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# Chapter 21

# Genetics and "Breeding as a Science": Kihara Hitoshi and the Development of Genetics in Japan in the First Half of the Twentieth Century

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**Abstract**
Through the career of Kihara Hitoshi, a prominent plant geneticist in Japan, I will show that genetics in Japan developed by maintaining a close connection with agriculture throughout the first half of the twentieth century. To exploit the socioeconomic context that valued applied science, Kihara gradually made the practical aspect of his projects more explicit and consequently created projects that were both basic and applied science. These projects not only allowed his group to expand successfully during wartime but also influenced the group's scientific approach. To gain full understanding of an organism, investigators took a multidisciplinary approach beyond genetics, an approach similar to what the Russian geneticist Nikolai Vavilov described in advocating "breeding as a science." Genetics, being placed within "breeding as a science," was also affected, and Kihara began advocating physiological genetics, along the lines advanced by German geneticist Richard Goldschmidt. The story of Kihara's career reveals how the national emphasis on agriculture had a significant impact on the disciplinary growth of genetics in Japan as well as on Japanese biologists' approach to organisms and genes.

**Keywords:** Richard Goldschmidt; Japanese genetics; Hitoshi Kihara; physiological genetics; plant genetics; Nikolai Vavilov.

## Introduction[1]

Japanese genetics as a discipline developed rapidly in the early twentieth century after Japanese breeders and biologists learned of Mendelian principles. As Matsubara Yoko has pointed out in 2000, Mendelism was quickly disseminated and began to be examined in the agricultural context of Japan, especially under the urgent need to develop agricultural industry for the expanding nation.[2] However, there are no detailed studies about how Japanese genetics subsequently developed in relation to breeding studies. In this chapter, I show that the development of genetics

[1] The Japanese convention of placing surname first, followed by the given name, has been adopted for all Japanese names in the main text. The reference list at the end uses English-language order for all Japanese names.

[2] Matsubara, "Menderu idengaku no juyō." English version: Matsubara, "The reception of Mendelism in Japan, 1900-1920."


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in Japan was deeply embedded in the agricultural context, and academic (university) geneticists did not clearly demarcate their area of study from breeding studies for a long time until around 1950; this close connection reflected a socioeconomic context that valued practical science.

Barbara Kimmelman's study of the early history of genetics in the United States has argued that genetics arose in agricultural institutions; her analysis is suggestive for the interpretation of Japanese genetics.[3] According to her, American breeders became interested in Mendel's results very early, believing that they might have relevance to hybridization work. By 1915, researchers working at agricultural institutions transformed into geneticists and created the foundation for a new discipline of genetics. During the early period, genetics had earned a place "as both an applied and a basic science," adapting to the aim of those institutions.[4]

Similarly in Japan genetics developed in the agricultural context and was promoted as both basic and applied science. Genetics as a discipline was shaped by its agricultural setting at least until the early 1950s. The Genetics Society of Japan emerged in 1920 through the reformation of the Breeding Society of Japan (*nihon ikushu gakkai*, established in 1915). It was 30 years later when a new Japanese Society of Breeding (with the same Japanese name, *nihon ikushu gakkai*) again branched off from the Genetics Society. Though this divergence in 1951 by no means signifies the end of the agricultural association with genetics, the event marks the emergence of newer genetic research that no longer had agricultural relevance. In turn, it also implies that such divergence was felt unnecessary until around 1950.

In the academic environment in the first half of the twentieth century, Japanese geneticists often chose agricultural organisms as their research materials under strong pressure to conduct applied science, and in turn capitalized on practical implications of genetics to attract public support. This appeal to practical applications was not just rhetorical and researchers often contributed directly to breeding studies. As a result geneticists were able to increase the importance of their discipline in relation to agriculture. At the same time geneticists working at universities had the desire to conduct fundamental work as academic scientists (they conceptually distinguished between "basic" and "applied" science). Consequently they created scientific research that could flexibly be considered as "applied" or "basic." I discuss how this type of research was influential in shaping Japanese approaches and concepts in genetics, in particular their preference for physiological genetics and for a multidisciplinary approach to understanding the whole organism.

I will discuss this early history of genetics in Japan as seen through the career of Kihara Hitoshi (1893-1986), a plant cytogeneticist who was a leader in the development of the discipline of genetics in Japan.[5] A graduate of Hokkaido Imperial University, where he first became interested in wheat genetics, Kihara went to Germany in 1925 and studied under Carl Correns. He returned to Japan in 1927 as Professor at the Faculty of Agriculture of Kyoto Imperial University, where he headed up a Laboratory of Experimental Genetics that became famous as Japan's "Mecca" of genetics. In 1942 he established the Kihara Institute for Biological Research in Kyoto, where a wide variety of problems in genetics, physiology, and cytology were studied in many species of plants (mostly crops). He also held important positions including president of the Genetics Society

[3] Kimmelman, "A Progressive Era discipline"; Paul & Kimmelman, "Mendel in America"; Kimmelman, "Mr. Blakeslee builds his dream house."

[4] Kimmelman, "Mr. Blakeslee builds his dream house," 273. Also Paul & Kimmelman, "Mendel in America," esp. p. 285.

[5] Crow, "Hitoshi Kihara"; Iida, "Practice and politics in Japanese science."


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of Japan (1944, 1949-1952) and director of the National Institute of Genetics in Japan (1955-1969), and perhaps it is fair to say that he was internationally the best-known Japanese geneticist in his generation.[6] Thus Kihara is an exceptionally good lens through which to view the early history of Japanese genetics. Mainly through his career, I will analyze how genetics in Japan developed and how their approach to genetic studies was shaped, with particular attention to agriculture and the wartime context of Japan in the first half of the twentieth century.

In the following I will first illustrate how some of the important institutions for the discipline of genetics emerged and developed in close connection with agriculture. Kihara's own laboratory in Kyoto, the first government-funded genetics lab in Japan, was established under a new department where biological research was to be conducted to solve agricultural problems. Since the 1930s, at Kihara's laboratory and at the Institute for Biological Research, the practical significance of his group's work was made explicit, and consequently Kihara was able to expand their projects. There they created a type of research in which there was no boundary between basic and applied work. I argue that as geneticists were committed to work with applied goals, it inevitably led the researchers to take a multidisciplinary approach beyond genetics to understand the full range of biological processes of the organism. The approach was very similar to what the Russian geneticist Nikolai Vavilov had proposed, "breeding as a science." Kihara was very interested in and influenced by Vavilov's work; the Japanese approach to genetic studies was similarly placed within the larger project of "breeding as a science." Japanese geneticists were generally also interested in the approach of German geneticist Richard Goldschmidt, who argued that the future of genetics lay in "physiological genetics" or the pursuit of genetics alongside the study of the physiology and development of organisms. I will end with a brief discussion of how such a holistic approach to organisms remained at the newly established National Institute of Genetics in the 1950s.

## Rise of Genetics in the Agricultural Context

Mendelism was introduced into Japan soon after the rediscovery of Mendel's work in 1900, and began to be examined at agricultural institutions. The earliest record to associate the Japanese with Mendelism is known to be in 1901, when Hoshino Yūzō, an agronomist at the Sapporo Agricultural College in Hokkaido, mentioned in his paper on corn the rediscovery papers by Hugo de Vries and Carl Correns. In the following year Hoshino introduced Mendelian laws, based on Correns's paper, to readers of a Japanese agricultural journal.[7] More publications on Mendelism subsequently appeared, including two well-known writings in 1906. One was a section in a book, *Phylogeny of Plants* (*Shokubutsu keitō gaku*), written by Ikeno Seiichirō, who was associate professor at the Agricultural College of Tokyo Imperial University. It is said that this book introduced Mendelian concepts widely in Japan. The other was an article of Toyama Kametarō who was also associate professor at the same College. (See the chapter by Lisa Onaga for discussion of Toyama's career and legacy). This reported new Mendelian data from his silkworm

[6] According to the American geneticist James Crow, the best-known Japanese geneticists in the 1950s were Kihara and a younger geneticist Kikkawa Hideo (personal communication 29 July 2009).

[7] Y. Moriwaki, "Hoshino Yūzo no kisenia kenkyū to 1902-nen no menderizumu shōkai" [Xenia study by Hoshino Yūzo and his introduction of Mendelism in 1902], presented on 26 May 2012 at the 59th annual meeting of the History of Science Society of Japan, Tsu, Mie, Japan; Noguchi, "Nōgyō ni okeru idengaku", 244. Hoshino's 1902 paper: Hoshino, "Kanseishi ni okeru ryōsei no bunkai ni tsuite."


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study conducted in Siam and was one of the first Mendelian results shown in animals in the international scientific community.[8] At experimental stations, too, breeders soon began examining Mendelism. In 1904, researchers at one of the experiment stations initiated large-scale breeding studies of crops, including Mendelian studies of various characters in rice, and created a new rice hybrid by 1909.[9]

This early interest in Mendelism (as part of broader studies of inheritance) by both scholars and practitioners was partly due to the long practice of breeding that had existed since the pre-Meiji era and to the pressing need for the Meiji government to develop agricultural industry. Around 1900 when Mendelism was rediscovered, for example, Japan was under pressure to improve the quality of silk. Silk, which had been an important industry for a long time, was considered to be a particularly important export product to obtain foreign currency because by rearing silkworms there was no need to import raw materials (such as in the case of cotton). Toyama examined various characters of silkworms in his crossing experiments and reported both Mendelian and non-Mendelian patterns of inheritance in his paper of 1906. Soon he began promoting the use of hybrids (from a cross between two different pure strains) in the Japanese silk industry, which drastically changed the silkworm business.[10]

Agriculture had additional importance for the nation's imperial expansion. In 1895, as a result of the Sino-Japanese War (1894-1895) Taiwan was ceded to Japan from China. After the victory in the Russo-Japanese War (1904-1905), Japan in 1905 declared Korea to be its protectorate and officially annexed it in 1910. As the Japanese Empire expanded, the Japanese government also established experimental stations in colonies (Taiwan, Korea, Sakhalin, and Manchuria). To train people who would manage agricultural projects in the expanding nation, imperial universities gained importance. Japan's first department related to colonization strategy (the Department of the Study of Colonization and Agricultural Administration) was established in the former Sapporo Agricultural College in 1907, when this college was integrated into one of the imperial universities (Tohoku Imperial University).[11] In fact, many graduates of this college led breeding projects in the colonies (especially in Taiwan and Manchuria).[12]

The relevance of agricultural studies to Mendelism led this college in Hokkaido to become one of the centers of genetic studies in Japan. Following the first known reference to Mendelism by Hoshino, the first known cases in Japan of a journal club to read genetics journals and of a course specialized in genetics also occurred in this college in the early 1910s.[13] Kihara's association with this college was enormously important for his career. During his college years (1915-1918), he majored in plant physiology but was also exposed to genetics. In his graduation year, he encountered his lifelong research material, wheat, because this college had a good

[8] Matsubara, "Menderu idengaku no juyō." On Toyama, see Onaga, "Toyama Kametaro and Vernon Kellogg"; See also her chapter 20 in this volume.

[9] Fujihara, *Ine no daitōa kyōeiken: Teikoku nihon no "Midori no kakumei,"* 74-75.

[10] Toyama, "Studies on the hybridology of insects"; Moriwaki, "Toyama Kametarō to meijiki no sanshigyō ni okeru kaiko no 'shurui kairyō'"; Matsubara, "Menderu idengaku no juyō."

[11] The college became independent again as Hokkaido Imperial University in 1918. About the department, Inoue, "Sapporo nōgakko to shokumingaku no tanjō."

[12] Tanaka & Imai, "Shokuminchi keiei to nōgyō gijutsu," 108-111. Yamamoto, "Taiwan ni watatta hokudai nōgakubu sotsugyōsei tachi." For case studies of such breeders, see Fujihara, *Ine no daitōa kyōeiken*.

[13] See for example, Tanaka, "Nihon idengaku no yoake (1)."


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collection of wheat varieties. Moreover, being a graduate of the college, he would later expand his projects over the large map of the Empire using the college network.

By the time of Kihara's graduation in 1918, two institutions that were critical for the development of the discipline of genetics in Japan were established. One was a new society related to genetic studies. In 1915 seven scholars (including Toyama), all working at agricultural institutions, founded the Breeding Society of Japan, the forerunner of the Genetics Society of Japan. At the founding meeting of the Breeding Society held in Tokyo, scholars gave ten lectures on the heredity or breeding of organisms familiar to the Japanese people: morning glories, *medaka* (small fish common in rice paddies), white snake (considered as good luck), rice, wheat, chestnuts, *shiso* (perilla, used as herb), bellflower, and garden peas. In the following year the Society published a journal, which discussed similar subjects.[14] The journal published only two issues, in 1916 and in 1918, and with Toyama's death in 1918 and the move of another central member to Taiwan the society became less active. By this time, however, about 200 people (many from agricultural experiment stations) were registered as members of the Society. This membership then became the basis for the Genetics Society of Japan.

The Breeding Society was reformed into the Genetics Society of Japan in 1920. While the main office was placed in the headquarters of the agricultural experimental station in Tokyo, the new Society was not just about breeding studies. One of the reasons for the reformation of the Society was, according to the silkworm geneticist Tanaka Yoshimaro (1884-1972), to accommodate recent discoveries in genetics beyond agricultural breeding studies, particularly the fruit fly genetics led by Thomas Hunt Morgan (1866-1945) in the U.S. (Using silkworm, Tanaka had been conducting genetic analysis similar to the studies done in fly.[15]) In the reformation, scholars from non-agricultural institutions also joined as board members. One was Fujii Kenjirō (1866-1952), a German-trained plant cytologist, who established the first genetics laboratory in Japan in 1918.[16]

The development of genetics and breeding studies was facilitated by and in turn further encouraged the development of cytology in Japan. Since 1905, in the laboratory of "morphological studies" at the Department of Botany of Tokyo Imperial University, Fujii had been training students in cytology. For example, the cytologist and a former student of Fujii, Tahara Masato (1884-1969), published in 1915 one of the earliest reports of polyploidy (i.e., having more than the normal two sets of chromosomes). He identified the chromosome numbers in different varieties of the chrysanthemum family and discovered that the numbers were multiples of nine (i.e., 18, 36, 54, 72, 90).[17] Others, also trained under Fujii, determined for the first time the correct numbers of chromosomes in rice (1910) and in wheat (1918).[18] Thus cytogenetics was developing fast in Japan particularly under Fujii's influence.

Fujii played a central role in establishing in 1918 Japan's first Genetics Laboratory (*idengaku kōza*) under the Department of Botany of Tokyo Imperial University. The importance of balancing basic and applied goals for sustaining the growth of genetics is underscored by comparing this laboratory to Kihara's own genetics laboratory, established nearly a decade later.

[14] See *Nihon ikushu gakkai kaihō* [Japanese Journal of the Breeding Society] 1, no.1 (1916).

[15] Tanaka, "Genetic studies on the silkworm."

[16] Tanaka, "Nihon idengaku no yoake (2)."

[17] Tahara, "Cytological studies on chrysanthemum, I-IV."

[18] For rice, Kuwada, "A cytological study of *Oryza sativa* L." For wheat, Sakamura, "Kurze Mitteilung ueber die Chromosomenzahlen."


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While Kihara's lab would be placed under the Faculty of Agriculture with the aim to conduct research to solve agricultural problems, Fujii's lab was in the Department of Botany of the College of Science, and Fujii's aim in establishing the laboratory was to develop "genetics based on cell biology" as a "purely independent field."[19] Clearly Fujii was hoping to conduct more basic research in the new laboratory.[20] One consequence was that unlike Kihara's lab, the establishment of Fujii's lab was made through a contribution from wealthy entrepreneurs, not through the government's support. These entrepreneurs were "commended" in an academic journal for their "praiseworthy act" of supporting "basic" science especially when it was rare that men of wealth would make contributions to "pure academic work that could not easily lead into direct benefits."[21] Although Fujii explained, in an official letter to the university requesting approval of the establishment of the new laboratory, that genetics was an "important" field with two potential applications, agriculture and eugenics, the "basic" nature of Fujii's laboratory might have made the establishment and support of this lab low priority for the government.[22] Because the funding for the lab came exclusively from an outside source, the imperial university did not allocate official faculty positions for the new laboratory. Fujii, who was the head of the existing laboratory for morphological studies, concurrently took a position as the head of the new genetics laboratory without abandoning the morphological laboratory.[23]

While conducting cytological analysis under the microscope, however, Fujii tried to maintain a connection with agricultural goals. Fujii recommended that students choose a "practically important plant," and they investigated cells of rice, corn, mulberry, chrysanthemum and so forth.[24] The use of practical materials worked advantageously for geneticists in Japan because it could be used to demonstrate that their research was needed for the progress of the nation through betterment of biological resources. This practical benefit was, however, not just rhetoric. The Ministry of Agriculture and Commerce was promoting the improvement of silkworm and crops, and more technical staff were needed at experimental stations of each prefecture. Therefore students must have been encouraged to be trained with agricultural organisms to be able to fit into the job market of the time.[25]

With this overall demand for agricultural research, it may not be a coincidence that the first *government-funded* genetics laboratory in Japan – although the second genetics laboratory in the country – was established under the Faculty of Agriculture. Kihara started directing the newly established Laboratory of Experimental Genetics at the Faculty of Agriculture of Kyoto Imperial University in 1927. This university founded departments for physics, chemistry, and mathematics when it was established in 1897 as the second national university after the first one in Tokyo. Only after 22 years was the Department of Biology established (1919), followed by the Faculty of Agriculture (1923). The university acquired experimental forests in Taiwan, Korea, and Sakhalin

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[19] Fujii, "Tōdai rika daigaku shokubutsugakka ni okeru idengaku kōza no shinsetsu: Nomura-ke no bikyo". Also see Fujii's letter, reprinted in: Nihon kagakushi gakkai, ed. *Nihon kagaku gijutsushi taikei,* 277–278.

[20] See for example, Fujii, "On the conceptions of 'id.'"

[21] Fujii, "Tōdai rika daigaku shokubutsugakka ni okeru idengaku kōza no shinsetsu."

[22] The letter is in Nihon kagakushi gakkai, *Nihon kagaku gijutsushi taikei*.

[23] Shinotō, ed. *Idengaku no ayumi: Menderu iden hōsoku 100-nen kinen*, 382-384.

[24] Tahara, "Sonokoro no omoide". A newsletter that came with the *Japanese Journal of Genetics* (or *idengaku zasshi*); bound with the *Journal* in some libraries in Japan.

[25] Abe, "Meiji no makkigoro nihon iden kenkyū no omoide," 27.


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over the years as the nation expanded. Because of this expansion, it became necessary to establish the new Faculty of Agriculture.[26] One of six departments under the Faculty was the Department of Biology for Agriculture and Forestry, which conducted biological research closely linked to agricultural problems. An author who had written for the compiled "70-year history of the Faculty of Agriculture of Kyoto University" notes that the establishment of this new department was viewed as "unorthodox" by agriculturalists.[27] It is said that Kihara's undergraduate adviser, Kōriba Kan (1882-1957) who was a plant physiologist and had just moved from Hokkaido to Kyoto, played a central role in designing the new department by modeling it on the departmental structure in Hokkaido (where basic biology had been conducted within the agricultural department). As a result of Kōriba's integration of biological research in the agricultural department, Kihara and another Hokkaido graduate were able to secure positions under the new department in Kyoto.

Under the Department of Biology for Agriculture and Forestry, three laboratories (*kōza*) were established initially: plant pathology, entomology, and experimental genetics. Kihara, who had just submitted his doctoral dissertation on cytogenetic studies of wheat, was promoted to associate professor (*jokyōju*) at the Faculty of Agriculture and was named as a future director of the new Laboratory of Experimental Genetics in 1924. In 1925, the Ministry of Education sent Kihara to Germany. This was because the Japanese government had made it mandatory for all professors to have the experience of studying in Europe or the U.S. Kihara went to Germany to work with Carl Correns for two years. Upon returning to Japan in 1927 as Professor, Kihara started running the new Laboratory. In the same year Fujii retired. Though his disciples continued running the laboratory, the university did not allocate official faculty positions until 1951.[28] Therefore within academic institutions Kihara's lab remained for a long time the only independent and government-supported genetics lab in Japan. This lab would later be known as Japan's "Mecca" of genetics.[29]

After returning to Japan in 1927, Kihara rapidly developed his research program and he became a recognized authority in cytogenetics, particularly for his superb analysis of polyploidy in wheat. As will be discussed in the next section, the devoted assistance of his collaborator, Flora Lilienfeld, ensured that he was able to communicate internationally. The imperial context was also critical for the development of his group. Kihara's laboratory was expected to contribute to the state's agricultural needs through biological research since its inception. In wartime, Kihara was isolated from the international community but was able to expand his group by successfully integrating genetics into agricultural projects. The role of genetic research within the agricultural department might have been seen with skepticism by agriculturists in the mid-1920s; however, by 1940, various agricultural industries asked Kihara's group for advice and collaboration for their breeding projects.

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[26] Kyoto Imperial University, ed. *Kyoto teikoku daigakushi,* 1069.

[27] Kyoto daigaku nōgakubu 70-nenshi henshū iinkai, ed. *Kyoto daigaku nōgakubu 70-nenshi*, 256.

[28] Shinotō, *Idengaku no ayumi*, 384.

[29] Genetic research was conducted and geneticists were trained in many places in Japan at that time in laboratories under older disciplines. A notable geneticist was Komai Taku (1886-1972) at the Department of Zoology under the Faculty of Science of Kyoto Imperial University. Komai was at Morgan's laboratory for two years, returned to Japan with fruit flies in 1925 and then started the first fly group in Japan. On the reference to "Mecca," see Kimura, "Kihara Hitoshi hakushi o shinobu," 726.


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## Evolution of Kihara's Group through Basic and Applied Studies of Polyploidy

In the new laboratory in Kyoto, Kihara conducted cytogenetic studies and published a series of important articles in wheat studies and plant genetics. In 1929, Flora A. Lilienfeld (1886-1977), Kihara's most important collaborator in his lifetime, joined his laboratory.[30] Lilienfeld had been a student of Correns from Poland and had shared an office with Kihara at the Kaiser Wilhelm Institute. She came from a well-educated Jewish family in Lvov and had studied botany at Lvov University, obtaining her Ph.D. in 1914. After leaving Correns's lab, she had hoped to find a permanent position in Poland. However, she was unable to do so, and in 1929 accepted Kihara's invitation to come to Japan. Kihara was trying to train students in presenting and discussing research results in German and was hoping to get some help from foreign scholars. Fortunately Lilienfeld agreed to move all the way to Japan. She was hired as "lecturer" (a rank between *joshu*, "assistant," and associate professor) but functioned more as "associate professor" (*jokyōju*) who would assist the professor in both research and education.[31]

As soon as Lilienfeld arrived, they started to formalize a method that Kihara had developed and gave it a name: *Genomanalyse* or genome analysis.[32] The purpose of this analysis was to identify types of chromosome sets. It was known that wheat varieties were polyploids with the base chromosome number, seven (i.e., 14, 28, 42). Based on his previous study, Kihara concluded that seven chromosomes should be treated as one unit, and referred to this unit as "Genom." Seeking to analyze the chromosomal composition of the entire genus, Kihara along with members of his lab identified what kind of a genome each polyploid plant had in all species and varieties of wheat (genus *Triticum*) and a closely related genus (*Aegilops*) over many years. According to the American botanist and evolutionary biologist George Ledyard Stebbins (1906-2000), "In the history of polyploidy, Kihara was the first person to analyze a whole genus," and his polyploid analysis was quickly followed by other botanists in the 1930s.[33]

Lilienfeld's role in this enterprise as a researcher and as a translator was vitally important to its success. In the year following her arrival in Japan, Kihara published the first paper on "genome analysis" in the series.[34] She rewrote Kihara's German draft into more formal-style German, which even Kihara later had some difficulty understanding.[35] (This paper was published as Kihara's single-authored article.) Among a total of ten articles of the series, she co-authored three articles, the fourth (1932) to the sixth (1935), until she left Kihara's lab for the U.S. just before the outbreak of war, and single-authored the final tenth article (which was a review of the past articles of the series) in 1951 after she returned to Japan. Lilienfeld not only helped edit Kihara's (and often his lab members') publications but also wrote letters for Kihara's international correspondence in German or English.[36] When the official network among wheat scholars (called

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[30] Majewski, "Flora Lilienfeldówna (1886-1977)." Also see Kihara, *Komugi,* 74, 130.

[31] Kyoto daigaku nōgakubu 70-nenshi henshū iinkai, ed., *Kyoto daigaku nōgakubu 70-nenshi*, 259.

[32] Kihara, *Komugi,*134.

[33] Stebbins, "Botany and the synthetic theory of evolution," 145.

[34] Kihara, "Genomanalyse bei *Triticum* und *Aegilops*."

[35] Kihara, *Komugi: Ichi-seibutsugakusha no kiroku,* 147.

[36] Lilienfeld to Brandes, 26 February 1940, reprinted in *Zihō* 1 (1941): 13. A journal published by Kihara's group; currently held at the library of the Kihara Institute for Biological Research, Yokohama, Japan.


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the Wheat Information Service) was later established in 1953, Kihara played a central role in its organization, which suggests that he had successfully become an important part of an unofficial network of wheat exchange in the prewar period. This network was, however, mediated effectively by Lilienfeld. She essentially connected Kihara and his lab with the research community outside Japan.

One of the goals of their comprehensive genome analysis was to understand the evolution of bread wheat and to identify a close ancestral species of the wheat. (He and the American team of Edgar McFadden and Ernest Sears would independently identify the species in 1944.[37]) Thus polyploidy was an important tool for investigating evolution and cytogenetics of plant species, and Japanese work contributed significantly to the development of such fields.

However, polyploidy was also important for applied work. Expectations about the use of polyploidy for plant breeding were high because it was at the time "the most powerful tool yet available to a geneticist for molding living matter into new shapes."[38] During the war years in Japan (especially from the Manchurian Incident in 1931 to the end of the Second World War in 1945), the need to mobilize science for the war effort further encouraged an emphasis on applied research, and geneticists came under stronger pressure to present the practical value of their research. Polyploidy thus became a critical tool for Kihara's survival and success as a scientist during wartime.

Lilienfeld left Japan in 1936 before Japan entered a full-scale war against China. Starting in 1937, Japanese scientists became increasingly isolated from the rest of the world. In isolation, Kihara would develop a research center based on the connections with former students, friends, and college alumni and on accumulated experiences in cytogenetics in his laboratory. There he would expand practical projects aiming at the production of new polyploid crops in order to adapt to the wartime climate. At the same time, their approach to genetics would diverge even more from the study of nuclear chromosomes to the whole cell and whole organisms.

Just at that time a new method was discovered that made the production of polyploidy easier and more reliable. In 1937 two American researchers, Albert Blakeslee and Amos Avery, reported that they had succeeded in inducing polyploidy using a chemical inducer, colchicine.[39] Colchicine brought a significant change in plant breeding and horticulture. As one cytologist described, beginning in 1938, a "Colchicine fad" took hold among plant breeders.[40] Kihara's group was not an exception.

Using polyploidy and colchicine, Kihara shifted his research direction toward more practical work beyond wheat. Kihara expanded his research projects, materials, and the geographical range of research fields. He formed ties with industry and developed new research programs on plants that were valuable *and* polyploid (such as sugar beet, sugarcane, barley, and cotton). One of the products of this expansion of research was the creation of the seedless watermelon. Kihara's group created the fruit by converting the normal diploid (having two sets of chromosomes) into a triploid (having three sets) because there had been several examples of triploid plants being seedless or sterile. (After the war they would successfully harvest seedless watermelon.)

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[37] Kihara, "Futsū komugi no ichisosen taru DD-bunsekishu no hakken, yohō"; McFadden & Sears, "The artificial synthesis of *Triticum spelta*."

[38] Dobzhansky, *Genetics and the origin of species*, 207.

[39] Blakeslee & Avery, "Methods of inducing doubling of chromosomes in plants"; Curry, "Making marigolds."

[40] Eigsti, "Induced polyploidy," 273.


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In the middle of the war in 1942, with financial support from industries, Kihara established the Kihara Institute for Biological Research in Kyoto to accommodate the new projects.[41] Kihara commented at the opening ceremony that people should appreciate that there was also a "science war" in agriculture, not just in engineering. The research at the Institute was their way to fight a quieter yet important "science war," which would contribute to making "the best use of Greater East Asian (*daitōa*) resources."[42]

Since the beginning of the Pacific War in December 1941, Japan quickly occupied a vast area, including Burma, Malay, Indonesia (Dutch), the Philippines, some Pacific islands, and part of New Guinea. The Kihara Institute's research zone was in fact as vast as the Japanese Empire: from Hokkaido and Manchuria (sugar beets and barley) to Saipan (sugarcane and watermelon). The Institute in Kyoto was headquarters for all projects. Kihara envisioned that his Institute was a type of "dojo" (school for martial arts) to train biologist-warriors who could eventually help fight the "sacred war" in Greater East Asia.[43] He had already been sending his students to experimental stations and industry in various places in the Empire such as Manchuria, Taiwan, and Saipan. In isolation during wartime, it became necessary for Japan to train all technicians and scholars within its own geographical boundary, and Kihara began to train technical staff for industry. For example, five employees at the fiber industry Tōyō bōseki (Toyo cotton spinning company) entered the Kihara Institute in 1942 for training in theory and practice.[44] These botanist-warriors were to be sent to the South for cotton agriculture.

## A Holistic Approach to Organisms, Cells, and Genes

Plant breeding required a multidisciplinary approach to achieve better growth, flowering, and fruition of plants. I argue that because of the applied interests of Japanese scientists, they pursued a holistic approach to biological study. In Kihara's work, and elsewhere in Japanese biology, there was no clear distinction between "basic" and "applied" science in actual research. Fundamental research was pursued with applications in mind, in particular the need to control and improve species that had economic value. Such an approach included genetics but also a variety of other disciplinary approaches that had to be deployed to understand the full range of biological processes within the organism.

The research program at the Kihara Institute was similar to what the Russian geneticist Nikolai I. Vavilov (1887-1943) had proposed in advocating the development of "breeding as a science." Vavilov, director of the Institute of Applied Botany and Plant Breeding in Leningrad, had visited Kihara in 1929. Earlier during his European sojourn, Kihara had been particularly excited to visit Vavilov's Institute, considered to be the world's leading research institute on crops and the world's first seed bank. During Vavilov's subsequent visit to Japan, he lectured on the origin of cultivated plants at Kyoto Imperial University. Kihara took great interest in Vavilov's

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[41] About Kihara Institute, also see Iida, "Practice and politics in Japanese science," 544-546; in that article, all three references to *sweet potato* on pp. 544-546 are errors and should be corrected to *sugarcane*.

[42] Kihara, "Rakuseishiki", 104. *Seiken zihō* was a journal published by Kihara's group, currently held at the library of the Kihara Institute for Biological Research, Yokohama, Japan.

[43] Kihara, "Aisatsu", 108.

[44] Yamashita, "Menka-han no kaisetsu."


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theory of the origin of cultivated plants and was in general sympathetic to his approach to biology and to the science of breeding.

According to Vavilov, breeding was a complex "scientific system" that borrowed various methods from other "fundamental sciences" for the production of a new variety. He wrote: "In controlling heredity it relies wholly on the findings of genetics, cytology, and embryology, while in the study of breeding technique it depends upon the biology of flowering, physiology, chemistry, technology, phytopathology, entomology."[45] These all contributed necessary knowledge for plant breeding. Vavilov had also noted the centrality of including the environment as part of this scientific enterprise. As he wrote, "The question of environment and the interaction of the organism and the environment is one of the most important branches of breeding." The environment represented by the various climate zones of the Empire became one of the biggest concerns for plant breeders of Japan. To develop crops adapted to various climates of the expanding Empire, it was inevitable for the researchers to examine interactions between organisms and the environment. As a result, Japanese breeders were compelled to extend their approach in a multidisciplinary direction, particularly physiological and developmental studies that went beyond chromosome-oriented cytogenetics. Studies at the Kihara Institute, for example, involved testing various conditions affecting plant growth, including low and high temperature, day length, plant hormones, chemicals in the soil, fertilizers and insecticides, as well as the genetic background of plants.

As applied goals encouraged multidisciplinary approaches, Japanese geneticists began voicing the importance of non-chromosomal factors (i.e., the cytoplasm and internal and external environmental factors) for genetic studies, and of aiming their research direction specifically toward "physiological genetics" as was proposed by the German geneticist Richard B. Goldschmidt (1878-1958). Goldschmidt had visited Japan twice (in 1914 and again in 1924 for two years) and had close ties with Japanese biologists. In 1938, he again attracted much attention in Japan because that year he published a new book, *Physiological Genetics*.[46] Goldschmidt's goal was to connect genes and an organism's development by elucidating the gene's biochemical and physiological actions.

Kihara began advocating physiological genetics and also emphasizing his study of the cytoplasm (instead of chromosomes). Others also referred to Goldschmidt and suggested that genetics in the future should be developed into physiological genetics.[47] Scott Gilbert has described Goldschmidt as a "leader and prophet" of future genetics.[48] The Japanese took Goldschmidt's prophecy seriously.

Some genetic studies were indeed heading toward the direction of physiological genetics in and out of Japan at the time and began revealing functions of genes.[49] In 1941, the Japanese geneticist Kikkawa Hideo (1908-1990), who was an employee at a national sericulture experiment

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[45] Vavilov, *The origin, variation, immunity and breeding of cultivated plants*, 8.

[46] Goldschmidt, *Physiological genetics*. See Richmond, "The cell as the basis for heredity, development, and evolution."

[47] For example, Tanaka, "Idengaku no shōrai."

[48] Gilbert, "Cellular politics," 340.

[49] Earlier studies include Caspari, "Uber die Wirkung eines pleiotropen Gens"; Kühn, Caspari & Plagge, "Uber hormonale Genwirkungen bei Ephestia kühniella Z."; Beadle & Ephrussi, "The differentiation of eye pigments in Drosophila." For historical studies see Rheinberger, *An epistemology of the concrete,* ch. 6; Sapp, *Beyond the gene,* ch. 5.


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station, and the American team of George Beadle and Edward Tatum published independently on the chemical process of eye pigment formation in silkworm and fruit fly, respectively.[50] They proposed that in a series of biochemical steps (in the production of pigment precursors), each step was controlled by a different gene, mediated by an enzyme. For example, "*v*+ hormone" (kynurenin) in flies was a product of an oxidation of tryptophan, a process catalyzed by an enzyme controlled by "*v*+ gene." This type of study was what Goldschmidt considered to be "physiological genetics" because it would be an important step in connecting genes and development.

By 1941 when their paper appeared in print, Beadle and Tatum had already switched their research material from flies to a completely different kind or organism, bread mold (*Neurospora*). According to Jonathan Harwood, the American team was as a result no longer studying "even *part* of a developmental process in a higher organism," and their research was only about the chemistry of gene action.[51] This switch would lead them to the famed One-Gene-One-Enzyme hypothesis.

In contrast, Kikkawa's work appeared to be much more deeply committed to the organism's biology and to a multidisciplinary approach. Kikkawa wrote that the problem of tryptophan metabolism went beyond genetics and required knowledge in other disciplines such as biochemistry, photochemistry, "protoplasma study," physiology, and developmental biology.[52] For example, photochemistry was essential for him because he was interested in the physiological functions of pigments. Genes and enzymes were necessary to produce pigments but why did insects need pigments, he wondered. He was conducting experiments to determine the spectrum of light absorbed by a pigment, hoping to understand the relation between insect biology (especially phototaxis) and pigments. Kikkawa hoped to cover everything about pigments, from the genes to the biological functions in the insect, because he was interested in the organism more than the genes.

This type of biological research was remarkably similar to the approach to "breeding as a science" that we observed in Kihara's laboratory. With the general emphasis on applied aspects in Japanese science, many geneticists engaged in multidisciplinary work. As the overall approach became multidisciplinary and sought full understanding of the organism's biological processes, physiological genetics was preferred as the approach to genetic research, and many of the leading geneticists in Japan believed that Goldschmidt had correctly identified the way in which future genetics had to develop. In addition, many including Kihara began shifting the emphasis of their interest from chromosomes to the cytoplasm. Kikkawa would also develop a new model of gene expression immediately after the war and incorporated the cytoplasm as an important factor in the model.[53]

## "Breeding as a Science" in the Postwar Years

The fine balance between basic and applied science characterized the development of genetics through wartime and became the basis for further development of genetics in the postwar years.

[50] Beadle & Tatum, "Experimental control of development and differentiation"; Kikkawa, "Mechanism of pigment formation in Bombyx and Drosophila."

[51] Harwood, *Styles of scientific thought,* 92-93.

[52] Kikkawa, "Konchū no toriputofan taisha o meguru shomondai (2)," 324.

[53] Ishidate, "Hideo Kikkawa's works on eye pigment in *Bombyx* (1937-1950)"; Kikkawa, "Idenshi no honshitsu to sayō."


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After Japan's defeat in 1945, Japanese geneticists immediately started rebuilding the research environment. One of their biggest accomplishments was the establishment of the National Institute of Genetics (NIG) in Mishima in 1949.[54] Most research projects at the newly established Institute had relevance to agriculture. Among the initial eight laboratories at the NIG, two were run by the former members of the Kihara Institute, who worked on agricultural crops. Another principal investigator, Sakai Kan-ichi (1910-1999), conducted theoretical/quantitative study of genetics for the purpose of plant breeding of crops including rice, red pepper, barley, plants in the genus *Abelmoschus* (such as okra), and eggplant.[55] In the early 1950s, NIG researchers often used agricultural organisms for their genetic study: silkworm, virus infecting silkworms, various crops, and *Aspergillus* (a type of fungus used in the fermentation process of soy sauce, rice wine, and soybean paste).

In addition, the NIG began collaborative applied projects with agricultural industry. Shortly after the establishment of the NIG, poultry breeders asked for improvement of strains for higher egg production, and the Japan Monopoly Corporation of Tobacco and Salt requested improvement of the varieties of tobacco plants.[56] Starting in 1951, Kihara supervised a large project, "basic research for improvement of tobacco strains." Lilienfeld also returned to Japan from the U.S. in order to work with Kihara in 1950, and joined the tobacco team.[57]

The characteristic feature of the projects conducted at the NIG was not only their use of agriculturally relevant organisms but also their approach to "breeding as a science." For example, the members of the tobacco project examined physiological and chemical characters of the secretion of the plant (thought to be contributing to the aroma of tobacco), the plants' resistance to diseases, various environmental effects on the plants, cytogenetic studies, and creation of mutants by the use of polyploidy and X-ray.[58] This multidisciplinary approach was not just a manifestation of Kihara's own style. Two of the NIG labs used silkworm and both covered various aspects of silkworm biology, such as effects of day length and other environmental factors on silkworm physiology and development, transmission of virus infecting silkworms, viral development, and differentiation of silkworm embryos.[59] Such diverse knowledge was necessary to gain control of the organism.

Such "breeding as a science" was different from the mainstream approach to genetic studies outside Japan. During the planning of the International Genetics Symposia of 1956, for which Japan was selected as a host country, there were disagreements over the proposed program between the Japanese organizers and members of the International Union of Biological Sciences (IUBS), which was to support the symposium. In 1954, after reviewing the Japanese proposal for the symposium program, the IUBS responded that they could not approve it. The Japanese had proposed the following two sections: (1) "Physical and chemical approach to the problem of chromosomes"; (2) "Genetics of cultivated plants and domesticated animals (polyploidy breeding,

[54] About the establishment of the Institute, see Iida, "Practice and politics in Japanese science."

[55] Kokuritsu idengaku kenkyūjo ed., *Kokuritsu idengaku kenkyūjo nenpō* v.2 (1952), 44-52; v.3 (1953), 50-60.

[56] Kokuritsu idengaku kenkyūjo ed., *Kokuritsu idengaku kenkyūjo nenpō* v.2 (1952), 4.

[57] Majewski, "Flora Lilienfeldówna."

[58] Kokuritsu idengaku kenkyūjo ed., *Kokuritsu idengaku kenkyūjo nenpō* v.2 (1952), 81-89.

[59] Kokuritsu idengaku kenkyūjo ed., *Kokuritsu idengaku kenkyūjo nenpō* v.2 (1952), 8-13, 52-59.


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resistance, microorganisms and viruses, breeding systems)."[60] These were, in short, non-agricultural and agricultural sections, respectively.

To the top members of the IUBS, this proposed program looked like a random package of "quite disparate and disconnected fields."[61] Before the official IUBS letter was sent to the Japanese, Claudio Barigozzi and I. Michael Lerner (the President and Secretary of the Genetics Section of IUBS, respectively) internally exchanged their opinions earlier about the Japanese proposal. Barigozzi wrote: "I remark simply, that the topics chosen for the Symposium are of so little interest."[62] He wished to propose the inclusion at least of quantitative inheritance and of immunogenetics. Lerner also could not help but feeling that "what they want to have is not a Symposium but an unsystematic collection of topics." He wrote: "I see no relation … within the second division, I am wondering since when a virus has become either a cultivated plant or a domestic animal."[63]

What Barigozzi and Lerner did not grasp was that the Japanese style involved examining multiple biological problems related to an organism of interest in the agricultural context. The point was not that a virus was considered to be a domesticated animal or cultivated plant, but that viruses infected domesticated animals and cultivated plants that were being studied by Japanese geneticists. What appeared as a random or disconnected set of problems to them actually was thus logically connected in the Japanese context. Quantitative genetics and immunogenetics, which Barigozzi hoped to be included in the program, must have been already included in the "agricultural" section of the program to some extent. As seen in Sakai's theoretical work on various crops, the Japanese had used a quantitative approach for breeding studies.[64] Many veteran geneticists in Japan were revolving around a particular organism, rather than a particular scientific problem. Thus it made more sense for them to put what Barigozzi and Lerner thought to be "disparate" subfields of genetics together, in order to have comprehensive understanding of an organism.

However, it is notable that the Japanese Society of Breeding (*nihon ikushu gakkai*) branched off from the Genetics Society of Japan in 1951. At the founding meeting of the new society held at the Faculty of Agriculture of Tokyo University, 260 people gathered. Many older generations of geneticists, including silkworm geneticists, former members of Fujii's laboratory, and Kihara and his former students, joined the new Society as central members (board member, secretary, editor, or honorary member, etc.).[65] This shows that even Japanese researchers felt that a gap between genetic studies within "breeding as a science" and newer (non-agricultural) types of genetics was growing. In turn this indicates that Japanese "genetics" had maintained a very close relation with breeding studies until around this time. It should be noted however that the emergence of the new breeding society by no means implied the split of genetic studies with agricultural relevance from "basic" genetic research. Many had membership in both societies and

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[60] IUBS rejection letter, Montalenti to Shinoto, 9 November 1954; the Japanese proposal in Barigozzi to Lerner, 8 February 1954, both in folder "Permanent International Committee on Genetics Congresses, Correspondence (1953-1954)," I. Michael Lerner Papers, American Philosophical Society (APS), Philadelphia, U.S.A.

[61] Montalenti to Shinoto, 9 November 1954, folder "Permanent International Committee," Lerner Papers, APS.

[62] Barigozzi to Lerner, 8 February 1954, folder "Permanent International Committee," Lerner Papers, APS.

[63] Lerner to Barigozzi, 12 February 1954, folder "Permanent International Committee," Lerner Papers, APS.

[64] In fact, "breeding systems," included under the second section, was later replaced by "polygenic inheritance" (which was part of quantitative genetics) in the actual program of the Symposia.

[65] See *Ikushugaku zasshi* (or *Japanese Journal of Breeding*) 1, no.1 (1951).


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Kihara in particular was at this time the president of the genetics society. Moreover, as we saw, the NIG members continued projects that had agricultural relevance.

Even if some breeders began leaving the circle of genetics, what stayed was the approach of "breeding as a science." For example, the NIG acquired in 1952 a temperature-controlled room (suitable for "experiments with all kinds of temperature treatments"; likely for animals such as silkworms) and a "controllable greenhouse" (*chōshetsu onshitsu*, or "phytotron" in English), in which temperature, humidity, and light could be controlled "for physiological genetic research on germination and growth."[66] Because of their interests and needs in examining organisms' responses to various environmental effects, these two rooms must have been essential and were thus established at the same time as the other essential facilities such as a microbe lab, an optical and chemical lab, and facilities for electron microscopy and irradiation.

Furthermore, because Kihara served as the director of the NIG from 1955 to 1969, his idea of genetic research must have been influential. Kihara obtained a large sum of funding from the Rockefeller Foundation for a project, "research on the origin of cultivated rice," for a total of eight years starting in 1957. (When the International Rice Research Institute in the Philippines was established in 1960 with support from the Rockefeller and Ford Foundation, Kihara became a member of the board of trustees.) Through their rice project, the NIG also acquired new facilities, including Japan's first phytotron designed specifically for rice (i.e., experimental rice fields were contained within a phytotron). Moreover in the same year (1957-1958), the NIG established another phytotron, in which temperature, humidity, day length, and wavelength of light were adjustable for "research of physiological genetics."[67] The world's first phytotron, a new type of laboratory for the experimental study of whole organisms, had been built in 1949 under the direction of American plant physiologist Frits W. Went at the California Institute of Technology. Went, originally motivated by the perception that organism-environment relations were being neglected at Caltech, later came to see the multidisciplinary research done in the phytotron as helping to counter the divisive trends of molecular biology.[68] It would be highly interesting to know what type of social and cultural roles the multiple phytotrons at the NIG played in the 1960s. While the NIG rapidly incorporated various newer branches of genetics by sending younger scholars to the U.S. for training (such as Kimura Motoo in population genetics), both the agricultural connection and a holistic, physiological approach hardly ended in the new era.

Throughout this chapter I have argued that Japanese genetics expanded by maintaining a close relation to practical goals in agriculture and horticulture. Applied goals created projects that were both basic and applied and nurtured a holistic understanding of organisms, cells, and genes. In the second half of the twentieth century the scheme to attract funding to genetics would change, particularly with the growing connection between genetics and medicine. However, the role of genetics in agriculture would remain extremely important. How the relation between genetics and agriculture developed further with the increase of genetic knowledge and techniques and with various other issues such as food security, population growth, and war, and how that relation affected interdisciplinary interactions, approaches to genetic studies, agriculture, and our view of life would be themes for future research.

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66 Kokuritsu idengaku kenkyūjo ed., *Kokuritsu idengaku kenkyūjo nenpō* v.3 (1953), 78.

67 Kokuritsu idengaku kenkyūjo ed., *Kokuritsu idengaku kenkyūjo nenpō* v.8 (1958), 131-132.

68 Kingsland, "Frits Went's atomic age greenhouse."


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