thongchai Winichakul, *Siam Mapped: A History of the Geo-Body of a Nation* (University of Hawaii Press, 1997). Disciplining the landscape as a process of enacting corporeal control can take place in many different ways. We can understand these processes as various kinds of mapmaking, in which the previously unknown "terra incognito" identify, for those in the position of colonial power, who or what will prove most useful to their means and ends (Burnett, pp. 126–130). Although each of their histories are unique, Japan and Siam share something in common as two Asian countries that managed to resist colonization and have approached the act of mapmaking in ways that engender and retain greater control. The emergence of the Siamese "geo-body" came about in response to the threats of colonization by way of an "effect of the hegemony of modern geography and mapping," but Winichakul calls the presence of the geo-body something that is always "subject to challenge," reminding us that the map is an "active mediator" (Winichakul, pp. 130–131).
[11] James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998).
[12] Greg Bankoff and Sandra Swart, eds., *Breeds of Empire: The Invention of the Horse in Southeast Asia and Southern Africa 1500–1950* (NIAS Press, 2007), p. 33. Pinpointing a stable notion of "breed," for

Of course, different aspects of silkworm physiology and the silkworm's ecological life history limit what the insect can or cannot do. Understanding the role of commercial branding in the designation of uniqueness provides insight into how biological categorizations of the insect manifested on a practical level. It is also important to note that multiple kinds of human–worm partnerships existed, but the rich if not frustrating minuscule and major differences between breeds especially motivated the work of identifying and nominating silkworms, in which different priorities coexisted for parsing these organisms.[13] One of those priorities was called *tōitsu*, or unification. Unlike the immediate connotation the term has with homogeneity and conformity, this *tōitsu* of silkworms and silk that emerged and that is discussed in this dissertation is one that managed and valued a nominal level of plurality in the living organism. The *tōitsu* of silk and silkworms might be seen as a technology of power centered on the management of life, in which permission to reproduce governed the population of silkworms useful in defining the nation.[14]

This dissertation helps answer the broader question of how dependence upon the aforementioned categories of silkworm classification was reinforced over time to the point of making silkworms appear to have always already been racialized bodies.[15]

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instance, has been a challenge for other organisms, such as horses. The "invention" of different breeds of horses is discussed, introducing this issue in a way that gestures history of labor, transportation, cavalry, and recreation, toward an integration of discussions of the biological, toward equine genes. It highlights some of the challenges of studying about breeds, considering how "authors rarely specify the criteria they have used when they, for instance, distinguish two breeds in a certain area, while someone else records only one and yet another observer reports the existence of two varieties within one breed, in even two 'sub-breeds'" (p. 33).

13 For example, cultivators often assigned new names to existing silkworms to reflect their brand, whereas newly created silkworm strains might not have received new names.

14 Michel Foucault, *The History of Sexuality* (New York: Vintage Books, 1990), pp. 144–147.

15 Brett Walker, *The Lost Wolves of Japan* (Seattle: University of Washington Press, 2005), pp. 24–56. The violence incurred by the classification of the silkworm I refer to does not refer to Linnaean classification but more to an opportunistic division of types. In other instances, however, the categorization of wild animals under the Linnaean taxonomic system intersected with the rise of Japanese nationalism and imperialism during the early 1900s. Circumstances helped lump various wild canines named after a "folk-biological past" into the homogeneous category of the "Japanese" wolf, based on the "modern biological present."

This questioning also relates to a broader concern with how a development in Japanese genetics mapped onto a toolkit of silkworm variation identified by what we may recognize today as single-locus genes; this dissertation explores how these particular groupings reflected Meiji values. Historicization of the categories of silkworms that today's silkworm scientists wound up inheriting is by no means a legitimization of them, however. As Naoki Sakai pithily explains, "a text is always inscribed in some material body."[16] Hans-Jörg Rheinberger discusses the "epistemic thing" as a purveyor of scientific knowledge lodged within a biological experimental system.[17] Bringing together what may seem like two disparate discussions of materiality concerning that which can be read and that which can or cannot be experimented on, I suggest that the silkworms of Meiji (1868–1912) and Taishō (1912–1926) Japan were read in very particular ways that both shaped and hindered the scope of the intellectual biology work that surrounded it. The experimental system based on the racial cataloguing of the silkworm did as much to conceal, through discriminatory practices, as it did to reveal the biology underlying apparent diversity. Questioning the scientific languages that developed to describe "the silkworm" facilitates an investigation of how silkworm science and genetics in particular were informed by the project of *tōitsu*; it allows for an understanding of what "belonging to a language" came to mean for scientists and their institutions, as part of a project of nationhood at the time.[18] Unification here can be understood as a cultural development that engendered change in ways more subtle than the overt political violence that pervaded the sixteenth century as Toyotomi Hideyoshi (1536–1598) brought Japan under centralized

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[16] Naoki Sakai, *Voices of the Past: The Status of Language in Eighteenth-Century Japanese Discourse* (Ithaca: Cornell University Press, 1992), p. 9.
[17] Rheinberger, *An Epistemology of the Concrete.*
[18] Sakai, *Voices of the Past*, p. 2. Sakai draws upon the Saussurian concept of sign and explains that a text is a possible sum of "the verbal signification evoked by a certain pattern of signs inscribed in some material and, second, the coded body including both signification and material."

control.[19] In the process of questioning both silkworm and nation, this dissertation reflects equally on the historiographies of both biology and Japan.

Unification serves both as an actor's category and as analytical concept in an arc of modern Japanese history centered on the years 1910 and 1911, when the relationships between silkworm and humans altered dramatically. The new descriptive languages used to talk about silkworms that began to develop at that time reflect the development of new practices in sericulture and science that embraced experimentation and order to "improve" Japanese silk. These developments constituted changes in relationships and ideas about responsibilities pertaining to the ownership, authorship, and stewardship of life, and ideas of hybridity, kinship, and national belonging. The creation of a cohesive Japanese identity required a number of things, according to Stephen Vlastos: "The wide circulation of common practices that claimed to represent continuous and stable culture."[20] The scope of this history of sericulture relates to the formation of and use of new biological languages to describe each and every silkworm in Japan and those that came into friction with Japan. It makes clear that new biological knowledge was intended to be as much about harnessing the techniques and know-how of hybridization for the formation of a system that could produce and reproduce silkworms as it was about identifying and thus cultivating good (silkworm) parents.

Continuous production of stable silk cocoons motivated Japanese sericulture and the study of the silkworm as an experimental and industrial organism. To elaborate upon their function in unification, I refrain from using the English word standardization, because the direct translation for standardization, *hyōjun*, rarely appears within the discussions amongst sericulturists and scientists with respect to

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[19] Mary Elizabeth Berry, *Hideyoshi* (Cambridge, MA: Harvard University Asia Center, 1989).
[20] Stephen Vlastos, ed., *Mirror of Modernity: Invented Traditions of Modern Japan* (Berkeley: University of California Press, 1998), p. 11.

silkworms' biological variation in the trade journals and writings I have studied. Rather, the word *ittei* complements *tōitsu*, expressing the imperative to *decide* how to stabilize the unruliness of diversity necessary for acts of unification.[21] The movement may be seen as a rationalization process, but bringing "the silkworm" together to unify the qualities of discrete silk strands produced in the nation also came from a place of anxiety about what to do and how to reach any consensus as the scale of silk production increased across Japan.

Japan illustrates what Benedict Anderson calls "official nationalism," which helped propel an impression of an "authentic representation of the nation of which Japanese were coming to imagine themselves members."[22] Whereas Anderson focuses on how an imagined community might encompass difference, the silkworm suggests to us how scientists in Japan also worked toward the production of similarity, in which Bombyx was ultimately an organism used to carry out a certain unification on behalf of national interests.

2. Historicizing Silkworms, Science, and Nation

This dissertation follows an arc that shows why the developments of sericulture and genetics in the late Meiji and Taishō periods were inextricably linked such that understanding the history of one requires a firm grasp of the other. Matters of the silk industry and silkworm genetics at that time had also notably intertwined with the project of Japanese nationhood. These three strands came together most evidently around the 1911 enactment of the Sericultural Industry Law, a moment which produced both direct and indirect effects that reverberated with sericulture, science, and the project of nationalization for nearly two decades after. Chapter One addresses

[21] *Sangyō Shimpō* 4, no. 42 (1896): 508–511. The *ittei* of silkworm seeds, or *sanshu*, is first mentioned in this trade journal in 1896, in the third year after publication began in October 1894.
[22] Benedict R. Anderson, *Imagined Communities: Reflections on the Origin and Spread of Nationalism*, rev. ed. (London: Verso, 2006, 1991 [1983]), p. 97.

the silk industry, especially sericulture. Chapter Two introduces the growing connections between sericulture, genetics, and nation by exploring the work of the scientist Toyama Kametaro (1867–1918). Chapter Three continues to analyze the work of Toyama to address experimental genetics more specifically, and Chapter Four details how the three strands are necessary to understand the 1911 law. Chapter Five shows how sericulture, nationhood, and genetics moved forward out of the 1911 law, using two case studies. One centers on the work of Tanaka Yoshimaro (1884–1972), a geneticist whose experiments ultimately had to align with national interests; the other case examines the growing use of hybrid silkworms across Japan facilitated by entrepreneurs associated with the Katakura silk-reeling family.

The first chapter surveys how increasing innovation in silkworm seeds as biological and branded things contributed to a growing discourse of "improvement" in Meiji Japan. Innovations in raw silk had actually undergone considerable advances before, according to Tessa Morris-Suzuki, who explains that the "exacting standards" of Tokugawa-era (1603–1868) silk technologies referred more to the importance of the production of different kinds of silkworms and cocoons than to the processing of raw silk through throwing and weaving.[23] After the ports of Japan opened to trade in 1859, the growing number of individuals who forayed into reputedly profitable sericulture contributed to an especially unruly situation that made control over any notion of "the silkworm" elusive.

Businessmen and factory operators in Japan who sought to meet the demands and criticisms that their overseas customers had of raw silk found the activities of "improvement" to be a source of opportunity and consternation, for silk quality depended on multiple issues: the mechanics, labor, and skill related to silk filature and reeling; the varietal characteristics of silkworms and their cocoons; and the constraints

[23] Tessa Morris-Suzuki, *Technological Transformation of Japan* (Cambridge: Cambridge University Press, 1994), pp. 36–43.

of an organism and its life cycle and disease susceptibility, not to mention dependence on mulberry leaves, different styles of husbandry, and environmental factors such as temperature, humidity, and air and water quality. All these factors had the potential to introduce inconsistencies in the qualities among a cohort of silkworms' silk cocoons that reverberated in the form of consumer complaints from buyers overseas and the associated fortune or shame. Pinpointing the exact reasons for why cocoons and silk turned out the way they did motivated sericulturists and scientists, as the rest of this dissertation shows. Later, in early-twentieth-century Japan, the appeal of invention that accompanied the breeding of new fertilized silkworm eggs, or *sanshu* (silkworm seeds) as they were called colloquially, readily yielded scientific experimentation on hybridization, as had also been the case in Europe, where researchers interested in the phenomenon of heredity brought Gregor Mendel's pea experiments into greater public light in 1900.[24]

The scientific experiments of Toyama highlight the tensions concerning ideas of the "present" and the so-called tradition of Japanese silkworm seed production.[25] Toyama's different approaches to measuring and evaluating the silk cocoon and the way its features changed in successive generations are central to Chapter Two. This section also delves into the practice and concept of "hybridization" through examination of Toyama's dispatch to initiate a silk industry on behalf of the kingdom of Siam – a diplomatic ploy to discourage European colonization in Asia. Toyama cross-hybridized Japanese silkworms with "native" Siamese silkworms and

[24] Charles Benedict Davenport and Gertrude Crotty Davenport, *Elements of Zoology, to Accompany the Field and Laboratory Study of Animals* (New York: Macmillan, 1911), p. 43; Gregor Mendel, Versuche über Pflanzen-Hybriden. Verhandlungen des naturforschenden Vereines, Abhandlungen, Brünn. 4 (1866): 3–47. English translations include William Bateson, "The Problems of Heredity and Their Solution," *Journal of the Royal Horticultural Society* 25, parts 1 and 2 (1900), reprinted in *Mendel's Principles of Heredity: A Defence* (Cambridge: Cambridge University Press, 1902); and Curt Stern and Eva R. Sherwood, eds., *The Origin of Genetics: A Mendel Source Book* (W. H. Freeman and Company, 1966). The Davenports refer to the fertilized silkworm eggs parenthetically as "grains," drawn likely from the French term *graines de soie.*

[25] Vlastos, *Mirror of Modernity,* p. 11.

demonstrated how the basic genetic principles of inheritance operated in the silkworm. His additional demonstration of the phenomenon of "hybrid vigor" helped fuel the objectification of silkworm variation by the state and, later, for the commercial production of scientific hybrid silkworms.

Chapter Three shows how and why silkworm seeds presented complicated expressions of the natural and artificial as their purposes for research traversed between farms and "science for science" arenas of research. Toyama's Mendelian investigations of inheritance continue to be the subject of historical inquiry, but this chapter examines how his research was vetted in English-language publications in a scholarly spar with the American entomologist Vernon Kellogg, through the early 1910s. The conundrum of whether the silkworm was sufficiently "natural" as an organism that it could elucidate the principles of inheritance accurately played a large part in the formation of silkworm genetic studies in early-twentieth-century Japan. Lamentations about dyads such as natural or artificial, member or individual, particular or universal remind us that the silkworm, at first an object of study for the purposes of refining and harnessing silk production, later also became a tool for the study of genetic phenomena.

Chapter Four explores the processing and solidification of ideas about the problem and solution of "unification" (*tōitsu*) of silk that characterized discussions about how to address the then still-resonating effects of the rampant overproduction of shoddily manufactured silkworms from the late nineteenth century. The chapter examines how an interest in making all of the highly localized varieties of domesticated silkworms in Japan legible for industrial management across the nation developed, ultimately gaining sharper definition in terms of *tōitsu* through various efforts and debates in sericulture, silkworm science, and national politics as people sought to harmonize the production of raw silk demonstrating even quality. As mentioned earlier, the establishment of the Sericultural Industry Law in 1911 is a key moment that demonstrates how these three aspects came together in Japan. It helps illustrate an important change in the gaze of state scientists and sericulturists toward the methodology, skill, and craft of sericulture as the discipline of genetics began to take shape. The promises of greater biological intervention for commercial gain sparked systemic changes in Japanese silk cultivation as well as moral dilemmas associated with the displaced ownership of sericultural knowledge from local producers to professionals and scientific experts working for the government.

The combined study of silk production and the formation of a biological research community demonstrate that Japanese biology had a more composite character than might be gleaned from histories that focus on the growth of formal, national, scientific infrastructures built at the time. Chapter Five demonstrates how research on silkworms developed and was framed after the 1911 law. I first examine Tanaka Yoshimaro's formation of a new genetic language to describe silkworms used for research purposes, which differed from but nonetheless remained conversant with the state's scheme of registering commercial silkworm varieties. Tanaka's study of the heredity of silkworm mutations grew out of his own classification work, whereas the entrepreneurial work of Imai Gosuke of the Katakura silk-filature and -reeling family shows how key lessons of hybridization developed initially by Toyama to gave rise to a commercially successful varietal cross of silkworm cocoons. The processes of making silkworms legible for science *and* state together show how two ways of knowing the silkworm emerged over the course of the 1910s and 1920s that facilitated heterogeneous research in academic genetics and industry.

Efforts to produce the kinds of silk threads best suited for overseas markets ensued throughout much of the Meiji and Taishō periods using knowledge accumulated by scientists about silkworms. This dissertation ends by reflecting on how the articulation of the *tōitsu* movement by 1910 began to enable Japanese state scientists to fully take stock of silkworms on a national scale.[26] This shift is one that foreshadows another, more constricting 1934 legal decree regulating the management of silkworm varieties that would transfer the control of silkworm cultivation more comprehensively to the state. *Tōitsu* of the early 1900s, however, marked the beginning of deliberations about how to promote greater simultaneity between the life history and features of the silkworm and the behaviors of its human caretakers, as the idea of a silkworm bearing a highly local identity as a living thing resulting from a localized practice altered dramatically. The pages that follow discuss silkworm culture in modern Japan in terms of what it represented and what end it served, whether directed at making and meeting standards of silk production or enhancing the production of biological knowledge about inheritance.

[26] By contrast, Japan's first human population census was conducted in 1920.

CHAPTER ONE:

SEEDING SILK

The silkworm is not a worm. Like many other six-legged insects, it undergoes metamorphosis, and like other butterfly and moth relations, its body undergoes a remarkable change. Laden with liquid silk, the smooth-skinned larva anxiously seeks something to climb, perhaps remembering a former life when it sought the shelter of a mulberry branch in the open air. Having overindulged in mulberry leaves, it cannot wait to spit its innards out and drools a long single thread around itself in a perfect knot made of tiny figure eights. Infinities. Within its cocoon, the silkworm drifts into a slumber and slowly shape-shifts into a pupa, hardening into a chrysalis form that provides yet another protective layer from the outside elements. There, the silkworm comes of age, and when it feels sufficiently cloistered, it secretes a liquid that melts a small opening in the cocoon. Through a small hole emerges a silky white moth. You can see its fur. Its bug eyes are big, shiny, alien-like in proportion to its head. The silkworm moth also has scaled wings, which slowly dry and expand after ecdysis. It tests them out for a flutter. Perhaps it has a desire to fly, but the silkworm moth can't lift off the ground. And it can barely see. Despite what may seem its odds, it waves its antennae and wings wildly upon debuting into the world. The lucky one catches a chemical whiff of a partner's perfume, and fulfills a purpose.[1]

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[1] This vignette is a composite panel based on the amalgamation of my field observations of sericulture and interviews with sericulturists and scientists in Japan in farms and breeding facilities between 2006 and 2009. Although fictional, the scenarios present a plausible situation of the nervous wait from rearing hatchling silkworms until they spin cocoons, and the verdict of silk quality that may ensue. Conceptualization of the "panel" is informed by Liisa Malkki's analysis of the memory of historical events experienced by those who leave behind no written records (1995).

The silkworm moth species, *Bombyx mori*, has been domesticated over so many centuries that its ability to fly has been severely hampered by the size and weight of its abdomen, which contains the gametes necessary to produce the next generation of silkworms. The dingy greenish-brown "wild" silk moth, *Bombyx mandarina*, known in Japan as the *kuwako*, blends into the shrubbery of mulberry and, in contrast, has the means of winged flight. Of course, the silkworm moth's wings do have a purpose, for the males flap rapidly to communicate their pheromones to the much larger females, which contain ovaries full of eggs that must be deposited. The moths rely on their feathery antennae to detect each other, and when they do, they lock into a mating position for hours, usually until a breeder physically detaches them.

The human mediation of silkworm breeding stands as the main concern of this chapter. In order to understand how the push to "improve" export-bound silk grew, I focus on the production and business of the human production of fertilized silkworm eggs, or "silkworm seeds" (*sanshu*), in Meiji Japan. I show how discussions concerning the cultivation of silkworms involved discussions about different skills and practices, sericultural knowledge and expertise, the silkworm, and some of the early science surrounding the organism. The chapter also raises questions about how new biological insights stemming from the articulations of silkworm cultivation could relate to Japanese interpretations of "maintaining" its world, for instance in relation to the importance of technology and wealth to protecting national autonomy, in addition to considerations of how Japan used the newly developing science and industry of silkworm and silk fibers to negotiate the nation's place within the larger world.[2]

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[2] Richard J. Samuels, "*Rich Nation, Strong Army": National Security and the Technological Transformation of Japan* (Ithaca: Cornell University Press, 1996), pp. 36–9. Samuels explains that in 1855, Ōkubo Takusui, an ardent promoter of *fukoku kyōhei*, called technical capacity, in addition to financial control and wealth, the grand foundation for "maintaining the world" and protecting Japan from danger.

During the early Meiji period, sericulturists enjoyed relative autonomy, and silkworm-farming practices differed from place to place and from household to household. For example, some sericulturists expressed little preference about which moth mated with which, and they would let swarms of moths locate one another in order to mate randomly en masse, sending up a dust-storm of allergy-inducing wing scales.[3] Other farmers would instead select mates on behalf of their moths.

Figure 1. *Yōsan Shinron,* by Tajima Yahei, included a number of illustrations depicting the entire process of sericulture. This image depicts egg sheets, which were transported and sold in wooden boxes. Reproduced from Tajima Yahei, *Yōsan Shinron* (Tokyo: Izumoji Manjirō, 1872), reprinted in *Meiji Nōsho Zenshu*, *dai 9-kan* [Meiji Compendium of Agricultural Texts, no. 9] (Tokyo: Nōsangyōson Bunka Kyōkai, 1983), p. 60.

The lived experience of sericulture was also often supplemented with books and manuals. The publication of guidebooks predated the Meiji period, and they often focused on the how-to aspects of sericulture. Tajima Yahei (1822–1898), a prominent

[3] Allergies to silkworm moths are a serious issue for sericulturists, and today it is common practice for moth-handlers to wear masks that prevent the inhalation of wing scales.

egg producer from Gunma Prefecture, had written one of the best known of such books, *Yōsan Shinron* [New Debates in Sericulture], in 1872. The Tajima family had by then established themselves by producing good-quality eggs that surpassed the qualities of other producers' in the turbulent years of the early Meiji period. Later, Tajima would travel to Italy with his cousin Tajima Buhei in 1889 to sell fertile silkworm eggs directly to Italian sericulturists and to assure them of the quality of this Japanese product (see Figures 1 and 2).[4]

Figure 2. The processes of moth mating and egg-depositing on paper cards. The eggs adhere to these sheets and are hung to dry before being packed in boxes or stored for the winter. Reproduced from Tajima Yahei, *Yōsan Shinron* (Tokyo: Izumoji Manjirō, 1872), reprinted in *Meiji Nōsho Zenshu*, *dai 9-kan* [Meiji Compendium of Agricultural Texts, no. 9] (Tokyo: Nōsangyōson Bunka Kyōkai, 1983), p.88.

The Tajima travels have been largely credited with solidifying Japan's proactive involvement in the global silk trade, but before that, another trip defined the history of silk production within Japan, when the empress invited members of the

[4] Yahei Tajima, *Itaria tabi nikki* [Italy Travel Diary] 1872, reprinted in Tsutō Wada, *Nihon nōjinden.* (Tokyo: Ie No Hikari Kyōkai, 1955), pp. 173–188. For more information on Tajima Yahei, see Chapter Three.

Tajima family and others from the village of Shimamura to teach *yōsan,* or silkworm rearing. The commoners took three egg sheets with them to the Imperial grounds in 1871. To these cards were affixed "silkworm seeds," the fertilized eggs laid by female moths, and the larvae that hatched from these eggs spun both yellow and white cocoons, inaugurating a new spring for sericulture and its newly forming nation (see Figures 3 and 4 for depiction of cocoon colors and larvae).[5]

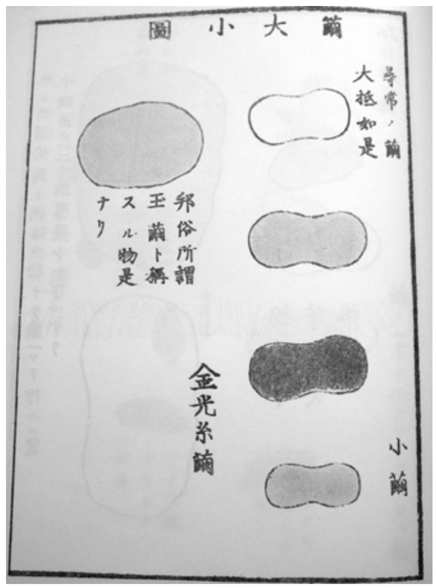

Figure 3. Tajima Yahei depicted three general shades of cocoons, white, yellow and bright yellow in *Yōsan Shinron*. The cocoon in the lower right shows a small cocoon, and the upper left is a *tama mayu*, a cocoon in which two silkworms spin a cocoon together. Reproduced from Tajima Yahei, *Yōsan Shinron* (Tokyo: Izumoji Manjirō, 1872), reprinted in *Meiji Nōsho Zenshu*, *dai 9-kan* [Meiji Compendium of Agricultural Texts, no. 9] (Tokyo: Nōsangyōson Bunka Kyōkai, 1983), p. 85.

[5] Yahei Tajima, *Yōsan Shinron* [New Discussions on Sericulture] (Tokyo: Izumoji Manjirō, 1872) reprinted in *Meiji Nōsho Zenshu*, *dai 9-kan* [Meiji Compendium of Agricultural Texts, no. 9] (Tokyo: Nōsangyōson Bunka Kyōkai, 1983); Tajima, *Itaria tabi nikki* [Italy Travel Diary]; *Nōrin gyogyō kenshō gyōsekiroku: meiji hyakunen kinen* [Commemoration of Achievements of the Ministry of Agriculture, Forestry, and Fisheries: Meiji Cenntenial Anniversary] (Tōkyō: Nihonnōringyogyōshinkōkai, 1968); Eitarō Tamura, *Jinbutsu kinsei sangyō bunkashi* (Tōkyō: Yūzankaku, 1984).

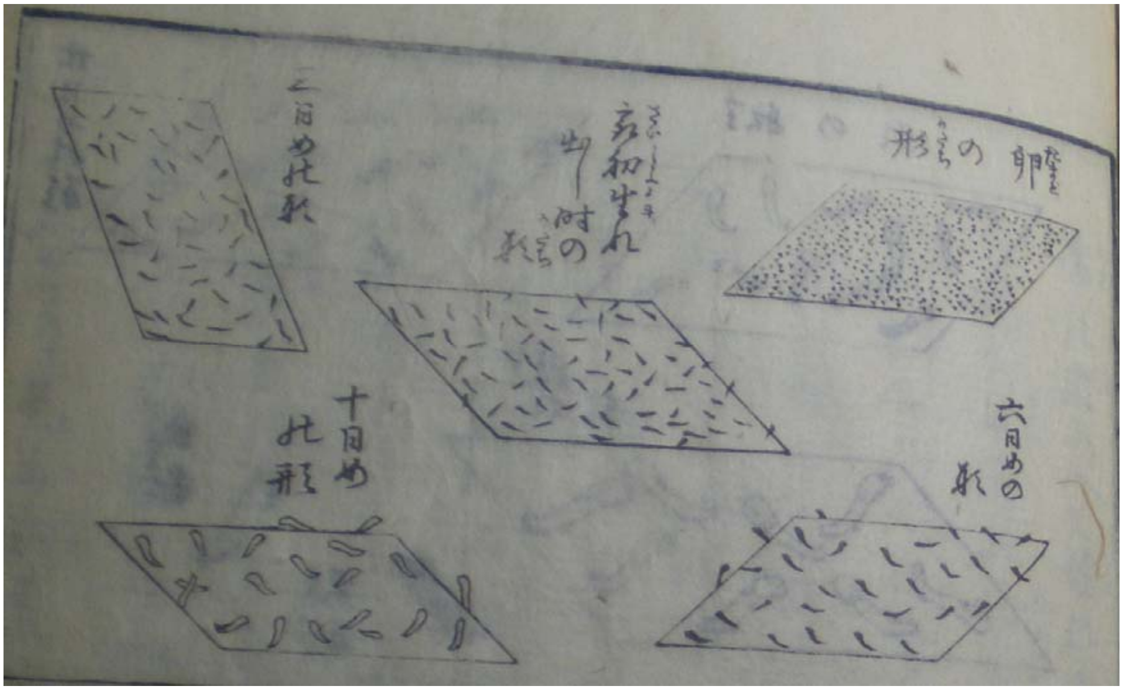

Figure 4. Diagram in *Yōsan Hiroku* by Kamigaki Morikuni depicting the growth of silkworm larvae from eggs (upper right) to ten days. Reproduced from Morikuni Kamigaki, *Yōsan hiroku* (Edo: Suharaya Mohē, 1803), n.p.

Before introducing the connections between new sericulture methods and nation to the history of silkworm experimentation, a brief consideration of the history of the new Meiji state and the creation of its subjects will help explain why the silkworm came to matter to Japan and Japanese genetics. The end of the Tokugawa-shogunate rule in the mid-nineteenth century marked the decline of the feudal system and increased Japan's interaction with the outside world, in addition to sanctioning relationships such as with Dutch traders. Catalyzed in part by the gunboat diplomacy of Commodore Matthew Perry in 1854 and economic crises, the disaffection of formerly loyal *daimyo*s (local landholding rulers) led to the declaration of a new system of rule on January 3, 1868, in the name of the Meiji emperor. The Tokugawan system of rule was gradually dismantled through both violent and nonviolent means, such as changes to land tenure and taxation. The new oligarchy promoted the ideology of the emperor as both a political authority and a divine Shintō figure.[6]

According to Oguma Eiji, these changes grew out of the Liberty and People's Right Movement, which opposed the power held by the southern Satsuma and Chōshū domains in the Meiji government. The attempt to raise the stature of democracy "had elements of a nationalistic movement that aimed for national unification." By the late 1880s, leaders had expounded upon this nationalism, reacting to the growing threats of colonization in Asia.[7] The new Japanese constitution introduced in 1889 followed a Prussian model that recognized an emperor as the sovereign. It established a number of governmental bodies and a bicameral national parliament, the Imperial Diet, whose upper house consisted of men appointed from the hereditary Peerage, a list of 500 former *daimyo*s (established alongside the Imperial Household Ministry), civil aristocrats, and other imperially appointed life-term Peers; and whose lower-house members were elected by voters from a pool of initially 450,000 property owners.[8] The Imperial Rescript on Education further outlined the relationship between the emperor and the people, and the hereditary responsibilities shared by all, in 1890:

> Our Imperial Ancestors have founded Our Empire on a basis broad and everlasting, and have deeply and firmly implanted virtue; Our subjects ever united in loyalty and filial piety have from generation to generation illustrated

[6] Conrad D. Totman, *A History of Japan* (Malden, MA: Wiley-Blackwell, 2000), pp. 278–289; Ryūsaku Tsunoda, William Theodore De Bary, and Donald Keene, eds., *Sources of the Japanese Tradition*, Introduction to Oriental Civilizations (New York: Columbia University Press, 1958), pp. 552–553; 638–645. Japan annexed Taiwan and Korea in 1895 and 1910, respectively, after defeating the Chinese in 1895 and the Russians in 1905.

[7] Oguma Eiji, *A Genealogy of "Japanese" Self-Images* (Melbourne: Trans Pacific Press, 2002), pp. 10–11.

[8] Totman, *A History of Japan,* pp. 278–289; Susan L. Burns, *Before the Nation: Kokugaku and the Imagining of Community in Early Modern Japan* (Durham [NC]: Duke University Press, 2003); George Oakley Totten III, "Adoption of the Prussian Model for Municipal Government in Meiji Japan: Principles and Compromises," *Developing Economies* 15, no. 4 (December 1, 1977): 487–510. Shintōism of the Meiji Empire absorbed Shugendō, and traces of Buddhism were removed from Shintō shrines (Totman, *History of Japan,* p. 293).

> the beauty thereof. This is the glory of the fundamental character of Our Empire, and herein also lies the source of Our education.[9]

The Rescript mobilized a new order that aimed to channel the volatility of the changing time to reach a common goal. Reflecting a Tokugawa-era morality code grounded in Confucianism, it continued,

> The Way here set forth is indeed the teaching bequeathed by Our Imperial Ancestors, to be observed alike by Their Descendants and the subjects, infallible for all ages and true in all places. It is Our wish to lay it to heart in all reverence, in common with you, Our subjects, that we may all attain to the same virtue.[10]

A unified sense of identity stated so explicitly on behalf of the nation did not exist in Meiji Japan before this time. The notion of "being Japanese" developed largely after the formation of the nation-state, much as in the United States or within Europe.[11] Mariko Tamanoi argues that Japanese homogeneity could not have served as a starting point for producing the nation. She points out some congruencies with Benedict Anderson's analysis of the imagined community, which suggests that particular groups, whether exploited, suppressed, or idealized, contribute to the representation of an image of nationhood to the world; however, his model did so at the risk of ignoring the importance of materiality in configuring the notion of the nation-state. Tamanoi's study of the rhetoric used in processes of national subject formation, focusing on rural women silk-factory workers since the 1880s, makes a confident observation: "The silk industry was indeed the centerpiece of Japanese

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9 Totman, *History of Japan*, p. 297; Tsunoda et al., *Sources of the Japanese Tradition*, pp. 646–647. The rescript was primarily work of the Kumamoto samurai Inoue Kowashi, who later became a Minister of Education.

10 Ibid.

11 Stephen Vlastos, ed., *Mirror of Modernity: Invented Traditions of Modern Japan* (Berkeley: University of California Press, 1998), p. 11.

nationalism from the day it was founded."[12] The scholarship on the intensely gendered work of silk manufacture during Meiji highlights the tensions this industry faced in terms of what governed the quality of silk and ideas of the nation in a competitive world.

Japan's first European-modeled factory, built in the 1870s, has attracted the attention of scholars, especially those who have investigated the formation of a female workforce.[13] Analyses of the Tomioka Silk Mill show how Japanese industrialization depended on these workers. To persuade girls from the countryside to reel "for the sake of the country," samurai investors of such factories initially sent their wives and daughters to work; women from surrounding rural areas followed them. For the larger part, however, poor peasant girls were recruited to work.[14] Barbara Molony and Elyssa Faison showed, for instance, how the growth of a rural silk industry depended on a feminization of work to justify if not exploit the employment of shockingly large numbers of married and unmarried "rural," working women at the time.[15] Yamamoto Shigemi's oral histories and E. Patricia Tsurumi's analysis of "factory girls" and their songs highlight the importance of studying the ordinary people who rarely left behind written records. These people had just as much to do with the making of imperial

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[12] Mariko Tamanoi, *Under the Shadow of Nationalism: Politics and Poetics of Rural Japanese Women* (Honolulu: University of Hawaii Press, 1998), pp. 14, 19; Benedict R. Anderson, *Imagined Communities: Reflections on the Origin and Spread of Nationalism*, rev. ed. (London: Verso, 2006, 1991 [1983]).

[13] Yukihiko Kiyokawa, *Transplantation of the European Factory System and Adaptations in Japan: The Experience of the Tomioka Model Filature* (Tokyo: Hitotsubashi Academy, Hitotsubashi University, 1987); Yukihiko Kiyokawa, *The Transformation of Young Rural Women into Disciplined Labor under Competition-Oriented Management: The Experience of the Silk-Reeling Industry in Japan* (Kunitachi Tokyo: Hitotsubashi Academy Hitotsubashi University, 1991).

[14] E. Patricia Tsurumi, *Factory Girls* (Princeton: Princeton University Press, 1992), pp. 32, 59–56.

[15] David Wittner, *Technology and the Culture of Progress in Meiji Japan* (New York: Routledge, 2008); Elyssa Faison, *Managing Women: Disciplining Labor in Modern Japan* (Berkeley: University of California Press, 2007); Tamanoi, *Under the Shadow of Nationalism*; Barbara Molony, "Activism among Women in the Taisho Cotton Textile Industry," in *Recreating Japanese Women, 1600–1945,* by Gail Lee Bernstein (University of California Press, 1991). Tamanoi considers "rural women" a subcategory of women, connoting work in the way "reproductive and productive labor are intertwined" (p. 8).

Japan as did the ruling elite.[16] Detailed analyses about the silk mill and a republication of the memoir of Tomioka worker Wada (Yokota) Ei together help shine attention upon the value of paying attention to those who are easy to ignore.[17]

Women from Japan's interior were not the only ones recruited to lend their labor to the delocalizing silk industry. This dissertation leads us to consider the full worth of silkworms and their materiality in relation to the history of the silk industry, especially as they were gathered across the archipelago of Japan and beyond. Susan B. Hanley has stressed the importance of studying material culture, considering how a focus on the new, borrowed, "modern," and innovative has often dominated studies of the Meiji period. Material culture, especially at the grassroots level, makes it possible to gauge the changes that accompanied new technologies, goods, and ideas.[18] In her study of the role of fabric as a symbol of social order and power in late imperial China, Francesca Bray analyzes how females controlled technical knowledge of production and did much more to manage the entire process of making silk in rural areas by the end of the Song dynasty, but divisions of labor in commercial and home settings gradually marginalized women's economic contributions by the end of the Qing. Bray's close attention to women's material experiences in silk production and weaving points to the ways by which gender roles were reconfigured across classes in the process of "proto-industrialization."[19] The premodern China example of changes in sericulture, especially concerning women workers, involves a different time and

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[16] Yamamoto Shigemi, *Aa Nomugi tōge* [Ah! The Nomugi Pass] (Tokyo: Asahi Shinbunsha, 1969); E. Patricia Tsurumi, *Factory Girls* (Princeton: Princeton University Press, 1992), pp. 26–34.

[17] Wada Ei, *Teihon Tomioka Nikki* [Tomioka Diary, the Authentic Text], Sōju sensho (Tōkyō: Sōjusha, 1976); Ei Wada, *Seikai tomioka nikki: Tomioka nyūjō ryakki,* ed. Mikio Imai (Maebashi, Gunma Pref.: Gunma ken bunkajigyō shinkōkai, 1999).

[18] Susan B. Hanley, *Everyday Things in Premodern Japan: The Hidden Legacy of Material Culture* (Berkeley: University of California Press, 1997), p. 173.

[19] Tessa Morris-Suzuki, *Technological Transformation of Japan* (Cambridge: Cambridge University Press, 1994), p. 39; Francesca Bray, *Technology and Gender: Fabrics of Power in Late Imperial China* (Berkeley: University of California Press, 1997), pp. 183–237; S. J. Vainker, *Chinese Silk: A Cultural History* (Rutgers University Press, 2004).

place from that which is examined in this dissertation. Despite this, the example helps highlight relevant questions with respect to how knowledge related to silk production grew beyond subsistence toward more commercial purposes in modern Japan.

1. Writing Sericulture, Sharing Secrets?

Tajima Yahei's book contained much useful information about sericulture that reflected two generations' worth of experiences amassed between him and his father. Their approach to experimenting with sericulture involved paying great attention to the processes by which they reared silkworms and their cocoons. Silkworms are very sensitive to temperature and humidity, and Tajima made his mark through this book with discussions about how to control airflow in the structures used to house silkworms.[20] Many topics were subject to discussion in these publications during and preceding the early Meiji period. Yet, one category of information seems conspicuously absent from the books of Tajima and many others. How did one determine which silkworm moths deserve to be paired, aside from using those that were robust and devoid of disease? What methods were used to control the inheritance of certain kinds of characteristics of larvae and their silk cocoons? We can only assume that the answers to these kinds of questions were handed down within multiple generations of sericulturists orally and through practical experience. Such knowledge would not be seen fit to replicate in woodblock print. In addition to being secrets of the trade, access to such discrete information had its limits, even as methods of producing silkworms changed into the twentieth century.

Whether such unwritten knowledge regarding the control of any patterns of phenotypic inheritance in silkworms was shared among the more recent dabblers in

[20] Tajima, *Yōsan Shinron* [New Discussions on Sericulture] (Tokyo: Izumoji Manjirō, 1872), reprinted in *Meiji Nōsho Zenshu, dai 9-kan* [Meiji Compendium of Agricultural Texts, no. 9] (Tokyo: Nōsangyōson Bunka Kyōkai, 1983). The word for a structure for silkworm rearing is *magnanerie*. This French term was also used by the Japanese during the Meiji period in English documents.

sericulture remains unclear for now, but breeders surely dealt with the main question of the time: How does one produce only yellow silkworms? Europeans in the mid-nineteenth century were accustomed to silkworms that spun colored cocoons, but the majority of Japanese silkworms spun white cocoons at that time. This did not mean silkworms exported from Japan spun only white cocoons, as Tajima's summary of his visit to the Imperial grounds indicates. Yellow-cocoon-spinning fertilized silkworm eggs counted among the one million egg sheets traded from the 1850s through 1877.[21]

The commercial silkworm varieties bred to appeal to buyers at the time often resulted from breeding experimentation that took cues from conventional practices of silkworm cultivation but relied less upon the curatorial knowledge among more established sericulturists. Although these methods differed from what we understand today to be a feature of industrial animal breeding reliant on inbreeding siblings to promote genetic homogeneity, sericulturists increasingly strove to develop what seemed to be "fixed strains" of silkworms by differentiating between different physical characteristics. These acts of fixity, however, necessarily combined with *kakeawase,* the cross-breeding of male and female silkworms, often directed at the immediate goals and rewards related to creation of a new brand.[22]

Instability defined silkworms, even when they were presumably inbred. Silkworms of one type in the Meiji period did not all exhibit the exact same traits. First, larvae of a commercial variety could look identical but sometimes spun silk of different colors. Breeders might have called these "colored" or "white" versions of the

[21] Tamura Eitarō, *Jinbutsu kinsei sangyō bunkashi* [Talented Personalities: Cultural History of Modern Industry]. Tōkyō: Yūzankaku, 1984; Koizumi Katsuo, *Sanshigyō no ayumi to kono teihen o sasaeta hitobito* [The Path of the Silk Industry and the People Behind it] (Yokohama: Koizumi Katsuo, 1997); Tazima, *Kaiko no Hinshu Ikusei,* p. 20.

[22] I am indebted to a number of silkworm scientists for productive discussions about silkworm breeding practices, especially Eiichi Kosegawa and Yutaka Banno, who steward and curate the Japanese national commercial and mutant silkworm biobanks, respectively.

same commercial variety or separated them further into distinct brands. Their descriptions also varied. For instance, one type of silkworm commonly exported until the 1880s included the *Seihaku* variety of "green" cocoons.[23] This example serves to show how a distinct type of silkworm may have produced multiple colors of cocoons, while only one cocoon color gained recognition as representative of that silkworm variety.[24]

Second, variability in physical appearance among silkworms due to the environment, now referred to by scientists as phenotypic plasticity, often required discerning sericulturists to pick individuals they thought were most representative of the ideal form they wished to cultivate. Sometimes, these would be isolated and renamed. Sometimes, identifying biologically based difference was not even necessary, and extant varieties were simply renamed because the sericulturist changed.

The popularity of certain silkworm breeds also changed with the times. During the first fifteen years of the Meiji period, the popular cocoon types such as *Seihaku* produced for export were generally small, and due to the preference of the Europeans, these were also yellow or "green." Other varieties began to be raised, including *Akajuku*, in response to the demand for the large white cocoons that were favored around 1887. In 1890, small white cocoons such as *Koishimaru* gained popularity for their ease of reeling. By 1895, the popularity shifted toward yet other varieties, such as *Kakumata* and *Shirotama*.[25]

Experimental breeding on the domestic front as well as simple cross-breeding "experiments" between so-called native varieties of Japan and the foreign varieties

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[23] T. Sakudoh et al., "Carotenoid Silk Coloration Is Controlled by a Carotenoid-Binding Protein, a Product of the Yellow Blood Gene," *Proceedings of the National Academy of Sciences* 104, no. 21 (2007): 8941–8946. Domesticated silkworms can spin a yellow-green cocoon. These are not true green cocoons, such as those produced by the *erisan*, a species of wild moth called *Antheraea pernyi*. We now know that some of the different hues of yellow cocoons in the domestic silkworm are due to the silkworm's genetic abilities to digest carotenoids or flavanoids.
[24] Kanji Watanabe, *Yousangaku* [Sericulture Science] (Tokyo: Azumi, 1948), p. 72.
[25] Ibid.

brought to Japan contributed to a further wave of silkworm diversity. These were not the kind of scientific experiments that took place in a laboratory – the system of sericultural experiment stations was yet to be established. Rather, experimental "backyard breeding" began to establish Japan as more than a passive trade partner supplying Japanese silkworms to merely tide Europeans over a rough time. Early Meiji Japanese sericulturists at one time actively brought Italian silkworm seeds back to rear to adulthood and to breed with Japanese moths. By 1870, the business of resupplying living, fertilized silkworm eggs to Europeans in the wake of the *pébrine* blight turned at least one village in Japan into a test-bed to determine whether blight-ridden Italian varieties of silkworms would actually grow and thrive in Japan. The tests yielded little success.[26]

Silk Road history reminds us that Japan, a geographic end point of sorts, was a mixing bowl for technologies and know-how, especially those from China and Korea. Although Japanese silk today occupies an iconic status especially due to the national garment, the kimono, the raw material of silk was brought in from elsewhere for a long time. Japan has had close encounters with "non-Japanese" silk since the centuries preceding the Tokugawa era, long before the initiation of Dutch trade in 1613. Japanese silk was thought to be substandard, and during the Edo period, much of the silk used in the archipelago came from the Jiangsu, Sichuan, Hubei, Zhejian, and

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[26] Francis Ottiwell Adams, secretary of the British Legation in Japan, observed several egg-producing villages on one of his tours of the silk districts of Japan. In Shimamura, located in present-day Gunma Prefecture, he found that Italian egg cards had been sent there with hopes of making not cocoons but eggs. These sericulturists had essentially been outsourced by Italians to try and reproduce Italian silkworm seeds that seemed suspiciously afflicted with pébrine, judging by the poor quality of the cocoons and the 10,000 out of 26,000 survivorship. Surviving cocoons were infected by parasites called *uji*, despite their healthy-looking shapes, and adult moths seem to have managed to lay eggs, for Adams wrote, "The cards produced from the moths which had come out, and some of which were then laying their eggs, were to be sent to Yokohama – for re-exportation, we conclude, to Italy. We had heard at Fujiôka and Tomiôka in Jôshiu, and at Yashiro in Shinshiu of similar experiments being made . . ." F. O. Adams, *Third Report on Silk Culture in Japan* (Yokohama: Japan Mail Office, 1870).

Shandong Provinces in China.[27] The co-option of "foreign" silkworms in Japan was not unheard of at the time, and Japan played an active role in silkworm exchanges through the occasional piracy of Chinese cocoons. It was only after the Tokugawa shogunate prohibited the importation of silk, after Japan's policy of self-isolation developed in the mid-1600s, that domestic silk cultivation gained more importance.[28]

In Meiji, different reasons drove the desire to identify varieties of silkworms, including the identification of varieties that were newly invented in name or in physicality.[29] The task of helping to overcome the European silkworm blight morphed into one that entangled Japan's silkworms physically and genetically with those from the rest of the world while raising the challenge to articulate existing knowledge about silkworms within newer frameworks of management of the biological. As the export of silkworm seeds gave way to that of raw silk, the direction of the export silk market shifted from Great Britain to other points in Europe, especially France, when Chinese silk traders re-entered the market after recovering from the Taiping Rebellion (1850–1864). At this time, Americans also began to emerge as participants of the silk market, and Japanese merchants and producers began to feel new competitive pressures.[30] In the 1870s and 1880s, Chinese silk remained the commodity of choice among Americans, who regarded Japanese silk as the cheaper alternative, and as irregular and inferior.[31] Raw-silk businessmen such as Arai Ryōichiro, who transacted the first direct Pacific and overland silk import in 1876 by a Japanese to America,

[27] Teijiro Yamawaki, *Jiten kinu to momen no Edo jidai* [Encyclopedia of Silk and Cotton of the Edo Period] (Tōkyō: Yoshikawa Kōbunkan, 2002). For more on kimono, see Liza Crihfield Dalby, *Kimono: Fashioning Culture* (Seattle: University of Washington Press, 2001).
[28] Katsuo Koizumi, *Sanshigyō no ayumi to kono teihen o sasaeta hitobito*, 1997, pp. 138–139; Conrad D. Totman, *A History of Japan* (Wiley-Blackwell, 2000), p. 222.
[29] Koizumi, *Sanshigyō no ayumi to kono teihen o sasaeta hitobito* [The People behind the the Silk Industry] (Yokohama: Koizumi Katsuo, 1997).
[30] Jonathan D. Spence, *God's Chinese Son: The Taiping Heavenly Kingdom of Hong Xiuquan* (W. W. Norton & Company, 1997). Also called the Anglo–Chinese Opium Wars.
[31] Li, *China's Silk Trade*, pp. 81–83.

faced numerous challenges in convincing Americans to buy Japanese silk.[32] Even within Japan, as late as 1895 the silk-reeling entrepreneur Katakura Kentaro opted to import 10,000 Chinese cocoons for his business, since the resulting silk would yield greater profit than that derived from Japanese cocoons.[33]

Studying the history of the science of the silkworm requires finer-grain analyses of the management of historical tensions between the emergence of a research discipline, industrial manufacture, and national identity. A number of historical studies have considered the topic of Japanese sericulture, including within works about the Chinese silk industry. Lillian Li measures China's performance in the silk market against that of Japan and cites disease as one of the most fundamental technical problems that literally plagued producers through the 1930s. Preceding the rise of the National Government in China in 1927, decentralized efforts made "the problems of the Chinese silk industry in modern times . . . economic and institutional in nature, not technological."[34] Competition between China and Japan recurs as a theme in economic and business histories of the silk industry, where technology often serves as a heuristic. Debin Ma, for instance, argues that machine-reeling and its

[32] Jacqueline Field, Marjorie Senechal, and Madelyn Shaw, *American Silk, 1830–1930: Entrepreneurs and Artifacts* (Lubbock: Texas Tech University Press, 2007), p. 99; Yasuo Sakata, *Meiji Nichi-Bei boeki kotohajime: Jikayu no shishi Arai Ryoichiro to sono jidai* (Tokyo: Tokyodo Shuppan, 1996); Naomi Hirahara, *Distinguished Asian American Business Leaders* (Westport, CT: Greenwood Publishing Group, 2003), pp. 7–9.

[33] *Sangyō Shimpō* 1, no. 1 (1893): 25. Katakura Kentarō, Hayashi Kunio, and Ozawa Kinsaburo contributed to a brief report of their importation of cocoons from China.

[34] Lillian Li, *China's Silk Trade: Traditional Industry in the Modern World, 1842–1937* (Cambridge, MA: Harvard University Press, 1981), p. 36. Proposals for the establishment of a national institute of sericulture, sending students to study sericultural techniques in France and Japan, and to use Pasteurian methods for staving off blight, began to form in the late 1890s. However, other issues, such as the Japanese reliance on foreign trade, and other historical contingencies such as the Tokugawan period of innovation as noted earlier by Morris-Suzuki, led to a paradoxical situation wherein Japan "caught up" with China, according to Li (p. 36). She notes that while technological change in Japan had occurred alongside changes in production organization, such as Japanese government backing of the Yokohama Specie Bank and Bank of Japan, which helped provide loans to Japanese silk reelers in order to assist Yokohama wholesalers, similar changes in China did not occur until after the introduction of steam filatures. A discussion of sericultural reform is limited to pages 188–196.

financial infrastructure in Guangdong, China, were just as competitive as Japan during the late nineteenth century.[35]

A historiographical perspective on scholarship about silk shows that most studies have emphasized the raw-silk industry's tenacious navigation of turbulent economic situations, such as that represented by the Matsukata deflation of the 1880s, the importance of infrastructures such as educational institutions that promoted industrialization, and the development of spinning machinery as reasons why Japan retained its independence from the West.[36] During Meiji, the experimental entrepreneurial spirit of sericulture changed gradually into a state affair designed to compete especially with China for markets in Europe and the United States. Business and economic histories have cited Japanese standardization and mechanization as reasons for Japan's having taken the lead by 1909.

By 1910, three countries – China, Italy, and Japan – controlled 85 percent of the world's silk market, which seemed to grow with no end in sight.[37] The fervor to establish commercial distinction led Japanese silk industrialists to demand greater attention of governance and reform of sericulture policies. To strengthen any one brand, it would be imperative to improve and standardize cocoons from the bottom up. Of Japanese silks, those from an area in Jōshū, roughly current-day Gunma, were considered to be the finest quality, but for every good skein of raw silk, many coarser ones existed. Many silkworm-egg producers had intimate knowledge of their

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[35] Debin Ma, "Between Cottage and Factory: The Evolution of Chinese and Japanese Silk-Reeling Industries in the Latter Half of the Nineteenth Century," *Journal of the Asia Pacific Economy* 10, no. 2 (May 2005): 195–213.

[36] Kanji Ishii, *Nihon no sangyō kakumei: Nisshin Nichi-Ro Sensō kara kangaeru* [Japan's Industrial Revolution: Thinking from the Sino–Japanese to Russo–Japanese Wars] (Tōkyō: Asahi Shinbunsha, 1997); Tetsu Hiroshige, *Kagaku no shakaishi: Sensō to kagaku* [The Social History of Science: War and Science] (Tōkyō: Iwanami Shoten, 2002), pp. 125–130; Tetsurō Nakaoka, *Nihon kindai gijutsu no keisei : "dentō" to "kindai" no dainamikusu* [The Structure of Modern Japanese Technology: The Dynamics of "Tradition" and "Modernity"] (Tōkyō: Asahi Shinbunsha, 2006).

[37] Giovanni Federico, *An Economic History of the Silk Industry, 1830–1930* (Cambridge: Cambridge University Press, 1997); Li, *China's Silk Trade*, p. 83.

silkworm varieties in the mid-1800s, but the rise of hastily executed breeding to create novelty brands by both experienced and new breeders following the port openings of Japan, enabled by the movement of seeds, created an urgent need to associate larvae and law.

Any such laws would also have to embrace new ideas and competing ideas about inheritance that were then brewing. The emergence of Mendelian knowledge about inheritance biology in the early 1900s, which reflected new theories about the ways in which characteristics are passed between generations through sexual reproduction, posed ramifications for redefining existing categories of silkworms. New articulations of Mendelism in the context of sericulture recast ongoing questions about human intervention in silkworm life, such as about the physical aspects of breeding environments, and the biological aspects of selecting silkworm moths for breeding. These realizations fostered a new partnership between silkworms and scientists. Within the parameters of a growing sericulture industry, new experts traversing between sericulture and the science of inheritance came to play an important role in the mediation of knowledge produced and communicated between the way of the worm and national identity.

Biologists in Europe and the United States during the 1900s began to accept the idea that genetic principles work universally across different life forms, but using an angle involving a specific organism to ascertain a history of Japanese genetics cannot afford *de facto* positions or assumptions about biology. Nor is it easy to draw conclusions between the similitudes of human and silkworm individuals and collectives. Yet, they do constitute important tensions about the ways in which people can or cannot generalize locally produced biological knowledge. Investigating these tensions in drawing conclusions about humans based on invertebrates, for example by addressing why a silkworm scientist or a zoologist of the first quarter of the twentieth century would become "expert enough" to command the language of inheritance and *then* furnish any commentary on the notion of "Japanese," would help frame a better understanding of this interspecies history.[38] Rather than affirm ideas of national exceptionalism, these tensions and common grounds between different realms of experts and stakeholders help draw attention to ideas about the management of identity and belonging. Awareness of the acute sensitivity and consciousness of evaluation by outside "advanced" worlds helps guide, but not dictate, an understanding of the relationships that formed between silk makers and makers of biology and how those relationships were shared with the humble silkworm. Concerns about possibilities of being colonized or erasure of control contributed to a perception of "vulnerability to cultural, or virtual imperialism of the 'advanced world,'" which had actually also contributed to the formation of new disciplines in Japan, such as the social sciences, as described by Andrew Barshay. The development of sericulture, though more a practice than an academic, scholarly discipline, might reflect this phenomenon of discipline formation in Japan, as well in other locations such as the kingdom of Siam.[39] Whether that final judgment of advancement concerning the intellectual or material product be real or imagined, making sense of both requires simultaneous analysis of silkworms and their people if the history of the formation of

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[38] E. M. East and D. F. Jones, *Inbreeding and Outbreeding: Their Genetic and Sociological Significance* (Philadelphia; London: J. B. Lippincott Company, 1919). This kind of rhetoric may seem matter-of-fact to those who are familiar with the history of American eugenicists. Many prominent biologists who studied nonhumans easily wrote and talked about humans by the mid-1910s. Edward Murray East studied corn, but this well-cited book, coauthored with Jones, expanded beyond the matter of plants and couched discussions of "exogamic" marriage between "unrelated" individuals who are not in the same kin group: "Correct answers to these questions are a matter of more importance than a superficial consideration indicates. Settled in accordance with the biological facts, they aid in establishing a concrete scientific basis for marriage, divorce, and immigration laws; they give grounds for predicting the changes to be expected in the body politic due to differential fecundity, birth control, and other agencies by which the character of the population is shifted; they even have some relevancy to many problems which one might suppose were wholly of an economic nature, such as minimum wages and mothers' pensions" (p. 16).

[39] Andrew E. Barshay, *The Social Sciences in Modern Japan: The Marxian and Modernist Traditions*, *Twentieth-Century Japan* (Berkeley: University of California Press, 2004), p. x.

genetics in Japan is to be understood. Without engaging historically with the newly configuring cultural practices of science or concepts, whether of inheritance, hybridization, or otherwise, we run the risk of ignoring the contingencies that shape the formation of a scientific discipline. Such limitations also make it too easy to take for granted the existence of these sciences, in this case, various branches of biological science, as "signs of a distinct and unified Japanese culture," as comes with the territory of the study of heredity, which can lend to the understanding of so many things about our selves and others at any given time.[40]

2. Eggsplosion of the Seed

The next few sections present a multidimensional overview of the arc of silkworm seed sales and how it gave way to the production of silkworms for the sake of producing more silk, not "just" more seeds. Material on the formation of the silkworm-seed trade of Japan still has opportunity for scholarly synthesis in English, and Japanese analyses of the topic have often focused on the experiences of silk businessmen, if not more squarely on the economics. The sale of silkworm seeds played a key part in helping Japan maintain a trade surplus for a number of years before it came to trade large quantities of raw silk, and later, woven silk fabrics, with Britain, France, Italy, and the United States.[41] One of the most decimating silkworm blights hit in 1853, reducing the value of the French silk industry at the time from 25 to 5 million dollars.[42] The cause of the blight yet unknown, the die-outs resulting from the epidemic disease called *pébrine* that spread especially through the silk regions of France and Italy spurred Japan's egg trade. The timing coincided with the

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[40] Vlastos, *Mirror of Modernity,* p. 11.
[41] Kären Wigen, *The Making of a Japanese Periphery, 1750–1920* (Berkeley: University of California Press, 1995), p. 140.
[42] Joseph Leidy, *An Address on Evolution and the Pathological Importance of Lower Forms of Life* (Detroit, MI: George S. Davis, Publisher, 1886).

Taiping Rebellion (1850–1864), which forced European traders, already familiar with tea and silk trade partners in China, to visit the newly opened Japanese ports.[43] The shogunate also paid for French arms with raw silk in 1865, according to verifications by concerned members and associates of the British legation.[44] When France beseeched Japan to export eggs, the *bakufu* complied, sending 15,000 sheets (cards on which female moths lay their fertilized eggs), which arrived in the spring of 1866. This delighted Napoleon III greatly, who sent 26 of his best horses to Japan in appreciation.[45] The silkworm egg trade, in short, had roots in the shadow of a colonial threat that had already destabilized China.

The disruptions to domestic markets within China that occurred when Taiping forces drew around areas near Shanghai that were important for mulberry cultivation and silk production also allowed Japan to take a place in the silkworm egg trade.[46] Japanese participation in a global market grew as a necessity, considering the geopolitically fragile atmosphere. The silkworm eggs and silk from Japan did not have a reputation in Europe in the 1850s, which complicated the delicate, volatile situation, especially when promises of capital exchange for lucrative silkworm seeds tempted producers to cheat the system.

Silkworm moths normally lay translucent eggs the size of small, flattened black rapeseeds or poppy seeds. The similarity of silkworm seeds to vegetative seeds appealed to some individuals motivated by a combination of desperation and greed, creating problems for honest brokers, who did not attempt to pass off black rapeseeds

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43 Ibid.; Jonathan D. Spence, *God's Chinese Son: The Taiping Heavenly Kingdom of Hong Xiuquan* (New York: W. W. Norton & Company, 1997).
44 Wittner, *Technology and the Culture of Progress in Meiji Japan,* p. 46, citing Kenichi Iida, *Tetsu no kataru nihon no rekishi* (Tokyo: Shoshiete, 1979)*,* p. 83. Particularly, by the young German interpreter and translator, Alexander von Siebold.
45 Yatarō Tazima, *Kaiko no Hinshu Ikusei* (Tokyo: Science House, 1993), p. 19, citing Itō, 1992.
46 Spence, *God's Chinese Son*; Li, *China's Silk Trade,* p. 105.

or poppy seeds as silkworm eggs.[47] Silkworm seeds could not be replaced by any other kind of seed or similar object. This could not have been more clear when a European grower incubated an egg sheet, only to meet a photosynthetic surprise of salad sprouts.[48] In order to circumvent such problems of embarrassment, as early as 1865 a decree was enacted to require silkworm egg cards to carry a special seal.[49] Japanese producers and merchants came to enjoy a near monopoly on the short-lived egg market due to a number of factors. The timely troubles faced by China under transition following the unequal Treaty of Nanking in 1842 and civil strife certainly reflect the place of contingency in this history. Various efforts on the part of silkworm-seed producers in Japan such as Tajima Yahei and his family to go directly to Italy and create good relations with European buyers also played important roles in cultivating international trade relations.

a. Saving Silkworms, Saving Seeds, Saving Face?

As a sustainable trade, the sales of *graines du Japon* – the seeds of Japan – could last only as long as it took to resuscitate the blighted European silk industry.[50] Believing that Japanese eggs were disease-free, French and Italian traders bought and sold these

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[47] Norifumi Fukuda, *Wagakuni no sanshigyō o sasaeta omo na sanshi kagaku to gijutsu* [The Main Sericultural Science and Technology Supported the Development of the Sericultural Industry] (Tokyo: Nihon Sanshi Shinbunsha, 1990).

[48] Ibid., p. 10; Takao Kajishima, *Shiryō Nihon dōbutsushi* [Documents: Japan Animal History], *Shinsōhan* (Tōkyō: Yasaka Shobō, 2002), pp. 226–227. Trickery in cocoon sales and the raw-silk trade itself was also common, for raw silk and cocoon prices fetched higher prices according to their greater weight. Weights were sometimes nestled within shipments, or higher quality silk hanks were bundled on top of poorer quality hanks. Such issues of quality are related to an overall discourse of "improvement," but perhaps not as directly pertinent to matters of silkworm breeding.

[49] Kajishima, *Shiryō Nihon dōbutsushi* [Documents: Japan Animal History], *Shinsōhan,* pp. 226–227. This seal was called *kiito sanshu-shi kaiin*. The use of stamped seals had been in place since 1773 to indicate silk variety in order to prevent the production of "imitation" silkworm seeds from the otherwise famous area of Yūki, Fukushima, famed for its woven silk products.

[50] The official *Journal of the Empire of France* routinely published on the importation of "Graines du Japon," or the "Seeds of Japan." The French used the term "seed," *graines,* to describe silkworm seeds: *graines de vers a soie*. See Louis Pasteur, *Études 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), pp. 310–311.

to sericulturists in Europe, who then reared the silkworm larvae that would spin the cocoons needed for silk manufacture.[51] Japanese silkworms, although hardier than most French silkworm strains, were actually also susceptible to disease in Europe.

Requested by the French Minister of Agriculture to investigate the blight and other silkworm diseases, Louis Pasteur (1822–1895) took to the silkworm nursery *qua* field laboratory of Pont Gisquet in Alais of southern France, a center of the silk industry each summer between 1865 and 1870. There, he cultured and compared diseased silkworms in order to understand how the peppery silkworm spots surfaced on the delicate skin of silkworm larvae and were related to *pébrine* disease. Peasants by then recognized these spots as predictors of a poor cocoon harvest.[52]

In 1866, Pasteur developed a method for monitoring the presence of disease using a microscope before fully understanding the exact etiology of the disease. After allowing moths to lay their eggs, microscopic analysis of the female moth would indicate the value of allowing those seeds to hatch the following season. Even a woman or child could carry out this "egg-selection method," Pasteur wrote to the Minister. Even though Pasteur's studies of the exact biological identity of the protozoan parasite remained inconclusive (we know it today as *Nosema bombycis*), the effectiveness of his egg-selection techniques gained wider trust among the most seasoned egg breeders in France, and by 1870 they spread to Italy and Austria. The

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[51] The "Rapport sur les études sericocoles faites par une mission italienne dans l'interieur du Japon" from *Extrait de la Revue Universelle de Sericiculture*, Septembre 1869, describes the surprise that "The atrophy that has been around for years already on the European silkworm has given rise to the fear of destroying the source of wealth for our country. Although the introduction in Italy of silkworm [egg cards] imported from Japan has been successful, it was rumored, for some time in Italy and France, that the Japanese silkworm was also infected of this disease. From there, fear of being obliged shortly to look elsewhere, and maybe months with success, the seed for several years that Japan provides us in such great quantity" (reprinted in Pasteur, *Études sur la maladie des vers à soie,* p. 317).

[52] Gerald L. Geison, *The Private Science of Louis Pasteur* (Princeton, NJ: Princeton University Press, 1995); Rene J. Dubos, *Louis Pasteur: Free Lance of Science* (New York: Da Capo Press, 1960). The Minister of Agriculture at the time was Jean Baptiste Dumas, who came from a silk-growing region (Dubos, *Louis Pasteur,* pp. 209–232). Pasteur had little to no awareness of the silkworm blight until then, and among Japanese circles it is well known that Pasteur had gone to Fabre to learn more about the silkworm itself.

gradual recovery of the European silkworm stocks relieved Pasteur of his Napoleonic service to silk and marked the implosion of the Japanese seed trade.[53]

Like other seed crops such as corn or wheat, silkworm seeds until around the 1870s served both means and ends as propagator of their own living kind and the commodity itself, embodying the "problems" facing the formation and retention of seed as commodity. Jack Kloppenburg's analysis of the widening gulf between maize farmers and the act of reproducing their own seeds provides great insights into how new intellectual products of scientific and technical research reached farmers in the form of private enterprises rather than as public goods: "the seed presents capital with a simple biological obstacle: Given appropriate conditions the seed will reproduce itself manifold. This simple, unavoidable biological fact of reproduction poses significant difficulties for commercial interests that would engage in the development of new plant varieties for profit."[54] To retain its hold on the European market, the Japanese silkworm seed had to be made to address this "biological obstacle" of reproduction and to embody instead the "problems" of its nature, the technological and scientific interventions that not only had to nurture the desirability of the product itself but had to force a significant alteration of the social relationships between European sericulturists and silkworm-seed reproduction.

The unregulated reproduction of the silkworms intended for the production of export seeds held ramifications for the future of the Japanese sericulture industry even though silkworm seeds had little to no monetary value as objects of international exchange by the mid-1870s. Even though the European silkworm seed market had

[53] Pasteur, *Études sur la maladie des vers à soie,* pp. 49–206; Dubos, *Louis Pasteur,* pp. 217–219. Each summer, Pasteur left Paris for the silkworm nursery in southern France, where he grappled with the question of understanding two diseases at the same time, *pébrine* and *flacherie.* Pasteur did not completely resolve the latter's etiology.

[54] Jack Kloppenburg, *First the Seed: The Political Economy of Plant Biotechnology, 1492–2000* (New York: Cambridge University Press, 1988), pp. 35, 37.

collapsed, Japan's response to its earlier boom created a greater subdivision of labor within its sericulture industry than had existed before its ports opened.[55]

The International Exhibition in Vienna was the first of its kind in which Japan participated voluntarily. There, in 1873, the Japanese delegate Sasaki Chōjun (1830–1916) learned Pasteur's methods for producing healthy silkworm seeds by detecting *pébrine* spores, prompting Japan to implement a system for controlling the disease. Sasaki accompanied a group of leading governmental officials in the Iwakura Mission that toured Europe and the United States on behalf of the Home Ministry. Along with Tanaka Bunsuke, Sasaki served as a technical trainee in order to learn French and Italian methods of silk cultivation and reeling.[56] There, he learned the Pasteurian technique of inspecting for *pébrine*, and he continued to research the methods at the Naito Shinjuku experiment station after he returned to Japan.[57]

Sasaki Chōjun played a key role in the promotion and realization of new agricultural policies in Japan, but it was his son, Sasaki Chūjirō, who devoted his life to the study of insects and served instrumentally in developing a method for *pébrine* spore detection based on Pasteur's work. This method, under the stewardship of the

[55] Morris-Suzuki, *Technological Transformation of Japan,* pp. 36–43.

[56] See "Chapter 1: Silk-Reeling Technology and Female Labour," in Masanori Nakamura and Corrado Molteni. *Technology Change and Female Labour in Japan*. (Tokyo: United Nations University Press, 1994), pp. 25–58; Tomoda, K., "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. The decision to participate in the Vienna Exposition was not taken lightly. One of the ambassadors in the Iwakura Mission, Kido Takayoshi, wrote on 4 May 1873: "The people of our country are not yet able to distinguish between the purpose of an exposition and of a museum; therefore, they have tried to display a mountain of tiny and delicate Oriental objects without regard for the expense. This seems to invite contempt for the dignity of our country on the part of others" (in Brown and Hirota, 1985, p. 321, as quoted in Ian Hill Nish, ed., *The Iwakura Mission in America and Europe: A New Assessment* [London: Routledge, 1998], pp. 4–5).

[57] Sasaki Chōjun's given name can also be read "Nagaatsu." The lack of information exchange between Japan and France at this time is interesting and deserves further examination, especially considering the outcome of the Franco–Prussian War (1870–1871), which led to the union of Germany as a nation-state. Sasaki learned the technique of pébrine inspection from "G. Bolle." Watanabe, *Yousangaku*; Tadao Yokoyama, "The History of Sericultural Science in Relation to Industry," in *History of Entomology,* ed. Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith, 267–284 (Palo Alto, CA: Annual Reviews Inc., 1973).

Sasaki father-and-son duo, spread throughout Japan through a growing network of experiment stations. The Sericultural Experiment Station, *Sangyō Shikenjō*, established by the Japanese Ministry of Agriculture and Commerce in 1884, enabled the elder Sasaki to house his research on silkworm disease. By the time the institution became known as the Sericultural Training Institute (*Sangyō Kōshūshojo*), in 1896, the program for *pébrine* research transferred formally to Sasaki Chūjirō, a professor at Tokyo Imperial University.[58]

Since *pébrine* transmits vertically from mother to offspring, an effective system for detection must successfully identify the infected female moths before their eggs hatched in order to abate the spread of disease. This method to preserve healthy silkworm seeds depended on the systematic incineration of infected females and their progeny.[59] Such new approaches to controlling contagion by eliminating parent and offspring generations together factored greatly in the demise of the international silkworm seed trade, but its end also had much to do with a flood of seed production from increasing numbers of people in Japan attempting to profit in the marketplace.

b. Producing and Burning Inferiority

At the docks of Yokohama, a great egg-export controversy bubbled and decimated silkworm-seed prices in 1870. The growing health of European silkworm stocks left more and more seeds idle in the port. Known as what Japanese historians call the "one-third *sanshu* reduction affair," shippers and producers faced the accumulation of over a million and a half silkworm-seed cards from around the country, and heated debates ensued among egg consignors about how to carry on. They decided to burn the

[58] Watanabe, *Yousangaku*, pp. 8–9. The Kyoto Sericultural Training Institute was established later, in 1899.

[59] Norifumi Fukuda, *Wagakuni no Sanshigyō wo Sasaeta Omona Sanshikagaku to Gijutsu* (The Silk Science and Technology that Supported our Country's Silk Industry), p. 14. This inspection method has not significantly changed to this day.

worst of the surplus seeds in order to help prevent silkworm-seed prices from bottoming out. The pile-up also derived from the sheer numbers of people who flocked to take part in the hot enterprise of sericulture as the *sanshu* trade gained its reputation as a lucrative business. The phrase *sosei ranzō* began to be used to describe the resulting "mass production of inferior goods." By the time the market fell, seed producers began to realize in what ways they had brought this situation of *sosei ranzō* upon themselves.[60]

Who produced these bad eggs? Some historians suspect that the specialization of egg production and professional roles such as the silkworm egg producer were established in Japan as early as 1500.[61] These producers were not just generators of seeds; some were active experimenters. Before the terminology for hybridization science developed, for instance, in 1845, one of the earliest recorded silkworm-crossing experiments concerned the hybridization of summer and autumn crops of silkworms in Nagano, in order to generate more harvesting opportunities.[62] Differences in how sericulturists bred their silkworms in the simple act of choosing two individuals for *kakeawase*, or cross-breeding, made all the difference in entrenching the links between the reputation of the provenance of seeds and the people they represented.

Geography also compounded the results of breeding. A mountainous terrain feathered and lined by water not only created an astonishing number of microclimates in Japan, but prior to Japan's increased participation in the global silk trade during the Meiji period, silk producers were geographically more isolated from one other. People

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[60] Ibid.; Yokohama Kaikō Shiryōkan, ed. *Yokohama Shōnin to Sono Jidai* [Yokohama Businessmen and the time] (Yokohama: Yurindō, 1994).

[61] Inoue Zenjiro, *Sansho Kenkyu* [Study of Sericulture Texts] (Saitama, Japan: Yurin Co, 2006); Morris-Suzuki, *Technological Transformation of Japan*. Yokoyama, "The History of Sericultural Science in Relation to Industry."

[62] Yukihiko Kiyokawa, *The Development and Diffusion of Improved Hybrid Silkworms in Japan: The First Filial Generation* (Tokyo: United Nations University, 1981).

overcame such isolation with increased travel, which allowed the flow and heterogeneous admixture among otherwise "conventional" cocoons and silkworms. The appellation of silk products lent a certain degree of cachet to the families residing in the Japanese mountains. Not only did the reputation of a family or cooperative make a name brand reputable, but distinction also resulted from the particular craft practices used by the individual sericulturists, the environment (including disease pathogens and the physical environment), and the biological profiles of the nonhuman organisms.[63]

Particular areas, especially Fukushima's Date district, were reputed for producing high-quality silkworm eggs, but their quality did not stem from the lasting effects of isolation, but from the fact that in its overwintering state the organism could travel well and be transported through mountain crags and passes, over and through rivers and tributaries, and, of course, across distant seas.[64] By the Meiji period, seed production had spread out from very specific areas of northern Japan, and the allure of seed production in the face of capital accumulation helped to subsequently hasten the proliferation of not only the number of silkworms of known strains but reputedly novel silkworm kinds and, therefore, new kinds of cocoons.[65]

Encouragement of this hyperbranding also resulted partly from a relaxed attitude toward agriculture that was encouraged initially by the politician Matsukata Masayoshi.[66] In a disease-regulated but breeding-unregulated sericulture period, the

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[63] Silk farming was best suited to arid, mountainous lands where mulberry could grow instead of rice.
[64] Most Japanese silkworms are univoltine, meaning they undergo one overwintering state in the form of an egg. This is known as diapause. For more on Fukushima silkworm varieties, see *Kichinosuke Shōji, Kindai Fukushima-Ken Yōsan Seishigyōshi* (Aizuwakamatsu-shi: Rekishi Shunjū Shuppan Kabushiki Kaisha, 1986).
[65] Hiratsuka Eikichi, *Nihon Kaiko Hinshu Jitsuyō Keifu* (Tokyo: Sanshi Kagaku Kenkyūjo, 1969), p. 21.
[66] Later a prime minister, as a finance minister Matsukata was also linked to the 1885 Matsukata Deflation. Haru Matsukata Reischauer, *Samurai and Silk: A Japanese and American Heritage* (Cambridge, MA: Harvard Belknap Press, 1986); Steven J. Ericson, "'Poor Peasant, Poor Country!' The Matsukata Deflation and Rural Distress in Mid-Meiji Japan," in *New Directions in the Study of Meiji Japan*, ed. H. Hardacre and A. L. Kern (Leiden; New York; Köln: Brill, 1997).

quasi-laissez-faire atmosphere provided degrees of freedom and scale that sericulturists could enjoy, allowing them to potentially produce many “new” breeds and brands. Relaxed regulations were intended to give rise to reliable, lucrative, and therefore desirable products. Instead, confusion transpired about the multitude of choices regarding rearing methods and breeding.

As seed-making grew more popular as a livelihood, distinctions between “conventional” and new varieties of silkworms began to blur. This blurring led to the aforementioned *sosei ranzō*, which we can understand as the permitted survival of silkworms that in a previous era might have been thrown away, perhaps as by-products of experienced selective breeding. One controversial answer to the problem of *sosei ranzō* lay in the decisions by tradesmen who wanted to steel themselves by reducing the original seed reserve by one-third. For the first time, the Japanese silkworm-egg men, consisting of about 70 shipping merchants and 1,000 egg producer-sellers, were forced to grade their silkworm seeds and to explicitly recognize the relative merits and demerits of their Japanese products in order to distinguish those that deserved higher commissions than others. This policy devastated many seed producers who produced low-grade *sanshu* and were forced to come to terms with the consequences of triage.[67]

The seed grades reflected geographic locations whereby seeds from the northeast in Ōshū and Ushū (present-day Fukushima and Yonezawa) were deemed a

[67] *Yokohama Kaikō Shiryōkan,* p. 25; Ikawa Katsuhiko, “Meiji yonen ‘Sanshu Sanbunichi Sakugen Jiken’ Ni Tsuite” [On the ‘One-third Silkworm Seed Reduction Incident’ in the Fourth Year of Meiji], *Yokohama Kaikō Shiryōkan Kiyō* 4 (1986): 28–66. Most merchants worked together as part of this agreement, but some also conducted sales to foreigners under the table. Continued losses created a standoff between merchants and egg producers. On one hand, producers often could not cover the handling fees to the middleman if the cost of production exceeded them. On the other hand, the merchants were concerned mainly with the proper arrival of goods to their overseas ports, and they competed with each other to give advances to the producers. These advances were often not earned back by the producers, thereby driving up the overall cost of production. While small to middle-sized businessmen managed to avoid bankruptcy, the effects of the price drops were felt even more acutely by the producers.

higher grade than those from the Shinshū area (present-day Ueda, Nagano, for instance). Only the remaining two-thirds' supply would be available to sell, and this balance was kept in check by burning and discarding unwanted egg cards at the Yokohama docks. This helped ensure that the worst products would not be sold abroad, lest they further damage Japan's reputation; it also mitigated the risks of lowest-grade silkworm seeds that would otherwise propagate the following spring within Japan, which could lead to the production of other trade goods of questionable quality. During most of October 1874, the burning and discarding of about 600,000 sheets of the lowest grade of silkworm seeds took place.[68]

This experiment in capital accumulation made producers reflect upon the futility of merely magnifying the quantity of silkworm seeds for overseas trade, and efforts to examine egg sheets began to be centralized. For example, Tajima Buhei was encouraged to establish a company called the Kangyō Kaisha to inspect and grade silkworm seeds by his relative working at the Ministry of Finance, Shibusawa Eiichi (known later as the "father of Japanese capitalism").[69] The combination of issues also directed producers' attention even more anxiously to questions concerning the technologies of quality. The burnings did not solve the problems immediately. Following the period of dwindling purchase orders, some speculators hung back to scavenge for discarded silkworm-egg sheets, only to sell them at half or less than the original price of three hundredths of a yen – a little over a penny. Not only would the

[68] Wada "Itarii Tabi Nikki," p. 177; Ikawa, "Meiji yonen 'Sanshu Sanbunichi Sakugen Jiken' Ni Tsuite"; "Kajō de Geraku, Sūmanmai wo Yakisute" [Price Drops Due to Surplus, Several 10,000 Sheets Burned and Rejected] *Shinbun Zasshi*, October 12, 1874; "Yokohama de Rokujyumanmai wo Yakisute" [600,000 Sheets Burned and Discarded At Yokohama], *Tokyo Nichinichi Shimbun,* October 20, 1874. Good silkworm seeds had once corresponded to a Fukushima origin in northern Japan, but seed production there had grown into new areas such as in Gunma and Nagano prefectures.

[69] Edward E. Pratt, *Japan's Protoindustrial Elite: The Economic Foundations of the Gōnō* (Cambridge, MA, and London: Harvard University Asia Center, 1999), p. 75; Louis Frédéric, *Japan Encyclopedia,* trans. Käthe Roth (Cambridge, MA: Belknap Press of Harvard University Press, 2002), p. 851. In 1870, Shibusawa was tapped by the Meiji Emperor to reorganize the system of weights and measures. In 1873, he left to establish industrial corporations, and helped found around 500 companies in total.

producer be doubly taken advantage of, but presumably poor-quality seeds would be able to hatch into bona fide silkworms overseas.[70]

With problems of reputation management already clear, ranging from the blatant substitution of black rapeseeds for silkworm seeds, to less-than-hardy eggs that could not withstand the sea voyage from Japan to Europe, the resulting variable to unfavorable silkworm and cocoon qualities, and of course, the Pasteurian rehabilitation of European silkworm production, sericulturists could no longer afford to hastily produce eggs for an overseas market. They could afford even less to produce poor-quality silkworm seeds for domestic production. By 1875, the government capped the production of the inferior silkworm seeds, while recognizing that silkworm-seed producers themselves would not disappear. They now reflected a significant profession that demanded more secure means to earn a profit.[71]

c. Persistence of the Seed

Keeping *pébrine* at bay remained an imperative. Aside from actually saving the silkworms from myriad diseases, especially *pébrine*, "saving" the newly expanded egg sector hinged on cashing in on the silkworm and social metamorphoses that would lead to increased growth in the trade of actual silk.[72] In addition to producer-level inspections of mother moths, new measures also aimed to control disease through restrictions on licensing and permissions as to which humans could be trusted to produce eggs without decimating harvests. These tactics began to expand the focal point of the industry to enable the repurposing of seed production for the sake of silk rather than for seeds in and of themselves. The challenge of transforming sericultural

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[70] "Kajō de Geraku," 1874. This news refers to reduced purchase orders from Italy.
[71] "Soko Nashi No Sanraku" [Bottomless drop in Silk[worm seeds], *Tokyo Nichinichi Shimbun,* November 24, 1875.
[72] Kitamura Chikayoshi and Nozaki Minoru, *Nōrin Suisanshō Ni Okeru Sanshi Shiken Kenkyū No Rekishi* (Tsukuba: Nōgyō Seibutsu Shigen Kenkyūjo, 2004), ch. 1.

industry goals in order to support an export silk industry resided in the piecemeal processes of addressing questions about identity of silkworms and their selection. This selection of silkworms for breeding involved ongoing discussions about how to prioritize the "improvement" of the inanimate objects and how to manage the collective and individual life forms yielding the silk.

The loss of the seed trade had not meant complete loss of the seeds' value, but the place of the organism's value had shifted to the stage of metamorphosis that humans deemed important at the time. The shift arising from the humiliating egg-burnings brought more scrutiny upon the prepupated juvenile form of silkworms, the larvae. Egg producers before and through the early Meiji period used highly individualized practices of assigning local names to silkworm varieties. A silkworm name could reflect some combination of its breeding or ancestry, variety or type, or native place.[73] For export-bound silkworm products, the concern about embarrassment or shame over shoddy workmanship, whether at the level of the insect or its silk, often circled back to the fact that anything taken out of the country would ineluctably share the point of origin: Japan.

The harvesting of raw silk took over as an objective as silkworm seeds lost their international commodity status by the 1880s. The organisms that hatched from *graines du soie* were not the actual objects used in the textile industry, which stands in contrast to the example of value-shifts for edible plant seeds, which serve definitely as both commodity and progenitor. Raw silk is a by-product of the silkworm's metamorphosis from larva to adult moth. Each stage of the silkworm's life cycle – egg, larva, metamorphosing cocoon and chrysalis, and adult moth – entails a set of social relationships discretely associated with the specific human work contributing to the productivity of the silkworm or its ability to reproduce. The values associated with

[73] Eikichi Hiratsuka, [*Silkworm Breeding*], trans. Alamelu Gopal (Rotterdam, Netherlands; Brookfield, VT: A. A. Balkema, 1999), p. 1.

developmental stages of the silkworm changed as human ideas of "the commodity" shifted and engendered changes in the work and practices of production to ultimately control the reproduction of the species on a national scale.

The enduring emphasis placed on seed production in silk cultivation points to the importance of apprehending life cycles, seasons, and metamorphosis, making the economic upset of the silkworm seed trade between Japan and Europe but one thread weaving through this fabric of relations between science and sericulture.[74] While the seed may seem to have been demoted to international economic irrelevance, it was hardly irrelevant in the grand scheme of the culture of the silkworm. My analysis suggests that the silkworm seed plays a central role as both a physical object and a metaphorical term for a biological category. Its power to perplex especially resides in its conflation at times with the idea of a type, which I use to probe the role of biology in Japanese industrial production and science as the nineteenth century gave way to the twentieth. During this time of transition, many discussions among various practitioners of the silkworm, from producers to scientists to bureaucrats, sought to identify the elusive thing that best controlled the modulation of raw-silk qualities. Was it something inherent in silkworms, or the human hand, that mediated their abilities to maximize their "genetic endowment," or both? Why and how could the human–silkworm partnership come to be perceived by the Japanese as something that informed perceptions of their status in the world order of the time? As the rest of this dissertation will demonstrate, much of the discourse related to these questions circled back to questions about the seed. The localized naming practices of silkworm seeds as brands during the early Meiji period remind us of the facility with which groupings

[74] David Wittner and Debin Ma have already investigated issues pertaining to manufacture, mechanization, textile processing, or ironworks in greater detail than the present work covers. Rather than offer a holistic analysis of the entirety of the silk industry, I discuss the most pertinent features of the aforementioned aspects of the silk industry insofar as they inform the cultivation of silk cocoons and insofar as sericultural practices matter concretely to the developments of activities leading beyond the cocoon.

have been made, and the ease with which we humans forget how that happened. Depending on how things are sorted out, we can come to understand how the notion of the silkworm seed as a brand idea could reinforce connections between objects and living things thought to be highly similar, if not actually related.[75]

3. On Making Silk(worms)

Taking silkworm seeds seriously as biological representations and as living histories necessitates a vantage point that complicates and incorporates history, science studies, and biology from the alternative perspective of the nonhuman. William Cronon, in his examination of the trade and movement of grains, shows how a plant commodity could be made equivalent to capital: "by severing physical grain from its ownership rights, one could make it abstract, homogeneous, liquid."[76] The commodification of the nonhuman requires it to be nonparticular to a culture; it requires it to be exchangeable across borders. The silkworm is also a nonhuman biological entity that depends on humans in order to cross borders, including those of nations; yet its ecological life history – its process of metamorphosis– forces us to engage with it much differently to understand a history of science and nationhood that it helped shape.

The silkworm might seem to resemble the opportunistic spirit of the naval shipworm *Teredo navalis*, a boring mollusk that constantly hindered the projects of laying down oceanic telegraph cables. On Barak argues that Teredo was an active yet invisible participant in the project of European colonialism and even shaped its

[75] Geoffrey C. Bowker and Susan L. Star, *Sorting Things Out: Classification and Its Consequences* (Cambridge, MA: MIT Press, 2000). The ease with which we forget the practical politics of the decisions that established formal or informal classification systems comprises the "silence" of mundane classification work inherent in social life that Star and Bowker address.
[76] William Cronon, *Nature's Metropolis* (New York: W. W. Norton, 1991), p. 195.

colonial project, its own history, as it traversed oceans.[77] The silkworm is more passive than a parasitic marine symbiont, but both exhibit the relentlessness of organisms, invertebrate or otherwise, in their persistence to reproduce that engenders disturbances of various kinds for people. While the silkworm hardly exerts willfulness or makes sentient decisions the way humans may, Bombyx's life history involves a forward momentum; even its dormant state involves the potential of movement and reflects a relentless pace that humans, an undeniable part of its domesticated community ecology, must keep up or intervene with. As a consequence, the biologies of these organisms can facilitate and hinder various processes of knowledge production, as this dissertation continues to demonstrate.

The study of nonhumans decenters the assumption that human agency is an inevitably "given" condition; attention to the nonhuman helps show how apparently human decisions have been shaped by the hybridity of technology and politics. For example, in his analysis of the power of personified capital, Timothy Mitchell illustrates how human agency and intention alone do not motivate the circulation of things such as water and electricity or commodities such as sugar and cotton. A thorough understanding of the manufacture of nature, the lived environment that results from human activities in pursuit of moving inanimate things around, means that humans must be considered alongside nonhumans.[78] This multistranded history of silk manufacture in Japan reinforces this vein of scholarship that takes the presence of the nonhuman, biological and nonbiological, into serious account.

At the peak of silkworm-seed overproduction, 1,200 silkworm varieties were said to have existed during Meiji.[79] Humans facing the imperatives of the silk

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77 On Barak, *"Resurfacing Middle Ground," Egyptian Times: Temporality, Personhood and the Techno-Political Making of Modern Egypt, 1830–1930* (Ph.D. diss, New York University, 2009).
78 Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley: University of California Press, 2002).
79 Hiratsuka, [*Silkworm Breeding*].

industry began to categorize and manage these silkworms. Histories of the silk industry have often portrayed a success story about how the crossing of moths from two scientific pure lines gave rise to hybrid silkworms used across the industry, a story in which humans master the silkworm in an increasingly rationalizing world.[80] By not taking for granted the domestication of the insect as an easily performable activity, we approach a more complete understanding of the possible kinds of changes that silkworms and humans experienced together. Humans, for instance, could not easily produce an ideal type of commercial silkworm cocoon in the Meiji period. The processes by which the multitude of varieties developed in the first place resulted partly from the ease with which silkworms could be bred and their fecundity, as well as the difficulty in coaxing an exactly desirable cocoon to form that required at least one year per generation to obtain any results.

Although governmental leadership, grassroots movements, technology, and market forces each play important roles in shaping a history, I argue that these invertebrates provided important, unique sites of contestation in industrialization processes reflective of the state's interest. These issues may resemble human subject-formation in Imperial Japan, although such an explicit comparison lies beyond the scope of this writing. The intense familiarity that many people had with their silkworms played into the dynamic of limitations and potentials that defined these interspecies partnerships from the late 1800s through the mid-1900s.

The challenge of taking control in order to shape the processes of producing profitable silk at that time depended on harnessing the seeming unruliness and limitations that stemmed from the materiality posed by silkworms, as understood through their responsiveness to environment, human handling, and hereditary

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[80] Araki Mikio, *Nihon sanshigyō hattatsu to sono kiban: Yōsan nōka keiei* (Kyoto: Mineruva Shobō, 1996); Reischauer, *Samurai and Silk*; Li, *China's Silk Trade*; Kiyokawa, *Development and Diffusion of Improved Hybrid Silkworms in Japan*; Morris-Suzuki, *Technological Transformation of Japan,* pp. 93–96.

endowment. By that logic, silkworms could later, as a result of intensified scientific investigation, become more easily envisioned as systematic and knowable, standardized and manageable. Their reproduction had to be integrated as part of industrial production, but not without first a great deal of disquiet.

Some discussion of the industry and production is useful to explain how the sexually reproducing silkworm's life history posed certain challenges for human producers of silkworm seeds or cocoons while silkworms also became scientific. The homonym *sangyō* helps explain some of this relationship between silk and the organism. One set of Chinese characters that can be read as *sangyō* means "industry," or a business of production. Another set of characters that can be read as *Sangyō* means "silkworm business," referring to the business of producing both silkworms *and* silk.[81] The division of the activities associated with the industry as a whole is captured through the pluralism of words used to describe the many activities that both defined *Sangy*ō. *Yōsangyō* refers to sericulture business; *seishigyō* to reeling raw silk from cocoons; *sanshigyō* to the work and business dealing with all aspects of silk cocoons, raw silk, and/or silk waste products. Together, these different valences of production represented in the homonym of *Sangyō*, in which one character corresponds to "birth" and the other to "assembly," underscore a need to comprehend how the "production" of silk involves the condition or capacity to project something into the world (an egg, a silkworm, silk) as well as the making or crafting of something (silkworm varieties as represented by the seed egg, silk).

The industrial interventions of life and the ways in which an organism is "made" or "made to be" reflect a conflation worth noting in order to illuminate how matters of the biological and technological related in the Meiji and Taishō periods. This pause to consider the differences between producing and reproducing the

[81] The term *Sangyō*, meaning silk and sericulture business and/or industries, will hereon be capitalized to distinguish it from the more general *sangyō*, meaning business and/or industry.

silkworm will reverberate later in the course of inheritance experiments carried out by Toyama Kametaro. The written forms of *Sangyō* and *sangyō* make it easier to grasp how ideas of industrial output relate to distinctions of reproduction and production differently, but it seems plausible that the meanings may have undergone a process of greater separation over the course of the early 1900s, especially in consideration of scientific discourse about whether the silkworm's features are natural or unnatural insofar as inquiries of heredity were concerned.

In contrast to the succinct conveyance of meanings offered through written Japanese, aurally, *sangyō*, used to describe the businesses of silk and silkworm work, might also gesture toward a proximity between the industry's reproductive and productive aspects. Debates about differences between speech and writing and between truth and fiction are well discussed by Marilyn Ivy, who explains that "Anxieties about cultural transmission, valorizations of the unwritten, discoveries of the marginal, and textual construction of the 'folk' are the replicable constituents of modern cultural nationalisms throughout the worlds"; but in Meiji Japan, a "crisis in representation" emerged in which reconciling the written, spoken, and the "real" constituted a core issue.[82] Considering what made the silkworm "real" in this supposed crisis might make sense in terms of making plural silkworms legible as "the silkworm." The enmeshed meanings of *Sangyō* would not only be subject to rearticulation in Japan; the uneasy unraveling of the different parts of production, in which knowledges and practices of sericulture would be rearranged in terms of national production, would also require explicit analysis of the biological, organismal aspects of silk work, such as silk cocoon harvesting, larvae rearing, and seed production.

[82] Marilyn Ivy, *Discourses of the Vanishing* (Chicago: University of Chicago, 1995). Ibid., pp. 73–74. Particularly, Ivy particularly credits Katie Trumpener, *The Voice of the Past: Anxieties of Cultural Transmission in Post-Enlightenment Europe* (Ph.D. diss., Stanford University, 1990).

Problematization of *Sangyō* challenges the facile idea that sericulture and silkworm reproduction changed solely in response to the introduction of new technologies or the industrializing march of rationalization. What seem compelling explanations for the transformation of the systematized production of silkworm reproduction would actually depend on the slow accumulation of knowledge from multiple angles, including those in the sciences, and especially including those resulting from transnational interactions over a long period of time.[83]

a. Sericultural State of Affairs

The embarrassment over *sosei ranzō* served as a constant reminder of how a decent reputation overseas could be easily dismantled depending on the export of good- or poor-quality silkworm seeds. As the experimental, entrepreneurial spirit in seed production gave way to a focus on silk culture itself, Japan's reputation seemed prone to fraying all over again. For instance, Londoners deemed the coarse silk coming from Japan in 1870 unfit for making not just good textiles but, particularly, good textures, the softer of which were thought to be better.[84]

The Imperial family began to play a more direct role in promoting and encouraging the silk industry. This direct intervention centered on the rearing of the worm. As mentioned earlier, in March of 1870, the empress ordered Tajima Buhei, from current-day Gunma prefecture, to teach and give lectures on silkworm-rearing to a group of women on the Imperial palace grounds. Within 40 days, they achieved results, and some of those cocoons were presented to the ancestral shrine of the

[83] Theodore C. Bestor, *Tsukiji: The Fish Market at the Center of the World* (Berkeley: University of California Press, 2004), p. 14. Bestor's analysis of the Tsukiji fish market shows how individual actors and institutions both socially construct economic systems through the slow accretion of social knowledge and practice "that over time come to seem timeless . . . ."

[84] F. O. Adams, *Report by Mr. Adams, Secretary to Her Majesty's Legation in Japan, on the Central Silk Districts of Japan. Presented to Both Houses of Parliament by Command of Her Majesty*, no. 1, *Great Britain, Legation (Japan)* (London: Harrison and Sons, 1870).

Imperial family at Ise, with the remaining cocoons used to make silk worn by the emperor and empress.[85] That same month, the former prince of Uwajima, Date, crafted and distributed 600 copies of a "Notification" throughout silk-making regions of Japan:

> Silk culture is an industrial pursuit of the highest importance to this Empire, and it is not only profitable to the persons engaged in it, but it also contributes largely to the increase of the national wealth. In course of time this art will be brought to perfection, and all the Silk-cultivators will be skilled in its exercise. But at present the yield of Silk depends on the skill or want of skill of the Silk cultivators, and the consequence is that some make large profits whilst others sustain considerable loss. Of late years the competition in the Silk-districts for the profits of this industry excited in some persons an envious feeling, and many have attempted it although unacquainted with the art of producing Silk, notwithstanding that it was a task beyond their strength, and unsuited to their station in life. We have been informed that there have been frequent instances where persons, instead of bettering their positions, have lost their all in this way. This is very sad. Such a misfortune is to be attributed entirely to their own covetous desires, still, inasmuch as there have been no scientific principles laid down for their aid and guidance, people imperfectly acquainted with the art of cultivating Silk have contracted the idea that good or bad yields are blessings sent by Heaven. The consequence is that our knowledge makes no progress; a state of things which must not be allowed to continue.[86]

"Art," describing silk cultivation in this official translation, directs us to the tensions that continued to be drawn as complete novices gained the skills associated with a craft of cultivation known for its specialized knowledge that was once learned generationally. The surge of people pursuing a new industry of "silk culture," as suggested by Date, resulted in colossal personal failures due to a lack of scientifically informed practice. His writing further suggests that measures needed to be taken in

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[85] Horikoshi Zenjuro, "Japan's Silk Industry," *SILK: Published in the Interest of the Producer* 5, no. 3 (1912): 33–36.

[86] Date, quoted in F. O. Adams, 1870. "Appendix 1," *Third Report on Silk Culture in Japan*. Yokohama: Japan Mail Office, p. 17. Ernest Mason Satow and Ken Yamaguchi, *Kinse Shiriaku: A History of Japan from the First Visit of Commodore Perry in 1853 to the Capture of Hakodate by the Mikado's Forces in 1869* (Yokohama: "Japan mail" office, 1873). The author does not state the full name of the "ex-Prince of Uwajima," but presumably, this was Date Tōtōmi no kami (ex-Prince of Uwajima in Iyo), according to Satow.

order to enable progress by making the distribution of knowledge a priority. Indeed, a new "state of things" would be required.

> Theretofore Silk-culture has been considered to be an employment suitable for women, and to be an art which impressed itself on the mind by means of manual practice, but now that it has taken such a development, it ought to become the main occupation of whole families. In particular those persons engaged in the manufacture of cards, who have devoted special attention to this branch of industry, have noted down the conclusions which their practical experiments have led them to form. The present Notification, which will be circulated throughout the Silk districts, is intended to elicit general information on this subject, irrespective of difference of soil, climate, or methods of culture. When the replies shall have been received, the important points will be selected, and trivial observations will be rejected. In this way a body of information respecting the ode of silk-culture will be collected and published, so that mistakes arising form ignorance of principles may be corrected, and a way opened for their successful application.[87]

By August 1870 the Ministry of Popular Affairs distributed regulations and policies for egg production, the Silk Thread Manufacture Ordinance (*Sanshi Seizō Kisoku*).[88] These rules outlined the requirement to maintain a license to produce more than 25 sheets of eggs, or to produce eggs for the sake of export, or to purchase raw cocoons for the sake of export. In particular, the restrictions required those wishing to participate in this business to pay taxes through the acquisition of egg-card stock with a government imprimatur showing proof of license.[89]

With the new "state of affairs" and the policies with which to maneuver them, 1870 signaled initiation of a systematic approach to the selection of individual silkworms that would be permitted to reproduce. Circumvention of *pébrine* disease would now permit the continuity of life, calling attention to the meaning and potential of the seed in spite of waning foreign trade interests. The processes of silk cultivation, reliant on control of the silkworm egg, would remain critical to the success of the

[87] Ibid.
[88] Kitamura and Nozaki, *Nōrin Suisanshō.* The Minbushō lasted from 1869–1871.
[89] "Sanshu Seizō Kisoku," 1870 [OS].

foreign exchange of raw silk as a viable enterprise. In 1870, the Japanese government began to seek knowledge of and control over the sericultural state of affairs more proactively. Silk-producing representatives from the silk districts of Japan were called upon to share their opinions about how to prevent individuals from undergoing financial ruin by way of quality deterioration and loss of trust. The information that would return to the governing center following the Date inquiry marked just the beginning of efforts to determine how to make even qualities of silk within Japan and prevent the "adulteration" of the market. The idea of selling factory-manufactured silk to foreign buyers emerged as a partial solution to this problem.[90]

b. Capturing the Raw-Silk Market

Date's explicit focus on the "manufacture of cards" speaks to the abstraction of the live silkworm in its portable, inanimate form.[91] More measures sought to ensure some level of consistency among the egg cards bought and sold. The Silkworm Egg Control Ordinance (*Sanshu Torishime Kisoku*) of 1873 aimed to prohibit the breeding of *natsugo*, or summer silkworms, known for spinning poorer-quality cocoons than their springtime counterparts. Producers were also encouraged to form companies so that they might cooperate and consult with each other about sericultural methods, and the production of silkworm-egg cards was restricted so that only a limited number of cards could be sold domestically and overseas. Such ordinances were repealed after 1878 as the export of silkworm seeds dwindled.[92]

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90 Takahashi Nobusada, ed., *Descriptive Notes on Silks and Cocoons Exhibited in the World's Columbian Exposition* (Tokyo: Tokyo Tsukiji Type Foundry, 1893).

91 Date, in Adams, "Appendix 1," p. 17.

92 Takahashi,. *Descriptive Notes,* pp. 6–7; Ōsakafu*, Genshi Sanshu Kiito Gokisoku: Meiji Rokunen Kaisei* [Policy for Raw Silk Silkworm Seed Egg Sheet] (Ōsaka: Ōsakafu, 1874), pp. 276–277; Kiyokawa, "Diffusion of New Technologies in the Japanese Sericultural Industry: The Case of the Hybrid Silkworm," *Hitotsubashi Journal of Economics* 25 (1984): 31–59. The English for "*sanshu torishime kisoku*" is from a translation of the phrase by Yukihiko Kiyokawa. *The Development and Diffusion of Improved Hybrid Silkworms in Japan* (Tokyo: United Nations University, 1981).

The transition from silkworm seed to raw silk export did not happen instantly. A decade after the initial downfall of the egg market, raw silk was not yet a nationwide industry in the eyes of Consul Takahashi Shinkichi. The consul, stationed in New York, felt that the enhancement of raw silk still needed attention by a structure of awards that encouraged the production of those Japanese goods that were the most refined, or manufactured most carefully. He also recommended the establishment of a public association for raw silk as well as an inspection facility in Japan for export-bound silk. Understanding that silk imported from other countries was supported by economic-protection policies, he saw that protection from price fluctuation was also necessary. Most important, Takahashi stressed the importance of *torishimari*, or tightened control, of the sale of silkworm-egg sheets and, instead, of making raw-silk production the backbone of Japan's source of wealth.[93] Historical accounts of *torishimari* have mainly been covered by former participants in the silk and sericulture industries and sciences, who explain that this kind of silk-work governance continued from the volatile early Meiji into the Taishō period, when more formalizing laws were enacted. The act of *torishimari* would later incorporate silkworm surveys across Japan by the 1910s.[94]

Indeed, the language of *torishimari*, in addition to *tōitsu* and the complementary *ittei*, introduced previously, all relate to matters of decision making concerning the management of silk and silkworms that were reflected in the creation of the 1911 Sericultural Industry Law. To gather the significance of this arc, we need to understand how political efforts to tighten or loosen the controls over the flow of silkworm seeds out of Japan in the late 1800s occurred in light of practical and

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[93] Kiyokawa, *Development and Diffusion of Improved Hybrid Silkworms in Japan*.
[94] Fukuda Norifumi, *Wagakuni no Sanshigyō wo Sasaeta Omona Sanshikagaku to Gijutsu* [The Main Sericultural Science and Technology Supported the Development of the Sericultural Industry]; Koizumi Katsuo, *Sanshi Daikoku Nihon to Kanagawa no Tenmatsu* [Circumstances of the Great Silk Nation of Japan and the Height of Kanagawa] (Yokohama: Koizumi Katsuo, 2006).

personal choices surrounding the ongoing cultivation of the silkworm. This need comes from the fact that *torishimari* policies in the 1880s also directed a change in the flow of seeds *within* Japan, further complicating the physical and intellectual handling of silkworms as palpable commodities as well as living things.[95]

Understanding the silkworm seed – what it was, what it represented, and what it would produce – affords us a greater comprehension of issues created by interests to uphold both quantity and quality, two basic interests of both silk and silkworm producers. The seed as a living thing had the potential to give rise to the silk for which Japan would come to be known and then use to attempt to tighten its grip on its own future. Seeds, after all, are objects of potential, and their growth is not inherently guaranteed. In 1876, the businessman Arai Ryoichiro oversaw Japan's first direct-export shipment of raw silk to the United States (earlier transactions took place between Europe and the United States), which heightened interest, since the Japanese product was said to be on a par with, but cheaper than, European silk. American factories and their workers grew accustomed to using this raw material. When Japanese money markets underwent upheaval in 1881–1882 as paper currency began to recover from a state of long depreciation, however, a large number of silk companies dissolved, leading factories to halt and, ergo, stall Japanese silk exports.[96]

The lull in the Japanese silk industry not only raised the price of Japanese raw silk but also forced American factory owners to purchase European raw silk, and these proprietors gradually re-shifted their factory looms to accommodate the shapes of European cocoons and their silks. To the chagrin of the Japanese, in 1881, the European share of the raw-silk market essentially doubled from the previous year, from USD$1,628,446 to USD$3,225,902. Taking a paternalistic tone, Takahashi

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[95] Koizumi, *Sanshi Daikoku Nihon to Kanagawa no Tenmatsu,* p. 158.
[96] Takahashi, *Descriptive Notes*, p. 7; Takahashi to Yoshida and Inoue, October 11, 1883 [DRO].

stressed to superiors in Tokyo the importance of weighing the hope of Japan's wealth *not* upon the exportation of seeds, but on silk.[97]

The potential re-evacuation of the technology inhabited by made-in-Japan silkworm seeds was apparent to some, but not others. In the mid-1880s, Americans' eagerness to seed a sericulture industry using Japanese silkworms challenged the hope of the Japanese government to supply more silk to the newer American market. Cashing in on American desires to home-grow silk by selling them lucrative silkworm seeds likely seemed the most sensible thing to do from the point of view of Japanese producers, whose European market had shriveled up.

In 1883, the Kawajiri Company of Yokohama presented twenty silkworm-egg cards to the North American Silk Exchange of New York. The Japanese company intended to demonstrate to Americans the reliability, viability, and quality of Japanese seeds. W. B. Smith of the newly created Silk Exchange wrote to the consul general Takahashi in New York City to note how pleased the Americans were after experimenting with the Japanese seeds. Not only were the larvae robust and the cocoons of a beautiful consistent quality and shape; the threads' luster was also admirable. The Americans, already keen to produce silk, wished to order large quantities of Japanese silkworm seeds in order to forge their own industry, which created an existential dilemma for the Foreign Ministry.[98]

The decline of seed sales in the United States did not automatically lead to increased silk exports. That Japan might wind up an unwitting supplier of silkworm eggs, not to reseed, but to newly seed America's sericulture industry gnawed at the

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97 Ibid.

98 Okui to Yoshida, "Secret document no. 15," August 11, 1883; Smith to Takahashi, "Translated document," 1 August 1883. 3-5-2-27. [DRO] The Americans distributed between 100 and 1,000 seeds each to people in various regions of the country. W. B. Smith had long been interested in promoting sericulture. See "A Projected Silk Exchange." *New York Times*, 1882, p. 12; "A Silk-Rearing Exhibition; What Was Seen in Turn Hall Yesterday – Objects Which Deserve Support." *New York Times*, 1882, p. 5.

conscience of general consul Okoi Kiyokaze. If Japanese silkworm seeds would be used to produce silk in the United States, Okoi wrote to his superior Yoshida Kiyonari in Tokyo, "To what other country do you want to sell several 10,000s of bales of raw silk? We gain tens of millions of yen in profit each year with that product. If you think about it, I can only feel pain and worry." Whether to limit the export of seeds or to heavily tax the sales of seed, Okoi stressed the urgency to immediately *torishimaru,* or enact control of the situation.[99]

Although by 1883 a clear strategy for creating demand for raw silk was not yet in place, Takahashi was convinced that the export of raw silk to the United States could help restore the financial losses that resulted from Seinan War, which had forced the Meiji government to issue paper currency after it steered off of the gold standard.[100] Between 1877 and 1882, the dollar amount of sales of Japanese raw silk had steadily increased, from USD$776,917 to USD$6,379,115, but Takahashi remarked that even greater profits could have been made if the protests at Yokohama, which virtually halted silk exports to the United States, had never occurred. Preventing a "seeding" event would only help, not hurt, Japan.

c. The Sangyō Spectrum

The raw silk exported from Japan was processed into various kinds of textile materials and fabrics, from lightweight chiffons to heavy brocades to short-fiber yarns. Despite their differences in texture and appearance, the raw materials all came from the same source: the cocoons of the domestic silkworm. Humans harvested and processed these cocoons through a boiling and reeling technique called filature. Through filature, the long individual filaments of many silk cocoons are reeled and spun together into single-stranded hanks of "raw silk." While there was also some trade of Japanese

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[99] Okui to Yoshida, August 11, 1883 [DRO].
[100] The Seinan War was also known as the Satsuma Rebellion, 1877.

woven silk cloth, the iconic trade item was the packaged skein of silk that was further processed in the factory looms of industrializing America.[101]

More original research on the silkworm developed after 1887.[102] As an imperative of the Agricultural Bureau of the Agriculture and Commerce Ministry, experiments with different varieties of silkworms were conducted at the Sericultural Experiment Station (*Sangyō Shikenjō)* between 1887 and 1896. Institutional support for sericulture science addressed the fact that mechanized production increasingly required large quantities of uniformly made cocoons. The problems of inconsistent raw silk frustrated not only reelers and filaturists within Japan, who processed cocoons increasingly on machines, but also the machinists who processed the silk into finished goods. The raw silk that then shipped from Japan to Europe and America also had to perform well on thread-twisting machines and looms. With cocoons made by living things, cultivated by people living in various locations around Japan with preferences for particular kinds of silkworms, the enormous task of orchestrating a reliable, reputable product for a singular country could not have been more worrisome.

The pressure not just to produce but to consistently reproduce consistency in raw silk burdened many of the new scientists and engineers employed in state institutions meant to support silk and sericulture production. In 1897, Honda Iwajiro, the director of the Sericulture Training School, relayed a number of complaints he collected while on a trip to the United States, a growing importer of Japanese silk. Among the numerous complaints were issues that pointed to the conundrum of standardizing a product based on harnessing the work of the silkworm. These included nonuniform thread qualities, the excessive varieties of raw silk, and the irregular qualities among products shipped from the same company or bearing the same

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101 Field et al., *American Silk, 1830–1930: Entrepreneurs and Artifacts*.

102 In 1896, the Sericultural Experiment Station, *Sanshi Shikenjō*, changed names and became the *Sangyō Kōshūjo*, a short-term sericultural training school. Watanabe, *Yousangaku* [Sericulture Science], p. 25.

trademark. Other problems were particularly noticeable in woven silk products, such as the presence of knots and fluff, or imperfect twills, or inconsistent deniers, or fabric weights.[103]

This kind of comparison, grounded in measuring a product of Japan, was, I argue, one of the important ways in which Japanese nationhood was defined concretely against the performance of other countries. Uniformity in silk quality was something achievable only through judging, through which self-perceived concerns about Japanese cultural vulnerability and autonomy could perpetuate. Honda concluded that the overall Japanese irregularities were due to the many regions in Japan, each of which cultivated a number of varieties, whereas European silk cocoons generally reflected a single variety. That characteristic, a perception of being of one variety, was what Honda thought contributed to the decided (*ittei*) grade or quality of European silk. European silkworms were not devoid of diversity, of course. Honda's assertions at the time stressed, however, the role of geography and environment in shaping Japanese silk. This explanation of some of the sources of Japanese silk's shortcomings helps to highlight the sheer haste felt at the time to offer naturalizing rationales as to why the Japanese had produced so many kinds of silkworms.[104]

The tensions within the spectrum of *Sangyō*, from the production of silk to the reproduction of silkworms, ran taut between the producers of the biological and those who worked the machine end of silk, the latter of whom began to insist that egg and cocoon producers needed to sort out the number of breeds and standardize silkworms. Since unprocessed raw-silk skeins were subject to various manipulations by machines and chemicals, the compatibility and uniformity of silk fibers became more important. These fibers came from single-strand filaments from boiled cocoons, which were spun by larvae, which hatched from an egg. Working backwards, the silkworm egg, which

[103] Honda Iwajiro, "Ōbei ni okeru Honpō Kiito no Shuyō," *Dainihon Nōkaihō* 90 (1897), n.p.
[104] Ibid.

results from the sexual reproduction of adult silkworm moths, funnels us back to the human hands that play a role in the mate selection of the insects. In the early Meiji period, it could be argued that all sectors of *Sangyō* were equally scrambling to improve their product, to but traveling the pathway of production in reverse highlights how silkworm seeds prominently occupied the base of the blame cascade for any and all problems. Explaining the source of silkworm varieties spoke to a whole range of issues that were subject to arguments and discussions that characterized the atmosphere surrounding the silk-reeling industry's insistence on the standardization of cocoons.[105]

d. Toward Legibility of the Silkworm

By the 1890s, over 300 dedicated silkworm experiment stations were established throughout Japan as a result of both governmental and local, private interests. Governmental policies began to mandate that *sanshu* for commercial use come only from approved, disease-free parental silkworm stocks maintained and released by licensed silkworm experiment stations. These changes in accreditation, approval, and signification of authority linked to the initial purpose of controlling for *pébrine,* the culture and cultivation of silkworms, made it more and more possible to manage a diverse sericultural field, filled with multiple voices and multiple kinds of silkworms. One of the cornerstone projects that began to help make "the silkworm" legible for the implementation of a rationalized silk industry was the Chart of Sericulture Standards, issued in 1889. Taking around a decade to complete, it consisted of comparative breed information, listing temperature, humidity, mulberry feed, and various other features necessary to cultivate silkworms.[106] The charting of different silkworm varieties and

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[105] Kitamura and Nozaki, *Nōrin Suisanshō Ni Okeru Sanshi Shiken Kenkyū No Rekishi.*
[106] Townsend Harris, in "Sericulture in Italy, Japan and China: From the View-Point of Disinterested and Distinguished Observers in the Diplomatic and Consular Service of the United States" (New York: Silk Association of America, 1905), p. 22; Watanabe, *Yousangaku* [Sericulture Science], p. 25; Kazuko

their rearing requirements was a critical first step toward national regulation of the local practices of silkworm cultivation. The Sericulture Standards, while focused on the practices of cultivation, initiated a movement toward the larger tabulation of silkworms on the level of their intrinsic characteristics, in addition to their performance in response to particular feeding and cultivation environments.

This emphasis on comparison of silkworm varieties paved the way for the scientist Toyama Kametarō (1867–1918) to pursue the study of the scientific improvement of silkworm cocoons and patterns of inheritance, or what we now call genetics. Toyama underwent scientific training at the Imperial University of Tokyo. There, he worked under his major advisor Sasaki Chūjirō, who worked in entomology, but Toyama's research mentor was Ishikawa Chiyomatsu (1861–1935), who had greater interests in evolution. In Toyama, theoretical and organism-based research combined during a time that required him to straddle research on the specific scale of the silkworm without losing complete sight of larger biological questions. He also had various professional obligations in the Agricultural Society of Japan and in the Sericultural Association of Japan, established in 1892 to support the sericulture industry, and because he was considered an expert, his speeches and writings often appeared in trade journals and even newspapers.[107] As he later argued that producers should pay greater attention to the *honsei*, or the "true character" of silkworms, Toyama's work on silkworm inheritance patterns while in service of the state planted a seed for the formation of the discipline we call genetics today, within the language of sericulture.

Tsuchikane "Meiji ni okeru Nihon yōsangyō no gijutsuteki dōkō to 'yōsan hyōjunhyō'" *Nihon Joshi Daigaku Daigakuin Bungaku Kenkyūka Kiyō* 15 (2009): 29–49. The directive for producing this information came from the government, and was overseen by the Naito Shinjuku Research Institute, which was part of the Ministry of the Interior. Between 1879 and 1881, the research institute remained stagnant, while jurisdiction of sericultural matters changed hands to the Ministry of Agriculture and Commerce. It was not until 1889 that it was completed by Matsunaga Gosaku, an engineer in the Sericultural Experiment Station.

[107] The association also had close ties to the Imperial family and businesses.

Toyama's experimentation on silkworm hybridization, which catapulted him into a position of notoriety by 1906, was preceded by his studies in cytology. His familiarity with the movement of chromosomes in *Bombyx* reproductive cells, described in his 1894 college thesis "On the Spermatogenesis of the Silk-Worm," poses retrospective intrigue about Toyama's arrival at Mendelian inheritance studies, how his attitudes toward such work in Siam and Japan were informed, and finally, how the findings from his 1900s contributed to Japanese sericultural practices.[108] Toyama's undergraduate thesis reflected his full grasp of the "reduction" of chromosomes – the stages of meiosis – that took place during the spermatogenesis of *Bombyx mori*.[109] Although the history of cytology in Japan does not occupy the central concern of this dissertation *per se*, Toyama's swerving attention and responsibilities to sericulture may explain why cytology seems to have played second fiddle to Mendelian genetics in silkworm science, and may lead us toward an answer to the question of what good the study of this creature served, and to whom.

Under the tutelage of Ishikawa, who worked with August Weismann (1834–1914), Toyama researched the developmental history of the silkworm spermatozoa at the Zoological Institute of the Agricultural College of the Tokyo Imperial University. He explored "the most interesting question in the development of genital cells, namely: the reduction of the chromosomes."[110] The study compared the cell division processes of "Verson's cell" in the silkworm's testicular follicle with those of other follicular cells known to produce spermatozoa. While Toyama found that Verson's cell generated structural support cells rather than reproductive cells, his

108 Toyama Kametarō, ''On the Spermatogenesis of the Silk-Worm,'' *Bulletin of the College of Agriculture, Tokyo Imperial University* 2, no. 3 (1894): 125–157. Toyama graduated in 1892 and submitted this publication in December 1893. The data were also published in "Preliminary Note on the Spermatogenesis of Bombyx mori, L," *Zoologischer Anzeiger* 17, no. 438 (1894): 20–24.

109 Toyama, "On the Spermatogenesis of the Silk-Worm." Toyama was careful to refrain from using general terms, opting instead to use simple yet descriptive expressions used by Ishikawa, Hertwig, and vom Rath, who had worked on spermatogenesis in other organisms (pp. 127–128).

110 Ibid., p. 125.

comparative methodology using cellular staining required him to also identify the four stages of spermatogenesis in the silkworm: the formative, growing, ripening, and metamorphosis stages.[111]

Toyama's observations of the chromosomal movements within these reproductive cells suggest how he might have been aware of the association between chromosomal reduction and hereditary patterns. At each stage, Toyama described the shape of the nucleus and, therefore, the nucleolus and the chromosomes. He observed the movement of and changes to the chromosomes through cell division, and counted up to 28 chromosomes in the germ cells of the "formative" stage. In the "growing" stage, these germ cells enlarged, and Toyama observed marked changes in their nuclei. He followed the changes and movement of chromatin and chromosomes as they prepared for division. The "ripening" stage involved two successive divisions that produced four cells. In the "first reducing division," Toyama recorded 28 chromosomes in each cell before and after division. In his account of the second cellular division, Toyama claimed to have observed 14 chromosomes per cell, although the accuracy of this is questionable even though he showed that last, during the stage of metamorphosis, these four cells changed into spermatozoa without dividing.[112] These results seemed to corroborate or fine-tune the findings of Enrico Verson, who mistook chromosomes for a nucleolus during germ-cell division.[113]

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[111] Ibid. Toyama named "Verson's cell" after Enrico Verson, the director of Stazione Bacologica Sperimentale in Padua, Italy, who had published two papers on spermatogenesis in 1889. Toyama derived the English terms for the stages in spermatogenesis from the German research context: *Keimzone*, *Waschsthumsperiode*, *Reifungsperiode*, and *Umwandlungsperiode*.

[112] Toyama's cytologic study requires further scrutiny. Contemporary karyotype and gene-mapping studies of *B. mori* confirm 28 haploid chromosomes. See Yuji Yasukochi, "A Dense Genetic Map of the Silkworm, Bombyx mori, Covering All Chromosomes Based on 1018 Molecular Markers," *Genetics* 150, no. 4 (December 1, 1998): 1513–1525; Atsuo Yoshido et al., "The Bombyx mori Karyotype and the Assignment of Linkage Groups," *Genetics* 170, no. 2 (June 1, 2005): 675–685.

[113] Toyama, ''On the Spermatogenesis of the Silk-Worm,'' pp. 131–146. "First reducing division" is Toyama's reference to Weismann.

Despite the detailed study, it was unclear how, if at all, Toyama's research agenda made any explicit connections between the heredity of traits and the chromosomal reduction in spermatogenesis, even though his teacher, Ishikawa, had published a paper on spermatogenesis in 1891. Toyama noted in English, "our researches on the spermatogenesis of Bombyx mori corresponds so exactly with the descriptions given by these authors, that it seems almost superfluous for me to publish them."[114] He seemed unconvinced of the originality of his work but exhibited a sense of duty to publish this material while indicating that he would publish an investigation into the pollen formation of *Lilium tigrinum* (tiger lily) and *Allium fistulosum* (spring onion), countering Guignard's work on *Lilium martagon* (Turk's-cap lily), in order to show that chromosome reduction occurs in both plants and animals.[115]

Two years later, as the founding principal at the Fukushima Sericultural School in 1896, Toyama shifted his gaze from down the microscope to that of a more panoptic lens looking across a multitude of silkworm varieties. Out of a multitude of pressures to enter the foreign market and perform without embarrassment first in the trade of eggs and then silk, a growing network of official institutions, schools and experiment stations, and individuals of different areas of expertise began to noticeably coalesce and corral the multitude of silkworms in Japan and beyond. This chapter surveyed how the scientific study of silkworms gained attention by the end of the nineteenth century in Japan. A consideration of the silkworm, in particular the silkworm seed as a commercially viable object and a potential life form, was a key aspect of the analysis of breeding and the formation of silkworm biology in the

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[114] Ishikawa Chiyomatsu, "Studies of Reproductive Elements. I. Spermatogenesis, Ovogenesis and Fertilization in Diaptomus," *Jour. of the Coll of Science. Imperial. Univ. Japan.* 5 (1891). In the vein of Weismann's 1891 *Essays upon Heredity and Kindred Biological Problems, vol. I.*, Toyama listed W. Flemming 1891; V. Hacker 1891; H. Henking 1890, 1893; O. Hertwig 1890; G. Platner 1886; and O. vom Rath 1892, 1893 (''On the Spermatogenesis of the Silk-Worm,'' p. 146).

[115] See also a "Preliminary Note" by Toyama, written in 1893 (published January 1894). Unfortunately, this article mistakes Toyama's last name as "Nogakushi," the word for "Master of Science." Toyama disagreed with the suggestion that plants did not undergo nuclear division, as raised in Guignard 1891.

transformative time of the early Meiji period as the idea of Japanese nationhood came to the fore. The promotion of sericulture by the Imperial family not only demonstrated the importance of silkworms to the state; the materiality and constraints presented by the silkworm and its ecological life history in relation to production and reproduction, especially as seeds, interacted with diplomatic and economic issues. The production of seeds for export gave way to the production of seeds for producing raw silk. This section of the dissertation makes apparent how the ways of understanding and appreciating the silkworm shifted toward the scientific, as Toyama's early experiments investigated the cellular mechanics of the silkworm's reproductive system.

Reform of the variegated methods of sericulture in Japan not only subjected cultivation methods to close scrutiny but also won the silkworm, in the form of egg, larvae, cocoon (and chrysalis), and moth, greater attention from a new generation of scientists. This included Toyama, who undertook his own *sanshu* charting in the spirit of the 1889 standard chart.[116] Toyama's seminal silkworm inheritance study, published in 1906 and conducted in the context of strengthening an industry in two Asian countries while enduring colonial threat, catalyzed a reorientation of the industry in Japan, where efforts to catalogue the messy diversity of silkworm breeds continued into the 1910s as silkworm parentage and production began to require new certifications to verify their provenance. Quests for control of not just the organisms and their products but also the reputation of Japan were about to give traction to the spread of a practiced Mendelism in Japan, for which Toyama would be made flag-bearer.

[116] Kiyokawa, "The Diffusion of New Technologies," 1984. Licensed parent silkworm production facilities included major silk-reeling factories, such as Katakura Industries in Nagano Prefecture, which helped popularize the use of F1 hybrid silkworms. See also Yokoyama, "The History of Sericultural Science in Relation to Industry," pp. 267–284.

CHAPTER TWO:

ROOM FOR IMPROVEMENT: THE EXPERIMENTS OF TOYAMA KAMETARO IN JAPAN AND SIAM

Tiny eggs spread out side by side on a stiff sheet of paper, adhered where their mother deposited each of them. Some darken with the color of fertilization success as an embryonic larva grows. Some turn translucent, empty and uninhabited. In the early springtime, cued by the warmth of the sun or a kerosene heater, the gi-san, or "ant silkworms," venture hatch from their overwintering states. They resemble tiny picnic ants and crawl with the awkwardness of a newborn, exploring around and stepping over one another in search of something, a clue, a scent of why they exist. The sericulturist charged with their passage to the world performs the act of hakitate, using a feather to brush the gi-san gently off the card stock to a bamboo tray that contains both their feed and litter of leaves. The larvae begin to feast, mandible to mulberry. If their humans are kind enough to bother, the mulberry leaves are shredded so as to help the gi-san find an exposed leaf edge to latch onto. To keep the tiny larvae from drying out, two dampened cloths are laid on either side of the litter, keeping the air humid and yet aerated enough to ward the worms to the of their next instar.[1]

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In mid-April of 1900, about 200 silk men took pause from their mulberry fields, silkworm nurseries, filature and reeling factories, and storerooms to gather in Tokyo. Leaders, experts, and practitioners of the silk industry descended from the surrounding

[1] Instars are the developmental stages of insects.

areas of Nagano, Gunma, Fukushima, Saitama, Kanagawa, Chiba, and Ibaraki prefectures, and Tokyo, to exchange information about the state of their craft. At this ninth general meeting of the Sericultural Association of Japan, many discussions reflected a tone of urgency to accommodate the growing numbers of silk producers who sought higher yields of thread reeled from silk cocoons.[2] The mixed audience that filled the meeting room consisted of producers, tradesmen, scientists, and others attired in conventional Japanese style or Western wear. Despite their differences in dress, background, and professions, these men shared the same fabric of concern: improving the business of silk and improving the silkworm itself.

This chapter shows how conceptualizations of Japanese national identity and science grew alongside each other. This was by no means harmonious. For instance, people had different strategies for enhancing silk production at the turn of the twentieth century. On April 16th of the Sericultural Association gathering, the scientist Toyama Kametaro (1867–1918) walked up to the front of the meeting room and lectured that producers had been blindsided by appeals for increasing quantity or volume of silk in lieu of attention to quality (see Figure 5). Of the various presentations given at that meeting, the monthly *Bulletin of the Sericultural Association of Japan* (Dainihon Sanshi Kaihō) chose to reprint the manuscript of Toyama's talk on 100 years of silkworm varieties in Japan.[3]

The problem that Toyama explained hinged partly on the notion of *kairyō*, or "improvement," which individuals could interpret and act on independently. Larvae, cocoons, eggs, and silk – the living and the inanimate – represented improvable material things in sericulture and the silk industry. Silk, though a seemingly simple thing, has a number of "improvable" features, including the length of a single silk

[2] Held at the Agricultural Society of Japan meeting hall.
[3] Toyama Kametarō, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui," *Dainihon Sanshi Kaihō* 9, no. 7 (1900): 1–9.

filament drawn from a cocoon, filament diameter, strength, luster, and cocoon color. People involved with silkworm husbandry and silk factory workers, in addition to the silkworms themselves, shared disjointed responsibilities for the biological and technological mediation of the resulting qualities of all the features of silk.

Figure 5. Toyama Kametaro (c. 1912–1913). Courtesy of National Institute of Agrobiological Science, Japan.

The operative word under question, *kairyō*, did not always correspond to linear progress or betterment of silk characteristics and the living agents that contribute to those characteristics. *Kairyō* also related to the sentiment of making changes rather than "improvements," for instance, for the purposes of product distinction, brand distinction, or quality distinction. Buyers of silkworm seeds (fertilized eggs), cocoons, raw silk for wholesale, and foreign buyers could all exercise an act of selection by contract or purchase, which suggests how personal preference could, in combination with the different adjustments of techniques and details in raw-silk production processes, thrust the direction of so-called improvement of the silkworm into multiple directions.[4] As the objectives of *kairyō* gained more distinction, this theme penetrated many different areas of everyday life in sericulture, from formal to informal education about the practical aspects of silkworm-rearing to the professional study and research of silkworms that would inject a supply of experts into a growing network of experiment stations.

The tasks of *kairyō* depended especially on how one would recognize "the silkworm." The meeting in 1900 served as a crucible in which mundane, practical questions about the silkworm discussed by sericulturists began to rearticulate in a framework reflecting new biological thought within the existing vernacular of silkworms and their culture. Ideas about the collective of "the silkworm," resulting from a diverse series of ad-hoc decisions about improvement, would receive scrutiny in this framework. Growing numbers of sericulturists and efforts to improve silkworm breeds through cross-breeding and other techniques had contributed to an elusive grasp of improvement that accompanied heightened production in the number of cocoons. Recognizing this futility, Toyama had stepped in to hold the reflexive mirror up to the Sericultural Association: "Unfortunately, we are troubled by a significant lack of academic research regarding evidence for the actuality that which we call *shurui* [variety]. To this end, many say do this or do that, but those are but mere opinions. Without stopping to understand the actual matter [of variety], much confusion will remain."[5]

[4] Pierre Bourdieu. *Distinction: A Social Critique of the Judgment of Taste* (Cambridge, MA: Harvard University Press, 1984). Determining exactly why certain kinds of silk were preferred over others would require a larger sociological study that would complement the history of the science and technology of silk production. Bourdieu, for example, describes how one's position in society determines "taste." By limiting the scope of analysis to Japan, the present study does not yet examine the driving factors of fashion, style, and other developments that motivated the very particular decisions about the purchase of raw silk. The fourth chapter of this study will, however, discuss the development of grades and classifications for raw silk in the United States and how the testing mechanisms extended to Japan during the mid-1920s.

[5] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui," p. 1.

Toyama's two analyses in 1900 provide us with insight into the biological and technological contributions of sericulture (silkworm and cocoon production) and raw-silk processing (filature and reeling) to the deliberations surrounding the notion of improvement. Toyama's critiques of sericulture and silk business-as-usual, detailed through his reprinted speeches, provide a window to understanding the scientist's thoughts about inheritance in 1900. These critiques gave Toyama a broader understanding of the circumstances that later allowed him to conduct pioneering cross-hybridization experiments and contribute to a foundational moment in the formation of a genetic science in Japan. Toyama's instigation of a newly articulated biological rationality began to emerge from these exercises of comparison. From this perspective situated within a domestic practice, Toyama weighed the different means to achieve *kairyō* in the context of the pressures of international trade. This perspective involved an appreciation of precision and past that enabled Japanese sericulturists to shift their thoughts about their contributions to silkworm histories.

Disentanglement of silkworm varieties and their methods of production, metaphorically gummed together by various interpretations of *kairyō,* would eventually, as this chapter shows, allow scientists to view or create greater distinctions among the different *shurui*, or kinds, of silkworms.[6] Such articulation of difference in the name of improvement would begin to signify a rupture in sericulture practices toward changes that would redefine "the silkworm" and the bases underlying the production of silk in Japan.[7] Toyama's initial examination of definitional questions

[6] The written form of the word *shurui* is composed of two characters: *shu*, meaning sort, kind, type, class, or category, and, on a biological level, a species or variety; and *rui,* which bears an extremely broad meaning that encompasses sort, kind, variety, class, genus, type, and order. Of the formal terms of biological classification in Japanese, only *shu* is used to refer explicitly to the Linnaean "species."
[7] Takashi Fujitani, *Splendid Monarchy: Power and Pageantry in Modern Japan* (Berkeley: University of California Press, 1996). Fujitani analyzes "historical rupture" and the moment of "imperial institution's new emergence in modern Japan." This dissertation corrals examination of the role of science and technology, as understood through sericulture and the silk industry, to examine similar change in the collective understanding of nationhood.

about *shurui* and *kairyō* of silkworms sets the stage for this chapter, which covers the first dozen years of the twentieth century. Analysis of Toyama's public discussions, reprinted in major trade journals, and silkworm inheritance experiments that took place in both the kingdom of Siam and Japan, will demonstrate why and how a general enthusiasm for enhancing greater yields of raw silk, considered necessary for survival and success in the global silk market, began to reflect a more explicitly biological consciousness.

1. Cocoons as Proxy for Past and Present

Toyama's springtime call introduced the notion of quantification as a means to understanding *shurui*. He sought to make tangible a temporal understanding of how the borders and limits of the characteristics of distinct silkworm types had changed by measuring and collecting information about larvae, their cocoons, and thread. By gathering "as many truths as possible" about the "original state" of silkworms and extant *shurui* of silkworms in Japan, Toyama wanted to urge Meiji-period producers and growers to stop "debating in the dark" by showing them what went wrong and when, in order to help them make better-informed decisions.[8]

Displaying a photograph illustrating sixteen representative cocoon specimens at the 1900 meeting, Toyama described the characteristics of the silkworms that sericulturists had reared over a 50-year time span to show how little progress had been made. Toyama presented a systematic comparison of different kinds of silkworms between contemporary silkworms and those from the beginning of the Hōreki period (1751–1764), about 100 years preceding the Meiji period.[9] The actual comparison depended on using preserved cocoons as a proxy for once-living silkworms, and from

[8] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui."
[9] Ibid., p. 8. Toyama acknowledged the assistance of Nakamura Saheiji of Date County, Fukushima Prefecture, Satō of Sakuro village, and Asano Tokumi, Yokoyama Kiyojiro.

these, their shapes, dry weight, silk-thread density, and rearing records of silkworm varieties could be quantified through 1803.[10] Toyama eyed the comparison as a means to convince his audience that their current concern with a single characteristic, cocoon size, did not sit upon a firm foundation (see Figure 6).

Toyama walked his listeners methodically through all of the different characteristics he had measured of the different silkworm cocoons. While different cocoon shapes went in and out of fashion between the late 1700s and early 1800s, the silk content of individual cocoons did not vary much.[11] Cocoons from the older period remained smaller than those produced around 1900, Toyama explained, pointing out, “these cocoons are remarkably small, but they actually have some heft.”[12] In fact, he found that after the 1780s, cocoon length and width measurements increased gradually without much increase in weight.[13] Similarly, Toyama found little quantitative difference in measures of fiber thickness between the samples of silk thread from the mid-1800s and 1900. Cross sections of each thread, a triangular fusion of two strands that come from the two spinnerets of the silkworm, showed that silk threads ranged from 0.02 to 0.03 millimeters in width.

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[10] The year is also the end of the Kyōwa period.

[11] Toyama, “Hyakunen Izen ni Okeru Honpō Kaiko no Shurui.” First, he discussed two general shapes of cocoon. The first shape resembled the contemporary *koishimaru* variety, short in length and slightly cinched in the middle, prevalent during the Hōreki period. The second shape was slightly larger and gained popularity during the An’ei period (1772–1781), but was still smaller than the contemporary ones of 1900. Longer cocoons then came into increasing fashion during the Tenmei (1781–1789) and Kansei (1789–1801) periods.

[12] Toyama based his measurement of 1 gram as 2 *fun,* 6 *rin,* and 6 *mo.* Toyama, 1900. A useful list of Japanese weights and measures appears in Mikiso Hane, *Peasants, Rebels, and Outcastes: The Underside of Modern Japan* (New York: Pantheon, 1982).

[13] Toyama, “Hyakunen Izen ni Okeru Honpō Kaiko no Shurui.” Since a good number of the preserved cocoons had holes in them, and an emerging silkworm moth had to melt through what would otherwise be a single long strand of silk in order to emerge into the open, he had to take the dry weights of the cocoons after cleaning their insides of any remnants of the silkworm chrysalis in order to accurately measure the amount of silk thread samples.

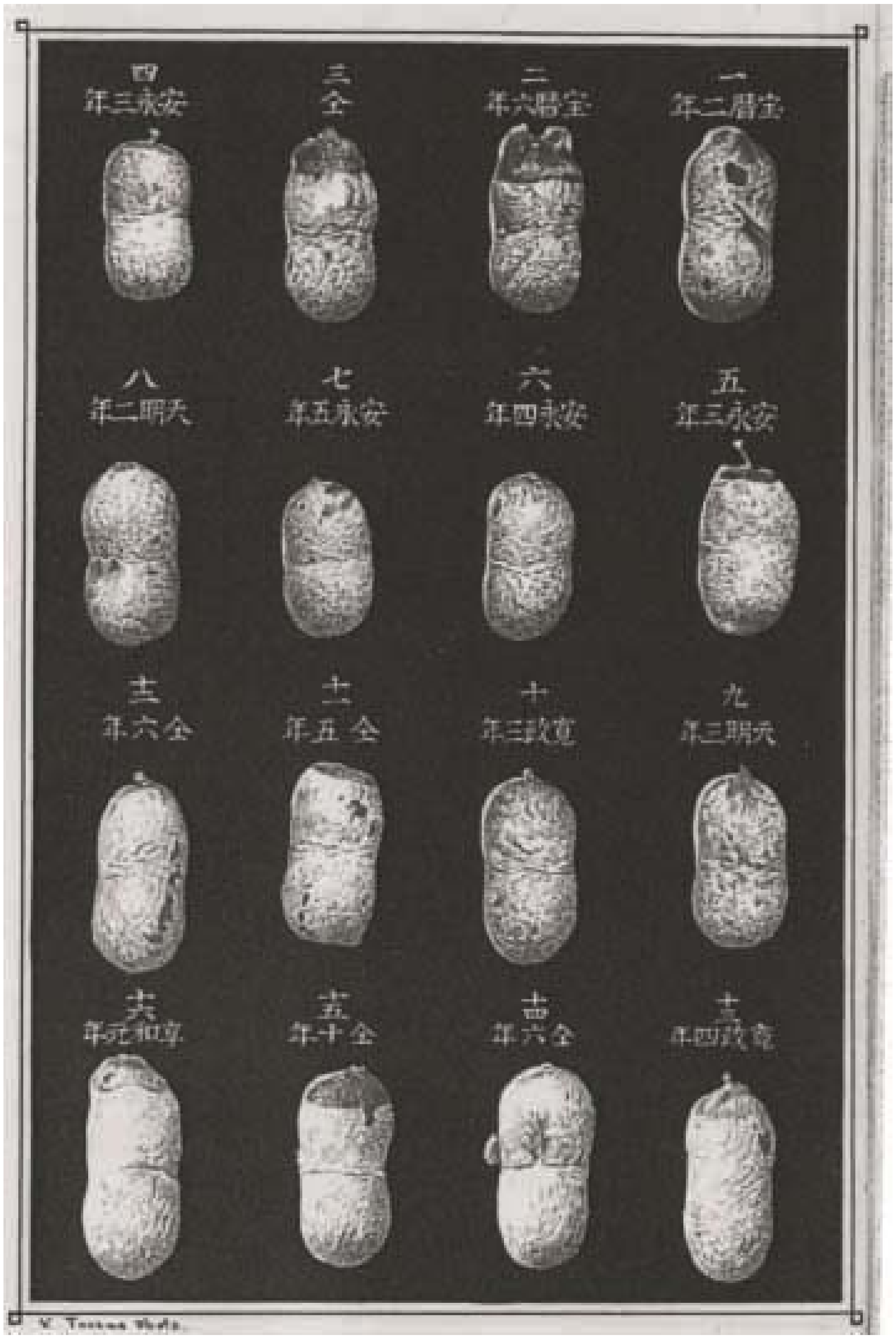

Figure 6. Photograph by Toyama, displaying silkworm cocoon specimens dating from the mid-1700s. The first two rows resemble the *Koishimaru* shape, small and slightly cinched in the middle. The bottom two rows reflect how cocoons with longer appearances trended in the early 1800s, similar to the long and thin *Hakuryū* variety used in contemporary Nagano Prefecture, according to Toyama, who explained that the quantity of its silk had not degraded over a half-century. Reproduced from Toyama Kametaro, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui," *Dainihon Sanshi Kaihō* 9, no. 7 (1900): 1–9, frontispiece.

The dry weight of cocoons provided a final piece of information. After the 1830s, silkworm varieties developed noticeably in size, meaning they "improved" insofar as the cocoon lengths and widths grew to just over one *sun* (roughly three centimeters) and four to six *bu* (1.2–1.8 cm), respectively.[14] Among the older cocoons, the dry weights of the cocoons did not show distinctive differences regardless of whether the varieties came from an older period or exhibited round or long cocoon shapes.[15] The problem resided in the comparison of the different varieties: Toyama could not find a major distinction between the cocoon weights of samples of the past and the present. This did not necessarily bode well, Toyama explained:

> As you can see, *shurui* from 100 years ago were smaller, but the thread weight was greater and they were also easy to rear. They are exceedingly good compared to the present. We can believe that some very good things came out during the Tenpō period. Those declined bit by bit, and by the Meiji period, [the quality of] *shurui* dropped dramatically. My survey may not be sufficient, but in any case, we cannot get into our hands cocoons today like the ones from the Tenpō period . . . Meiji period *shurui* are advanced with respect to size compared to those from 100 years ago. However, with regard to thread weight and thickness, there is no difference between [cocoons] of the past and present. Depending on what you look at, there are some things today that seem to have worsened, especially if you compare them to foreign *shurui*. For example, if you compare with the French Var or Alps *shurui*, the thread weight from the Tenpō era varieties are not inferior to the finest foreign varieties.[16]

Although Meiji-period silkworm experiment stations had maintained various records about silkworms and their cocoons, Toyama criticized the relative myopia that came with the territory of "improvement." While growing concerns about current-day

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[14] Ibid. During the period analyzed by Toyama, specifically, after the Bunka (1804–1818) and Bunsei (1818–1830) periods, thread or cocoon dry weight reached 0.19 grams during the latter half of the nineteenth century. In the Tenpo period (1830–1844), the average grew by 0.2 grams or more, with the largest cocoons exceeding 0.3 grams in dry weight. 1 *sun* =30.30 mm or 10 *bu.*
[15] Ibid. Investigating qualities of these silkworm larvae posed greater difficulty for Toyama. Toyama tracked down the houses where sericulturists would have been rearing these silkworms. He noted for his audience that he did not notice any concerns in the records he found, which included information such as the dates of silkworm eggs hatching, timing of cocoon spinning, and the weights of larvae or moths.
[16] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui," pp. 6–7.

silkworms had led to the collection of silkworm information in the contemporary Meiji period, the qualities of silkworms from Japan's past had become intangible. It was only now with the re-orientation of questions touching upon the quantified knowledge of silkworms, posed by Toyama's pursuit of "what is a *shurui*," that the information could be put into service for the comparison of cocoon qualities over time. Toyama's comparative presentation helped reveal an instance in which Japanese silk of the *past* could exceed some of the quality thought to be that of *present-day* European silk, which surprised him. "That is a truth even we were truly surprised by," he reflected. Sharing this revelation served to emphasize that Japanese sericulturists had a long-standing ability endemic to Japan. Its mention helped create a moment in which a notion of a Japanese past, despite the chaos of the Meiji period, was once more tangible and seen as worth returning to, in response to overcoming the "degeneration" (*taika)* and inferiority that Toyama observed of silkworm *shurui* produced after the Meiji period. By highlighting that the Japanese had once been able to produce silk cocoons that were better than the Europeans, Toyama created a just-so Japanese past worth returning to.

This maneuver to implant remembrance of an "original" past characterized by inherent, recognizably Japanese wisdom and ability, gestures toward an important question: How did "Japan" or "Japanese" acquire a meaning that both transcended and displaced existing identities of people in silkworm culture? Forceful geographical redefinitions may seem the most obvious ways to see "Japan" in a unified sense, but it wasn't only an act of expansion that mattered to the mental re-envisioning of Japan as something with a distinctive past that could lay over the present so easily.[17] Stephen

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[17] Michael Weiner, "Invention of Identity in Pre-war Japan," in *The Construction of Racial Identities in China and Japan: Historical and Contemporary Perspectives,* ed. Frank Dikötter, 96–117. (Honolulu: University of Hawai'i Press, 1997), p. 112. Andrew Gordon, *A Modern History of Japan: From Tokugawa Times to the Present* (New York: Oxford University Press, 2003) p. 74. Meiji thinkers, having observed how Western diplomats justified colonization as part of their civilizing missions in a time when social Darwinist thought was common, had promoted border expansions that incorporated

Vlastos argues that Japanese rural villages have recently come to be seen as "a reservoir of national culture," in which Japan's core values and habits are preserved and reproduced.[18] Then again, the creation of Japan as a nation-state not only penetrated these vestiges of "national culture," but the idea of the nation had to link the rural and urban together as well. In his historical ethnography of the modern Japanese regime's folklore, Takashi Fujitani argues that the "purposeful fabrication" of the modern monarchy was built upon things such as cities, shrines, monuments, buildings, monuments, and pageants.[19]

While the evocation of a wiser and skilled past fully in touch with the ways of the worm occupies a different valence than that of imperial pomp and circumstance, both operate in ways that engender a communal response to the prompt. In this case, Toyama wanted sericulturists to pull themselves up. However, what gets pulled up are also ties to an idealized past, which reminds us of the reach toward the past in Susan Burns's account of the discourse of *kokugaku* (the study of our country) among Tokugawa-era scholars who reified founding myths of an authentic Japanese language. These in turn provided a vocabulary and set of epistemological strategies upon which ideas of Japanese identity and modern nationalism could develop in the late nineteenth century. Such developments of community had to span the purported nation and transcend the local. Toyama's involvement in the nationalization of sericultural practices turns out to have been centuries in the making, if we consider his long reach into the idealized history of this practice in Japan, and thus contributed to ongoing social homogenization processes that characterized the formation of an imagined

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the northern island of Ezo as Hokkaido in 1869, and the Ryukyu Islands as Okinawa in 1879. These far reaches were not immediately named "Japan," in order to stave off conflict with China.

[18] Stephen Vlastos, ed., *Mirror of Modernity: Invented Traditions of Modern Japan* (Berkeley: University of California Press, 1998), p. 80.

[19] Fujitani, *Splendid Monarchy*, p. 24.

nation. This case also illuminates how a foundation for the execution of the *tōitsu* movement in sericulture could lodge even more solidly into place later, by 1910.

a. Toward a Strategy for Selection

Planting a proud moment about Japan's not-too-distant sericultural past within the imaginations of sericulturists allowed Toyama to raise awareness of what he called the "degeneration" (*taika*) and inferiority of hastily made cocoons during the Meji period. "If you look at the history of Japan's silkworm [varieties], the sericulturists (*sangyōka*) of the nation of Japan have been concentrating their energy on the shape of the cocoons . . . This indicates that selection was taking place plenty, but [beyond that], not a bit of selection was taking place."[20] Toyama recognized that the source of inferiority didn't hinge solely on silkworms' inherent properties. He worked up, against the cascading blame-shift that often placed blame on poor silkworm seeds, or the variety embodied in the fertilized eggs, to point out that the silk industrialists' push for more silk put silkworm-egg producers "in the service of the superficial over any endeavor to address the characteristics of the thread."[21] Toyama stressed how this cognizance of change in silk quality over the course of the Meiji period required a response. For any remarkable change to take place, however, people would first need to give keen attention to silkworm varieties and glean sufficient facts about them before benefiting from any "improvement."

From Toyama's point of view, rather than try and return things back to a previous state, practitioners of the silkworm had to stop quibbling over what they called a *shurui*. The defining matters of a variety had to come from confidence based on scientific, numeric facts. Taking measurements for each *shurui* in order to distinguish between them would allow Toyama and others to gauge the precise values

[20] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui," p. 8.
[21] Ibid.

required to improve.[22] "Taking this [recognition of the focus on the superficial] as a departure, looking at the state of silkworm varieties in our country after the Meiji period, I have observed that Japan's varieties have markedly degenerated. I have witnessed that the cocoon characteristics and larval characteristics have become inferior."[23] Toyama initially faulted the silkworm-egg producers for making entrepreneurial decisions to promote only silk cocoon size or to haphazardly try to brand personal distinction in the market through the production of unique silkworm *shurui*, for "it had become an aim of egg producers at the time to offer collections of uncommon varieties." Egg producers had managed to stand apart from one another based on their abilities to offer sericulturists choices about the silkworms they would breed. The issues of quality would not be left to the egg producers alone, but rather, Toyama felt that the responsibility bore upon the whole industry: ". . . we can say that [breeders] took fixed varieties and crossed this with that, and along the way destroyed the *shurui*, and [we can also say] this situation came about because they blundered their method of selection as well. It does not do any good to just leave it at that. I think we have to face this together."[24] This problem of silk workmanship hovered at the level of the nation. Toyama's call represents a kind of response to this sort of conundrum, an answer that had to have meaning at the level of the nation.

Toyama's rationale for scolding silkworm breeders came from recognition of the long-term problems that accompanied a singular and narrow approach to selection.

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[22] It is useful to note here that the most predictable crosses come from combining two consistent strains. Strains with unknown amounts of variation pose hurdles to breeders interested in carrying out selection. Silkworm breeders would have to pay more attention to the problem of using more than a single character such as cocoon size to identify breeding groups.

[23] Toyama's mention of degeneration to explain the inadequacy of how brand-oriented breeders merely selected cocoons for their size suggests a Darwinian undertone in his understanding of the natural world and the biological. This should not surprise us, given that Toyama's university teachers included Ishikawa Chiyomatsu, who worked closely with Edward Sylvester Morse. A discussion of Ishikawa appears in Gerard Clinton Godart, *Darwin in Japan: Evolutionary Theory and Japan's Modernity (1820–1970)* (Ph.D. diss., University of Chicago, 2009).

[24] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui."

In addition to his interest in redirecting the industry's methods of selection, Toyama made the critical point that such methods should be scientifically informed. Toyama never explicitly uttered the word "evolution," but his pattern of rationality reflected a basic engagement with biological thought that allowed him to explicitly question and investigate a fundamental question: What is a silkworm variety?

With many different kinds of silkworms, pinpointing what distinguished a silkworm from others on a level of categorical difference posed a challenge. For one thing, the meanings of the Japanese term *shurui* can range from kind, sort, variety, and class to "a species," to describing a form, "a type," to describing a characteristic, a "nature." To determine what details would be necessary to discern any group of distinction, or *shurui*, however, would require a recognition of all the different characteristics of silkworms. This interest informed Toyama's orientation toward the biology of silkworms that he manifested in his public lecture. To Toyama, answering the question of *shurui* required an examination of not only the silkworm's cocoon but also characteristics and behaviors of the larvae, the moth, the eggs, and perhaps even the pupae, nestled inside its silken swath. His effort to obtain and study silkworms and cocoons from previous generations could lend rhetorical power to a reading of Japanese silkworms to show how continuous generations of selection for larger cocoon size conflicted with the intentions of humans. While an increase in overall quality once accompanied the growth of silk cocoon size, the matter of thread quality sat second in concern as breeders' familiarity or concern with the entire process of silk production diluted amidst the sericulture boom in the early Meiji period. This made the matter of poor quality unavoidable by 1900.

Without comprehending the multitude of *shurui* in the contemporary period, Toyama implied, ongoing practices would spoil the accomplishments of egg producers who still were stewards of (for the most part) “unspoiled” true-breeding varieties.[25] Toyama ended his lecture by recommending that local silkworm growers resign themselves to a strategy of silkworm-variety improvement based on tests and experiments carried out by experts like himself at experiment stations and schools. His interest in quantifying the characteristics of cocoons and the behaviors of larvae indicate an understanding of the variation within a variety; his study of silkworms also suggests that he wanted to know more about how new varieties changed and how they become distinct *shurui*, if at all. Attention to the gradual changes concerning the entirety of the silkworm, in addition to the cocoon, gave him hope that he could detect this kind of change, the creation of a kind due to the human hand of selection.[26] In short, the production of dependable figures gave Toyama a way to compare among Japanese varieties as well as between those of different countries, over time. Quantification of the silkworm would make it possible for the scientist to tell one *shurui* from another and to consistently use silkworms strains with known ranges of variation for a characteristic such as cocoon weight, in order to gauge the objective values for improvement.

b. Beyond Quantification

Toyama’s quantification of silkworm types, or *shurui,* played a critical role in his attempt to objectively explain Japan’s inferiority to Europe. Yet, his discussion of the source of inferiority did not hinge solely on the silkworms’ inherent properties. His views about this so-called inferiority chided but stopped short of scapegoating silkworm-egg producers exclusively. Quantifying *shurui* allowed him to remark on the skill and willpower of the Japanese by raising a larger, holistic range of issues, which, in his view, demanded cooperation across different members of the industry. In

[25] Ibid.
[26] Ibid.

October 1900, Toyama presented a comparison of European and Japanese silkworms to the Sericultural Association. Examining Japanese, French, and Italian rearing methods, size of cocoons, shapes, color and luster, thread lengths, and strength and elasticity, he concluded that Japanese silk quality was clearly inferior to French and Italian silk because Japan had comparatively excessive numbers of filaturists and factories that introduced poor silk quality control.

Toyama emphasized that the "young" technologies of filature needed to mature in Japan and referred to growing appeals for "*ittei*," a word used to describe the state of settlement, or constancy. In the context of sericulture, it described the need to stabilize the range of small-scale variation in the cocoon characteristics of specific silkworm types. Toyama stressed, "The application of scientific principles speak truth to *kairyō*," and new reeling technologies ought to be deployed unapologetically. "To have any hope of making [extremely] excellent *shurui* by *ittei*, we have to have an excellent plan to allow for the practice of [consensus]. On top of that, the variation (*henyi*) of living things is a principle of nature (*shizen no ri*)." The relationship between these "principles" and the spirit of *kairyō* is captured by an understanding of the degree of instability that characterized the features of raw silk threads, such as weight, length, or size among cocoons and their fibers.[27] The differences in features, although very small, could indicate the deficiencies of silk.

Toyama's use of the word *henyi* refers to the natural variation found among individuals composing a species, between varieties of the same species, and definitely within a single variety. To Toyama, variation was a rule, not the exception. In the October 1900 comparison, he examined the Ascoli strain of silkworms from Italy and found that they ranged in size.[28]

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[27] Toyama Kametarō, "The Relationship between Silkworm Varieties and Silk Reeling Methods," *Dainihon Sanshi Kaihō*. 9, no. 100 (1900): 42–52.

[28] Ibid. "For example, it goes without saying that something born from the same parent is not completely the same as the parent itself. A cocoon of the Ascoli variety [*shu*] that grows large has a

> Similarly, of the *shurui* produced in our country, there is remarkably different variation in the thread thicknesses from [larvae] born from the same moths. What is more, because of the inherent variation due to the outside world and various artificial (*jinyi*) selection, assuming even if *shurui* were standardized to one and the same, in several years it will not be possible to maintain the same situation.[29]

Toyama believed that while biological variation in silkworms, their varying responses to environment (and human handling) during metamorphosis, and different degrees of human intervention during each step in the transformation of cocoons into silk skeins all contributed to the result of the final product, addressing the last issue could yield results most immediately. Yet, the issue of human "ability" that Toyama felt important resided less in the physical realm, pertaining to the skill of humans or a combination of human and machine, than with a sense of will or commitment. The act of determining why silk didn't exhibit uniform or even quality could have suggested a biological problem. Despite his previous position promoting more careful and thoughtful silkworm selection in order to address the fraught qualities of cocoons, Toyama occupied a seemingly contradictory space wherein he seriously and passionately advocated for the improvement – *kairyō* – of filature and reeling, as well as that of the human spirit.

Toyama acknowledged that some people believed that the nonuniformity of characteristics within a strain of silkworms could produce variable kinds of cocoons that would then trouble silk-yarn reeling. Indeed, not even the cocoons of Italian and French raw silk could fully avoid the troubles stemming from shoddy production that introduced variation in cocoons. But, Toyama noted, the Italians and French were still able to take this raw material and reel "excellent" raw silk. He believed that human

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length of 37.3 millimeters and width of 17.6 millimeters and produced 760 meters of thread. A large cocoon of the Ascoli variety [*shu*] had a length of 37.3 millimeters and width of 17.6 millimeters and produced 760 meters of thread. A small one had a length of 33 millimeters and a width of 18 millimeters and a total thread length of 653 meters."

[29] Toyama, "The Relationship between Silkworm Varieties and Silk Reeling Methods."

attentiveness and ability – a sense of will or commitment – greatly mediated the resulting quality in addition to any role played by the properties inherent in silkworms. Toyama navigated these tensions between silkworm *shurui* and human skill by pointing out that unlike factory filature and reeling, the more matured sericultural craft, conducted largely by dedicated producers, would require more theoretical, rather than immediate and pragmatic practical improvements to both skill and technology. The regrettable circumstances facing reeled silk yarn came from well-articulated and known problems about the specific relationships among hot water, *shurui*, machines, and reeled silk in the production of reeled silk, Toyama explained. Without sufficient desire to disengage from this tendency to scorn egg producers, measures for standardizing a silkworm variety would just go to waste, he warned. He predicted that the development of any so-called excellent silkworm varieties able to overcome the known problems of heterogeneity or variation would require serious consensus and planning among sericulturists and egg producers.[30]

Toyama's boldness is worth noting, for its tone of confidence and authority bordered on disrespect of the two existing giants in the field of sericulture science, one of whom was his own advisor, Sasaki Chujiro, and the elder Sasaki Chojun. The paradigm for silk production in Japan had centered around the pathogen, not variation, meaning different kinds of experts indebted to the work of Pasteur, who made a profound discovery of a protozoan pathogen causing *pébrine* disease. The Sasakis enjoyed positions of authority that hinge on finessing a system of egg production to ensure the manufacture of healthy silkworm seeds. Toyama's more recent emergence as a sericulture spokesperson and his suggestions for a practical strategy for achieving *kairyō* set all eyes on the filature and reeling processes and the need for machine-based solutions. At the same time, he also brought attention to biological questions

[30] Ibid.

about the governance of inheritance that would begin to lead Japan's sericulturists onto a new path for success.

Toyama's positioning made clear that the practice of silkworm selection had to take into account not just the presence or absence of disease; it had to also take into account a new body of home-grown expert advice that emerged from an increasingly refined understanding of inheritance stemming from a reflection of Japan's own sericultural know-how and its apparent degradation during Meiji capitalism.[31] Many sources of inconsistent silk-thread qualities could be identified, depending on which way one looked up or down the blame cascade in relation to the silkworm's life cycle and the transformation of cocoons to raw-silk hanks. Solutions to these problems attracted biological inquiries as well as scrutiny of Japanese skill and ability. Identifying and characterizing a variety, or *shurui*, and the ability to sustain stability among a silkworm cohort, or to achieve *ittei*, numbered among the first steps toward recognizing a need for the later management of silkworm diversity by the end of the Meiji period.

Toyama's efforts to persuade producers to wait for and trust scientific experts did not come from a deference to foreign scientific opinion. It rather emerged from a set of knowledge that formed in response to a comparison of imagined and real archetypes that required the measurement of silkworm and cocoon *shurui*. These measurements, in turn, would help Toyama and other sericulture scientists gauge the precise extents to which various Japanese silkworms warranted improvement, and in turn, place responsibility upon Toyama as a technical advisor to the government's interests in sericulture and industry.

[31] For more on Meiji capitalism, see John H. Sagers, *Origins of Japanese Wealth and Power Reconciling Confucianism and Capitalism, 1830–1885* (New York: Palgrave Macmillan, 2006).

c. Balance of Categories: Shurui and Standards

The question of what counted as a *shurui* still presented problems. Toyama's critiques about the different sources of "variation" that could be woven into a silk product and his seemingly paradoxical recommendations to producers in 1900 that they disabuse themselves of the singular goal to enhance cocoon size together suggest how questions often returned to those about the biological principles that govern the nature of the silkworm, couched repeatedly in terms of *kairyō*. Toyama focused on urging technological improvement in most of his writings of 1900; he also provided great insight into the limits of biological leveraging in the game of improvement. Measurements of the characteristics of silkworms and especially their cocoons addressed Toyama's qualms about what counted as a *shurui*; however, out of this process emerged even more questions pertaining to the categorization of silkworms. The fine lines between completely unique *shurui* and *henyi,* or the range of variation in particular qualities of a particular type, were prone to blurring. This propensity for confusion made it all the more urgent to understand variation thoroughly. Variation was not just a theoretical issue left to scientific minds to study; it occupied the root of practical problems that went beyond the physical practicalities of filature and reeling, as Toyama had noted earlier, to biological elements.

The practical issue concerning biological variation in sericulture at the time boiled down to one of a balancing act of categories. For instance, Toyama pointed out that among one so-called *shurui* of silkworms at the time, cocoon silk thread densities ranged from two to just over three deniers. If someone paid attention only to thread quality, that tiny difference could have misled one to perceive them as possibly different *shurui*. Toyama anticipated that such a situation could arise routinely, for different silkworm-selection methods in localities with different regional climates and seasons would demonstrate marked changes in cocoon or silk fiber qualities. One *shurui*, in other words, could have very different silk cocoon appearances, whether in Japan or in Europe.

Toyama had great suspicion about whether the resolution of variation within a *shurui* across geography or among selection could be achieved through a standardization of the thread of any given kind of *shurui*. His hesitancy reflected his appeal to the businessman's mind, for ". . . whether or not *shurui* are standardized, following that rearing locations and rearing practices differ for the same *shurui*, the production of *henyi* would raise doubt about the materialization of any profit."[32]

As mentioned previously, Toyama had no problems positioning himself as an engineer, or *gishi*, who looked at every aspect of production to optimize the product and said that it behooved the industry to first address the technologies of reeling, in which the hands of many unskilled laborers continuously introduced differences in the quality of spun silk.[33] In fact, most formally trained sericulture experts were called *gishi* and were expected to work in these kinds of settings. Addressing this human–machine relationship would bring about a more rewarding change more easily than a gradual process of *ittei*, which would require much more deliberation and time, Toyama explained, having positioned himself from the inside of this profession. The discussion of the stabilization of variation within silkworm varieties thus emerged in the discourse of improvement as a counter to the discussion of the role of labor displacement by machines. Even though debates of quality frequently foisted responsibility time and again onto egg producers, the time had come for this to stop, according to Toyama, who finally noted that the American Silk Association had begun to urge the Japanese Minister of Agriculture and Commerce to draft a proposal for reform. "In other words, what is the road to produce excellent raw silk? We must make it desirable to transfer the burden that is on the shoulders of egg producers and

[32] Toyama, "The Relationship between Silkworm Varieties and Silk Reeling Methods."
[33] See Bartholomew, *Formation of Science in Japan* for a discussion of scientific workers in Japan.

sericulturists to those of the filaturists . . . the necessity of research relating to filature will become more and more ardent."[34]

d. First Crossings

In the annual reports of the Fukushima Prefecture Sericulture School, where Toyama had served as the founding headmaster between 1896 and 1900, two detailed surveys containing data about the qualities of various silkworm larvae were published in 1901 and 1902.[35] These said that it would be possible to ascertain the relative merits, or *yūretsu*, of silkworm varieties by understanding each variety's "natural disposition" with respect to larval development, mulberry consumption, and the qualities of the cocoons and silk that would be produced.[36] This survey should sound familiar, for it resembled the earlier movement to standardize sericultural practices in 1887 described in the previous chapter.[37] A detailed survey would serve as a resource for the improvement of silkworm varieties, and with data presented in a table, readers could quickly see how various silkworms stacked up against each other and thus gain a sense of *yūretsu*, an understanding of the advantages and disadvantages, or merits and demerits, of different varieties. *Yūretsu* derives its meaning from the combination of characters for "superior" and "inferior." Together, they refer to the difference between the two ends of a spectrum. This ability to quantitatively and qualitatively gauge the strengths and weaknesses of slightly similar as well as vastly different silkworm varieties was hugely important. It indicated a promising capacity to recognize and

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[34] Ibid.
[35] Toyama Kametarō, ''Kaiko no Shurui Hikaku Shiken'' [Comparative Tests of Silkworm Varieties], *Fukushima Kenritsu Sangyō Gakkō Nenpō* 3 (1901); 4 (1902).
[36] Ibid. Toyama collected information at different stages of silkworm development, such as the time it took for eggs to hatch, the weight of silkworms at each instar (per 100 larvae), and the time it took for their overall development. He also looked at various cocoon characteristics such as size and weight, cocoon thread qualities, and the amount of mulberry consumed by each variety.
[37] Kazuko Tsuchikane, "Meiji ni okeru Nihon yōsangyō no gijutsuteki dōkō to 'yōsan hyōjunhyō,'" *Nihon Joshi Daigaku Daigakuin Bungaku Kenkyūka Kiyō* 15 (2009): 29–49. Tsukchikane provides one of the most recent and thorough reviews of the Sericulture Standard Chart.

define the boundaries that would outline the categorical boxes that could represent each *sanshu* necessary for the eventual improvement of Japanese silk.

These reports presented data on twenty types of silkworms at any given time during the two-year study. Although this activity of describing and flattening the quantitative information of the silkworm constituted the normal process of silkworm standardization, the appearance of the variety *Var kakeawase* in the 1902 chart suggests a sign of growing interest in inheritance. This cross, or *kakeawase,* between an unspecified Japanese variety and a French strain, *Var*, had to have been conducted in 1901, which raises the question of why Toyama busied himself with testing a European crossbreed if sericulturists were supposed to operate under the premise of improving Japanese varieties.[38] Analyzing this cross helps make it possible to ascertain how and why genetic thinking changed in sericultural science. While Toyama worked in Fukushima, a local sericulturist, Sato Kudo, developed a new strain of silkworm based on the hybridization of a Japanese breed called *Matamukashi* and an unknown variety of silkworm directly imported from China. It has been suggested that Toyama knew of this new breed, called "*Shinamata*," which was easy to rear, matured two days earlier than *Matamukashi*, and whose silk reeled off well from its cocoons. Overall, *Shinamata* gained momentary regard as an excellent variety.[39]

Cross-breeding experiments had already long existed. Hybridization between Japanese and French silkworm moths is known to have taken place as early as 1868 in France, when Japanese silkworm eggs were once exported to Europe. These forays in

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[38] Toyama, "Kaiko no Shurui Hikaku Shiken." To compare the 20 various silkworm types, Toyama removed all eggs from cold storage on the same day, and reared all of the silkworms from the egg stage, keeping the temperature raised in order to incubate them. In addition to using an "ordinary" rearing method, Toyama and his students, mostly sons of Fukushima egg producers, had to make sure that the conditions were not the same as the outdoors.
[39] Hiratsuka Eikichi, *Silkworm Breeding*, trans. Alamelu Gopal (Rotterdam, Netherlands; Brookfield, VT: A. A. Balkema, 1999), p. 67; Moriwaki Yasuko, "Toyama Kametarō to Meijiki no Sanshigyō ni okeru Kaiko no 'Shurui Kairyō,'" *Kagaku shi Kenkyū* 49, no. 255 (2010): 163–173.

hybridization tested mainly the hardiness of the Japanese insects over anything else, for the protozoan disease *pébrine,* known for decimating silkworm nurseries, was yet to be discovered by Pasteur. By 1900, however, effecting greater control of the cocoon could be possible as disease management grew more sophisticated.[40]

Toyama returned to Tokyo in 1900 to begin his graduate work on silkworm inheritance while also serving as an instructor at the Tokyo High School of Agriculture and Forestry. His research program began that year with a parental cross between yellow and white silkworms that gave rise to all yellow silkworms in the F1 generation. Toyama later described in the introduction of his 1906 doctoral dissertation, *Studies on the Hybridology of Insects, I.* a cross-breeding experiment between a Japanese "white race" and a French "yellow race" of the *Var* variety of silkworms that he had "bred true," or cultivated by interbreeding siblings of the same cohort, since 1885.

> The crosses thus raised, amounting to 2,300 heads in the case of "white ♀ + yellow ♂" and 968 in the case of "white ♂ + yellow ♀," spun yellow cocoons without any exception.[41]

A sample sibling cross from the resulting generation gave rise to 118 larvae, 89 of which produced yellow cocoons, and 29 of which produced white cocoons, roughly in a 3:1 ratio. A back-cross of a yellow F1 hybrid with a pure white breed of silkworm

[40] M. de Rodez, "Essais Précoces de ala Magnagnerie Expérimentale de Ganges," 1868, in Louis Pasteur, *Études 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), p. 308. An account is offered of crossing experiments between the yellow and white cocoon-producing moths that the experimenter already had cultivated, and "green" cocoon producing silkworms from Japan. In these tests, it was noticed that the "the color of the male has prevailed over that of the female to the color of the cocoon," the main point of the experiment served to show how *pébrine* infection occurred. This particular experiment showed that Japanese silkworm moths tended to generate more robust seed lots.
[41] Toyama Kametarō, "On the Hybridology of the Silkworm," *Bulletin of the Tokyo Imperial University College of Agriculture* 7, no. 1 (1906): 259–393. All English is original to Toyama. Voltinism refers to the number of generations a cohort of silkworms undergoes in a year (p. 262).

gave way to white and yellow cocoon-spinners in ratios close to 1:1.[42] Thus, Toyama explained, "we see that on crossing a white and a yellow race, the offspring raised in the first generation exhibit only the yellow character, which in the next generation appears to split up into their parent-characters, the white and yellow, according to a definite law."[43]

Toyama's mention of a "definite law" hints at his recognition of what we now call a pattern of segregation in the sibling crosses of the F1 yellow silkworms. He framed the rest of his doctoral thesis on silkworm hybridology, which he wrote after his return to Japan from Siam in 1905, as a study that would "prove whether there is such a general law or not."[44]

Mendelism began to attract the attention of scientists in Japan after Toyama published his silkworm study in 1906. *Bombyx mori* is known in Japan as the first case in which Mendelism was shown in an insect, following the independent "re-discoveries" of Gregor Mendel's pea experiments by Carl Correns, Hugo de Vries, and Erich von Tschermak in 1900.[45] The three scientists each cross-hybridized "true breeding" plants that produced only one type of progeny, which exhibited the same traits as the parents. When different true breeding plants were hybridized, they yielded offspring with different parental characteristics appearing in ratios of 1:3. Under the Mendelian principle of segregation, the paired "factors" responsible for the phenotype, or allele pairs, as they are now known, separated during the formation of gametes. During sexual reproduction, they would reunite with a complementary allele from the

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[42] Ibid., p. 262. Toyama reported two back-cross results that gave rise to 143:149 and 216:249 ratios of white to yellow worms.
[43] Ibid.
[44] Ibid., p. 263.
[45] Garland Allen, *Thomas Hunt Morgan* (Princeton: Princeton University Press, 1978), pp. 129–130, 148–153. In contrast, T. H. Morgan began *Drosophila melanogaster* breeding experiments during the period 1908–1909. After having found a white-eyed male mutant in 1910, he published on sex-limited inheritance in *Science* the same year, confirming the Mendelian laws of inheritance and the Sutton-Boveri hypothesis. For information on Mendelism, see Bateson, *Mendel's Principles of Heredity*; Olby, *Path to the Double Helix*; Stern and Sherwood, *Origin of Genetics*.

reproductive partner. In crossing experiments of plants with two characters, four different types of offspring could occur exhibiting distinct phenotypes in ratios of 9:3:3:1. In Mendel's principle of independent assortment, two discrete hereditary units that might be the same or different transmitted to the next generation independently of each other to determine the characteristic of an offspring. By 1902, William Bateson had coined the term "allelomorph" to refer to the character that resulted from the heterozygotic or homozygotic combination of "unit-characters" through the union of gametes.[46] While the exact physical manifestations were not yet known, Bateson's analysis indicated that "each character in each organism" would require separate investigation.[47]

In the early 1900s before genetics was called that, scientists debated competing theories of Darwinian evolution vigorously. These discussions centered around questions of what produced variation in animals and plants, and mainly took place in England and Europe among Mendelists such as Bateson and Hugo deVries, who began to advance his mutation theory in 1900 about discontinuous leaps Darwinian evolution, which irked the sensibilities of biometricians such as Karl Pearson, who promoted theories of continuous variation in which evolution took place in smaller steps.[48] Mendelism did not seem to develop in Japan in terms of these exact or at least,

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[46] William Bateson and E. R. Saunders, "Report I.–Experiments Undertaken by W. Bateson, F.R.S., and Miss E. R. Saunders," *Reports to the Evolution Committee of the Royal Society* (London: Harrison & Sons, 1902), p. 126. "By crossing two forms exhibiting antagonistic characters, cross-breds were produced. The generative cells of these cross-breds were shown to be of two kinds, each being pure in respect of *one* of the parental characters. This purity of the germ-cells, and their inability to transmit both of the antagonistic characters, is the central face proved by Mendel's work. We thus reach the conception of unit-characters existing in antagonistic pairs. Such characters we propose to call *allelomorphs*, and the zygote formed by the union of a pair of opposite allelomorphic games, we shall call a *heterozygote*."

[47] Ibid., p. 159.

[48] William B. Provine, *The Origins of Theoretical Population Genetics*, 2nd ed. (Chicago: University of Chicago Press, 2001), pp. 56–89. Hugo de Vries, *The Mutation Theory* (Open Court Pub. Co., 1909); Hugo de Vries, *Die Mutationstheorie. Versuche und beobachtungen über die entstehung von arten im pflanzenreich, von Hugo de Vries* (Leipzig: Veit & comp., 1903), http://www.biodiversitylibrary.org/item/43179. The original *Mutationstheorie* by de Vries appeared in two volumes, 1900–1903.

explicit debates; nor did it seem to take root through the receptions of translations alone. While one of the first scholarly interpretations of Mendel's work was included in botanist Ikeno Seiichiro's 1906 text *Shokubutsu Keitōgaku* [Plant Phylogenetics], it has been suggested that one of the earliest known popular introductions of Mendelism was made around 1903 by a science teacher in Nagano Prefecture, Usui Katsuzo, who translated a dense *Popular Science Monthly* article, "Mendel's Law," by W. J. Spillman.[49] Usui's translation was considered excellent, but it appeared in *The Sinano Journal of Natural History*, which had a limited rural circulation.[50] Rather, Mendelism in Japan found a substrate in the world of sericulture. Toyama's 1906 study on silkworm inheritance, which demonstrated Mendelism based on actual experiments, would gain wider exposure due to his ties to state and industry efforts. Toyama himself did not seem to have encountered the Spillman translation, and his travel to Siam suggests that he found other ways to read current scientific texts directly, whether before his departure or when he revisited Japan during a brief return visit to pick up supplies and assistants in 1902.[51] The subsequent development of F1 hybrid silkworm seeds came as an industrial movement in response to Toyama's work and the pressure to produce greater quantities of uniform-quality silk cocoons that produced longer lengths of raw silk.[52] This chapter illuminates the scope of Toyama's experimental work situated within the greater political context of the relations between what are recognized as Japan and Thailand, the two Asian nation-states that managed to avoid European colonization.

[49] William G. Spillman, "Mendel's Law," *Popular Science Monthly* 62, no. 3 (1903): 269–280.

[50] Katsuzo, Usui, "Menderu no hōsoku," *Sinano-hakubutsu-zasshi* 7 (1903): 2–6, (8):10–15, (9):13–16. For more on the reception of Mendelism in Japan, see Matsubara, "Reception of Mendelism in Japan"; Sinoto, "Mr. Katszo Usui, the first introducer of Mendelism to Japan."

[51] After his 1905 return to Japan, no more than four months passed before his paper submission. Citations were added in May 1906 to update his literature review.

[52] The current paper does not focus on sericulture practices and laws regarding silk production, but their mention provides some context about the timely use of Mendelian principles in connection to growing interests in silkworm improvement in Japan.

2. Sericultural State Affairs of Siam and Japan

The Declaration of Amity and Commerce between Japan and Siam was signed in 1887.[53] At the time, flanked by British and French colonial possessions, Siam faced constant risk of losing territories on two fronts. Relatively powerless in these humiliating border struggles, the king, who came into power the same year in which the Meiji emperor was restored, 1868, became convinced of the merits of science and recognized the value of inviting foreign consultants as part of a greater process of securing recognition as an independent sovereign nation.[54] By the early years of the twentieth century, part of this scheme included the promotion of sericulture in northeastern Siam, which was anticipated to be a possible next target of expansionist France. Japan, too, had vested interests in Siamese independence and sought to cultivate it as a trade partner.

Inagaki Manjiro, the Japanese resident minister in Siam, viewed the stimulation of "modern" (i.e., Japanese-style) silk works as a necessity for the protection of Siam's independence, especially from the encroachment of the French east of the Mekong River. This view developed in the 1890s while he studied at Cambridge University under the historian John Robert Seeley. Inagaki had then appealed to England about the value of a shared geopolitical strategy with Japan, as "Without doubt the Pacific will in the coming century be the platform of commercial and political enterprise."[55]

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[53] Hane, *Peasants, Rebels, and Outcastes*.

[54] William Theodore de Bary, Carol Gluck, and Arthur E. Tiedemann, *Sources of Japanese Tradition, vol. 2.* (New York: Columbia University Press, 2006); David Wyatt, *Thailand: A Short History* (New Haven: Yale University Press, 1984).

[55] Manjiro Inagaki, *Japan and the Pacific* (London: T. F. Unwin, 1890). The year 1893 was also particularly significant for two reasons. First, Inagaki became the chief secretary of the Oriental Society (Tōpō Kyōkai). Second, in July, France created a blockade to the west of the Mekong River, infringing on Siam, which was a buffer between British possessions in Burma, and the French in Annam, Cochin China, and Cambodia. In the Paknam Incident, a French gunboat prepared to bombard Bangkok if the conditions were not accepted, and Britain accepted the conditions, despite initially threatening to retaliate by force.

a. Staging Japanese Sericulture

By 1893, Inagaki became chief secretary of the *Tōhō Kyōkai* (Oriental Society), and in November 1895, the society's journal outlined a position on conditions for protecting peace in Asia. To do so, it emphasized the important need to maintain the existences, or *sonzai*, of Korea, China, and most notably, Siam.[56] Two suggestions were directed to the prime minister Itō Hirobumi and foreign minister Saionji Kinmochi:[57] 1) Maintain balance among Eastern countries, and 2) build a device for maintaining that balance.

Through Inagaki's writings, it is possible to ascertain that as of mid-Meiji, a framework was arguably in place to protect the sovereignty of the Pacific regions. In June 1897, Inagaki was appointed the first ambassador to Siam, and Japan–Siam trade agreements were drafted.[58] By guiding the reform of Siam's domestic government, Inagaki sought to indirectly benefit Japan. He wrote in 1898 that it was desirable to promote development of Siamese sericulture and reeling by ushering in Japanese technologists.[59]

This view was crystallized when two travelers, known only by their last names, Watanabe and Ueno, surveyed northeastern Siam. Watanabe and Ueno are reputedly recorded as having strongly recommended the encouragement of sericulture in Khorat. They also stressed, it "goes without saying that the consular general [Inagaki] should take some means to promote Japanese influence in Thailand."[60] It was around 1900,

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[55] "A Projected Silk Exchange," *New York Times*, 1882, p. 12; "A Silk-Rearing Exhibition; What Was Seen in Turn Hall Yesterday – Objects Which Deserve Support," *New York Times*, 1882, p. 5.
[56] "Siam" is used mainly to reflect the common use of this term by historical actors.
[57] Inagaki also had Iwamoto Chizuna, who had previously traveled to Bangkok, lecture on Siam to the society, which quickly piqued the interest of Japanese about Thailand.
[58] Ishii Yoneo and Yoshikawa Toshiharu, *Nichi Tai Kōryū Roppyaku-nenshi* [History of 600 Years of Japanese–Thai Exchange] (Tokyo: Kodansha, 1987). In 1896, the journal published the Japan–Thai treaty establishing diplomatic relations, and a treaty of commerce was created in 1898.
[59] Inagaki, "Nichi-Shamu Jōyaku Seishin Oyobi Jōken."
[60] Toshiharu Yoshikawa, "Shamukoku Sangyō Kōmongishi" ["Japanese Sericultural Experts in the Thai Government in the Age of King Chulalongkorn"], *Settō Ajiya Kenkyū* 18, no. 3 (1980): 361–86. In 1902 Foreign Ministry Records, as described in Yoshikawa, 1980, p. 363.

the same time the Siamese Minister of the Interior, Prince Damrong,[61] heard from Inagaki that while the quality of Siam's silk was poor and the product was used only domestically, Siam's raw silk could become a powerful export product if sericulture industry were to be broadly improved.[62]

In 1901, Inagaki delivered Watanabe and Ueno's survey report to Prince Damrong, which contained "A few suggestions as to the Improvement of Sericulture in Siam," and "A Brief History of Sericulture in Japan." The historical overview of sericulture in Japan explained that the encouragement of sericulture by the government after the Meiji Restoration had increased the sales of Japanese silk to Paris. The second report suggested that given Japan's progress, Siam should follow suit and establish a model sericulture station and a model factory, and should train people under experts, improve silkworm varieties, spread the ability to recognize silkworm diseases, improve sericulture tools, and distribute a hand-cranked, wooden *zaguri* reeling machine to every household. Inagaki became convinced enough to persuade Prince Teves.[63] That same year, after gaining the support of King Chulalongkorn (Rama V), the Japanese Minister of Foreign Affairs Sone Arasuke approved Toyama's dispatch to Bangkok for three years.[64] Siam eventually put into practice a policy similar to Japan's intended to increase the country's wealth through the development of sericulture, thus heightening its export abilities.

Vetted by the Ministry of Agriculture in Japan, Toyama was appointed as the Chief Sericultural Expert of the Sericulture Bureau under the Siamese Ministry of Agriculture to lead the way to raise the level of sericulture, or silk cultivation, and ultimately, make raw silk a viable export product. Toyama viewed his dispatch abroad

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[61] Phrachao Nongyathoe Kromluang Damrongrachanuphap.
[62] As cited by Yoshikawa, "Shamukoku Sangyō Kōmongishi," KS 13/13, Krasuang kaset chang pr. toyama chao yipun ma truat kan tham mai.
[63] Inagaki to Teves, March 11, 1901.
[64] 31 August 1901, translated letter from Sone Arasuke to Luang Sanpakitch Brecha.

as an honorable duty that could not be refused.[65] Two days before he departed for Siam in 1902, he was made an assistant professor at the Imperial University's College of Agriculture, likely in order to promote his status before the Siamese government.[66] As Toyama stepped aboard the Bingumaru postal steamship on February 7, 1902, he was no longer just a teacher or a researcher, moving from post to post. Toyama's work over the next several years served as part of Siam's modernization movement, and his presence also symbolized a larger political mission envisioned by Inagaki. Toyama's contract with the Siamese government forbade him to undertake unrelated work, underscoring his expected commitment, as a scientist, to support diplomatic efforts.[67]

Toyama's presence in Siam served to "improve" Japan's place in the world as much as Siam's. As a result of the sericultural investment in Siamese agriculture, Inagaki highly anticipated economic and political returns for Japan. His assignment to Siam provides a departure from narratives of Meiji Japan as a recipient of Western science, especially for biology and in particular zoology, through Edward Sylvester Morse (1838–1925) and Charles Otis Whitman (1842–1910). The employment of foreign teachers in Japan and the travel of Japanese students and scholars abroad to Europe and the United States brought distinctive forms of knowledge production in the Japanese sciences at the turn of the twentieth century.[68] Toyama's movement brings attention to the production of knowledge through Japanese travel overseas in contrast to the more common narrative of Japanese reception of new knowledge; as a result of his work as an agricultural consultant in Siam, he both imparted and gained technique and knowledge through his self-directed learning and application of experience. Moreover, the political mood hugely shaped the rationale for Toyama's

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[65] Toyama to his father, January 1902. [TY]
[66] Takeuchi, 1942.
[67] Contract signed in February 1902.
[68] Mohri Hideo and Yasugi Sadao. *Nihon no Dōbutsugaku no Rekishi* [The History of Zoology in Japan] (Tokyo: Baifūkan, 2007).

sojourn in what we might only now recognize as a form of development aid, the kind that took root in Japanese envisionings of a new East Asian order. For instance, by 1941, technocrats and reform bureaucrats promoted the mobilization of so-called integrated technologies, a broadened conceptualization of technology including political, management, economic, in addition to legislative and scientific technologies, meant to prepare the building of the New Order for Science and Technology.[69] The Japanese assistance of agro-biological expertise in Siam, though not specifically tied to the same heritage as that of the 1940s New Order, stands as the first tractable example of the Japanese empire's proactive involvement with a nation in a somewhat paternalistic role, fashioned rhetorically in terms of brotherhood.

b. Building a Model Sericulture System in Siam

Toyama began his work in Siam by conducting preliminary experiments with local varieties of silkworms and surveyed the prevalence of sericulture in the Khorat Plateau region. He identified several things necessary to boost production: the development of infrastructure, such as schools, experiment stations, and a small reeling and filature factory, in order to educate and train students, farmers, and female workers. Of most interest to Toyama, he was certain that local Siamese silkworms and their cocoons could be improved to raise the quality of export-level silk. Toyama appealed to the government of Siam in January 1903 to establish a model system capable of teaching and promoting sericulture, or silk production. However, he was critical of the scope of his role as an expert consultant:

> In our country, about twenty years ago, it was first intended to introduce the results of western civilization into agricultural practice and many agricultural

[69] Aaron Moore, "Subjective Technologies of Mobilization: Aikawa Haruki's Wartime Theory of Technology," in *The Technological Imaginary of Imperial Japan, 1931–1945* (Ph.D. diss., Cornell University, 2006). Miyamoto Takenosuke and Mori Hideoto developed the idea for the New Order in 1941.

> schools and Colleges have been organized by Western methods. Most of Professors are Western gentlemen & Japanese who have studied in Europe and America, and know very well about Western methods but little about Japanese. The results are not good and after some years these come to the fate to close and seem to have produced more harm than good. This is our first lesson . . . [70]

As a foreign expert in relatively underdeveloped Siam, Toyama made an appeal to the Siamese Minister of Agriculture that played to the conscience of the government of Siam as well as the local people. This meant acknowledging the contradiction of being a Japanese foreigner who recognizes the limitations of receiving foreign expertise but who is responsible for "improving" the situation on the ground, in Siam, through this very act. According to Toyama, efforts to improve Siamese sericulture would require "the education of men and to introduce the results of modern sciences into practice, but it is not [such an easy] matter because every country has her own nationality and the climate, customs and general surrounding differ to one another."[71] He continued to warn that "Hence, what may suit one country need not [necessarily] suit the other. This is a principal point to be considered when we intend [to] introduce the results of modern sciences into practice."[72]

Inasmuch as Toyama made a case for building a model sericulture system that benefited Siam, he also had to explain what that system was modeled after. Because Toyama was from Japan, his experiences qualified him to design a system based on the Japanese experiences of so-called "failed" introductions of "western civilization into agricultural practice."[73] In his mind, the massive, French-style Tomioka silk mill was a classic example of how the rush to introduce new technologies did not necessarily work: everything about the Tomioka factory was proportionately large and had to be "improved" in order to accommodate the height and working styles of

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[70] Toyama to Teves, January 8, 1903. Original in English.
[71] Ibid.
[72] Ibid.
[73] Ibid.

Japanese women reelers. In this sense, we can understand how the process and period of importing and relying on Western technologies and teachings, meaningful to historian Hiromi Mizuno's study on science and empire, depended on comparison with another world, in this case, Siam, to turn a technology and science into something *of* Japan.[74] The resulting new system had been under development in Japan since around 1890 and was based around a network of nationalized agricultural experiment stations. These were vehicles of "introducing" science promoted by Toyama:

> In this station, we have adopted the results of highest sciences into practice and the best results obtained there [were] introduced [to farmers'] practice[s].
>
> Therefore, the method is quite Japanese, but the principle was based on recent civilization.[75]

When writing this, Toyama was both a Japanese state scientist and chief sericultural expert for Siam. He had, in the name of casting a scientifically informed model, cast himself in a double bind in which he was to oversee the building of yet another foreign-inspired (i.e., Japanese) model apparatus, while expressing disdain for the introduction of systems without sufficient understanding of local knowledges and practices.

How or whether the silkworm-breeding program that Toyama designed was intended to "improve" the local Siamese varieties of silkworm deserves critical attention. Without sustained viability of commercially ideal and viable silkworms, the model sericulture apparatus would fail. Although Toyama himself did not refer to his work as producing a model, the work he accomplished during his three-year sojourn in Siam could be thought of as his own model system for testing out his ideas about Mendelian inheritance, and in turn, helping to spur a revolution in the state of the

[74] Hiromi Mizuno, *Science for the Empire: Scientific Nationalism in Modern Japan* (Palo Alto: Stanford University Press, 2009).
[75] Toyama to Teves, January 8, 1903.

silkworm-production craft in Japan. Toyama's views were very much expressed and shaped within a dichotomy between those with and without so-called higher scientific knowledge. For Meiji Japan, securing and maintaining autonomy – avoiding colonization – depended on realizing the mantra of *shokusan kōgyō* and *fukoku kyōhei* ideals. These ideals were thought to let Japan overcome a perceived gap between the haves and have-nots of technology and knowledge that could be used to be on the same plane as with the West without becoming them – while retaining their own identity.[76] To help secure Siamese autonomy, Japanese industrialization by way of sericulture was an experience worth emulating, a model hitherto known to have worked, Toyama argued. His presence in Siam served to "improve" Japan's place in the world as much as Siam's. No one understood this better than Inagaki Manjiro, the first Japanese resident ambassador to Siam.

As a result of the sericultural investment in Siamese agriculture, economic and political return was highly anticipated for Japan. Considering Japan's manufacturing industry and other points regarding the balance of power in the Orient, Inagaki wrote in 1905 that it is Japan's "life calling: as a developed country of the Orient to exhaust her power to make Thailand completely independent."[77] Toyama's visions of a model system in 1902 would seem to complement this view, for it included the establishment of research stations, schools, and a model filature, based directly on experiences in Japan.[78] Of these, the experiment stations interested Toyama greatly, and he praised

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[76] Richard J. Samuels, *"Rich Nation, Strong Army": National Security and the Technological Transformation of Japan* (Ithaca: Cornell University Press, 1996); Ishii Kanji, *Nihon no sangyō kakumei: Nisshin Nichi–Ro Sensō kara kangaeru* [Japan's Industrial Revolution: Thinking from the Sino–Japanese to Russo–Japanese Wars] (Tokyo: Asahi Shinbunsha, 1997).
[77] Inagaki Manjiro, "Shamukoku no Genjō," *Tōhō Kyōkai Kaihō* 132 (1906): 20.
[78] Toyama to Teves, January 8, 1903. Toyama further extolled the benefits of a system of agricultural experiment stations, and if anything is evident at all, it is in the sheer numbers of stations and schools that could train people in various aspects of agriculture. "As the natural sequence, agricultural schools have again organised according to the Japanese methods of teaching and at present there are 54 Agricultural stations (among which 11 stations belong to the Central Government and the others to the Local Government and there are two special sericultural training and experiment stations under the

their roles in a report to the Minister of Agriculture, Teves. The experiment stations would first "give farms an object lesson about the profit to introduce the results of modern sciences and also how they make use of them; secondly to supply agricultural schools the material of practical teaching or Champs d'experience; thirdley [sic] not only conduct experiments but analyze soils, suggest the proper manures and encourage co-operative purchase on a large scale."[79]

The first station was built in Bangkok near Saladaeng, not far from Dusit Park on the Royal grounds. Toyama conducted most of his breeding experiments there. Another station was established in Khorat city, which directly extended sericulture know-how to farmers, and another station was later set up in Buriram, which focused on reeling and weaving. Like schools, experiment stations were considered to be places of learning.[80]

Toyama had a common view in which promotion of sericulture in Japan should consist of teaching and encouragement. In the same way that the Tomioka model silk filature in Gunma Prefecture designed by French silk industrialists was instrumental for fanning the flames of interest in machine-reeling silk, building an adapted model filature in Siam in 1903 would be additionally instrumental for several reasons, Toyama felt. First, as a model filature, it would to show the public the profitability of the reeling industry. Second, it would be a means to train and teach women workers who would serve in the industry. Third, it would produce some income for the government. Fourth, it would also encourage farmers to rear more silkworms.

All of these activities were at first organized within the Sericulture Bureau, under the Central Department. In his January 1903 report, Toyama asked the King to

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Central Government) with 59 branch stations and one University, 81 local agricultural schools and training schools (one higher agricultural and dendrological college now in preparation to establish)."

[79] Toyama to Teves, January 8, 1903.

[80] The organizational pattern that developed in Siam under Toyama's oversight deserves further analysis, considering that the state control of silkworm varieties that would take place later in Japan, in 1911.

enlarge the section as a distinct Department of Agriculture "to make various experiments and encouragement to improve and promote Siamese Agriculture in general, as for Mining, Surveying Departments etc." Moreover, he emphasized,

> The Director of the Department should be Siamese gentleman, never foreigner however he may be able, because it is a general rule and best way that the right of superintendency and directorship of any Governmental business as a chief should never be given to foreigner's hands.
>
> As this reason, it is best way to appoint a Siamese Prince having some knowledge of Agriculture as the director of the department. Then we shall be very happy to do any business under Siamese gentleman's superintendency.[81]

This final request that a Royal family member oversee the Bureau helped emphasize that the Japanese were communicating their support of local leadership, but we should also consider that in Japan, sericulture thrived because of the strong support of the Imperial family, especially the empress. We can only imagine that Toyama perhaps channeled this, and being partly familiar with Prince Benya's ability and enthusiasm, saw this as a natural move. Finally, we are reminded that Toyama was not only a scientist or a designer of the model sericulture system, but his voice represented Japanese authority as an appointee of Inagaki, setting the conditions under which productive trade and other business could occur between Japan and Siam.

c. Scoping Siam's Silkworms

When Toyama initially surveyed the Khorat plateau in April 1902, he found "two kinds of worms [within] the same blood; the one is the 'Vers tigrés,' while the other, common white worms having no marking on the skin; both of these have white blooded and yellow blooded ones, the former spinning yellowish white and the latter yellow cocoons."[82] He found that the body sizes of Siamese silkworms were also very

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[81] Toyama to Teves, January 8, 1903, p. 33.

[82] The first reference to "blood" refers more readily to "bloodline" rather than to blood color.

small, explaining that they secrete less silk compared with "other good varieties in Japan, Italy or China which attain to 60–80 mm in length and 4 to 6 grams in weight . . ."[83]

The cocoons were spindle-shaped, with thin walls constituted by flossy, or very thin and brittle, threads. Usually, a single long silk filament can be reeled off from a cocoon, but the cotton-candy-like texture of Siamese cocoons made their silk filaments prone to breakage, leading to reduced quality. Toyama had a low opinion of the silk, as he described in English to the agricultural minister of Siam: "From the above brief examination, we may certainly say that the worms reared now in this country are of [a] primitive kind and must be improved. [With] such [an] inferior variety, we can not get best silk even when we use best reeling machine and best workmen."[84] Toyama's use of the word "improvement" at this stage did not refer to a particular method or approach.

Toyama eventually deemed this situation salvageable. In January 1903, he issued a survey in English, the language used to communicate with the Siamese officials, on the silkworms he gathered around Khorat and suggested a change of mind while articulating the choices before him regarding improvement:

> When we consider Siamese silk-worms [sic] from [an] economical point of view they are not bad and if we select them under good breeding they will become one [among] good worms in future. It is not an easy matter to solve the question which is [more profitable] and easier, whether to introduce good foreign worms or to select and improve native worms, we must wait for the result of further experiments and inquiries.[85]

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[83] The silkworms surveyed in Siam were multivoltine, meaning these varieties did not overwinter and could live through up to eight life cycles in one calendar year.
[84] Toyama to Teves, April 9, 1902. Toyama wrote his reports in English.
[85] Yoshikawa, "Shamukoku Sangyō Kōmongishi." Toyama to the Ministry of Agriculture of Siam, January 8, 1903. The survey took place in December 1902 with Prince Phenphattanapong (Benya), who became the director of the Sericulture Bureau after Toyama.

The new position reflected Toyama's realization that the greater hygiene and diligent feeding methods used in Japan could yield favorable results and improve the silk-filament length of Siamese cocoons from 240 to 300 or 330 meters. This still paled in comparison to the 600 meters of silk that a Japanese silkworm could yield in the early 1900s.[86] Toyama saw limited benefits to silk qualities that could be accounted for by changes in human labor or techniques. He had calculated that the cost of labor necessary for sericulture in Siam would exceed the amount of capital that could be gained from silk sales. Rather, Toyama found it necessary to improve the silkworm breed by addressing production issues through the insect's biology.

Toyama shifted the gaze from work to worm, and as a consequence, he was able to address the earlier question of how exactly to selectively breed the silkworms in Siam. He proceeded with experiments that were deliberately designed to improve the local Siamese varieties by hybridizing Japanese and Siamese silkworms. Most local people produced crops of both "white" and "striped" silkworm types, but Toyama decided that rearing only white worms would boost productivity by 30%.[87]

This was the stage that was set for Toyama's subsequent silkworm-breeding program. A model magnanerie, a house for rearing silkworms, was built. In 1903, he began his experiments hybridizing Siamese and Japanese silkworms at the experiment station in Bangkok. Because the Japanese variety was univoltine, meaning the silkworms undergo one diapause in a year, and because they often had to be reimported from Japan, relying on Japanese parent stocks was a major obstacle. Japanese silkworms were also easily eaten by ants, infested by parasitic flies, and carried pébrine disease. Regardless of the fact that the local Siamese variety of cocoon was clearly less superior in comparison to the hybrid, the notion that Japanese

[86] Toyama to Teves, January 8, 1903. European and Chinese varieties could yield 500 to 800 meters and 500 meters, respectively.
[87] Ibid.

silkworms could be used to "improve" Siamese silkworms seemed incongruous if they could barely survive in the different environment. At the time, it was not clear to Toyama whether the good-quality hybrids would continue to be produced or if they would exhibit senzōgaeri, a return to the state of their ancestors.[88] Toyama continued his experiments up to four generations, and after that he himself fell ill and could not continue working, so his silkworms died.[89]

Toyama returned to Japan, and a sericulturist named Tahara re-started the experiment in February 1905. Tahara managed to sustain six generations of these hybrid silkworms.[90] Again, this was not without importing Japanese silkworm eggs from Japan three times in November 1905, which allowed production of an eighth-generation multivoltine hybrid resulting in cream-colored cocoons with high thread content.[91] These silkworm eggs were sent to Khorat for distribution to farmers, while at Bangkok, a portion were kept to cross-breed with Japanese varieties. Despite these efforts, it remained a challenge to rely on the hybrids, for in the face of diseases, the available hybrids would eventually somehow get mixed together with other varieties. Perfecting a good commercial variety was an elusive goal, and without better facilities or able technical staff, by 1911, all the varieties reverted back to the local kind, and the Japanese variety eventually faded away.[92]

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[88] These issues resemble somewhat the efforts to acclimatize European silkworms to Japan, and together raise interesting fodder for further discussion of colonization theories.

[89] Yoshikawa, "Shamukoku Sangyō Kōmongishi."

[90] In the first filial hybrid cross, the Thai variety produced better thread than the Japanese one. The hybrid resulted in a deeply cream-colored cocoon. In subsequent breeding, a lighter cream-colored hybrid variety was developed and eventually produced at the experiment station in Khorat for distribution to farmers.

[91] This resulted in cocoons with high thread content in the dark-cream and white-colored cocoons, double that of the local Thai variety. The light-cream color was the parent color and was seemingly a well-established trait that could be inherited.

[92] Despite such efforts, at Khorat, the branch experiment station, where the hybrid eggs were hatched and larvae reared, the silkworm varieties were actually mixed together with those that came from Toyama's station at Bangkok and from Buriram.

Experiments in varietal improvement often depended on an initial one-time crossing, and those progeny were subjected to inbreeding to make what would amount to a new variety. Early Meiji-period crosses, carried out by the Ministry of Agriculture and Commerce, of Japanese native varieties and "foreign" silkworms from Hokkaido, and later in the 1880s with Chinese and other foreign varieties, resulted in fixed strains that didn't hinge on segregation. This was actually what Toyama was trying to accomplish in Siam: to create a novel pedigree based on crosses with imported Japanese and local Siamese silkworms. This is a crucial point: It was after he noticed the Mendelian patterns of inheritance that consciousness about silkworm varieties and silk became invigorated with the allure of hybridity, not as something to create and then homogenize, but as something to retain in the form of the parental organisms that would be cross-hybridized. The prior practices of *kakeawase* (cross-breeding) could be <u>explained</u> by hybridization. In this shift, an older undifferentiated cultural practice of mixing started to become re-articulated with scientific language that would describe particular crossings.

Cocoon values often depended on weight, and the notion that bigger silkworms give rise to bigger cocoons had held for tens of years.[93] Over the course of the early Meiji period, the existing mentalities about silkworm production responded to a desire to increase the yield of raw silk and therefore the trade volume of raw silk in Japan. By 1912, approximately 28,500 bales of raw silk were shipped to the United States.[94] The push to produce was also part of the mutually identified pressures of state reputations and sovereignty that faced officials in both Japan and Siam. However, Toyama's work in Siam served the dual purpose of conducting original research to test the principles of inheritance in silkworms in addition to improving the local variety for

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[93] Today, some commercially produced silkworms are so adept at producing cocoons that they cannot fully emerge from their cocoons without the help of a human hand.
[94] Henry L. Gwalter, "Review of the Raw Silk Market of 1913," *American Silk Journal*, Jan. 1914.

commercial reasons. Although much of the institutional organization that Toyama set out to establish in Siam was drawn from his own experiences in Japan, it is not too far-fetched to consider the possibility that the organizational flow by which hybrid Siamese–Japanese silkworms were made, stabilized, and distributed for some degree of practical use was just as experimental as the genetics itself. These experiences would not only be applicable to Siam through 1911, but it was after 1911 that the method of silkworm breeding and distribution in Japan, too, was completely reformed, based on the recognized value of heterosis, or hybrid vigor.

The creation of a mirror system in Siam by the team of Japanese sericulturists led by Toyama germinated the kernel of a new agricultural industry for Siam.[95] Toyama's insistence that the promotion of Siamese sericulture required the organization of a government-led system came from an awareness that foreign teachings and methods could not simply be applied in a new location, even though he himself had the requisite experience. Toyama was not just a hard worker; he was a hard driver, somewhat oblivious to the importance of human relationships. He had brought his brother-in-law with him to work in Siam, leaving him there to continue working and eventually to perish while he returned to Japan.[96] Toyama aimed to rear silkworms economically, teach apprentices about the methods, and "show the public the profit of the sericulture and teach the method to anyone who wishes to know sericulture within a short period of one or two months," demonstrating a keen awareness of the on-the-ground needs of a successful silk industry.[97] Toyama also made evident the need for officers who, not unlike the traveling sericulture teachers in Japan, would move through villages and teach farmers personally the best methods for

[95] The sericultural school that Toyama established in Bangkok is the site of today's Kasetsart University, Thailand's main academic agricultural institution.
[96] Yoshikawa "Shamukoku Sangyō Kōmongishi"; Takeuchi Nagamasa, ed., *Toyama Kametarō Kinenroku* [Toyama Kametarō Commemorative Record] (Kanagawa Prefecture, Koayumura: s.n., 1940); Nagashima Yasutaro died on June 14, 1907.
[97] Toyama to Teves, January 8, 1903, p. 27.

cultivating mulberry plants and rearing worms. Despite Toyama's vocalized concerns about the overhandling of the silk industry by foreigners in Japan during the 1880s, it seems that the system he designed was clearly adapted from the Japanese style, in which the duties of silkworm-egg production had been separated from rearing. In particular, Toyama introduced a top-down system in which "the whole produce of sericulture will be bought up by the Government with a proper price. So it is necessary for a time, to prohibit free trade of cocoons and to deal the matter as a government monopoly namely from 1904."[98] Toyama's attitudes about the limitations of foreign teachers seemed to contradict the distinctly Japanese policy recommendations he made, although this was, perhaps, the most expedient way to rapidly encourage the nascent silk industry of Siam.

The dispatch of Japanese silk experts to Thailand between 1902 and 1912 and particularly of Toyama's silkworm breeding and inheritance experiments has made it possible to outline a historical development of the extension of Japanese science to developing nations in Japan's course of staking a place on the global stage, in the realms of both geopolitical contests and international biological research. Toyama's time in Siam is a counterexample to Japan's own experience as a nation growing scientifically and technologically endowed on several planes. On one hand, as an example of actively imparting scientific and technological knowledge, Japanese sericulture in Siam offers a counterexample to material and cultural histories of the formation of Japanese factories that are part of a narrative of reception of science and technology.[99] On another level, the Japan–Siam relationship itself offers a unique opportunity to understand some Japanese visions for achieving a "place in the world," not only because Siam was independent and never colonized, but because of the

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[98] Toyama to Teves, January 8, 1903, p. 33. Original in English.
[99] David Wittner, *Technology and the Culture of Progress in Meiji Japan* (New York: Routledge, 2008).

explicitly biological project that would mediate such a "place." While it was probably not a blatant plan on Toyama's part to make Siam into an experimental model system for Japanese sericulture, he could not help but be in a position where the possession of Japanese scientific knowledge was both demonstrated and cultivated in Siam in a way that stood to benefit Japan.

After returning to Japan, Toyama had to consider the substantive methodologies necessary for carrying out *kairyō* in a more politically charged atmosphere. The Japan that he returned to had just emerged valiant in the Russo–Japanese War in 1905, and with the rise of national sentiment and greater concerns about increasing provisions for military purposes, especially in the wake of the 1907 financial panic, sericulture grew into an industry of capital importance that Japan could no longer treat in a laissez-faire fashion. The wasteful use of capital and labor could not be condoned. To his informed eye, Toyama could build on his earlier conversations of 1900 about holistic selection of cocoon qualities for overall insect quality (as opposed to selection of just one quantitatively measurable characteristic, such as cocoon size or thread length), and incorporate new knowledge produced through the hybridization experiments of Japanese and Siamese silkworms, to understand the relative potential and importance of being able to select for one particular characteristic. By examining Toyama's experiments up through his return to Japan in 1905, we can start to understand how the case of introducing Japanese-style sericulture may have done more to help Japan than Siam at the time, though perhaps not in the way Inagaki Manjiro had envisioned, through the cultivation of a robust silk trade. Rather, it helped affirm a very localized understanding of Japanese genetics that was grounded in hybridity. It was definable through biological comparison by comparing the behaviors of what was in English called continuous and discontinuous forms of variation in silkworms; the differences and similarities between Siamese silkworms of past and present and the Japanese × Siamese hybrids would foment in their own ways the means for a new revolutionary moment in Japan's industry of silkworm seed, and of course, silk production.

Kairyō unchecked had once bordered on becoming a caricature of itself in the way the label of "new and improved!" might help entice someone to buy a product with newly redesigned packaging. The question of why something had improved, or had undergone *kairyō,* echoes discussions of the history of technological change. The looseness of the definition of "improvement" in the parlance of *kairyō*, ranging from making silk more compatible with fast-reeling machines to making changes to technologies and techniques related to the rearing of silkworms or the filature of cocoons, suggests that everything is subject to *kairyō*. Such a quasi-mantra teetered between meaning everything and nothing at the same time. Toyama's ideas of biological rationality concerning silkworm breeding began to relay synergistically with silk mechanized production. Until then, the resulting fibers tended to represent a myriad of technologies whose results merged in an ad-hoc manner, contingent on various circumstances.[100] As for the "improvement" of silk, the vagueness as to what merited being subject to *kairyō* catalyzed a great need to sort things out, starting with the very notion of what a silkworm variety was.

Toyama's concern with silkworms posed a problem of the definition of biological borders. Defining the boundaries of one *shurui* and another had begun to pose a serious biological question that had to answer to industry. Without a definable concept, the pursuit of the parameters and means with which to carry out *kairyō* would have remained hindered. The sprawling variation among silkworms, most apparent through examination of just one aspect of the silkworm's life cycle – the inanimate

[100] The "culture of improvement" is characterized by the "ascendancy of values and beliefs permeating all levels of society that 'things could be done better,'" and perceptions of improvement thus differ between peoples and over time, according to Robert Friedel, *A Culture of Improvement: Technology and the Western Millennium* (Cambridge, MA: MIT Press, 2007), p. 2.

cocoon – pressed forth a need to decide how to stabilize varieties so that they could be better managed. The decision of how to deal with silkworms in their splendorous but troublesome variation, *ittei*, was subject to debate. Sometimes, it related to a decision to limit the number of useable varieties of silkworms. On the other hand, the concept was prone to another interpretation, to settle on the use of a particular variant of a *shurui*. This multiplicity of conceptualizations of "variation" regarding *shurui* contributed to the ongoing discussions of *kairyō* and how to decide how to execute it.

The Sericultural Association meeting in April 1900 thus marked the beginning of a new way of cultivating silkworms that would displace the control concerning the ability to create or maintain silkworm strains. The silk industry's gradual recognition of its limitations, as conveyed by Toyama, created a space, if not a necessity, for practical change. As a scientific expert and a public speaker whose words were promoted in trade journals published by an imperially sanctioned organization as well as by producers, Toyama managed to make a case for transformation without denigrating or creating a gulf between him and his listeners. Not once in the speech did he utter words that would have raised his position above the social group, such as "scientific," "science," "rational," "logical," or "Western." Such a change, however, reflects Toyama's evocation of a deep, "originary" history of Japanese sericulture to shame his contemporaries and the deterioration of their skill.

The human ability to continually produce high or consistent quality silk cocoons, to say the least, was not hereditary insofar as skill is concerned; nor was it inherent or maintained in the silkworm. Toyama used lay terms within the sericulture field to gently upset the worldview of that moment, specifically through a call to resurrect the know-how and careful ways of a not-too-distant past. He framed Japan of the past to serve as a model for Japan of the present. As far as Toyama was concerned, Japan of the present served as an appropriate model for the development of Siam's sericulture industry, as well. Together, these developments show how sericulture and the idea of the nation were forged together in the Meiji period.

CHAPTER THREE:

RETURN TO JAPAN: FIELDING KELLOGG'S CRITIQUES OF MENDELISM IN SERICULTURE

A creature of silence keeps its secrets close. The silkworm larvae do not utter so much as a sound except as a collective chorus, when hundreds of worms munch on mulberry plants for hours on end, filling the air with the soft zā-zā-zā sound of a summer rain. The silkworm never seems to tire of eating, except when it must pause to molt. In such shedding moments between developmental moments called instars, the worm rears its head as if to roar. It then stands at a quiet attention and enters a sleep. Its outer skin stiffens, dulls, and dries. The larva grows. When the silkworm reanimates, it walks forward and sheds its skin to move into the open. Its tiny feet have little hairs that help it grip the surface of the leaves it treads over. That underfoot world is where one goes to tell the silkworm's fortune, whether it will spin a cocoon of a certain color, whether it is male or female. But its dorsal skin is what we see, for the most part. It is baby-soft, cool to the touch; each advancement in its life history exposes the silkworm's skin once again to the elements, warmth and cold, disease and hygiene, humidity and aridity, wind and stillness, to bring it closer to telling us what secrets it keeps.

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The silkworm hybridization work carried out by Toyama began to create a space in which to intervene in existing practices of sericulture. In his critique of April 1900 discussed in the previous chapter, Toyama highlighted the contradiction by which Japanese sericultural practices prior to the Meiji period seemed to produce better-quality cocoons than those of the "modern" period. The state of being modern did not equate to being "better" than the past, and status quo practices of silkworm production were thus unacceptable to Toyama.

This chapter continues the discussion of the transformative changes in the processes of silk production and elaborates on why and how Mendelian principles of genetics came to be justified as part of cocoon-making and, later, how that would engender further changes in sericultural practices in Japan. The analysis is carried out through a comparison of the silkworm inheritance experiments of Toyama and the American entomologist Vernon Kellogg (1867–1937). Their intellectual exchange was not merely about the confirmation of the laws of genetics. The question of whether the silkworm or its cocoon was suitably "natural" as an organism with which Mendelism could be reliably demonstrated was central to the exchange. The chapter highlights the kind of tensions that accompanied the use of an industrially relevant organism in scientific research in an international arena.

Toyama performed his investigations of Mendelian inheritance largely in Siam and rushed back to Japan to write up his results in his doctoral dissertation in 1905. The research itself took place at a time when scientists such as A. D. Darbishire conducted breeding experiments using "pure-bred" Japanese "waltzing" and albino "races" of mice to test the inheritance patterns of coat color and dancing or spinning behavior.[1] I point out these tests in mammals to demonstrate how different kinds of

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[1] A. D. Darbishire, "Note on the Results of Crossing Japanese Waltzing Mice with European Albino Races," *Biometrika* 2, no. 1 (November 1902): 101–104; A. D. Darbishire, "Second Report on the Result of Crossing Japanese Waltzing Mice with Europea Albino Races," *Biometrika* 2, no. 2 (February 1903): 165–173; Robert Mearns Yerkes, *The dancing mouse: a study in animal behavior* (New York: Macmillan, 1907); Provine, *Origins of Theoretical Population Genetics,* pp. 73–80. The dancing mouse was first widely studied for its spinning behavior. Yerkes reviews the literature and history of this organism in great detail, and suggests it was not from nature, but had developed as a result of "rigid artificial selection" in China and Japan. Darbishire assures of the pure breed by stating that the offspring of the two original parents he used had a uniform appearance: "This fact is emphasized in order to remove any suspicion which may arise in the mind of some careful critic that the waltzing mice dealt with may have been dominant hybrids" (Darbishire, "Note on the Results of Crossing Japanese Waltzing Mice," p. 102). The origin of the waltzing mice is not described in Darbishire's first report, although Yerkes makes clear that these mice had been cultivated for some time by mouse fanciers.

organisms were being used to test theories of dominance and independent assortment, and, in addition, that some of the hybridization experimentation in these contexts depended on crossing organisms of the same species that originated outside of the country of experimentation.

Darbishire and Toyama do not appear to cite each other's work as far as the present investigation is concerned, but the cases of the waltzing mouse and the silkworm help emphasize how the baggage of supposed artificial selection had to be addressed within the respective experiments of these contemporaries. Questions of domestication would be immensely important in vouching for the reliability of the animal – *Bombyx mori* – as an appropriate experimental organism with which to test Mendelian patterns. The details of Toyama's experiments described in this chapter proceed in a way that responds in part to critiques by Kellogg. In these exchanges and experiments, it becomes clearer how research on the silkworm was no longer for the sake of the silkworm, but it had to pass muster as a natural, unadulterated organism trustworthy of the Mendelian claims its geneticist would make.

1. Why the Silkworm

Control of the silkworm cocoon remained critical to improving silk quality in 1900 as Toyama embarked on his graduate work on silkworm inheritance in Tokyo, where he also served as an instructor at the Tokyo High School of Agriculture and Forestry. His research program began in 1900 with a cross between yellow and white that gave rise to all yellow silkworms in the offspring generation. A sample cross of yellow male and female siblings from that generation gave rise to 118 larvae, 89 of which produced yellow cocoons, and 29 of which produced white cocoons, in a roughly 3:1 ratio. A back-cross of a yellow "hybrid" from the offspring cohort with a member of the pure-white breed of silkworm that the parent came from gave way to white and yellow cocoon-spinners in ratios close to 1:1.[2] Thus, Toyama explained, "we see that on crossing a white and a yellow race, the offspring raised in the first generation exhibit only the yellow character, which in the next generation appears to split up into their parent-characters, the white and yellow, according to a definite law."[3]

Toyama's mention of a "definite law" hints at his recognition of what we now call a pattern of segregation in the sibling crosses of the F1 yellow silkworms. Toyama observed that his preliminary findings seemed to support the Mendelian laws of inheritance, and he framed the rest of his doctoral thesis on silkworm hybridology, written after he returned to Japan from Siam in 1905, as a study that would "prove whether there is such a general law or not."[4] This positioning calls into question whether Toyama planned to conduct Mendelian experiments when he went to Siam in 1902 as a government consultant, and why he traveled to help Siam's silk industry at such an exciting timing in the history of the life sciences.

Untangling the processes of *kairyō,* or improvement, of silk and, ultimately, the silkworm, remains key to understanding how silk work gave rise to academic silkworm genetics in Japan. The process of examining the "occupational extension" of the silkworm from locales of practical breeding to locales of academic experimentation on inheritance raises the rather simple but confounding question that threads its way through this project: Why study the silkworm? Toyama had actually studied various organisms, before and after his sojourn to Siam, but his attention to the silkworm helped fortify greater connections between agricultural, sericultural, and biological research in Japan. Historical analysis of Toyama's silkworm inheritance work leading up to and beyond his paper "On Some Silkworm Crosses, with Special

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[2] Toyama, Kametarō, "On the Hybridology of the Silkworm," *Bulletin of the Tokyo Imperial University College of Agriculture* 7, no. 1 (1906): 259–393. Toyama reported two back-cross results, which gave rise to ratios of 143:149 and 216:249 white to yellow worms. See p. 262.
[3] Ibid.
[4] Toyama, "On the Hybridology of the Silkworm," p. 263.

Reference to Mendel's Law of Heredity," which appeared as a chapter in his 1906 doctoral dissertation, *Studies on the Hybridology of Insects*, provides a way to understand the multifaceted situation facing sericulture, silk trade, and research at the time.[5]

Fueled by newer understandings about hybridization, the management of commercial silkworm breeds in Japan underwent vast changes through the 1920s. Pertinent to the expert leadership that formed in relation to guiding such change, this chapter addresses Toyama's work in Japan and former Siam and how the silkworm was fashioned into a larger dialogue on inheritance with non-Japanese researchers, such as Kellogg.

The conversation between Toyama and Kellogg took the form of a number of silkworm studies published mainly during the first decade of the 1900s. All together, they highlight some of the delicate tensions that emerged during the growth of research in agriculture, sericulture, and experimental biology.[6] The crux of their conversation stemmed from Kellogg's conviction that Mendelian principles could not be used to describe patterns of inheritance for larval color and patterns *and* cocoon color; Toyama's work showed that both traits were Mendelian. Analysis of the scholarly exchanges between the two scientists reveals how the silkworm was qualified as a valid animal with which to study the Mendelian principles of independent assortment and segregation. Comparison directs our attention to the issues that scientists who worked with agricultural or sericultural organisms faced as biological experimentation developed during the early twentieth century. By placing a

[5] Toyama's doctoral thesis was written completely in English and submitted in May 1905 before its publication in 1906. Additional citations in Toyama's literature review were added in May 1906 before publication in October 1906. A fifteen-page abstracted version of his paper was published in English in the back of the trade publication *Dai Nihon Sanshi Kaihō*, May 1906.

[6] Kellogg and instructor Ruby Green Smith (née Bell) began experimenting with *Bombyx* in 1902. See also Kellogg and Bell, 1903. Isabel McCracken was also an instructor in entomology and worked on *Bombyx* research a few years later, around 1905, resulting in a 1909 paper on the inheritance of voltinism.

necessary focus on the silkworm, comparison facilitates a greater understanding of the localized production of biological knowledge. Examining the intersections of American entomology, Japanese sericulture, and, to a degree, Siamese imperial development, clarifies the importance of the relationships between agriculture, sericulture, and biology that made possible the negotiation of *Bombyx mori* onto the Mendelian research landscape.

Toyama and Kellogg navigated their silkworms through claims of naturalness and artificiality in order to qualify their degree of reliability as a source of biological information. The silkworm trait in question, cocoon color, was deemed unnatural by Kellogg, because its cultivation as a product of historical human interference tainted the fidelity with which these newly articulated laws of inheritance could be clearly exhibited. These issues point out how institutional differences could bring Toyama and Kellogg to draw their own ways of handling and reading these organisms. Their unique interactions with the species, manifested in their intellectual and material engagements with it, produced competing rationalizations that were used to define silkworm breeds or races and, therefore, competing interpretations of silkworm heredity to police or resolve. Analyzing the abrasions and concordances between Toyama and Kellogg's work—their responsiveness to each other's scholarship—is necessary to understand why and how the silkworm came to "pass" from the status of a commonly bred insect, subject to human manipulation and supposedly unpredictable mutations, to a creature that could reliably demonstrate the laws of Mendelian inheritance.[7]

This comparison plays an important part of a larger project to reconstruct the history of the hybrid silkworm. As a private university professor in a relatively more

[7] Raj, *Relocating Modern Science,* informs my interest in studying localities of biological research in a way that recognizes an analytic shift from the "original" bearers of universalized science to the "intercultural contact zones," in which people and objects of unequal power are complicit in reconfiguring what ends up "passing" as "Western science." See Pratt, *Imperial Eyes*.

stable position than Toyama, Kellogg was not held to an obligation to improve the silkworm. I examine Kellogg's academic background as an entomologist and why he used *Bombyx mori* to carry out his bionomics research and investigate questions concerning natural selection. He established a research program in bionomics, a British-based research approach hinging on the "controlled observation and experimentation of organisms within settings that approximated their natural environments."[8] A discussion of the scholarly tensions between Toyama and Kellogg emerged from their intersecting research on silkworm cocoon colors and larval patterns. Toyama and Kellogg were contemporaries with interests in insects and inheritance. Their paths were not parallel, but crossed because of silk. This chapter ends with an analysis of the insights that the individual scientists would each contribute to and gain from the same species in order to unravel and explain the phenomenon of inheritance.

a. A Mendelian Interpretation

Toyama's February return to Japan in 1905 was immediately followed by the publication of his doctoral thesis, part of which included the chapter "On Some Silkworm Crosses, with Special Reference to Mendel's Law of Heredity."[9] The results of Toyama's shifted view on the potential to improve Siamese silkworms appeared in his 1906 doctoral thesis, which was based largely on his work abroad. All together, he analyzed ten experiments between 1900 and 1905, seven of which were hybridization cases that supported Mendelian theory.[10] Despite all previous discussion about longer silk cocoon thread length as a measure of improvement, the doctoral thesis reported little on cocoon characteristics such as shape, amount of silk floss (the fluff

[8] Mark Largent, "Bionomics: Vernon Lyman Kellogg and the Defense of Darwinism," *Journal of the History of Biology* 32 (1999): 465–488.
[9] This research is dated as having been completed on June 20, 1905.
[10] Toyama also found a Japanese–European mosaic in 1901.

surrounding the actual cocoon from which silk is reeled), and texture.[11] Instead, the overall study, written in English, concentrated on questions concerning the heredity of cocoon colors, with egg color and larval markings receiving peripheral attention.

Toyama concentrated his analysis on crosses between Siamese white and yellow races, in which "yellow" females and "white" males produced all-yellow cocoon spinners. Toyama referred to silkworms as "yellow" or "white" not just because of their cocoon colors, but because of their corresponding blood color, which could be seen through the translucent skin of their abdominal legs.[12] Toyama carried out nine generations of sibling crosses, observing the number of white and yellow larvae that resulted from various combinations of sibling crosses in order to make a pedigree chart. He summarized his findings thus: "the white character, when once separated from the yellow, persists, the yellow form never being produced from it."

> With the yellow form it was different. Although they were bred inter se, they never produced uniform offspring: Some of them produced only yellow offspring which remained constant, as in the case of the white; others produced yellow offspring, which, however, split up into the two parental characters in subsequent generations . . . [13]

Toyama's 1906 study included a report of another experiment on cocoon color conducted in the spring of 1903. Toyama crossed white univoltine Japanese silkworms with yellow multivoltine Siamese silkworms, which yielded larvae that produced all-yellow cocoons.[14] Yellow was the dominant color (see Figure 7). Toyama felt that

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[11] The 1906 work totals 391 pages, not including illustrative and photographic plates. Discussion of cocoon construction and morphology begins on page 359, lasting five pages. This data did not explicitly relate to Mendelian laws.

[12] Toyama, "On the Hybridology of the Silkworm," p. 263. During the Meiji period, both yellow and white cocoon colors were marketed, but in comparison to characteristics specifically tied to quantity, color preference was not the only driver of silk improvement.

[13] Toyama, "On the Hybridology of the Silkworm," pp. 279–280.

[14] Toyama Kametarō, "On Certain Characteristics of the Silk-Worm Which Are Apparently Non-Mendelian," *Biologisches Centralblatt* 32, no. 10 (1912): 593–607. Voltinism is a character that was known among breeders to follow normal patterns of inheritance but could adjust with temperature. The Japanese variety was *Aobiki* (Toyama, "On the Hybridology of the Silkworm," p. 311). Of 29 worms,

Mendel's law would be useful for breeders to select cocoons and larvae. He wrote in English:

> the results obtained with the silk-worm may have some economic importance, since they would give some help for the selection of cocoons and larvae which is one of the difficult and most important things for silk-worm breeders . . . This difficulty will be overcome if we follow Mendel's law, which is highly [] recommended to worm-breeders for the selection of their breeds.

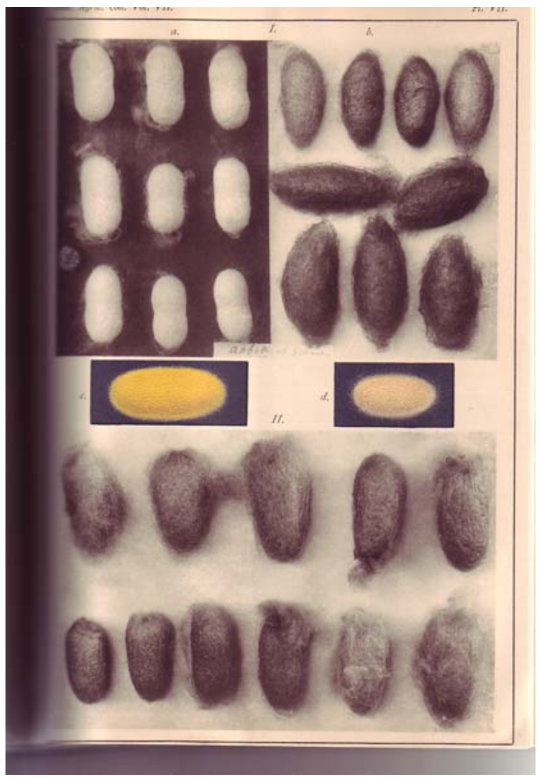

Figure 7. Plate from Toyama 1906 depicting Japanese cocoons (upper left), "Siamese" cocoons (upper right) and the resulting cocoons of their hybrid cross. Reproduced from Toyama Kametarō, "On the Hybridology of the Silkworm," *Bulletin of the Tokyo Imperial University College of Agriculture* 7, no. 1 (1906): 259–393, plate 7.

Here, we see how the concerns expressed in Toyama's thesis were grounded in practical application of Mendelism to sericulture. Separating different cocoon colors

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Toyama noted that 12 survived to spin yellow cocoons. Toyama added that most of the moths produced from this first cross-generation were univoltine (Toyama, "On the Hybridology of the Silkworm," p. 280).

biologically, rather than by physical cherry-picking, was just one potential outcome of hybridization science if producing consistent qualities were an aim. This likely seemed useful at the time, considering consumers who had preferences for white or yellow raw silk.

Harnessing these laws of heredity would make it possible to reduce the time it took to extract certain qualities out of a variety. Within a variety, multiple colors could exist, much in the same way there are different animal coat colors. Toyama noted in his dissertation that in France it became possible only after about 75 years to cultivate a "pure white race" from a "mixed yellow race" of silkworm.[15] Now, Toyama accorded, scientific hybrids would allow people to distinguish and select within a variety to segregate between "races." This was not exactly the same as making a new variety, and also differed from the usual lengthy process of selecting individuals within an inbred line, generation by generation.[16]

Let us return to the crossing experiment that resulted in all-yellow offspring. Toyama cross-hybridized a male and female from that sibling cohort. This mating event yielded 412 eggs, of which 138 hatched into larvae. Interestingly, when Toyama counted the survivors, he observed 35 white and 103 yellow worms, which respectively yielded white or greenish-white cocoons (12 and 24, respectively), and yellow or pale-pinkish-yellow cocoons (70 and 21, respectively). His data on larval leg color reflected a Mendelian ratio, but in assessing the cocoon colors, Toyama wrote,

> the worms raised were not [all] derived from a single parent and consequently we are unable to draw an exact conclusion [with regard to] the mutual relation between those various kinds of worms, yet it is [an] interesting phenomena of

[15] This was parenthetically called "Sina," presumably from China in origin.
[16] A complete analysis of Toyama's doctoral thesis in comparison with the silkworm inheritance experiments of Vernon Kellogg is undertaken in Onaga, "Toyama Kametaro and Vernon Kellogg: Silkworm Inheritance Experiments in Japan, Siam, and the United States, 1900–1912."

heredity, since both parent races hitherto have never spun any pale-pinkish-yellow or greenish white cocoons, as far as we have experimented.

> We may, therefore, conclude that as a result of the crossing, new characters – which perhaps have lain hidden for ages – appeared in this case.[17]

Toyama focused on the yellow form and crossed them. The broods were produced in the following groupings:

1. uniform yellow

2. yellow 3 : white 1

3. yellow 3 : pale-pinkish-yellow 1

4. yellow 56.43% (60.99) : pale-pinkish-yellow 19.57% (17.02) : white and greenish-white 23.98% (21.98)[18]

The second filial generation gave rise to four combinations of offspring, and the third filial generations consisting of a yellow sibling cross once again yielded the aforementioned proportions and kinds of offspring. Toyama discussed this experiment as evidence of the "truth of Mendel's opinion" on mono- and dihybrids. In the silkworm, which produced four kinds of offspring from different combinations of parental characters, Toyama suggested that the first three kinds of offspring reflected a monohybrid situation and that the fourth was a dihybrid.

Toyama found a constant relationship between the four characters and concluded that there are some compound variables that act as one independent character. In this case, the greenish-white color was active and the white color was latent in crosses where the yellow character was not part of the parentage; and white was present at 6.25 percent, whereas greenish-white was present at an 18.75 percentage. When white was completely "active," it accounted for a full 25 percent of the progeny. Toyama suggested that the compounded characters were visible only

[17] Toyama, "On the Hybridology of the Silkworm," p. 281.
[18] Ibid., p. 375.

upon crossbreeding with other new characters. Commenting on work by Castle and by Allen, which suggested that albino organisms also possess pigment-producing traits that segregate, Toyama suggested, "there are many compound characters which behaved exactly like a single character, when paired inter se."[19] Toyama explained that the pale-pinkish-yellow character was not an intermediate form, but that it was instead transmitted through Japanese white parents, that is, it was lying "dormant" in whites, which Toyama was able to call "absolutely recessive."[20] It was only possible to see this recessive character after a cross with Siamese yellow parents.[21]

He noted that in the "highest dominant form, all the others may lie dormant for a generation sometimes more." It was from this latency of the recessive characters that Toyama could tease apart the phenomenon of segregation of the parent-characters, thereby strongly suggesting a verification of the Mendelian principle.[22]

b. When Traits Combine

One feature that Toyama came to believe as a result of his research was that the characteristics of organisms reflect a combinatory process of production. For the purposes of comparison with the work of Vernon Kellogg, one more crossing

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[19] William E. Castle and G. M. Allen, "The Heredity of Albinism," *Reports to the Evolution Committee of the Royal Society*. London, 1903; Glover M. Allen, "The Heredity of Coat-Colour in Mice," *Proceedings of the American Academy of Arts and Sciences* 40, no. 2 (1904): 61–163; Toyama, "On the Hybridology of the Silkworm," p. 377.

[20] Toyama, "On the Hybridology of the Silkworm," p. 313. Toyama may not have counted all of the greenish-white cocoons apart from the white cocoons, which may clue us in to the possibility that Toyama analyzed his data after gaining more knowledge of Mendelism. He seems to have sometimes combined data for greenish-white and white cocoons (Ibid., p. 283). He notes of the greenish-white cocoons, "In this form, as in the preceding [pale-pinkish yellow, the sib-cross of which gave rise to 25% white and 75% pale-pinkish-yellow], we have two kinds of worms, one spinning pure white cocoons and other light-greenish-white cocoons, in the next generation. Although we failed to count the number of both forms, yet we have good reason to believe that they will follow the same law governing the heredity phenomena of the other colours mentioned above" (Ibid., p. 313).

[21] Toyama found that the pale-pinkish-yellow silkworm cocoon appeared in crosses of French yellow (*Var*) and any Japanese whites (*Usuaka* or *Kuniichi*, for example) or some divoltine races. Ibid., p. 313.

[22] Ibid., p. 386.

experiment deserves particular attention.[23] In a hybrid cross between Japanese silkworms with common larval markings (C) and Siamese striped breeds (S), Toyama arrived at an intriguing distinction between "natural" and "artificial" combinations of colors or patterns appearing in filial generations.[24] The artificiality referred to the surprising observation of the "pale" variety (P) of silkworm that resulted alongside common and striped silkworms in Mendelian ratios.

Toyama had already known of the "pale" variety, but he was surprised to observe it appearing in combination with common and striped as a result of the common–striped hybrid cross, the results of which he described in his dissertation.[25] He found the occurrence of the "pale" variety in the F1 generation surprising and called it "artificial" because he had never known it to appear before in this particular constellation of cross-hybridization. This itself did not disturb his view of Mendelian inheritance, however.[26] In fact, this experiment would allow Toyama to assert that the "phenomena of the segregation of parental colors in the second generation" was the same in both "natural" and "artificial" cases.

When Toyama hybridized common silkworms with striped silkworms, he found that the random matings resulted in three kinds of groupings of larval offspring: uniform striped; a mixture of striped and common worms in a 1:1 ratio; and a mixture of three kinds of worms in the ratio of 2 S : 1 C : 1 P. A second-generation sibling

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[23] Of the seven hybridization experiments, two are not discussed in the present paper: 1) larvae with striped patterns × "pale" breeds; and 2) "pale" breeds spinning yellow cocoons × striped larvae spinning white cocoons. Toyama's case studies included analyses of silkworm egg color, and cocoon morphology. While egg color and cocoon morphology is pertinent to the current paper and will be discussed as needed, the information about the mosaic data is discussed in Onaga, "Tracing the Totsuzen in Tanaka's Silkworms: An Exploration of the Establishment of Bombyx mori Mutant Stocks."

[24] Toyama, "On the Hybridology of the Silkworm," p. 379.

[25] Ibid., p. 326.

[26] This experiment allowed Toyama to assert that the "phenomena of the segregation of parental colors in the second generation" was the same in both "natural" and "artificial" cases. For more discussion of Toyama's silkworm inheritance experiments and their significance, see Onaga, "Toyama Kametaro and Vernon Kellogg."

cross of the striped larvae gave rise to further segregation of the parental characters, giving rise to a roughly 12 S : 3 C : 1 P ratio. A further sibling cross of striped silkworms from this cohort gave rise to a variety of kinds of larvae. Toyama called the pale characteristic "dormant" to that of the common or striped form.[27] He explained that this occurrence of a variety of larval forms bears similarity to the occurrence of multiple cocoon colors from a previously observed cross between a white Japanese and yellow Siamese cross. "In the latter case, however, the combination "yellow+pale-pinkish-yellow+greenish white and pure white" is natural, while in the former the combination "striped+common+pale" is artificial. Toyama saw this distinction between the natural and artificial based on his knowledge of what kinds of combinations of larval characters had hitherto been known to occur in sericulture. That there is a distinction at all may seem odd, if not artificial, and this was not entirely lost on Toyama, who concluded that the resulting biological phenomena were quite the same in both cases. According to Toyama, this was the first time a "new combination of characters" appeared as a result of his experiments.[28]

The combinatory effects intrigued and inspired Toyama. He compared the phenomenon of the production of a "new constant form having both parental characters commingled" to Bateson's 1905 work on the creation of the "walnut" comb in poultry. For silkworms, Toyama wrote that George Coutagne showed that black and striped characters both appeared to be "active" characters in 1902, which Toyama claimed to have verified in Chinese races of silkworms.[29] Evoking de Vries's work on Antirrhinum (snapdragon), Toyama also suggested that these results together "may afford excellent illustrations for the hybridological analysis and synthesis of plants and animals." He added, "These very facts and considerations referred to in the preceding

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[27] English descriptions are Toyama's original terms.
[28] Ibid., p. 351.
[29] A record of this experiment does not appear in Toyama, "On the Hybridology of the Silkworm."

paragraphs furnish a further welcome proof for the correctness of the Mendelian theory and confirm that his theory may be applied, with equal exactness, both for animals and plants."[30]

2. Vernon Kellogg and Darwinism

Where Toyama interpreted the production of a new character as corroborating evidence for understanding Mendelism, the binary on which it hinged—the artificial and the natural—represented a far weightier kind of boundary to the research concerns of Vernon Kellogg, who challenged Toyama's idea that all cocoon colors of all silkworms "behaved" in agreement with Mendelian principles.

Kellogg was trained as an entomologist at the University of Kansas, Cornell University, and the University of Leipzig. In 1894, Stanford's president, the natural historian David Starr Jordan, hired him to begin an assistant professorship in entomology at the university following the hiring of Kellogg's teacher and mentor, John Henry Comstock, from Cornell. Kellogg shared Comstock's view that evolution should be a concern to all researchers in biology.[31] In an extensive study of Kellogg's career and intellectual interests, the historian of biology Mark Largent discusses in detail Kellogg's work in bionomics, "the study of organisms in controlled settings that approximated as nearly as possible their natural environments." Kellogg sought to combine approaches in experimental biology with natural settings of organisms in order to study their evolutionary history in as close to a natural state as possible.[32] While recognizing theoretical weaknesses in Darwin's theory of natural selection,

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[30] Toyama, "On the Hybridology of the Silkworm," p. 379.

[31] Mark Largent, *These are the Times of Scientific Ideals: Vernon Lyman Kellogg and Scientific Activism, 1890–1930* (Ph.D. diss., University of Minnesota, 2000), pp. 39–51. Jordan hired Comstock in 1892.

[32] For discussion of Kellogg's adoption of bionomics, and information on Kellogg and Comstock's interests in evolution, see Largent, "Bionomics: Vernon Lyman Kellogg and the Defense of Darwinism"; *These are the Times of Scientific Ideals*.

Kellogg sought to inform and overcome these problems through the use of bionomics in concert with experimental biology. By 1898, Kellogg headed the Bionomics Department at Stanford.[33]

In addition to research pertaining to this field, Kellogg offered an explicit discussion of bionomics in *Evolution and Animal Life*, co-authored with Jordan in 1907. Taken as a philosophically unburdened synonym for Organic Evolution, a term coined by Patrick Geddes, Jordan found bionomics interesting as a discipline that would bridge the gap between the biological and social sciences, while Kellogg viewed bionomics as a methodology dependent on the creation of controlled environmental settings that would be as proximate to nature as possible.[34] In his 1907 publication *Darwinism To-Day*, Kellogg surveyed the state of Darwinism in the biological sciences. He also emphasized that the methods of experimental biology should be used to contribute to the understanding of evolution. In short, Kellogg was a defender of Darwinism: "To my mind every theory of heterogenesis, of orthogenesis, or of modification by the transmission of acquired characters, confesses itself ultimately subordinate to the natural selection theory . . ."[35]

Kellogg's promotion of bionomics occurred around the same time as Toyama's silkworm experiments. Both researchers worked in response to burgeoning research trends in biology, especially Mendelism, but while Toyama sought to present as clear a proof of Mendel's laws as possible using the silkworm, Kellogg was concerned with

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[33] Largent, "Bionomics: Vernon Lyman Kellogg and the Defense of Darwinism."
[34] David Starr Jordan and Vernon Kellogg, Evolution and Animal Life; an Elementary Discussion of Facts, Processes, Laws and Theories Relating to the Life and Evolution of Animals (New York: D. Appleton and Co, 1907), p. 1; Largent, "Bionomics: Vernon Lyman Kellogg and the Defense of Darwinism," p. 472.
[35] Vernon Kellogg, *Darwinism To-Day: A Discussion of Present-Day Scientific Criticism of the Darwinian Selection Theory, Together with a Brief Account of the Principal Other Proposed Auxiliary and Alternative Theories of Species-Forming* (New York: Henry Holt, 1907), p. 375. Darwinism Today numbered among the timely surveys of the state of Darwinism at the turn of the twentieth century discussed in Bowler, *Eclipse of Darwinism*. Largent, "Bionomics: Vernon Lyman Kellogg and the Defense of Darwinism," analyzes Kellogg's seminal text in order to disengage it from the "eclipse of Darwinism" (p. 7).

the rapid growth in experimental biology that would steamroll Darwin's theory of natural selection without more critical understanding. With regard to experimental biology, raising T. H. Morgan's "Experimental Zoology" (1907) as an example, Kellogg explained,

> This work includes the controlled modification of conditions attending development and behaviour, and the pedigreed breeding of pure and hybrid generations. Now this combination of destructive critical activity and active constructive experimental investigation has plainly resulted, or is resulting, in the distinct weakening or modifying of certain familiar and long-entrenched theories concerning the causative factors and the mechanism of organic evolution. Most conspicuous among these theories now in the white light of scientific scrutiny are those established by Darwin, and known, collectively, to biologists, as Darwinism.[36]

Kellogg also acknowledged what Darwinism could not do: explain the "beginnings of change, the modifications in indifferent characters and in indifferent directions."[37] *Darwinism To-Day* ultimately made a case for an "*intensive study of variability*" in order to understand the "causes-of-evolution problem." To pursue this, Kellogg called for "experimental study of the stimuli, external and internal, the influences, extrinsic and intrinsic, which are the factors and causes of variation, – this is the great desideratum; this is the crying call to the evolution student."[38]

The text contained a thorough survey of the theories of species formation that are "auxiliary" or "alternative" to selection. Of particular concern to Kellogg were three general groupings of theories that had potential to "replace the selection theories

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[36] Thomas H. Morgan, *Experimental Zoology* (New York: Macmillan, 1907); Kellogg, *Darwinism To-Day*, p. 2. Kellogg took care to emphasize that his interest focused on Darwinism, the "causo-mechanical theory to explain the transformation of species and the infinite variety of adaptive modification of natural selection" (p. 15). He distinguished it from the theory of descent, which would depend on a "satisfactory explanation of the . . . stages in the modification of organisms . . . to relieve Darwinism of its necessity of asking natural selection to find in the fluctuating individual variations a handle for its action; an explanation of how there ever comes to be a handle of advantage or disadvantage of life-and-death-determining degree" (p. 376).
[37] Ibid.
[38] Ibid, p. 378.

as explanations of species-forming and evolution": Lamarckian theory, orthogenesis, and heterogenesis (mutation theory). Kellogg wrote that few would hold any of these theories exclusive to natural selection, but that they offered "distinctly substitutional methods of species-forming, and one of them includes certainly the most favoured explanation, next to selection, of adaptation, while the others or later up-holders of some of them actually deny any constructive, that is adaptational, species-forming or descent-controlling, influence of natural selection."[39] That is, acceptance or rejection of Lamarckism "depends almost entirely on one's attitude toward a single fundamental part of it, namely, the assumption that variations, modifications, or characteristics acquired during the lifetime of an individual . . . can be transmitted by this individual to its offspring."[40]

Kellogg was not interested in a blanket dismissal of these theories; nor was he interested in simply proving the validity of one theory over another.[41] Rather, he felt that "one of the most obvious reasons for the present strong reaction against the selection theories" was due to the selectionists who had neglected to pay "sufficient attention to the origin and causes of the variation which is such an indispensable basis of their theory . . ."[42] Kellogg wanted to encourage research of these theories through a bionomic research program. This investigational program would make it possible to understand species formation by overcoming the explanatory loopholes presented by natural selection.[43] As for natural selection alone, Kellogg thought it provided insufficiently for the possibility of a double explanation for cumulative variation: "1)

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[39] Ibid, p. 262.
[40] Ibid, p. 263.
[41] "Certainly the mutations theory is not yet ready to offer itself as an explanation of adaptation, however confidently it may claim to be enrolled among species forming factors . . . Nor can Lamarck's beautiful explanation of adaptation claim validity, until the actually of its fundamental postulate, the carrying over of ontogenic acquirements into phylogeny, be proved . . ." (Ibid., p. 377).
[42] Ibid., pp. 378–379.
[43] This will be elucidated in Kellogg's counter with Toyama over silkworms in subsequent pages of this paper.

orthogenetic or determinate variation as the outcome of plasm preformation or of epigenetic influences, and 2) the segregation of similar variations by physiological or topographic conditions."[44]

Oversubscribing to one theory was a problem in Kellogg's view, and he found Luther Burbank's plant-breeding work to be of particular concern. In 1906, he published an article in *Popular Science Monthly*, which he reprinted in *Darwinism To-Day,* that both lauded the "Wizard of Horticulture" and assessed the science behind his ability.[45] This began with a curt introduction: Burbank "has so far not formulated any new or additional laws of species-change, nor do his observations and results justify any such formulation, and we may rest in the belief that he has no new fundamental laws to reveal."[46] Continuing, Kellogg revealed,

> He is wholly clear and convinced in his own mind as to the inheritance of acquired characters; . . . and also convinced that the only unit in organic nature is the individual, not the species . . . He does not agree at all with de Vries that mutations in plants occur only at certain periodic times in the history of the species, but rather that, if they occur at all, they do so whenever the special stimulus derived from unusual nutrition or general environment can be brought to bear on them. He finds in his breeding work no prepotency of either sex as such in inheritance . . . He believes that no sharp line can be drawn between the fluctuating or so-called Darwinian variations and those less usual, large, discontinuous ones called sports.[47]

Kellogg then clarified:

> Ordinary fluctuating variation goes on under ordinary conditions of nutrition, but with extraordinary environmental conditions come about extraordinary

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[44] Kellogg, *Darwinism To-Day*, pp. 379–381. This reasoning echoes Kellogg's reflection of Yves Delage's *variation générale.* Under this theory, species change takes place because of "inducing influences," or "use and disuse and the 'conditions of life' (nutrition and climate) that go on to impact the germ plasm and produce variation" (Ibid., p. 289).

[45] See Kellogg, *Darwinism To-Day*, pp. 310–319 or Kellogg, "Scientific Aspects of Luther Burbank's Work," pp. 363–374. For a popular overview of Burbank, see "Luther Burbank, Wizard of Horticulture –The Man and His Work," *New York Times*, 1905.

[46] Kellogg, *Darwinism To-Day*, p. 310.

[47] Ibid.

> variation results, namely discontinuous, sport or mutational variation. These variations are the effects of past environment also, having remained latent . . . So-called *new* qualities are usually, if not always . . . simply new combinations of old qualities, both latent and obvious. . . .[48]

In this critique of Burbank's Lamarckism, Kellogg's carefully utilitarian view of the phenomenon of the inheritance of acquired characteristics emerged: the occurrence of mutations could be catalyzed by external stimuli. This alternative explanation for the production of variation would lend support to Kellogg's suspicion that Mendelian principles did not solely govern the appearance of new characteristics in organisms. In a biological experiment that manipulated the environment of silkworms, Kellogg would be able to contrast his views with those of Toyama.

a. Bombyx for Bionomics

Kellogg was in charge of a research group in the entomology department at Stanford that undertook bionomic methodologies. His nuanced views regarding the "destructive criticism" of the theory of acquired characteristics and ergo his promotion of "experimental study of the stimuli" are further understood by an examination of his bionomic research.[49] First, a glimpse at Kellogg's stance toward Weismann's germplasm work, stated earlier in *Darwinism To-day*, provides critical insight into the orientation of his experiments. He praised Weismann's many analyses that found "alleged cases" of inheritance of acquired characters to be false or uncertain, and concurred, "Our knowledge, too, of the mechanism of heredity makes strongly against the theory of the inheritance of acquired characters." Kellogg then pressed the issue, raising many questions about the external conditions, such as temperature, humidity, magnetism, and "certainly anything influencing the food supply and nutrition," that

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[48] Ibid.
[49] Ibid., p. 378.

may affect germ cells.[50] Kellogg's own case study of the inheritance of acquired characteristics centered on the mulberry silkworm, *Bombyx mori*.

Two of Kellogg's scientific publications on *Bombyx* are notable. One appeared in *Science* in 1903 and tested the effects of starvation on silkworm larvae; the other addressed the topic of Mendelian inheritance in 1908. Both adhered to Kellogg's support and promotion of bionomical research methods.[51] In light of Kellogg's concern for the state of natural selection studies, the issue of Mendelian inheritance was given more deliberate consideration in the 1908 paper, which appears to be a response to Toyama's 1906 study.

Between 1901 and 1903, Kellogg and Ruby Green Bell worked to achieve the "exact quantitative relation which quantity and quality of food bear to the development and variations of the individual insect and its progeny." They measured a number of characteristics, including weight, the duration of each instar or larval growth stage, time of spinning, weight of silk, weight of pupae, and so forth, in order to understand the effects of underfeeding in either successive or alternating generations.[52]

Kellogg found a "definite and constant relation" between food and larval weight over two to three generations. By the third generation, he was able to produce a "diminutive, but still fertile, race of Lilliputian silkworms, whose moths, as regards wing expanse, might join the ranks of the micro-Lepidoptera almost unremarked."[53] Successive silkworm cohorts produced from previously starved silkworms were also more susceptible to premature death, even if environmental cues such as food,

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[50] Kellogg was not interested in opposing the distinction between soma- and germplasm (Ibid., p. 267).
[51] Vernon Kellogg and Ruby G. Bell, "Variations Induced in Larval, Pupal and Imaginal Stages of Bombyx Mori by Controlled Varying Food Supply," *Science* 18 (1903): 741–748; Vernon Kellogg and Ruby G. Smith, *Inheritance in Silkworms, I.*, Leland Stanford Junior University Publications University Series, Stanford: Stanford University, 1908.
[52] Kellogg, *Darwinism To-Day*, p. 298.
[53] Ibid., p. 299.

temperature, room size, and humidity were made identical. Moreover, normal feeding did not make larvae, "which undoubtedly varied *congenitally* at the start" or "in embryo," develop to full-size if their parents were starved.[54] Starvation also affected survivorship of subsequent generations. The offspring of these subsequent "lots," or generations, were "testimony for the existence of individual variations which cannot be defined anatomically, and yet which serve as 'handles' for natural selective agents." He called this a "physiological variation," and larvae that survived metamorphosis were deemed "in best trim physiologically."[55] Most revealing with respect to his stance toward Weismann was Kellogg's analysis of the effect of food reduction on fertility, or the number of eggs produced, as well as their quality: "a famine suffered by the parents works its way into the germ-cells so that most of their progeny have but a poor birthright." However, the survivors had "congenital qualities of adaptability," according to Kellogg.[56]

3. Kellogg, Bombyx, and Mendelism

If the environmental impression on the germ cells of successive progeny was the crux of Kellogg and Bell's 1903 message, then their key methodological point was that they could produce "authentically determined data" for a single animal species and show a definite and constant relationship between varying nutrition and variation. The generational data should "afford us exact evidence . . . touching the prepotency of sex, of sports, of particular characters and of vigor, as well as evidence regarding fertility in relation to age, and evidence concerning genetic and physiological selection."[57]

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[54] Ibid., pp. 300–301.
[55] Ibid., p. 304.
[56] Ibid.
[57] Kellogg and Bell, "Variations Induced in Larval, Pupal and Imaginal Stages of Bombyx Mori by Controlled Varying Food Supply," p. 741.

Kellogg's intimate knowledge as an entomologist of a wide range of insects had gained him various insights into the study of natural selection. In "Studies of Variation in Insects," cowritten with Bell in 1904, he marveled at the steadfastness of insect body structures and physiological processes despite the diversity of individual insects. He especially noted that insects sharply compete for space and food, and that "At the same time the abundance of individuals insures a wealth of small variations, and an increased chance for larger variations, *i.e.,* 'sports.'"[58] To Kellogg, the combination of abundant variation and sharp competition meant that natural selection was clearly operating and observable in insects. As a researcher, he found insects easy to collect and study, and it was easy to breed multiple generations "in the vivarium or laboratory, under practically natural conditions, or under conditions of controlled varying nutrition, temperature, light, humidity, etc., thus affording opportunity for studies in heredity and for experimental studies demanding accurately determined controlled changes in conditions of life."[59]

The emphasis on either maintaining natural conditions or creating strictly controlled environments for captive insects was methodologically critical to Kellogg because of the tangibility of observational fidelity in the postembryonic development of insects. This would ultimately bolster Kellogg's programmatic objective of distinguishing between "strictly blastogenic (congenital)" and acquired variations.[60] For example, in insects that metamorphose (winged insects such as *Bombyx mori*), identical levels of external stimuli, such as nutrition, temperature, humidity, or light could be directed at members of a brood so that little to no external stimuli could actually cause variation. Only by achieving such a condition, Kellogg explained, could

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[58] Ibid. See page 207 for discussion of the appropriateness of using insects for studying natural selection.
[59] Ibid.
[60] Ibid.

any resulting variations be ascribed to “prenatal influences,” or blastogenic “intrinsic causes.”[61]

Although in the introduction to their 1908 monograph Kellogg and Smith claimed that they had actually begun studies on the modes of inheritance of about fifteen races of silkworms in 1904 in order to examine the inheritance of eggs, larvae, and cocoon characters, Kellogg’s conception of the congenital or blastogenic in 1904 offered no discussion of Mendelism. By using controlled inbred and hybrid matings of individual silkworms, they aimed to test the Mendelian principles of inheritance and the “potency in heredity of vigor, of sex, and of special characters.”[62]

a. A Debate over Larvae and Cocoon Characters

The analysis that Kellogg and Smith offered in *Inheritance of Silkworms* (1908) outlined what he deemed the differences between larval and cocoon inheritance, which provided the premise of his main critique of Toyama’s support of Mendelism. Kellogg differentiated between silkworm characters at each life history stage of the insect, and he further demarcated characters between those that had been the object of long-term breeding and those that had not. He drew a line between silkworm characteristics that resulted whether by “fluctuating variation and by occasional sport (reversional or mutational) variation,” and the more “commercial” characters such as tenacity, diameter, length of thread, as well as cocoon color, larval colors and patterns, adhesiveness of egg, and egg size. Yet, the line involved more than just recognizing commercially important traits. The “commercial” characters had “long been bred pure” and led to a separation of races. Commercially valuable qualities of silk, disease

[61] Kellogg and Bell, “Studies of Variation in Insects,” pp. 210–211.
[62] Kellogg and Smith, *Inheritance in Silkworms, I*, pp. 4–7. Kellogg began his monograph with an overview of the races and characteristics of the silkworm (Bagdad, Istrian, Japanese White, Japanese Green, Chinese White, Italian Yellow, French Yellow, Persian Yellow, Turkish and French Yellow, etc.) The characteristics were broken down for egg, larval, cocoon, and adult stages.

resistance, larvae tameness, and other characteristics had been the object for centuries of conscious and unconscious efforts to increase silk quality and quality. As a result, Kellogg found the fixedness of various races to be stable and reliable for inheritance experiments.[63]

Despite lauding the results of breeding, Kellogg tabled discussion of any commercial implications of his 1908 monograph.[64] Rather, the "nature and distinctness of the varying distinguishing characteristics of the races and their steadfastness in transmission (in pure matings) were the important matters of silkworm differentiation rather than the geographical or historical or commercial relations of the various races."[65] Kellogg believed that silkworms were already purified into many stable kinds and that this ease of recognition would make it possible to conduct research, despite any present-day or historical intermixing of silkworm "races." Kellogg appreciated that he could study the "behavior in inheritance" of both discontinuous and continuous variation in a single organism, the silkworm.[66]

In answer to this, Kellogg found Toyama's 1906 silkworm inheritance research intriguing. Toyama's report reflected a full awareness of Mendel's laws and presented data in a Batesonian style, but Kellogg's enthusiasm about Toyama's study was grounded in the fact that their respective work had commenced at around the same time and examined essentially the same characteristics, but achieved different results.[67] In comparison to the work of Georges Coutagne, who published a silkworm study in 1902 without prior knowledge of Mendel or his rediscoverers, the exactitude of Toyama's Mendelian knowledge prior to experimentation remains ambiguous.[68]

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[63] Ibid., pp. 6, 9. I am grateful to Mark Largent, who kindly bequeathed me a copy of *Inheritance in Silkworms.*
[64] Ibid., p. 4.
[65] Ibid., p. 7.
[66] Ibid., p. 8.
[67] Ibid., pp. 10–11.
[68] Georges Coutagne, *Recherches Experimentales sur l'Hérédité chez les Vers a Soie* (Serie A, Théses présentées a la Faculté des Sciences de Paris, 1902).

Coutagne had already been vetted by researchers such as Bateson himself, and "needs no particular exploitation or summing up by me," whereas, Kellogg continued, Toyama's work was not yet publicly evaluated and was open for commentary. It was apt that he compared his work with Toyama's. Through extensive hybrid crossings between silkworms of distinct racial lineages, Kellogg was able to articulate in his own research that characters such as larval color and larval patterns behaved in a Mendelian manner, whereas silkworm cocoon color behaved less consistently. In contrast, Toyama's results suggested that Mendelism guided both larval and cocoon characters. Kellogg found this suspicious and deserving of scrutiny. After all, if they were studying the same species, shouldn't there have been some basic congruence in their overall findings? In their process of seeking a resolution through scientific publications, articulation of the connections between breeding practices and related scientific theories took shape. The dependability of the silkworm as a means to describe the fidelity of Mendelism was questioned.

Kellogg found that his data corroborated Toyama's and that, to an extent, they were "working on sure ground."[69] Kellogg agreed that inheritance patterns for larval color were Mendelian, but he asserted that cocoon colors reflected different, if not irregular, patterns of inheritance depending on the strain or even individual. In fact, Kellogg stressed, ". . . there are irregularities in the inheritance behavior which make it difficult or impossible for me to accept Toyama."[70]

What accounted for this stern criticism? To investigate Mendelian inheritance, Kellogg conducted two reciprocal hybrid crosses between the gold-yellow variety of an Istrian race of silkworms and a white variety of Bagdad silkworms.[71] In one cross,

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[69] Kellogg and Smith, *Inheritance in Silkworms*. "Our science of heredity, based on experimental study, is too new not to welcome gladly independent confirmation of results already once attained" (p. 11)
[70] Ibid., p. 24. Emphasis added.
[71] Istria refers to the largest peninsula of the Adriatic Sea, currently shared by Croatia, Slovenia, and Italy.

the F1 generation yielded all-yellow cocoons, whereas the other yielded all-white cocoons. Further analysis of the F2 generations allowed Kellogg to confirm that the inheritance pattern was actually Mendelian for each crossing, yet he still found the inconsistencies between them puzzling. He found many other conflicting patterns of Mendelian inheritance in which either yellow or white was dominant.[72] Furthermore, this "erratic" behavior was not limited to the dominance patterns of white and yellow cocooners. In crosses between Bagdad white and Japanese green silkworms, all the offspring produced yellow cocoons. He also noticed that in some crosses, a spectrum of colors would appear. He surmised that cocoon colors, while following Mendelian patterns, did not follow strict patterns of dominance and recessiveness, or were barely "rigorously alternative," meaning two characters of an allelomorph did not behave consistently in all silkworm populations. Kellogg put forth a different perspective for analysis of this character by borrowing the phrase "individual idiosyncrasy" from Luther Burbank. In a section of the 1908 report titled "Strain and Individual Idiosyncrasies," Kellogg presented what he believed was actually taking place by coupling silkworm cocoon colors with the concept of "strain idiosyncrasy" to "indicate a varying inheritance behavior of certain characteristics <u>according to races or strains of long breeding</u>."[73]

Kellogg conducted reciprocal crosses of male and female "Bagdad pure race, white larva, white cocoon" with "Italian Salmon, pure race, tiger-banded larva, salmon cocoon" to test the prevalence of individual or strain idiosyncrasies. First,

[72] Kellogg and Smith, *Inheritance in Silkworms*. Kellogg followed a notation convention such that the male would be listed before the female in a "male × female" fashion. He additionally listed that yellow cocoons were dominant in many kinds of crosses, such as Italian Yellow × Chinese White, Italian Yellow × Japanese white, for instance. White cocoons were dominant in the following crosses: Turkish and French yellow × Bagdad white, Persian yellow × Bagdad white (p. 17). Kellogg was not seeking to understand cocoon-color inheritance in terms of what we now call sex-linkage, and he deemed any such correlations as simply coincidental (ibid., p. 20). Sex-linkage became a clearer *Bombyx* research question with Tanaka, "Gametic Coupling and Repulsion in the Silkworm, Bombyx mori."
[73] Kellogg and Smith, *Inheritance in Silkworms*, pp. 18, 23. Emphasis added.

unpredictability of cocoon-color inheritance from the same kinds of parental crosses exhibited "individual idiosyncrasy," according to Kellogg. While larval characteristics could be explained easily by patterns of homozygosity or heterozygosity, he demonstrated the ambiguities guiding cocoon character inheritance in the fore-mentioned crossing experiment. Three kinds of cohorts consisting of all white, all salmon, or a 1:1 ratio of salmon and white cocoons resulted.[74]

In the case of "strain idiosyncrasy," Kellogg showed different patterns of dominance for white cocoon color when he hybridized "Istrian golden-yellow" cocooners with three other kinds of silkworms that spin white cocoons. In a cross with the "Bagdad race," the white cocoon character was dominant. These irregularities led Kellogg to find Toyama's "sweeping conclusions as to the rigorous alternative and Mendelian or in any way thoroughly consistent behavior of the silkworm cocoon colors" unacceptable. While they are a kind of variation, Kellogg began to call these anomalous instances "deviations" from a strictly alternative Mendelian character that can appear within the same race crossings and even within a single group of F2 and F3 generations derived from a common parental or grandparental crossing. Otherwise, the deviations themselves may be characteristic of particular races or strains with a certain cocoon color, he continued.[75]

The reason why larval and not cocoon characteristics were strictly alternative, Kellogg argued, was that humans had subjected the latter to intensive artificial selection during the previous five thousand years, while paying no such attention to the larval characters. Out of the silkworm's entire life cycle, the silkworm's cocoon, not the organism itself, was ultimately the object of cultivation, whereas Kellogg believed that the inheritance of larvae color strictly followed Mendelian principles (of alternative inheritance) because those characteristics were uninteresting to breeders.

[74] Ibid., pp. 18, 23.
[75] Ibid., p. 24.

The silkworm cocoons had furthermore been subject to artificial selection by man for the purposes of producing "more silk, better silk, silk of one color, silk of another color." Larval patterns represented a "natural" diversity, which had "appeared and persisted according to natural processes."[76] The larval and cocoon characters further differed in that the former were "unbreakable, behave consistently and rigorously in inheritance through all possible manipulation." On the other hand, cocoon characteristics "break down" under manipulation and were thought to be "inconsistent in their inheritance behavior and [to] reveal an instability."[77]

Kellogg's tendency to entertain all biological theories became increasingly evident as he sought to explain the inheritance of cocoon colors. However, rather than synthesizing them Kellogg made room for new explanations by eliminating the plausible operation of others: neither artificial selection nor natural selection played any part in the history of larval diversity, since breeders had no interest in larval characters. Even though he had previously stated that larval patterns "behave rigorously in inheritance," he asserted that the silkworm had not been exposed to natural selection for over 4,000 years, so "they have probably arisen as discontinuous variations or sports, or as mutations, if the mutationists will admit them to their charmed circle." To explain the survival of these mutations through inbreeding or otherwise, Kellogg suggested that they must have needed to be endowed with a "certain potency or prepotency," as shown by discontinuous variations, such as mutations.[78]

Kellogg risked potential theoretical self-contradiction in order to conclude that there is a "reality" to mutations in the process of species production that may be more

[76] Ibid., p. 34.
[77] In addition, Kellogg was quite convinced that the double mating of one female with one or more males could give rise to an unpredictable mixture of larval and cocoon characters. He wrote, "The reality of strain potency over character potency is made manifest in these double matings" (ibid., pp. 35, 68).
[78] Ibid., pp. 34–35.

stable than the accumulation of fluctuating variation by a method of selection.[79] Assessing the inheritance of larval and cocoon characters allowed Kellogg to articulate the differences between naturally and artificially established characters. As a result, Kellogg could illuminate the “difficulty of explaining fixed strain, race, and species differences on the basis of selection of fluctuating variations; they seem to point toward explanation of such differences on the basis of continuous variations or mutations.” It was not that the conditions governing the inheritance patterns of larvae and cocoons were wholly different, Kellogg surmised. Although the distinctions between continuous variations and mutations bring about differences in character traits, he suggested that they both give rise to the eventual appearance of “full-fledged” potent discontinuous variation and exhibit the same inheritance behaviors.[80]

b. Toyama’s Experiments in Response to Kellogg

In 1912, Toyama published a further study on “white” breeds of silkworm to respond to Kellogg’s points about the case of “strain idiosyncrasy” regarding the inheritance of cocoon and larval characteristics.[81] The ambiguity of the “white” designation relates to Toyama’s understanding of the link between blood color and cocoon color. In the 1912 publication, Toyama did not distinguish between races that bred true based on human-selected characteristics such as cocoon color or other characters as Kellogg had. Instead, Toyama distinguished between “yellow-blooded breeds” and “white-blooded races” based on examination of the blood color of the larvae visible through the skin of their abdominal legs. Toyama explained that of silkworms that produce yellow cocoons, there are Japanese, European, Siamese, and some Chinese yellows that squarely belong to the yellow-blooded group, whereas Japanese and Korean

[79] Ibid., p. 67.
[80] Ibid., pp. 35–36.
[81] Toyama Kametarō, “On the varying dominance of certain white breeds of the silkworm, Bombyx mori,” *Zeitschrift fur induktive Abstammungs- und Vererbungslehre* 7 (1912): 252–288.

green-cocooners and some Japanese silkworms that produce greenish-yellow cocoons actually belong to the white-blooded race of silkworms. Blood color was a Mendelian allelomorph that corresponded to cocoon color, Toyama explained. He tabulated all previously published hybrid crosses in which white silkworms were shown to be recessive and showed that in Kellogg and Coutagne's experiments, yellow-blooded breeds were generally being used.

He also conducted three crosses between Japanese whites, derived from some conventional Japanese breeds, *Asakanishiki, Aojiku,* and *Onodahime,* which he had bred to be homozygous white since 1907. He hybridized these with homozygous yellows extracted from sibling crosses of European white varieties called "Italian white" and *Sina blanc*. Toyama concluded, "in spite of the same white colour, the nature of Japanese whites is not the same as that of European, since the former are recessive and the latter dominant towards the same yellow."[82] As Kellogg had suspected, not all "white" inheritance patterns were identical. Toyama went on to conduct crosses between the homozygous yellow *Onodahime* with "Italian white No. 11." These white varieties produced a mixture of heterozygous and homozygous whites, which helped explain the production of a 1:1 white to yellow ratio of cocoons in the F1 generation.[83]

Eventually, Toyama outlined a proof that would explain everything and show that cocoon inheritance behaved systematically, not by mutations or other individual idiosyncrasies. In a major study on the "order of inheritance" of white-blooded breeds known to spin colored cocoons separately, he conducted crosses between four varieties of Japanese white silkworms (*Shinkawachi, Aojiku, Asakanishiki,* and *Onodahime*) and two varieties of European white silkworms (Italian white and *Sina*

[82] Toyama, "On the Varying Dominance of Certain White Breeds of the Silkworm," p. 259.
[83] Ibid.

blanc).[84] The crosses either yielded white offspring that bred true, or the offspring produced a combination of white and yellow offspring at a 1:1 ratio. In other words, as shown in birds and plants, Toyama suggested that there might be some white breeds that are composed of antagonistic, meaning both dominant and recessive, whites. He suggested in an extensive proof involving the heterozygous white that the gametic combinations would look like WW × ww = Ww = all whites, or WY × ww = Ww + wY = 1 white + 1 yellow.[85]

The results, according to Toyama, corroborated his 1906 study:

> On the whole, we are, I believe, justified in concluding that the chief causes of so called inconsistent phenomena with Mendelian principles such as Kellogg's strain or individual idiosyncrasies or perturbation in the order of inheritance by double mating are due to the presence of mixed white breeds which were considered as homozygous.[86]

This Mendelian proof involved a heterozygous white in the monohybrid formula. He raised the possibility that there may be a suppressing or inhibiting factor at play, but hesitated to add to that conjecture without further experimentation. "Suffice it now to say that there are two kinds of Mendelian whites in the silk-worm, the one always behaving as epistatic and the other as hypostatic towards the yellow. When both characteristics come together in one breed, they will produce seemingly contradictory results to Mendelian principles," Toyama wrote.[87] In essence, he suggested that the inconsistent cocoon-color patterns were due not to what Kellogg thought—individual

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[84] Ibid., pp. 255–256.

[85] Toyama cited Bateson (1909) to reference crosses between birds in which white is dominant over colored varieties. He noted examples of the same phenomenon in *Primula sinensis* as described by R. P. Gregory, "Experiment with Primula sinensis" and F. Keeble and C. Pellew, "White Flowered Varieties of Primula sinensis." Japanese recessive white was noted as ww; European dominant white WW, and heterozygous dominant white WY (Toyama, "On the varying dominance of certain white breeds of the silkworm, Bombyx mori," p. 261).

[86] Toyama, "On the Varying Dominance of Certain White Breeds of the Silkworm," pp. 285–287. Emphasis added.

[87] Ibid., p. 287.

idiosyncrasies or behaviors—but the mixture of two different whites in one breed of silkworm.

In the same 1912 study, Toyama re-examined Coutagne's and Kellogg's data and found that three kinds of F1 broods were produced, which, when sib-crossed, segregated into white and yellow in the F2 generation. When white dominated in the F1 generation, the F2 generation exhibited a 3 white : 1 yellow ratio. The reverse was true when yellow dominated in the F1 generation. This match between expected and actual data confirmed for Toyama that cocoon color was a regular Mendelian character and that the whites that Kellogg questioned were "mixed races" of dominant and recessive whites – not the result of strain or individual idiosyncrasies.[88]

Including leg color in his analysis allowed Toyama to draw insights that afforded him the theoretical basis not just to believe that silkworm cocoon color was a Mendelian trait, but to set up the detailed proof that offered quite a different reasoning from that of Kellogg. In this instance of mixed dominance and recessiveness of white cocoons found by Kellogg, Toyama ultimately concluded that "Occidental whites" were dominant, "some being a mixture of both antagonistic whites," and that the majority of "Oriental whites" were recessive. Toyama could not recall any record of dominance between Japanese or Chinese white breeds. Rather than strain or individual idiosyncrasies, Toyama took advantage of his understanding of the parallel between "blood color" and cocoons in order to confidently ascertain that the effect of a "mixed breed" more plausibly explained the phenomenon that produced inconsistent dominance and recessiveness of the white cocoon color.[89]

[88] "Double mating" was also ruled out (ibid., pp. 274, 287).
[89] Ibid., p. 287.

4. Institutional, Material, and Practical Understandings of Silkworms and Their Breeds

Although Toyama and Kellogg were contemporaries who seemed to work on the same kind of question using the same species, they reached different conclusions about the inheritance of silkworm cocoon colors, which led them to spar over the suitability of the silkworm to tell a Mendelian tale of inheritance. Each time Kellogg or Toyama picked up a silkworm between their fingers, they managed to glean different kinds of information. For instance, every time Toyama handled a silkworm, he flipped it over to discern its blood color with a glimpse of the inner side of its wriggling legs. Offering a vivid point of comparison, the historian Shigehisa Kuriyama explains, "Greek and Chinese doctors *knew* the body differently because they *felt* it differently," but there was also interdependence in terms of the converse: the doctors felt what they knew.[90] Of course, Toyama and Kellogg were not physicians of the silkworm, and this study does not intend to lay associative claims between knowing the human body and that of the silkworm. Yet, to consider the present case alongside the notion that there can be two different interpretations of the body highlights an opportunity to delve into the simple question of why the scientists knew what to look for when examining a silkworm. Kuriyama explains how that which is sensed shapes language and, in turn, language labels what is felt.[91] Styles of speaking suggest styles of knowing, as seen in the distinct theoretical and practical orientations that informed the silkworm work of Toyama and Kellogg. A consideration of the silkworm in all stages of metamorphosis,

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[90] Shigehisa Kuriyama, *The Expressiveness of the Body and the Divergence of Greek and Chinese Medicine* (New York: Zone Books, 2002), pp. 9–13, 55. In a comparison of Chinese and Greek "ways of thinking" about the body and the medicine, Kuriyama discusses the distances between "'places' in the geography of medical imagination" that accompany varying perspectives. He explains that Greek and Chinese doctors could place their fingers on the "same" place but feel different things, whether a pulse, or a palpation of the skin that serves as an "interrogation" of the *mo* that follows the circulation of blood. For more discussion of East Asian science, see Nakayama, *Academic and Scientific Traditions in China, Japan, and the West*.

[91] Kuriyama, *The Expressiveness of the Body,* p. 64.

then, illustrates how differing perspectives are engendered in institutional and experimental localities.

Tracing the production of new silkworm knowledge across three different geographic locations and intersecting vantage points of American entomology, Japanese sericulture, and, to a degree, Siamese imperial development suggests that different handlings and readings of silkworms led to different distinct rationalizations about the nature of silkworms and their breeds. In American biology, attention to genetics benefited from new experimentation that responded to economic pressures and demands experienced by agricultural breeders.[92] However, Kellogg's bionomic approach to biology did not necessitate silkworm studies, nor did any agricultural or sericultural industry affiliation require it. Toyama's career contrasted with Kellogg's because sericulture developed more clearly as a result of Japan's state efforts to increase its economic capacity through the promotion of scientific institutions.[93] Consequently, analysis of Toyama and Kellogg's research provides an opportunity to further understand the precipice between Darwinism and Mendelism while illuminating the historical institutional relationships between agriculture and biology. As Jonathan Harwood notes, growing social issues related to agricultural industrialization reflect a need to better understand the mutual relationships between agriculture and the development of biological research.[94] In this vein, through

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[92] Diane Paul and Barbara Kimmelman, "Mendel in America," in *The American Development of Biology*, ed. Ronald Rainger, Keith R. Benson, and Jane Maienschein, pp. 281–310 (Philadelphia: University of Pennsylvania, 1988). See p. 282.

[93] Ardath W. Burks, *The Modernizers: Overseas Students, Foreign Employees, and Meiji Japan* (Boulder, CO: Westview Press, 1985), pp. 378, 386; Yoshida Tadashi, "Educational Systems for the Training of Scientists and Engineers in Meiji Japan," in *The Introduction of Modern Science and Technology to Turkey and Japan,* ed. Feza Günergun and Shigehisa Kuriyama, pp. 97–118. (As part of the civilization and enlightenment (*bunmei kaika*) movement in the 1870s and 1880s, many changes and reforms were carried out, and state modernization through the promotion of science and technology education became a priority. Most scientific advancement was directed toward industry and the military.

[94] Jonathan Harwood, "Introduction to the Special Issue on Biology and Agriculture," *Journal of the History of Biology* 39 (2006): 237–239.

examining the tensions within industrializing sericulture work, the present research helps to show why and how the mass production of living things developed.

a. Locating Institutions of Silkworm Research

Even though the business and practices of sericulture existed already, institutional support for Japanese sericulture grew in the Meiji period.[95] Toyama, a landowner's son, did not pursue silk or science because of a familial obligation or privilege. As social order and governance changed in Japan, science and technology gave way to new utilitarian and pragmatic profit-making pursuits, often with the nation's interest in mind.[96] Training for engineering and agriculture was incorporated early on as part of the organization of Japanese universities.[97] The Imperial University took the Tokyo Senior High School of Agriculture and Forestry under its umbrella in 1890, calling it the College of Agriculture. Whereas the initial models for science education were English, American, and German, the Imperial University, which came to include four scientific colleges, Science, Engineering, Medicine, and Agriculture, eventually served as the organizational model for other Japanese universities.[98]

Toyama was a product of Japan's developing educational system, but despite his scholarly achievements, he experienced some instability during the course of his

[95] Tessa Morris-Suzuki, *Technological Transformation of Japan* (Cambridge: Cambridge University Press, 1994).
[96] According to Nakayama, *Academic and Scientific Traditions in China, Japan, and the West*, pp. 206–207, many members of the former samurai class were forced to locate new sources of revenue after the end of the Tokugawa era in 1867. They composed the majority of engineering students compared with conventional fields such as farming or medicine that were dominated by others.
[97] Yoshida Tadashi, "Educational systems for the training of scientists and engineers in Meiji Japan," in *The Introduction of Modern Science and Technology to Turkey and Japan,* edited by Feza Günergun and Shigehisa Kuriyama, 97–118 (Kyoto: International Research Center for Japanese Studies, 1996). Established in 1877, Tokyo University consisted originally of four faculties: Law, Science, Literature, and Medicine. The Science faculty consisted of six departments, chemistry, physics-mathematics-astronomy, biology, engineering, geology, and mining. In 1886, Tokyo University became known as the Imperial University of Tokyo after restructuring to include the engineering college of the Ministry of Public Works.
[98] Ibid.

entire scholarly and professional career, even though the sericulture field was important to the economy of Japan. Toyama entered the Tokyo High School of Agriculture and Forestry in 1885 and graduated in July 1892, after the institution effectively became the Tokyo Imperial University College of Agriculture in 1890. Employment was a function of availability as well as responding to official postings, whether in the Tokyo area, Fukushima, or on a diplomatic mission to Siam. Toyama's studies at the College of Agriculture, working in the Zoological Institute, and working in sericultural education, reflect the tensions that came with pursuing academic scientific research and serving industrial and governmental interests at the same time. After his return to Japan in March 1905, Toyama worked part-time at the College of Agriculture in September 1905 and was officially reappointed as an assistant professor in 1908. In 1909, he was given a dual appointment as an instructor of the Tokyo High School of Agriculture and Forestry. Though Toyama had strong opinions about Japan's silk industry, as a commoner he was less free to direct his work in Japan based on his particular interests, contrary to his experience as a Japanese expert in Siam. Despite his greater responsibilities to establish a new silk industry, in Siam he could work under his own directorship so long as he could acquire the necessary financial and material resources. In Japan, his work had to meet certain orders of his superiors, and his time was also limited by his teaching duties in the new sericultural institutions. The integration of the College of Agriculture into the Imperial University could have made it possible for Toyama to conduct practical research in a scholarly setting; however, his unsettled professional titles and employment suggest other realities about social class, as well as hierarchies and disciplinary structures between the Colleges of Agriculture, Science, or Medicine that may have limited his academic freedom. Ultimately, whether due to a personal choice or because others made it necessary, Toyama had to work where the silkworms were.

Toyama's work coincided with the growth of a network of experiment stations that gained the capacity to diffuse new varieties, provide scientific training, and close links between officials and farmers in order to promote technical change.[99] This was especially apparent when Toyama was called upon to serve on the Production Survey Committee in 1910 by the Japanese government to plan sericultural reform laws. In 1911, Toyama was appointed as an engineer of the National Institute of Silkworm-Egg Production, tasked with conducting research that would lead to the production of parental lines for making commercially viable F1 hybrids.[100] His overall career reflected how scientific research, work, and teaching were inseparable from economic development, politics, and social changes that scientists faced in Japan when expectations about their work were oriented toward state growth. Professional responsibilities took priority as educational and research institutions coordinated their effots, and value was placed on useful, if not profitable work. Most of all, stepping into the sericultural world committed one to the practical issues of working with silkworms, and coordinating within a bureaucratic work structure made it difficult to stray from an expanding network of schools, universities, and experiment stations, whether in the capacity of educator, researcher, or technological expert and advisor.

Although Toyama had considerable exposure to broader theoretical ideas in biology and held ongoing interests in evolution, his workplaces all answered to an obligation to the silk industry. In contrast, Kellogg's employer, Stanford University, did not have nearly the same kind of obligation as American state schools, which participated in a network of diverse kinds of agricultural institutions. Of the various

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[99] Penelope Francks, *Technology and Agricultural Development in Pre-War Japan* (New Haven: Yale University, 1984), pp. 79, 155–160. The first national agricultural experiment station was established in 1886, but not until after the Industrial Co-operative Association Law of 1900 that subsidized the establishment of prefectural experiment stations. Kiyokawa, "The Diffusion of New Technologies in the Japanese Sericultural Industry" also discusses the establishment of silkworm experiment stations.
[100] Takeuchi Nagamasa, ed., *Toyama Kametarō Kinenroku* [Toyama Kametarō Commemorative Record] (Kanagawa Prefecture, Koayumura: s.n., 1940).

educational facilities, some but not all state agricultural colleges were also affiliated with larger research universities or experiment stations. Together, they were meant to address practical, educational, and administrative issues pertaining to the improvement of crops, livestock, and American agriculture in general.[101] Scientific research and agricultural improvement efforts grew along with the demand for application of scientific theories through promotion of experimental breeding by the U.S. Department of Agriculture in the 1880s and 1890s, and by members of the American Breeders Association.[102] Kellogg, himself an ABA member, was already familiar with the responsibilities and expectations of entomological extension work, starting with his experiences at the University of Kansas, and he was aware of agricultural and industrial issues. Quite interested in agriculture and the potential for breeding work to elucidate evolutionary theories, Kellogg and Jordan went to great lengths to support and learn from Luther Burbank.[103] However, Kellogg's silkworm studies were not couched in terms of the economic advancement of a sericulture industry.

At Stanford, Kellogg was not expected to contribute directly to industrial improvement. Under the guidance of Jordan, Stanford culture was said to have encouraged academic freedom, integrity, and activism, but Kellogg's friendship and overlapping scholarly interests with the university president especially helped his

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[101] Research about different kinds of scientific institutions and their relations show how distinct constituents and social goals were associated with various research universities, research bureaus, experiment stations, botanic gardens, agricultural colleges, and private institutions (Kimmelman, "The American Breeder's Association: Genetics and Eugenics in an Agricultural Context, 1903–13," p. 167; *A Progressive Era Discipline: Genetics at American Agricultural Colleges and Experiment Stations, 1900–1920*; "Mr. Blakeslee Builds His Dream House: Agricultural Institutions, Genetics, and Careers 1900–1915," p. 277).

[102] Paul and Kimmelman, "Mendel in America," p. 282; Barbara Kimmelman, "The American Breeder's Association: Genetics and Eugenics in an Agricultural Context, 1903–13," *Social Studies of Science* 13, no. 2 (1983): 163–204, see p. 177. In the 1870s, the USDA sought to increase variation of agricultural products and to produce stable hybrids, but it was in the 1880s and 1890s that agricultural colleges and experiment stations explicitly promoted experimental breeding.

[103] Sharon Kingsland, "The Battling Botanist: Daniel Trembly MacDougal, Mutation Theory, and the Rise of Experimental Evolutionary Biology in America, 1900–1912," *Isis* 82, no. 3 (1991): 479–509; Largent, *These are the Times of Scientific Ideals*.

research program. While Kellogg's research interests related to some of the interests of agriculturalists, he could also afford to take new directions and develop the bionomics field as a result of his inquiries of evolution that expanded while working with Comstock at Cornell and eventually at Stanford.[104] At the time, Stanford University was undergoing a tight economic period following its establishment in 1894, which likely gave Kellogg insight into the importance of institutional authority. Jordan managed the hiring of new faculty and was interested in education reform, but because it was a private institution, the university's benefactor, Jane Stanford, also held great sway over the hiring and tenure of faculty based on the principle of nonpartisanship. The university could not always afford to risk its reputation when scientists had provocative ideas.[105]

Despite having exposure to various issues that would have helped him recognize the kinds of institutional and financial issues related to developing American agriculture, promoting various ideals, or protecting a public image, Kellogg displayed little sympathy for the economic and practical contexts of Toyama's work. Kellogg did not have to fulfill a certain professional role as a state scientist or engineer and did not have to engage with concerns about economic improvement explicitly. However, Kellogg's dispassionate attitude toward the use of the silkworm may also reflect the fading importance of domestic silk culture by the early 1900s and the distinction between sericulture and agriculture. Although the California State Board of Silk Culture was established by the state legislature in 1883 to promote silk cultivation, the governor disapproved a $10,000 appropriation in 1889 on the grounds that the organization "had accomplished nothing" and that California silk could not

[104] Largent, *These are the Times of Scientific Ideals*, p. 38.
[105] Ibid., pp. 16–60. According to Largent's account of the Ross–Stanford incident, Jordan made many efforts to maintain harmony between the university's main benefactor and a controversial social scientist, but it was clear that the title of "scientist" was not enough to ensure job security.

compete with the silk of countries where the cost of labor was lower.[106] These issues of labor economics suggest how sericulture was valued differently from domestic agriculture, which helps explain why silkworm hybridization may not have received as widespread interest among agricultural scientists when many other organisms were subjected to experimentation. The dominant concerns of entomologists working in American agricultural institutions were also different, for insects were understood to be injurious.[107] These various circumstances may have supported Kellogg's academic freedom at Stanford to explore bionomic questions using different organisms and in kind make the continuity of *Bombyx* research difficult. Even though a Japanese entomologist familiar with silkworms, Kuwana S. Inokichi (1871–1933), had worked with Kellogg while a student, Kellogg's focus on *Bombyx* had a temporal limit. In addition, Kellogg's more explicit interests in insect breeding became clearer in 1910, after his *Bombyx* phase of research faded.[108]

In Japan, entomology and sericulture were largely treated as distinct disciplines, given that one had more productive industrial significance than the other. Sericulture was also treated as a separate field from agriculture, despite their scientific overlaps, for unlike crops or livestock, the aim of silkworm cultivation was not to feed people but to exchange silk for foreign capital. Kellogg could conduct his academic research in natural selection and bionomics with little external mandate, but Toyama was responsible to the Japanese and Siamese governments and to the pressures of national survival through industrial development. As an interpretive tool for

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[106] U.S. Department of Agriculture, *Report of the Commissioner of Agriculture* (Washington, DC: Government Printing Office, 1883), p. 101; California Bureau of Labor Statistics, *Biennial Report of the Bureau of Labor Statistics of the State of California, 4* (Sacramento: State of California, 1890), p. 44.

[107] This is exemplified in Kellogg's book *Common Injurious Insects of Kansas,* 1892.

[108] Vernon Kellogg, *Common Injurious Insects of Kansas* (Lawrence: University of Kansas, Dept. of Entomology, 1892). Kuwana studied at Stanford during the period 1898–1902. During this time, he conducted a field collection of insects in the summer of 1900 for Kellogg (Stanford University Entomological Collection: Records, 1891–1929). He had also worked with Comstock.

understanding natural phenomena, Toyama used the silkworm to test and demonstrate the laws of inheritance, but his choice to use the silkworm was not a free one. Obliged to serve the Siamese and Japanese silk industries, Toyama could not afford to stray from *Bombyx mori*. The silkworm's presence in the growing practices of early-twentieth-century experimental biology hinged on its inescapable role in places that prioritized the growth of a silk industry.

b. Interpreting the Silkworm

An understanding of Toyama's and Kellogg's individual experimental approaches to the organism helps clarify why or whether their silkworm work may have depended more on their local circumstances rather than solely on the shared use of the "same" species. The unique histories and cultures of Japan, Siam, and the United States certainly may have informed the individuality of each scientist, but this is meaningful most of all in light of their respective work.[109] Between 1900 and 1912 those who studied the silkworm did so mainly for the sake of the sericultural organism itself. Even though *Bombyx* eventually came to "pass" as a Mendelian organism, in practice, Toyama and Kellogg had distinct understandings of silkworm breeds that informed their technical approaches to the insect.[110] Toyama framed his research priorities and teaching duties in terms of industrial needs, as reflected by his decision to publish

[109] This emphasis on the individuality of experimental systems is illustrated in Rheinberger, *Toward a History of Epistemic Things*. Creager, *Life of a Virus,* which discusses tobacco mosaic virus research, notes that experimental systems involve multiple decisions by researchers about how to isolate or visualize the object or phenomenon of study: "the system registers and reflects the laboratory habit, culture, and training of the researcher." These unstable experimental systems underlie model systems that produce unexpected results (pp. 48, 333).

[110] Such distinctions question whether Toyama's and Kellogg's experimental work could exhibit "a certain material style of research" characteristic of an "experimental culture," in which different experimental systems are held together by material interactions and epistemological compatibility, as described in Rheinberger, *Toward a History of Epistemic Things*. Indeed, numerous living things have also attracted the attention of researchers in heredity and genetics without becoming the model organisms that research communities make and maintain in order to "prototype" questions about biology (Endersby, *Guinea Pig's History of Biology*; Creager, *Life of a Virus*, pp. 5–6, 329).

Sanshuron [Theory of Silkworm Varieties], a lengthy two-volume tome envisioned somehow for a broad audience.[111] His studies of the silkworm served as both the means and the end for understanding its inheritance and consequent improvement. At the time, Toyama's comparison of the silkworm's nature to that of other organisms was couched in order to assure breeders that its genetics was like that of other sexually reproducing animals and plants: tangible and manageable for the purposes of precise and deliberate breeding work.[112]

The silkworm that came under study had already undergone years of crafting by humans, in order to maintain or produce useful or desirable breeds, before hybridization science became widespread. It was not for the purposes of biological investigation per se that scientists fashioned silkworm research at the turn of the twentieth century. Urged by industrialists, the Japanese government promoted experimentation with the aim of increasing the production of silkworms capable of producing cocoons with more uniform raw-silk content that could also withstand the increasing speeds of reeling machines.[113] This was not easily done. Economic and political pressures, the materiality of the silkworm, its silk, labor, filature and reeling machines, and existing ideas about inheritance in the academic literature and farm practices were all issues that Toyama grappled with as he carried out experiments that spanned between Siam and Japan. Toyama's proximity to the issues informed his awareness of the silkworm at each life stage and generated the opportunities to ascertain and analyze the inheritance patterns of the silkworm through close examination of their bodies.

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[111] Toyama Kametarō, *Sanshuron. Vols. 1 and 2* (Tokyo: Maruyama, 1909).
[112] Toyama Kametarō, "Futatabi Shurui Kairyō to Kaiko no Iden ni Tsuite Ichigensu," *Dai Nihon Sanshi Kaihō* 200 (1909): 1–6.
[113] Kiyokawa Yukihiko, *The Development and Diffusion of Improved Hybrid Silkworms in Japan: The First Filial Generation* (Tokyo: United Nations University, 1981). For a detailed account of the materiality and history of silk-reeling and ironworks, see Wittner, *Technology and the Culture of Progress in Meiji Japan*.

Toyama's level of attention to leg color was not just a methodological tactic; it represents how he reconciled the relationship of blood color to cocoon color in a way that decoupled the concept of color from human categorizations of silkworm breeds, varieties, and races. Toyama's success at rearing silkworms came from his familiarity with sericulture and breeding silkworms in Japan and especially Siam, where disease-prone Japanese silkworms in tropical conditions required a heightened alertness in order to keep them alive or to collect data before they expired. Although Toyama was skilled at rearing silkworms, in order to abate the effects of silkworm mortality between silkworm larvae and pupae stages and to preserve the fidelity of data, he examined their leg color as a proxy method for counting cocoons. Leg color "always corresponds to that of the cocoon it will spin; so that, by observing these, we can exactly tell of what colour the cocoons will be. To avoid the loss of worms incidental to rearing the countings were mostly made during the larval stage, but sometimes also by the cocoons."[114] Any ambiguity that emerged in Toyama's reports reflected his understanding that color was embodied in the silkworm's blood and that the cocoon was its externalized form. Most important, Toyama knew that silkworms were not constant entities. They were capable of change, and he strove to understand them with the purpose of improving different silkworm breeds or making new ones.

In contrast, Kellogg's analysis rested upon an understanding that silkworms were already well-bred. He believed that individual silkworms could be mated with ease and certainty. Since large numbers of silkworms could be reared in a limited space, he could run more series of experiments. However, he also believed that races were stable and reliable as a result of hundreds of generations of breeding.[115] This perspective was reinforced by Kellogg's interpretation of silkworm materiality:

[114] Toyama, "On the Hybridology of the Silkworm," p. 263.
[115] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui" countered that humans can quickly damage the integrity of silkworm breeds that have otherwise taken hundreds of years to produce.

silkworm characteristics represented clear life-history points critical to his argument about the implications of domestication, and they were easy to describe and illustrate. Kellogg's methodological point rested on the production of sound data based on numerous repetitions per lot, per experiment. He was quick to admit that one of Toyama's advantages was that he could rear his silkworm broods to "safety" and benefit from working with as close to a complete cohort as possible in order to obtain accurate phenotypic ratios.[116] Kellogg's rationalized *need* to repeat experiments, guised by methodological favorability attributed to greater numbers, provided a way to overcome his higher mortality rates.

For Kellogg, the silkworm's domestication explained the inheritance patterns of certain silkworm characters. Kellogg's stance on the relationship between breeding and the natural and unnatural surfaced in the process of analyzing Toyama's data. Although Kellogg had borrowed the concept of individual and strain idiosyncrasy from Luther Burbank to explain Toyama's data, Kellogg's actual criticism of Burbank's work shows how his opinions on the practice of breeding were formed before critiquing Toyama.

> No new revelations to science of an overturning character; . . . No new *laws* of evolution, but new facts, new canons for special cases. No new categories of variations, but an illuminating demonstration of the possibilities of stimulating variability and of the reality of this general variability as the fundamental transforming factor. No new evidence either to help the Darwinian factors to their death-bed, or to strengthen their lease on life; for the 'man' factor in all the selecting phenomena in Burbank's gardens excludes all 'natural' factors.[117]

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[116] Kellogg and Smith, *Inheritance in Silkworms*, p. 9. In another study by Toyama, Kellogg's data did not match Toyama's hypothesized Mendelian ratios, which he deduced was due to "the small number of worms reared in each mating." Toyama addresses Kellogg's suggestion that some traits were "non-Mendelian" when he stated, that all the characteristics of the silk-worms he studied since 1900, including those which seemed to be non-Mendelian, were really Mendelian (Toyama, "On Certain Characteristics of the Silk-Worm Which Are Apparently Non-Mendelian").
[117] Kellogg, *Darwinism To-Day*, p. 318.

To Kellogg in 1908, Mendel's law operated stably and clearly only when humans had not interfered with breeding. In the silkworm, larval colors and markings were untainted from human manipulation, whereas cocoon colors were not. This stance suggests how Kellogg's lack of experience in practical silkworm-rearing, let alone breeding, colored his interpretations of Toyama's work. While larval characters were not directly economical or practical to silk production per se, silkworm breeders actually had personal preferences that guided the production of markings and colorations of silkworm varieties or helped sericulturists distinguish between varieties. However, lack of experience existed in conjunction with a belief in particularistic manifestations of human selection choices in the heredity of domesticated organisms. Kellogg argued against the naturalness of cocoon color on historical grounds, which kept him from articulating an assumption, this time on Toyama's part, that random breeding, and not just randomicity at the gamete level necessary for Mendelian inheritance, was actually taking place every time Toyama reared full cohorts and allowed them to hybridize.

Toyama's and Kellogg's judgments about the naturalness or artificiality of silkworm characteristics or the general appropriateness of the silkworm to explain Mendelism solidified with each one's response to the other's ideas. Although the two never met, their intellectual work and research practices intersected as the silkworm served dually as *Bombyx mori,* a potential evolutionary puzzle and key to the causes of natural selection, and as *kaiko*, an object of improvement for the enhancement of its coveted silk thread. Toyama's earlier cytology work and association with Ishikawa moored his inheritance work not very far adrift from the teachings of Weismann. This indirectly introduced friction between Toyama's support of Mendelism and Kellogg's concern that Weismann's reductionist theory of the germplasm would erode thoughtful studies of the inheritance of acquired characteristics and natural selection.

Kellogg wanted to improve explanations for species-formation and incorporated various theories, and to this end, his unfamiliarity with breeding licensed him to make creative assumptions based on sericultural practices. Through the process of investigating the inheritance patterns of certain silkworm characters, Toyama and Kellogg each articulated their ideas and experiences regarding silkworm materiality as they discussed their handlings and interpretations of various points of the silkworm's metamorphosis. These silkworm struggles and moments of nonconvergence between the two researchers helped position new knowledge about silkworm nature on a variegated biological research landscape. By 1912, Toyama would catalog at least thirteen independently assorting Mendelian characters. On the other hand, Kellogg's examinations of silkworms were tied to questions about their dependability before they could be trusted for use in further experiments. His *Bombyx* publications stopped in 1908, and reference to them faded from Toyama's literature.[118]

For students of Toyama, it is tempting to claim his place in history as one of the rediscoverers of Mendel's laws (Toyama is said to have lamented over this himself) or that his logic prevailed.[119] More important, the interactions between Toyama and Kellogg in the first decade of the twentieth century show how the silkworm was first and foremost understood as an organism of industrial and commercial importance shrouded in a history of *kakeawase*, mixing, and *kairyō*, improvement, even though it played a central role in the scientists' unique investigations of Mendelism. The work performed on the silkworm during the period

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[118] Toyama Kametarō, "On Certain Characteristics of the Silk-Worm Which Are Apparently Non-Mendelian," *Biologisches Centralblatt* 32, no. 10 (1912): 593–607, especially pp. 596–597; Toyama Kametarō, "Maternal Inheritance and Mendelism," *Journal of Genetics* 2 (1913): 351–405. The 1913 paper appears to be a follow-up to Toyama's 1906 paper, based on a request by Bateson to undertake a similar series of experiments using a variety of silkworm breeds. Breeds exhibiting different egg characteristics were examined, symbolizing a juncture in Toyama's research concerns as he began to study maternal inheritance.

[119] Nakazawa Singo, "Articles published relating to Toyama," *Folia Mendeliana* (1993): 28–29, 69–71. Nakazawa, a historian of science, recounts Toyama's lament that he had not published his silkworm experiments in 1900.

of Japanese empire and Siam's maneuvers to avoid colonization provides a different perspective with which to expand our historical understanding of the relationships between living things, industrial development, international trade, and the various cultures these come into friction with.

This chapter has shown through comparative analysis of silkworm experimentation spanning different places that despite the apparent universalistic features of scientific laws – in this case, of inheritance – the production of biological knowledge was quite localized to the scientific cultures that Toyama and Kellogg inhabited. This was especially striking even though the organism in question was shared. These differences mediated critical questions about how to deal with the fact that the silkworm was already domesticated and modified for human benefit long before it could be understood scientifically. As a consequence of deliberations over its naturalness or artificiality, this chapter has shown how the silkworm could eventually "pass" as a viable medium with which to show the mechanics of Mendelian inheritance.

CHAPTER FOUR:

THE MANUFACTURE OF SILKWORMS AND "UNIFICATION"

The silkworm grows in response to its surroundings, sometimes out of sync with its brothers and sisters as each advances into its momentary sleep at a different moment. They might eventually spin their respective cocoons at different times from one another. Human caretakers must carefully, yet quickly, move larvae that seem ready to spin into mabushi, what look like glassless window frames built of many small, squares panes, or if those are not available, onto the V-shaped folds of an accordion made of rice straw. The silkworms nestle one to a square or crevice, and once they seem to be swathed in their own silken cubicle, a day or two must pass until the cocoons fully form. It is only then, as the silkworms slumber off and begin to pupate, that they declare their judgment of the human hand. If reared soundly, the resulting cocoons appear mostly the same across the cohort – relatively the same size, weight, and shell thickness, and devoid of disease. The cocoons otherwise serve their cacophonous verdicts. Some show the rotting stains of disease, some are incompletely spun and the translucency of the cocoon resembles a ghost. Some might look malformed or have thin shells that crumple easily or seem dwarfed. Others just reveal the marvel of breeding, manifest in the form of different sizes, shapes, and colors.

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If we look from a broad point of view at international trade or war with the outside, it is my opinion that we must adopt a middle ground in order to solve this problem . . . from the beginning, we are not talking about making the country's silkworm breeds into one or two varieties. We will tōitsu *what we can tōitsu. In other words, we are planning to diffuse good varieties that would be appropriate for each region and climate by organizing the confusion of silkworm breeds.*

– Shimo'oka Chūji, 1911[1]

A greenish copper bust of Toyama Kametarō stands before a backdrop of cherry trees in the front grounds of the former Fukushima Prefectural Sericulture School.[2] Located in the Tohoku region of Japan near some of the most renowned and oldest areas of silkworm-egg production, this school was established in 1895 by the Prefectural Sericulture Business Association in order to educate and train young men in sericulture and science. Toyama served as the founding headmaster of the school beginning on April 10, 1896.[3]

More than a century later, today at the Fukushima Meisei Senior High School, this new sculpture of Toyama bears a benevolent expression, eyes crinkled and lips upturned in a smile to welcome male and female students. He is commemorated in Japanese agricultural and biological history as a teacher, a first demonstrator of Mendel's laws, and for introducing the use of genetic knowledge into sericulture, among other things. These recent laudatory memories of Toyama overshadow the fact that the scientists may not have had such an easy time communicating the intellectual

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[1] Shimo'oka Chūji, "Sanshu Tōitsu-an No Jikkō to Risō" [The Practice and Ideal of the Proposed Unification of Silkworm Variety], *Dainippon Sanshi Kaihō* 227 (1911): 33–35.

[2] Fukushima Sangyō Gakkō is now known as the Fukushima Meisei Senior High School. While the school no longer teaches sericulture exclusively, nor just to men, it provides instruction in the agricultural arts and sciences writ large.

[3] Fukunō Hyakunen-shi Hensan Iinkai, eds., *Fukunō Hyakunen*-shi [100 years of Fukushima Agriculture] (Fukushima, Japan: Fukushima Kenritsu Fukushima Nōsan-kōtō Gakko; Fukushima Nōsan-kōtō Gakko Sōritsu Hyakunen Kinenkai, 1997), p. 521; Fukushima Kenritsu Fukushima Meisei Kōtō Gakkō, *Gakkō Yōran* (Fukushima: Fukushima Meisei Gakkō, 2007), 4. By that time, Toyama had spent a couple of years teaching as an assistant professor after completing his baccalaureate at the Imperial University of Tokyo College of Agriculture.

scientific knowledge to the sericultural community given its pragmatic needs.[4] Caught somewhere between his scientific peers, politically and economically minded superiors, and silkworm cultivators, Toyama had to pitch himself and his ideas across realms of both science and the farm in order to uphold his responsibilities to both. As momentum for the nationalization of the Japanese silk industry grew as Japan endeavored to be recognized on a par with European and American powers by the end of the Meiji period, Toyama faced a number of tensions concerning a problem we can understand best as *tōitsu*.[5]

A wide range of different people, from elites, politicians, and silkworm-seed producers to scientists, addressed the notion of *tōitsu* of silk and silkworms in different ways. The discussions that preceded the formation of a Sericultural Industry Law in 1911 highlight how people understood the silkworm and how the quality of cocoons could be controlled, if at all. This chapter thus sheds light on how corralling silkworms for the purposes of greater state intervention in the sericulture industry gave some contours of nationhood to the Japanese archipelago.

Use of the term *tōitsu* appears readily in historical analyses and descriptions of national unification, such as *tenka tōitsu* to describe political rule during sixteenth-century Japan, or *tōitsu doitsu* in the context of a united Germany. *Tōitsu* in the vein of this dissertation has a more subtle manifestation that is less obviously political. It makes sense to start from a position of not assuming the entity of "Japan" as we know it today. Scholars have, for instance, considered the formation of Japanese language as a way to understand the formation of "Japan" as a recognizable

[4] Yoko Matsubara, "The Reception of Mendelism in Japan, 1900–1920," *Historia Scientiarum* 13 (2004): 232–239; 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, no. 2 (2010): 215–264; Yasuko Moriwaki, "Toyama Kametaro to Meijiki no Sanshigyō ni okeru Kaiko no 'Shurui Kairyō,'" *Kagaku shi Kenkyū* 49, no. 255 (2010): 163–173.
[5] James R. Bartholomew, *The Formation of Science in Japan* (New Haven, CT: Yale University Press, 1993).

community beyond its geographical outline. A standard language did not exist in eighteenth-century Japan, when people identified themselves according to their local situations, whether in terms of class or occupation, village or region, or religion. Japanese as a language unity and as an ethnos developed out of "an unprecedented organization of discourse in which various differentiations, which otherwise would have formed a field of differences, converged to constitute an ethnocentric closure."[6] Development of the notion of "Japanese" provides a useful analogue for contemplating the formation of a language used to make sense of the silkworm in terms of how it relates to the nation.

In early-twentieth-century Japan, the word *tōitsu* surfaced frequently in various conversations about resolving problems about silk production, but discussions often left the endpoint unclear. *Tōitsu* could refer to a problem of inconsistent quality among the threads of export-bound raw silk in the nineteenth century. It could also refer to a solution to this problem, characterized by a systematization of silkworm production enacted by 1911. The arrival at otherwise elusive consensus about the greater contours of the *tōitsu* problem, its causation, and solution subjected *tōitsu* to frequently deliberate flexible interpretation.[7] In lieu of settling on one interpretation, I use the English word "unification," based on a translation of the term published by the *Bulletin of the Sericultural Association of Japan* in 1911.[8]

Resolution of the problem of *tōitsu* meant that different groups of people would have to envision their expertise in relation to a common purpose so as to recast Japanese silk in ways that would enhance Japan's repute in the world. Ambiguity

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[6] Sakai, *Voices of the Past*, pp. 311–312.
[7] Understanding the stabilization of a technological artefact requires an investigation of multiple social groups, according to Pinch and Bijker (1984), who use the example of the "air tyre" to describe their "interpretive flexibility" beyond the physical realm of design. Reference to interpretive flexibility here helps highlight how individuals and social groups engage with the content of the same artefacts in distinct ways appropriate to their particular problems and solutions.
[8] The 20 January 1911 issue of the *Dainippon Sanshikaihō* uses "unification" for the first time in its English table of contents when describing the titles of articles that refer to *tōitsu*.

about how to execute *tōitsu* created a space for pragmatic discussions and debates that also touched on matters of national identity as it referred to the need to bring divergent (silk) threads together to appear as one and the same. This pull toward synchrony recalls a familiar story in the new conceptualizations of time that reconfigured life in the Meiji period. Beyond the sharing of time within the interior of Japan, the switch from the lunar to the solar calendar in 1872 enabled the Meiji government to achieve commensurable exchanges with Europeans and Americans. The adoption of a twelve-month calendar with seven days to a week also symbolized a coalescence wherein the new Japan could be seen as rational, scientific, and efficient.[9] Along this line, the changes to sericulture in the late-Meiji and early-Taishō periods contributed to homogenization as goals to export consistent qualities of silk from Japan required greater synchronicity and compatible practices among different features of silkworm and silk cultivation. This dissertation homes in on one important aspect that characterized one of the major foundations for such change – the *tōitsu* of silkworms.

I analyze the *tōitsu* problem in order to examine how and why different biologically inflected solutions, ranging from breeding and rearing methods to hybrid vigor and Mendelian genetics, were made to make sense in sericultural practices as biological rationality and politics converged. I first discuss some of the early concerns about silk quality and how state scientists initially cast their eyes on standardizing methods in sericulture. This helps to elaborate how new intellectual understandings about the biology of silkworms and the articulation of sericultural practices together contributed to understandings of the *honsei*, or "original nature" of the domesticated organism, as raised by Toyama later. A rupture in the Tokugawa-style "normalcy" of the business and sociality of silkworm breeding receives further attention through analysis of the creation of the 1911 Sericultural Industry law, which involved various

[9] Stefan Tanaka, *New Times in Modern Japan* (Princeton: Princeton University Press, 2006).

discussions about how to carry out *tōitsu*.[10] Different stakeholders appropriated *tōitsu* and assigned different meanings to it that ranged from practical to theoretical ideas concerning standardization, revolution, governance, and family. *Tōitsu* would draw taut the different aspects of silk production in ways that made ever more tangible the need for a tractable solution through the management of silkworm bodies and redistribution of the expertise of sericulture on the scale of the nation.

1. Search for Standards: Emergence of a Problem

The problem of *tōitsu* emerged gradually as an issue in silk and sericulture in response to *sosei ranzō*, the chaotic overproduction of commercial breeds and brands of silkworms that characterized the business of sericulture by the 1870s. The growth of sericulture that responded to the growing economic importance of raw silk exports had amplified the severity of problems of craftsmanship, business, and breeding that manifested in the form of variable qualities of raw silk fibers spun from silkworm cocoons. The struggle to define the basic parameters for the *tōitsu* of silkworms had begun to develop well before that time as the export of silkworm eggs bottomed out and gave way to that of raw silk. One newspaper offered this illustrative lament:

> Silkworm egg seeds are a great noted product of the Japanese empire. After the port opening, their export overseas has increased over many years. Thanks to this, fortune has increased and family properties have been stimulated. Nevertheless, people rush to make personal profit right in from of themselves

[10] Tessa Morris-Suzuki, *Technological Transformation of Japan* (Cambridge: Cambridge University Press, 1994); William H. Sewell, *Logics of History: Social Theory and Social Transformation* (Chicago: Chicago University Press, 2005). Sewell discusses the historical "event" as having a fractal character consisting of a complexity of events that occur in overlapping sequence and spaces that produce lasting and durable transformational changes in society. In his example of the "taking of the Bastille," an "event" is marked by a deep insecurity that facilitates creativity. While the example of Sewell's event may not seem to map neatly onto this case of the transformations associated with the technologies and sciences of the silkworm, this concept informs my analysis of the ambiguity of *tōitsu* as a way to think about the processes of changes in the interrelationships between different stakeholders, including the nonhumans in this history.

> and recently are overproducing corrupted products. Because of this our reputation goes down.[11]

The 1870s surplus of silkworm eggs intended for export to Europe that famously led to their burning at the Yokohama shipyards during the height of the *sosei ranzō* problem presented new questions about the nature of the silkworm as well as the strategies for strengthening Japan's performance in international silk trade. Jostling for a place in the market generated war metaphors from governmental officials such as General Consul Takahashi Shinkichi, based in New York City, who conveyed a sense of urgency for Japan to prepare itself by reassessing its strategy to vie against reputable European silks:

> If you wish to compete against fine and beautiful European threads, you must choose the finest of the fine and you need to have the best pick of machines and have ample supplies and provisions. We are ready to go to battle, but when you look at European countries like France or Italy, I hear that they do not have any taxes for export, and addition, they receive some government support. We Japanese have an additional export tax so even before leaving Japan, we are handicapped . . . That should not be the way to win fights . . . you have to know your enemy and your self.[12]

These fighting words by Takahashi in 1883 reflected an economic war, in which raw-silk exports stood as the soldiers that would battle with Europe in the American market, and Japan's ability to capture a profitable share would represent Japan's superiority.

Although the term *tōitsu* does not appear here, we can understand how the stakes of Japanese reputation were raised through hyperbolic use of language and their stimulation of the imagination about the reputation of the nascent nation-state. In this

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11 *Sanranshu Ranzō* [Overproduction of Silkworm Egg Seeds], in *Nissin Shinji Shi*, 30 Nov. 1873. Reprinted in *Meiji Nyūsu Jiten* (Tokyo: Mainichi Komyunikēshonzu, 1983).

12 Takahashi to Inoue and Yoshida, "Suggested Expectations for the Future of Direct Export of Raw Silk," October 11, 1883, Sanshi sanran kankei zakken, 3-5-2-27 [DRO]. All translations are mine unless stated otherwise.

instance of the "fight" for direct orders from American patrons rather than through European traders, the actual battle would, Takahashi warned, depend on the performance of sericulturists and silk filatures and reeling factories on the domestic front. These stakes about the place of Japan in the market would underlie many of the concerns that the *tōitsu* problem came to be founded upon.

The *sosei ranzō* issues of the late 1870s made very clear to people that national standards for rearing silkworms did not exist. The lack of consistent sericulture practices posed one very obvious challenge to the production of silkworm varieties (or silkworm seeds, as they were commonly called, referring to the fertilized egg) and silk of consistent qualities.[13] Driven in part by demands of the foreign silk market that Japan found itself thrown into, efforts to understand what exactly counted, why, and how in the manufacture of "improved" silk gained attention, on one hand, at the level of machinery, and on the other, at the level of the insect and steward. Individual efforts to popularize specific sericulture methods by sericulturists grew, and new books illustrated the growing competition among silkworm egg producers to spread word of one rearing methodology over another based on tested results.[14] Despite publications that promoted good sericulture methods by renowned silkworm-egg producers such as Tazima Yahei in 1872, the activities of studying, managing, and preventing disease still dwarfed efforts to collect comparative data per silkworm breed for the purposes of standardizing and optimizing sericultural practices during the 1880s.

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[13] I will refer to silkworm "eggs" when discussing issues pertaining to individuated eggs, but I use the phrase "silkworm seeds" to refer to an amalgamation of eggs that would accentuate the meaning of "varietal type" in the Japanese context. The previous chapter specifically discusses the egg trade, as well as the layered meaning of seed and species.

[14] Nakamura Zensaemon in Fukushima and Tazima Yahei in Gunma authoring their own books to popularize their honed methods for optimized sericulture by modifying warm and cool environments for rearing silkworms.

The collection of data for what would be called the first "Standard Table of Silkworm Breeding" began formally in 1887 at the *Sangyō Shikenjō* (Sericultural Experiment Station).[15] In 1889 the sericulture expert Matsunaga Gosaku, a former pupil of Sasaki Naga'atsu at the Naito Shinjuku Experiment Station, publicly presented a standardized chart for the rearing of *Aojuku* and *Akajuku* "garden varieties" of commonly reared silkworms. Careful sericulturists usually keep track of the temperature and humidity (made possible especially with the *santōkei*, a glass thermometer developed specifically for sericulture by Nakamura Zenzaemon (1810–1880) in 1849), feeding, and other such environmental cues as they watch over their silkworms.[16] Now, for two silkworm breeds, an official chart would begin to guide sericulturists.[17] With the intent to locate the best practices for rearing specific silkworms in a particular place, the creation of this chart gestured toward the development of a means to promote the unification of different cultivation practices

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[15] Yōsan hyoujun hyō, 1889. See Tajima, 1872. In 1884, the national government renamed the former Naito Shinjuku Experiment Station directed once by Sasaki Naga'atsu, who had begun some of the earliest data collection on rearing methods. Now under the auspices of the new Ministry of Agriculture and Commerce and re-established as the Sanbyō Shikenjō, or Silkworm Disease Experiment Station. Sericultural experiments resumed and continued at the new experiment station, but with contagion still occupying the central concerns of Ministry officials, the laboratory grounds were cohabited by researchers studying cereal crops and other plants' pathogens. Only after the disease experiment station moved to a new location in Nishigahara could sericulture research focusing on rearing practices following the earlier work of Sasaki Chōjun, Tazima Yahei, and Nakamura Zenzaemon gain more momentum, but even so, the dominance of pébrine disease detection and prevention continued. 1884 also marked the establishment of the Ministry of Agriculture and Commerce and signaled the recovery from the Matsukata Deflation, which had served to curb rampant inflation. The *Sanbyō Shikenjō* was required to publish its results in the *Nōshōkō Kōkoku* [Reports of the Ministry of Agriculture, Commerce and Industry], reflecting the responsibilities that came with institutional support from the Ministry of Agriculture and Commerce at the time. In April 1887, the name of the research station was changed again, to the *Sangyō Shikenjō,* or Sericulture Experiment Station. See Tsuchikane, 2009, Kitamura and Nozaki, 2004.

[16] Zenzaemon Nakamura, *Santōkei Hiketsu* [Secrets of Sericultural Measurements], in *Nihon Nōsho Zenshu,* vol. 35 (Tōkyō: Nō-san-gyoson Bunka Kyōkai, 1981), pp. 423–440.

[17] Kazuko Tsuchikane, "Meiji ni okeru Nihon yōsangyō no gijutsuteki dōkō to 'yōsan hyōjunhyō'" *Nihon Joshi Daigaku Daigakuin Bungaku Kenkyūka Kiyō* 15 (2009): 29–49, citing Matsunaga, Tomonaga, *Dainippon Sanshikaihō* 194 (1908). The Naito Shinjuku Experiment Station strove to carry out studies in silkworm-rearing patterns, diseases, temperature effects with the use of a thermometer, and details about newly hatched silkworm survivorship. The lab operated under the directorship of Sasaki Chōjun, who served from 1873 until 1879. See Yōsan hyoujun hyō, 1889.

among individuals. This expertly tested information would help mediate the ways in which sericulturists could mediate the environments of their silkworms.

Despite the capacity of the *Sangyō Shikenjō* to provide sericulturists with education and training, it had a limited ability to fully achieve the industry's goals and ideals regarding quantity and quality silk production. Still, Matsunaga's work had symbolic meaning.[18] Until the Standard Table was established, the popularity of different sericultural methods was debated frequently. These discussions appeared often in earlier generalist agricultural journals such as the *Mannenkai Hōkoku* and the *Dainippon Nōkai Hōkoku*, focusing initially on matters of disease control and mulberry harvesting. According to the historian Kazuko Tsuchikane, the focus of these questions after 1886 increasingly included topics such as egg-screening policies, heating silkworm houses, and the relationship between natural temperatures and disease prevention. Release of the Standard Table in 1889 initiated the reassignment of responsibility in terms of guiding the improvement of silkworm rearing.[19]

The central government intervened very little with regard to the vague touchstone matter of improvement, or *kairyō*, until 1889. This responsibility had largely been left to the devices of folk who were resourceful enough to seek the advice of experts who expressed their opinions in these printed venues, such as Sasaki, Tazima, and even some engineers from the Ministry of Agriculture and Commerce. As an official government document, the "Standard Table of Silkworm Breeding" helped

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[18] Kazuko, "Meiji ni okeru Nihon yōsangyō no gijutsuteki dōkō to 'yōsan hyōjunhyō,'" This was the third version of essentially the same experiment station devoted to sericulture following the Naito Shinjuku Experiment Station and the *Sangyō Shikenjō.* In August 1886, a proposal to build facilities for screening silkworm eggs was approved through a silkworm-seed testing policy issued by the Ministry of Agriculture (Policy No. 9). The experiment station now served to educate people in sericulture, and between 1887 and 1889, it notably provided training for 80 people in the methods of screening silkworm eggs infected with pébrine. The newly renamed institution also trained other instructors of regional experiment stations as well as traveling instructors who circulated throughout the countryside. Other research concentrated on pathology and fiber science. By 1896, the Experiment Station changed its name again to *Sangy*ō *Kōshūjō*, the Sericulture Institute, which reflected growing emphasis on short-course teaching. This name was used until 1899.

[19] Ibid.

address ongoing questions about how to curb contagion by clearly presenting the appropriate temperature and humidity for two particular kinds of silkworm. This kind of knowledge increasingly helped sericulturists plan how to feed their silkworms by taking into greater consideration the cost of mulberry and the rate of cocoon production. Such things may seem mundane, but the "setting" of the chart engendered new priorities within the economics of sericulture.[20] The Standard Table of 1889 began to make information on optimal sericulture for two particular kinds of silkworms accessible – for the experienced and inexperienced alike. This table would ultimately develop into a style of inquiry taken up with greater frequency by sericulture experiment stations in Japan as an activity that took microclimates and location seriously to clarify the best practices of rearing silkworms from eggs to cocoons.

a. *Honsei:* More than a Standard

The "standard," or "*hyōjun*," appearing in the title of the 1889 Standard Table referred to the human behaviors governing sericultural practice and did not actually engage with the idea of rendering the silkworm itself into a homogenized, standard form. *Hyōjun* rather functioned to encourage individual cultivators to conform their sericultural techniques with others, leaving the question of silkworm inheritance untouched. The Standard Table represented an inadvertent bifurcation between the internal and external realms of a domesticated organism. Grappling with two different ways of locating optimization solutions related to the silkworm characterized some of the work of Toyama Kametaro, who emphasized the importance of both.

The Standard Table reflected what human actions would be applied to the silkworm and manipulations of its environment. This system described the parameters

[20] Ibid.

of practice rather than reflecting any engagement with the biology of "the silkworm" in a singular collective sense. Toyama advocated for an understanding of the *honsei*, or the "true character" of the silkworm.[21] This reference to *honsei* did not correspond to reductionist ideas of a Mendelian character or the gene concept, although it may seem to suggest these. Toyama's work aimed at knowing the silkworm from multiple angles, which played an instrumental part in shaping the scientist's contributions to the *tōitsu* discourse.[22] One might expect that Toyama was an unflagging champion of Mendelism, given his career-long enthusiasm about the benefits of emergent genetic knowledge. Toyama's evocation of *honsei* helped his critique of the deficiencies of common sense of current breeders, who tended to breed for single traits in relation to cocoon characteristics. This would seem to align with Mendelian teachings, but Toyama stressed that alone, it could not provide the basis for breeding and producing the whole experience of the silkworm, from larvae to cocoon to mature moth.

Instead, Toyama had a more complex vision. Sericulture-production reforms increasingly required Japanese silkworm growers and experts, including Toyama, to render the domesticated silkworm into intelligible objects of industry and science. As an unconventional silkworm scientist prone to disregard the limits of routine science and its bureaucracy, Toyama used nonscientist angles from which to convey phenomena pertaining to silkworms and silk. Readiness to appreciate alternative first-person angles appears in his writing in a way that evokes some styles of sericulture manual writing initiated by the father of Sasaki Chūjiro, Sasaki Chōjun, who wrote *Kaiko no yume* (Dream of the Silkworm, 1890), and later, *Wagahai wa*

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21 Toyama, "Sanshigyō no Hanjōhō" (part 2).

22 Toyama Kametarō, *Fukushima-ken Sangyō Gakkō Hōkoku* 1 (1898): 1–15, 38–69, 50–83, 83–85, 87–102, 102–120; Toyama Kametarō, "Kaiko no Shurui Hikaku Shiken" [Comparative Tests of Silkworm Varieties], *Fukushima Kenritsu Sangyō Gakkō Nenpō* 3 (1901); 4 (1902). Toyama published numerous research papers in 1898 and 1899 in the Fukushima Sericultural School Bulletin, starting with articles about the incubation of silkworm eggs, the relationship between temperature and sericulture, larval molting, larval diseases, pébrine disease, varieties of silkworms, and humidity during metamorphosis, all practical issues.

kaiko de aru (I Am a Silkworm) by Nakatani Sōjitsu in 1908, which took on the voice of a silkworm. The novelist Natsume Sōseki had notably introduced a satirical literary style in his very famous *Wagahai wa neko de aru* (I Am a Cat), written in installments between 1905 and 1906 as social commentary on vanity during the Meiji period. In all of these examples, the animal observer is better placed to understand the human and itself.[23]

Toyama used such a storytelling maneuver in a 1908 speech in which he personified a demanding silkworm: "Arrange my marriage so that my bloodline will be good. Just because we make cocoons when you give us mulberry leaves doesn't mean you can recklessly throw it at us . . ."[24] As seen in an earlier chapter, by punctuating his speeches and writings with occasional humor, references to allegory, and storytelling, Toyama made some of his scientific ideas easier to digest, especially when aiming to fine-tune the skills of other experts, farmers. While not all scientific men in Japan during the Meiji period wrote from the point of view of their organisms, we can deduce that many of those who did were considered experts already. Toyama's maneuvers of planting himself within the plane of his audience likely helped remind people of his status as a degree-holding kind of expert without appearing to talk down to practicing sericulturists, experts in their own rights.

Straddling the ongoing debates about the determining factors of silkworm qualities as the *tōitsu* movement grew, Toyama introduced genetic ideas in a way that gradually encouraged sericulturists to recognize that the *honsei* of a silkworm is an expression of the combination of both its biological endowment as a living organism and the manner of the human caretaking it receives and the consequences thereof.

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[23] See Nakatani Sōjitsu, *Wagahai Wa Kaiko De Aru* [I Am a Silkworm] (Tokyo: Kyūkōkaku Shoten, 1908); Natsume Sōseki, *I Am a Cat* [Wagahai wa neko de aru], trans. Aiko Ito and Graeme Wilson (Tokyo: Tuttle Publishing, 2002); Sasaki Chōjun, *Kaiko No Yume* [Dream of the Silkworm] (Tokyo: Sasaki Chōjun, 1890).

[24] Toyama Kametarō, "Kokoro no Okidokoro, Me no Tsukedokoro," *Dainihon Sanshikaihō* 17, no. 190 (1908): 13–15.

Based on Toyama's use of the term, *honsei* was neither a discrete scientific law nor a unitary thing; it was something more innate that a farmer would *know* or, rather, ought to know and therefore act upon wisely. For instance, in July 1908, Toyama delivered another speech in Fukushima to a meeting of the Sericultural Association of Japan. There, he actually joked that he wished the sericulture industry had been hit harder by the economic panic of 1907 when silk prices dropped. There is a saying, he said, "*kawaii ko ni wa tabi wo sasero*" (Let a dear child go on a journey). Analogizing sericulture to the child, Toyama's comment was met with applause. He had, in fact, chastised the audience earlier for not paying attention to what he had been saying all along before the crisis, that the sericulture industry had been completely backwards, or had not really begun to mature, until that moment. Sericulture management, Toyama claimed, was based on the *honsei* of the silkworm.[25]

Talking through the silkworm facilitated more public observations about the connections between the characteristics of these creatures and their cocoons. These changes resulted from adjustments in breeding and cultivation methods aimed at coaxing the production of certain kinds of features deemed favorable and increasing silk yields. Among the outcomes included was the growing study of the underlying biological principles that guided the inheritance of characteristics belonging to the silkworm that, in turn, gave rise to a greater genetic consciousness that would resonate across the sericultural landscape of modern Japan. The combination of discussions about *honsei* and the troubled silk industry in the wake of 1907 gesture toward the complicated and iterative processes by which sericulturists' mentalities changed. That is, as scientists cultivated biological knowledge about inheritance, they also brought these ideas into friction with existing conventions in sericulture introduced earlier in this chapter. Recent trends such as the building of palatial silkworm nurseries,

[25] A note of applause was written in Toyama, "Sanshigyō no Hanjōhō" (part 1). An alternative reading of *honsei* is *honshō*.

overfeeding, and overfertilizing with the hope of enhancing the amount and quality of silk, Toyama indicated, pointed to a lack of awareness of *honsei* among sericulturists who unwittingly squandered their resources on sericultural labor.

Sericulture techniques and methodology had not just intensified, but by 1908 exhibited an overbearing complicatedness that Toyama called *hai kara* (high collar) and criticized: “To be hands-on in an unnecessary place means you make your own dear child weaker.”[26] In this speech, he also warned that financial losses were no longer acceptable, since the cottage industry of sericulture now constituted a major economy linked to foreign markets. Any damage would strike a fatal blow to entire regions of Japan. He used the analogy of a clock’s pendulum to show that while the environment, including inputs such as labor, food, temperature, and so forth, could sway the pendulum of performance favorably or unfavorably per silkworm; no matter how much labor or capital was exerted to enhance the rearing effect, the silkworm’s *honsei* determined the pendulum’s amplitude.

This reference to the pendulum highlights one of the ways by which ideas about biology, though quite vague, were articulated in a metaphorical fashion in an appeal to a mental change regarding the approach to practice. *Honsei* represented a limited range of ability or possibility. Toyama indicated in the 1908 Fukushima speech that through experimentation, he knew that the performance of living things could swing from good and bad, but that there were upper and lower limits to how much the environment (in this case, labor) could actually boost sericultural productivity. The notion that better results come from more effort or labor amounted to little more than *darōgaku* (probably-ology), Toyama explained. His *honsei* argument was fashioned to implore people to stop spending their resources in ways that otherwise did not reduce the cost of production. Doing so would allow the

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[26] Toyama, “Sanshigyō no Hanjōhō,” pp. 1–2.

Japanese to weather volatile economic conditions as in 1907, while still producing good products. Toyama interestingly did not promote the production of high-quality goods, as one might expect. He rather extolled the efficiency and profitability of the mass production of low-quality goods. He praised Germans and Italians as masters of keeping their costs of goods manufacturing low, and he additionally lauded the Chinese, who could produce up to six crops of silkworms a year in Canton.[27] In short, Toyama critiqued Japanese producers for trying to maximize silkworms' *honsei*, whereas in reality, the mass market had no need or ability to purchase anything as exquisite as the Japanese sericulturist strove to make. Here, we see how the discussion of the way silkworms work in terms of *honsei* was brought into relation to a larger domestic industry that could now be compared with other countries.

The question remains: How did issues concerning what we can call genetics specifically fit into these developments about silkworms' *honsei* and rehabilitating the sericulture and silk industries? So far, it is clear that Toyama's orientation toward ideas of inheritance is understandable through his dismissive attitude about the mismanagement of resources in cultivation practices. He felt that skewed sericulture priorities reflected the swinging prices of silkworm eggs. In the second half of his 1908 speech, Toyama recalled, fittingly for the location, that Fukushima Prefecture was once famed for its silkworm seeds.[28]

The famous *Yōsan Hiroku* (Secret Notes on Sericulture), published in 1803 by Kamigaki Morikuni, helped ingrain in the minds of people that silkworm-seed production had begun only as recently as the 1730s.[29] The mythologized history of seed production that people passed down to following generations posed an obstacle,

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[27] Toyama, "Sanshigyō no Hanjōhō" (part 1). For more on the 1907 financial panic, see Bruner and Carr, *Panic of 1907*.
[28] Toyama, "Sanshigyō no Hanjōhō" (part 2).
[29] Morikuni Kamigaki, *Yōsan hiroku* (Tokyo: Nō-san-gyoson Bunka Kyōkai, 1981); Takao Kajishima, *Shiryō Nihon dōbutsushi* (Tokyo: Yasaka Shobō, 2002).

Toyama argued, to an understanding that a great silkworm-seed market actually existed earlier, in the Genroku period (1688–1707) in Datezaki, Fukushima. Cultivators at that time, he added, were patient and produced good results. This comment echoed the same rhetoric discussed in an earlier chapter, when in 1900, Toyama measured and compared silkworm cocoons' qualities and complained about the erosion of farmers' wisdom compared to that of the past. Now in Fukushima rather than Nagano, Toyama again scolded cultivators for their myopia and inadvertent disavowal of their legacy:

> To speak about the struggles that those people endured would be good for everyone . . . it is hard to do this work in five to ten years. First, it is transmitted from generation to generation, and there were many people who [strove to achieve] until new varieties were made. Along those lines, people long ago had already emphasized, saying "*hon o, hon o*" (it's the origin, the foundation), and they were not doing only economical work. [Today's] generation, however, has forgotten the [issue] of the *hon gen* (origin or root), and again, they just cry during difficult times these days instead of using progressive academic results. To think this is the nation called the England of the East is an attitude I cannot accept.[30]

In this indictment of 1908 Japan, Toyama expressed chagrin that people would dare compare Japan to a scientifically advanced empire. He saw sericultural practice in Japan plunging forward without prior acquisition of knowledge, which offended his sensibilities.

At this point, having gone through discussions of *honsei*, the economy, international competition, and the perils of ignoring knowledge, Toyama had finally made his audience privy to a set of new knowledge. This was the combinatorial silkworm breeding that had been so compelling in his 1906 dissertation: " . . . whether they are new characters or excellent characters or it's just one good character, you can

30 Toyama, "Sanshigyō no Hanjōhō" (part 2), p. 8.

simply take that one and combine and collect it; it is possible to make a completely new [character]. This is not just talk but actual truth."[31]

Although the utterance of *honsei* seemed to have faded at the time, it is important to pause for a moment and note that a more explicit introduction to genetics began to take root then in Toyama's speech, signaling how the expanse of biological solutions to sericultural problems began to shift. He hooked his audience with a humorous and fantastical analogy between human heredity and sushi in order to make them hear the "truth" about the phenomenon of independently assorting characteristics: if one were interested in having a high nose, or white skin, or an excellent bodily constitution, those individual features could be combined like *gomoku sushi*, a nonhomogeneous sushi rice dish composed of a mixture of ingredients. This mixture of different characteristics would essentially result in a new breed or type that had not existed before. "This is not an empty idea, but on top of being true, it is possible to do," Toyama asserted, even though he had not experimented on humans.[32]

Toyama also discussed more familiar examples of chickens, followed by silkworms. He explained that through breeding, it is possible to convert *hime-ko*, or the princess silkworm, which has no markings and has a white coloration, so that its offspring would include some *kata-ko* individuals, which have a half-moon crescent on their dorsal side. Revealing the "truths" about inheritance amounted to little more than showing the secret behind a magic trick, the scientist explained. A cross between *kata-ko* and *kata-ko* resulted in a mixture of progeny of some *hime* and some *kata*, but this was not only predictable but could be executed on demand and the situation was no different for cocoons, he continued.

> To change colors and take them out and put them back in is not a debate but a factual thing that you can do the way you think. People in ancient times knew a

[31] Ibid.
[32] Ibid.

> little bit about this kind of thing, and it had been taking place for the most part, but they could not actually explain it. "If you do this, it will accordingly do that, so if you do this, you can do this kind of thing." This kind of talk has been around since a long time ago.[33]

Appealing to the notion that Japanese sericulturists had always already carried out "academic-style" breeding, Toyama indirectly expressed his disdain for the current state of the art. It was at this juncture that the silkworm scientist showed the very real possibility of how he could take advantage of knowledge about inheritance documented in "correctly demonstrated" studies of the "changes" in color of the fur of horses, cats, rabbits, guinea pigs, and mice.[34]

Toyama saw an "extraordinary revolution" taking place:

> . . . it has today come to a point where it is possible to speak correctly about how you can clearly tell, for the most part, which characteristic passes down (*iden suru*) to then [decide which characteristics to keep] and [which] to put aside.[35]

The revolutionary change, in Toyama's view, entailed the new understanding that Mendelian genetics could be used to synthesize new kinds of organisms quickly. This posed a potentially dramatic way to cultivate exact and favorable changes in the characteristics of creatures than would result in more incremental processes associated with breed improvement, Toyama argued. He also presented this in a way to appeal to this science's entrepreneurial merit:

> If this academic field progresses, it can even become possible to make human beings. To make any number of Napoleon[s] or *Ononokomachi*, I think you can do this. If this becomes the case at that time, we can become a human production company to respond to orders to make soldiers, or academics, or geishas or actors, or anything. When that time comes, we should make sure to

[33] Ibid., p. 9.
[34] Ibid.
[35] Ibid.

> secure ourselves as stockholders. This is a [futuristic plan], but silkworms are not [a plan] but an actuality.[36]

The idea of creating little armies of Napoleons or the beautiful Heian-period poet *Ononokomachi* may seem far-fetched, but these wild stories served a purpose in 1908. Toyama managed to convey a sharp understanding of his personally accrued knowledge, and tailored it in a way to make sense to laypersons without mentioning Mendel. Toyama's deliberate absurdity in relating his first original reference to the potential uses of genetics to human enhancement made it possible to think that silkworms' unruly inheritance patterns could be understood and harnessed. In this detailed analysis of Toyama's 1908 speech, it is possible to see how, through humor, candor, and an appeal to capital acquisition, the scientist introduced another facet of the silkworm's *honsei* and thus planted a metaphorical seed of interest in the lucrative prospect of academically – genetically – informed silkworm production.

2. Back to the Seed

Toyama's argument centered on a critique of resources. Money spent on hiring additional labor could be better spent on better eggs, he felt, and otherwise would ultimately bode poorly for the resulting raw silk. These concerns stood in the way of achieving *tōitsu*, the central issue that this chapter now returns to. The tail end of Toyama's 1908 speech helps illustrate how the *tōitsu* debate grew from an interest in locating a source or origin of the problem of quality. The following quote shows the importance of the silkworm seed, the fertilized egg that represented the variety that would soon hatch into the world, and how human responsibility was perceived to link to it:

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[36] Ibid.

> If we look at today's circumstances, in which bad thread is said to be uneven, it often means the conditions are this way because of the raw material, meaning the cocoons of Japan are bad, the [types] are bad and thus the seed shops are bad. On the contrary, to return to the humans who carry the burden of responsibilities, first, it comes down to the person who rears the silkworm, and then [] to the person who makes the seed. It is this damnable wretch whom we say we should crack down upon, and we finally come down upon the seed, one way or another. The seed, oh, the dear seed.[37]

In this quote, Toyama traveled down the blame-shift cascade to show how responsibility for the quality of raw silk always doubled back on the production of the seed. It was not just the viability of the silkworm seed, as in the fertilized egg, but the pedigree of the breed represented by the varietal type, or *shurui*, represented by the silkworm seeds, that mattered in ongoing discussions of quality.

Toyama recognized the need to stabilize silkworm breeds, given the great burden that quality egg production bore for the rest of the silk industry. He felt that silkworm breeders received undue blame and that the bottleneck of the blame-shift was not in fact due to egg producers and fertilized eggs alone. Rather, he saw the issue as resting more on the people who reared larvae. These cultivators purchased the silkworm seeds and exercised key decisions about their livened states that limited the ability of seed producers to make further assessments about their products. At that time, because sericulturists could switch between new kinds of silkworm every year if they wanted to, it may have been difficult for egg producers to receive longer-term feedback about the performance of a "bloodline."[38]

For a sustainable industry, Toyama expressed the need for more policies that supported the breeder, emphasizing more organizational intervention to provide resources and therefore the institutional means for developing higher-performing silkworm breeds. He complained that most resources went to the prevention of

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[37] Ibid.
[38] Translated from *keitō*.

silkworm diseases and fault-finding and wasted no words in expressing his disdain for the current system, in which fundamental aspects of sericulture improvement went unregulated. Through good breeding work, Toyama believed, the Japanese silkworm would reach the same kind of success as Luther Burbank's potato in the United States. The *tōitsu* of silkworm varieties would require the establishment of a prefectural silkworm-egg breeding facility to produce pure breeds of silkworms, Toyama said.[39]

This reference to the California plant breeder, then a source of puzzlement for Vernon Kellogg as seen in the intellectual sparring about Mendelism undertaken with Toyama, points notably to the things that Toyama likely admired: the link between the breeder's ingenuity and the creation of a novel and desirable plant, and a system to enhance its profitability. It is also important to note that some of the problems identified at the top of the cascade of blame regarding quality described by Toyama did not merely result from discord between sericulture and seed production; it also reflected the demand for more raw material by the quickly expanding filature and reeling industry. This meant factories had to source more silk cocoons from locations farther from the factory than ever before.

a. *Tōitsu* as Governance

The representative phrase that people began to use to talk about the organization of silkworms and their variation at the time was *tōitsu*, often as part of the phrase "*hinshu tōitsu*," which gestured toward the "unification" of commercial breeds and hence "brands" of silkworms. The discussions concerning *tōitsu* were extensive, difficult, and gave cause to much reflection about the practical and ideological aspects of managing and unifying silkworms in Japan. At this crossroad of silk, science, and politics, the identification of and accounting for unique silkworm breeds emerged as a

[39] Ibid.

necessary step, although the national scale of this task would reverberate as one of many questions and concerns about *tōitsu*.

Tōitsu, then, was an issue not just of the seed, but of cocoons of disparate cohorts and geographic origins. The concern with unification in the silk industry grew as Japan's assertions of empire grew, shaped by two successive victories, first over China in the Sino–Japanese War (1894–1895) and then the Russo–Japanese War (1904–1905). In October 1909, before the annexation of Korea, the government asked the Sericultural Association of Japan to explore possible methods for realizing the *tōitsu* of cocoon qualities. This had emerged as an issue because the growing appetite for raw silk meant that filaturists began to purchase cocoons from locations farther away due to the insufficient amount of cocoons that were available in their immediate, narrow vicinities. While beyond the scope of the present work, it would be imprudent to not mention that the Japanese colonies were also seen as potential locations for silk cultivation, warranting their own sericultural experiment stations.[40]

With the bureaucratic apparatus moving to address these matters at the factory end of silk production, the urgency of the cocoon quality *tōitsu* problem now required more support for the kind of studies similar to those Toyama had initiated nearly eight years before, when he took biometric measurements of cocoons and rendered them into statistically knowable objects that showed how long-term changes progressed.[41] The Sericultural Association recommended that the government establish a central silkworm-egg experiment station with branches in various regions of Japan. It was thought that the results of experiments on silkworm varieties conducted there would enable the manufacture of parent silkworm stocks. These stocks would be reared systematically at the experiment stations. As for the method of practical enforcement

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[40] November, according to Dainihon Sanshikai, 1992:55. See also Kitamura and Nozaki, *Nōrin Suisanshō*, p. 20.

[41] Toyama, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui."

outside of the experiment stations, the Association further recommended that so long as the individuals manufacturing foundational seed stocks were limited to qualified silkworm-egg producers, the parents of the foundational stock would be distributed gratuitously. It was also recommended that counselors help egg producers select silkworm varieties at each sericulture experiment station.[42]

The issues continued to be deliberated in the 26th Imperial Diet, and in March 1910, a proposition for the *tōitsu* of Japan's silkworm varieties was formally presented. A Production Survey Committee was enacted, led by the head of the Ministry of Agriculture and Commerce. Toyama also was called upon to participate in this committee, joining the company of silk businessmen, the agronomist Yokoi Tokiyoshi, the sericulture educator Honda Iwajiro, and other prominent members of the silk and sericulture business and industries. After much deliberation, the seventeen members decided on two major opinions under a tone of great urgency. It first recommended the establishment of a central sericulture experiment station and regional branches, known as the Gen Sanshu Seizōjō (Parent Silkworm Seed Manufactory), which would produce the parental silkworm stocks for the whole country. The resulting silkworm seeds would be distributed to all prefectures in Japan.[43]

The Production Survey Committee's second recommendation recognized the importance of locality for sericulture. One centralized location would control the movement of silkworm seeds by bearing the responsibility of curating and "improving" silkworm stocks through scientific breeding. Silkworm seeds of these stocks would then be sent to experiment stations at the regional level, where

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[42] See Akashi, Kindai Sanshigyō Hattatsushi for account of the Silk Association's recommendation. The Japanese term for this counselor position is *shōgi'in.* Kitamura and Nozaki *Nōrin Suisanshō* , pp. 20–21.
[43] As described in Sanshigyōhō Sericultural Industry Law, Law No. 47 of 1911, and Kitamura and Nozaki, *Nōrin Suisanshō*.

sanctioned seeds could be bought by licensed egg producers, who would make hybrid seeds to sell to locals. Despite the recommendation that the government make and distribute parent silkworms, the selection of superior native varieties would also be permitted. Within each region, silk scientists wanted to make sure that the silkworm varieties offered could eventually produce the desired kinds of cocoons necessary to avoid problems of inconsistency.[44]

b. *Tōitsu* as Balance: Sericultural Skill versus Varietal Preservation

This section focuses on how discussions about *tōitsu* made their mark in the heightening production of silkworms in Japan as people tried to define *tōitsu* and all of its parameters by balancing ideas about the relation between sericultural skill and the production of silkworm varieties. The debates about *tōitsu* dealt not only with the practical questions of "how" to carry it out but also with "what" was most critical to make uniform. The cataloging processes of making silkworm diversity legible to state planners highlight the controversial ways by which the institutionalization of Japan's silkworm reproduction policies took place ten years before the first human census of the Japanese empire.[45] This concept of legibility refers to the violence incurred by which an entire species, *Bombyx mori*, could become knowable. More than taking stock of a snapshot profile of a population the way a census might, my use of the word "legible" gestures to a transition from the days of Tajima Yahei's *Yōsan Shinron* and Kamigaki Morikuni's *Yōsan Hiroku,* when very scant information about silkworm varieties appeared in two-dimensional form in the leaves of a book.

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[44] Kitamura and Nozaki, *Nōrin Suisanshō*, p. 20.

[45] Naikaku Tōkeikyoku, *Taishō Kyūnen Kokusei Chōsa Hōkoku* (Tokyo: Sōrifu Tōkeikyoku Tokyo Tōkei Kyōkai, 1928 [1920]); Jennifer A. Winther, "Household Enumeration in National Discourse: Three Moments in Modern Japanese History," *Social Science History* 32, no. 1 (2008): 19–46; Shirō Shimamura, *Nihon tōkei hattatsushi* (Tōkyō: Nihon Tōkei Kyōkai, 2008).

Even though Kamigaki's text was titled to suggest great confessions, sericulturists in the Tokugawa period did not divulge all secrets of sericulture. Growing requirements in the form of managing the hereditary constitutions of silkworms through the flattening of breed information into written form suggests a change that began to take place in sericulture that relates very much to the change in the terms of authorship and ownership of the organisms, let alone the changes in the kinds of knowledge that could be generated from the silkworm. These written forms taken up by individual sericulturists and, later, national silkworm scientists, reflect how different kinds of choices were made available for evaluation by readers at a given time, on the one hand to inform sericultural practice at the level of rearing, and on the other to make all silkworms available as candidates for breeding. While different people authored these texts and projects of the state, their shifting content indicate different options that both defined the enterprise and the norms of the discipline of sericulture at two ends of the *tōitsu* spectrum.[46]

The *tōitsu* of newly organized and relabeled silkworms would later make them even more amenable to scientific hybrid crosses based on Mendelian laws of inheritance. With the enactment of *tōitsu*, the newer approach to hybridization would depend on identifying candidate silkworms represented through not just the two individuals in the parental generation, but through four grandparental silkworms.[47] It may make sense to think of the use of the hybrid technology, along with the project of *tōitsu* that helped take stock of silkworm diversity, functioning together to establish a standardization of variation.

[46] Charles Bazerman, *Shaping Written Knowledge: The Genre and Activity of the Experimental Article in Science* (Madison: University of Wisconsin Press, 1988), pp. 13, 47.

[47] It seems that at this stage, the hybrid crossing of silkworms was limited to the final stage of producing the commercial seed, as opposed to the parental or grandparental generation. In the analogy of plant breeding, in 1919, East and Jones published about "doubly-crossed plants," which were "the finest specimens of corn so far obtained under the conditions in which they have been tested" (pp. 223–224).

Tōitsu encapsulated the effort to align raw-silk qualities across Japan through orchestration of silkworm variation across different environments, despite different human skills, abilities, and technologies. It especially related to a negotiation of diversity as part of a unifying movement. Instead of homogenizing silkworm varieties or forcing living things to conform to a certain behavior or pattern in order to grow to a certain standard, *tōitsu* as a policy recognized the impossibility of corralling such intense variation or the expectation of true homogeneity across a growing nation and empire involving various microclimates. This topic of weather patterns and climate warrants much more attention than can be afforded in the space of this chapter, but it is worth noting that while the regions best known for silk production in the Meiji period included Nagano and Gunma prefectures, silk production had expanded across the nation, especially as factories established new locations, as will be discussed in the Conclusion. The task of *tōitsu* focused on the need to respect and maintain variation so that people in their localities could choose the most appropriate varieties of silkworms according to where they lived. The formation of the Gen Sanshu Seizōjō more or less provided an apparatus for preserving, ordering, and managing a unified state of silkworms.

In 1910, the factory bill came under discussion and was explicitly called by some a silkworm *tōitsu* bill.[48] The possibility that the Sericultural Association's opinion would solidify into a law fueled much debate when it came to discussions about the appropriateness of extending the notion of *tōitsu* from inanimate silk thread and cocoons to the living silkworm and its eggs. The agricultural scientist Hirose Jiro had warned earlier in 1910, "However much the raw silk trade has become seriously intertwined with Japan's fate, it is remarkable to see such a cruel bill in this twentieth century that tramples over human rights so excessively." While the *tōitsu* movement

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[48] The 20 January 1911 issue of the *Dainippon Sanshikaihō* uses "unification" in its English table of contents when describing the titles of articles that refer to *tōitsu*.

aimed to streamline production of silkworm varieties as a measure to control chaos, Hirose pointed out that silkworm-rearers faced various uncertainties. He raised concerns that producers would have to step to the regulated and sped-up pace of a new and unfamiliar silkworm culture in vain. Hirose drew attention to the detailed work that would actually take place, and felt that the governmental management or limitation of the useable number of *shurui*, or types of silkworms that people could use to produce cocoons, overlooked the capacity of people to self-govern and figure out how to create cocoons of consistent qualities.

This critique of the loss of autonomy, or the right to govern oneself, was not actually limited to the realm of sericulture, but scholarship on the mobilization of the Japanese countryside toward national goals suggests that sericulture was part of a larger phenomenon. Local improvement causes started to spread in 1905, instigated by the Home Ministry and the Ministry of Education, leading to the standardized membership of young men through youth groups in Japanese villages in what was called the Local Improvement Movement (*chihō kairyō undō*) by the 1920s.[49] Hirose criticized the deliberation procedures, which seemed to involve the voices of elites and academics without sufficient interaction or earlier measures to address the issues at the local level, with villages and towns. His skeptical stance toward the curbing of types of silkworms useable by people at the local level made him an ardent opponent of *tōitsu.*[50]

Hirose observed that the ongoing discussions created little opportunity for the average producer to participate in debate, even though it seemed that such voices would come to "matter" in shaping the vehicle of *tōitsu*. Nor did it seem that measures

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[49] Tamanoi, Mariko, *Under the Shadow of Nationalism: Politics and Poetics of Rural Japanese Women* (Honolulu: University of Hawaii Press, 1998), pp. 139–140; Ann Waswo, "The Transformation of Rural Society, 1900–1950," in *The Cambridge History of Japan, vol. 6: The Twentieth Century,* ed. P. Duus, 541–603 (Cambridge: Cambridge University Press, 1989).

[50] Hirose, Jirō, "Shurui No Tōitsu ni Tsuite," *Dainihon Sanshi Kaihō* 19, no. 221 (1910): 10–13.

were being entertained to address the issues from the local level first. For instance, Hirose had suggested to momentarily embargo the production of raw cocoons. He also recommended that within in each district, several co-located chrysalis extermination facilities and cocoon markets be established. Hirose felt that localized solutions were within reach to help meet the desired outcome of cocoon *tōitsu* without devastating peoples' livelihoods.[51] Merely expending sericulturists' energy and labor by creating higher volumes of silk cocoons rather than practicing sufficient selection to remove diseased cocoons, in his mind, overlooked the kind of care necessary to reduce inconsistency in the commercial products that did concern various stakeholders.[52]

c. *Tōitsu* as Uncertainty: A Call for Revolution

"Whenever confronted with questions, whatever they are, one must be able to explain one's silkworm seeds as though they are a part of one's self," implored Takezawa Akira, the editor of the trade journal *Sangyō Shimpō* and a leader among seed producers. In discussions with egg producers in 1910 concerning more biological matters pertaining to the business of silkworm reproduction, professionals in the field such as Takezawa argued for the importance of a sense of continuity between cultivator and the silkworms' bodies.[53] This issue held particular meaning for Takezawa; by then, seed producers had been under fire for years for assigning brand names to silkworm varieties without sufficient consideration of the meaning of varietal distinction and their apparent consequences.

The debates of 1910 have been preserved largely in key trade journals, the *Dainihon Sanshi Kaihō*, and the *Sangyō Shimpō.* The former was an industry-wide association trade publication read by everyone from members of the Imperial family

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[51] Specifically, types as in *shurui.*
[52] Hirose, Jirō, "Shurui No Tōitsu ni Tsuite"
[53] Takezawa, Akira, "Sanshukai Kakumei No Ki Wa Chikazukeri," *Sangyō Shimpō* 18, no. 206 (1910): 1–6.

down to the producer. It tended to print more material by governmental officials and elites, as Hirose had indirectly criticized, although some of those individuals also had very critical views of *tōitsu*. The latter publication was a sericulture courier, published mainly in the interest of producers and sericulturists. It expressed views that were slightly anticipatory of significant changes yet also reflected on the associated uncertainty. Takezawa subjected many issues to deliberation under his editorship and dedicated a special issue in May 1910 to themes related to silkworm seeds. The special issue was designed as a resource for the seed-producing community – those whose worlds, livelihoods, and businesses revolved around the production of silkworm eggs and varieties at once.

In his editorial, Takezawa confronted the question of *tōitsu* and the growing interest of Japan's national sericultural experiment stations in changing silkworm-production methods. "The time for a revolution is nearing for the *sanshukai* (silkworm seed world)," Takezawa proclaimed, as he laid out a list of issues that suggested that he and his colleagues stood on a precipice: it was unclear what they might be facing, and whether it would be good or bad.[54] This declaration of a revolution but uncertainty as to how to proceed is key to understanding why, for instance, more widespread opposition to *tōitsu* did not form despite the problems at hand.

The reasons for such uncertainty about how to act upon this so-called revolution were manifold: a lack of clarity as to how many more silk industrialists there should be and moreover what to object to; the growing financial difficulties faced by seed producers every year; greater competition between new and old regions of silkworm production; and the anxiety that developed out of the urgency to improve silkworm seeds. The seed producers began to recognize that the whole country would

[54] Ibid.

be made *tōitsu* (unified or made homogeneous) at the level of silkworm cocoons if a foundational seed-stock manufactory were placed in each prefecture. Takezawa wrote, "its popularization has temporarily halted from a business standpoint; it can also be called the final nail in the coffin for silkworm egg producers." Realizing that the issue would continue to be deliberated, he continued, "We industrialists have to face this event and, moreover, make preparations to agree or to oppose."[55]

"If we are to improve silkworm egg producers, an effort to acquire knowledge of the silk industry must be made first," Takezawa began. He wished for his fellow producers to have the will to work independently of the government or officials and to always keep in mind the goal of producing high-quality products with distinction, whether in terms of the *shurui* produced or the methods used to produce them. This wary stance may perhaps be understood best as a bottom-up strategy on the part of Takezawa and fellow seed-makers as a way to internalize and appropriate *tōitsu* for themselves in order to avoid the consequences of its imposition from above. He stressed the importance of always protecting a belief in the value and responsibility of one's own position without succumbing to the desire to merely produce large quantities of silk cocoons. It was up to the sericulturist to adjust the rate of change in rearing practices precisely, especially in different regional climates, in order to attain raw silk exhibiting the threads of the specifically desired lengths, strengths, and thicknesses.

Takezawa's editorial, while calling for a revolution among his peers, uniquely made explicit much of the common sense that seed producers had largely internalized until then. "As sericulturists, we must always expect that one long day is not enough to obtain experiential knowledge; for instance, it is also useless to built amazing [production rooms] or have ostentatious ways, which do nothing but lead to debt . . . ."

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[55] Ibid.

To Takezawa, sericulture consisted of intangible, hard-earned, experience-based practical knowledge that would slip farther away by compromises of basic excellence. He wished for nothing more than the silkworm-seed industry to believe in the benefits, albeit modest in terms of returning profit, of taking a simple and earnest business stance. The process of *tōitsu,* he expected, would still make it important to maintain excellence while affording the "discovery" of new silkworm varieties. Takezawa referred to the renaming of silkworm varieties, on the other hand, as a low act: "If it is a new *shurui* (type), it should decidedly exhibit a new feature. A new *shurui* should be produced and put out there without enduring any embarrassment."[56] This editorial emphasizes how Takezawa seemed to appreciate the intent of *tōitsu* to bring about beneficial changes but to be deeply skeptical of the actual ability:

> It is a decidedly wonderful thing that because the government, as a large organization, is making all of the prominent scholars in the land compete in order to develop a survey of silkworm seeds to date, the development of new silkworm seeds can be possible. While that may be, each and every member of industry right now cannot have peace of mind and throw caution to the wind by entrusting one's own responsibility to a nationally run business. If you recognize and think about our agricultural products today, there is nothing yet that scholars have actually developed that have fundamentally surprised us.[57]

The apparently waning willpower of producers to maintain control over their harvests, according to Takezawa, was symptomatic of the very need to embrace a revolution by expanding their gazes within the industry to think about both the discrete task of making new silkworm seeds and envisioning the final silk fibers that others would work with. Takezawa put forth, " . . . We have regrettably come to a place in which we [silkworm seed producers] have to look at a broad view of the whole situation for the sake of the silkworm world. For a number of years, silkworm seed producers have

56 Ibid.
57 Ibid. "Nationally run business" is a translation of *kansetsu jitsugyō.*

been oppressed by just furnishing seed after seed."[58] Now, they had to voice their interests and disinterests if they were to survive.

Here, believability and trust in the academic justification of *tōitsu* came under fire from Takezawa. While scholarly experiments on the *tōitsu* of *sanshu* at the level of larvae and cocoons were understood as necessary, the greater issue was not about just getting surveys and tests done. The government faced a huge challenge if people were expected to subsequently believe those results and, in general, find the designers of *tōitsu* credible. The matter of convincing ordinary people to believe in and trust the state seemed disconnected from the practical necessities to make this work. Yet, what pushed the changes of *tōitsu* through? The sheer interest of the state may not be unexpected, but Takezawa's support for some kind of solution despite his heavy criticism of *tōitsu*'s execution alludes, at best, to a piecemeal mental scramble among people for a more cogent Japan after the Russo–Japanese War. Julia Adeney Thomas discusses how the nation had started to become distinctively naturalized by 1910 as the *kazoku-kokka*, the family-state. It might be argued that the *tōitsu* activities of sericulture helped characterize this moment, in which the stability of nationhood was not just important but desired, especially in a time that included an assassination attempt on the Meiji emperor, his impending death, and relatedly, the generational decline of the Meiji oligarchy.[59]

"Until today, the experimental research of each ministry has been the pastime and in the hands of other scholars," Takezawa wrote. To become believable by "the

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[58] Literal translation of sankai is "silkworm world."

[59] Julia Adeney-Thomas, *Reconfiguring Modernity: Concepts of Nature in Japanese Political Ideology* (Berkeley: University of California Press, 2002), 193–201. The family-state offered a more "authentic" way of doing things in which nature could replace history, and gradually impose an ethic of filial piety by changing educational rhetoric, that personal interests should be set aside and conform to the purposes of the "eternal state." My point in raising this is not to equate the Japanese national unity with the unity of silkworms, but the *tōitsu* movement might also be taken into consideration of a larger historical development concerning nationhood. Thomas also cites Miyata Takeo, ed., *Dōtoku kyōiku shiryō shūsei* [Compilation of Moral Educational Materials], vol. 1 (Tokyo: Daiichi hōki, 1959), 499.

world," he expected the Ministry of Agriculture to train and cultivate people to address the discrepancies between degree-holding experts and land-learned experts such as himself. Takezawa seemed to express congruency with rising nationalist thought, although he was skeptical of its measures. The major discrepancies in the education, training, and overall cultivation of people in sericulture alarmed Takezawa, who found it disingenuous of the Ministry of Agriculture and Commerce to expect him to follow the lead of their experts when so few had demonstrable, in-depth knowledge of the most pertinent issues before wasting decades on minimally fruitful research. "For the time being, the Ministry should request universities to separately train people in *sangyō* (silkworm business) . . . the point of doing so would be at least to increase understanding of the silkworm," Takezawa urged. This quote identifies not only Takezawa's disdain for the situation at hand but also the vast knowledge gulf between university-trained experts and ordinary people, often in the countryside, as he effectually offers a critique of a growing imposition of the naturalizing state. He wanted to see researchers and officials dabble in sericulture much in the way the educated elite traveled abroad to learn from fields overseas.

Takezawa's disdain grew from knowing how little capital investment translated into what we may consider the vitality of the sericultural knowledge economy, at the risk of cheapening the entire industry. If the new law is designed without sufficient research or just "makes a racket about the *tōitsu* of cocoon qualities, the resulting suffering of loss by the public will be difficult to take stock of," he warned. Practitioners such as Takezawa looked for politicized shenanigans or ulterior motives that could compromise producers' interests. "It is hard to say whether the present agricultural researchers are the best sort of people. If they keep doing experiments that just deceive laymen, twenty years will be required [to make a profit];

in other words, the work of scientists must be relevant and useful to the business world."[60]

Although Takezawa strongly criticized the scientific establishment, his support for Toyama came easily, considering he had also supported Toyama's expertise in the trade journal *Sangyō Shimpō* over the years (both the journal and Toyama's magnum opus *Sanshuron* [On Silkworm Varieties] were published by Maruyama-sha).[61] Takezawa's earlier reminder to treat silkworms as though they are "a part of one's self" exemplified some of the peculiarities of cultivating living organisms aligned with Toyama's espousal of the importance of understanding the silkworm's *honsei*. During this struggle to achieve uniform silk qualities for export, attention to the changing silkworm–human relationship as indicated by Takezawa's words and the inclusion of Mendelian teachings in Toyama's conceptualization of *honsei* hint at how the tenor of the conversations changed among the bearers of knowledge – those of science, and those of the worm.[62]

d. *Tōitsu:* Managing Boundaries of Life and Nation

While Takezawa and his silkworm-seed producers expressed great frustration regarding the lack of attention and engagement with sericulture by the government, the trade journal *Dainihon Sanshikaihō* published voices occupying the other end of the spectrum of concern. For instance, the January 20, 1911 issue reprinted transcripts or "interviews" of the deliberative statements made earlier by various discussants of the upcoming bill. One voice belonged to Marquis Ōkuma Shigenobu, a former finance minister and the founder of Waseda University, known as a "man of the people."[63]

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60 Takezawa, "Sanshukai Kakumei No Ki Wa Chikazukeri."
61 Toyama Kametarō, *Sanshuron. Vols. 1 and 2* (Tokyo: Maruyama, 1909); Toyama Kametarō, "Mayu Tōitsu Mondai no Atoshimatsu," *Sangyo Shimpo* 19, no. 215 (1910): 16–19.
62 Ibid.
63 These seem transcribed based on their vernacular style, despite the fact that some of those "interviewees" were some of the leading intellectual figures who could comment on Japan's agricultural

Ōkuma's views on sericulture and *tōitsu* reflected the interest of the state and Japan's success in the silk industry in that he did not categorically oppose the ideals of *tōitsu*. Even so, he offered a skeptical response, believing that the *tōitsu* of silkworm seeds would not guarantee the *tōitsu* of cocoon qualities, nor would it naturally engender the *tōitsu* of thread qualities. He was certainly aware of the pressures from the silk industries of France and Italy: "The constant voices of criticisms, especially that our silk qualities are inconsistent, have reached our ears and we can bear it no longer."[64] By comparison, he pointed out that while France and Italy were certainly developed countries, Japan and China's trade of silkworm seeds not only helped the silk industries in Europe turn around. Those European countries, Ōkuma stressed, also succeeded in the *tōitsu* of their silk threads. These threads, more tolerant of market volatility than the silk of Japan, served as the industry standard. Despite this urgency to come up to speed, Ōkuma remained enormously skeptical of governmental intervention in the management of silkworm parent-stock manufacture. He did not think the nation's silkworm seeds could possibly achieve *tōitsu*.

As mentioned earlier, the microclimates of Japan posed a large obstacle to maneuver around in *tōitsu* discussions. Ōkuma thought about geography in combination with the reality that silkworm seeds are living things. He argued that even a three-year-old child knows that people cannot treat them the same way as they treat mail, tobacco, or salt.

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development. This salonlike publication on the one hand reflected some of the sentiments and relationships to the imperial family and served to promote sericulture in Japan overall. On the other hand, it also provided a salonlike forum for discussion among practitioners across the entire silk industry and, in addition to various expert commentaries and industry reports, it was known to run occasional works of literature, a recipe column, photographs, and poetry. Okuma's "Memorial on a National Assembly" in 1881, which leaked information about corrupt Hokkaido land sales, led to his expulsion him from politics but earned him a reputation for protecting popular rights. See de Bary, Gluck, and Tiedemann, 2006, pp. 58–62.

[64] Ōkuma Shigenobu, "Kyokugai Yori Mitaru Sankai no Nimondai," *Dainihon Sanshikaihō* 20, no. 227 (1911): 29–32.

> Japan may be small, but from the northern extremity to the southern extremity, there is a considerable temperature difference of ten or fifteen degrees. Moreover, due to the relations of the warm winds and cold winds, even if we are talking about the same sea-shore, the weather has enormous divergences. In Honshu's central region, there is a long chain of mountains that continue and the climate in that direction is similarly not all the same. As for soil quality, in the same way that Hokkaido and Kyushu are not the same, if the soil quality varies from place to place, it becomes necessary to have a command over the climate or soil since *sanshu* are living things. Then, it will be absolutely clear that the *tōitsu* of silkworm seeds is impossible.[65]

Ōkuma greatly supported the success of Japan and the nation's recognition by the world as a civilized commercial power, but he also believed that the people had a say in the country's public affairs. As a great proponent of education, he also valued emulating and supporting only the most well-informed or successful approaches to reaching national goals. It makes sense that Ōkuma held a highly nuanced, if not evidence-based, view of *tōitsu*, perhaps informed by his horticulture hobby.[66] Consideration of environment and geography, including mulberry cultivation and silkworm-rearing practices, highlight how Ōkuma believed that a fixed gaze upon *tōitsu* of breeds would not alone bring about *tōitsu* of the thread quality. Ōkuma saw problems that could arise when people take whatever possible means to achieve standardization, which in his mind was a good but idealized notion. Ultimately against political intervention, he urged the consideration of other methods, such as education. He continued,

> . . . the knowledge level of our business men is low, so if it is low then even if a good method [for *tōitsu*] is pointed out, the practical use is not a certainty, and those without knowledge, even if they do not have bad intentions, they might end up doing something irregularly . . . there is nothing more annoying than dealing with those with low knowledge. The knowledge level must either be raised, meaning it would depend on education, but aside from that, there is nothing else so if improvement of *Sangyō* (silkworm industry) is truly to be

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[65] Ōkuma, "Kyokugai Yori Mitaru Sankai no Nimondai," p. 30.
[66] J. Morris, *Makers of Japan* (Methuen & Co., 1906), pp. 253–254.

> strategized, then first, the diffusion of silkworm industry education must be spread. If at least, silkworm industry education can flourish, large problems such as the *tōitsu* of silkworm seeds can naturally become resolved.[67]

The professor of agronomy Yokoi Tokiyoshi also opposed the proposed *sanshu tōitsu* law, calling the nation irresponsible. Yokoi specialized in soil chemistry at the Imperial University of Tokyo, but not long before, in 1897, he had written "Nōhonshugi" (Principles Underpinning an Agriculturally Based Economy), a seminal essay that critiqued the increasing industrialization of agriculture in Japan, warning that it would destroy the very fabric of society.[68] In his 1911 article appearing along with Ōkuma's in the DNSK, he maintained his critique of the commercialism that was weakening the integrity of communal solidarity in rural Japan.[69] Yokoi believed the policy presented a dangerous situation because it required the management of unification at a regional level. At the time, it was unclear where the funding for the *sanshu tōitsu* would come from, and Yokoi also believed the plan was ill-conceived because it was not clear that adequate support and skill at the regional level would develop even if regional seed-manufacture stations were built. The encouragement would make it attractive to place a seed manufactory in each prefecture, and Yokoi suspected that if the new law proved little more than an improvement of the pre-existing Silkworm Disease Prevention Law, existing resources for disease control would be diverted.

Following discussions in 1896 about silkworm-disease inspection policies and the reality that silkworm diseases cannot be destroyed completely, the need for national management of silkworm seeds was intently discussed. The government had

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67 Ōkuma, "Kyokugai Yori Mitaru Sankai no Nimondai," p. 31.
68 For more discussion of Yokoi Tokiyoshi and "Nōhonshugi," see also Havens, *Farm and Nation in Modern Japan* and Vlastos, *Mirror of Modernity*.
69 Yokoi Tokiyoshi, "Naniyue ni Sanshu Tōitsuan ni Hantai suru ka," *Dainihon Sanshi Kaihō* 227, no. 20 (1911): 35–40. Pyle, "The Technology of Japanese Nationalism," discusses Yokoi's position in the Local Improvement Movement (*chihō kairyō undō)*.

recognized that it would not be dangerous to force localities to manufacture and rear foundational silkworm stocks, and moreover, Yokoi noticed, the state was beginning to transfer the responsibility for making these foundational stocks to the regional level. This emphasis on the regional was well founded because it was understood that silkworm seeds produced locally did well.

Yokoi, who supported local control of farmers while also expressing nationalistic sympathy, adamantly voiced concern about the displacement and loss of livelihood of silkworm-seed producers in Fukushima, Gunma, Nagano, and elsewhere who had worked hard to achieve success over the years. He pointed to the necessity of silkworm varieties for producing particular goods for domestic use, whether as silk cotton, silk raw fibers, short silk fibers, or strong fibers. The cowardice that seemed to be cropping up among "those who have knowledge and experience in silkworm seed production who would allow the nation to take responsibility and put things in danger" appalled Yokoi, who felt that *tōitsu* should be carried out in each prefecture, overseen by individuals there with sufficient abilities and skill.[70]

Yokoi also shared some of the same concerns as Ōkuma about the variable weather within prefectures, the political boundaries of which did not reflect climatologically realistic categories of *tōitsu*. He felt it was unrealistic to limit the movement of silkworm seeds within prefectures and likened it to the former isolationist policy of Japan, for cutting people off from each other would incur greater detriments and missed opportunities. A policy of closed doors between prefectures within Japan would stifle the work of filaturists and reelers who were tasked with processing as many cocoons as possible. Yokoi rather placed greater faith in the "natural" ability of people to reach their own *tōitsu*, especially in areas where there mght be only four or five different silkworm varieties. So long as it only involved the

[70] Yokoi, "Naniyue ni Sanshu Tōitsuan ni Hantai suru ka," p. 35.

renaming of the silkworm varieties, the issue would eventually iron itself out, he felt: "Although filaturists such as in Suwa source their cocoons from various prefecture and of course press for *tōitsu*, but such a prefectural isolationist policy for silkworm seeds will also result in . . . major inconveniences [for those filaturists who rallied for silkworm seed *tōitsu* by prefecture] . . . ."[71] Yokoi pressed for greater logic and clarity in terms of what it would actually mean if silkworm seeds made in one prefecture could not be sold elsewhere. "The technology of silkworm seed manufacture cannot be acquired easily; that this technology would be buried away in vain is too bad."[72] According to Yokoi, it was a waste to supplant the knowledge and experience of the seed producer with that of an experiment station engineer, for that would make it exceedingly difficult to retrieve that knowledge, not only because of their differences in know-how and approaches, but because governmental regulations provided only a low monthly salary of between 30 and 50 yen.[73]

Yokoi did not flatly oppose the establishment of the Foundational Parent Silkworm Manufactory *(Gen Sanshu Seizōjō*) and its various branches. After all, Japan had already a similar network of agricultural experiment stations where seeds could be tested. The *tōitsu* problem did not sit well with him particularly because he claimed he knew that the workers at those bureaus knew it would not be possible to *tōitsu* silkworm seeds on a general level, but nonetheless, transferred that responsibility to do so to the localities. Yokoi, although quite critical, occupied a middle ground on *tōitsu*. His background as an agronomist rather than as a producer reflected a concern to avoid the conflation of labels or labor. This differed from the concerns of those interested in building upon *tōitsu* as a platform for biological improvement of the silkworm.[74]

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[71] Ibid., pp. 36–37.
[72] Ibid., p. 38.
[73] Ibid., 1911.
[74] Ibid.

The agronomist's concerns dealt mainly with the matter of forcing human labor where it was unnatural to do so (old seed producers, who were natural, vs. the new system, which was unnatural). Yokoi felt that the *tōitsu of* cocoons was not objectionable as long as they were taken as commercial objects; however, he worried that farmers would make too many sacrifices that would affect the prices of the cocoons, which needed to be kept low for filaturists. Yokoi encouraged greater opposition. A large variety of silkworm seeds, while not categorically bad, in his view meant that in various regions, appropriate varieties should be usable at any given time. The great number of varieties had the potential to lead to better varieties, so Yokoi argued for the desirability of a large number of silkworm *shurui*, using the word for "type" rather than the term "silkworm seeds," which perhaps suggests his distance from the colloquialisms of the profession.[75]

Yokoi saw an abundance of *shurui* as a sign of progress, whereas the lack of variety was a sign of its absence, as in China's relatively few *shurui*. In what also seemed a contradiction, Yokoi made a distinctive exception for commercial products, for he did not believe that large numbers of *shurui* would lead to profit. Rather than concern oneself with the *tōitsu* of silkworm seeds, the *tōitsu* of raw silk for commercial sale is more critical, he explained. This reasoning based on a return to the matter of raw silk shows the fluidity of the subject of *tōitsu* relative to the familiarity one had with the dynamic between the collective variation of silkworms and the resulting threads. Yokoi's reminder that the point of *tōitsu* was to address the resulting silk illuminates the difficulty in determining which stage of silk production to invest resources in at the time.

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[75] Ibid.

e. *Tōitsu* as Stabilization of Family?

Despite all of these issues voiced by Ōkuma and Yokoi, there was an even larger dimension to the *tōitsu* debate. Some of the participants connected sericulture to larger geopolitical concerns about Japan's place in the world. The Agricultural Affairs director, Shimo'oka Chūji (later a chief civil administrator in colonial Korea), emphasized a point that connected the significance of sericulture to some of the general anxieties concerning Japan's place in the world:

> If we look from a broad point of view at international trade or war with the outside, it is my opinion that we must adopt a middle ground in order to solve this problem . . . from the beginning, we are not talking about making the country's silkworm breeds into one or two varieties. We will *tōitsu* what we can *tōitsu*. In other words, we are planning to diffuse good varieties that would be appropriate for each region and climate by organizing the confusion of silkworm breeds.[76]

Shimo'oka's comments sought to disengage from the usual polarized debates about whether *tōitsu* should or should not proceed. Many of the debates presented extreme ends of the argument, in addition to engaging with deliberations over natural and artificial selection. The discourse of selection, which Yokoi had alluded to in calling the top-down model of *tōitsu* "artificial" and the nonintervening model "natural," reflected those different poles and their propensity to be splintered by contradictions. "This is a fair and impartial debate, which is why I acknowledge that the Ministry of Agriculture and Commerce takes the resolution of this Production Survey Committee as a basis in order to make principles that will make allowances for these methods in a fair manner," Shimo'oka wrote.[77] In addition to being realistic about the issues, he framed them to consider the question of whether the industry should stay on due course or not given the international trade and foreign competition.

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[76] Shimo'oka Chūji, "Sanshu Tōitsu-an No Jikkō to Risō [The Practise and Ideal of the Proposed Unification of Silkworm Variety]," *Dainippon Sanshi Kaihō* 227 (1911): 33–35.
[77] Ibid.

According to Shimo'oka, the best of the local varieties would first be chosen for manufacture as official silkworm varieties and then undergo testing. "Only after manufacturing *gen genshu* (parent of parent silkworm seeds) will it then be possible to believe that we have advanced to the point in which we can attain a *shurui* close to the ideal."[78] The use of the phrase "*gen genshu*" reflected Shimo'oka's point that there should be enough official control in the overall silkworm-seed manufacturing process such that the grandparental generation remained uncompromised. In order to carry this out, he felt that one facility should conduct experiments to identify the choicest varieties, while several other facilities should test the same *shurui* to assess their pros and cons. Shimo'oka also realized that in order to achieve any goal for the *tōitsu* of cocoon qualities, his technicians would have to face all of the townspeople, villagers, and *buraku* (outcasts) in every region and earn their cooperation to manage the silk industry. As one tactic, he hoped to amass greater support to establish cooperative silkworm-rearing as a vehicle to help advance sericulturists' knowledge and technology, as well as to contribute to the *tōitsu* of cocoons that filatures so badly sought.[79]

Shimo'oka understood that the establishment of the facility would not cure all of the various ills that undermined productivity at the time, but he tried to create greater harmonization and achieve common goals through the encouragement of cooperatives and manufactory research institutions. Shimo'oka was quite aware of the gap in understanding between sericulturists and filaturists. Much like the way a family consisting of parents and children are interdependent, he explained how each of the disciplines within the silk industry, sericulture, seed production, and filature and reeling, inescapably affected the prosperity or health of the other. This was particularly noticeable in the case of Suwa described earlier by Yokoi. With filaturists

[78] Ibid, p. 33.
[79] Ibid.

increasingly purchasing cocoons from all over the country, Shimo'oka saw only intensifying friction between filaturists and the sericulturists who would receive the former's blame for inconsistency, though geography would have already dictated it so. If filature and sericulture were to be considered related at the level of siblings, from the Ministry's point of view where Shimo'oka stood, the ill feelings fomenting between the two would harm the silk-industry family. Rather than having sericulturists and seed producers relate only to each other directly, Shimo'oka's idealized situation consisted of establishing a centralized filature for each region which silkworm seed producers would cater to, while the sericulturists would assist in the rearing of the larvae and harvest of the cocoons. If such a system were in place, Shimo'oka felt, *tōitsu* would also take place automatically. Yet, he also knew that the immediate *tōitsu* of cocoons would be unrealistic, so in addition to recommending that facilities for the *tōitsu* of silkworm seeds be established, he concluded by suggesting that cooperative silkworm rearing as well as improvements at the filature level be implemented.[80] To Shimo'oka, this need for harmony among the different components of the sericulture industry, likened to family members, ultimately gestured to the potential degree of wealth that Japan as a whole familial network could accumulate. It also reflected a possible connection, as mentioned earlier, with the political developments of the time that stemmed from the early Meiji *kazoku-kokka* policy, in which subjects were increasingly considered as part of a naturally existing nation through which patriotism could be expected of the country's inhabitants.[81] Whether the sericulture stakeholders

[80] Ibid.
[81] Tamanoi, *Under the Shadow of Nationalism*, pp. 93–95; Thomas, *Reconfiguring Modernity,* pp. 66, 198. The *kazoku kokkaa* depended on a population of "putative children," according to Thomas, who notes that the 1930s ideology of the *kokutai*, the homogeneous space in which the emperor was the head of an enormous extended family, involved a "particular celebration of the Japanese people." Twentieth-century Japanese ideology also drew upon the idea of an organic community, or *kyōdōtai*, translated from the German *Gemeinschaft*.

at the time also participated in more explicit imaginings of the family state remains open to investigation.

3. Hybrid Solutions

The Sericulture Industry Law passed in 1911 with a budget of 260,312 yen, or 130,156 U.S. dollars at the time.[82] The newly enacted *Gen Sanshu Seizōjō* would serve as the manufactory for producing foundational silkworm seed stocks. Shimo'oka offered particular insight to the role of industry in the institutionalization process of sericulture as science. Had the facility alone been planned just to conduct only research, calling the place *Sangyō Shikenjō* would have remained unproblematic. It was necessary to name the facility with functionality in mind so that researchers would not co-opt the facility to conduct academic work alone. Although the many different names represented essentially the same institutions as far as personnel was concerned, the new name, *Gen Sanshu Seizōjō,* more importantly signified the intention to produce foundational silkworm stocks, beginning with the spring silkworm season of the year after the next.[83] The workers, in addition to the chief of the institution, included 11 engineers, 16 assistant engineers, and 9 clerks.[84]

The 1911 law was one of the first institutional steps to standardizing the variation of silkworm breeds and their resulting cocoons across the nation of Japan. The law signaled a moment of entanglement as management of reproductive control

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[82] Law 47 was announced in October 1911. See "Sanshigyōhōritsu ni Sanshi Shikō Gyohō Kisoku," in *Dainihon Sanshi Kaihō* 20, no. 237: 65–79. See also Haga, *Sanshigyōhō Sekkō Kisoku ni Tsuite.* Japan used the gold standard from 1897 to the mid-1920s, and the nominal exchange rate was set at two yen per dollar.

[83] The establishment of the *Kōshūjō* was a sore point for Takezawa Akira, who pointed out how its mandate of teaching and training was actually eclipsed by the emphasis on research. See Takezawa, 1910.

[84] Kitamura Chikayoshi, and Minoru Nozaki, *Nōrin Suisanshō Ni Okeru Sanshi Shiken Kenkyū No Rekishi* (Tsukuba: Nōgyō Seibutsu Shigen Kenkyūjo, 2004), pp. 22, 87. The use of the terminology of *gishi* to describe these sericulture scientists as engineers would persist through the end of the Second World War.

intertwined with the state's increasing involvement with industry and commerce. Part of that entanglement associated with *tōitsu* would involve a reassignment of silkworm work and permission to carry out certain tasks and skills that allowed one to "know" the silkworm. The law involved directives that limited who may be an egg producer, the permissions that were required to undertake this task, copious orders about what, where, and when to sterilize, and limitations as to the permissions required to produce cocoons if you were also an egg producer. At most, Toyoma noted that at the organismal level, Article 8 of the law discussed what kinds of breeds a silkworm-egg producer may not produce, such as those where the cocoon is too small, defective, or which have low cocoon yields or slow development. This understated rule articulated the obverse of a rule that prohibited egg producers from making cocoons, which, to the scientist, did not add anything unique beyond what he called the mere masking "perfume" of *tōitsu*. Given the requirement that egg producers use only government-approved silkworms to make commercial eggs, poorly resulting cocoons would indicate that the egg producer kept the hybrid offspring, as seed-savers often had in the past, to make their own eggs. Now a deviant practice, seed-saving of the offspring of government-approved hybrid silkworms would result in revoked licenses for selling eggs. Formalized division of labor combined with accountability aimed to limit the egg producers' opportunities for introducing "flaws."[85]

Toyama had similarly designed a centralized scheme for producing silkworms in Bangkok when he served as a governmental consultant to Siam during the period 1902–1905.[86] In the process of establishing a silk industry there, he created a centralized experiment station system, remnants of which exist today. Yet, Toyama had doubts about the growing entanglement in Japan and felt that much more

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[85] Toyama Kametarō, "Mayu Tōitsu Mondai no Atoshimatsu," *Sangyo Shimpo* 19, no. 215 (1910): 16–19; Toyama Kametarō, "Sanshigyō Hōan wo Hyōsu," *Sangyō Shinpō* 19, no. 215 (1910): 104–109; Sanshigyōhō Sericultural Industry Law, Law No. 47 of 1911.

[86] The next chapter pursues these details further.

remained to be understood about inheritance and the phenomenon of hybrid vigor, which had gained a following by 1910. His 1906 study, which showed the remarkable growth of the size of silk cocoons in the F1 generation of silkworms that were the hybrid offspring of Japanese and Siamese silkworms, had deeply impressed his superiors. As a single notion, the F1, or first filial, hybrid has limited specificity and refers broadly to the generation of offspring resulting from a mating event between a male and female of the same species.[87] For sericulture in the early 1900s of Japan, the notion gained an additional connotation as the exhibition of hybrid vigor, or heterosis, resulting in offspring after a mating between two distinct silkworms.

Popular enthusiasm for hybrid vigor overwhelmed Toyama's skepticism, and the F1 hybrid began to be taken up more as a shorthand for cross-breeding of scientifically inbred strains of silkworms used to produce hybrid vigor, or more robust silk cocoons in the offspring generation than that of the parents. *Ichidai kōzatsushu,* or F1, described the generation of offspring resulting from one particular parental mating in heredity experiments. In the realm of silkworm breeding, the best kind of "F1 hybrid" would result from a mating between a male and female from two different scientifically inbred, genetically homogeneous parent lines. The notion of the "F1 hybrid" started to be conflated with the notion of hybrid vigor as "hybrid" silkworms gained notoriety for their promise of yielding more desirable and larger quantities of silk than either of their inbred parents. In contrast to the skepticisms aired by some of the politicians and agriculturalists mentioned earlier, the idea of the hybrid silkworm would not budge from the desires of state scientists. By 1911, Kagayama Tatsushiro, the director of the newly instituted Gensanshu Seizōjō, who also had a strong belief in hybrid vigor, put Toyama in charge of developing the eggs that would eventually yield F1 hybrids in three years' time.[88] According to a reflection by the Ministry of

[87] The Japanese term for "F1 hybrid" is *ichidai kōzatsushu*.
[88] Kitamura and Nozaki, *Nōrin Suisanshō*.

Agriculture bureaucrat Ishiguro Tadaatsu (1884–1960), the paucity of specific regulation regarding technical aspects of the improvement of silkworm breeds in the 1911 law irritated Toyama, who felt that the distribution of the silkworm stocks that would seed the parents of scientific hybrid silkworms was scientifically premature.[89]

As an expert scientist in his field, Toyama had been called upon by the state to contribute his opinions during the deliberation stage preceding the formalization of decisions about *tōitsu.* His inclusion represented the high regard that the state had for science; however, because he occupied an advisory position, his measured voice of caution may have played a minimal role in determining the final policy. Toyama felt that the proposed sericultural law lacked sufficient guidelines to nurture the growth in academic or commonsensical knowledge about the technical improvement of silkworm breeds themselves, finding that it overemphasized attention to further divisions of labor.[90] However, appointed to work under Kagayama, Toyama found himself committed to developing scientifically inbred stocks of parental and grandparental silkworms under a time pressure imposed not by the silkworms but by the state. The resulting silkworm eggs would help to gradually transform the sericultural landscape by facilitating the harvest of hybrid cocoons.[91] Under this scheme, sericulturists would only gain permission from experiment station authorities to allow larvae hatched from "F1 hybrid" silkworm eggs to mature and spin cocoons for the purposes of textile production.[92]

In contrast to their parents' stocks, hybrid silkworms presented a challenge to reproducibility. As sexually reproducing organisms, male and female silkworms must

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[89] According to the account of Ishiguro and Ōkama, *Nihon no Sanshigyō ni Tsuite Kataru*. The literature cites Article 8, but my examination of the legal text suggests this is actually Article 18. Toyama's criticisms of the new policy also appear in Toyama, "Sanshigyō Hōan wo Hyōsu."
[90] Sanshigyōhō Sericultural Industry Law, Law No. 47 of 1911; Toyama, "Sanshigyō Hōan wo Hyōsu."
[91] Chapter Five will discuss the role of the Katakura Silk Factory in popularizing the use of the hybrid silkworm in Japan in the 1920s.
[92] See also Kiyokawa, *Development and Diffusion of Improved Hybrid Silkworms in Japan*.

mate to produce viable offspring. Letting valuable hybrid silkworms breed with each other would not automatically yield more of the like kind, even if they hatched from viable eggs. Without following the genetic laws that Toyama studied the chances of degrading the pedigree increased. The institutionalization of the national silkworm manufactory, focusing on the production of improved inbred stocks of silkworms that spin silk of consistent qualities, aimed to prevent independent egg producers from allowing unruly or unguided silkworm reproduction to take place. These changes in silkworm parentage and production would require new certifications to verify that they were produced from approved parental silkworm stocks maintained and released by licensed silkworm experiment stations or trusted local varieties. Even though language describing the F1 hybrid silkworm was vague in the new policy, the F1 hybrid emerged as a direct consequence of policy reform as it began to turn the local craft of silkworm cultivation into a nominally local practice under centralized control, as scientists began to take serious stock of the available diversity in order to select the best parent silkworms to produce the raw silk that would feature as an export product of Japan. The new limitations of breeding practices would gradually deskill this aspect of sericulture from individuals to expert bodies in new institutions. This partnered metamorphosis of silkworms and their caretakers characterizes the multidirectional pursuit of *kairyō*, or improvement, of raw silk, the support of which required the social fabric of Japan to change with each attempt to alter the processes of production.

Hybridization-based cocoon improvement for Japanese export in the late Meiji era presented a curious situation when held in contrast with popularly held assumptions that racial interbreeding among humans is biologically unfavorable.[93] When the journalist Takahashi Yoshio wrote *A Treatise on the Improvement of the Japanese Race* (*Nippon Jinshu Kairyôron*) in 1884, he promoted mixed-blood

[93] Jennifer Robertson, "Japan's First Cyborg? Miss Nippon, Eugenics, and Wartime Technologies of Beauty, Body, and Blood," *Body and Society* 7, no. 1 (2001): 1–34.

marriages between "yellows" and "whites" in order to make a taller and more beautiful race of Japanese and propel Japan forward from a "semi-civilized" to a fully "civilized" state, capable of competing with the West.[94] Kato Hiroyuki, a former Tokyo University president, opposed this proposal fervently, insisting that the Japanese were not inferior to the West and that while intermarriage might change qualities of the Japanese race, it would not necessarily improve it.[95] Silkworms by the 1910s seem to crudely approximate this experimental biological approach to improving on the notion of "race," but we are also reminded that the performance of the silkworm especially mattered with respect to its inanimate proxy form, given the end of improving the quality of its silk. Reeling Japanese silkworms' silk with those of another variety was never a desirable option; it was important for reelers to work with standardized cocoon shapes and sizes. The improvement of cocoons as things that represented Japan to the West in the international market depended on the production of biological sameness, along with the enhancement of size, weight, and length.

Indeed, silkworms and their eggs were recognized in Japan as commercial entities well before the mundane practices of *kakeawase*, or cross-breeding, became reconfigured as hybridization science and selective breeding, as we call it today.[96] However, the manufacture of new silkworm seeds, both in the physical sense of eggs and in terms of distinct varieties, occurred alongside the growth of a new biological, particularly genetic, consciousness. This began to undergo increasing rearticulation as the business of authorities and experts. The mandates of 1911 required stricter as well as additional degrees of professionalization that reflected further divisions of labor

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94 Ibid., pp. 4–5, in reference to Suzuki Zenji, *Nihon no yûseigaku: sono shisô to undô no kiseki* [Japanese Eugenics: The Foundation of Its Idea and Development as a Movement] (Tokyo: Sankyo Shuppan, 1983); Fujino Yutaka, *Nihon fuashizumu to yûsei shisô* [Japanese Fascism and Eugenic Thought] (Kyoto: Kamogawa Shuppan, 1998).
95 Robertson, "Japan's First Cyborg?," p. 6.
96 For a general discussion of selective breeding, in addition to Darwin's *The Variation of Animals and Plants under Domestication*, see Wood and Orel, *Genetic Prehistory in Selective Breeding*; Muller-Wille and Rheinberger, *Heredity Produced*.

circumscribed by the distinctions drawn at and within different stages of the silkworm's life cycle.

Such compartmentalization would continue to accentuate the rationalization of silkworm cultivation that grew in response to a multitude of different economic, political, scientific, and cultural concerns throughout the Meiji period. The new Sericulture Industry Law was designed to alleviate some of the questions and issues that had been raised by various stakeholders, from the elites to the scientists to the advocates for laborers and localities, and to the seed producers, whether on behalf of their own selves or their silkworms. Toyama's 1908 speeches aired tensions about the problems that the silk industry could face with the separation of tasks such as egg production or breeding and larvae-rearing. Whether *tōitsu* could appease all the concerned and skeptical individuals remained an open question. The pluripotency of *tōitsu* represented the rich, if not at times perplexing, array of ways in which the national management of silkworm varieties could possibly proceed.

4. Summary

The extraction and organization of information about silkworms that began in the late nineteenth century laid down the foundation of new "languages" with which to officially describe hundreds of different types of silkworms (as well as their inherited characteristics) by the Taishō period. These rearticulations of silkworms now seem to reflect the silkworm's entanglement with concerns about the viability of Japan's international competitiveness, as state-led management of the industry increasingly brought individuated silkworms with their particular histories together more concretely within an apparatus for enhancing productivity throughout the first decades of the twentieth century. Indeed, *tōitsu* evokes a biopolitical power executed through the creation of norms understood through qualifying, measuring, appraising, and recognizing hierarchies.[97]

The different potential ways by which *tōitsu* could manifest itself at the levels of silk, cocoons, silkworms, seeds, methods, or the sociality of human work had fanned a great debate among various leaders in the sericulture industry that would continue to metamorphose through the ensuing decades. As the notion of *tōitsu* took on a greater legal form by 1911, and as the structure and objective of the associated network of experimental manufactory stations gained clarity, the proximity of individuals and groups to the actual day-to-day ways of the worm shaped the discussion of *tōitsu* as a principle and practice. This chapter focused on matters of *tōitsu* pertaining to the matters of silkworm breeding and its politics, and showed how individuals – from sericulture scientists, agriculture and agronomy scientists, and a leader among silkworm-egg producers, to officials, including a former finance minister and the agricultural affairs minister –responsed to the problems and solutions of *tōitsu*.

Before broader national discussions developed under the heading of *tōitsu*, silkworm experts such as Matsunaga began to address the need to standardize rearing practices on a local scale. These emphases on managing the external environments of the silkworms differed from the responses of Toyama, who began to use the notion of *honsei* to call people's attention to the biological endowment of the silkworm, in addition to external mediations. Shifts in the emphases in silkworm breeding from the environment to the inherent seem to have overlapped with another shift described by Adeney Thomas, Japan's growing trend, in the early twentieth century, of embracing an ideology of nature. The increasingly resource-poor state recognized the limits of nature, and awareness of the finite ability to exploit physical land stood in contrast to

97 Michel Foucault, *The History of Sexuality* (New York: Vintage Books, 1990).

the opportunities of a "genealogized natural nation," in which activities such as colonization, emigration, and centralized supervision grew into a divine matter of course after 1910. It is compelling to think about how historical actors such as Toyama and others working in Japan's experiment stations may have mapped silkworms and their populations onto this version of the nation. Japan's vision of itself was "neither traditional nor evolutionary" after 1900 as the Imperial-household analogy of early Meiji became true, at least in the form of revised textbooks that removed lessons about social Darwinism in favor of emperor worship.[98]

Sericultural activities were thus not at any mere commercial crossroads in 1911. While not all individuals stated their personal motivations, we can understand that debates about the legislation and governance of silkworms and their silk were also slowly being framed as part of a nationalistic emperor system. The transformation of humans and their silkworms into new configurations of national subjects runs a peculiar line that brushes against the kind of developments described by Eugen Weber in his analysis of the "condition" of French peasantry and the slow formation of French national subjects, understood through the connections between rural and urban areas through "city ways and values flowing into the countryside, of the country's colonization by the town."[99] In the case of the sericultural countryside, rather than a purported loss of tradition due to the infiltration of transportation or education, a reappropriation of an invented tradition helped coalesce the formation of national subjectivity, as this dissertation has touched upon. This reappropriated past was important as something to prop up for the purpose of spinning together a national community. If anything, I argue that a colonization of the Japanese interior occurred through an inversion process that commanded the countryside's complicity in defining

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98 Adeney-Thomas, *Reconfiguring Modernity,* pp. 178, 184–185, 194–197.

99 Eugen Weber, *Peasants into Frenchmen: The Modernization of Rural France, 1870–1914* (Stanford, CA: Stanford University Press, 1976), pp. 241, 245.

"Japanese." This foreshadows coalescences seen later in the 1930s. As Tamanoi describes the folklorist Yanagita Kunio's 1930s writings, which elevated the *jōmin*, or nonelite peasants and farmers, to "Japanese identity," "city life is a mere metamorphosis of country life in Japan."[100] The silkworm, in all of its shrouded silence, was also made complicit in modern Japan's project of identity formation. It was not only a standard bearer of what silk craft ought to be. As a rural object of affection, its mutability, located in its multitude and instability, in its hybridity and hybridizability, had constantly challenged people who sought to improve it and make some version of it, as a species, represent Japan, while for the purposes of mass production, its biology all but resisted this in practice.

The flattening of silkworm breeds and brands by 1910 performed an erasure of existing genealogies that facilitated the writing of new breeding practices in which the silkworm could be reasserted as functioning for Japan in a way that "obscured competition yet acknowledged change." This echoes the increasing refabrications of the national history of Japan that were expressed in the Meiji period.[101] By 1914, Toyama remained uncertain about the exact differences in variation (*henyi*) between different *shurui* and what exactly counts as "fixed" *henyi*. He stressed that actualizing the *tōitsu* cocoon qualities desired among reelers required accurate studies of genetics and evolution.[102] Considering the doubts expressed by Toyama alongside the momentum of the industry, *toitsu* in this case appeared to 1) reduce the confusions of

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[100] Tamanoi, *Under the Shadow of Nationalism,* pp. 127–128, citing Yanagita Kunio, *Kyōdo seikatsu no kenkyū* [Research on Everyday Life in the Countryside] (1935; repr. Tokyo: Chikuma Shobō, 1967).
[101] Mary Elizabeth Berry, *Japan in Print Information and Nation in the Early Modern Period, Asia* (Berkeley: University of California Press, 2006). The genealogical practices stemming around lineage charts in the early modern period, used to determine succession, without requiring a formula for how that would be determined (heredity, talent, usurpation, marriage), or why, was not a kind of continuity that equated to stasis, but pliant ambiguity. Berry stresses that genealogy construction in Japan was heterogeneous and open to interpretation by the Meiji period, which could be used to the advantage of nation builders (pp. 236–237).
[102] Toyama Kametarō, "Mayushitsu tōitsu mondai no atoshimatsu" ["Settling the Affairs of the Cocoon Quality Tōitsu Problem"], in *Sanshu yōroku* [Key Points on Silkworm Seeds] (Tōkyō: Sangyō Shinpōsha, 1913), p. 632.

discontinuous and continuous variation through more systematized study of breeds, and 2) reflect an obfuscation of actual heterogeneity by cross-breeding distinct silkworm breeds in order to produce Japanese raw silk.

This chapter showed that the human efforts to coordinate around the circus put on by the silkworm, starting with the description of silkworms for the government, required a banding together of the rural, the learned, the elites, and the women and children who were their wardens. The stress placed upon the biological positioned Toyama to recommend measures that would help breeders improve their silkworm varieties. As the Sericultural Association put forth a proposal for institutionalizing the breeding and improvement of foundational stocks, scientists in agriculture and agronomy such as Hirose and Yokoi decried the loss of autonomy for egg producers. Egg producers and their advocates such as Takezawa understood the basic need for *tōitsu,* but were uncertain about the trustworthiness or dependability of taking cues from bureaucratized sericulture science. Takezawa, who worried about the loss of skill and ability among sericulturists, found an ally in Toyama's dedication to highlighting the *honsei* of silkworms in discussions of how to overall improve sericultural practices. The skeptical responses of Ōkuma reemphasized the difficulty of achieving *tōitsu* of silkworms due to the variable climate and soil conditions of Japan, whereas Shimo'oka, who saw Japan in a larger world picture, responded by framing *tōitsu* as something that all sectors of the silk industry had to cooperate with.

The combination of these different sentiments contributed to the public airing of the practices of silkworm breeding and rearing that informed the very understandings of *tōitsu*. Much rather than merely responding to it as a static notion, the voices of those involved with the *tōitsu* debate brought ideas about the biological considerations, limitations, and opportunities of the silkworm into sharper definition. The resulting *tōitsu* policy, while exhibiting previous concerns about the methods of rearing silkworms and the avoidance of contagion, had come to reflect a greater commitment to the idea of managing human behaviors in the processes of silk production by managing the reproduction of silkworm stocks and the eventual production of commercially viable cocoons. While not all people could have or afford full awareness of the silkworm's habits on the level that Takezawa or Toyama advocated, the development of *tōitsu* as a policy of implementing institutional technologies of silkworm breeding could occur because of the increasing articulation of the biological aspects that otherwise constituted *honsei*. Those most familiar with the daily doings of the silkworms had distinct experiential and learned knowledge and could pose as being privy to the silent speech of the silkworm, as Toyama had done. The verbalized conveyance of details not only about their breeding, but experiment-based information on their patterns of inheritance led to a new scaffolds upon which to place the reasons and rationales in support of or in criticism of *tōitsu* as it came into form.

The style of national management of silkworm reproduction that came to manifest in the "solution" of *tōitsu* reflected a shift in the understanding of the technologies and biologies that constituted sericulture. Initial endeavors to describe the methods of sericulture in the form of a chart of standards focused on aligning the very human activities involved in the rearing of the larvae from the egg stage to that of the cocoon. New sericulturists could use such a chart to learn how to follow particular protocols for certain varieties of silkworms, while more established sericulturists could have the means to work toward adjusting their craft in the name of consistency.[103] Growing experimentation in sericulture increasingly helped tailor this craft technology to particular kinds of silkworms with greater specificity, despite the

[103] Kiyokawa Yukihiko, *Kindai seishi gijutsu to Ajia: gijutsu dōnyū no hikaku keizaishi* [Modern Filature Technology and Asia: Comparative Economic History of Technological Introductions] (Nagoya-shi: Nagoya Daigaku Shuppankai, 2009), pp. 98–105.

various manuals and handbooks in existence since the 1700s.[104] With the hundreds of silkworm varieties that had come to the fore by the end of the Meiji period, achieving consistency through the alignment of rearing methods had a limited gross effect, especially considering the growing number of households in Japan participating in sericulture.[105] The biological interventions represented by the Sericultural Industry Law imposed a more direct control over the heredity of the organisms.

If we allow ourselves to consider sericulture as a practice involving two general tasks – the methodological craft and technology of rearing on the one hand and selective or scientific breeding on the other – we can understand how members of the sericulture industry could easily have emphasized one aspect over another in the name of improvement. Even though the two tasks must coexist, if not enmesh with each other, the tenor of discussions concerning *tōitsu* signaled a shift in how state scientists and other strategists chose to emphasize the technical methodologies of rearing or biological interventions of breeding. Both of these were actually important, as Toyama had expressed the importance of both through his skepticism and advocacy of greater regulation.[106] Yet, the stress upon biological interventions would continue, and boundaries would once again blur, and as we shall see by the end of this dissertation, private and corporate entities would gain recognition of their expertise and reliability in silkworm breeding and, thus, permission from the government to operate autonomously from the gaze of regulation.

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[104] Morris-Suzuki, *Technological Transformations*, describes the abundance of Tokugawa-era sericulture manuals.

[105] Araki Mikio, *Nihon sanshigyō hattatsu to sono kiban: Yōsan nōka keiei* (Kyoto: Mineruva Shobō, 1996), p. 121, citing *Nōshōmu Tōkeihyō* [Statistics of the Ministry of Agriculture and Commerce]. In 1896, the number of households rearing silkworms in the springtime was 1,306,253. By 1908, there were 1,436,806. What is even more striking is the increase in the number of people who reared silkworms in not only the spring, but summer and fall. For instance, in 1900, 536,576 households reared summer silkworms and 428,318 reared fall silkworms. By 1908, their numbers grew to 580,565 and 905,207, respectively.

[106] For instance, Toyama "Kaiko no Shurui no Ryōtei ha Ikan ni shite Hantei subeki ka."

This chapter showed how a new configuration of power emerged by 1911 as bearers of silkworm knowledge shifted from the tacit realm of sericulturists to that of the state and its scientists. This analysis of the formation of sericulture legislation demonstrated how the silk industry, science, and the project of nationalization began to come together in a tangible way. In these entanglements, the results of breeding played out in the hereditary material of the silkworms and ultimately their cocoons, and new biological knowledge was also used to regulate the art and science of breeding work.[107] This chapter shows that in these shifts of knowledge as relationships between cocoon producers and filatures changed, the research scientist frequently served as a mediator, including at the level of the factory. These processes of making the silkworm legible also show how the ownership of sericultural knowledge and the assumption of responsibility to protect as well as cultivate this knowledge was at stake. This chapter thus detailed some of the processes underlying the practical enactment of *tōitsu*, which, although on the surface quite cacophonous and frustrating, represented a constant clarification of communicative channels used by those who were authorized to speak knowingly with the proper credentials or were in a position to speak on behalf of the silk industry, or even the silkworm in all its iterations. The various changes engendered by the 1911 legislation would continue to have a lasting effect as the field of sericulture grew larger and commanded greater organization and attention of the state, as Chapter Five demonstrates next.

[107] This movement of knowledge hints at a new arrangement of power that could be recognized as a change in *epistemes* as described by Foucault: a "total set of relations that unite, at a given period, the discursive practices that give rise to epistemological figures, sciences, and possibly formalized systems . . ." (*Archaeology of Knowledge*, p. 211).

CHAPTER FIVE:

HYBRIDS AND MUTANTS: SILKWORMS AS OBJECTS FOR SCIENCE AND INDUSTRY

On the farms, silkworms are "all white," the near-retired tech said. Here, in the lab, depending on the silkworm, different patterns and colors appear on their backs, and by the time of the third or fourth instar, they are discernible enough to evaluate. All segments subject to scrutiny. Subject to grading, to study. Shades of colors, half-crescent moons, stripes, knobs, flecks, and other features, the expected and the unimagined, appear with different degrees of certitude on the silkworms' segments. Some have extra or missing appendages, fused necks. Some have patterns that resemble snakes and make your hairs stand on end. Others exude beauty. Not only am I to see colors, reds, browns, whites, or yellows. I am to tell light, grey, and dark. I am to discern between the feeble and the robust. The imperative of hygiene greets me in the form of a basin full of antiseptic. One cohort at a time, the workroom receives larvae piled into a pasteboard tray for sorting. Sensei is making a new silkworm. The new one will result by selecting dark silkworms so that eventually, the line – the offspring of these brothers and sisters – will unambiguously reflect the same brownish maroon. Right now, some have faint marks on all their segments. Some have an absence of marks on half a side, or none on segments five or six. Some have markings that are "normal," or katako, which consist of a distinctive pair of waxing and waning moons that curve into each other a third of the way down the back. Five groups and five smaller pasteboard trays for now. Among these, the darkest ones will one day seed a new line. "Your eyes will gradually get used to it," Sensei said, as I held one up to the sun.

– Field note, May 28, 2008

The seed producer Tanaka Sekiichi earned his living by rearing and selling silkworm eggs at his home in the Japanese village known today as Shiojiri, located in a valley of the mountainous countryside of Nagano Prefecture.[1] Using a silkworm seed (*sanshu*) – a variety of silkworm – known as Kakeawase, Sekiichi carried out his breeding work through much of the late 1800s and early 1900s, selecting large cocoons with thick shells and attractive textures, neither malformed nor stained. He would permit the adult moths emerging from exemplary cocoons to mate and lay eggs.

This chapter examines how silkworm-seed production was altered after the 1911 Sericultural Industry Law, through two cases. As seen through the work of a silkworm geneticist originally from the Tanaka silkworm seed-producing family, the first case, of Tanaka Yoshimaro (1884–1972), shows the formation of one of the staple tools of genetics, the mutant, developed initially from a position of disavowal of the sericulture industry, only to be framed to reflect national interests and the industry. The second case is a succinct consideration of how a major silk-reeling and filature company developed new scientific hybrid silkworms following the legislation. The case shows how the Katakura Company's "Diffusion Group" developed their silkworms on a national scale by drawing upon hybridization science, and how the names of the silkworms developed in the private sector were also subject to the ongoing *tōitsu* project.

1. The Tanakas, from Kakeawase to *Elongate*

Both cases stem from the matter of the hybrid silkworm in commercial settings. The varietal name Kakeawase referred more to a unique method of breeding than to one stable, recognizable kind of silkworm. The namesake came from the word *kakeawase*, meaning to cross or mix. In sericulture, *kakeawase* referred to specific mating events

[1] Hiratsuka Eikichi, *Nihon Kaiko Hinshu Jitsuyō Keifu* (Tokyo: Sanshi Kagaku Kenkyūjo, 1969), pp. 18–19, 28–29.

between two silk moths. Two Nagano sericulturists used the word to describe the offspring resulting from a cross between female silkworms reared during the summer and male silkworms reared during the spring. Their resulting eggs, sold as seeds under the "brand name" of Kakeawase as of 1845, gained popularity by the late 1870s and 1880s.[2] In other words, the descriptive term for hybrid crossings could be used to describe the fertilization behind the sexual reproduction of silkworms, as well as to the notion of a general type of silkworm variety.

Sekiichi, for instance, had been cultivating Kakeawase silkworms for years without incident, but he noticed one spring day that some of the larvae hatched exhibited subtle, yet markedly different features than he had ever seen before. These silkworms had plump, white bodies marked with pale eyespots. They also spun cocoons in which the fibers held together tightly, producing appealing grooves on the surface. Sekiichi decided that all these differences merited the silkworms a new name, Chiyotsuru*,* meaning a thousand-generation crane, to reflect a completely new brand. He bred the new silkworm apart from Kakeawase, and by 1892, the Tanaka family had scaled up the production of these silkworms enough to sell their eggs. Production of Chiyotsuru silkworm seeds continued into the early Taishō period (1912–1926).[3]

Nearly 20 years later, Sekiichi's son Tanaka Yoshimaro (see Figure 8) also noticed a new kind of silkworm appear within a cohort resulting from yet another

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[2] Fujimoto of Shokengun and Nakamura of Jomura crossed female silkworm moths reared during the summer with male moths reared during the spring. This preceded and differed from the method of producing a scientific hybrid silkworm. These had other common names, but those changed after trade regulations in 1872 began to require an embossed seal on egg sheets that read "*kakeawase*" to describe the feature of hybrid crossing, as opposed to brother–sister mating as a method of production. The use of this term was not intended to refer to a strict notion of a variety. This is an instance where the method of distribution and the requirement of a label engendered new ideas of *sanshu* or varietal distinctions between *sanshu*. Eventually, silkworms produced by crossing moths reared at different times bore the name Kakeawase, and other kinds of *sanshu* were also used in crossings such as Matamukashi, Ohgusa, Seihaku, Shokkei, or Soisemaro, to produce other kinds of Kakeawase. By the end of the Meiji period, roughly 110 varieties included crossbreeds with Kakeawase. See ibid., pp. 18–19, 28–29.

[3] Ibid., pp. 42–43, and photograph on plate 59. Chiyotsuru production survived the industry reforms that would follow with the Sericulture Law of 1911.

hybrid cross. The junior Tanaka (referred to hereafter by his surname) had left the family practice of silkworm-seed production in 1903 to pursue an education and became a scientist researching silkworm heredity. He identified what he would call in English the *elongate* silkworm. These silkworms had markedly long abdominal segments and a doughy body. They spun irregular, if not deformed, cocoons, resulting in flimsy shells that crumpled under the slightest duress. Their chrysalis had an unusual form, and instead of having a straight posture like a baby swaddled tightly in a blanket of wings, the *elongate* pupae resembled a crescent moon. Their brittle and poor quality silk made them commercially worthless, but the *elongate* had particular value for Tanaka, who kept it even though it would not have survived in the context of commercial sericulture.

Figure 8. Tanaka Yoshimaro. Photo courtesy of Sakamoto Bungo.

The *elongate* marked the first novel addition to Tanaka's eventual "toolkit" for the study of genetics, based on the analyses of heritable silkworm characteristics and their mutations (see Figure 9).[4] These silkworms began to produce a new kind of value as bearers of genetic mutations that would seem to enrich biological knowledge production rather than cater to the business and profit-seeking interests of the silk industry alone. The case of Tanaka's research shows how the growth of a science developed within Japan. The appearance of the mutant silkworm nods, perhaps, to the history of fruit fly research, although their stories have different trajectories. Unlike the moral economy of the laboratory that centered around chromosome mapping and the free exchange of research ideas concerning Drosophila, the researchers of silkworms in Japan were ultimately expected to contribute work that would relate to or benefit the nation, insofar as the silkworm produced a national export product.[5]

Mutations played a key role in the twentieth-century history of biology, and have been thought to usher in the growth of quantitative genetics.[6] Robert Kohler described the "invasion," "freshet," or "epidemic" of fruit fly (*Drosophila melanogaster)* mutants resulting from increased scales of fruit fly production in Thomas H. Morgan's experiments in 1910 as a transformative moment in experimental biology that altered the course of natural history research concerning evolutionary processes.[7] The attention to *Drosophila* mutants may appear to

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[4] My use of the phrase "toolkit" refers to a collection of organisms of the same ilk that can be used for a variety of research purposes. The concept relates to discussions of experimental systems, as described in Rheinberger, 1997.

[5] Robert Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994).

[6] Hugo de Vries, *Mutation Theory; Experiments and Observations on the Origin of Species in the Vegetable Kingdom*, trans. J. B. Farmer and A. D. Darbishire (Chicago: Open Court Press, 1909); Garland E. Allen; "Hugo de Vries and the Reception of the 'Mutation Theory,'" *Journal of the History of Biology* 2 (1969): 55–87.

[7] Kohler, *Lords of the Fly,* pp. 42–52. Hugo de Vries's theory that natural populations entered into "mutation periods" that served adaptive and responsive purposes in evolution initially captured Morgan's interest, but the challenges of ecological fieldwork gave way to the pursuit of laboratory work on *Drosophila*. The production of mutants resulting from increased scales of fruit fly production, rather

foreshadow how silkworms turned into research organisms, but the different qualities and varieties of silkworms hardly surprised breeders, who had been breeding silkworms in large volumes in Japan for a long time, especially after the Tokugawa period (1603–1868).[8] While they did not yet share the same terminology for mutations and variation as European and American scientists, biological differences between larvae and cocoons, as evidenced by competing numbers of silkworm varieties and commercial brands of silkworm seeds, had proxied as markers of originality and the improvement of resulting silk qualities.[9]

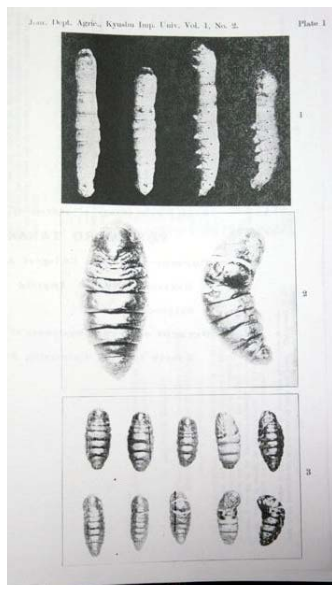

Figure 9. Elongate silkworm and chrysalises compared with nonelongated type. Reproduced from Tanaka Yoshimaro, "A New Sex-Linked Mutation in the Silkworm, Bombyx mori," *Journal of the Department of Agriculture, Kyushu Imperial University* 1, no. 2 (1924): 135–150, plate 1.

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than on the mutating period, made it less compelling to pursue this line of scientific inquiry. See also Allen, 1975, 1978.

8 Tessa Morris-Suzuki, *Technological Transformation of Japan* (Cambridge: Cambridge University Press, 1994).

9 de Vries, *Mutation Theory,* pp. 3–7; 38–39; 62–70. In his revision of Darwin's theory of natural selection, de Vries explained that the general notion of variation consisted of contrasting phenemona of mutability and "fluctuation," or "ordinary variation," in which mutations, considered the origin of new "units" or the "elements" of species, manifest in different degrees.

The emergence of the *elongate* silkworm and its generational persistence due to Tanaka presents a central concern about the connection between the existing practices of Japanese sericulturists and those of scientists who studied silkworm genetics and engaged with international scholarly communities.[10] The formation of mutation biology unfolded in Japan at a time when enhancing, not degrading, the quality of silk produced by silkworms took cultural precedence. Whereas sericulturists generally valued silkworms as lucrative living sources of Japan's most important exported textile fiber, the mutant, a living contradiction in this circumstance, emblematized a new shift reflecting the expanding presence of biological science in some aspects of Japanese culture.

The independent-minded young Tanaka began to play an important role in literally germinating a set of silkworm seeds for his doctoral research that would lead to the growth of genetics in Japan. This case study covers the early period during which Tanaka began his career in order to introduce key historical details that framed nationwide concerns about the silk trade and sericulture of the early 1900s, specifically, how to export silk of more consistent qualities from Japan. This period of intense scrutiny of silkworm production was couched in terms of *tōitsu.* This situation leads us to wonder how Tanaka could carve a space of his own in which to establish a repository of silkworms that would serve as a "problem-generating," rather than "problem-solving," toolkit for genetic research.[11]

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[10] The elongate strain continues to be maintained to this day and is part of the National Bioresource Project maintained at Kyushu University's Silkworm Genetic Resource Database. See http://kaiko.kyushu-u.ac.jp/

[11] This toolkit would bear some resemblance to that of the experimental system and an emphasis on individuality as illustrated in Rheinberger, *Toward a History of Epistemic Things*, and Creager's discussion of tobacco mosaic virus research. These discussions note that experimental systems involve multiple decisions by researchers about how to isolate or visualize the object or phenomenon of study: "the system registers and reflects the laboratory habit, culture, and training of the researcher." These unstable experimental systems underlie model systems that produce unexpected results (Angela N. H. Creager, *The Life of a Virus: Tobacco Mosaic Virus as an Experimental Model, 1930–1965* (Chicago: University of Chicago Press, 2002), pp. 48, 333). Discussion of crystallization of the TMV also shows how important social relations, institutional support, and an "intellectual and social milieu of shared

A brief discussion of Tanaka's research on the *elongate* mutant provides some insight into how his research program was set apart from Toyama Kametaro's, that is, how Tanaka, a non-state scientist, gradually codified and organized silkworm strains to later answer ongoing scientific questions about what counted as a unique variety of silkworm. The Tanaka case shows how silkworms recognized as "mutants" could come to persist and contribute to the foundation of genetic experimentation in Japan, creating research opportunities despite what may have seemed an environment of contradictory measures. Even though the scientific work carried out by Tanaka and state scientists each dealt with questions of how to manage the plurality of silkworms and how to ascertain the biology of "the silkworm," consideration is given to how both methods of classifying silkworms made possible the establishment of a foundation for a mutant silkworm seed bank.

An analysis of how Tanaka strove to bring his silkworm work onto the same plane as that of fruit fly research helps answer questions about how and why mutation biology found a space in which to grow in Japan during a time marked by a strong interest in uniformity. Combined analysis of the circumstances that faced sericulture at the time in Japan, Tanaka's interests in inheritance and genetics, and his familiarity and experience with silkworm cultivation help illuminate the confluence of reasons for the eventual coexistence of two different ways of knowing silkworms and the different languages used to describe them by the end of the 1920s.

The case on Tanaka ends with discussion of how Tanaka's academic objectification of silkworms and research remained embedded within sericulture. A complete separation from the everyday business and concerns of the craft and industry of sericulture and the state remained elusive for Tanaka, who would continue to cultivate support for his research based on a toolkit of mutant silkworms by managing

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scientific assumptions" were to the successful acceptance of a research technique (Lily E. W. Kay, "M. Stanley's Crystallization of the Tobacco Mosaic Virus, 1930–1940," *Isis* 77, no. 3 [1986]: 450–472).

a perception of relevancy to the national agenda. Together, these analyses make possible an understanding of why silkworms came to inhabit new roles as sources of genetic knowledge through the study of mutations when so many in Japan sought to homogenize and maintain the qualities of silk and their silkworms.

2. Trouble with *Tōitsu*

As noted earlier, the Japanese term for silkworm seeds, *sanshu,* encompasses multiple meanings ranging from a group of fertilized eggs to a variety, breed, species, strain, stock, or race of silkworms. This raised problems for those working in sericulture and science who wanted to know what counted as a distinct kind of silkworm. In the early 1900s, growth in the number of silkworm brands and breeds created by entrepreneurial silkworm producers continued to hinder people's abilities to control the quality of threads reeled from silk cocoons.[12]

As was discussed in detail in Chapter Four, different sectors across the silk industry found themselves increasingly embroiled in discussions about the problem of *tōitsu*, an anxiety-inflicting quandary of unification for all handlers of silkworms and silk about how to make consistency among silk fibers possible while sustaining growth.[13] To paraphrase, the problem of *tōitsu* referred to some of the issues in which multiple varieties of silkworms existed under one brand name, and multiple brand names existed for singular kinds of silkworms. Silkworms in the form of varietal seeds could be highly mixed like marbles in a bag, interbred, or inbred such that the fidelity between their labels and substance were fraught with doubt. Single kinds of silkworms didn't necessarily produce single kinds of cocoons, for names and brands did not

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[12] Detailed discussion of the term *sanshu* appears in Chapter One.

[13] "Seisan chōsakai kansei" [Production Survey Meeting Completed], *Yomiuri Shimbun*. March 19, 1910. See also Chapters One and Two.

necessarily map neatly onto categories of biological difference or similarity.[14] Unique to this case is that *tōitsu* also provided an environment in which Tanaka could develop a system for genetic experimentation during a time of increased state intervention in sericulture. Tanaka carried out a project of clarifying silkworm variation even though he did not at first have any direct or official responsibilities to the *tōitsu* movement and defined his early career in a way that avoided a clear tie to the family business.

By September 1905, Japan emerged as the victor of the Russo–Japanese war, fought on Manchurian soil. The year also marked the first in which Japan's silk exports exceeded China's, and the growing U.S. silk market made acute the long-standing pressures for reform of silk manufacture at the level of the organism.[15] A mixture of the arrogance of recent success met with uncertainty about how to retain such control characterized the state of affairs. The discourse of *tōitsu* in the silk industry began to focus on silkworm-making processes more than ever.

An official census of Japan's silkworms in 1904 showed that over 1,000 kinds of silkworms existed throughout the main administrative regions of the Japanese islands, which by then included Hokkaido.[16] As described earlier, by March 3, 1910, a

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[14] Takezawa Akira, "Sanshu Shurui Tashutsu no Hei," *Sangyō Shimpō* 9 (1894): 1–3. Takezawa, for instance, described that all "the *taneshi* (egg producers) are creating new names [of silkworms] to their own satisfaction, which brings only disingenuous benefit. They use this to move the *kokoro* (heart and spirit) of innocent sericulturists." He likened the rampant overbranding of silkworm seeds to the deceitfulness of medicine sellers who merely change the name of the medicine. Translations are mine.

[15] Togo Kazuhiko, "The Contemporary Implications of the Russo–Japanese War: A Japanese Perspective," in *The Treaty of Portsmouth and Its Legacies,* ed. S. Ericson, S. J. Ericson, and A. Hockley (Hanover, NH: UPNE, 2008); Debin Ma, "Between Cottage and Factory: The Evolution of Chinese and Japanese Silk-Reeling Industries in the Latter Half of the Nineteenth Century," *Journal of the Asia Pacific Economy* 10, no. 2 (2005): 195–213. The exact year of Japan's overtaking of China as the world's leading silk exporter has been determined to be 1905, according to recent work in business and economic history, although studies such as Lillian Li, *China's Silk Trade: Traditional Industry in the Modern World, 1842–1937* (Cambridge, MA: Harvard University Press, 1981), have pointed to 1909 as the key year.

[16] Watanabe Kanji, *Yousangaku* [Sericulture Science] (Tokyo: Azumi, 1948), p. 72 and Koizumi Katsuo, *Sanshi Daikoku Nihon to Kanagawa no Tenmatsu* [Circumstances of the Great Silk Nation of Japan and the Height of Kanagawa] (Yokohama: Koizumi Katsuo, 2006) dispute this figure for all silkworms (univoltine, bivoltine, and multivoltine silkworms, referring to the number of life cycles the *sanshu* goes through each year) as either 1,220 or 1,003, respectively. Note that Korea was annexed August 22, 1910.

resolution to the *tōitsu* problem began to take shape within the realm of law. The Agricultural Affairs bureau chief Shimo'oka Chūji submitted a proposition suggesting that the responsibility for maintaining *gensanshu,* or parental stocks of silkworms, should belong to an institution geared for this explicit purpose.

The proposed institution, Gensanshu Seizōjō (hereafter the Parent Silkworm Manufactory), would emphasize the manufacture of parental silkworm stocks for commercial purposes – not just for research. Until that point, state scientists at the existing national and prefectural system of sericultural experiment stations had been involved with surveying different kinds of silkworms and collecting information about them. The new institution would require silkworms to undergo governmental examinations in order to determine what breeds could be manufactured as parent silkworm stocks on a greater scale with the "*kokusan*" or "nationally produced" label. The proposed system would not use these parental breeds to give rise to factory-bound silk cocoons directly. They would rather serve as a quality-controlled repository of original stocks to produce the means to reproduce parent silkworms. These parent silkworms would generate the seeds that other egg producers in the private sector could use to carry out government-approved hybrid crossings in order to sell scientific F1 hybrid silkworms to rearers. Ideally, peasants would rear only these hybrid larvae to produce and sell cocoons to the silk-reeling and filature factories for processing. Reproducing identical silkworms from these hybrids was actually very difficult; part of the benefit of the well-designed F1 hybrid was in the secrecy of its parental constitution.[17]

A number of different people participated in the *tōitsu* movement.[18] The Ministry of Agriculture and Commerce especially pressed for the necessity of *tōitsu*

[17] Sanshigyōhō [Sericulture Law], Law No. 47 of 1911.
[18] Discussions among egg producers dominated the pages of the *Sangyō Shimpō.* See Takezawa Akira, "Sanshukai Kakumei No Ki Wa Chikazukeri," *Sangyō Shimpō* 18, no. 206 (1910): 1–6; Chapter Two, this volume.

for silkworm seeds, and its deputy director, Oshikawa Norikichi, spoke to those concerned with the sericultural business in June 1910. Addressing the challenge posed not just by the sheer number of eggs and the traded silkworm-egg sheets that carried the hundreds of fertilized eggs deposited by female moths, Oshikawa suggested a gradual method toward *tōitsu.* This method would first entail the separation of silkworm egg sheets according to different standards with the aim of conducting *tōitsu* of each of those.[19] In this vein, *tōitsu* went beyond grouping individuals according to a broad set of parameters. It involved a process of identifying finer-grain distinctions within those groups represented by individuals that would hatch from these eggs. This served to help identify additional groups of similar individuals and, subsequently, to help streamline which silkworms peasants could farm.

The rules of the 1911 Sericultural Industry Law charged national experiment station scientists and technicians with the responsibility of managing the top of a sanctioned cascade of breeding events so as to prevent silkworm qualities from spinning literally out of control. The new rules established limits on sericulture that permitted only licensed egg producers to make crosses from official parent silkworms made by governmental scientists. The centralized manufacture of parent silkworms would ensure the Ministry of Agriculture and Commerce's control of the distribution of these official breeds within parts of Japan to seamlessly complement *zairaishu* known to have cocoon characteristics that already met certain standards in appearance, volume, and texture.[20]

Thus, *tōitsu* provided a multifaceted answer to the pressing need to organize sericulture in a way that would allow Japanese silk to appear to have greater

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[19] "Sanshu Tōitsu Hōhō," *Yomiuri Shimbun*, June 5, 1910. At the Jitsugyō Shinkōkai, a meeting of an association to promote business.

[20] Sanshigyōhō [Sericulture Law], Law No. 47 of 1911; Kitamura Chikayoshi and Nozaki Minoru, *Nōrin Suisanshō Ni Okeru Sanshi Shiken Kenkyū No Rekishi* (Tsukuba: Nōgyō Seibutsu Shigen Kenkyūjo, 2004).

uniformity. Its legal manifestation as the Sericulture Industry Law represented a shift in the decision-making responsibilities from localities of self-regulating producers and factories to a higher level reflecting a growing relationship mediated by the government as to which silkworms could be used to generate export-bound raw silk. In addition to the formation of a dedicated Sericulture Bureau within the Ministry of Agriculture and Commerce, its main goal, as explained by Shimo'oka, was to create an apparatus that would at first produce one-tenth of the silkworms usually produced annually, around 1,700 egg sheets. These egg sheets would each contain hundreds, if not up to a thousand eggs each, laid by around 28 silkworms.[21]

Shimo'oka's parent-silkworm manufactory represented the centralized apparatus to test, improve, and diffuse government-approved parental stocks of silkworms. Connected to a network of regional manufactories and existing experiment stations, a nationally supported production of silkworms could turn into a reality through the greater involvement of and outreach to the countryside. Shimo'oka's vision for the adoption of *tōitsu* as a policy was one of gradual penetration rather than something enforced suddenly and universally. Much of the work additionally depended on the expectations set forth by the appointed director of the Parent Silkworm Manufactory, Kagayama Tatsushirō. The new director tasked Toyama to develop a reliable set of parent silkworm stocks that would convey the desired effects of hybrid vigor.[22]

a. *Tōitsu* as Apparatus of National Production

Tanaka came of age in this culture that had come to place increasing value on systematized, scientific production of silkworm varieties. While Toyama participated

[21] "Sanshu Tōitsu no Setsumei," *Yomiuri Shimbun*, January 11, 1911.
[22] Takeuchi Nagamasa, ed. *Toyama Kametaro Kinenroku* [Toyama Kametaro Commemorative Record] (Kanagawa Prefecture, Koayumura: s.n., 1940).

in committee work for the government and wrote popular articles to drum up interest in the lessons of heredity, Tanaka and his experiences as a college student at the Sapporo Agricultural School (renamed the Tōhoku Imperial University College of Agriculture in 1907) and as a young scientist in the first quarter of the twentieth century demonstrate how commerce-oriented enterprises informed the development of biological investigations particular to Japanese genetics. As a student, Tanaka did not have to respond with great urgency to the immediate mandates of the sericulture industry as Toyama had. Japan's new sericulture law did not include the goal of making scientific hybrid crosses specifically, but the procedures of evaluating, testing, and making nationally produced parent silkworms helped marshal the most capable researchers and technicians working on this to the cause of the nation. It makes sense to understand Tanaka's research in light of Toyama's work on inheritance and state interests, notably his 1906 silkworm hybridization research in then Siam that had brought him great acclaim.[23]

Toyama had gradually gained a larger audience as a scientist, lecturer, and popular writer by the time discussions of *tōitsu* and the advantages of hybrid vigor gained further traction in Japan.[24] Yet, his intellectual interests lay more in determining the exact mechanisms of Mendelian inheritance and using that knowledge to breed tailored forms of life.[25] In the new production scheme aiming to profit from the production of robust cocoons, a system based on scientific, nationally approved hybrids resulting from the cross-breeds of the official parental silkworm stocks was

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[23] See Chapter Two and Chapter Three. Toyama studied the effects of cross-breeding white-cocoon-spinning silkworms imported from Japan with yellow-cocoon-spinning "Siamese" silkworms. These progeny all gave rise to yellow-cocoon-spinning silkworms. Upon conducting further sibling crosses, Toyama found that the resulting cohort exhibited characteristics that fell within Mendelian ratios.

[24] Takeuchi, *Toyama Kametaro Kinenroku*. The edited memorial book by Toyama's son-in-law lists his career and activities.

[25] In 1908, he had written a serial article for the *Bulletin of the Japan Sericultural Association*, trying to convey to and excite people about the prospect of Mendelian inheritance by relating biological principles to familiar superstitions.

prioritized. The hybrid silkworms introduced to the sericultural landscape would not be permitted to endure through generations in the rural landscape. They would be knowable by their parentage, managed at the Parent Silkworm Manufactory.

Tanaka did not make proclamations as flamboyantly as Toyama did to explain inheritance. Tanaka's somewhat aloof tendency since boyhood to distance himself from the silkworm business may have actually afforded him opportunities to address other biological questions that did not cater obviously to the purposes of extracting economic value, or that rather fell away from the purview of state interventions in commercial silkworm breeding. At the age of 27, after receiving his Ph.D. from Tōhoku Imperial University, Tanaka was assigned the first chair in sericulture science within the entomology section of the zoology department there. Two years later, he taught what would be regarded as the first university course on genetics, or *idengaku*, in Japan in 1913.[26] This happened to be the same year he began the groundwork for creating and maintaining a collection of inbred silkworm strains that he could use in the silkworm studies.[27] Tanaka would later gain a reputation as a "pioneer" in Japanese genetics alongside Toyama, but in the process of creating a new system of knowing silkworms, he would need to negotiate much more so, perhaps, a tension between the pursuit of knowledge through research and the business of sericulture.[28]

The investigations of mutant silkworms and variation that Tanaka was later recognized for had roots deeply embedded in the *tōitsu* movement. Tanaka's mutation research and his eventual construction of a repository of silkworms for scientific investigation were situated in relation to questions at the time about what counted as a

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[26] Miyajima Shigetoshi suggests that the wheat geneticist Kimura Hitoshi gained an interest in genetics upon first hearing Tanaka's lectures. Miyajima Shigetoshi, "Idengaku no senkusha, Tanaka Yoshimaro," *Fukashi Jinbutsu Shi* 2 (1991): 106–115.

[27] Tanaka Yoshimaro, "Watashi no Seishun Jidai," *Iden* 10 (1956): 49–51; Miyajima, "Idengaku no senkusha, Tanaka Yoshimaro." This collection of inbred silkworm strains would compose the basis for today's mutant silkworm biobank in Fukuoka, Kyushu.

[28] On the other hand, he did seek recognition, which deserves further discussion in the context of later interactions with geneticists in Europe and the United States.

silkworm variety. This bore a similarity to that which motivated Toyama's work in 1900.[29] Attention to Tanaka shows how a space grew amidst practical research during the Japanese empire to incorporate new kinds of research questions. As silkworm larvae gained greater attention in addition to their inanimate cocoons, Tanaka's experience also makes it possible to see why and how investigations of mutations themselves could have played a role in the enterprise of sericulture over time.[30]

Tanaka's undergraduate thesis focused on silkworm gland anatomy, but his research interests shifted markedly by 1910. His work as an assistant in the sericultural science room at Tōhoku Imperial University centered on inheritance in silkworms and breed improvement. This work began with the grappling of an egg card obtained from China.[31] The egg card delivered to him had an assortment of hundreds of tiny eggs adhered all over in a haphazard fashion. It had presumably been bought from a market intended for local use and had resulted in a number of different kinds of silkworms with different larval markings, cocoon colors, and molting frequencies that Tanaka had to sort. It served as a fine illustration of some of the headaches of unruliness that the *tōitsu* movement strove to address, even if no one had tasked Tanaka with addressing this problem.[32]

Tanaka's initial approach to the Chinese silkworm-egg card may not have differed much from what his own father had done to recognize a distinction among like or variable forms of silkworms. Methods of seizing upon differences to create

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[29] Toyama Kametarō, "Hyakunen Izen ni Okeru Honpō Kaiko no Shurui," *Dainihon Sanshi Kaihō* 9, no. 7 (1900): 1–9.

[30] See Chapter One for description of silkworm metamorphosis.

[31] Tanaka Yoshimarō, "A Study of Mendelian Factors in the Silkworm, Bombyx mori," *Journal of the College of Agriculture, Tohoku Imperial University* 5 (1913): 91–113.

[32] Ibid. In Japan at the time, a common practice to prevent the spread of disease involved confining a mother moth within the area of a circle on a designated space on the paper. Foreign importers of eggs used to marvel at the perfect circles that Japanese mother moths somehow seemed to "know" how to make. In reality, the human egg producer ensured this only to make legible the link between the mother moth, which would be inspected later for disease spores, and her eggs, which a sericulturist would know to cut out and incinerate if an infection was detected.

new kinds of silkworms had long existed in sericulture, and many egg producers knew how to recognize these due to their intense familiarity with their silkworms.

Despite their methodological similarities, Tanaka's and his father's different goals led them to focus on different things. The selection criteria kept in mind by Tanaka's father had centered on the ideal qualities of the silkworm's cocoon. The subsequent accompanying larval distinction helped flag or predict the forthcoming attractiveness of the cocoon. Tanaka, by contrast, focused first on the larvae in order to isolate and cultivate unexpected traits and secondarily on the cocoon's characteristics.

The supposed absence of knowledge about the heritage of particular silkworms from China likely appealed to Tanaka, and his approach allowed him to build a personal stock of silkworms for research purposes as objectively as possible. This "problem" of identification could only gain resolution through the tedious, mundane work of sorting them out, resembling the actual work that *tōitsu* would come to entail. Ignorance of the parent silkworms forced upon Tanaka a more deliberate stance of objectivity that demanded, perhaps, a keener attention to the task of sifting out distinctions from a heterogeneous lot and winnowing out redundancies – the imperative of *tōitsu*.

Tanaka's decision to work from a mixed "cohort" is intriguing because it makes clear that the basis for his overall silkworm collection derived in large part from crosses between the newly isolated Chinese silkworms and conventional Japanese varieties. First rearing the newly received seeds in 1910, Tanaka recognized that they were Chinese tri-molting silkworms, meaning they would molt thrice before metamorphosing into the adult form.[33] He isolated five different strains of these

[33] It is also possible that Tanaka actively chose to work with silkworms from China because they often have shorter duration life-spans than conventional univoltine Japanese silkworms, but this is not addressed in Tanaka's 1913 paper.

silkworms from the original 1910 eggs.[34] Over the course of his doctoral research, Tanaka conducted sibling-crosses within each of these strains and cultivated inbred lines that could also be hybridized with Japanese silkworms. In the spring of 1913, Tanaka inscribed a chart in his notes depicting a cross between the tri-molting silkworm with language that appeared in earlier reports by Toyama to describe "normal" white speckled, or "moricaud" type.[35] ("Normal" larva denotes the mark of a single crescent shape near the top of its abdomen, whereas a "plain" larva has no such marks.) This yielded three general kinds of silkworms: normal yellow, striped, and plain yellow. Cultivating each of these three lines, he focused on the normal-yellow category and then conducted crosses between the silkworms from within that category that emerged from the lightest and darkest cocoons, in order to generate his own standard line of normal-yellow silkworms.[36]

Tanaka also began to use a shorthand system of alphabet letters in his notebooks over the course of breeding silkworms as he obtained so-called homogeneous inbred lines over a course of years.[37] He developed new lines from these acquired silkworms by separating a cohort of silkworm siblings into groups based on their larval characteristics and bred those particular siblings among each other. Tanaka assigned each new cohort of silkworms a letter reflecting a characteristic linked to that of its parental stock, such as "N" for a "normal" type, "S"

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[34] He described these as common or normal yellow; normal white; striped yellow, moricaud yellow, and plain yellow, according to Tanaka's 1911 notebook and experiment notebook entitled *Die Kreuzungsexperimente: 1911, 1912* [TY]; Tanaka, "A Study of Mendelian Factors in the Silkworm."

[35] "Normal" silkworms have some distinctive markings on their dorsal side, as opposed to "plain" silkworms, which have no dorsal markings. The French racial term moricaud has curiously been used to describe a darker kind of speckled marking thought to be similar to wild silkworms. In this case, it occurred in combination with the normal markings.

[36] Tanaka, "A Study of Mendelian Factors in the Silkworm."

[37] Wilhelm Johannsen, *Elements de Exakten Erblichkeitslehre* (Jena: G. Fischer, 1909). We can most likely understand Tanaka's conceptualization of the pure line not in terms of self-fertilizing plants, but through what Johannsen reported about the use of inbreeding to generate genetic homogeneity.

for "striped," "M" for "moricaud," or "P" for plain types of silkworm.[38] Each cohort was also designated a number and the last two digits of the Gregorian year. These three pieces of information constituted a lot number in Tanaka's slowly stabilizing notation system. Alphabetized representations emphasize the degree to which Tanaka sought to recognize discrete character differences among the silkworms. Familiar and long names such as Chiyotsuru identified the whole silkworm, including its life-cycle behaviors and cocoon characteristics. Tanaka's turn to the alphabet in his inscription of the silkworm importantly reflects how focusing his vision on discrete larval traits differed from the practices of producers for whom the eventual product – silk – weighed more heavily on their minds. Though the Tohoku region and Tokyo were separated by distance, Tanaka's intellectual mentor and foil was Toyama. The elder scientist had also used letters to illustrate patterns of inheritance for particular characters, perhaps also because international publication standards as well as journal publications of the imperial universities at the time required alphabet typesetting, but the two scientists did not share the exact same notation system.

Tanaka's early silkworm-breeding records reflect how he began to shape a system of management based on "readings" of the silkworm that offered a different kind of legibility than commercial sericulture emphasized. While Toyama had also studied larval colorings and other markings, Tanaka took the study of the insect's morphology to another level, perhaps because unlike the more senior scientist, Tanaka had not yet worked under the mandate of improvement that framed the goals of sericultural experiment stations in Japan. The clear segmentation of the silkworm larvae's body, especially tangible because of its large size, made the juvenile stage of the insect's life history appealing in Tanaka's later studies of inheritance.

[38] His choice to use alphabet letters gestures to publishing conventions reinforced by the writing of theses in English during the Meiji period.

Tanaka's early studies leading to publications in 1913 dealt mainly with identifying Mendelian factors for larval markings. Such focus on these markings might suggest that the larval body had mattered to Tanaka more so than the cocoon, which offered fewer obvious dimensions for analysis as a representation of the organism *incognito*. Indeed, the silkworm larvae, which measures about three millimeters upon hatching, grows to 12,000 times its original weight by the day before the onset of cocoon spinning: A microscope is unnecessary to observe the larval markings clearly. Each silkworm is composed of three main parts: the head, thorax, and abdomen totaling fifteen segments.[39] Tanaka's inheritance experiments in the late 1920s would pay close attention to the genetic control of the appearance of certain kinds of markings on the surfaces of each of these segments.[40]

The focus on larval markings differed on a basic level from scientists who studied *Drosophila* in the neo-Mendelian vein. They focused on organ groups of the adult form, which generally measured only 2.5 millimeters in length. The accounting of different mutations associated with fruit fly organs, such as wing shape, eye color, or body color, for instance, helped elucidate questions about the development of those morphological characters. The later work of genetic mapping required care to avoid allowing flies with genes of interest in different linkage groups from mating, in the practice of maintaining scientifically useful organisms.[41]

The state's reading of the silkworm took place at the level of the species, in which the reproducibility of new, unique silkworms for the purpose of creating sameness in cocoons took precedence. Tanaka's took place at the level of the individual, wherein reading the silkworm took on a much more literal meaning in

[39] Tazima Yatarō, *The Silkworm: An Important Laboratory Tool* (Tokyo: Kodansha, 1978), pp. 32–33, 40.
[40] Tanaka, "A Study of Mendelian Factors in the Silkworm."
[41] Kohler discusses in greater detail the reasons for why the Morgan group gave up on the organ-group system (*Lords of the Fly,* pp. 56–58).

terms of examining each segment of the nonworm. It is worth pointing out that Tanaka's initial concentration on larval characteristics did not focus intensively on organ groups as had been the starting point for research in the Morgan group in 1911. Tanaka's system began to provide the means to trace silkworm histories from 1910 onward. Starting with silkworms of unknown provenance in 1910 also meant that Tanaka had concerns about how to avoid making assumptions about familiar silkworms, yet attend to the characteristics of each individual. The scientist most likely steered clear of making the familial silkworms bred by his father the core "scientific thing" of research for this reason. Working with the new silkworm seeds afforded him a different familiarity, cultivated under a scientific gaze, that would enable him to identify different, novel silkworm features and skirt the auspices of official experiment stations. Whereas the sericulture industry needed to favor the use of certain varieties of silkworms and required winnowing and limited access, this mattered less to Tanaka, who cared more about Mendelian phenomena and locating candidates for further heredity experiments.

Silkworm larvae had markings, ranging from different kinds of spots to knobs, stripes, and colors, that offered a plentiful range of characteristics to experiment with. Tanaka's and Toyama's approaches bore some similarities to the work of C. C. Little, who obtained fancy mice from pet breeders and used coat color as a guide for directing inbreeding to "weed out" variation beginning in 1909. The approaches to the organisms eventually differed in that the mouse came to be used to "Mendelize" and study the susceptibility of cancer among mice by 1916, anticipated to elucidate important information about medicine.[42] Whereas the growing mouse research was characterized by the burgeoning production and sale of mice to other researchers, the

[42] Karen Ann Rader, *Making Mice: Standardizing Animals for American Biomedical Research, 1900–1955* (Princeton University Press, 2004), pp. 44–46. There were also numerous ethical concerns related to mice captive breeding voiced by American antivivisectionists that colored the history of mouse genetics.

silkworm had already come from a particular production past that now had to produce something new, a redefined Japan. This is not what Tanaka the nascent geneticist had planned for but rather what he was pulled back into, despite any interests he might have had in pursuing the study of genetic concepts.

Tanaka's readings of silkworms ultimately depended on producing larval variation, not minimizing cocoon variation. For the silkworm, breeding activities at the state and academic levels represented a shift in the claims of ownership of silkworms outside of the intellectual community. Whether it was a concern with the techniques of reproducing sameness among silk cocoons or for mutant breeds, both were part of a creation of distance between sericulture and its semblance of a former "tradition" while becoming part of contemporary mass movements that hinged on the idealized past.[43]

A positive appreciation for silkworm diversity in the time of *tōitsu* enabled the expansion of Tanaka's toolkit for genetic research. Although Tanaka's work was distinct in many ways from the work of seed producers such as his father, it had some methodological parallels with the state project, which sometimes retained names of commercial brands of silkworms in order to reflect their provenance. At the national level, however, colloquially used and named silkworms were relabeled *kokusan* to denote that they were nationally produced, followed by a kanji character and a number. These kanji characters were not trait-based, however. as Tanaka had organized his data using letters and numbers. The three main kanji characters used in this system also point to a reclassification of silkworms in the groups *nichi*, *shi*, or *ō*, which represent Japan, China (this particular character was considered neutral by the Japanese at the time but gradually gained a negative connotation among Chinese

[43] "To pry an object from its shell, to destroy its aura, is the mark of a perception whose 'sense of the universal equality of things' has increased to such a degree that it extracts it even from a unique object by means of reproduction." Walter Benjamin, *Illuminations* (New York: Harcourt, Brace & World, 1968), pp. 222–223.

related to colonialism), and Europe, respectively. The new labels signify an erosion of the right of the practitioner of breeding, the egg producer, to endow new varieties with a name of choice.

The importance of so-called origin as a way to understand silkworms had existed for a long time, but as a project of empire, this was particularly pronounced. The early Meiji government, for instance, had earlier imported "foreign" silkworms through the Hokkaido Development Commission. In the 1880s, the Ministry of Agriculture and Commerce also imported Chinese and other foreign varieties of silkworms and distributed them for experimental rearing to sericultural educational institutions and egg producers with the hope of enhancing domestic production of better silk. The avid cross-breeding between Japanese and Chinese silkworms that the empire had encouraged had, in part, contributed to some of the very issues embodied in the *tōitsu* problem.[44]

Between 1913 and 1937, a total of 180 silkworm breeds were registered in the national system, only 56 silkworm varieties were approved for distribution, of which 16 were Japanese, 16 Chinese, 13 European, and 11 so-called fixed lines of hybrids. These hybrids had originated from a known *kakeawase* mating event across or within these three categories and had subsequently been bred and inbred enough times such that they could be sustained through inbreeding.[45] A generous reading of the new system of nomination by national silkworm scientists signals a compulsion to understand each silkworm objectively by collapsing each collection of data concerning all phases of the insect's life cycle and physical properties of its silk into a discrete unit. It also presents a window to some of the Japanese geopolitical concerns at the

[44] Kiyokawa Yukihiko, "The Diffusion of New Technologies in the Japanese Sericultural Industry: The Case of the Hybrid Silkworm," *Hitotsubashi Journal of Economics* 25 (1984): 31–59. Japanese importation and use of "foreign" silkworms is discussed in Chapter One.
[45] Hiratsuka Eikichi, *Kindai sanhinshu ikushu kiroku* (Tokyo: Sanshi Kagaku Kenkyūjo, 1961); Hiratsuka, *Silkworm Breeding*, Trans. Alamelu Gopal (Rotterdam, Netherlands; Brookfield, VT: A. A. Balkema, 1999).

time that manifested in the silkworm. On the one hand, improvement entailed an aspiring to the finer qualities exhibited by either European or Chinese silk. On the other hand, by the 1900s, improvement began to strike a different tone, in which accommodating the standardizing needs of American textile machinery became paramount, although that meant the cocoons would actually remain subpar quality. For instance, by the 1930s, the official Silk Conditioning Houses in the cities of Yokohama and Kobe evaluated export-bound silk into one of nine grades: AAA special, AAA, AA, A, B, C, D, E, F, and G. Most silk reflected the B, C, or D range.[46]

Like Toyama and other scientists, Tanaka did use racial descriptions in his reports to designate where silkworms came from and to quickly orient readers to some familiar ground. He called his 1910 silkworms from China "*Sze-chuan*" silkworms; however, even if other such names, such as "Baghdad" (considered a European variety), were used to denote probable origin as well as varietal name, Tanaka always relabeled them in his own system using letters and numbers in the Arabic form (versus in kanji characters). He did not use the colloquial names as part of the descriptive names of lineages themselves in the long run. Nor did he refer to such phrasings to denote heritable characteristics.

Of Tanaka's early work in Sapporo and Fukushima, several experiments deserve brief mention to illustrate how this system actually reflected a coalescence between an organizational method and an intellectual program enabled by Tanaka's silkworm toolkit. One that constituted part of his doctoral thesis, "A Study of Mendelian Factors in the Silkworm, Bombyx Mori," completed in March 1913, provides important insight into how Tanaka positioned himself amidst the growing dialogue on the biology of inheritance. These Mendelian factors resonated with those

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[46] Central Raw Silk Association of Japan, *I Am Japan Raw Silk: Published on the Occasion of A Century of Progress International Exposition, Chicago* (Tokyo: Central Raw Silk Association of Japan, 1933).

Toyama had observed earlier of cocoon colors. Tanaka reviewed Toyama's 1906 work, affirming, "his system of analysis seems to have been based on the original view of Mendel. . . ." Yet, although Toyama had catalogued at least thirteen independently sorting Mendelian characters by 1912, Tanaka argued that Toyama's "system of analysis" did not apply easily to more complicated cases of Mendelian inheritance.[47] Tanaka chose other traits associated with larval patterns as Mendelian factors worth studying.

Tanaka's work concentrated on silkworm larval characteristics with greater focus than Toyama had. By 1913, Tanaka also began to publish on the phenomena of linkage, or "gametic coupling and repulsion," as seen in sweet-pea experiments by Bateson, Saunders, and Punnett.[48] This work sought to understand the basis for deviations from Mendel's law of independent assortment that would otherwise give rise to a ratio of 9:3:3:1 among the progeny of a dihybrid cross. This was one of the most pressing scientific questions at the time, which Tanaka took up in his paper published in English in the *Journal of the College of Agriculture, Tohoku Imperial University*. His experiments crossing doubly heterozygous silkworms demonstrated the "first record of partial gametic coupling found in animals," in which characters occur together more frequently than by chance alone, showing that "to-day we have no need to make such a distinction regarding animals as distinguished from plants."[49]

The notation used by Tanaka in his first 1913 publication reflected the increased stabilization of his nomenclature system used to organize silkworms and

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47 Tanaka, "A Study of Mendelian Factors in the Silkworm."

48 W. Bateson, E. R. Saunders, and R. C. Punnett, "Further Experiments on Inheritance in Sweet Peas and Stocks: Preliminary Account," *Proceedings of the Royal Society of London. Series B, Containing Papers of a Biological Character* 77, no. 517 (1906): 236–238.

49 Tanaka Yoshimaro, "Gametic Coupling and Repulsion in the Silkworm, Bombyx mori," *Journal of the College of Agriculture, Tohoku Imperial University, Sapporo* 5 (1913): 115–148+plt. Tanaka wrote his 1913 paper in English. Tanaka worked with Bateson's definition of "complete coupling" as "a perfect union of the characters which are known to depend on separate allelomorphs" because the "terms are already widely accepted." See Bateson et al., "Further Experiments on Inheritance in Sweet Peas and Stocks." Further discussion, see Collins, "Gametic Coupling as a Cause of Correlations."

their distinct traits as well as an ability to access relevant strains of organisms for experimentation, or to otherwise recognize unusual patterns that warranted further investigation.[50] Tanaka seemed to formulate his "system of analysis" in order to avoid the problem of appearing to produce data that statistically met Mendelian predictions too readily.[51] The paper indicated a need to study the conceptualization of so-called Mendelian genes by using theoretically guided investigations, such as the "presence or absence hypothesis," made known largely by Bateson, which would help better explicate the more complicated instances of Mendelian inheritance.[52] Larval characteristics were useful to Tanaka because of their multitude and ease of visibility. By 1914, Tanaka seemed to challenge the biological usefulness of categories such as "Japanese," "Chinese," or "European" that had hitherto been used in the vernacular of the national system of silkworm management. This was the same year Japan seized German colonial territories in China and the Pacific, yet contrary to what one might expect of someone working under nationalist circumstances, Tanaka curiously found "No racial peculiarities in hereditary behaviour of the marking and colour characters" in his experiments.[53] Geopolitical race categories, he found, did not contribute meaningfully to the processes of recognizing distinct patterns that depended on the inheritance of particular, physically observable larval characters.

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[50] Tanaka, "A Study of Mendelian Factors in the Silkworm"; Tanaka, "Gametic Coupling and Repulsion in the Silkworm."

[51] For instance, Kellogg suspected that Toyama had been seduced by the prospect of replicating the now well-known ratios determined by Mendel's pea experiments. See Kellogg and Smith, *Inheritance in Silkworms*.

[52] Tanaka, "A Study of Mendelian Factors in the Silkworm," pp. 92.

[53] Tanaka Yoshimarō, "Further Data on the Reduplication in Silkworms," *Journal of the College of Agriculture, Tohoku Imperial University, Sapporo* 6 (1914): 1–16. He studied striped, moricaud, and normal (one-crescent) larval markings and yellow and white cocoons.

3. Mutant Matters: New Values for New Silkworms

In Japan, the silkworm numbers along with rice and barley among the organisms linked to the history of Mendelism in Japan.[54] As the main investigator of Mendelian inheritance in silkworms,[55] Toyama had also mused upon the notion of mutation in 1909 when he published an article that outlined the various possible ways to produce new varieties of silkworms. In this paper, he agreed that mutations exist as a matter of course in the wild, as discussed by the Dutch plant physiologist and geneticist Hugo de Vries (1848–1935) in *Mutation Theory*; however, Toyama suggested the impossibility of ascertaining the presence of "pure mutations" in domesticated organisms because many varieties are "mixed," meaning their genetic heterogeneity posed an immense hurdle to identifying a *bona fide* mutation.[56]

The intensity of silkworm variation posed a large problem for Japan's silk industry by 1910. The government initiated public hearings and formed new policies to manage the breeding of these insects. Many producers recognized, though reluctantly, the necessity for these changes. New industry-oriented systems of cultivation led to a period that required a clearer understanding of what silkworms existed in the country, which Tanaka's identification of the *elongate* silkworm epitomized.

The development of both Tanaka's and the state's organizational styles took place at the same time and over the same span of years. Comparing Tanaka's focal points of organization with those of the state helps articulate more about what of Tanaka's mode of scientization made it possible to gradually understand more

[54] Matsubara Yoko, "The Reception of Mendelism in Japan, 1900–1920," *Historia Scientiarum* 13 (2004): 232–239.
[55] 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, no. 2 (2010): 215–264.
[56] Toyama Kametarō, "Futatabi Shurui Kairyō to Kaiko no Iden ni Tsuite Ichigensu," *Dai Nihon Sanshi Kaihō* 200 (1909): 1–6. Toyama did not explicitly state that he had read de Vries's Mutation Theory, but we must deduce from his writing that he must have at least read of it, if not the original source.

complicated examples of inheritance, or completely novel, unexpected phenomena. The criteria for recognizing a new silkworm variety changed over time as breeding work proceeded. Tanaka maintained some interest in tracking shades of cocoon colors, for instance, which exemplify how the exercise of personal preferences played a role in how silkworms were handled year to year as he hoped to create something new by continual visual separation, much like a conventional breeder who knows the organism by sight and touch.[57] His notations in 1913 reflected the increasing stabilization of a nomenclature system used to organize silkworms and their distinct traits as well as an ability to access relevant strains of organisms for experimentation, or to otherwise recognize unusual patterns that warrant further investigation.[58] By 1924, Tanaka solidified his note-taking procedure by designing and implementing a rubber stamp that provided him with spaces in which to record specific data he wished to collect.[59]

The organizational momentum of the *tōitsu* movement had created a climate in which it became possible for someone like Tanaka to know what kinds of silkworms he possessed. It also made the exchange of silkworms for scientific research even more possible, as evidenced by surges in the number of strains recorded within Tanaka's notebooks in certain years.[60] Even though Tanaka had initiated his studies in order to avoid sericulture, the day-to-day practice of his work would actually have him interacting for years to come with Japan's sericultural experiment stations in order to gain access to biomaterials, space, and a livelihood.[61]

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[57] As a matter of personal preference, I refer to the individual judgment that is exercised by the investigator in charge of yearly maintenance of the silkworm strains, in which choices are made about which individual silkworms to keep and remove over the course of determining what larval characteristics ought to be kept.

[58] Tanaka, "A Study of Mendelian Factors in the Silkworm"; Tanaka, "Gametic Coupling and Repulsion in the Silkworm."

[59] The same categories are still provided by a rubber stamp to this day.

[60] Tanaka's laboratory notebooks [TY].

[61] Tanaka married soon after receiving his doctoral degree.

The national cataloguing efforts that strove to know and make silkworms in and around Japan legible and tractable for commercial use by the end of the Meiji period can be thought of as expressions of an imperial apparatus for wealth creation that indirectly also heightened a sense of national community. They also provided the contour for advances in silkworm-mutation biology, considering how Tanaka identified with aspects of the silkworm that state sericulture science left unaddressed.

Tanaka refined his system for keeping track of silkworm traits as he continued to conduct further research for his doctoral degree. With growing numbers of silkworms to maintain, Tanaka moved to a larger space. In the summer of 1913 and spring of 1914, Tanaka cultured silkworms at the Sericultural Institute of Hokkaido, in Sapporo. Overseeing the Imperial Sericulture Institute located in Fukushima, Kagayama also permitted Tanaka to continue rearing silkworms at their facilities in the summers between 1915 and 1919.[62]

Tanaka wrote his seminal June 1916 paper, "Genetic Studies on the Silkworm," while carrying out work during this period of transiency spanning between his university and two institutes. Written as part of his doctoral thesis in English, as was customary at the time for academic theses when linguistic prowess signaled accomplishment and authority, Tanaka's work began to demonstrate how genetic work could be valued for the primary goal of producing biological knowledge.[63] He had not dismissed the importance of the economic interests altogether, but he made no visible effort to relate the fruits of genetic research to industrial potential in this paper, which

[62] Tanaka Yoshimarō, "Genetic Studies on the Silkworm," *Journal of the College of Agriculture, Tohoku Imperial University, Sapporo,* 7 (1916): 129–255, pl. I–VI; Tanaka Yoshimarō, "Sex-Linkage in the Silkworm," *Journal of Genetics* 12, no. 2 (1922): 163–178.

[63] The history of the silkworm and its place as an organism previously domesticated before entering the laboratory shows that it was largely studied for the sake of understanding it for practical purposes, rather than as a proxy or model for understanding another system or phenomenon. Despite congruence with model organism concepts raised by this dissertation (see, for instance, Rader, *Making Mice*; Creager, *The Life of a Virus*; de Chadarevian, *Designs for Life*; Ankeny "Model Organisms as Models"; Kohler, *Lords of the Fly*), temporality continues to pose a challenge in the analysis of this "turn" to "basic biology," considering ongoing commercial research at the time.

studied eleven larval-phase hereditary factors, in addition to molting frequencies and cocoon color. He was interested in bringing the silkworm onto the same plane as the fruit fly:

> In particular, the silkworm affords the material, perhaps, most appropriate for the genetic study, not only because there are a considerable number of races which freely mate together, but because the moth is polygamous and the feeding period lasts only 25–35 days.[64]

The use of the English word "race" seems to correspond closely to the notions of "kind," or "strain," or "variety" expressed through the term *sanshu* (silkworm seeds), rather than *shu* alone*,* which in the case of humans reflects ethnic or racial categories. In addition to acknowledging that the silkworm moths readily mate conspecifics and are thus amenable to experimentation especially because the same male, for instance, could be used as a stud in an experiment, Tanaka pointed out the importance of a somewhat short juvenile "feeding period" of about a month before the onset of metamorphosis. He made even more explicit the convenience of using silkworms that cycle through multiple generations per calendar year, yielding not more silk but more data.

The importance of a short generation time had already received attention with regard to *Drosophila melanogaster*, but unlike the *adult* form of the fruit fly, Tanaka explained how the *larval* form of the silkworm shaped his regard for these organisms as scientific objects:

> . . . the present experiments concern in the main not the adult characters, but the larval which are, therefore, to be regarded as the parental characters recapitulated in the course of ontogenetic development. A given character is

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[64] Tanaka, "Genetic Studies on the Silkworm," p. 129. This passage bears this footnote: "Besides these, we can see more than two generations a year in bivoltine and polyvoltine races; even in univoltines, the eggs may be forced to hatch repeatedly in the same year through artificial methods first discovered by Verson (with electricity) and Duclaux and Bolle (with acids), which have recently been improved by Japanese sericulturists."

> not only transmissible, but so precisely transmissible as to reappear in a stage or stages proper to it.[65]

Tanaka could thus bring the silkworm into more direct dialogue with *Drosophila* and the work of Morgan and his colleagues.[66] Methodologically, their investigations bore congruencies, as Tanaka elaborated: "In both the fruit-fly and the silkworm, the gametic series were tested not only by inbreeding, but also by reciprocally crossing the diheterozygotes with double-recessive individuals; the results were in accordance in many respects in both cases."[67] Tanaka studied eleven "hereditary factors" particular to the insect as a juvenile, in addition to molting frequencies and cocoon color. Tanaka could undertake new investigations by focusing on the relations between the absence or presence of particular characteristics that Toyama, for instance, had neglected, such as "moricaud," "quail," or "plain." Eventually, over the course of analyzing more than 101,000 silkworms over the course of several years, Tanaka could arrive at a point of explaining "gametic coupling," or what we now called "linkage," for at least eighteen different combinations of silkworm characteristics, for instance, based on the "absence" or "presence" of six discrete "factors."[68]

The number of different investigations Tanaka made to ascertain the epistatic relationships amongst silkworm characteristics for his 1916 paper were numerous, illustrating a kind of familiarity with these silkworms that Tanaka cultivated for himself as a scientist that differed from the familiarity that a commercial breeder had. These experiments depended on his systematic creation of heterozygous crosses, which in turn depended very much on his ability to maintain stocks of silkworms that were inbred homozygous for particular characteristics. Such attention and interest also

[65] Tanaka, "Genetic Studies on the Silkworm," p. 130. Original is in English.
[66] Tanaka cites widely from the single-authored publications of Morgan, such as Morgan, 1913, 1914, 1916. For more on the Morgan lab and the fruit fly, see Allen, *Thomas Hunt Morgan*; Kohler, *Lords of the Fly*.
[67] Tanaka, "Genetic Studies on the Silkworm," p. 186.

made it possible for him to notice and strive to understand unique or novel changes in the larvae.

Tanaka's 1916 paper symbolized another important moment in the development of the silkworm as a genetic research organism when he analyzed the appearance of eleven mosaics and mosaic gynandromorphs among hybrid and pure-breed silkworm matings (although more often from hybrid crosses) among silkworms of varying larval patterns, body color, and even size. The mosaic offspring exhibited different patterns split along the dorsal–ventral line, for instance, with the left side appearing to have normal larval markings and the right side of the body bearing stripes. In the gynandromorph cases, dissection confirmed that both male and female sex organs were present, split along each side of the body. Sometimes, the split features appeared in only a portion of segments of the larvae's body. A number of different theories existed to explain mosaics, but Tanaka surmised the cause "must, I believe, be explained by mutations taking place in the course of ontogeny."[69] This was one of the earlier, if not earliest, instances of Tanaka's use of the English word "mutation."

> By the term "mutation" I do not mean a sudden elimination or addition of certain factor or factors, but some reorganization or disturbance taking place among somatic cells or chromosomes, by which certain factor or factors are suppressed, or suppressed factors called into activity.[70]

Tanaka qualified his concept of mutation as 1) that which affects nonsexual characters only, giving rise to a simple mosaic, 2) gynandromorphs, in which sexual

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[68] Ibid.

[69] Ibid., p. 229. Tanaka refers to Boveri, 1915, Lang, 1912, Goldschmidt, 1912, and Morgan, 1913, 1914, 1916. It should be noted that Tanaka did not seem to consider changes in molting frequency between generations a "mutation" per se, but rather ascribed these to "physiological disorders" caused by volcanic ashes or coal that covered mulberry fields.

[70] Ibid.

characteristics only are affected, or 3) instances in which both are affected, giving rise to a mosaic gynandromorph.[71]

> I believe mosaics are produced by mutations, either major or minor, occurring in the segmenting cells in different stages of embryonal development. By "mutation" I mean assumed sudden check of physiological functions of a gene or genes, or a sudden revival of them in the egg cells.[72]

Tanaka suggested this distinct idea of mutation as something different from a "commingling of two characters" that "takes place as a result of crossing," as Toyama could only describe when he had observed gynandromorphs in 1901.[73] Further discussion of these rare gynandromorphs is beyond the scope of this dissertation, but its mention here helps stress that Tanaka's work, which temporally overlapped with the *tōitsu* movement, had the capacity to harbor these and began to make it possible for oddities to persist, including the previously mentioned *elongate* larvae.

a. Elongate Beginnings

The malformed *elongate* marked just the beginning of how Tanaka expanded his toolkit of mutant silkworms, while the national silkworm-unification scheme continued to emphasize greater parsimony among existing varieties.[74] The *elongate* had resulted from a hybrid cross between a "plain, smooth, white-blooded" female

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[71] Ibid., p. 239.
[72] Ibid., p. 244.
[73] Toyama Kametarō. "On the Hybridology of the Silkworm," *Bulletin of the Tokyo Imperial University College of Agriculture* 7, no. 1 (1906): 259–393, p. 358.
[74] Tanaka found that this strain (labeled 18am6) consisted of 241 normal and 77 elongate silkworms. He suspected that the 77 were all female because 23 surviving adult moths were female. The female parent came from a line that had been bred for about four generations without generating any "elongates." Interestingly, this line resulted not from conventional Japanese varieties, but from crossing a Chinese tri-molting strain from Shantung (likely from the 1910 silkworm eggs) in 1911, 1913, and 1915, using the conventional Japanese varieties Aojuku, Kojikisan, and Seihaku. The male parent was a distinct line of "multilunar" silkworms of Chinese origin. (Multilunar is a common larval marking of half-moons, on the dorsal side.)

parent and a "plain knobbed, white-blooded" male parent.[75] Tanaka continued breeding the *elongate* silkworms. He also bred them with conventional commercial varieties, such as Chiyotsuru. In the summer of 1921, he crossed elongate males and females to produce a pedigree of "pure" *elongate* strains in the spring of 1922, which he called "fixed" in 1923.[76]

Through experimentation, Tanaka also came to understand that the characteristic was actually sex-linked, and he reported that the elongate mutation is carried on the Z sex chromosome. (According to Tanaka, *Bombyx mori* sex chromosomes are ZZ ZW, in which W determines femaleness.)[77] By the time Tanaka wrote a paper on the "elongate" silkworm, he had returned from a sojourn to England where he had sought a collegial exchange with William Bateson, who had urged Tanaka to publish a previous paper in 1922 on sex linkage in the silkworm. In combination with this experience to help bring his work in line with the genetic language customs of one of the foremost geneticists of the time, the use of Tanaka's toolkit would grow and also gain recognizability.[78]

Tanaka reported that the elongate mutation was carried on the Z sex chromosome.[79] He worked through the pedigree history and determined that the first appearance of *elongate* had to have occurred from a heterozygous cross between a

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75 Tanaka continued a convention begun in Toyama, "On the Hybridology of the Silkworm," which referred to silkworm "blood color" as an indicator of silkworm cocoon color visible through the thin skin of the inside of the larvae's abdominal legs. This helped Toyama and Tanaka collect data on cocoons even if the worm never spun a cocoon.

76 The strain was labeled 22am6.

77 Tanaka Yoshimarō, "Sex-Linkage in the Silkworm," *Journal of Genetics* 12, no. 2 (1922): 163–178.

78 Tanaka Yoshimarō, "Bētoson Sensei," *Shokubutsu oyobi Dōbutsu* 1, no. 3 (1933): 395–405; Tanaka, "Sex-Linkage in the Silkworm." Tanaka went overseas, motivated by the prospect of meeting William Bateson. He arrived in London in February 1920 and studied the English language for three month and then wrote a letter to Bateson, who immediately replied and invited him to sup with him on May 27 for an initial meeting. Tanaka continued to visit with the Batesons over a period of seven months, during which time he read articles and had some opportunities to speak with Bateson and his family. Bateson had particularly encouraged Tanaka to wrap up a publication on the inheritance of *hansei iden*, or sex-linked inheritance, which he published in the *Journal of Genetics*.

79 Tanaka designated the letter "e" as a recessive gene and upper-case "E" as the normal form.

male and female carrying both a recessive and a dominant "factor" for "elongatedness."[80] The resulting cross gave rise to normal males, normal females, and elongate females in a 2:1:1 ratio. Tanaka deduced that the mutation itself must have arisen some time no earlier than in the spring of 1917 or 1916 and managed to pass undetected until 1918.

This elongate mutation represents an important moment. The event of this oddity silkworm shows how someone could deem an otherwise disposable living thing scientifically valuable, deserving to persist. The odd silkworm also represents how Tanaka's system made possible traceability of the generation of novelty. The act of locating novelty also translates to the addition of new alphabet letters in Tanaka's system, to represent original "factors" that only *he* had access to. Tanaka's toolkit could grow not because he explicitly did something deliberate to provoke mutations in silkworms, but because he put a system into place that let him keep a watchful eye across all of the silkworms reared in his laboratory and then notice small morphological changes.

4. Taking Stock of Silkworm Seeds

Silkworm geneticists such as Tanaka, despite their accomplishments, would struggle to maintain their research relevancy in both the biological sciences and in sericulture under the empire. Understanding the emergence of mutation biology in the sericultural landscape requires a handle on the problem that the Imperial government viewed in the number of silkworm varieties in the early 1900s. The unificatory movement to catalog and manage the reproduction of silkworms throughout Japan hinged on the great expectations for economic success, but such issues did not include the kinds of questions that Tanaka, or Toyama, for that matter, wanted to explore.

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[80] In other words, Ee (female) × Ee (male).

Tanaka in particular could not wait for or rely on state-registered silkworms, which occupied unstable categories. The sericulture experiment stations controlled the emergence and erasure of silkworm brands and breeds for years following 1910. The state system's interest in "unifying" and then "improving" so-called Chinese, Japanese, and European silkworms thus limited the ability to rely on a stable nomenclature that would have been useful for Tanaka's genetic experiments, even though his work responded to state sericulture activities by identifying with things that fell away from the purview of an increasing regulation. As Evelyn Fox Keller put it, "scientific language is not as different from ordinary language as it is commonly believed; it, too, is subject to imprecision and ambiguity and hence to imperfect understanding."[81] For someone like Tanaka, finding a language that could cross between two purposes was important to maximize intelligibility to others.

Their constant navigation between these two worlds began to make it necessary for the "silkworm scientist" to assume the identity of "geneticist" in the late 1910s and early 1920s. This chapter has traced how Tanaka gradually built his own system to keep track of silkworms including some of the very same kinds bred in the state repositories. His use of letters and numbers downplayed the idea of local or geographical provenance of silkworm varieties, and it even replaced character names used by other scientists in earlier experiments.[82] This silkworm labeling and record-keeping system engendered a second epistemic regime that afforded the appearance of mutations, whether slight or monstrous, as opposed to particular ideals of the state.[83]

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[81] Evelyn Fox Keller, *A Feeling for the Organism* (New York: W. H. Freeman and Co., 1983).

[82] Tanaka Yoshimarō, "Kaiko ni Okeru Mare rashiki Idengenshō," *Dainihon Sanshi Kaihō* 24, no. 276 (1915): 12–13. Tanaka replaced Toyama's "striped" notation with "zebra," and Ishiwata's *chahanmon,* or "tea pattern," with *kasshoku hanten,* or "brown specks."

[83] Chapter One introduces how silk production and trade was viewed by officials in the Ministry of Agriculture and Commerce as a war or battle to gain the American silk market. See Takahashi to Inoue and Yoshida, 1883 [DRO].

This first historical analysis of Tanaka's data-entry process has revealed insights about the tensions between the silkworm's material offerings and the theoretical interests of Tanaka, who underwrote the production of further mutant silkworms. In his postwar reflections on the historical development of genetics and his own silkworm experiments, Tanaka recalled how he gradually distinguished between heritable mutations and some nonheritable instances of "monsters."[84] Efforts to understand Tanaka's arrival at these distinctions between heritability and nonheritability illuminate his conceptualization of mutation and the recognizability of a discrete kind of silkworm, as articulated by his work with the "elongates." The creation of new silkworms by Tanaka, which stood apart from the work carried out by Toyama to enhance commercial breeding, cultivated a space for the development of a genetic research method in Japan. In the rest of the country, silk work to achieve and benefit from *tōitsu* remained important.

a. One Hybrid Silkworm at a Time: Imai Gosuke and Diffusion

Before continuing with analysis of Tanaka and how he positioned himself as a geneticist in a society defined by sericulture, the following interlude of a case study on the so-called diffusion of scientific, commercial hybrid silkworms helps illustrate how the 1911 Sericultural Industry law had helped shape the silk industry. The Katakura family in Nagano Prefecture owned and operated Japan's largest independent silk-reeling business as of 1895, the same year as Japan's victory in the Sino–Japanese war. The Katakura family, as an agricultural family, had increasing interests in steam filature and reeling, and one of its most entrepreneurial members was Imai Gosuke (1859–1946). The youngest son of Katakura Ichisuke, who began the family business with ten reelers in 1873, Imai helped change business norms in a fundamental fashion

[84] Tanaka Yoshimarō, "Genetics of the Silkworm, Bombyx mori," *Advances in Genetics* 5 (1953): 239–317. See p. 280.

in November 1914, when he established the First Generation Hybrid Silkworm Seed Diffusion Group, Japan, Ltd. (*Dainihon Ichidai Kōhai Sanshu Fukyūdan*. Its name was shortened to *Ichidai Kōhai Sanshu Fukyūdan* in 1922).[85]

As mentioned earlier, members of the silk industry had been discussing how to improve the overall quality of export-bound raw silk through the "unification" of cocoon qualities. Toyama's work on the scientific hybridization of silkworms required an understanding of how silkworm variation represented by the male and female adult moths might manifest in the desired cohort of offspring. He stressed the importance of artificial selection imposed by humans in the ability to create new varieties of silkworms "limited" to one generation, the F1, noting how the characteristics of two different silkworm varieties, the parents, could combine and be seen or not in the offspring. "With respect to the situation we face to preserve business in our country, this has become most necessary to take into account; otherwise, it will take several years to create and fix good varieties."[86]

Toyama's attitude toward silkworm breeding is important for putting the science into a business context. In his book *Sanshuron* (1909), Toyama preoccupied himself with imparting all of his knowledge of silkworms, the history of sericulture, evolution, and heredity in a tome numbering over 700 pages. As indicated by his keen interest in using the precision of Mendelian inheritance to "save" the businesses of Japan, considering that the book itself was written shortly after the financial panic of 1907, Toyama's book, though intended for the average sericulturist, was quite intimidating. Despite this, Imai Gosuke is thought to have taken a cue from Toyama's writings and public teachings. The entrepreneur was not interested in Mendelian genetics per se, but by the same token of promoting his silk business's productivity, he

[85] Katakura Kōgyō was the name of the business. Imai's surname changed from Katakura after he was adopted by the Imai family at age 19 in anticipation of his joining them through marriage.
[86] Toyama Kametarō, *Sanshuron. Vols. 1 and 2* (Tokyo: Maruyama, 1909), pp. 648–649. Variation here is a translation of *shurui*.

took silkworm matters into his own hands.[87] Imai rallied five sericulturists in Nagano Prefecture to find a way to cultivate and distribute superior commercial varieties of silkworms, leading to the Diffusion Group located in Matsumoto City, which the Katakura parent company absorbed in 1915.[88]

Imai's Diffusion Group aimed to produce robust, easy-to-rear silkworms that would give rise to high yields of cocoons. Rather than wait for the result of governmental experiments, the Diffusion Group created contractual relationships with sericulturists and delivered hybrid silkworm seeds to peasants directly. The Diffusion Group's efforts to advance improvement and "unification" of commercial silkworm varieties took cues from Toyama's research as they independently conducted scientific research on F1 hybrids, ultimately helping to engender revolutionary change in the improvement of commercial varieties of silkworms based on this new management of silkworm reproduction.[89] By 1922, the group had produced 4,972,968 moths.[90] The number of parent moths maintained grew along with the expansion of large-scale filature companies. In 1931, the Katakura filature, for example, not only had a presence in Nagano Prefecture, producing over 480,000 moths, but its production bases for parent moths and cocoon moths expanded to Shizuoka and Okinawa Prefectures, where parent moth counts amounted to 255,444 and 181,468 respectively. By 1935, moth production had extended to Fukushima and Saga Prefectures.[91]

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[87] Katakura Kōgyō Kabushiki Gaisha, *Nyū Katakura no Sōzō: Kabushiki Gaisha Setsuritsu 70 Shūnen Kinen Shashinchō* [Creation of New Katakura: 70th Anniversary of the Establishment of the Company Photograph Album] (Tokyo: Katakura Kōgyō, 1991), pp. 126–136.

[88] Takanashi Kenji, "Katakura Seishi no Sanshu Seisan Taisei no Kōchiku: Ichidai Kōhai Sanshu Fukyūdan wo Chūshin ni," *Senshū Daigaku Shakai Kagaku Nenpō* 44 (2010): 19–47, citing Katakura Seishi Bōseki Kabushiki Gaisha Chosa, eds., 1941, pp. 207–223.

[89] Imai Gosuke, *Nihon Sangyō Hattatsushi* [History of the Development of Silk Industry] (Tokyo: Katakura Kōgyō Bōseki Kabushiki Gaisha, 1927), p. 79.

[90] Takanashi, "Katakura Seishi no Sanshu Seisan Taisei no Kōchiku," citing Katakura Seishi Bōseki Kabushiki Gaisha Chosa, eds., 1941, pp. 207–223.

[91] Takanashi, "Katakura Seishi no Sanshu Seisan Taisei no Kōchiku."

b. Full Moon for the State

Filature factories involved with the production of cocoons had especially guarded the identity of parent silkworms used to supply cocoons, similar in spirit to the way a chef might take protective measures to keep competitors from obtaining a famous recipe. Under the directorship of Kobari Kisaburo at the Sericulture Research Center of the Katakura Company, two of their most well-known silkworm varieties were developed, *Mangetsu* (full moon) in 1923 and *Eikō* (glory) in 1931. Both sound like Japanese names, but *Mangetsu* derives from a Chinese bivoltine variety that lays purplish eggs spinning white cocoons. Its silk-filament quality was thought to be excellent. The use of a Japanese word as a representative brand name provides but a small hint of the fragility of identity in the activity of naming.

Eikō, also a bivoltine white-cocoon-spinning silkworm variety, resulted from a hybridization of the breed Seihaku with the offspring of a crossing between two Japanese varieties, Tanegashima and Aojuku.[92] The *Eikō* × *Mangetsu* cross yielded robust larvae with a light-green body and pale purple-red bands, and normal markings. Their cocoons exhibited a slight constriction in the middles, were mostly white, and had excellent reeling qualities.[93]

The success story of *Eikō* × *Mangetsu* points to the relative superiority of the resulting qualities of the F1 hybrid silkworm's cocoon. As silkworms resulting from bivoltine parents, these were used for rearing during the summer and fall seasons, which helped boost the annual production of raw silk in Japan, especially for Katakura. Conventionally, spring silkworms have the best reputation for disease-free and vigorous larvae and therefore spin generally unspoiled cocoons, while silkworms

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[92] Most *shashi*, or company histories, for instance, of Katakura and Gunze, two major silk-reeling companies active in eastern and western Japan, have rarely released details of their relationships to the sericulture industry. In addition to Hiratsuka, *Nihon Kaiko Hinshu Jitsuyō Keifu*, and Hiratsuka, *Silkworm Breeding,* pp. 126–139, the *Eiko* × *Mangetsu* cross was described in personal communication to the author by the fourteenth director of the Katakura Diffusion Group, Miyazawa, 30 August 2008.

[93] Hiratsuka, *Silkworm Breeding*, p. 126.

cultivated in the warmer and more humid summer and early fall endure more problems that can lead to unfavorable results. Moreover, unhealthy larvae tend not to yield as much silk per cocoon. With *Eikō* × *Mangetsu,* the enhanced viability of a second growing season helped increase the overall production yield of cocoons in Japan, and many believed the variety to be essentially flawless.[94]

Yet, other so-called flawed cocoons still existed. The laws of 1911 had also fed the intensification of parent silkworm variety regulation leading into the 1930s. Greater efficiency and lower costs in silkworm and silk cultivation increasingly motivated new deliberations about governmental intervention, and in February 1934, the National Diet Assembly enacted the Parent Silkworm Variety Management Law.[95] This legislation, while echoing many of the sensibilities of the 1911 law, facilitated the centralized production of a limited number of silkworms. Rather than rely on three regional experiment stations, the new policy required each prefecture to obtain cocoons created at the national station and then distribute these as the parent silkworms used to yield the F1 hybrids. Although egg producers would be permitted to produce parent silkworms for their own personal use, the parent silkworms distributed from the prefecture were to be used only for designated crossings, in order to produce silkworms that would yield cocoons for factory processing. These designated crossings had to be preapproved by the Ministry of Agriculture and Forestry, and the policy thus demanded that the laboratory directors at Katakura as well as at other eventual conglomerates, Gunze, Kanebo, and Shinei, release information about their respective silkworm-breeding programs.[96]

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[94] Hiratsuka, *Silkwor Breeding*, pp. 126; Katakura Kōgyō Kabushiki Gaisha, 1991, p. 136. See also Yokoyama Tadao, *Silkworm Genetics Illustrated* (Tokyo: Japan Society for the Promotion of Science, 1959), p. 141.

[95] Parent Silkworm Variety Management Law, 28 March 1934, Law No. 25.

[96] Tazima Yatarō, *Kaiko no Hinshu Ikusei* (Tokyo: Science House, 1993), p. 42; Parent Silkworm Variety Management Law, 28 March 1934, Law No. 25.

With the 1934 law, the government enforced a transparency of the constitution of these independently curated parent silkworms that had helped fan the use of hybrid silkworms in Japan. While the oldest, conventional varieties of silkworms in Japan could continue to be recognized by their original names, newer breeds branded by Katakura and others underwent a registration that would allow for their integration with the national classification system. In this extension of claiming and making silkworms legible, the "brand names" of parent silkworms used by the factories, which had concealed the exact identities of the silkworms, became tractable by the state. In 1937, *Mangetsu* was reidentified as "Shina 108" or "C108," adhering to the classifications standards that had begun in the years following 1911. In 1939, *Eikō* received the designation of "Nichi 115" or "N115" (See Figure 10)[97] The companies lost control of solitary ownership of the N115 × C108 cross, which the state promoted. It grew in popularity and was also used in springtime as well as in fall and summer.[98]

Figure 10. Present-day depictions of *Nichi 115* and *Shina 108* cocoons and cocoons of their resulting hybrid cross. Photo by author.

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97 Hiratsuka, *Silkworm Breeding*, pp. 74–75, 232–233.
98 By 1949, over 66% of the fall and summer silkworms used in Japan were N115 × C108 hybrids. Tazima,1993, pp. 44–48.

c. Positioning the Genetics of Improvement

Silkworm-breed improvement and progress in sericulture continued to occupy the forefront of the minds of producers, officials, and scientists. By creating new silkworms, Tanaka's genetic research in the 1910s and 1920s had folded into the mindset of "improvement" as silk production continued to play an important role in drawing foreign capital to Japan through global silk trade. Tanaka's genetic research did not at first yield commercially interesting results in the fashion of the Katakura Company. The creation of unique mutants could, at least, enhance the understanding of genetic principles, but silkworm scientists at the time could simply not afford to be distanced from the business of silkworm improvement.[99]

By the time Tanaka matured as a scientist in his own right, it was clear that he could not fully leave his connection to the sericulture industry. His work, if it was not to produce silkworms valuable for wealth production, had to be positioned nonetheless as something valuable. His affiliation with the Imperial Sericultural Institute in Fukushima not only offered some security, but in 1915, his work to put the silkworm on the same plane as the fruit fly came at the time of the Panama Pacific Exhibition in San Francisco. Tanaka prepared a research poster showcasing some of his work on sexual dimorphism in gametic coupling and repulsion, which read in English:

> [For case III] male and female F1 moths give different combinations of two pairs of characters – the larval marking and the cocoon color – female[s] producing only two kinds of gametes in equal numbers. . . . [and in the second case] males certain two combinations occur more frequently than others. *Prof. T. H. Morgan of Columbia University observed similar phenomena in the Fruit fly, but the relation of sex is reversed in his and my cases. No other examples*

[99] Tanaka Yoshimarō, "Shōrai no Idengaku," *Transactions of the Tottori Society of Agricultural Science* 1, no. 3 (1928): 266–278. By the late twenties, Tanaka felt that mutants might one day be used directly or indirectly to "improve" silkworms and their silk, reflecting the kind of passion, though not as flamboyant, that Toyama had for independent assortment in Mendelism.

> *like these have heretofore been found in the world of genetics.*[100] (emphasis added)

This research, described in fuller detail in papers published in 1914 and 1915, showed evidence of different linkage patterns occurring in male and female silkworms, particularly for yellow cocoon color and different larval markings.[101] The poster, which would have represented the state of Japanese genetic research, for reasons unclear never went to the Panama Pacific Exhibition in 1915, but was reprinted in the *Bulletin of the Sericultural Association of Japan*. Along with Tanaka's 1913 work on gametic coupling and repulsion, it suggests, first, how Tanaka saw himself as a scientist using the silkworm to make significant findings in conversation with genetic research in North America and Europe and, second, how his work, although much more theoretical than the concerns of most breed-improving sericulture scientists, could nonetheless gain social relevancy among those involved with the Sericultural Association, whose figurehead was a member of the Imperial family.[102]

Tanaka's willingness to relate his work to sericulture during this period, when interest in hybridization was increasing, was most apparent in 1917, when he published a textbook entitled *Kaiko no Iden to Hinshu Kairyō* (Genetics of the Silkworm and [Commercial] Breed Improvement), published by the Japan Sericultural Association. This small, easy-to-read book offered a pared-down version of his 1916 thesis, dedicating his genetic findings to this father, whose sericultural pursuits had

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100 English is original to Tanaka. Frontispiece accompanying Tanaka, "Occurrence of Different Systems of Gametic Reduplication in Male and Female Hybrids."

101 Normal, moricaud, or striped markings. Tanaka Yoshimarō, "Sexual Dimorphism of Gametic Series in the Reduplication," *Transactions of the Sapporo Natural History Society* 5, no. 2 (1914): 62–64; Tanaka Yoshimarō, "Further Data on the Reduplication in Silkworms," *Journal of the College of Agriculture, Tohoku Imperial University, Sapporo* 6 (1914): 1–16; Tanaka Yoshimarō, "Occurrence of Different Systems of Gametic Reduplication in Male and Female Hybrids," *Zeitschrift für induktive Abstammungs- und Vererbungslehre* 14, no. 1 (1915): 12–30; Tanaka Yoshimarō, "Kaiko ni Okeru Mare rashiki Idengenshō," *Dainihon Sanshi Kaihō* 24, no. 276 (1915): 12–13.

102 The history of the Japan Sericultural Association is recorded in *Dainihon Sanshikai Hyakunen-shi*, 1992.

given rise to the two silkworm varieties that built the Tanaka family, Chiyotsuru and Nihon-nishiki.[103] Although Tanaka had pursued education to avoid the silkworm business initially, he now stepped back into the sericulture world as a learned expert of an agricultural science, bringing to it a view that silkworms could be used to advance genetic studies while potentially benefitting the sericulture industry. Tanaka worked on issues that seemed far from the immediate concerns of wealth production, but he had to remain connected to the sociality of sericulture.

Tanaka's silkworm toolkit began to develop and coexisted with growth in the popularity of hybrid vigor and the great anticipation of economic success as reflected by the displacement of local silkworm knowledge regimes by the national system of cataloging and managing silkworms. Tanaka's maintenance of silkworms by focusing on the collection of Mendelian genetic factors had grown initially as an obverse response to the *tōitsu* movement and engendered a second epistemic regime that afforded the unknown, in comparison to that of the state, which anticipated the production of consistent qualities of cocoons. His use of letters and numbers downplayed the idea of local or geographical provenance of silkworm varieties, and it even replaced character names used by other scientists in earlier experiments, which entrenched a distinctive normalization in the codification of biological phenomena.[104]

Tanaka's silkworm labeling and record-keeping system reflects a new language of knowing the silkworm as an object of science that would coexist with another – a language of the silkworm used for breeding that had naturalized new conceptualizations of silkworms through increasing control by the state. The silkworm

[103] Tanaka Yoshimarō, *Kaiko no Iden to Hinshu Kairyō* (Tokyo: Dainihon Sanshikai, 1917).
[104] See footnote 89.

occupies a strange role, then, as a figment of pedigrees past and mutants of tomorrow, Foucault's monster and fossil in one.[105] It is this silkworm that Tanaka worked with.

Having gone to college at first to avoid working with silkworms in the family business, Tanaka may have also been the least likely candidate to create a new language of the silkworm because he was so fully embedded in the methods of conventional breeding and egg production. Education itself was seen as a form of escape from sericulture, but a confluence of situations related to the classificatory efforts of *tōitsu* and the sericulture industry, the opportunities cleared for Mendelian inheritance studies spurred by the work Toyama, and the opportunity to learn from Bateson made it possible for Tanaka to develop this second epistemic regime that afforded the appearance of mutations, whether slight or monstrous, as opposed to particular ideals of the state. His intense familiarity with silkworms stemming from his experiences while working with his father were far from a scientific hindrance.

This chapter showed how the 1911 Sericultural Industry Law, in particular the classification standards that it set and the efforts to isolate and then improve commercial silkworm brands, played out in the early stages of Tanaka's career and in the entrepreneurial work of the Katakura Company as led by the Diffusion Group organized by Imai Gosuke. These two case studies may seem disparate, but together, they help enhance an understanding of how the three strands of sericulture, science, and nation interacted with great consequences in light of the legal manifestation of the *tōitsu* movement.

Tanaka would go on to become one of Japan's most prominent silkworm geneticists. Indeed, Tanaka's story does not end yet, and in fact continues well into the postwar period. This dissertation's focus on the day-to-day practices illustrates how

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[105] Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Vintage Books, 1994), pp. 156–157. The fossil approximates identity and the monster "provides an account, as though in caricature, of the genesis of differences."

Tanaka's organization system made it possible to notice and keep novel changes in silkworms. It also became possible to know the short histories of new silkworm varieties and how they were made to populate a highly useful toolkit for producing new scientific questions to answer. Understanding Tanaka's work against the grain of ongoing activities in the sericultural industry makes it possible to appreciate how a culture of experimentation was created by different kinds of researchers in modern Japan, contributing to a composite view of the formation of sericultural genetics.

CONCLUSION:
ANATOMY OF A HYBRID

I know other silkworms will come and go. But, these, inside of their snug cocoons, will metamorphose into pupae and never emerge as moths. They are not seed-cocoons, but cocoons for harvest. These silkworms, hoisted up in their mabushi from the ceiling by the 80-something-year-old farmer and his wife at the wee hour of three in the morning, are oblivious that this time will be their last as breathing bodies. I wonder if it may be my last time, too, to see them. I say "them," as if "they" are constantly present. As if this year's worms are the same as the last year's, or as if this fall's crop is the same as the spring's. But, this is it. The last time, perhaps, to observe sericulture in a farm setting – before the surrounding construction razes the rest of the adjoining bamboo forest, before the land is sold off and turned into something concrete, something it has not yet been. The last time to see silkworms reared by the hands of people who worked the land, whose ancestors raised the 30-foot-long pine trunk that supports the roof of the barn in which the worms reside. Today's fall breeze heaves a sigh, a long breath that may yet last for a few more years of "lived" sericulture in Japan, before it washes away into a memory to be visited in photographs and museums, and becomes part of a past we reach for.

– Field note, September 10, 2008

1. Hybridization: Means to a Thread

Raw materials and their finished products each tell different stories, but they are tethered by our altered understandings of identity and belonging mediated through the exploitation of and erasure of hybridity. For cocoons and silk, the new voluntary standards that have emerged in the early twenty-first century, encapsulated in a trademark introduced in 2008 by the Japan Silk Center (*Nihon Kinu Gyōkyōkai*) that affords garment makers today the privilege of registering their woven silk bolts and other products in order to bear an exclusive tag, label, or sticker with the Silk Center's mark and phrases "*Nihon no kinu*" (Japanese silk; see Figure 11) and "*Jun kokusan*" (pure nationally produced). This lengthy registration process enables the differentiation of finished silk fabrics from those made with Chinese, Brazilian, or Thai silk, by listing the name of the commercial silkworm breed used; the location of cocoon production; the filature name; and the names of other textile companies involved, in order to display proof of the *seisan rireki*, or production history.[1]

Figure 11. *Nihon no kinu* mark. From Japan Silk Center website, http://www.silk-center.or.jp/.

As a historical analysis of sericulture and the rise of genetic experimentation, this dissertation has focused on the broader question of how universal claims about the principles of genetics could develop in a particular setting and time. It has also examined how the formation of genetics in Japan depended on an appropriation of a

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[1] In her study of Italian silk families and capitalism, Sylvia Yanagisako reminds us that the industry has always incorporated both "provincial" and "global," regional and international, relations of production and distribution (Sylvia Yanagisako, *Producing Culture And Capital: Family Firms In Italy* [Princeton: Princeton University Press, 2002], pp. 188–189).

Japanese past as the idea of Japan as a nation was developing. The development of the new "Japanese Silk" label suggests a self-essentialization of culture and capital evocative of the kind of Orientalization that scholars, especially anthropologists, have been critiquing over the last several decades. Such critiques note that the Weberian notion of "modern Western capitalism" leads all too easily to assumptions of a premodern, non-Western capitalism that rides upon binaries such as "Asian" and "Western" or "early" and "late."[2] These descriptions, though suggestive, overlook some of the processes that produce the very anxieties of difference evoked by historical actors at different times.

Changes in sericultural practices follow an arc that demonstrates the growth of scientific knowledge about the heredity and overall biology of the silkworm, and a shift from local control and production of silkworm seeds toward increasing state intervention. The history of experimental research and hybridization of silkworms examined in this dissertation provides insight into how silkworms, science, and national identity interacted within Japan, if not as part of the processes of the formation of modern Japan during Meiji. To enhance the qualities of popular silk fibers to suit machine reeling, the registration of parental stocks to create a commercial classificatory system enabled the development of scientific hybrids using distinctly categorized silkworms. The international trade related to these organisms highlights the importance of their identification as they crossed real and imagined national borders, often in the form of silkworm seeds.

As previous chapters indicated, by 1910 the inbred pure lines of the silkworm were grouped more clearly along the lines of geographical "races" while also receiving numerical labels. The 1911 Sericultural Industry Law that followed

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[2] Ibid., pp. 22–25; Aihwa Ong, *Flexible Citizenship: The Cultural Logics Of Transnationality* (Durham: Duke University Press, 1999); Max Weber, *The Protestant Ethic and the Spirit of Capitalism* (New York: Routledge, 1992).

reinforced the infrastructure of sericulture in order to identify, purify, reproduce, and improve silkworm parents. Scientific labeling for genetic research also had to be able to communicate with this kind of nomenclature, despite the use of alphanumerical labels developed by Tanaka. Together, these issues point to tensions between the ways in which silk and science have been cultivated and how silk, regardless of how it was made, was branded as "Japanese." [3]

The growth of corporate interventions in selective breeding and the transformation of silkworm varieties as intellectual property during the 1920s have introduced a new dimension to the study of the development of scientific research on silkworms. Examination from the industry's standpoint joins strands of analysis in the present study that have included a focus on scientific investigations by researchers such as Toyama Kametaro, who described Mendelian laws and developed parental stocks with which to make scientific hybrid silkworms, and Tanaka Yoshimaro, who made international contributions to the institutionalization of genetics in 1920s Japan and gained renown through his international and domestic publications.

The integration of scientific-breeding research and increased contractual control of sericulture in the design of silk-reeling companies following the 1911 law highlight the opportunity for greater understanding of the growth of scientific activities within private institutions. It's worth mentioning briefly here that Articles 5, 7, and 16 of the law described the need to acquire official permission from a regional experiment-station director to produce silkworm seeds; the use of only approved parental silkworm stocks to prevent biological deterioration; and the express prohibition against the saving of seeds, even for home use by people who reared silkworms as a side business. These rules separating the experienced from the

[3] Tanaka Yoshimarō, *Sericology* (Bombay: Examiner Press, 1964); Marian R. Goldsmith, Toru Shimada, and Hiroaki Abe, "The Genetics and Genomics of The Silkworm, *Bombyx mori,*" *Annual Review of Entomology* 50 (2005): 71–100. See Chapter Five.

nonexperienced direct our attention to some of the ways that companies were indirectly acknowledged for their expertise in breeding silkworms and how the ownership of knowledge was shifting from local practitioner settings to levels operating on a national, if not corporate, scale.

The government trusted that organizations such as companies, heavily vested in securing the export silk market, could avoid ruining silkworm cocoon qualities due to their long-standing expertise in breeding. This helped companies continue to shroud their breeding practices in the very secrecy that the *tōitsu* movement had nearly completely dismantled through the earlier governmental project of making silkworms "legible" for large-scale manipulation and scientific analysis at the local level. Of course, the genetics of scientific hybrid crosses made it very difficult for people to take males and females of the same hybrid crosses and breed more of the same exact kinds of individuals. Copying a biological product was not cost-effective without access to the same exact inbred parental stocks. The control over silkworm names remained important, too. The government permitted private entities to bestow their F1 hybrid silkworms with new, original names, which I believe helped protect prying eyes from accessing knowledge about the constitution of these crosses.

This analysis of the silkworm, genetics, and expressions of nationhood has depended on the articulation of the historical relationships between disciplines of the biological and technological in early-twentieth-century Japan, as well as on the fine lines drawn by scientists interested in distinguishing the natural from the artificial. The steadily growing attention to the histories of animals in Japan, ranging from the loss of wild species to the curation of animals in Meiji-period zoos, has increasingly shaped and enriched our understandings of Japanese claims about race and imperialism.[4]

[4] Emiko Ohnuki-Tierney, *The Monkey as Mirror: Symbolic Transformations in Japanese History and Ritual* (Princeton: Princeton University Press, 1987); Brett Walker, *The Lost Wolves of Japan* (Seattle: University of Washington Press, 2005); Gregory Pflugfelder and Brett Walker, *JAPANimals: History and Culture in Japan's Animal Life* (Ann Arbor: University of Michigan Press, 2005); Ian Miller, *The*

Highlighting different venues where experimental biological science formed in the sericulture industry, as this dissertation has done, provides different insights into the study of hybrid expressions of Japanese nationhood and empire. The dual existence of government-developed silkworms and those developed by major filature groups, for instance, shows how companies also played critical roles in the transformation of Japanese silkworm reproduction management in Japan, helping to explain why the notion of a singular silkworm of particular provenance actually depended on a foundation of hybridity.

2. Thinking with the Silkworm

The history of *Bombyx mori* could have been told in a fashion that narrowed in on its biology, but because it is a domesticated insect, the human element in the formation of its related science is critical. Recent work such as *Bugs and the Victorians* have highlighted how human culture has shaped the study of insects, which in turn has facilitated the pursuit of issues such as those related to God, governance, and life. The cultural history of entomology in Japan has demonstrated the birth of entomological science as something that grew out of wartime pest control in complicity with colonialism.[5] Aside from the histories written by retired silkworm scientists, the appearance of the silkworm beyond specificity of the species is rather uncommon in the histories of sericulture and silk, which center on cost analyses and management of labor in terms of increased yields, especially by enhancing autumn cocoon harvests. The domesticated silkworm is often ubiquitous but passive and undifferentiated in

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Nature of the Beasts: Empire and Exhibition at the Tokyo Imperial Zoo, 1882–1982 (forthcoming, UC Press); Ian Miller, "Didactic Nature: Exhibiting Nation and Empire at the Ueno Zoological Gardens," in *JAPANimals,* edited by Gregory Pflugfelder and Brett Walker (Ann Arbor: University of Michigan, 2005).

[5] J. F. M. Clark, *Bugs and the Victorians* (New Haven: Yale University Press, 2009); Akihisa Setoguchi, *Gaichū no tanjō: Mushi kara mita nihonshi* [The Birth of the Insect Pest: Japan History as Seen by Insects] (Tokyo: Chikuma Shobō, 2009); Hugh Raffles, *Insectopedia* (New York: Pantheon Books, 2010).

these histories.[6] These studies at heart are concerned with the economic development of the nation, and the silkworm has often remained "black boxed."[7] The economic analysis of the "diffusion" of hybrid silkworms in Japan by historian Yukihiko Kiyokawa is different for having regarded the living organism as an entity that reflects different breeds necessary to produce a scientifically knowable silkworm. His more recent work on the comparative appropriate technology in the development of silk industries acknowledges the use of different silkworm genera within the moth family, *Bombycidae*, in different parts of Asia, as well as the importance of voltinism, the number of life cycles a silkworm can undergo per year, depending on its location.[8]

The silkworm history offered here, however, does not aim to bring greater attention to an organism for its own sake. It attempts to analyze the lines between the artificial and natural that are so important in biological research. This study joins conversations about cultural histories of animal domestication for agriculture, pets, and biomedical research, and the differences between wild and nonwild organisms.[9] Here, the singular notion of "the silkworm" in Japan – the collapse of its brand name and its genetic plurality in the name of the nation – requires engagement with a constellation of concerns about life inhabited and shared by insects and their humans in the same productive time and spaces. The idea of a collectivized silkworm also

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6 Lillian Li, *China's Silk Trade: Traditional Industry in the Modern World, 1842–1937* (Cambridge, MA: Harvard University Press, 1981).

7 Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, MA: Harvard University Press, 1987).

8 Yukihiko Kiyokawa, *The Development and Diffusion of Improved Hybrid Silkworms in Japan: The First Filial Generation* (Tokyo: United Nations University, 1981). Yukihiko Kiyokawa, *Kindai seishi gijutsu to Ajia: gijutsu dōnyū no hikaku keizaishi* [Modern Filature Technology and Asia: Comparative Economic History of Technological Introductions] (Nagoya-shi: Nagoya Daigaku Shuppankai, 2009), pp. 45–51, 57–75.

9 Harriet Ritvo, *Noble Cows and Hybrid Zebras: Essays on Animals and History* (Charlottesville: University of Virginia Press, 2010); Harriet Ritvo, The Platypus and the Mermaid, and Other Figments of the Classifying Imagination (Cambridge, MA: Harvard University Press, 1997); Christian Reiss, "A Curiosity Becomes Standard: On the Mexican Axolotl's Journey from 'Nature' to Scientific and Popular 'Culture,' ca. 1860–1900," paper presented at History of Science Society Annual Meeting, 2008.

requires more biological understandings of the mechanisms of reproduction, although "the silkworm" in the early twentieth century was not a product of new biology alone. Indeed, as Carol Gluck indicated, the silkworm was also emblematic for Meiji farmers and represented economic uncertainties and only a partial solution to difficulties.[10]

As this dissertation shows, the relationship between sericulture and genetics in Japan developed such that the history of one cannot be told without the other. This fits in line with the historical development of ironworks in Meiji Japan as told by David Wittner, in which the relationship between the growth of national prestige and industrialization, especially through the use of select ironwork technologies, for instance, countered assumptions about the prominence of beliefs in technological determinism or smooth, linear progress in Japan at the time.[11] Indeed, this dissertation counters any assumptions of biological determinism that suggest that a grasp of Mendelian principles of inheritance elicited productive changes in the Japanese silk industry without many problems. Ironwork technologies were deeply connected to the ideology of progress in Meiji Japan constituting a particular "cultural materiality." This contrasted with the actually more fitful experiences of their development and economic viability, an analogous situation may be found in the silkworm as an inadvertent emblem of unified Japanese silk.[12] In reality, this association was more problematic than not.

The silkworm examined in this dissertation was part of the development of genetics in Japan, which involved a composite number of biological issues spanning local and regional sericulture and silk industry, academic scientific research, and concerns of the state at any given time. It may be argued that scientists' focus on

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[10] Carol Gluck, *Japan's Modern Myths: Ideology in the Late Meiji Period* (Princeton: Princeton University Press, 1985), p. 261.

[11] David Wittner, *Technology and the Culture of Progress in Meiji Japan* (New York: Routledge, 2008).

[12] Ibid., pp. 95–96.

silkworm seeds made it unclear whether they were studying the organism itself or ideas about the constitution of a variety of silkworm. Paying attention to the insect's life cycle situates historical activities such as sorting silkworms or fertilized eggs, cocoons, and silk fibers, which together point to a number of material constraints of the silkworm that helped shape the contours of the sericultural situation in Meiji Japan.

People cannot "see" the silkworm at the metamorphic stage between pupa and silk moth; therefore, when considered together with its cocoon, the insect inhabits two registers, of being and of thing. The vignettes that open many of the chapters of this dissertation similarly articulate aspects of the silkworm's everyday life that shed some light on what the silkworm can and cannot do. They also provide some insight into the work of silkworm breeders in farm and laboratory. While the vignettes do not describe the discussions and interactions amongst scientists and politicians, they do help situate critical moments of the silkworm's ecological life history. The attention to the silkworms' particular rhythm of reproduction and growth help show how they are also constrained to do certain things at certain moments, which also pose challenges for humans to negotiate around. The vignettes thus bring together insights of biology and sericultural practice so that it is easier to grasp what was occurring in the agro-ecological realm alongside the social, political developments described in each chapter.

The central role of the silkworm in the development of genetics in early-twentieth-century Japan also leads us to ask whether the silkworm can be identified as a model organism. Among approaches to the study of nonhumans in biology studies, the analytic of the "model organism" is well known, as catalogued for example by Ankeny and Leonelli. In the broadest interpretation of an experimental organism that can be construed as a model, a researcher can use a creature in an experiment to draw a conclusion about a relationship between "theory and world."[13] Studies of organisms in various experimental settings show that decision-making processes concerning biological technologies and methods of their distribution involve material constraints imposed by the organism. Such constraints refer to the kinds of experimental limitations or opportunities that are specific to an object of study and the scope or kind of knowledge that may be drawn from it.[14] The historical formation of the model organism is important to consider, for the material tractability of an organism both limits and guides an experimenter. Still, the model organism alone seems to account for only part of the issues important to a comprehensive historical analysis of the silkworm in Meiji Japan.

The relatively high fecundity, short life cycle, and mutability of silkworms resemble characteristics of organisms such as the fruit fly that have been standardized for use in genetic experiments.[15] But how is the materiality of the silkworm different from the fruit fly such that it contributes to any difference in their respective scientific findings? Although this issue requires much more work, especially delving into the work of Tanaka in the late 1920s through the 1930s, the silkworm offers some questions, if not an example, of how that universalistic congruency was imposed by Japanese scientists on an organism. Recognizing the prescriptive power in use of the phrase "model organism" to describe any living being subjected to biological experimentation in history and the present, I have, in this dissertation, described the use of the silkworm in its more concrete experimental terms, explicating how each

[13] Ankeny, R. A., Ankeny and S.& Leonelli, S. "What's So Special about Model Organisms?" *Studies in History and Philosophy of Science* 42, no. 2 (2010): 313–323, doi:10.1016/j.shpsa.2010.11.039.
[14] Adele Clarke and Joan Fujimura, eds., *The Right Tools for the Job* (Princeton: Princeton University Press, 1992); Ankeny and Leonelli, 2010.
[15] Hans-Jörg Rheinberger, "Cytoplasmic Particles: The Trajectory of a Scientific Object," in *Biographies of Scientific Objects,* ed. L. Daston, 270–294 (Chicago: University of Chicago Press, 2000); Hans-Jörg Rheinberger, "Experimental Systems, Graphematic Spaces," in *Inscribing Science,* ed. T. Lenoir, 285–303 (Stanford: Stanford University Press, 1998); Rachel Ankeny, "Model Organisms as Models: Understanding the 'Lingua Franca' of the Human Genome Project," supplement to *Philosophy of Science* 68, no. 3 (2001): S251–S261.

experimenter at the time may have viewed the silkworm and what it did or represented. The silkworm here provides a particularly useful means to explore the production of objectivity within agricultural biology but especially in relation to reconfigurations of conceptions of "Japanese" and Japanese international and regional leadership in the Meiji and Taishō periods.

The silkworm was made dependent on humans for survival hundreds of years before its use as an object and, later, as a tool of research, which calls us to question how historical analysis of it differs from that of other known model organisms today, such as the mouse, the yeast, the nematode, and especially the fruit fly as examined by Robert Kohler.[16] The embeddedness of sericulture in rural Japan seems to relate the silkworm to histories of other commodified agricultural products such as hybrid corn, which signal that the history of the silkworm necessitates a departure from the formal notion of the walled laboratory to consider a cultural history that recognizes the involvement of farming families, entrepreneurs, and state producers, in addition to scientists, in the formation of a scientific organism.[17]

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[16] Anne Fausto-Sterling and Gregg Mitman, "Whatever Happened to *Planaria*? C. M. Child and the Physiology of Inheritance," in *The Right Tools for the Job*, ed. Adele Clarke and Joan Fujimura (Princeton: Princeton University Press, 1992); Karen Ann Rader, *Making Mice: Standardizing Animals for American Biomedical Research, 1900–1955* (Princeton University Press, 2004); Angela N. H. Creager, *The Life of a Virus: Tobacco Mosaic Virus as an Experimental Model, 1930–1965* (University of Chicago Press, 2002); Soraya de Chadarevian, *Designs for Life: Molecular Biology after World War II* (Cambridge: Cambridge University Press, 2002); Robert E. Kohler, *Lords of the Fly:* Drosophila *Genetics and the Experimental Life* (Chicago: University Press, 1994).

[17] Edward M. East and Donald F. Jones, *Inbreeding and Outbreeding: Their Genetic and Sociological Significance* (Philadelphia: J. B. Lippincott Company, 1919); Barbara Kimmelman, "Organisms and Interests in Scientific Reasearch: R.A. Emerson's Claims for the Unique Contributions of Agricultural Genetics," in *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences*, edited by Joan H. Fujimura and Adele E. Clarke, 198–232 (Princeton, NJ: Princeton University Press, 1992); Deborah Fitzgerald, *The Business of Breeding: Hybrid Corn in Illinois, 1890–1940* (Ithaca: Cornell University Press, 1990); Jack Kloppenburg, *First the Seed: The Political Economy of Plant Biotechnology, 1492–2000* (New York: Cambridge University Press, 1988); Nathaniel C. Comfort, *The Tangled Field: Barbara McClintock's Search for the Patterns of Genetic Control* (Cambridge, MA: Harvard University Press, 2001). The work to distribute F1 silkworms through the "F1 Hybrid Diffusion Group" in 1914 took place slightly earlier than the development of hybrid corn as described by East and Jones, which suggests the alignment of the biological inquiries taking place in Japan and America at the time.

The propriety of cultural knowledge made the process of sharing knowledge one of constant negotiation between local producers and agricultural researchers. Historians of industrial animals have also shown the intellectual value of studying an organism as more than just a product of scientific research, or a beneficiary of data diffused. More than anything, a confluence of new cultures of competition, standardization, performance control, selection, and predictability together led to the creation of new kinds of useful organisms. For example, the story of silkworm science told here strengthens the arguments about the importance of genetics, culture, and markets in pure-bred breeding as told by Margaret Derry and others in their studies of the creation of the high-yielding cow as well as multiple breeds of horses, from the heavy draft horse to the army horse in the nineteenth and early twentieth centuries.[18] The silkworm obviously differs vastly from hoofed animals traded in the flesh – after all, Bombyx is sold either in embryonic form as fertilized eggs or as cocooned chrysalises, and the most lucrative part of the silkworm is its single filament of silk, reeled from cocoons degummed in boiling water.[19] Still, the numbers of emerging "types" and "breeds" that complicated their respective international markets of biological commodities are notable similarities shared by the insect and the working mammal, for which the new breeds would be better known in the market place than the "foundation" stocks used to make them. The history of silkworms joins other

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[18] Beth Orland, "Turbo-Cows: Producing a Competitive Animal in the Nineteenth and Early Twentieth Centuries," in *Industrializing Organisms: Introducing Evolutionary History,* edited by Philip Scranton and Susan R. Schrepfer, 167–189 (New York: Routledge, 2004); Margaret Elsinor Derry, *Bred for Perfection: Shorthorn Cattle, Collies, and Arabian Horses Since 1800*, Animals, History, Culture (Baltimore: Johns Hopkins University Press, 2003); Margaret Elsinor Derry, *Horses in Society: A Story of Animal Breeding and Marketing, 1800–1920* (Toronto: University of Toronto Press, 2006); Margaret Elsinor Derry, *Ontario's Cattle Kingdom: Purebred Breeders and Their World, 1870–1920* (Toronto: University of Toronto Press, 2001).

[19] Roger Wood, "The Sheep Breeders' View of Heredity before and after 1800," in *Heredity Produced: At the Crossroads of Biology, Politics, and Culture, 1500–1870*, edited by Staffan Müller-Wille and Hans-Jörg Rheinberger, 229–250 (Cambridge, MA: MIT Press, 2007).

histories of lucrative organisms that were objects of improvement based on various ideas that were not always scientific or pragmatic.[20]

A number of environmental historians and historians of technology who consider the importance of integrating biology also see domesticated organisms as evolutionary dispersers of genes.[21] Examining the connections among different people vested in these agriculturally valuable organisms, from elites to peasants, suggests how the notion of the moral economy of laboratory practices can be extended beyond the institutions of scientific research alone.[22] Thinking critically about or with species as mutable beings and breeds capable of bearing epistemological ramifications beyond the life sciences charts a peculiar vein in the history of the ownership and authorship of the biological.

The silkworm in the time of Mendelism illuminates further opportunities to inquire about the ways in which scientists in Japan engaged with more hardened concepts of the gene by the 1930s when, in Carlson's words, "the mutant gene . . . would become the geneticist's common currency."[23] My concern with the gene concept in this silkworm work may seem indirect at best, but this stems from my study of Toyama, which indicates that the register in which the notions about heredity and inheritance were conveyed (while those words were borrowed from everyday words in Japanese, as they had been in European languages) first inhabited more sericultural and folk contexts.[24]

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[20] Derry, *Horses in Society*, p. xiii.

[21] Greg Bankoff and Sandra Swart, eds., *Breeds of Empire: The Invention of the Horse in Southeast Asia and Southern Africa 1500–1950* (Copenhagen: NIAS Press, 2007).

[22] Kohler, *Lords of the Fly*.

[23] Elof Axel Carlson, *The Gene*, *a Critical History* (Philadelphia: Saunders, 1966), p. 88.

[24] Carlson, *The Gene*; Peter J. Beurton, Raphael Falk, and Hans-Jörg Rheinberger, eds., *The Concept of the Gene in Development and Evolution: Historical and Epistemological Perspectives* (Cambridge: Cambridge University Press, 2000); Robert C. Olby, *The Path to the Double Helix* (London: Macmillan, 1974); Falk, "The Gene – a Concept in Tension," in Beurton, Falk, and Rheinberger, *The Concept of the Gene*, p. 320, citing Johannsen 1911, 130; W. Johannsen, "The Genotype Conception of Heredity," *American Naturalist* 45 (1909): 129–159. Like the word for heredity, *iden* also had an everyday meaning that acquired scientific significance.

The post-Meiji silkworm represents a widening and a restriction of sericultural practices carried out at local levels by families and individuals and at levels managed by larger organizations. It also represents reconfigurations of ideas about national identity in Japan during the late nineteenth and early twentieth centuries as raw-silk exports grew, fueling the accumulation of foreign capital. A textured understanding of the silkworm as a heterogeneous living entity thus brings into greater relief the relationships among biological difference, human skill and technology, and raw silk in the late nineteenth century onward and enriches existing and growing studies of the material practices of silk work, which collectively help articulate its complicity in the intellectual formation of biological knowledge.[25]

3. Silkworm and Nation

Genetics was only one of the factors fueling scientific standardization of the silkworm's variation. What happened to the silkworm was much more than a laboratory process; the state support of the *tōitsu* of silkworms and silk seems to have built itself on a substrate that Toyama created, in which he naturalized the idea that sericulture in Japan came from a past in which originary Japanese skill resided, worthy of acknowledgment. While Japanese groupings of the domesticated silkworm species did not subdivide in a visibly Linnaean nomenclature system, the Japanese census of silkworm types by 1910 classified them not only terms of an arguably biological feature of the organism's life history, voltinism, but also in terms of their "race," Japanese or otherwise. As Foucault suggested, this task could take place "in so far as

[25] Bray, 1997; Dagmar Schäfer and Dieter Kuhn, *Weaving an Economic Pattern in Ming Times (1368–1644): The Production of Silk Weaves in the State-Owned Silk Workshops* (Heidelberg: Edition Forum, 2002); Luca Molà, *The Silk Industry of Renaissance Venice* (Baltimore: Johns Hopkins University Press, 2000). I thank Dagmar Schäfer for ongoing discussions on this topic and more generally sharing her expertise on the history of silk cultivation in twelfth- to fifteenth-century China.

things and language happen to be separate."[26] State scientists' observation of the silkworm and their grouping in the name of *tōitsu* incurred the violence of reinforcing a form of systematics that imposed Meiji and Taishō Japanese views of the world upon that of silkworms.

Discrete things, people, and places were all amenable to being rendered to convey some type of national unity.[27] The term for silkworm seed, in particular the character for seed, *shu*, referred to race, type, or kind, conflations of which complicated understandings of the Meiji proliferation of different kinds of cocoons and their silkworms in Japan that were subjected to the organizational project of *tōitsu*.[28] Names and novelty went hand in hand, and new iterations of silkworm cocoons often received new brand names. The easy equation of cocoons with a silk brand and therefore a commercially known silkworm suggests how boundaries between the unique did not always form along the lines of biological distinction that we might expect if "only" genetics, devoid of categories, ruled.

In the history of biology, Gar Allen has called the years 1900 through 1910 a period that preceded a more recognizable paradigm of heredity based on Mendelian and chromosome theories, leading to the importance of this decade for understanding the institutionalization of the biological sciences internationally.[29] Histories of

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[26] Michel Foucault, *The Order of Things; an Archaeology of the Human Sciences* (New York: Vintage Books, 1994), p. 132. Foucault especially refers to structure, referring not only to the parts of an organism, such as the parts of plants, but as that which "makes possible the description of what one sees . . . By limiting and filtering the visible, structure enables it to be transcribed into language. It permits the visibility of the animal or plant to pass over in its entirety into the discourse that receives it" (pp. 134–135.)

[27] Thomas S. Mullaney, *Coming to Terms with the Nation: Ethnic Classification in Modern China* (Berkeley: University of California Press, 2011). Though having taken place later in the twentieth century, the 1954 Ethnic Classification Project in modern China offers an insightful human example demonstrating the challenges of carrying out a rational inquiry to ascertain and describe the composition of the many ethnic communities within a nation.

[28] Michael Weiner, "Invention of Identity in Pre-War Japan," in *The Construction of Racial Identities in China and Japan: Historical and Contemporary Perspectives,* ed. Frank Dikötter (Honolulu: University of Hawai'i Press, 1997), p. 96.

[29] Garland Allen, *Thomas Hunt Morgan: The Man and His Science* (Princeton: Princeton University Press, 1978).

Japan's industrial revolution and social histories of science have regularly mentioned discussions of silk, pointing to ample opportunities for historians of science and Japan to research the histories of agriculture and biology in the early twentieth century. Ground-clearing historical work on the formation of scientific communities in Japan by Bartholomew has also included discussion of the institutional developments surrounding sericulture and its science, such as the 1911 Diet bill proposing greater support for silk research.[30] Histories of scientists such as Yamanouchi Shigeo and Kihara Hitoshi have brought greater attention to intellectual developments in Japanese genetics within discourses of eugenics and Lysenkoism of the early twentieth century.[31] These and other literatures mention the experimental research of silkworm geneticists; but the earlier *Yūseigaku* (Eugenics), by Zenji Suzuki, one of the few Japanese monographs explicitly on this topic in Japan, helped place the discussion of silkworm geneticists in terms of a social phenomenon.[32]

These developments of a science in a particular country remind us of Jonathan Harwood's interest in identifying particular "styles of thought," or discernible patterns, in the ways of doing and thinking about science. In his study of German geneticists, he suggests that apparent differences between countries should not be

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[30] James R. Bartholomew, *The Formation of Science in Japan: Building a Research Tradition* (New Haven: Yale University Press, 1993), pp. 158–159, 227.

[31] Sumiko Otsubo, "Between Two Worlds: Yamanouchi Shigeo and Eugenics in Early Twentieth-Century Japan," *Annals of Science* 62, no. 2 (2005): 205; Kaori Iida, "Practice and Politics in Japanese Science: Hitoshi Kihara and the Formation of a Genetics Discipline," *Journal of the History of Biology* 43, no. 3 (June 2009): 529–570.

[32] Tessa Morris-Suzuki, *Reinventing Japan: Time, Space, Nation* (New York: M. E. Sharpe, 1998), p. 359; Zenji Suzuki, "Genetics and the Eugenics Movement in Japan," *Japanese Studies in the History of Science* 14 (1975): 157–164; Yuehtsen Juliette Chung, *Struggle for National Survival: Eugenics in Sino–Japanese Contexts, 1896–1945* (New York: Routledge, 2002); Sumiko Otsubo, "The Female Body and Eugenic Thought in Meiji Japan," in *Building A Modern Japan: Science, Technology, And Medicine In The Meiji Era And Beyond*, ed. Morris Low, 61–82 (New York: Macmillan, 2005). Sumiko Otsubo and James R. Bartholomew, "Eugenics in Japan: Some Ironies of Modernity, 1883–1945," *Science in Context* 11, no. 3–4 (1998): 545–65. Suzuki shows that Tanaka made a recommendation for eugenics based on Mendelism and his silkworm studies in "Ningen honshitsu no kaizen ga kyūmu" ["An Urgent Necessity for Improvement of Human Nature"], *Ikai Oyobi Ningen* [Medicine and Human] 2, no. 3 (1924): 33.

taken as synonyms for inferior or misguided science; examining the activities within a country elucidates historically specific social conditions, and reasons for why scientists, while far from homogeneous, select particular research problems, whether pragmatic, theoretical, or other.[33] Indeed, Japanese sericulturists were able to combine particular kinds of information about phenotypes such as color, cocoon size, and silk-thread type to invent new silkworms and silk through breeding, but by the Taishō period, this work, in combination with existing knowledge about the social and cultural aspects of the organism, would proceed with the use of a language that reflected a hardening view of race. For Toyama, the silkworm was as much an object of study for the sake of its improvement as it was a way to elucidate the mechanics of Mendelian inheritance. Tanaka's experience was differently motivated, for he tried to avoid improvement-based projects and rendered silkworms into a toolkit to generate and answer genetic problems.[34] With the silkworm industry developed in step with the project of nationhood, many questions must be aired about the formation of an international discipline of genetics at the time. For the scientists, this organism, redefined by terms of the time, was the entry ticket to an international community of biologists – one that largely did not use the silkworm.

The practices of *tōitsu* in the realm of the silkworm were not just practical. They also related very much to creation of a national community, resting on beliefs about the permanence of the nation and ideologies.[35] This dissertation offers a

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[33] Jonathan Harwood, *Styles of Scientific Thought. The German Genetics Community 1900–1933* (Chicago: University of Chicago Press, 1993).

[34] Rader, *Making Mice*. Scientists developed various uses for standard inbred mice before they could be exploited as envisioned for the science of mammalian genetics. The usefulness of standardized mice was determined only later through processes of consensus among scientists; the development of Tanaka's toolkit, discussed in Chapter Five, bears some similarities, although its justification for industrial purposes was far more pronounced.

[35] Susan L. Burns, *Before the Nation: Kokugaku and the Imagining of Community in Early Modern Japan* (Durham, NC: Duke University Press, 2003), p. 102. This involved ideas about "the unity of the Japanese people despite their diversity," in addition to the combined divinity and morality of an emperor transcendent of yet implicated with politics, and the discrimination of women.

historical example involving a nonhuman that suggests that the development of an ideological language in the Meiji manifested not only in human relationships but also in settings where expressions of nationhood are not usually uttered in obvious ways. Taking further Gluck's observation that ideological "speech" that shaped the nation in the late nineteenth century also included social symbols, this project decenters the usual stories of the formation of nationhood by bringing that which has often been on the literal sidelines, sericulture, and relatedly, silk sciences, to the fore.[36] Some scholars suggest that the constitution of the Japanese language in the premodern period made it possible for the modern nation-state to formulate in Japan and reflect its characteristic cultural and racial essentialism during the time of colonialism.[37] In her examination of the "prehistory" of Japanese "nationnness," Susan Burns shows that the cultural difference in which Japan was posited as an antithesis to China, for instance, marked the ways in which a notion of a community and "body" of Japan was perpetuated in terms of language.[38] A new sense of national simultaneity, "a sharing of time among people who could not possibly have had face-to-face contact," came to the fore later in Meiji, according to Takashi Fujitani in his interrogation of Japanese imperial pageantry.[39] Both national ceremonies and the coordination of silkworms for the heightening production of a national export product seem to reflect what Burns has

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[36] Gluck, *Japan's Modern Myths*, pp. 262–267

[37] Kazuki Sato, "'Same language, same race': The Dilemma of *Kanbun* in Modern Japan," in *The Construction of Racial Identities in China and Japan: Historical and Contemporary Perspectives,* ed. Frank Dikötter, 118–135 (Honolulu: University of Hawai'i Press, 1997). *Kanbun*, or Chinese classics and classical writing, faced odds in Meiji Japan. While students studied *kanbun,* the foundation of Tokugawan education, through World War II, the significance of *dōbun, dōshu,* or "same language, same race," underwent a gradual reconfiguration during Meiji as scholars and various interest groups critiqued the commonalities between Japan and China. Sato explains that Japan's "traumatic experience in relating with Westerners" in the Meiji had increasingly made the Japanese view themselves independently from the Chinese, considered increasingly at that time a vestige of an uncivilized past.

[38] Burns, *Before the Nation,* pp. 4, 9, 12, 220–222. Burns shows that Tokugawa *kokugaku* scholars placed new values on the meaning of language of the *Kojiki* text as something written to preserve *Yamato kotoba*, the original language of Japan, or that ancient texts signified the formation of a Japanese community in the deep past, with which Confucianism from China, Buddhism from India, and knowledge from "the West" did not compete.

[39] Ibid., p. 28.

outlined as a formation of cultural difference. The national production scheme of silkworms was one that strove to demonstrate its ability to Europeans and Americans, but the Japanese silk industry transformed itself in the first quarter of the twentieth century in a way that embraced or enforced a loyalty to what Burns may call the "depth and majesty" of a so-called tradition of Japanese sericulture.[40]

The present work has centered on silkworms as articulated by governmental institutions and nationalizing local elites, including officials, politicians, businessmen, and landowners, among the kind of actors raised by Fujitani. I would add silkworm scientists, along with their networks of experiment stations that made the participation of ordinary people in this unificatory movement possible.[41] Given that this dissertation has focused on the relationships among the three strands of sericulture, science, and nation, it is helpful to consider some of the vigorous recent research on the discursive significance of science in the history of modern Japan. Analyses such as Hiromi Mizuno's work on "scientific nationalism" focus on engineering and suggest, for instance, that science lost its connotation as a "Western" thing by the 1920s and came to be "universalized" in Japan.[42] Meiji ideals such as *shokusan kōgyō* (production promotion) emphasized industrial development as the means to actualizing a "rich nation, strong army" (*fukoku kyōhei*). This policy was intended to

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[40] Ibid., p. 100.

[41] Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton: Princeton University Press, 1999). The formation of Indian civil society offers an illustrative comparative example, as Prakash explains; it had depended on the articulation of classical scientific texts and traditions as the nation's heritage, making it possible for nationalists to define the previously colonial territory and its people on the grounds of rationality and progress.

[42] Hiromi Mizuno, *Science for the Empire: Scientific Nationalism in Modern Japan* (Palo Alto: Stanford University Press, 2009), pp. ix–x, 11; Aaron S. Moore, *Constructing East Asia: Technology, Ideology, and Empire in Japan's Wartime Era, 1931–1945* (in progress); Aaron S. Moore, "Para-Existential Forces of Invention: Nakai Masakazu's Theory of Technology and Critique of Capitalism," *Positions* 17, no. 1 (2009): 127–157. Aaron Moore defamiliarizes assumptions about the formation of the notion of the term "technology" (*gijutsu*) during wartime by examining how technocrats and engineers directed energies toward the formation of a utopian "New Order in East Asia." Mizuno and Moore define "wartime" differently, with the former beginning in 1937 and the latter in 1931.

allow Japan to overtake the technical capacity of the "West" through the indigenization of Western technologies.[43]

The growing awareness of Japanese nationhood during Meiji seemed to accompany increasing tensions between the industrial and academic facets of silkworm science and silkworm genetics. Examination of developments such as Toyama's use of the silkworm in his seminal research illustrating principles of inheritance, however, makes one wonder why and how silkworm scientists later took part in discussions about the human condition while performing research that had nothing to do with human biology per se. Nor can human eugenics be the end point of this study. The ready acceptance that life scientists in the early twentieth century were eugenically inclined may color some of our understandings of the time, but this assumption is a slippery one to make without engaging with silkworm materiality first.[44] The changing practices of sericulture, as they shifted from rural localities to something serving the new nation, will eventually answer the question of *why* the silkworm may have, if at all, instigated any vein of ideological eugenic thinking in East Asia.

Growing scholarship in the history of biology and agriculture in Japan has brought greater attention to the intersections of animal and plant breeding and the

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[43] Richard J. Samuels, "*Rich Nation, Strong Army": National Security and the Technological Transformation of Japan* (Ithaca: Cornell University Press, 1996); George C. Allen, *A Short Economic History of Modern Japan* (New York: St. Martin's Press, 1981); Ishii Kanji, *Nihon no sangyō kakumei: Nisshin Nichi-Ro Sensō kara kangaeru* [Japan's Industrial Revolution: Thinking from the Sino–Japanese to Russo–Japanese Wars] (Tōkyō: Asahi Shinbunsha, 1997). The establishment of the Ministry of Engineering in 1870 marked the "inauguration" of *shokusan kōgyō*, a policy of industry protection, the provision of subsidies, leasing and transferring of new machinery, and establishing and transferring ownership of state-owned model factories. By 1913, textile exports, including cotton, led the Japanese economy (Samuels, "*Rich Nation, Strong Army,*" pp. 36–39).

[44] East and Jones, *Inbreeding and Outbreeding;* Punnett, *Mendelism*; Ruggles Gates, *Mutation Factor in Evolution*; Davenport, *Inheritance in Poultry;* Davenport, *Heredity in Relation to Eugenics*; Kellogg, *Mind and Heredity*, and others worked on plants and animals and actively discussed race and eugenics in humans. East and Jones flank their review of heredity research with discussions on race and eugenics.

formation of biological research in relation to Imperial Japan.[45] These suggest a much-anticipated ongoing maturation of Japanese history of biology, in which attention to the historical relationships between material culture and the formation of experiment-based scientific knowledge makes the relationship among science, nationhood, and identity formation even more palpable. For the history of these matters of silk, it is the reappropriation of the past that not only makes its related science national but also enables some of the silkworm scientists to interact with scientists and breeders in other national contexts.

4. Genetic Futures, Silk Futures

Commercial competition fueled continued efforts to develop silkworms that would yield larger quantities of silk, motivating the search for better parental silkworm candidates. As the number of households that conducted sericulture in the years following 1911 grew from just over 1.5 million to over 2 million by the early 1930s, so did the scale of experimental breeding as seen in the Katakura Company. Although the Meiji-period *tōitsu* problem, stoked by the number of new sericulturists producing their own silkworm eggs, resulted in curbed egg production and distribution, the expert entities permitted to breed silkworms continued to develop new parental silkworm breeds, which ballooned to 1,057 by 1921.[46] Although reputedly decreasing

[45] Fujihara Tatsushi, "*Ine mo mata Yamato minzoku nari – Suitōhinshu no Kyōeiken*" [Rice Becomes the Yamato Minzoku Again: The Co-Prosperity Sphere of Wetland Rice Brands], in *Daitōa kyōeiken no bunka kensetsu,* edited by Ikeda Hiroshi, 189–240 (Kyōto: Jinbun Shoin, 2007); Matsubara Yoko, "The Reception of Mendelism in Japan, 1900–1920," *Historia Scientiarum*, 13 (2004): 232–239; Kaori Iida, "Practice and Politics in Japanese Science: Hitoshi Kihara and the Formation of a Genetics Discipline," *Journal of the History of Biology* 43, no. 3 (June 2009): 529–570; 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, no. 2 (2010): 215–264; Moriwaki Yasuko, "Toyama Kametaro to Meijiki no Sanshigyō ni okeru Kaiko no 'Shurui Kairyō,'" *Kagaku shi Kenkyū* 49, no. 255 (2010): 163–173.

[46] Araki, *Nihon sanshigyō hattatsu to sono kiban*, pp. 212–213. The annual number of bales of raw silk produced yearly hovered around 700,000 throughout the 1930s, having increased steadily from 227,810 bales in 1912. The number of hectares of land used for mulberry cultivation had nearly doubled, from 449,800 in 1912 to 707,500 at its peak in 1930.

to 390 in 1926, the number of parent silkworm varieties leaped again, to 855, by 1930, contributing to the instability of raw-silk quality received by American importers.[47] Such production figures indicate volatility in the management of silkworms that characterized the Taishō and early Showa (1926-1989) periods, even though the overall production of raw silk continued to grow, peaking in 1930 at 730,176 bales.[48] Indeed, silk was once imperial Japan's dynamo, generating around $300 million in annual export revenue in the 1920s.[49]

As the Katakura case showed, hybridization remained very much an important technique for the breeding of silkworms in industrial settings. This was the case even as the maturation of genetic research opened up the field of mutation biology, discussed in Chapter Five. The mutant silkworm stocks that Tanaka had begun to cultivate in the 1910s today number around 428, and are part of the National Bioresource Project of Japan, maintained at Kyushu University as the Silkworm Genetic Resource Database.[50] Relatedly, the nationally registered commercial silkworm varieties, including a variety developed by Toyama, continue to be curated in a governmental biobank in a valley in Yamanashi Prefecture, where a crisp breeze ensures the best climatic condition in all Japan for rearing. In both cases, the silkworms are hatched and reared every year, and carefully maintained to keep stocks healthy for the future. The simultaneous but separate production of mutants and commercial breeds has helped create space and opportunities for the development of genetic research in Japan such that the silkworm could emerge eventually as a

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[47] Tazima Yatarō. *Kaiko no Hinshu Ikusei* (Tokyo: Science House, 1993), pp. 41–42.

[48] Where one bale is 60 kilograms. Araki, *Nihon sanshigyō hattatsu to sono kiban*, pp. 212–213.

[49] Even though the GHQ had permitted a reformed silk industry to recuperate during the U.S. occupation, the reduction of mulberry acreage converted to food production during wartime made it unlikely that Japan would ever regain the scale of production it experienced in the 1920s and early 1930s. General Headquarters Supreme Commander for the Allied Powers, 1947 [NA].

[50] See http://kaiko.kyushu-u.ac.jp/ and http://www.nbrp.jp/report/reportProject.jsp?project=silkworm.

twenty-first-century research organism, even as the silk industry it once supported fades into the fabric of Japan's history.

The obverse of this *is,* in fact, the fabric. In the textile district of Kyoto, Nishijin, silk-trading businesses specialize in the distribution of raw silk to those who process, dye, and weave the fibers into kimono fabric, obi belts, and other textiles. At one trading company, I took a closer look at the labels stamped on many of the cardboard boxes containing the raw-silk skeins. Their sides were inked with stamps denoting their countries of origin: Brazil and China. Not so "made in Japan."[51]

The labor required to convert these particular silk skeins into the national costume would appear to reside in Japan, as suggested by their arrival in Nishijin, but in the twenty-first century, few are interested in apprenticing with the last several remaining master kimono makers who can singlehandedly create a kimono from start to finish. The country's silk industry has, on top of seeing a reversal in import and export patterns, also seen Japanese businesses increasingly turn to garment factories in China and North Korea, and to weavers in Laos, to create kimono. To illustrate, in 2008 Japan imported 933,840 kilograms of raw silk but produced only 105,720 kilograms.[52]

These efforts to raise the local profile of Japanese silk continue as nationwide and worldwide consumption of raw silk declines. Gone are the days of the 1910s, when annual silk-production volume routinely exceeded ten million kilograms.[53] The Japan Silk Center today struggles to protect the notion of "Japanese silk." The

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[51] Observation made by author in December 2008 upon a visit to a distribution company in Nishijin. Photographs were forbidden.

[52] Nōrinsuisanshō, *Nōrinsuisan Tōkei: Heisei 21nen han* (2009) [Agriculture, Forestry and Fisheries Production Statistics, 2009 edition] (Tokyo: Nōrinsuisanshō, 2010), p. 300. Where one bushel of raw silk weighs 60 kilograms.

[53] Japan Department of Agriculture and Commerce, *Annual Report of Raw Silk, Floss Silk and Silkworm Eggs* (Tokyo: Japan Department of Agriculture and Commerce, 1912). For instance, 13,730,688 kilograms in 1912 (3,661,617 *kan,* where 1 *kan* = 3.75 kilograms). Of this raw silk, a quarter was directed to domestic consumption, and the remaining 75 percent was bound for overseas trade.

relationships between silkworm and humans are fluid, and considered alongside contexts of international pressures and state interests, analyses of sericulture help clarify how and why the discursive and material circumstances and anxieties concerning Japanese silk seem to have continued from the Meiji into the postwar period. The immediate prewar and postwar history of sericulture and silkworm genetics, however, remains beyond the scope of this dissertation. Yet, it is useful to mention that to many within the Japanese silk industry, it is now the kimono rather than raw silk that stands as the representative national product dictating the imaginary continuity and future of Japan's existence. From silk stockings and ribbons to curtains and parachutes, the American appetite for machine-processed silk goods seemed to have no end in the 1910s and 1920s. The situation changed irrevocably after the stock market crash of 1929, the U.S. condemnation of Japan's so-called Manchuria Incident of 1931, and the commercialization of rayon and nylon.[54]

The paramount emphasis on economic efficiency, especially in sericulture, and the rise of Showa-era militarism was unmistakable during the 1930s. By 1939, peasant farmers could only rear those silkworms designated by the state. Concerns about international status and repute had tethered the development of the silk industry of Japan to ideas of national identity since the mid-nineteenth century. These developments require further study. These latest changes in autonomy associated with rearing silkworms in the name of the state especially over the decade and half leading to Japan's involvement in the Pacific War, if anything, make clear how the processes of rendering silkworms legible for science and sericulture helped transform a craft practice into one that catered to a much larger project of national mobilization.

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[54] J. M. Atkins, "Wearing Propaganda: Textiles on the Home Front in Japan, Great Britain, and America during the Greater East Asian War, 1931–45," *Textile: The Journal of Cloth and Culture* 2, no. 1 (2004): 24–45. This dissertation has focused on silk for export, but it is worth mentioning that silk also provided a textile canvas for national expression.

Silk production in Japan today is minimal and no longer caters to large factories. Contemporary efforts to boost the sale of Japanese silk appeal more to domestic than to foreign consumers of silk. Within the world of silk, the theme of Meiji survival for a place in the world seems to repeat, only now in a new context and time marked by the economic bubble of the 1990s, an aging population, depopulation of rural communities, global trade, high costs of labor, and the implications of land redistribution after World War II.[55] A number of developments since the last century highlight new metamorphoses in which, in place of textiles, scientists in countries such as Japan and the United States now investigate the use of silk in biomedical and materials sciences, ranging in application from the development of artificial veins to the formation of ultrathin computer chips. The importance of silkworm varieties in these new technological renditions also leads one to wonder how biological repositories from a previous era may continue to function, perhaps more so in the sense of the Svalbard Global Seed Bank.[56] Researchers have also been investigating the uses of other species of wild silkworms in pursuit of new materials that can be produced in industrial settings or in countries where *Bombyx mori* cannot thrive.[57] What seem to be differently motivated kinds of research turn out, in fact, to be part and parcel of the same history of silkworm science in Japan.

This dissertation has focused more on the history of sericulture and silkworms and particularly suggests that scholarly genetics depended on a balance between a reappropriation of Japanese sericultural heritage *and* acting upon the need to participate in an international, intellectual conversation to maintain world relevancy as

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[55] Tamara K. Hareven, *The Silk Weavers of Kyoto: Family and Work in a Changing Traditional Industry* (Berkeley: University of California Press, 2002); John W. Dower, *Embracing Defeat: Japan in the Wake of World War II* (New York: W. W. Norton & Company, 2000).
[56] Elisabeth Rosenthal, "Near Arctic, Seed Vault Is a Fort Knox of Food," *New York Times*, February 29, 2008, International / Europe sec., http://www.nytimes.com/2008/02/29/world/europe/29seeds.html.
[57] Tom Gheysens et al., "Demineralization Enables Reeling of Wild Silkmoth Cocoons," *Biomacromolecules* 12, no. 6 (June 13, 2011): 2257–2266.

an independent nation. In concluding, I take the liberty of mentioning the kimono to show how identity issues that stemmed from the matter of the ownership of biological objects since early-twentieth-century Japan seem to curiously persist despite the shifting grounds of silkworm science. Kawamura Yasuto, the president of a five-generation kimono house, explained to the *Washington Post* in 2006: "The kimono is not just about our country. It is about the Japanese race – our daily rituals, our history, our religion, about who we are as a people."[58]

These words may seem to echo some of the rhetorical maneuvers used in the instantiations of the late Meiji to reframe the definition of a new Japan. In Kawamura's instance, the protection and survival of the garment necessitated its overseas production in Laos. Yet, requirements to use Japanese materials, labor, and assembly have kept the 2008 *Nihon no Kinu* standard at bay from the very people who try to hold on to the market so dearly. While it may appear that these discussions about maintaining Japanese identity are parsed today in terms of woven products, many of the strands of sericulture, science, and nation that gained definition during the Meiji and Taishō periods persist. The metaphorical fabric of the past composed of these strands has hardly disappeared. Rather than having disintegrated with time, these threads have managed to unravel and are now being rewoven into complicated new fabrics for another new Japan.

58 Anthony Faiola, "Twilight for the Kimono," *Washington Post*, 13 Dec. 2006; Phonsavanh Vongsay, "Lao Artisans Lend Skills to Kimono Production," *Vientiane Times*, 4 Nov. 2010, appearing on Asia News Network. http://www.asianewsnet.net/home/news.php?sec=2&id=15287.

ERAS

Time Periods Mentioned

Bunka	1804–1818
Bunsei	1818–1830
Tenpō	1830–1844
Tokugawa (Edo)	1603–1868
Meiji	1868–1912
Taishō	1912–1926
Shōwa	1926–1989

GLOSSARY

bakufu	tent government, shogunate	幕府
buraku	shorthand for *burakumin*, descendants of Japan's feudal outcast group	部落
darōgaku	"probably-ology" (a word made up by Toyama)	だろう学
flacherie	a silkworm disease caused by a virus	
fukoku kyōhei	Meiji policy of increasing wealth and strengthening military	富国強兵
genshu	pure breed; stock; strain; a foundation seed or stock; parent stock	原種
gen genshu	parent stock(s) of parent stock; grandparental stock	原原種
gi-san	newly hatched silkworms; "ant silkworms"	蟻蚕
gomoku sushi	sushi with several ingredients mixed in	五目寿司
hai kara	high collar	ハイカラ
hakitate	the hatching of silkworms and act of brushing them off of the egg sheet (*sanshi*) onto a litter of mulberry leaves	掃き立て
henyi	variation, change	変異
hinyi	standard, quality, a grade, fineness [the word also refers to dignity, grace]	品位
hinshu	commercial breed and brand	品種

hinshu tōitsu	unification of commercial breed and brand	品種統一
hon	origin, real	本
hongen	origin; root; cause; principle	本源
honsei	real (true) character, real nature	本性
hyōjun	standard	標準
ichidai kōzatsushu	first-filial hybrid cross	一代交雑種
iden	heredity	遺伝
idengaku	the study of heredity; genetics	遺伝学
iden suru	to pass down	遺伝する
ito	string, thread.	糸
ittei	to decide to make identical (something); something that has been decided to be at a certain level; to calm down or settle into a certain situation	一定
jinyi	artificial (human work)	人為
jitsugyō	business	実業
jōmin	(common) people, non-elite peasants	常民
jun	pure	純
kairyō	improvement	改良
kaiko	Silkworm, usually referring to the domesticated silkworm	蚕
kakeawase	a cross, to cross-breed	掛け合わせ
kasuri	Japanese term for a lightly speckled larval marking also	飛白

	known as "quail"	
kazoku-kokka	family state	家族国家
kego	same as gi-san; newly hatched silkworm	
kīto	raw silk	生糸
kīto sanshu shi kaiin	raw silk silkworm egg sheet	
ko	child	子
kokka keizai	national economy	国家経済
kokoro	heart and spirit	心
kokusan	nationally produced	国産
kokugaku	study of our country (Japan)	国学
kuwako	Wild silkworm moth species *Bombyx mandarina*; closest relative to the domesticated silkworm, *Bombyx mori*.	桑子
mabushi	a multi-frame structure made of paperboard or wood that silkworms spin cocoons in, one to a frame.	蔟
mondai	problem	問題
natsugo	summer silkworms	夏蚕
pébrine	pandemic silkworm disease caused by the protozoa *Nosema bombycis*	
rui	kind	類
Sangyō	sericulture	蚕業
sangyō	industry	産業
sangyōka	sericulturist	蚕業家
taneshi	seed producers	種師

Sangyō kōshūshojo	Sericultural Training Institute	蚕業講習所
Sangyō shikenjō	Sericultural Experiment Station	蚕業試験場
sanshigyō	silk fiber industry, which is inclusive of sericulture	蚕糸業
sanshu	silkworm variety, silkworm seed	蚕種
sanshukai	silkworm seed world	蚕種界
sanshigyō	work and business dealing with all aspects of silk cocoons, raw silk, and/or silk waste products	蚕糸業
Sanshu Torishime Kisoku	Silkworm Egg Control Ordinance	蚕種取締規則
santane	silkworm seed, silkworm egg	蚕種
seisan rireki	production history	生産履歴
seishigyō	silk reeling and filature industry	製糸業
senzōgaeri	return to the state of their ancestors	先祖帰り
shizen no ri	principle of nature	自然の理
shokusan kōgyō	national policy of encouraging industry during Meiji era	殖産興業
shu	type, species	種
shurui	a kind, variety	種類
sonzai	existence	存在
soseiranzou	mass production of inferior goods	粗製濫造
taika	degeneration	退化
tane	seed	種
tōitsu	unification, to unify	統一

torishimari	tightened control	取締
yaki sute	burn and dispose	焼棄
yamashi	speculator	山師
yōsan	sericulture, silkworm culture	養蚕
yōsangyō	sericulture business	養蚕業
yūretsu	superiority or inferiority, or merits and demerits	優劣
zairaishu	land race; conventional (endemic) breed	在来種
Dai nihon ichidai kōzatsushu fukyū dan	Great Japan First Filial Hybrid Diffusion Group	大日本一代交雑普及団

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